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

M. Tech 3rd semester report Submitted in Partial Fulfillment of the Requirements for the Degree of

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I, a student of the Department of Water Resource Engineering, Civil Engineering, Assam Engineering College, hereby declare that we have compiled this report on the topic titled **“Analysis of Long-Term Rainfall Trends in Tinsukia, Assam: Implications for Climate Adaptation and Water Resource Management”** in 3rd Semester as a part of my M. Tech curriculum.

I also declare that the same report or any substantial portion of this report has not been submitted anywhere else as part of any requirements for any degree/diploma etc.

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ABSTRACT

Understanding long-term trends in rainfall is critical for assessing the impacts of climate change and ensuring sustainable agricultural practices, water resource management, and disaster mitigation. This study analyzes over a century of rainfall data from the district of Tinsukia, a region with a high dependence on seasonal precipitation, to identify temporal trends and their implications. Using robust statistical techniques such as the Mann-Kendall trend test and linear regression analysis, this research provides a comprehensive evaluation of rainfall patterns across monthly, seasonal, and annual scales.

The Mann-Kendall trend test, a non-parametric method, was employed to detect monotonic trends in rainfall data, while Sen's slope estimator quantified the rate of change of rainfall. Linear regression analysis complemented this by providing insights into the strength and magnitude of the relationship between rainfall and time. The analyses were conducted using XLSTAT, a statistical software integrated with Microsoft Excel, which facilitated efficient data handling, computation, and visualization.

Results revealed significant decreasing trends in rainfall during several months, particularly January, February, and April, with p-values below the 5% significance threshold. Seasonal analysis highlighted a substantial decline in monsoon rainfall (June to September), which constitutes the primary agricultural period in the district. Annual rainfall trends also showed a consistent decline, indicating potential long-term impacts on regional water availability. Low R^2 values in some months suggest that additional climatic or anthropogenic factors may contribute to rainfall variability, underscoring the complexity of precipitation dynamics.

This study's findings emphasize the need for adaptive strategies to address changing rainfall patterns. The observed decline in monsoon rainfall could have profound implications for crop yields and water resources, while reductions in winter and post-monsoon precipitation might affect recharge rates of aquifers and ecosystems. The research highlights the value of integrating statistical tools like XLSTAT in climatic studies to ensure accuracy and clarity in trend analysis.

KEY WORDS: Mann Kendall Trend Test, Linear regression, Rainfall, Trend analysis, Seasonal trend

1.INTRODUCTION

Climate change and its implications on local and regional weather patterns have become critical areas of research in recent decades. 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.

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 :

- Summer (March to May): Hot and humid, with temperatures ranging from 24°C to 36°C.
- Monsoon (June to September): Heavy rainfall, influenced by the southwest monsoon.
- 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.

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.

1. **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.
2. **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.
3. **Winter and post-monsoon:**
    - Rainfall during winter and post-monsoon months is minimal, contributing to less than 10% of the annual total.

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.

This research helps in developing adaptive strategies to address changing precipitation patterns. The findings offer valuable insights into the regional implications of climate variability and provide a robust foundation for policy development and future research. The study also demonstrates the ability of integrating statistical techniques in climatic studies, ensuring accuracy in analyzing long-term trends.

- **STUDY AREA MAP**

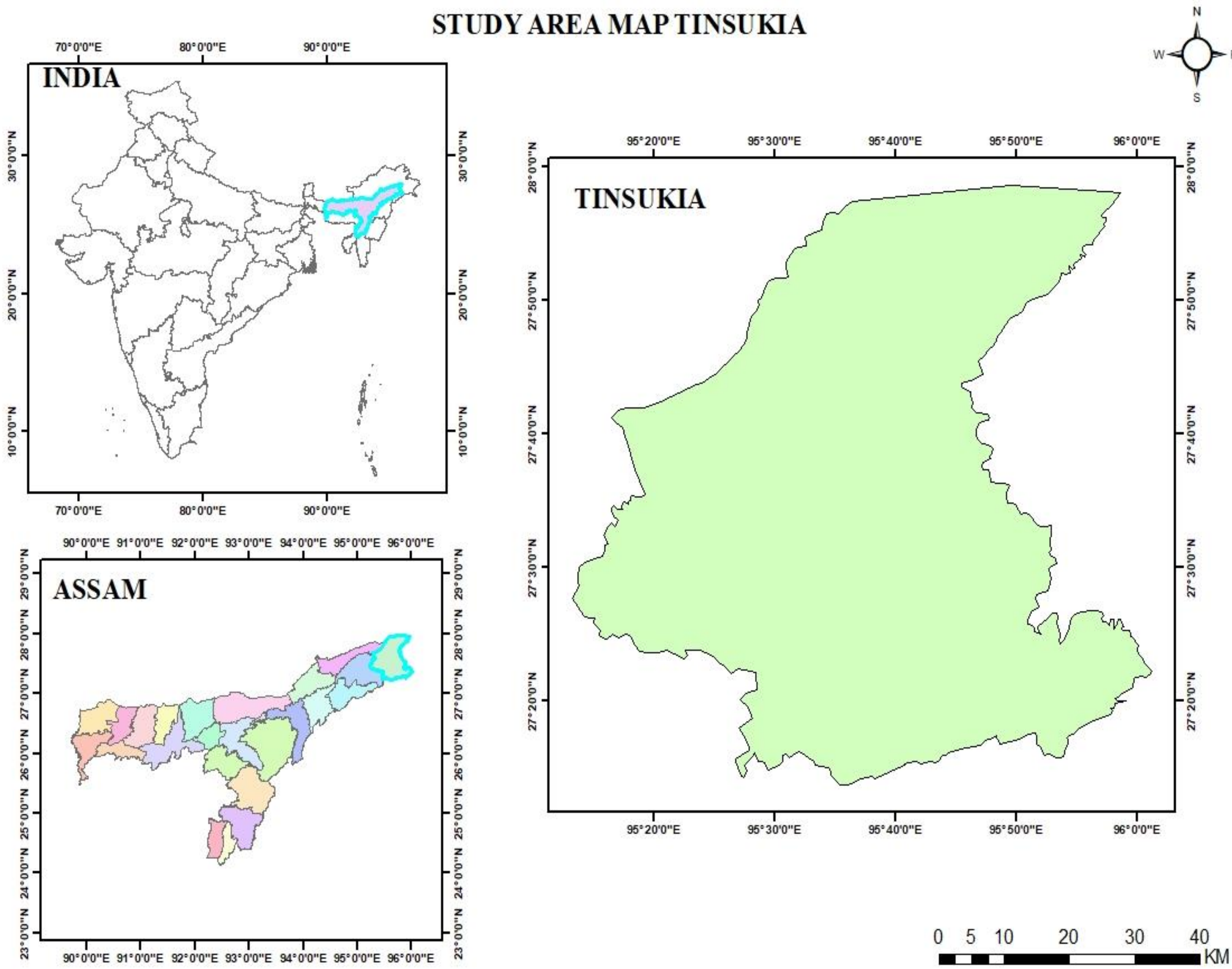

Fig 1: Study area map of Tinsukia District, Assam

The map i.e. Fig 1 depicts the study area of Tinsukia District, Assam, with a multi-level geographical representation. It consists of three panels: the first highlights India, with the state of Assam marked to show its location within the country. The second panel zooms into Assam, illustrating its various districts and emphasizing Tinsukia District. The third and largest panel provides a detailed view of Tinsukia District itself, showcasing its boundaries, geographic extent, and topographical layout. The map includes a coordinate grid for spatial reference and a scale bar indicating distances in kilometres, aiding in precise spatial analysis. This cartographic representation is vital for understanding the geographic context of the study area and serves as a foundational visual for study focused on Tinsukia District.

2. LITERATURE REVIEW

2.1 Mondal and Kundu 2012 Department of Water Resources Development & Management, Indian Institute of Technology, Roorkee,

Their study is mainly concerned with the changing trend of rainfall of a river basin of Orissa near the coastal region. It is facing adverse effects of flood almost every year. This is an effort to analyze one of the most important climatic variables i.e. precipitation, for analyzing the rainfall trend in the area. Daily rainfall data of 40 years from 1971 to 2010 was processed in the study to find out the monthly variability of rainfall for which Mann-Kendall (MK) Test, Modified Mann-Kendall Test have been used together with the Sen's Slope Estimator for the determination of trend and slope magnitude. Monthly precipitation trend was identified there to achieve the objective which was shown with 40 years of data. There were rising rates of precipitation in some months and decreasing trend in some other months obtained by these statistical tests suggesting overall insignificant changes in the area

2.2 Dutta et.al.2018, National Institute of Technology, Durgapur

Their study was an attempt to examine annual rainfall and temperature trends over ten selected stations of Assam. The Mann–Kendall test has been carried out to analyze the trend of mean rainfall and temperature data series during the period of 1901–2014. Though no clear trend has been observed for the region, there are seasonal trends for some seasons and for some of the hydro-meteorological subdivisions. However, there is an increasing temperature trend in all the selected stations. Mann–Kendall tests too clearly indicate the increasing trends for all the stations and their computed p-values are found to be less than or equal to 0.05 ($\alpha \le 0.05$).

2.3 Nyatuame et.al. 2019 Agricultural Engineering Department, HO Polytechnic

Their study was conducted to establish the rainfall trends in Volta Region and also to provide the evidence of climate change by analyzing available rainfall recordfor30-yearperiodof 1981 to2011.Records of monthly and yearly rainfall were obtained from the headquarters of Ghana Meteorological Department, Accra, for analysis. The region was grouped into three zones characteristic of the whole country, namely, coastal zone, middle zone, and northern zone, respectively. Graphs were constructed to illustrate the changing trends within the months and years of the zones. Statistical analysis (i.e., LSD, ANOVA) was performed to assess any significant difference among the three zones and within the months and years under study. Significant differences were observed among the three zones. The northern zone recorded the highest precipitation followed by the middle zone and lastly the coastal zone. However, the rainfall trends within the zones were oscillatory. The highest annual mean rainfall was202.6mm and the lowest was 29.9 mm. Linear regression analysis revealed upward and downward trends in the data in some months and years in the mentioned zones but statistically insignificant.

2.4 Gusmayanti et.al 2021, West Kalimantan, Indonesia 2 Study Program of Environmental Science, Graduate Programme, Tanjungpura University,

This study examines rainfall variations and changes at West Kalimantan, focusing on Mempawah and Kubu Raya from 2000-2019. The Mann-Kendall (MK) and Sen's Slope estimator test, which can determine rainfall variability and long-term monotonic trends, were utilized to analyze 12 rainfall stations. The findings revealed that the annual rainfall pattern prevailed in all locations. Mempawah region tends to experience a downward trend, while Kubu Raya had an upward trend. However, a significant trend (at 95% confidence level) was identified in Sungai Kunyit with a slope value of -33.20 mm/year. This trend indicates that Sungai Kunyit will become drier in the future. The results of monthly rainfall analysis showed that significant upward and downward trends were detected in eight locations. Rainfall trends indicate that climate change has occurred in this region.

2.5 Tuğba et.al (2024) Gebze Technical University, Faculty of Engineering, Department of Environmental Eng., Kocaeli

A half-century precipitation dataset was selected and analyzed to reveal the effects of global climate change on the rainfall amounts of Türkiye. Precipitation data of each geographical region have been analyzed with respect to annual and seasonal basis in the period of 1969-2018. For this purpose, the non-parametric Mann-Kendall trend test which is recommended by World Meteorological Organizations (WMO) and linear regression method have been implemented to each geographical region of Türkiye. As a result of analysis belonging to 85 meteorological stations, the presence of any increasing and decreasing linear trends in annual and seasonal precipitation series have been studied on a regional scale. While the Black Sea Region has the highest increase with 148 mm/50 years, the total annual precipitation in the Southeastern Anatolia Region has decreased by 3.2 mm/50 years. Another important finding of linear regression has been observed that increase in precipitation has occurred in the Black Sea Region in all seasons, because of seasonal analysis. To determine whether these trends are statistically significant, they used Mann-Kendall test results. The test proved the existence of an increasing trend at 99% significance level in the annual precipitation series of the Black Sea Region. A statistically significant increasing trend was also obtained for the autumn season of the Black Sea Region at a 95% confidence level.

3. OBJECTIES OF THE STUDY

The primary objective of this study is to identify and analyse long-term trends in rainfall patterns in Tinsukia. Specifically, it aims to:

- Assess the presence of monotonic trends in monthly, seasonal, and annual rainfall using the Mann-Kendall test i.e. the study aims to identify and analyse monotonic (consistent directional) trends in monthly, seasonal, and annual rainfall patterns in the Tinsukia District using the Mann-Kendall test. This statistical method is widely used to detect trends in time-series data.
- Quantify the rate of change in rainfall over time using Sen's slope estimator. The study seeks to calculate the rate of change in rainfall over time by employing Sen's slope estimator, a non-parametric method for determining the magnitude of trends.
- Evaluate the relationship between rainfall and time through linear regression analysis. The study examines the relationship between rainfall and time using linear regression analysis. This helps in understanding how rainfall patterns have evolved over the years.
- Interpret the implications of observed trends for agriculture, water resource management, and climate adaptation in the region. Finally, the study interprets the observed rainfall trends to understand their potential impacts on agriculture, water resource management, and climate adaptation strategies in the region

4. METHODOLOGY

4.1 Study Area and Data Collection

This study focuses on analysing rainfall patterns in Tinsukia, a region characterized by its dependence on agriculture and seasonal rainfall. The dataset comprises monthly, seasonal, and annual rainfall records spanning over a century. The data were sourced from historical weather records, ensuring consistency and reliability for trend analysis. Observations include rainfall measurements for all twelve months, aggregated seasonal data (winter, pre-monsoon, monsoon, and post-monsoon), and annual totals.

4.1.1 Data Preprocessing

Prepare the data for analysis:

- **Managing Missing Values**: Missing data points were identified and addressed using the mean or mode of the corresponding time series. This ensured that the dataset remained complete while maintaining statistical integrity.
- **Outlier Detection**: Visual inspection and basic statistical techniques were employed to identify outliers, which were retained to preserve the authenticity of long-term climatic trends.
- **Data Organization**: The data were structured into monthly, seasonal, and annual series, formatted for input into XLSTAT for statistical analysis.

