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Mann-Kendall and Sen's Slope Estimator Test to Analyze Trends for Temperature and Rainfall in Eastern Himalayas of Arunachal Pradesh, India

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Abstract:- In the past ten years, climate change has gained significant attention. Global climate change does not always affect various places in the same way. One important weather factor associated with climate change is rainfall. An appropriate first step in assessing how climate change may impact food security and water availability is to examine patterns in temperature and rainfall. The temperature, precipitation, and changes at several Arunachal Pradesh districts from 2001 to 2021 are examined in this study. We examined fourteen districts using the Mann-Kendall (MK) and Sen's Slope estimator test, which may identify long-term monotonic trends as well as variations in temperature and rainfall. The maximum and lowest temperature data revealed notable upward and decrease patterns, indicating that the region had experienced a change in climate. Nonetheless, there was an increase in rainfall patterns.

Keywords:- *Climate Change, Temperature, Rainfall, Mann–Kendall Test, Sen's Slope Estimator, Trend Analysis, Arunachal Pradesh.*

I. INTRODUCTION

Globally, the scientific community has paid close attention to how temperature and rainfall are affected by climate change. Numerous research projects have demonstrated that these changes in rainfall and temperature are becoming noticeable on a global basis (Karmeshu and Neha, 2012). Global warming has happened, although the effects of it frequently differ from one place to another (Trajkovic and Kolakovic 2009). Analyzing changes in meteorological variables is therefore a crucial step in the detection of climate change. By altering the hydrological cycle, which can result in a shortage of water resources and an excess of floods and droughts, climate change has a significant impact on natural ecosystems, society, and the economy, as multiple studies have demonstrated (Von Storch, 1999). There are already clear signs that rainfall patterns are changing both locally and worldwide as a result of global warming (Goswami et al., 2006). Numerous analyses of time series data have demonstrated that both temperature and rainfall are trending either downward or upward.

A trend is the direction and speed at which specific data points in a time series change. Understanding a phenomenon requires gathering data across an appropriate length of time or space, processing it to fill in any gaps, and then interpreting the results to look at the phenomenon's behaviour. Numerous parametric and non-parametric techniques are used to analyze the trend. The graphing approach, the least squares method, and the linear regression test are examples of parametric methods. The most popular and extensively used nonparametric tests for determining trends in climatic parameters are Sen's slope estimator test, Mann-Kendall Method, and Spearman's Rho (SR). Analyzing time series trends entails determining the trend's statistical significance and amplitude. The following researchers provided an explanation of the rationale behind the use of non-parametric testing rather than parametric approaches in a number of studies examining climate changes (Ali *et al.,* 2019). Certain assumptions that are uncommon to be met in meteorological and hydrological datasets are necessary for the development of parametric techniques. These assumptions include normality, stationarity, and time series independence. Furthermore, unlike non-parametric approaches, parametric tests exhibit high sensitivity to the existence of outliers in the data set.

Arunachal Pradesh in one of the largest states in north eastern states of India, with a monsoon-influenced subtropical humid climate. Climate change has an impact on the state and is seen in extreme weather occurrences like landslides and floods. Given that the region's economy is mostly focused on agricultural and animal raising, the water supply is of utmost socioeconomic significance. Flash floods are another serious climate danger that the area faces; these natural disasters have the potential to claim lives and seriously harm infrastructure. The population, infrastructure, and agricultural areas are all under risk from this increasingly common peril in the area.

Examining the trend of rainfall and temperate climate parameters in the study area in light of the previously given data is the aim of this research. The various hydrological processes, such as rainfall and the sequence in which they occur, will be impacted by temperature variations (Basistha *et al.,* 2008).

