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Rainfall Trend Analysis of Nagaland by using Mann - Kendall Test

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Abstract: ***This study examined the impact of climate change on rainfall trend of Nagaland's individual month, seasonal, and annual mean rainfall for 18 years (2004 - 2021). The non- parametric test Mann - Kendall's and Sen's slope estimator test is used to determine the rainfall trend and its magnitude. The result shows that some individual months, pre- monsoon, and monsoon seasons indicate a decreasing trend of rainfall while others show an increasing trend.***

Keywords: Trend analysis, Mann – Kendall test, Sen's slope estimator

1. Introduction

Human-induced climate change is causing severe consequences and widespread disruption in nature and affecting people's lives worldwide. Despite the efforts to reduce the risks, People and ecosystems least able to cope are being hardest hit (IPCC report 2022) [1]. The rapid change of climate affects the climatic elements which directly affect day-to-day weather conditions of the world and human activities. Precipitation is one of the major meteorological elements impacted due to climate change. Changes in run - off and distribution of precipitation will caused catastrophe with less availability of fresh water for use, flood, and drought which will depend on likely future climate scenarios [2]. Predicting long-term rainfall patterns is essential for developing effective water conservation strategies and planning storm water management infrastructure [3]. Deforestation, urbanization, changing patterns of land use, etc are some factors that lead to climate change.

India's mean annual temperature is rising at the rate of 0.05 °C/decade over 1901–2003 which is mostly due to the rise of maximum temperature (0.07 °C/decade) rather than because of the rise of minimum temperature (0.02 °C/decade) (Kothawale and Rupa Kumar, 2005). Climate change impact is visible in most of the climatic elements. Several research or study has done on rainfall trend analysis in India. India's annual and seasonal trends show a negative trend for annual and monsoon. The study in India also shows that the annual and monsoon rainfall pattern decline for Northeastern India, Central Northeast India, and West Central India [4]. The temperature and rainfall of India in the last 30 years indicate rapid warming and a decline in the amount of rainfall [5].

Nagaland an agrarian society needs favaourable weather conditions for agricultural productivity and also to contribute to the growth of the state economy [6]. Mann - Kendall (MK) test and Sen's slope estimator method is used to determine the rainfall trends by using XLSTATS 2022 for selected years (2004 - 2021).

2. Methodology

Trend analysis is a statistical tool used for spatial variations and temporal trend of hydroclimatic series. In this trend study, non- parametric method Mann Kendall Test (MK),the widely used test for hydro – meteorological time series is used for analysis. Mann Kendall test is preferred when various stations are tested in a single study (*Hirsch et al., 1991)*. Also Sen's slope estimator is applied for time series as Sen's slope is widely used for determining the magnitude of trend in hydrometeorology time series.

The arranged data were then tested by using XLSAT 2022 software, which is used for the Mann-Kendall test and Sen's Slope estimator. All the data were tested with 5% significance level and 95% confidence level.

Sen's Slope Estimator Test: The magnitude of trend is predicted by the Sen's estimator. Here, the slope (Ti) of all data pairs is computed as *(Sen, 1968)*

$$T_i = \frac{x_j - x_k}{j - k} \qquad \text{for } i = 1,2 \dots \dots \dots \dots, N$$

where x_j and x_k are considered as data values at time j and k (j>k) correspondingly. The median of these N values of Ti is represented as Sen's estimator of slope which is given as:

$$\beta = \begin{cases} T_{\frac{N+1}{2}} & N \text{ is odd} \\ \frac{1}{2}\left(T_{\frac{N}{2}} + T_{\frac{N+2}{2}}\right) & N \text{ is even} \end{cases}$$

A positive value of β indicates an upward (increasing) trend and a negative value indicates a downward (decreasing) trend in the time series.