4.1.2 Statistical Analysis Techniques

4.1.2.1 Mann-Kendall Trend Test

The Mann-Kendall test, a non-parametric statistical method, was used to detect monotonic trends in the time series data. The test operates under the following hypotheses:

- Ho: No trend exists in the dataset.

- Ha: A trend (either increasing or decreasing) exists in the dataset.

Key aspects of the Mann-Kendall test include:

- **Significance Level**: A 5% significance level (α=0.05\alpha = 0.05α=0.05) was used to determine the statistical significance of trends.
- **Continuity Correction**: Adjustments were made for tied ranks to ensure accurate test results.
- **Sen's Slope Estimation**: To quantify the rate of change, Sen's slope estimator was applied alongside the Mann-Kendall test. This provided an interpretable measure of the trend's magnitude.

➢ **Steps in the Mann-Kendall Test**:

a) **Define the Time Series**: A dataset of n observations: x_1, x_2…...x_n where xi represents the observed value at time i.

b) **Calculating the Test Statistic:** The Mann-Kendall test compares all possible pairs of observations. The test statistic S is defined as:

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

$$\text{sign}\ (x_j - x_i) = \begin{cases} 1 \\ 0 \\ -1 \end{cases} \quad \text{if } x_j-x_i>0, \text{ if } x_j-x_i=0, \text{ if } x_j-x_i<0$$

S summarizes the number of positive differences minus the number of negative differences in the dataset.

c) **Compute the Variance of S: If there are no ties (duplicate values), the variance of S is**

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

For datasets with ties, the formula incorporates correction terms:

$$\text{VAR (S)}= \frac{n(n-1)(2n+5)}{18} - \sum_t \frac{(t-1)(2t+15)}{18}$$

where t represents the number of tied values in each group.

d) Calculate the Standardized Test Statistic Z: The test statistic Z is computed to standardize S:

$$Z = \begin{cases} \frac{S-1}{\sqrt{VAR(S)}} \\ 0 \\ \frac{S+1}{\sqrt{VAR(S)}} \end{cases} \quad \text{if } S>0, \text{ if } S=0, \text{ if } S<0$$

e) Hypothesis Testing:

- Null hypothesis (H_o): There is **no trend** in the time series (S=0).
- Alternative hypothesis (H_1): There is a **monotonic trend** (increasing or decreasing).
- The p-value is derived from the z-statistic using the standard normal distribution.

f) Interpretation of Results:

- If the p-value < significance level (α typically 0.05), reject H_0, indicating a significant trend in the data.
- The sign of Z indicates the direction of the trend:
    - Z>0: Increasing trend.
    - Z<0: Decreasing trend

4.1.2.2 Linear Regression Analysis

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.

➢ **Steps in formulating a Linear Regression Model**

a) Defining the model

The linear Regression Model equation can be represented as -

$$y=\beta_0+\beta_1 x+\epsilon$$

Where:

- y: Rainfall in a specific year (dependent variable).
- x: Year (independent variable, ranging from 1901 to 2022).
- β_0: Intercept (rainfall when x=0).
- β_1: Slope (rate of change in rainfall per year).
- ϵ: Residual error.

b) Calculating the Slope (β1)

The slope (β1) is computed as:

$$\beta 1 = \frac{\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})}{\sum_{i=1}^{n}(x_i-\bar{x})^2}$$

- x_i: Year i.
- y_i: Rainfall in year i.

- $\bar{x}$: Mean of the years.
- $\bar{y}$: Mean of the rainfall values.

c) Calculate the Intercept (β0)

The intercept (β) is calculated using:

$$\beta 0 = \bar{y} - \beta 1 \bar{x}$$

This ensures that the regression line passes through the point ($\bar{x}$,$\bar{y}$)representing the means of the independent and dependent variables.

d). Formulate the Regression Equation

Once β0 and β1 are computed, the regression equation becomes:

$$y = \beta 0 + \beta 1 x$$

e). Calculating the Goodness of Fit ($R^{2)}$

The coefficient of determination (R^2) measures how well the regression line fits the data:

$R^2 = 1 - \frac{SSR}{TSS}$ where

SSR = $\sum_{i=1}^{n}(y_i - \bar{y}_i)^2$ Sum of squared residuals (unexplained variance).

TSS= $\sum_{i=1}^{n}(y_i - \bar{y})^2$ Total sum of squares (total variance in rainfall).

If the R^2 value comes nearly equal to 1 we consider the fit to be good in regression

4.1.3 Analytical Tools

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.

4.1.4 Steps in Analysis

a) **Trend Detection**:

- Monthly, seasonal, and annual data were input into XLSTAT.
- The Mann-Kendall test was applied to identify significant trends.
- Sen's slope estimates were calculated for each dataset to quantify the trends.

b) **Regression Modelling**:

- Linear regression models were developed for each time series, examining the relationship between rainfall and year.
- Goodness-of-fit metrics (e.g., R^2, adjusted R^2) and diagnostic statistics (e.g., residual analysis) were evaluated.

c) **Interpretation and Validation**:

- Results from the Mann-Kendall test and linear regression were compared to ensure consistency.
- Trends were interpreted in the context of climatic and regional variability.

4.1.5 Methodological Limitations

While the methodology provides a robust framework for analysing rainfall trends, certain limitations must be acknowledged:

- **Low R^2 Values**: In some months, the linear regression analysis yielded low R^2 values, indicating that only a small portion of the variability in rainfall could be explained by the temporal trends. This suggests the influence of additional climatic or anthropogenic factors not accounted for in the study.
- **Assumption of Linearity**: Linear regression assumes a constant rate of change in rainfall over time, which may not fully capture the non-linear and complex nature of climatic phenomena, such as sudden weather pattern shifts or extreme events.
- **Data Quality and Continuity**: The reliability of the findings depends heavily on the accuracy and consistency of historical rainfall data. Any gaps, inaccuracies, or biases in the dataset could affect trend detection and analysis.
- **Regional Specificity**: The findings are region-specific and may not fully represent broader climatic trends. Variability in microclimates within the district may lead to local discrepancies in rainfall patterns.
- **Unaccounted External Factors**: External influences such as land-use changes, deforestation, and industrial activities were not explicitly considered, though they may significantly impact rainfall variability.

4.2 DATA USED

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 experiences 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

The rainfall data collected is given below:

TABLE 4.2.1: MONTHLY RAINFALL DATA OF TINSUKIA

DISTRICT	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
TINSUKIA	1901	76.2	105.7	55.3	303.5	170.7	264.8	354	549.1	294.6	118.3	48	0
TINSUKIA	1902	18.6	26.9	155.3	268	104.7	463.6	513	453.1	523.9	155.5	7.6	5
TINSUKIA	1903	45.8	37.1	119.6	340	244.6	502.3	327.2	692.9	475.1	128.8	58.6	3.6
TINSUKIA	1904	14	50.4	150.5	431.3	225.4	306.5	493.7	453.2	169.6	123.5	64.5	0
TINSUKIA	1905	45	26.4	209.1	222.9	204	476.8	507.4	446.8	236.6	87.6	35.6	37.7
TINSUKIA	1906	30.5	97.7	276.9	596.4	259.1	290.5	366.9	605	133.8	119.3	29.9	0
TINSUKIA	1907	80.4	111.1	169.4	237.6	110.9	540.8	557.2	553.7	570.7	25.2	0	15
TINSUKIA	1908	63.7	50.2	42.7	377.3	254.8	569.9	695.6	388.7	431.3	188.8	3.6	0
TINSUKIA	1909	71.7	28.6	18.1	191.9	214.5	554.4	517.6	469.3	169.2	152.4	5.3	2
TINSUKIA	1910	28.9	86.3	175.6	253.7	229.3	544.6	465.9	447.8	272.2	243.9	29.7	15
TINSUKIA	1911	81.9	22.6	153.2	203.5	243.5	331	490.8	440.6	229.3	206	78.8	3.8
TINSUKIA	1912	24.7	119.7	109.9	220.8	225.2	666.8	551.3	390.6	374.3	121	21.3	5.4
TINSUKIA	1913	42.7	127.8	216.5	695.3	266.9	504.7	478.4	393.3	370.6	136.7	6.6	53.9
TINSUKIA	1914	7.8	108.6	117.8	167.3	158.2	302.7	299.7	634.8	253.5	146.8	13.5	0
TINSUKIA	1915	26.2	71.7	127.8	132.7	467.2	293.2	542.9	624.1	374.4	110.5	24.6	26.2
TINSUKIA	1916	31	71.8	180	284.6	205.7	354.3	609.6	440.5	164.5	198.8	19.3	0
TINSUKIA	1917	36.1	114	79.2	292.9	222.6	472.5	495.5	220.2	244.8	127.8	3.8	9.7
TINSUKIA	1918	20.9	57.1	179.4	126.3	290.4	511.3	489.3	540.7	481.8	113.3	4.8	5.4
TINSUKIA	1919	48.9	68.3	12.7	174	155.8	517.7	624.1	225.5	472.8	105.3	28	4.9
TINSUKIA	1920	6.6	71	254.2	174.7	263.8	437.5	227.3	500.2	207.1	116.8	2.8	4.8
TINSUKIA	1921	70.2	32.7	217.5	420	230.3	207.7	523.7	506.9	321.8	154.9	0	19.3

TABLE 4.2.2: MONTHLY RAINFALL DATA OF TINSUKIA

DISTRICT	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEP	OCT	NOV	DEC
TINSUKIA	**1922**	**64.1**	**17.8**	**117.9**	**336.6**	**121.9**	**559.3**	**464.4**	**446**	**268.1**	**107.8**	**23.4**	**23.3**
TINSUKIA	**1923**	**0**	**60.4**	**19.3**	**230.8**	**233**	**340.7**	**641.1**	**417.9**	**480.6**	**118.4**	**38.6**	**9.4**
TINSUKIA	**1924**	**26.7**	**54.8**	**48.4**	**269.5**	**255.2**	**406**	**519.3**	**466.1**	**226.8**	**211.5**	**59.4**	**0**
TINSUKIA	**1925**	**37.5**	**32.6**	**197.1**	**243.3**	**490.7**	**350**	**382.2**	**615**	**187**	**144.4**	**0**	**0**
TINSUKIA	**1926**	**75**	**36.5**	**203.8**	**145.7**	**269.4**	**346.6**	**508.6**	**454**	**318.1**	**322.3**	**15**	**14**
TINSUKIA	**1927**	**21.1**	**85.8**	**143.1**	**381.1**	**192**	**335.2**	**352.7**	**286.4**	**408.4**	**116.6**	**25.1**	**0**
TINSUKIA	**1928**	**20**	**46.9**	**148.8**	**120.5**	**229**	**407.9**	**332.4**	**424.5**	**452.5**	**184.8**	**17.6**	**7.4**
TINSUKIA	**1929**	**69.5**	**11.2**	**81.8**	**361.7**	**308.5**	**470.6**	**480.5**	**273.4**	**435.6**	**178.3**	**48.8**	**33.3**
TINSUKIA	**1930**	**29**	**33.5**	**76.7**	**231.6**	**225.3**	**254.7**	**320.3**	**472.3**	**635.3**	**214.4**	**95**	**17.6**
TINSUKIA	**1931**	**33.1**	**124.2**	**106.4**	**442.4**	**235.5**	**490.5**	**651.5**	**312.4**	**367.1**	**189.7**	**30.3**	**20.1**
TINSUKIA	**1932**	**29.1**	**42.5**	**150.4**	**111.5**	**450.1**	**641.7**	**341**	**429.1**	**404.6**	**47**	**106.7**	**43.4**
TINSUKIA	**1933**	**23.8**	**73.6**	**47.5**	**261.7**	**244.9**	**543.5**	**616**	**672.9**	**155.6**	**83.2**	**21.6**	**3.8**
TINSUKIA	**1934**	**47.5**	**59.6**	**82.6**	**420.2**	**253.4**	**406.8**	**703.5**	**261.3**	**385.9**	**174.6**	**88.3**	**18.6**
TINSUKIA	**1935**	**5.6**	**105.5**	**101.2**	**219.4**	**227.4**	**559.2**	**568.7**	**524.4**	**413.6**	**39.7**	**35**	**0**
TINSUKIA	**1936**	**28.7**	**135.8**	**29.7**	**246.3**	**290.8**	**394.6**	**669.9**	**384.3**	**364.1**	**149.3**	**40.1**	**34.8**
TINSUKIA	**1937**	**0**	**83.6**	**55.6**	**126.1**	**427.9**	**346**	**418.6**	**314.5**	**451.8**	**133.5**	**7.4**	**0**
TINSUKIA	**1938**	**52.5**	**50**	**217.9**	**228.3**	**193.9**	**655.4**	**662.4**	**445.2**	**432.2**	**84.4**	**48.2**	**0**
TINSUKIA	**1939**	**0**	**106.7**	**0**	**548.2**	**393.2**	**411**	**645.5**	**215.4**	**277.5**	**182.3**	**6.6**	**17.3**
TINSUKIA	**1940**	**3**	**56.6**	**184.2**	**127.5**	**426.9**	**316.5**	**546.3**	**279.6**	**260.7**	**0**	**0**	**7.6**
TINSUKIA	**1941**		**24.2**	**133.3**	**391.6**	**314.7**	**484.4**	**524.3**	**360.6**	**404.7**	**74.9**	**0**	**20.9**
TINSUKIA	**1942**	**5.3**	**31**	**193.4**	**263.3**	**588**	**604.1**	**355.9**	**359.5**	**381.1**	**27.9**	**15.2**	**0**
TINSUKIA	**1943**		**80.3**	**343.8**	**269.1**	**265.6**	**359.2**	**427**	**553.7**	**311.7**	**65.6**	**0**	**9.4**
TINSUKIA	**1944**	**54.4**	**86.5**	**84.7**	**115.1**	**383.8**	**629.7**	**323.2**	**182.6**	**540.4**		**10.7**	**78.1**
TINSUKIA	**1945**	**34.6**	**41.4**	**48.2**	**79.5**	**241.1**	**417.2**	**426.8**	**433.3**	**191.7**	**63.7**		
TINSUKIA	**1946**			**30.8**	**202.9**	**166.4**	**608.8**	**694.4**	**411.7**	**261.4**	**185**	**0**	**0**
TINSUKIA	**1947**	**14.2**	**71.6**	**112.8**	**444.1**	**401.4**	**406.2**	**800.3**	**434.4**	**112.7**	**239**	**0**	**37.9**
TINSUKIA	**1948**	**45.2**	**49**	**75.2**			**588**	**567.2**	**469**	**241.1**	**145**	**51.1**	**9.4**
TINSUKIA	**1949**	**45.8**	**118.9**	**197.6**	**237.8**	**355.9**	**953.5**	**444.2**	**379.7**	**254**	**277.1**	**37.6**	**18.8**
TINSUKIA	**1950**	**77**	**46.7**	**76**	**115.5**	**410.2**	**356.4**	**529.1**	**547.1**	**234**	**180.2**	**57.5**	**123.7**
TINSUKIA	**1951**	**8.1**	**8.1**	**98.7**	**410.1**	**181.1**	**521.7**	**453.3**	**335.6**	**215.8**	**114.1**	**46.4**	**30.7**
TINSUKIA	**1952**	**10.7**	**32.7**	**140**	**216**	**292.2**	**429.9**	**475.2**	**512.8**	**345.9**	**201.8**	**53.1**	**10.2**
TINSUKIA	**1954**	**56.9**	**87.1**	**69.1**	**381.4**	**681.3**	**386.8**	**511.3**	**521.3**	**148.6**	**171.7**	**3.3**	**51**
TINSUKIA	**1955**	**34.4**	**28**	**278.5**	**146.9**	**179.7**	**261.3**	**868.3**	**529.3**	**342.3**	**258.6**	**25.4**	**5.6**
TINSUKIA	**1956**	**130.4**	**6.6**	**278.6**	**238.3**	**289.9**	**490.5**	**513.3**	**338**	**113.2**	**285.6**	**47.6**	**26**
TINSUKIA	**1957**	**54.1**	**68.1**	**42.9**	**399.2**	**605.4**	**549**	**479.3**	**434.9**	**172.6**	**39.1**	**25.4**	**40.4**
TINSUKIA	**1958**	**48.4**	**57.2**	**13.5**	**106.5**	**501.5**	**205**	**453.4**	**467**	**212**	**249.6**	**0.2**	**17**
TINSUKIA	**1959**	**38**	**127.5**	**82.8**	**251**	**499.5**	**336.2**	**529.2**	**392.4**	**364.7**	**204.9**	**7**	**0**
TINSUKIA	**1960**	**34**	**48**	**215.5**	**373.5**	**268.09**	**644.5**	**653.2**	**432.3**	**429.6**	**15**	**20**	**12**
TINSUKIA	**1961**	**43**	**44**	**304.5**				**337.5**		**147**		**39**	**22**
TINSUKIA	**1964**											**10.5**	**37.4**
TINSUKIA	**1965**	**17**	**40.1**	**38.7**	**76.3**	**158.4**	**301.5**						
TINSUKIA	**1966**	**8.8**	**85.4**	**75.6**	**267.6**	**165.8**				**291.1**	**84.6**	**12.6**	**1.1**
TINSUKIA	**1967**	**11.7**		**143.7**	**59.9**	**230.5**		**465.1**	**383.5**	**347.5**	**154.5**		