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II. MATERIAL AND METHODS

- *Study Area*

Arunachal Pradesh is located in the northeastern region of India, between latitudes 26°30'N and 29°31'N and longitudes 91°30'E and 97°30'E. Located in the far northeastern region of India, Arunachal Pradesh is bordered on three sides by sovereign nations and on one side by the states of Assam and Nagaland. This state shares borders with Indian states like Assam and Nagaland to the south, and to the west, northeast, north, and east are Bhutan, Tibet, China, and Myanmar, respectively. It is the nation's largest northeastern state. 'Aruna' signifies Sun God's charioteer, while 'Achal' denotes mountain. In this state, India's Sun appears first. The study was conducted in 14 stations of Arunachal Pradesh. The weather and the climate of Arunachal Pradesh are quite distinct from the rest of the country. The Himalayan system and altitudinal fluctuations influence the state's climate. At lower elevations and in valleys covered by swampy dense forest, especially in the eastern side, the environment is extremely hot and humid; at higher elevations, however, the temperature drops dramatically. With around 3500 mm of annual precipitation, Arunachal Pradesh has some of the nation's heaviest rainfall (Drema *et al.,* 2024). Winter months have average temperatures in the range 15ºC to 21ºC, and the monsoon month temperatures are in the range of 22ºC – 33ºC, and the summer months temperatures sometimes are higher well over 37ºC. The foothills experience maximum temperatures around 40ºC during summer. Approximately 54.6 percent of the population works in agriculture or related fields, 80% of people in rural areas depend on agriculture, and 62% of all working people are employed in agriculture.

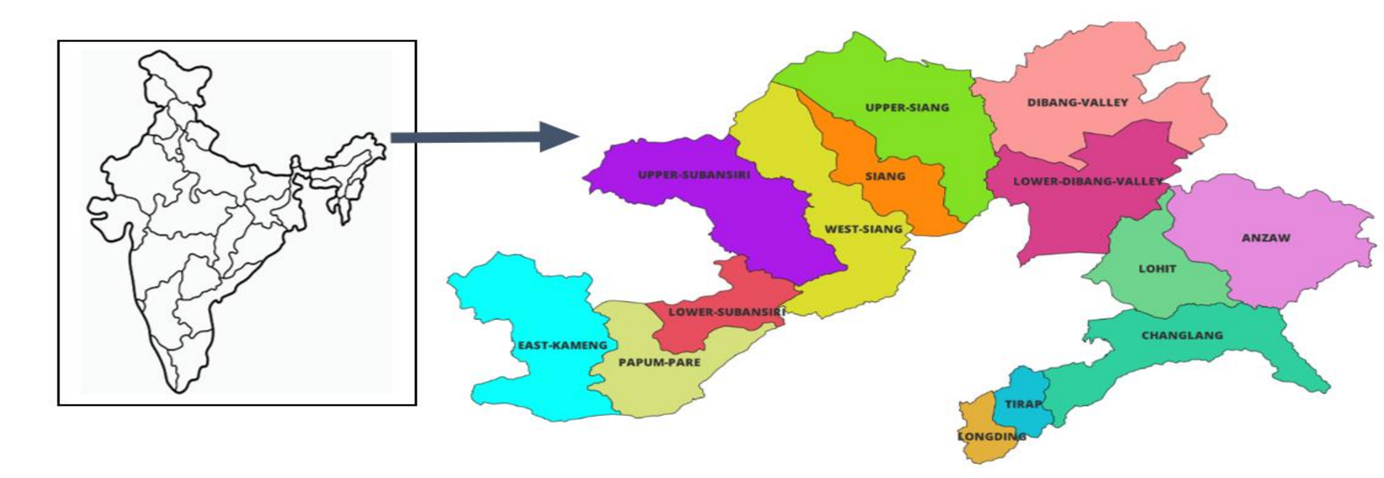

Fig 1 Study Area (Arunachal Pradesh). The 14 Districts have been Highlighted in Different Colours.

- *Data Collection:*

Arunachal Pradesh, India's 14 districts' maximum and minimum temperatures as well as rainfall over a 21-year period (2001–2021) were gathered from the ICAR Research Complex for NEH Region, Basar Centre, Lepa Rada District.

Table 1 Districts of the Study Area

Sl. No.	Districts	Latitude	Longitude	Elevation
1.	Anjaw	28.07	96.54	1296
2.	Changlang	27.25	96.62	580
3.	East Kameng	27.36	93.03	780
4.	Lohit	27.92	96.15	750
5.	Longding	26.87	95.30	822
6.	Lower Dibang Valley	28.11	95.82	1413
7.	Lower Subansiri	27.54	93.81	1500
8.	Papumpare	27.08	93.60	355
9.	Siang	28.06	95.32	841
10.	Tirap	26.99	95.50	786
11.	Dibang Valley	28.79	95.90	3417
12.	Upper Siang	28.62	95.03	2142
13.	Upper Subansiri	27.98	94.22	2241
14.	West Siang	28.16	94.80	1816