Mann-Kendall Test*:* The Mann-Kendall statistic *S* is given as

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

Where N is the number of data points. Assuming (xj – xi) = θ, the value of sgn(θ) is computed as follows:

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

when n ≥ 8, the statistic S is approximately normally distributed with the mean.

$$E(s) = 0$$

The variance statistic is given as

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

where t_i is considered as the number of ties up to sample i. The test statistics Z is computed as

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{\mathrm{Var}\,(S)}} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \dfrac{S+1}{\sqrt{\mathrm{Var}\,(S)}} & \text{if } S < 0 \end{cases}$$

If Z >Zα/2, the null hypothesis is rejected. Confidence level of 95% and significance level of 5 % were used to test in this trend analysis.

2.1 Study area

Nagaland lies in the Northeastern part of India. About 90% of the land is mountainous with tropical and sub-tropical type of climate. It has a total geographical area of about 16,579 sq. km and lies between 25º6' N - 27º4'N latitude and 93º 20' E – 95º 15' E longitude. The state has a total population of 19, 78, 502 (2011, Census) and 15 districts. About 90% of the total population of Nagaland is agrarian. Most of the agriculture field and allied activities depends on the monsoon rain. Precipitation plays a crucial role in the state development and provides other means of livelihood to people.

Figure 1: Location map of Nagaland

2.2 Data

The rainfall data were collected for the period of 15 years (2004 – 2018) from the Directorate of Soil and water conservation, Kohima, Nagaland, the sole nodal agency in the state. Due to lack of data and weather stations in various parts of Nagaland, numerous data could not be generated for the analysis. The following 9 weather stations (rain guage) data were collected: Dimapur, Jalukie(Peren), Kohima, Phek, Wokha, Kiphire, Mokokchung, Mon and Zunheboto. Daily rainfall data was collected and sorted monthly and annually from each weather station. All the rainfall data collected were expressed in millimeters.

Table 1: Meteorological stations (rain gauge) data collected, Nagaland

Name of Station	Latitude	Longitude	Altitude (m)	Max Temp(ºC)	Min Temp(ºC)	Rainfall(mm)
Dimapur	25º 49′ 40″	93º 41′ 15″	160	30.05	20.2	951.3
Jalukie (Peren)	25º 39′	93º 40′ 10″	415	28.5	18.9	1406.3
Kohima	25º 39′	94º 07′	1420	22.9	12.7	1647.9
Kiphire	25º 58′	94º 47′	1195	25.7	14.8	864.3
Phek	25º 43′ 30″	94º 28′	1360	23.6	14	1474.5
Mokokchung	26º 19′ 30″	94º 31′	1180	23.6	15.3	1994.6
Mon	26º 42′	95º 01′ 30″	734	26.3	16.1	1986.8
Wokha	26º 05′ 45″	94º 15′ 45″	1360	22.7	15.2	2135.6
Zunheboto	26º 34′	94º 31′25″	1780	20.7	12.4	1317

3. Results and discussion

The trend analysis of annual rainfall of Nagaland for 18 years i.e. 2004 – 2021 is shown in fig. 2 with maximum amount of rainfall 16415.5mm in 2007 and minimum amount of rainfall 9360mm in 2006. Hence, 2007 can be considered as the 'wet year' and 2006 as 'dry year' in this study period. The average annual rainfall is 13573.9 mm.

During this study period, the wettest month is observe in June, July and August with average annual rainfall of 2343.82mm, 2697.23mm and 2324.76mm respectively whereas the driest month is observe in December, January and February with average annual rainfall of 72.26mm, 107.63mm and 117.97mm respectively. It is observe, that July is the wettest month and December is the driest month through-out the year. It is due to the influence of Southwest Monsoon and North West monsoon in India respectively. May, August, and October shows consistent of Statistic, Kendall's tau and Sen's slope of negative (downward) trend. January, February, March, April, June, July, September, November and December show a positive (increasing) trend.