TABLE 4.2.3: MONTHLY RAINFALL DATA OF TINSUKIA

DISTRICT	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEP	OCT	NOV	DEC
TINSUKIA	1968	32.8	72.9	132	127.5		317.2	450		229.5	27.9	7.1	1.4
TINSUKIA	1969	64.1	8.1	129.5	232.6	192.5			494.2				
TINSUKIA	1970								719.4		161.9	23.4	
TINSUKIA	1971	40.9	44.6		87	184.6	343.7	512.4	525.5		274.3	40.2	30.2
TINSUKIA	1972	44.1		184.8			273.7	251.7	292.4	301.8	116.8	2.9	25.7
TINSUKIA	1973					79	638	330.2	472.8	391	64.6	17	0
TINSUKIA	1974	64.8	48.8	42.2	58.6								
TINSUKIA	1975	29	32.1	76.7	231.6	225.3	352.7	320.3	472.3	635.3	214.4	95	17.6
TINSUKIA	1977	63.7	50.2	42.7	377.3	254.8	569.9	695.6	388.7	451.3	48.1	52.8	48.2
TINSUKIA	1978	23	26	76.1	142.8	154.3	395.8	433.4	151.1	314.9	74.3	102.3	0
TINSUKIA	1979	16.6	16	63.7	94.3	180.4	265.9	594.3	250.6	329.2	272.5	52.7	59.4
TINSUKIA	1980	41.5	74.8	187.4	369.4	217.9	479.8	389.2	327.9	283.3	137.1	2.1	0.8
TINSUKIA	1981	33.5	72.3	162.5	144.4	175.8	395.8	578.3	435.7	297.2	55.8	20.1	17.7
TINSUKIA	1982	1	65.3	86.9	330.1	173.1	378.8	586.8	375	375.1	45.9	43.1	50.6
TINSUKIA	1983	24.9	56.6	96	230	212.2	340.5	571.5	385.3	449.7	98.1	2.8	34.3
TINSUKIA	1984	23.1	15.3	82.8	353.6	377.9	322.8	500.5	404.4	321.4	149.9	1.8	37
TINSUKIA	1985	8.2	20.1	98.3	207	86.5	401.7	787.7	303.7	191.2	23.6	4.3	15.1
TINSUKIA	1986	22.9	44.3	79.3	269.8	127	153.4	558.5	224.8	187.8	95.3	24.7	22
TINSUKIA	1987	1	14.6	132.2	185.9	161.2	410.6	614.5	379.5	348.8	73.5	30.3	16.8
TINSUKIA	1988	5.3	47	133.4	213.8	213.2	286.7	597.7	542	314.4	210.8	27.6	0
TINSUKIA	1989	11.3	136.8	77	368.4	103.8	356.3	713.1	329	272.9	135.1	15	20.8
TINSUKIA	1990	57	97.4	185	261.4	276	378.7	355	309.3	440.8	101.1	0	9.2
TINSUKIA	1991	10.9	83.8	82.6	188.1	451.1	406.3	485.8	332.2	247.8	71.2	16.7	58
TINSUKIA	1992	29.6	94.5	200.5	224.3	315.9	335.3	437.8	325	341	227	15.2	9.6
TINSUKIA	1993	57.1	87.1	95.1	74.5	373.7	378.1	500.6	431.5	229.8	56.7	4.5	0.6
TINSUKIA	1994	26.4	53.7	259	185.1	135.1	263.1	337.5	175.8	209	112.8	10.4	1.9
TINSUKIA	1995	12.2	80.6	70.1	197.2	425.3	532	422.1	584.5	530.7	73.1	33.1	15.7
TINSUKIA	1996	32.7	44.1	231.7	163.3	365.8	104.5	449.5	408.9	127.1	163.2	13.5	0.2
TINSUKIA	1997	29.7	76.6	234.6	94.2	166	461.8	402.5	211.2	318.1	47.2	50	22.3
TINSUKIA	1998	41.4	55.6	157.9	116.9	296.7	575.8	437.6	331	119.8	106.5	13.9	0.4
TINSUKIA	1999	1.6	0.3	82	211.4	260.7	436.9	482.9	337.7	276.1	165.8	20	0
TINSUKIA	2000	32.3	30.9	122.5	513.9	212.5	403.6	677.4	417.8	427.7	23.4	39.9	0
TINSUKIA	2001	10.3	25.7	64.6	149.5	203.1	511.1	394.6	237.3	230.7	168.8	5.7	6.1
TINSUKIA	2002	86.6	22	67.2	249.2	253.8	274.4	397.6	361	195.4	91	57.9	10.1
TINSUKIA	2003	19.1	61.7	101.5	195.3	210	405.6	573.2	244.1	253	129.8	4.3	2.6
TINSUKIA	2004	29.2	40.9	193.7	189	375.6	290.7	687.9	314.3	351.7	149.9	1.7	16.3
TINSUKIA	2005	63	177.1	286.3	172.4	270	311.8	526.8	428.2	110.1	151.3	27.7	0
TINSUKIA	2006	0	124.8	98.6	197.1	248.5	312.3	338.5	310.9	248.5	43.8	72.2	19.6
TINSUKIA	2007	3.6	65.9	34.2	273.4	130.6	306.6	505.6	177.3	423.3	45.9	74.7	6.2
TINSUKIA	2008	66	59.4	149.3	215.6	147.2	359.1	533.4	552.5	171.6	96.8	6.2	5.8
TINSUKIA	2009	23.1	52	27.4	218.2	122.3	272.1	305.9	533.6	227.5	118.1	39.9	18.1
TINSUKIA	2010	0.9	15.2	183.2	589.3	529.3	565.8	398.6	280.7	111.4	249.1	31.6	38.9
TINSUKIA	2011	1.75	3.58	49.42	145.99	323.07	435.93	343.22	220.22	215.21	5.63	5.3	1.01

DISTRICT	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEP	OCT	NOV	DEC
TINSUKIA	2012	3.41	4.94	2.72	149.9	265.64	107.14	406.54	385.77	234.37	47.91	72.3	0.86
TINSUKIA	2013	0.24	11.36	57.66	187.9	435.3	356.3	549.6	331.6	148.83	37.32	34.6	1.76
TINSUKIA	2014	0	13.92	19.21	173.6	147.37	434.17	539.97	405.92	145.44	10.91	0.22	0.78
TINSUKIA	2015	8.7	11.11	14.62	161.62	245.57	404.61	489.2	529.79	219.49	89.74	5.44	6.03
TINSUKIA	2016	34.4	28	278.5	146.9	179.7	261.3	868.3	529.3	342.3	248.6	25.4	5.6
TINSUKIA	2017	37.5	32.6	197.1	243.3	490.7	350	382.2	600	187	144.4	0	0
TINSUKIA	2018	22.9	44.3	79.3	269.8	157	253.4	508.5	224.8	187.8	95.3	24.7	22
TINSUKIA	2019	14	30.4	150.5	431.3	225.4	306.5	443.7	453.2	169.6	123.5	64.5	0
TINSUKIA	2020	14.1	17.8	117.9	336.6	121.9	559.3	464.4	446	268.1	109.8	23.4	23.3
TINSUKIA	2021	0.41	4.94	2.72	49.9	165.64	147.14	387.54	305.77	234.37	57.91	50.3	0.86
TINSUKIA	2022	28.9	86.3	175.6	253.7	229.3	544.6	465.9	447.8	275.2	243.9	29.7	15

TABLE 4.2.4: MONTHLY RAINFALL DATA OF TINSUKIA

The above tables (4.2.1-4.2.4) depicts the monthly rainfall data that were collected from Indian Meteorological Department.

From these monthly rainfall data seasonal and annual rainfall were calculated as shown in Table (4.2.5-4.2.7) considering that January, February (JF) representing winter season, March, April, May, (MAM) Pre-monsoon season, June, July, August, September, (JJAS) as Monsoon season and October, November, December (OND) as post-monsoon season.

Table 4.2.5: Calculated Annual and seasonal rainfall over the years (1901-39)

YEARS	ANNUAL	JF (Winter season)	MAM (Pre-Monsoon Season)	JJAS (Monsoon season)	OND (Post Monsoon season)
1901	2340.2	181.9	529.5	1462.5	166.3
1902	2695.2	45.5	528	1953.6	168.1
1903	2975.6	82.9	704.2	1997.5	191
1904	2482.6	64.4	807.2	1423	188
1905	2535.9	71.4	636	1667.6	160.9
1906	2806	128.2	1132.4	1396.2	149.2
1907	2972	191.5	517.9	2222.4	40.2
1908	3066.6	113.9	674.8	2085.5	192.4
1909	2395	100.3	424.5	1710.5	159.7
1910	2792.9	115.2	658.6	1730.5	288.6
1911	2485	104.5	600.2	1491.7	288.6
1912	2831	144.4	555.9	1983	147.7
1913	3293.4	170.5	1178.7	1747	197.2
1914	2210.7	116.4	443.3	1490.7	160.3
1915	2821.5	97.9	727.7	1834.6	161.3
1916	2560.1	102.8	670.3	1568.9	218.1
1917	2319.1	150.1	594.7	1433	141.3
1918	2820.7	78	596.1	2023.1	123.5
1919	2438	117.2	342.5	1840.1	138.2
1920	2266.8	77.6	692.7	1372.1	124.4
1921	2705	102.9	867.8	1560.1	174.2
1922	2550.6	81.9	576.4	1737.8	154.5
1923	2590.2	60.4	483.1	1880.3	166.4
1924	2543.7	81.5	573.1	1618.2	270.9
1925	2679.8	70.1	931.1	1534.2	144.4
1926	2709	111.5	618.9	1627.3	351.3
1927	2347.5	106.9	716.2	1382.7	141.7
1928	2392.3	66.9	498.3	1617.3	209.8
1929	2753.2	80.7	752	1660.1	260.4
1930	2605.7	62.5	533.6	1682.6	327
1931	3003.2	157.3	784.3	1821.5	240.1
1932	2797.1	71.6	712	1816.4	197.1
1933	2748.1	97.4	554.1	1988	108.6
1934	2902.3	107.1	756.2	1757.5	281.5
1935	2799.7	111.1	548	2065.9	74.7
1936	2768.4	164.5	566.8	1812.9	224.2
1937	2365	83.6	609.6	1530.9	140.9
1938	3070.4	102.5	640.1	2195.2	132.6
1939	2803.7	106.7	941.4	1549.4	206.2

Table 4.2.6: Calculated Annual and seasonal rainfall over the years (1940-83)

YEARS	ANNUAL	JF (Winter season)	MAM (Pre-Monsoon Season)	JJAS (Monsoon season)	OND (Post Monsoon season)
1940	2208.9	59.6	738.6	1403.1	7.6
1941	2733.6		839.6	1774	95.8
1942	2824.7	36.3	1044.7	1700.6	43.1
1943	2685.4		878.5	1651.6	75
1944	2489.2	140.9	583.6	1675.9	
1945	1977.5	76	368.8	1469	
1946	2561.4		400.1	1976.3	185
1947	3074.6	85.8	958.3	1753.6	276.9
1948		94.2		1865.3	205.5
1949	3320.9	164.7	791.3	2031.4	333.5
1950	2621.64	123.7	601.7	1666.6	361.4
1951	2423.7	16.2	689.9	1526.4	191.2
1952	2720.5	43.4	648.2	1763.8	265.1
1954	3069.8	144	1131.8	1568	226
1955	2958.4	62.5	605.2	2001.1	289.6
1956	2758	137.1	806.8	1455	359.1
1957	2910.4	122.2	1047.5	1635.8	104.9
1958	2331.3	105.6	621.5	1337.4	266.8
1959	2833.1	165.4	833.3	1622.5	211.9
1960	3417.49				47
1961	3489.58	87			
1964	1605.72				
1965	3731.79	57.1	273.4		
1966	4520.98	94.2	509		98.3
1967	3992.72		434.1		
1968	2790.53	105.7			36.4
1969	2359.1	72.2	554.6		
1970	2311.29				
1971	2619.12	85.5			344.7
1972	4999.52			1119.6	145.4
1974	4325.92	113.6			
1975	2698.35	61.1	674.8	2105.5	327
1977	3042.99	113.9	373.2	1295.2	149
1978	2736.67	49.1	373.1	1295.2	176.6
1979	3005	32.6	338.4	1440.1	384.6
1980	4068.77	116.3	774.7	1480.1	140
1981	2389	105.8	482.7	1706.9	93.6
1982	2511.8	66.3	590.2	1715.7	139.6
1983	2502.1	81.6	538.3	1747	135.3

Table 4.2.7: Calculated Annual and seasonal rainfall over the years (1984-22)

YEARS	A NNUAL	JF (Winter season)	MAM (Pre-Monsoon Season)	JJAS (Monsoon season)	OND (Post Monsoon season)
1984	2590.3	38.3	814.2	1549.1	188.7
1985	2147.3	28.3	391.8	1684.3	42.9
1986	1809.7	67.2	476.1	1124.5	141.9
1987	2688	15.6	479.3	1753.4	
1988	2958	52.3	460.4		238.4
1989	2539.5	148.1	549.2	1671.3	170.9
1990	2470.8	154.4	722.4	1483.7	110.3
1991	2434.6	94.7	721.9	1472.2	145.9
1992	2555.7	124.1	740.7	1439.1	251.8
1993	2289.2	144.2	543.3	1539.9	61.8
1994	1769.9	80.1	579.2	985.4	125.2
1995	2976.6	92.8	692.6	2069.3	121.9
1996	2104.4	76.8	760.7	1089.9	177
1997	2113.9	106.3	494.7	1393.6	119.4
1998	2253.5	96.9	571.6	1464.2	120.8
1999	2275.2	1.9	554	1533.6	185.7
2000	2901.9	63.2	848.9	1926.5	63.3
2001	2007.5	36.1	417.3	1373.6	180.6
2002	2066	108.6	570.2	1228.3	158.9
2003	2200.2	80.8	506.8	1475.9	136.7
2004	2640.9	70.1	758.2	1644.6	167.9
2005	2524.7	240.1	728.7	1377	179
2006	2014.8	124.8	544.2	1210.2	135.6
2007	2047.3	69.5	438.2	1412.8	126.8
2008	2362.9	125.4	512.2	1616.7	108.7
2009	1958.1	75.1	367.9	1339.1	176
2010	2994	16.1	1301.8	1356.5	319.6
2011	1750.33	5.33	518.48	1214.58	11.94
2012	1688	8.35	418.26	1133.82	121.07
2013	2152	11.6	680.86	1386.33	73.68
2014	1893	13.92	340.18	1525.5	11.91
2015	2185	19.81	421.81	1643.09	101.21
2016	2940	62.4	605.1	2001.2	279.6
2017	2664	70.1	931.1	1519.2	144.4
2018	1889	67.2	506.1	1174.5	142
2019	2411	44.4	807.2	1373	188
2020	2502	31.9	576.4	1737.8	156.5
2021	1407	5.35	218.26	1074.82	109.07
2022	2795.56	115.2	658.6	1733.5	288.6

5. RESULTS AND DISCUSSIONS

5.1 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.

1. Mann-Kendall trend test / Two-tailed test (JANUARY):

Kendall's tau	-0.205
S	-1272
Var(S)	158134.000
p-value (Two-tailed)	0.001
alpha	0.05

Sen's slope:

	Value	Lower bound (5%)	Upper bound (5%)
Slope	-0.191	-0.196	-0.187
Intercept	403.618	399.413	407.822

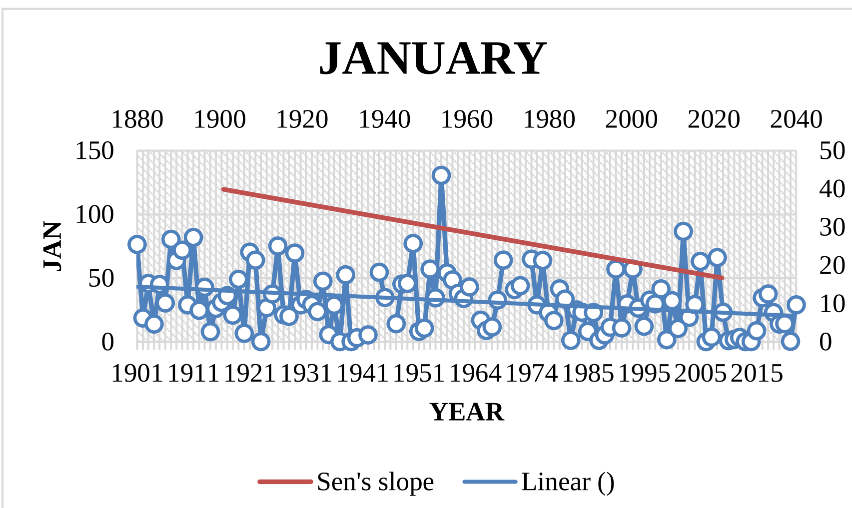

Fig 5.1: January month rainfall trend

• The Mann-Kendall test identified a significant decreasing trend with Kendall's tau of - 0.205 and a p-value of 0.001.

• Sen's slope of -0.191 highlights a consistent decline in rainfall over time, reflecting changing climatic patterns.

2. Mann-Kendall trend test / Two-tailed test (FEBRUARY):

Kendall's tau	-0.185
S	-1149
Var(S)	158151.667
p-value (Two-tailed)	0.004
alpha	0.05

Sen's slope:

	Value	Lower bound (5%)	Upper bound (5%)
Slope	-0.256	-0.263	-0.247
Intercept	553.726	545.141	560.769

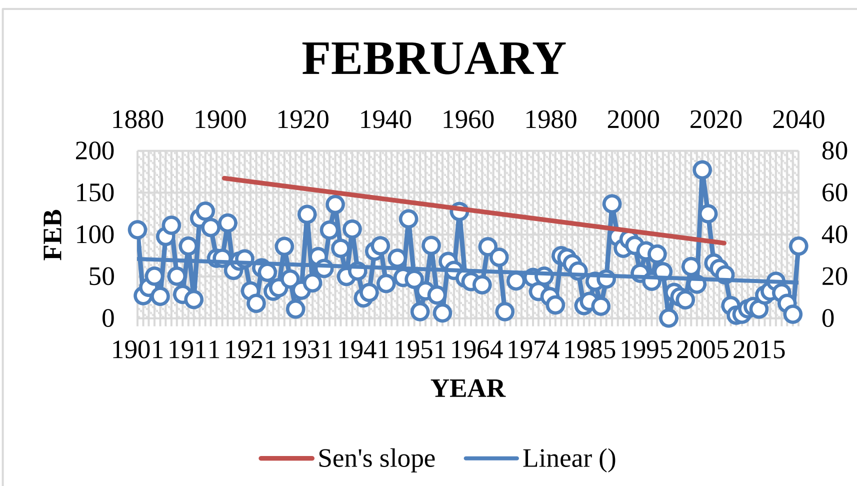

Fig 5.2: Trend test for February month rainfall

- The declining trend is statistically significant (p-value = 0.004) with a Kendall's tau of -0.185.
- A slope of -0.256 indicates a noticeable reduction in rainfall, possibly linked to reduced winter precipitation

3. Mann-Kendall trend test / Two-tailed test (MARCH):

Kendall's tau	-0.065
S	-418
Var(S)	166739.333
p-value (Two-tailed)	0.307
alpha	0.05

Sen's slope:

	Value	Lower bound (5%)	Upper bound (5%)
Slope	-0.211	-0.224	-0.200
Intercept	521.978	511.144	534.671

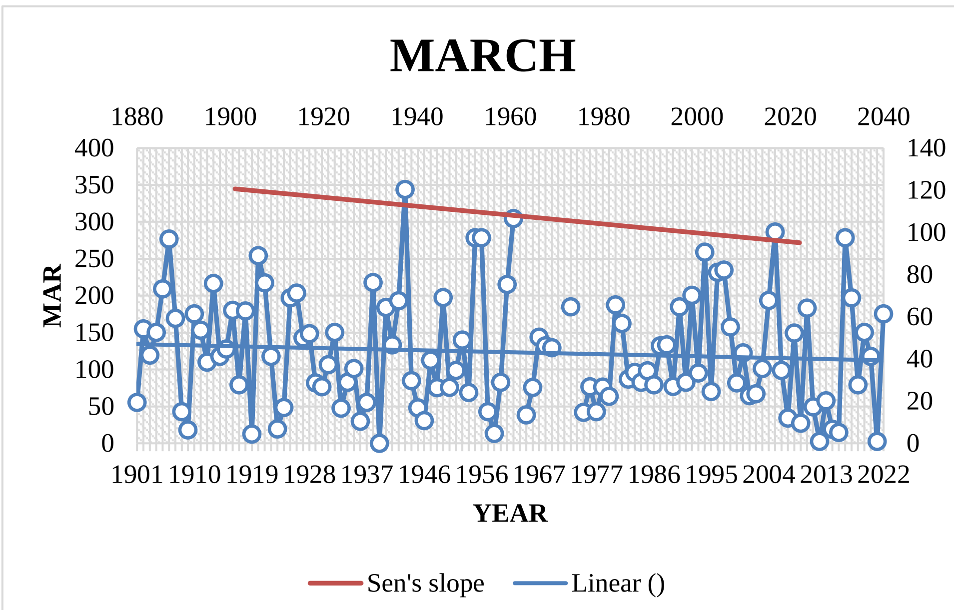

Fig 5.3: Trend test for March month rainfall

- This month exhibits no statistically significant trends, as its p-value 0.307 exceeds the 0.05 threshold. It may require additional investigation into other influencing factors.

4. Mann-Kendall trend test / Two-tailed test (APRIL):

Kendall's tau	-0.145
S	-903
Var(S)	158153.667
p-value (Two-tailed)	0.023
alpha	0.05

Sen's slope:

	Value	Lower bound (5%)	Upper bound (5%)
Slope	-0.629	-0.644	-0.614
Intercept	1457.336	1442.988	1471.830

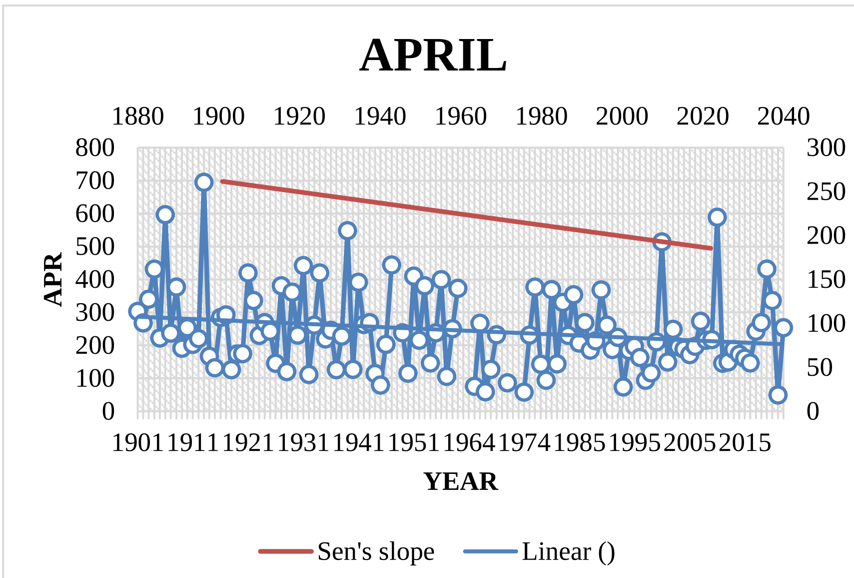

Fig 5.4: Trend test for April month rainfall

- This month show substantial decreasing trends (p-value < 0.05) with Sen's slopes of 0.629.
- This demonstrates changes during transitional and monsoon periods, affecting water availability and agriculture.