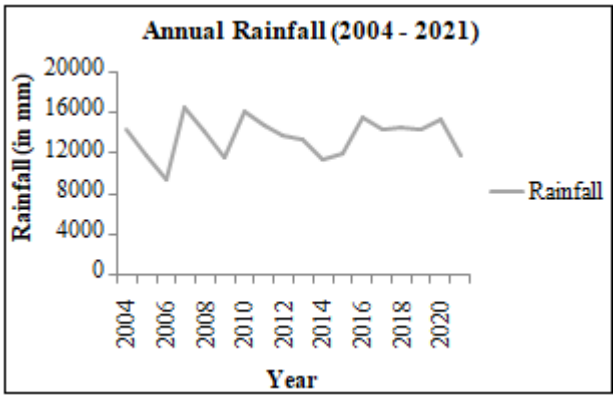

Figure 2: Annual Rainfall, Nagaland (2004 – 2021)

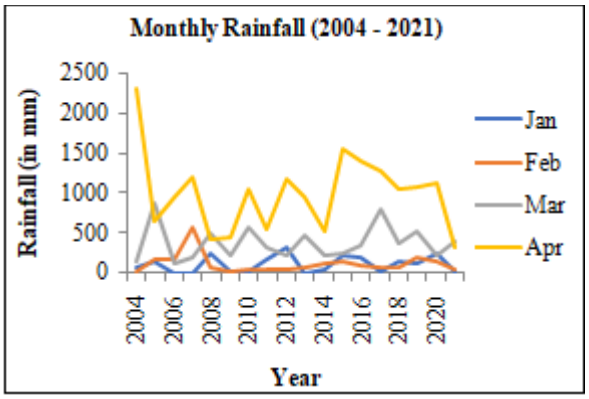

Figure 3: Monthly Rainfall, Nagaland (2004 – 2021)

The above fig 3, 4 and 5 are quarterly individual month of amount of rainfall for 18 years i.e. 2004 – 2021. The figures were divided into quarterly for better understanding and more precise visual interpretation. The state also recorded the highest amount of rainfall in this study duration in June 2011 with rainfall of 3327.5 mm and the least amount of rainfall is January 2013 with rainfall of just 0.2 mm through - out the state.

Fig 6, 7, 8 and 9 indicates the various amount of seasonal amount of rainfall for 18 years in Nagaland

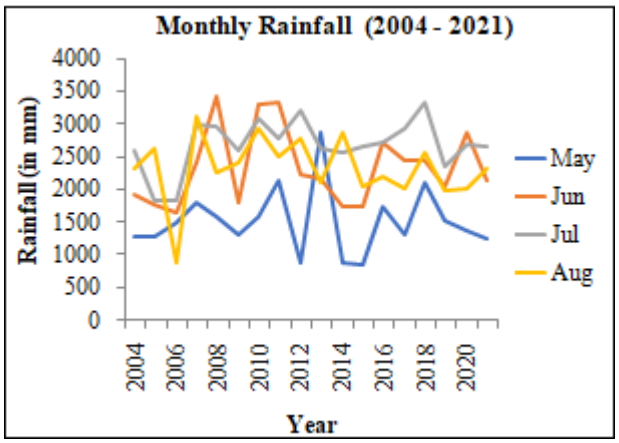

Figure 4: Monthly Rainfall, Nagaland (2004 – 2021)

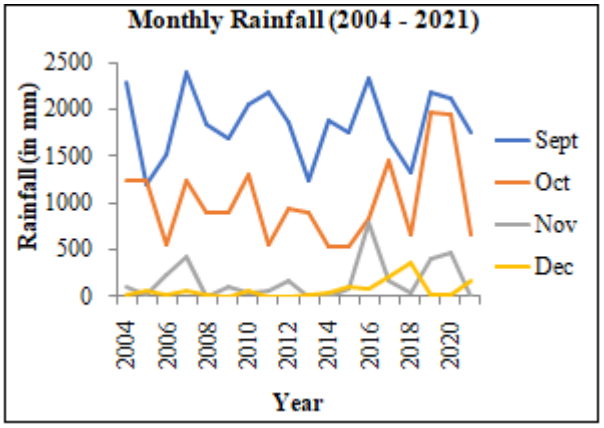

Figure 5: Monthly Rainfall, Nagaland (2004 – 2021)