5. Mann-Kendall trend test / Two-tailed test (MAY):

Kendall's tau	-0.034
S	-206
Var(S)	153974.667
p-value (Two-tailed)	0.601
alpha	0.05

Sen's slope:

	Value	Lower bound (5%)	Upper bound (5%)
Slope	-0.135	-0.150	-0.119
Intercept	498.942	466.021	528.250

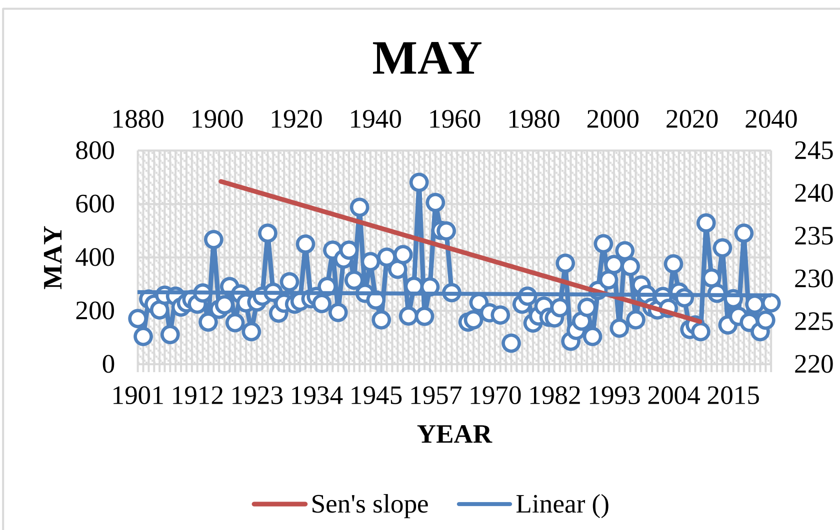

Fig 5.5: Trend test for May month rainfall

- May exhibit no statistically significant trends, as the p-value 0.601 for March exceed the 0.05 threshold.
- It does not show significant changes, indicating stable rainfall. This stability could be critical for transitioning into the monsoon season, providing consistent water availability for agricultural preparations

6 Mann-Kendall trend test / Two-tailed test (JUNE):

Kendall's tau	-0.161
S	-984
Var(S)	153972.667
p-value (Two-tailed)	0.012
alpha	0.05

Sen's slope

	Value	Lower bound (5%)	Upper bound (5%)
Slope	-0.871	-0.888	-0.835
Intercept	2110.486	2037.929	2142.085

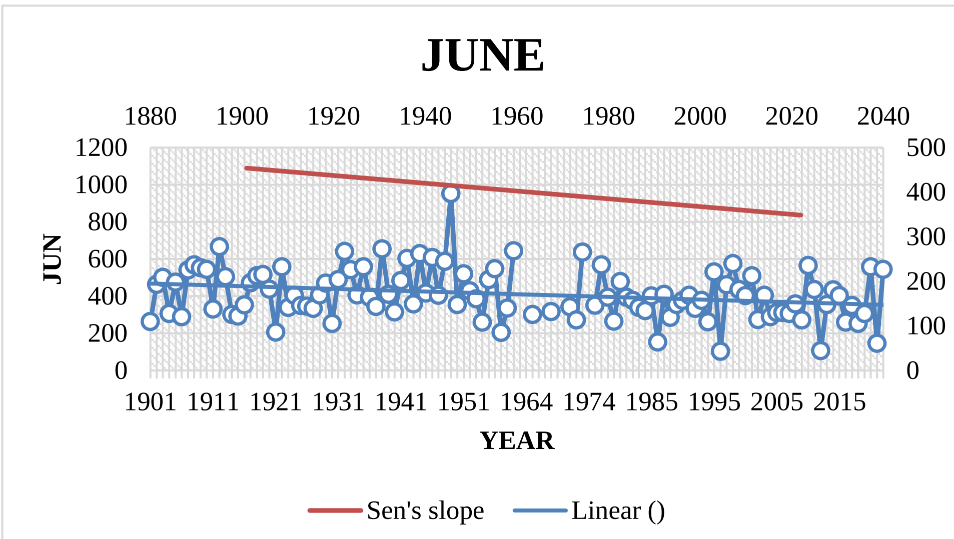

Fig 5.6: Trend test for June month rainfall

- The June month shows substantial decreasing trend of p-value 0.012< 0.05 with a Sen's slope of -0.871.
- A declining trend in June's rainfall is concerning as it marks the start of the monsoon season. Reduced rainfall during this month could delay sowing activities and affect early crop growth

7. **Mann-Kendall trend test / Two-tailed test (JULY):**

Kendall's tau	-0.035
S	-215
Var(S)	158155.667
p-value (Two-tailed)	0.591
alpha	0.05

Sen's slope:

	Value	Lower bound (5%)	Upper bound (5%)
Slope	-0.184	-0.202	-0.161
Intercept	850.920	828.215	869.547

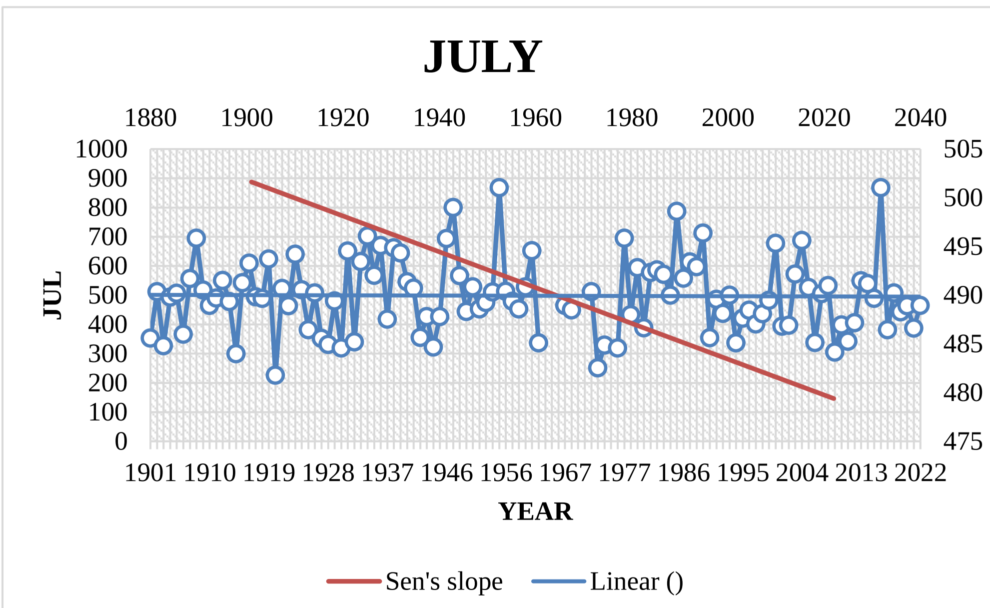

Fig 5.7: Trend test for July month rainfall

- The July month shows a high p-value 0.591>0.05 that implies insufficient evidence to reject the null hypothesis of no trend.
- The Sen's slope of -0.184, indicates a minor reduction in rainfall per year over time.
- July shows no significant trend, indicating relatively stable rainfall. This stability is crucial for maintaining water levels during the peak monsoon period, supporting agricultural and ecological needs.

8. Mann-Kendall trend test / Two-tailed test (AUGUST):

Kendall's tau	-0.198
S	-1228
Var(S)	158154.667
p-value (Two-tailed)	0.002
alpha	0.05

Sen's slope:

	Value	Lower bound (5%)	Upper bound (5%)
Slope	-0.946	-0.963	-0.939
Intercept	2256.060	2248.774	2272.727

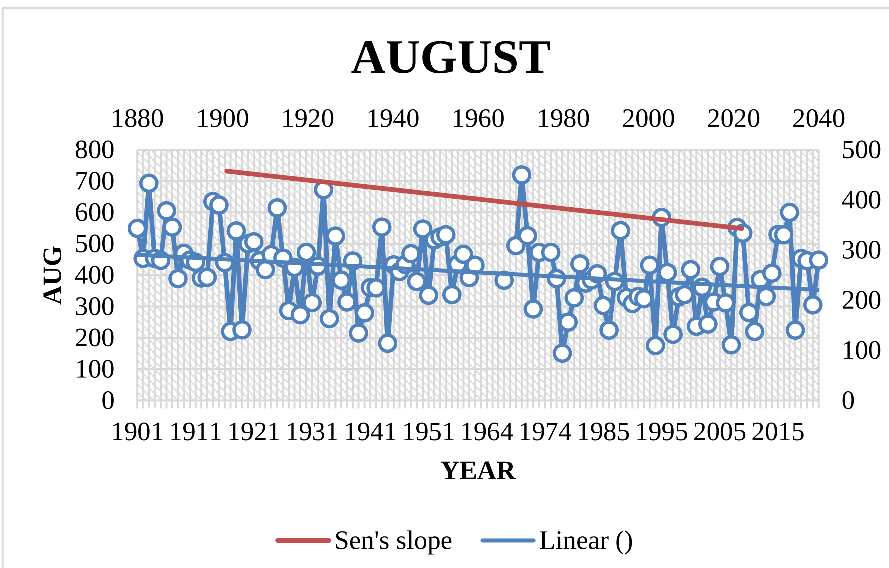

Fig 5.8: Trend test for August month rainfall

- The August month shows substantial decreasing trend of p-value 0.002< 0.05 with a Sen's slope of -0.946.
- This exhibits a marked decline in rainfall. This reduction could severely impact mid-monsoon water availability, potentially disrupting crop irrigation and increasing water scarcity risks.

9. Mann-Kendall trend test / Two-tailed test (SEPTEMBER):

Kendall's tau	-0.203
S	-1258
Var(S)	158154.667
p-value (Two-tailed)	0.002
alpha	0.05

Sen's slope:

	Value	Lower bound (5%)	Upper bound (5%)
Slope	-1.000	-1.019	-0.968
Intercept	2255.371	2223.796	2274.646

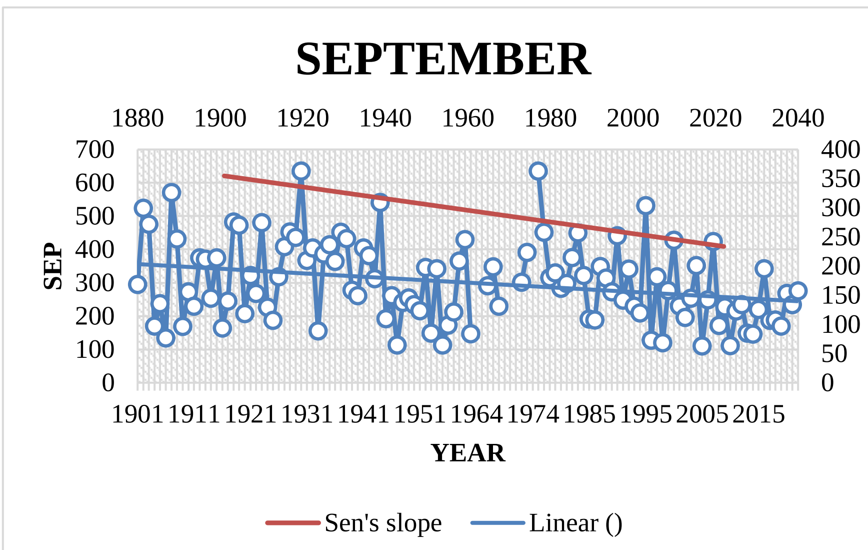

Fig 5.9: Trend Test for September Month rainfall

- The September month shows substantial decreasing trend of p-value 0.002< 0.05 with a Sen's slope of -1.000.
- This month's significant decline suggests a weakening of the monsoon towards its end. This can affect late-stage crops and reduce the replenishment of surface water bodies and aquifers.

10. Mann-Kendall trend test / Two-tailed test (OCTOBER):

Kendall's tau	-0.133
S	-827
Var(S)	158153.667
p-value (Two-tailed)	0.038
alpha	0.05

Sen's slope:

	Value	Lower bound (5%)	Upper bound (5%)
Slope	-0.376	-0.387	-0.364
Intercept	856.342	845.533	866.736

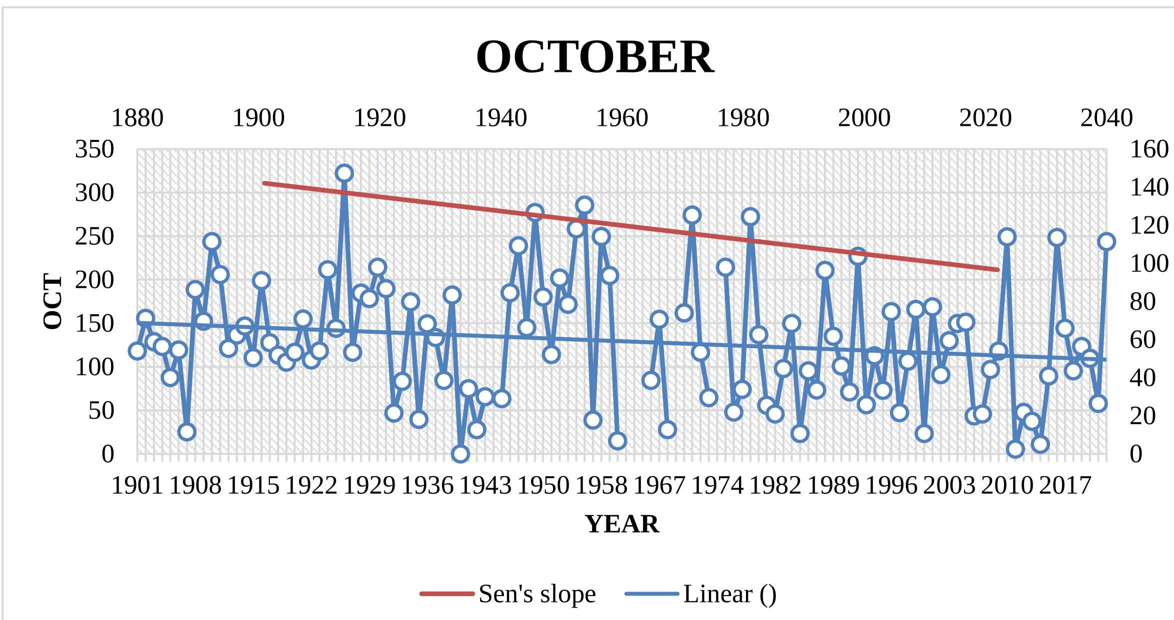

Fig 5.10: Trend test for October month rainfall

- The October month shows a decreasing trend of p-value 0.038< 0.05 with a Sen's slope of -0.376
- October shows a decline in post-monsoon rainfall. Reduced precipitation during this period can hinder aquifer recharge and soil moisture restoration, critical for the winter cropping season

11. **Mann-Kendall trend test / Two-tailed test (NOVEMBER):**

Kendall's tau	0.010
S	61
Var(S)	162272.333
p-value (Two-tailed)	0.882
alpha	0.05

Sen's slope:

	Value	Lower bound (5%)	Upper bound (5%)
Slope	0.000	0.000	0.003
Intercept	23.400	17.395	23.400

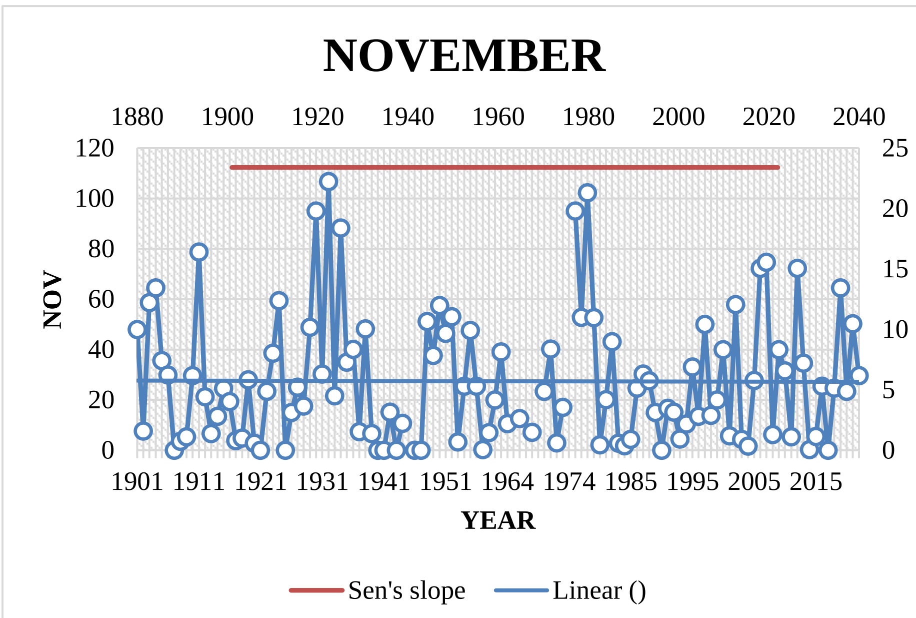

Fig 5.11: Trend test for November month rainfall

- The November month shows no trend of p-value 0.882> 0.05 with a Sen's slope of 0.00
- November shows no significant trend, suggesting stable rainfall. However, the negligible slope highlights minimal rainfall during this month, typical for the post-monsoon dry season.

12. Mann-Kendall trend test / Two-tailed test (DECEMBER):

Kendall's tau	0.017
S	102
Var(S)	156712.000
p-value (Two-tailed)	0.799
alpha	0.05

Sen's Slope:

	Value	Lower bound (5%)	Upper bound (5%)
Slope	0.000	0.000	0.000
Intercept	9.400	9.400	9.400

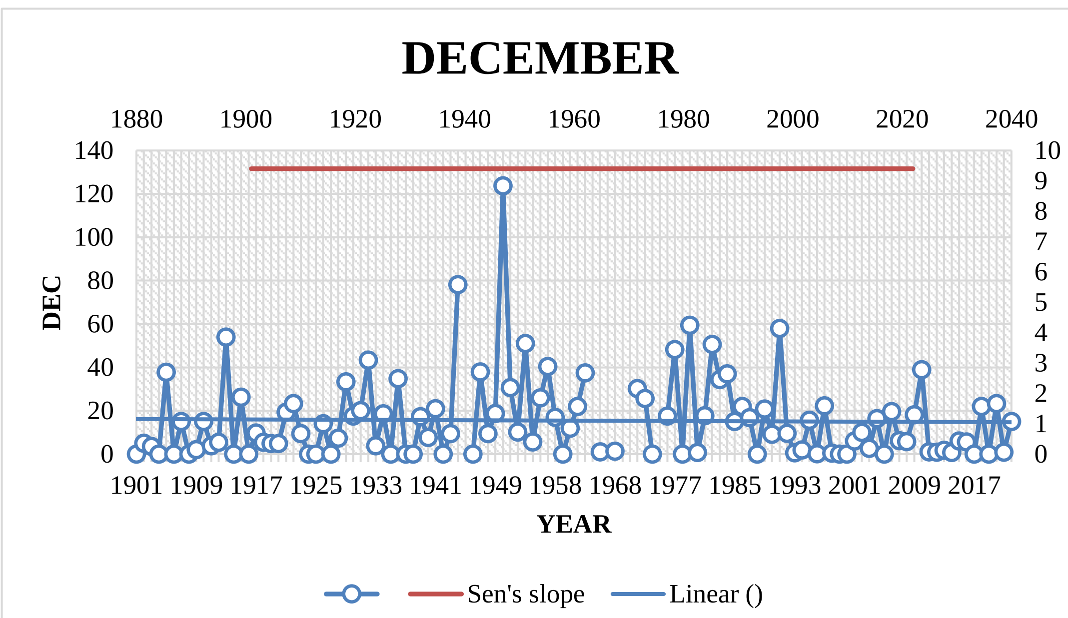

Fig 5.12: Trend test for December month rainfall

- The December month shows no trend of p-value 0.799> 0.05 with a Sen's slope of 0.00
- December also does not exhibit a significant trend. Like November, rainfall remains negligible and stable, consistent with its role in the dry winter season.

13. Mann-Kendall trend test / Two-tailed test (ANNUAL):

Kendall's tau	-0.217
S	-1348
Var(S)	158162.667
p-value (Two-tailed)	0.001
alpha	0.05

Sen's slope:

	Value	Lower bound (5%)	Upper bound (5%)
Slope	-3.778	-3.855	-3.722
Intercept	10007.667	9954.283	10081.248

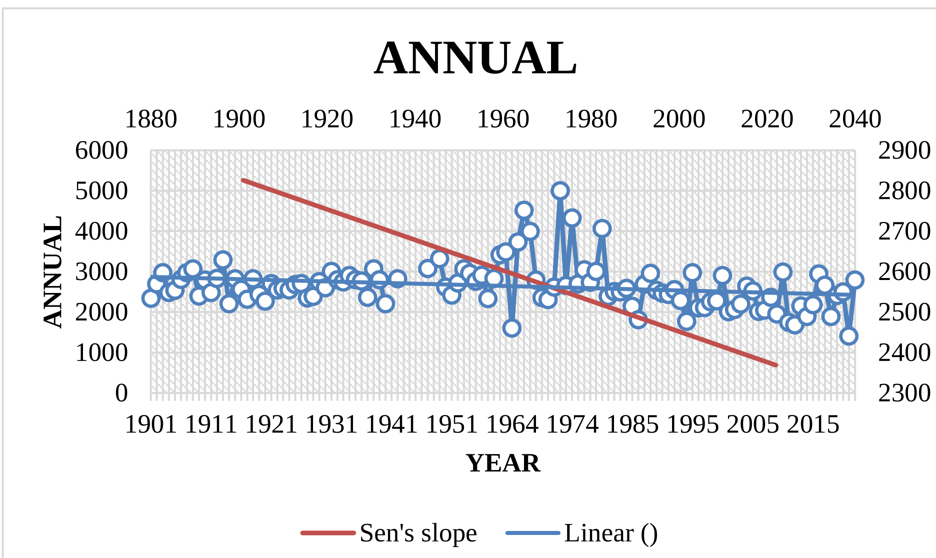

Fig 5.13: Trend test for Annual rainfall

- The Annual rainfall shows a decreasing trend of p-value 0.001< 0.05 with a Sen's slope of -3.778
- This shows a decline in annual rainfall. Reduced precipitation implies hinder aquifer recharge and soil moisture restoration, critical for cropping and other water related activities

14. Mann-Kendall trend test / Two-tailed test (JF (Winter season):

Kendall's tau	-0.244
S	-1434
Var(S)	145833.333
p-value (Two-tailed)	0.000
alpha	0.05

Sen's slope:

	Value	Lower bound (5%)	Upper bound (5%)
Slope	-0.441	-0.447	-0.435
Intercept	954.311	941.069	966.435

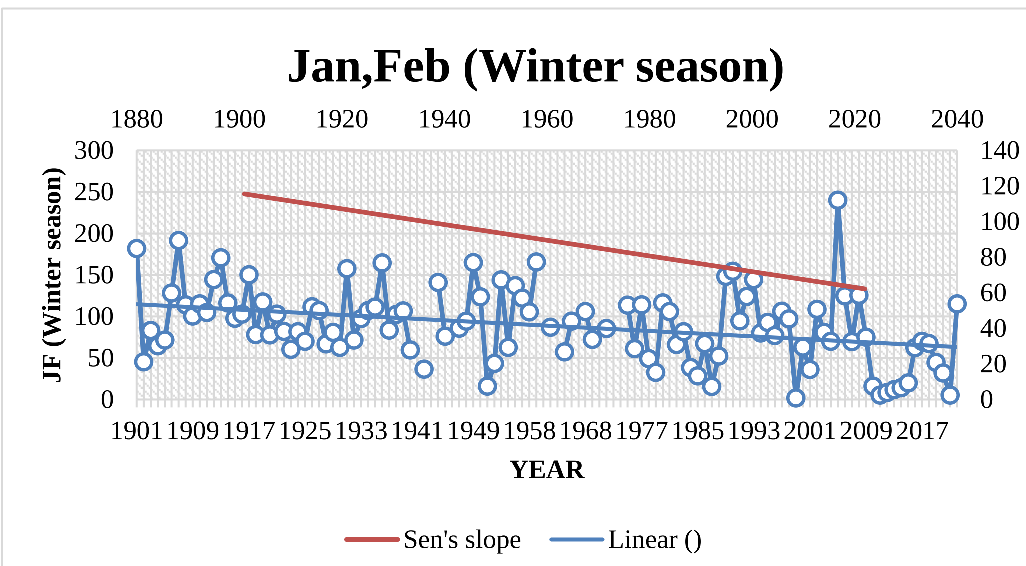

Fig 5.14: Trend test for Winter season rainfall

- The Winter season rainfall shows a decreasing trend of p-value 0.00< 0.05 with a Sen's slope of -0.441
- This shows a declining rainfall trend that might cause potential effects in agriculture and ecosystem.

15. Mann-Kendall trend test / Two-tailed test (MAM) (Pre Monsoon Season):

Kendall's tau	-0.117
S	-678
Var(S)	141880.000
p-value (Two-tailed)	0.072
alpha	0.05

Sen's slope:

	Value	Lower bound (5%)	Upper bound (5%)
Slope	-0.859	-0.877	-0.839
Intercept	2281.562	2261.840	2298.877

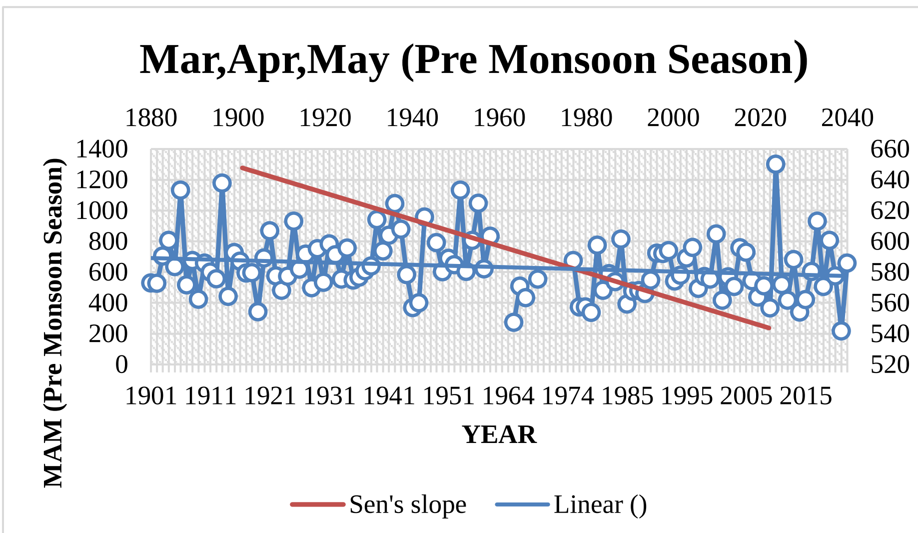

Fig 5.15: Trend test for Pre-Monsoon Season rainfall

- The Pre-Monsoon season rainfall shows slightly declining trend of p-value 0.072< 0.05 with a Sen's slope of -0.859
- This shows a declining rainfall trend that might cause potential effects in agriculture and ecosystem

16. Mann-Kendall trend test / Two-tailed test (JJAS (Monsoon):

Kendall's tau	-0.274
S	-1523
Var(S)	134176.333
p-value (Two-tailed)	<0.0001
alpha	0.05

Sen's slope:

	Value	Lower bound (5%)	Upper bound (5%)
Slope	-2.852	-2.895	-2.800
Intercept	7186.755	7135.892	7228.240

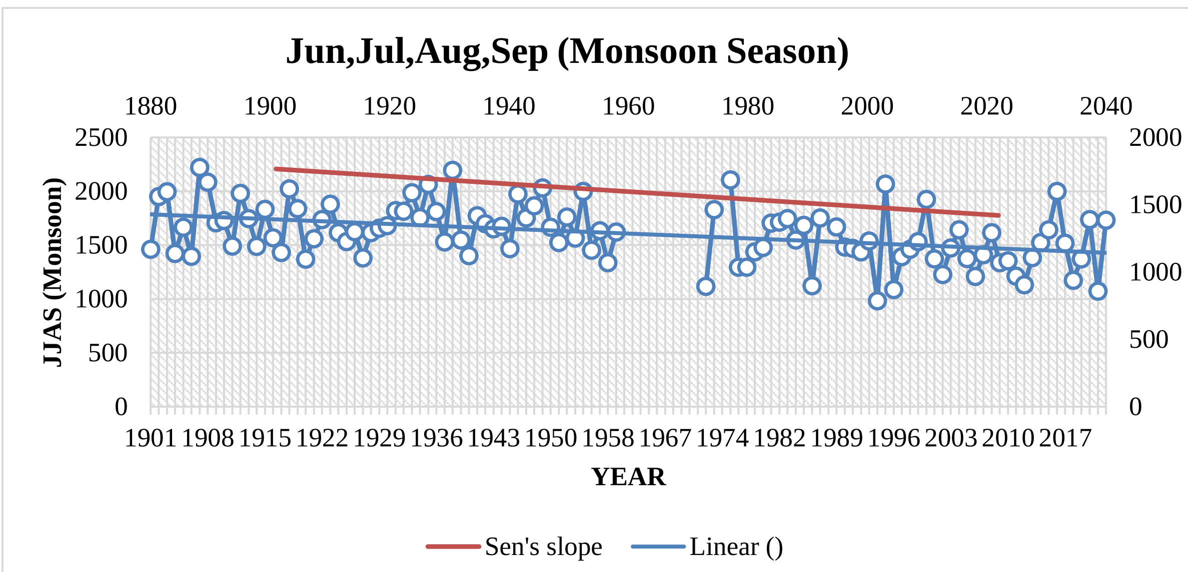

Fig 5.16: Trend test for Monsoon Season rainfall

- The Monsoon season rainfall shows a decreasing trend of p-value 0.0001< 0.05 with a Sen's slope of -2.852
- This shows a declining rainfall trend that might cause potential effects in agriculture and ecosystem