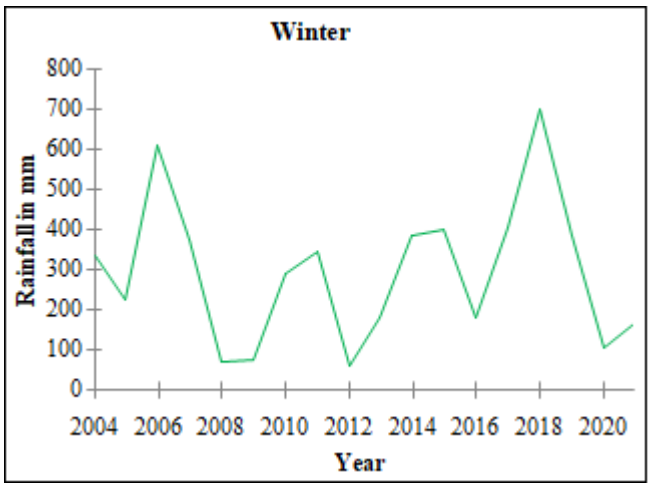

Figure 6: Rainfall in winter season, Nagaland (December, January and February)

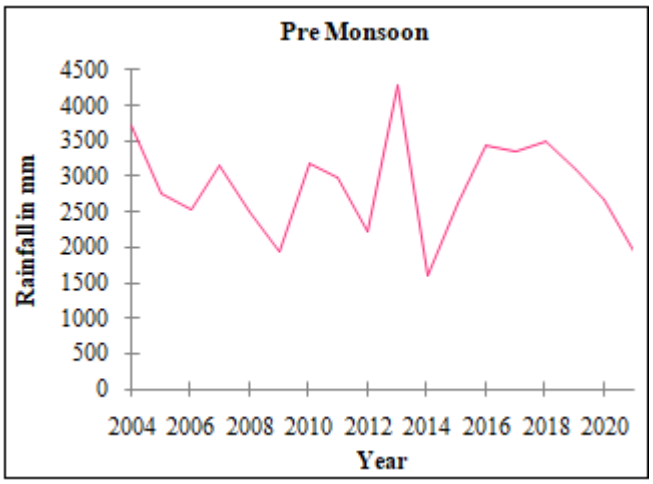

Figure 7: Rainfall in Pre- Monsoon Season, Nagaland (March, April and May)

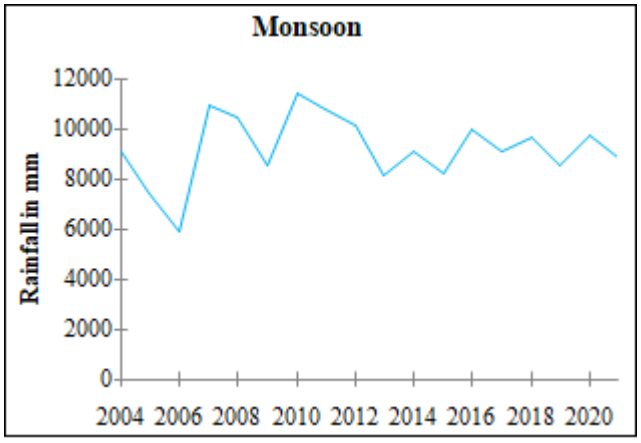

Figure 8: Rainfall in Monsoon Season, Nagaland (June, July, August and September)