17. Mann-Kendall trend test / Two-tailed test (OND (Post Monsoon)):

Kendall's tau	-0.133
S	-770
Var(S)	141875.333
p-value (Two-tailed)	0.041
alpha	0.05

Sen's slope:

	Value	Lower bound (5%)	Upper bound (5%)
Slope	-0.356	-0.368	-0.339
Intercept	852.517	836.287	863.771

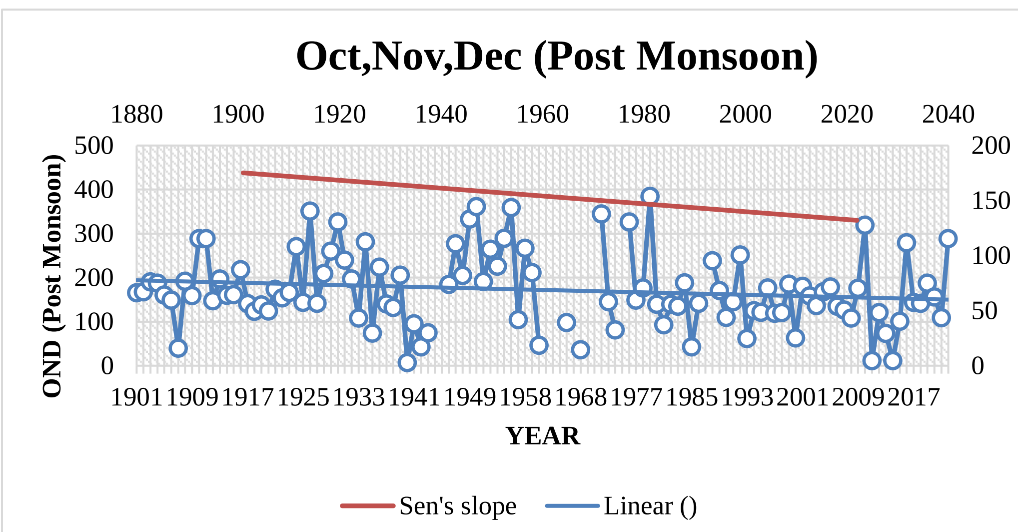

Fig 5.17: Trend test for Post Monsoon Season

- Post Monsoon season rainfall shows a decreasing trend of p-value 0.041< 0.05 with a Sen's slope of -0.356
- This shows a declining rainfall trend that might cause potential effects in agriculture and ecosystem.

Table 5.1: Summary of Mann Kendall's Trend Test Statistic

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

From the above results shown in Table 5.1 it can be justified that the results provide:

1. **Statistical Significance**: The Mann-Kendall test identified significant decreasing trends in monthly rainfall for critical periods, such as January, February, and the monsoon season (June–September). These trends are evidenced by p-values below the 5% significance threshold, confirming the reliability of the findings.
2. **Seasonal Variability:** The monsoon season, which contributes significantly to the region's water resources and agricultural productivity, exhibits a substantial declining trend with a Sen's slope of -2.852. This decline poses potential challenges for water resource management and necessitates adaptive measures in agricultural practices.
3. **Annual Trends**: The annual rainfall data further support the hypothesis of a declining trend, with meaningful results (p-value = 0.001) indicating a consistent reduction in total rainfall over time. The findings align with broader climatic changes observed globally and regionally.
4. **Methodological Robustness**: By employing both non-parametric and parametric methods, the study ensures comprehensive validation of trends. The Mann-Kendall test's ability to handle non-normal distributions and missing data makes it particularly suited for historical datasets. Additionally, Sen's slope estimation provides an interpretable measure of trend magnitude, enhancing the practical implications of the study.
5. **Implications**: The declining rainfall trends, particularly during the monsoon season, highlight critical implications for agriculture and water availability in Tinsukia. Furthermore, the study underscores the need for integrated water resource management and adaptive agricultural strategies to mitigate potential risks associated with reduced precipitation.

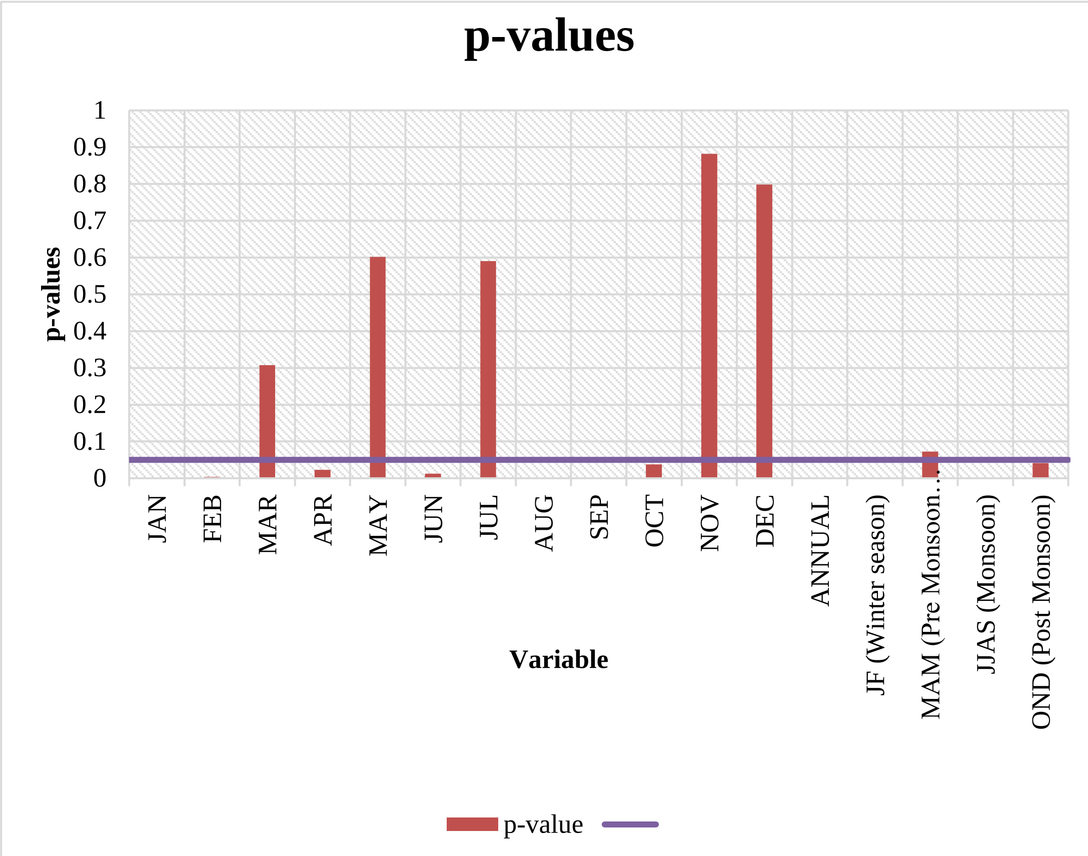

Fig 5.18: P values for rainfall trends

Figure 5.18 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

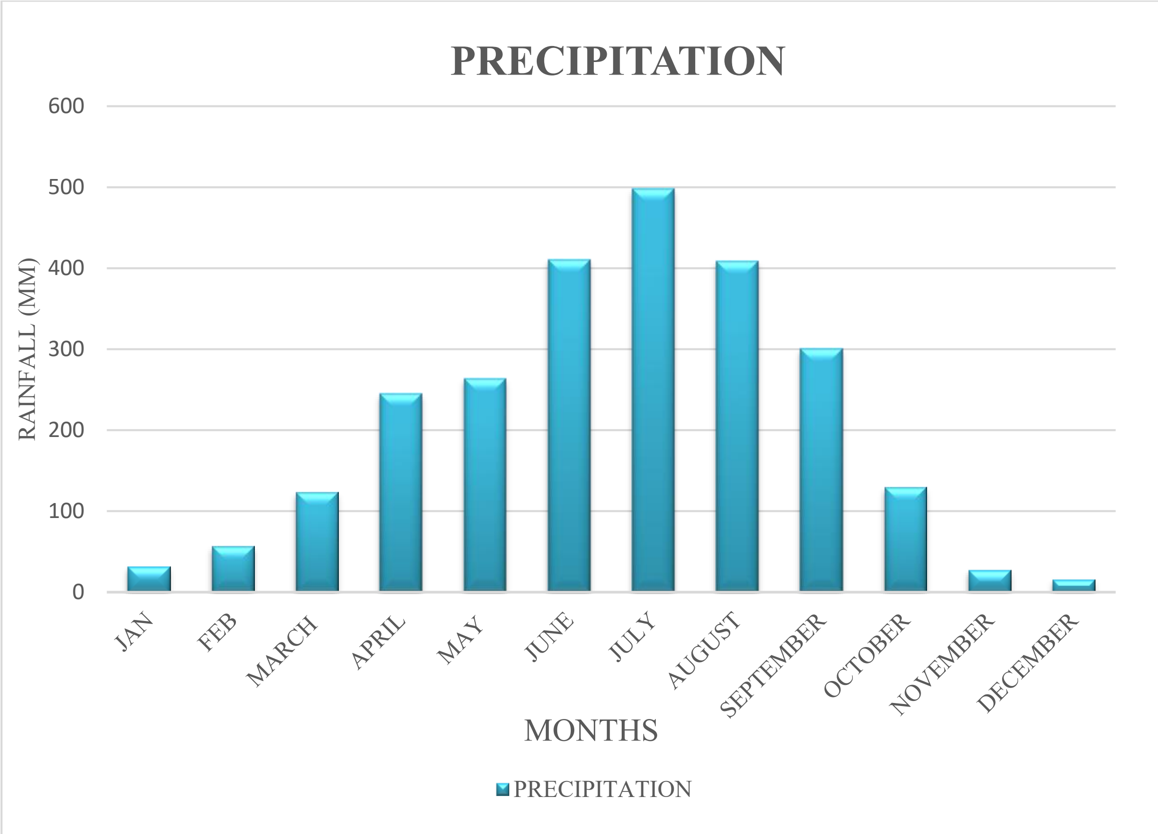

Fig 5.19: Average Monthly rainfall (1901-2022)

Figure 5.19 clearly demonstrates the typical rainfall pattern for the district of Tinsukia, the highest mean monthly rainfall was recorded in July and August and the lowest in January, November, December. It is also evident from the graph that the highest average minor season rainfall occurred in September.

5.2 Linear regression was applied to assess the relationship between rainfall (dependent variable) and year (independent variable) for each month and aggregated annual data. The analysis included key statistical metrics like R^2, p-values, and regression coefficients to determine the trend and strength of associations.

Results of Linear regression for different months and seasons:

a) **January**:

- **R^2**: 0.078, indicating 7.8% of variability in January rainfall is explained by the year.
- **Regression Coefficient**: -0.185, suggesting a decrease in rainfall by 0.185 units annually.
- **p-value**: 0.002 (**significant**), showing a statistically significant downward trend.

b) **February**:

- **R^2**: 0.055, explaining 5.5% variability.
- **Regression Coefficient**: -0.228, indicating a decline.
- **p-value**: 0.011 (**significant**).

c) **March**:

- **R^2**: 0.007, indicating negligible variability explained.
- **Regression Coefficient**: -0.179.
- **p-value**: 0.357 (**not significant**), suggesting no clear trend.

d) **April**:

- **R^2**: 0.042, explaining 4.2% variability.
- **Regression Coefficient**: -0.374.
- **p-value**: 0.026 (**significant**), indicating a decreasing trend.

e) **Other Months**:

- Results vary across months, with some showing insignificant trends (e.g., May and July) and others indicating slight declines in rainfall.

Seasonal and Annual Trends:

a) **Annual Rainfall**:

- **R^2**: 0.237, with 23.7% of variability explained by year.
- **Regression Coefficient**: Significant decline observed (details truncated in the provided data).

b) **Winter and Monsoon Seasons**:

- Significant trends observed in winter and monsoon rainfall, correlating with broader climatic changes.

The regression results highlight consistent decreasing trends in rainfall for specific months and seasons, particularly during the monsoon period. The statistically significant negative coefficients for January, February, and April indicate that climate variability or other anthropogenic factors might be influencing precipitation patterns. The low R^2 values in many months suggest other factors (e.g., geographic, or atmospheric influences) may play a role in rainfall variability.

This analysis projects the necessity for targeted studies to explore the underlying causes of the observed trends and their implications for water resources, agriculture, and disaster management in the region.

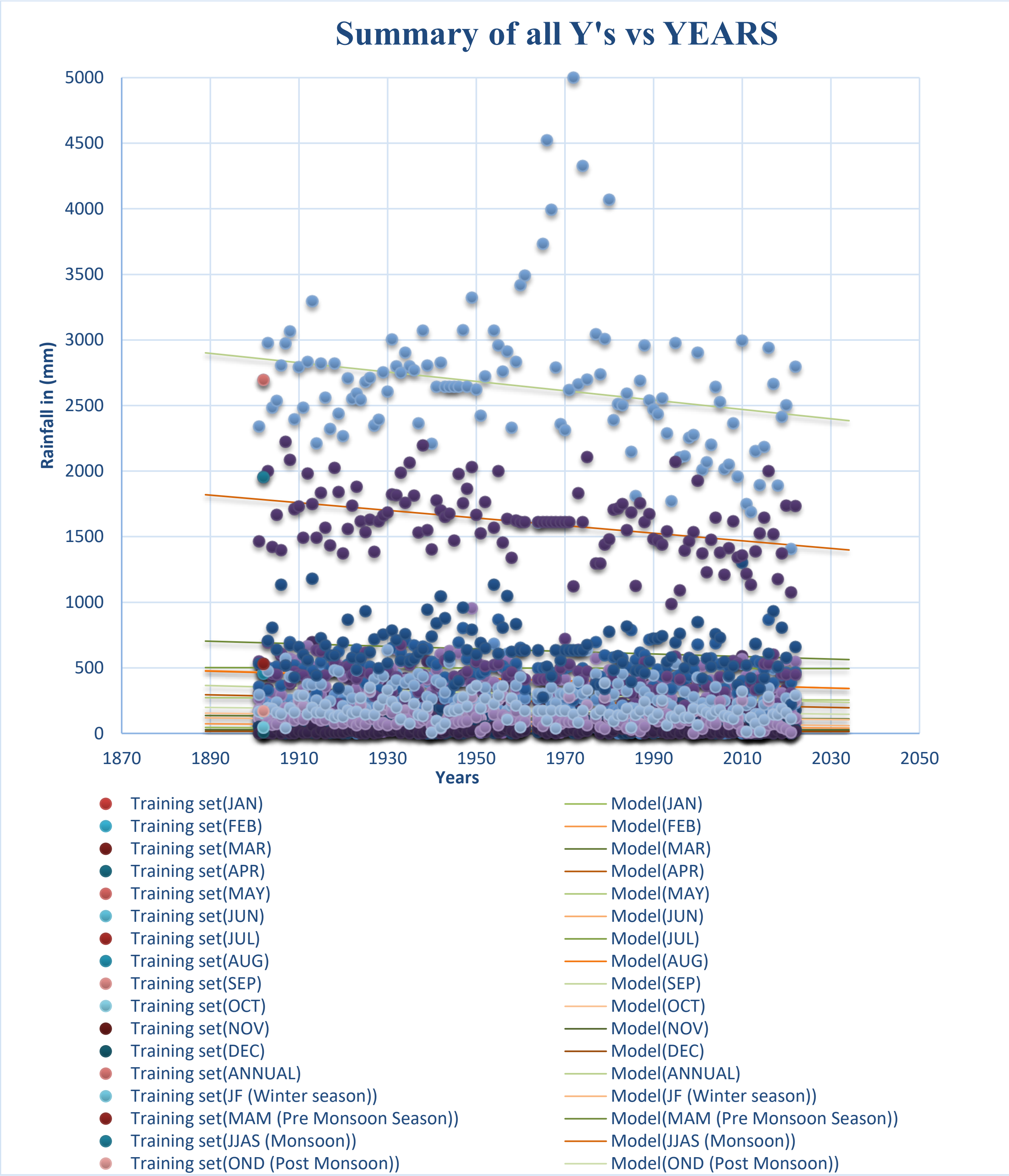

Fig 5.20: Summary of all Y’s vs Years done in XLSTAT

Table 5.2: Regression Statistic Results of monthly, annual, seasonal rainfall

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 results of the linear regression trend analysis are presented in **Table 5.2** 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 in fig 5.20. 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 REGRESSSION.**

TABLE 5.3: 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**
1916	213.342	189.4	184.34	33980.5	0.43	0.888788532	609.6	0	609.6	**2560.1**
1917	193.258	174	165.52	27396.4	-0.30	0.756023625	491.7	3.8	495.5	**2319.1**
1918	235.058	152.85	215.61	46486.9	-1.74	0.415931801	535.9	4.8	540.7	**2820.7**
1919	203.167	130.55	215.37	46386.1	-0.28	1.070593828	619.2	4.9	624.1	**2438**
1920	188.9	190.9	162.77	26495.4	-0.23	0.645848567	497.4	2.8	500.2	**2266.8**
1921	225.417	212.6	184.70	34114.5	-1.04	0.443920319	523.7	0	523.7	**2705**
1922	212.55	119.9	194.55	37849.5	-1.12	0.674430255	541.5	17.8	559.3	**2550.6**
1923	215.85	174.6	213.37	45525.7	-0.49	0.774480139	641.1	0	641.1	**2590.2**
1924	211.975	219.15	179.92	32370.1	-1.09	0.474284881	519.3	0	519.3	**2543.7**
1925	223.317	192.05	201.24	40497.9	-0.47	0.656897033	615	0	615	**2679.8**
1926	225.75	236.6	170.87	29195.2	-1.20	0.185310001	494.6	14	508.6	**2709**
1927	195.625	167.55	151.04	22813.9	-1.70	0.114983512	408.4	0	408.4	**2347.5**
1928	199.358	166.8	168.18	28283.8	-1.48	0.368547905	445.1	7.4	452.5	**2392.3**
1929	229.433	225.85	180.43	32553.7	-1.73	0.190081153	469.3	11.2	480.5	**2753.2**
1930	217.142	219.85	189.71	35988.9	0.77	1.046492965	617.7	17.6	635.3	**2605.7**
1931	250.267	212.6	204.97	42011.5	-0.56	0.622043879	631.4	20.1	651.5	**3003.2**
1932	233.092	130.95	208.82	43607.3	-0.83	0.709310996	612.6	29.1	641.7	**2797.1**
1933	229.008	119.4	246.17	60602.0	-0.63	0.982418215	669.1	3.8	672.9	**2748.1**
1934	241.858	214	206.20	42517.1	0.66	0.983660895	684.9	18.6	703.5	**2902.3**
1935	233.308	162.45	224.22	50276.6	-1.46	0.570031257	568.7	0	568.7	**2799.7**
1936	230.7	197.8	199.21	39686.0	0.47	0.871274001	641.2	28.7	669.9	**2768.4**
1937	197.083	129.8	180.61	32620.9	-1.80	0.325340031	451.8	0	451.8	**2365**

TABLE 5.4: DESCRITIVE STATISTICS OF ANNUAL RAINFALL IN TINSUKIA

YEARS	**Mean**	**Median**	**Standard Deviation**	**Sample Variance**	**Kurtosis**	**Skewness**	**Range**	**Minimum**	**Maximum**	**Annual**
1938	255.867	205.9	237.34	56328.3	-0.78	0.77551173	662.4	0	662.4	**3070.4**
1939	233.642	198.85	224.42	50365.8	-0.85	0.590543813	645.5	0	645.5	**2803.7**
1940	184.075	155.85	184.35	33986.6	-0.52	0.684747817	546.3	0	546.3	**2208.9**
1941	248.509	314.7	200.20	40081.2	-1.86	- 0.040287568	524.3	0	524.3	
1942	235.392	228.35	224.75	50512.8	-1.15	0.454474816	604.1	0	604.1	**2824.7**
1943	244.127	269.1	182.07	33151.1	-1.01	0.021512035	553.7	0	553.7	
1944	226.291	115.1	211.53	44745.2	-0.38	0.982394931	619	10.7	629.7	
1945	197.75	135.6	171.08	29267.0	-1.67	0.559339249	398.7	34.6	433.3	
1946	256.14	193.95	244.63	59845.5	-0.43	0.811277864	694.4	0	694.4	
1947	256.217	175.9	243.85	59461.4	0.55	0.94937017	800.3	0	800.3	**3074.6**
1948	224.02	110.1	230.34	53058.2	-1.20	0.834362027	578.6	9.4	588	
1949	276.742	245.9	254.63	64834.4	4.29	1.774856684	934.7	18.8	953.5	**3320.9**
1950	229.45	151.95	184.85	34167.7	-0.94	0.790801107	500.4	46.7	547.1	**2621.64**
1951	201.975	147.6	184.46	34026.2	-1.16	0.604997626	513.6	8.1	521.7	**2423.7**
1952	226.708	208.9	184.13	33904.3	-1.40	0.27421268	502.6	10.2	512.8	**2720.5**
1954	255.817	160.15	229.01	52445.3	-1.05	0.644336998	678	3.3	681.3	**3069.8**
1955	246.525	219.15	250.67	62837.0	2.60	1.508727862	862.7	5.6	868.3	**2958.4**
1956	229.833	258.45	169.83	28840.8	-0.84	0.312858329	506.7	6.6	513.3	**2758**
1957	242.533	120.35	230.27	53024.5	-1.75	0.478790772	580	25.4	605.4	**2910.4**
1958	194.275	155.75	188.04	35358.8	-1.10	0.684419088	501.3	0.2	501.5	**2331.3**
1959	236.1	227.95	188.35	35476.3	-1.37	0.204595342	529.2	0	529.2	**2833.1**
1960	262.141	241.795	243.26	59174.5	-1.22	0.454476281	641.2	12	653.2	**3417.49**
1961	133.857	44	134.54	18100.2	-1.21	0.928267447	315.5	22	337.5	**3489.58**
1964	23.95	23.95	19.02	361.8	#DIV/0!	#DIV/0!	26.9	10.5	37.4	**1605.72**
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**
1969	186.833	161	171.40	29379.4	2.01	1.27412472	486.1	8.1	494.2	**2359.1**
1970	301.567	161.9	368.42	135734.1	#DIV/0!	1.460764078	696	23.4	719.4	**2311.29**
1971	208.34	135.8	196.03	38428.3	-1.01	0.764962656	495.3	30.2	525.5	**2619.12**
1972	165.989	184.8	121.08	14660.2	-1.95	- 0.237017321	298.9	2.9	301.8	**4999.52**
1973	249.075	204.6	241.10	58127.6	-1.39	0.465803546	638	0	638	**2660.46**
1974	53.6	53.7	10.06	101.1	-2.49	- 0.040768771	22.6	42.2	64.8	**4325.92**
1975	225.192	219.85	193.67	37507.5	0.21	0.868327563	617.7	17.6	635.3	**2698.35**
1977	253.608	159.25	236.39	55882.0	-0.98	0.660496894	652.9	42.7	695.6	**3042.99**

TABLE 5.5: DESCRIPTIVE STATISTICS OF ANNUAL RAINFALL IN TINSUKIA

YEARS	**Mean**	**Median**	**Standard Deviation**	**Sample Variance**	**Kurtosis**	**Skewness**	**Range**	**Minimum**	**Maximum**	**Annual**
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**
1983	208.492	155.15	189.11	35762.7	-0.74	0.697759979	568.7	2.8	571.5	**2502.1**
1984	215.875	235.65	181.31	32874.6	-1.76	0.102690269	498.7	1.8	500.5	**2590.3**
1985	178.95	92.4	231.13	53419.7	3.91	1.898147593	783.4	4.3	787.7	**2147.3**
1986	150.817	111.15	152.61	23289.3	4.34	1.900078191	536.5	22	558.5	**1809.7**
1987	197.408	146.7	197.50	39007.4	-0.03	0.92443505	613.5	1	614.5	**2688**
1988	215.992	212	197.40	38965.5	0.01	0.851905768	597.7	0	597.7	**2958**
1989	211.625	135.95	206.91	42811.7	1.94	1.326208847	701.8	11.3	713.1	**2539.5**
1990	205.908	223.2	151.48	22945.8	-1.45	0.03050735	440.8	0	440.8	**2470.8**
1991	202.875	135.95	175.94	30953.9	-1.42	0.527431904	474.9	10.9	485.8	**2434.6**
1992	212.975	225.65	145.75	21242.1	-1.28	- 0.217962447	428.2	9.6	437.8	**2555.7**
1993	190.775	91.1	181.95	33104.3	-1.38	0.629233859	500	0.6	500.6	**2289.2**
1994	147.483	155.45	109.84	12064.5	-1.06	0.147895024	335.6	1.9	337.5	**1769.9**
1995	248.05	138.9	230.44	53103.9	-1.88	0.383249989	572.3	12.2	584.5	**2976.6**
1996	175.375	145.15	157.03	24658.1	-0.84	0.708913668	449.3	0.2	449.5	**2104.4**
1997	176.183	130.1	151.36	22910.3	-0.61	0.802523249	439.5	22.3	461.8	**2113.9**
1998	187.792	118.35	182.59	33339.4	0.24	1.070078353	575.4	0.4	575.8	**2253.5**
1999	189.617	188.6	173.25	30014.9	-1.15	0.382291156	482.9	0	482.9	**2275.2**
2000	241.825	167.5	234.69	55080.8	-1.14	0.555137058	677.4	0	677.4	**2901.9**
2001	167.292	159.15	161.73	26157.4	0.38	0.949579239	505.4	5.7	511.1	**2007.5**
2002	172.183	143.2	133.78	17897.1	-1.26	0.401393226	387.5	10.1	397.6	**2066**
2003	183.35	162.55	172.38	29713.3	1.08	1.112512758	570.6	2.6	573.2	**2200.2**
2004	220.075	191.35	199.68	39870.4	1.45	1.063944395	686.2	1.7	687.9	**2640.9**
2005	210.392	174.75	160.29	25692.8	-0.19	0.629986997	526.8	0	526.8	**2524.7**
2006	167.9	160.95	122.72	15059.3	-1.66	0.045876377	338.5	0	338.5	**2014.8**
2007	170.608	102.65	169.50	28729.2	-0.32	0.933191552	502	3.6	505.6	**2047.3**
2008	196.908	148.25	188.45	35515.0	0.08	1.097380931	546.7	5.8	552.5	**2362.9**
2009	163.183	120.2	155.79	24270.6	1.58	1.262001806	515.5	18.1	533.6	**1958.1**
2010	249.5	216.15	223.40	49909.2	-1.41	0.443129803	588.4	0.9	589.3	**2994**
2011	145.861	97.705	158.27	25049.9	-1.07	0.634488867	434.92	1.01	435.93	**1750.33**
2012	140.125	89.72	149.39	22316.6	-0.71	0.821142855	405.68	0.86	406.54	**1688**
2013	179.373	103.245	192.09	36896.7	-0.74	0.811949872	549.36	0.24	549.6	**2152**

TABLE 5.6: DESCRIPTIVE STATISTICS OF ANNUAL RAINFALL IN TINSUKIA

YEARS	Mean	Median	Standard Deviation	Sample Variance	Kurtosis	Skewness	Range	Minimum	Maximum	Annual
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**

From Table 5.3, 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 2020 with an amount of 1407mm (table 10).

In Table 5.4 it can 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 follow 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 symmetric if it looks the same to the left and right from the centre 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)[vi]

As can be observed from Table 5.5 and 5.6 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.

The standard deviation is one way of summarizing the spread of a probability distribution; it relates directly to the degree of uncertainty associated with predicting the value of a random variable. High values reflect more uncertainty than low values.

Table 5.5 clearly revealed that September month had the highest standard deviation. The highest amount of average monthly rainfall was recorded in July (497.97 mm) and contributed to 18.8% of annual rainfall, followed by June with 15.58%, and the lowest was in December with 5.8% of annual total followed by November and January with 1.2%. From the analysis, it was observed that rainfall is usually at its peak between June to September in the major season and between March and April in the minor season.

6. 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 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.

Further studies are required to be carried out to establish other rainfall characteristics such as extreme rainfall, rain days, and other climate change parameters for this region to verify whether the significant trend has occurred and also to establish a correlation between temperature and extreme rainfall

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