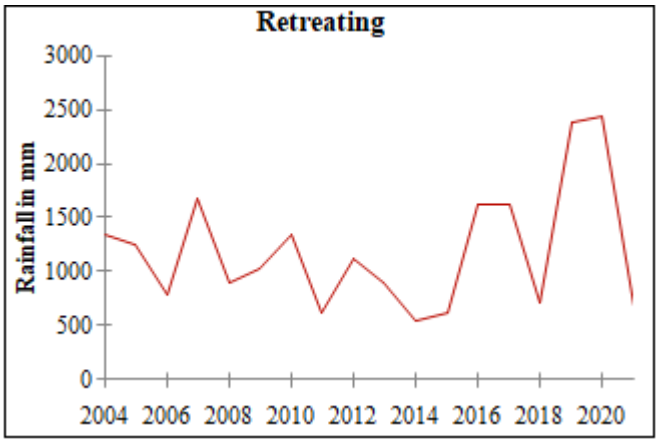

Figure 9: Rainfall in Retreating Season, Nagaland (October and November)

In the winter season, the highest amount of rainfall was observed in 2018 and the lowest in 2008. The Statistic, Sen's slope and Kendall tau results shows positive trend. In 2013 and 2014, the highest and lowest amount of rainfall was recorded respectively during the pre – monsoon season. In the monsoon season, 2011 was recorded the highest amount of rainfall or the 'wettest year' and 2006 recorded the lowest amount of rainfall or the 'driest year'. Both pre- monsoon and monsoon test results indicate Statistic, Kendall's tau and Sen's slope are consistent to one another and a negative trend is observe at statically significance at 5%.During retreating season, the highest amount rainfall was recorded in 2020 and lowest in 2014. The Statistic, Sen's slope and Kendall tau are consistent and showed positive trend.

Table 2: Monthly, Annual and Seasonal rainfall (Nagaland) for the Mann – Kendall and Sen's slope test (2004 - 21)

Variables	Kendall's tau	S	Var(S)	*p* – Value	Sen's Slope	95% Confidence Level	
						Lower	Upper
January	0.124	19	697.00	0.495*	3.183	-5.838	10.800
February	0.072	11	697.00	0.705*	1.367	-7.487	7.531
March	0.242	37	697.00	0.173*	8.327	-10.138	24.343
April	0.033	5	697.00	0.880*	7.160	-62.164	46.150
May	- 0.007	- 1	697.00	1.000*	- 0.825	-42.650	51.950
June	0.098	15	697.00	0.596*	12.818	-42.590	61.119
July	0.124	19	697.00	0.495*	7.664	-23.214	60.700
August	- 0.229	- 35	697.00	0.198*	- 21.475	-54.700	24.614
September	0.020	3	697.00	0.940*	2.088	-43.467	42.467
October	- 0.046	- 7	697.00	0.820*	- 2.125	-41.443	44.200
November	0.098	15	697.00	0.596*	2.369	-8.217	23.450
December	0.255	39	697.00	0.150*	3.767	-1.140	13.029
Annual	0.072	11	697.00	0.705*	17.127	-162.120	214.780
Winter	0.072	11	697.00	0.705*	2.825	-17.031	15.000
Pre – Monsoon	- 0.033	- 5	697.00	0.880*	- 11.533	-99.555	56.963
Monsoon	- 0.033	- 5	697.00	0.880*	- 14.994	-147.250	131.056
Retreating	0.020	3	697.00	0.940*	0.275	-44.950	76.236

*As the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis H_o.

4. Conclusion

In this study attempt is established to determine the rainfall trend analysis of Nagaland for 18 years i.e. 2004 to 2021. Annual, Winter and Retreating seasons of rainfall show a positive trend and Pre- Monsoon and Monsoon show a negative trend. Individual months of May, August and October show a negative rainfall trend while January, February, March, April, June, July, September, November and December show a positive trend of rainfall. Sen's slope also indicates both positive and negative trends corresponding to the Mann- Kendall Test value. There are three months that shows Mann – Kendall test negative trend along with negative trend in Sen's slope while nine months show positive trend in both of the test. The rainfall analysis of Nagaland shows some evidence of change in rainfall

activity due to impact of global climate change. More micro study is required to understand the effects and causes of rainfall in Nagaland.

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