➢ *Mann–Kendall (MK) Test*

The Mann Kendall test is a widely used statistical test for analyzing trends in climatological (Mavromatis and Stathis, 2011) and hydrological (Yue and Wang, 2004). data sets. There are two advantages to use this test. the test has low sensitivity to sudden breaks due to non-homogeneous time series (Tabari et al., 2011). All data reported as unobserved are included by assigning it, a common value smaller than the smallest measured value in the dataset (El Kasri *et al.,* 2021). According to this test, the null hypothesis H_0 assumes that there is no monotonic trend (the data are independent and randomly ordered) and this is tested against the alternative hypothesis H1, which assumes that there is a monotonic upward or downward trend in climate time series data (Onoz and Bayazit, 2003). The trend can be assumed to be monotonic when (mathematically speaking, the trend is constantly increasing and never decreasing or never decreasing and never increasing).

It is based on the test statics S defined as

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn\,(Xj - Xi) \qquad \text{(eq. 1)}$$

Where, x1, x2, … xn represent n data points where xj represents the data point at time j.

➢ *Sen's Slope Estimator Test*

Test of Sen's Slope Estimator: Simple linear regression is one of the most frequently used models for the linear trend identification. This method requires however the assumption of residual normality (McBean and Motiee, 2008). Viessman et al. (1989) stated that, due to the influence of natural phenomena, many hydrological variables show a pronounced right skewedness and do not adopt a normal distribution. Thus, the Sen (1968) slope estimator is found to be a powerful tool to develop the linear relationships. Sen’s slope has the advantage over the slope of regression, in the sense that gross data series errors and outliers do not affect in much. The slope of the Sen was determined to be the mean of all pair-wise slopes for any pair of points in the dataset. The following equation is used to estimate each individual slope (mij):

$$m_{ij} = \frac{Y_j - Y_i}{j - 1} \qquad \text{(eq.2)}$$

Where,

i = 1 to n - 1,
j = 2 to n,

Y_j and Y_i are data values at time j and i (j > i), respectively. If in the time series there are n values of Y_j, estimates of the slope will be N= n(n-2)/2. The slope of the Sen Estimator is the mean slope of such slopes N values. The Sen's slope is:

$$m = \begin{cases} m_{\left[\frac{N+1}{2}\right]} & \text{if } n \text{ is odd} \\ \frac{1}{2}\left(m_{\frac{N}{2}} + m_{\left[\frac{N+2}{2}\right]}\right) & \text{if } n \text{ is even} \end{cases} \qquad \text{(eq.3)}$$

Positive Sen's slope reveals an upward trend while negative Sen’s slope suggests a downward trend.

III. RESULTS AND DISCUSSIONS

A. *Trend analysis of Temperature*

➢ *Maximum Temperature*

Table 2 displays the MK test and Sen's slope estimator results. The trend analysis and trendline's MK statistics (Z value) and Sen's slope (Q value) are shown graphically in Figure 2. Anjaw, Lohit, and Tirap districts demonstrated a significant decreasing trend at the 5% level, while Upper Siang and West Siang demonstrated a significant downward trend at the 10% level of significance, according to the results displayed in Table 2. Changlang, Lower Dibang Valley, Siang, and Upper Subansiri, on the other hand, displayed a noteworthy negative trend at the 15% significance level.

Table 2 Results of Maximum Temperature Trend analysis using MK Test and Sen’s Slope Estimator

Districts	Z	Q
Anjaw	-3.02**	-0.055
Changlang	-1.85+	-0.028
East kameng	-0.03	0
Lohit	-3.02**	-0.055
Longding	-1.09	-0.023
Lower dibang valley	-1.95+	-0.032
Lower subansiri	-1.22	-0.015
Paumpare	-0.7	-0.015
Siang	-1.95+	-0.032
Tirap	-2.58**	-0.07
Dibang valley	-1.89+	-0.025
Upper siang	-2.5*	-0.037
Upper subansiri	-1.92+	-0.03
West siang	-2.11*	-0.034

Significant trends at 1 % indicated by bold numbers, significant trends at 5 % indicated by **, significant trends at 10 % indicated by *, significant trends at 15% indicated by +

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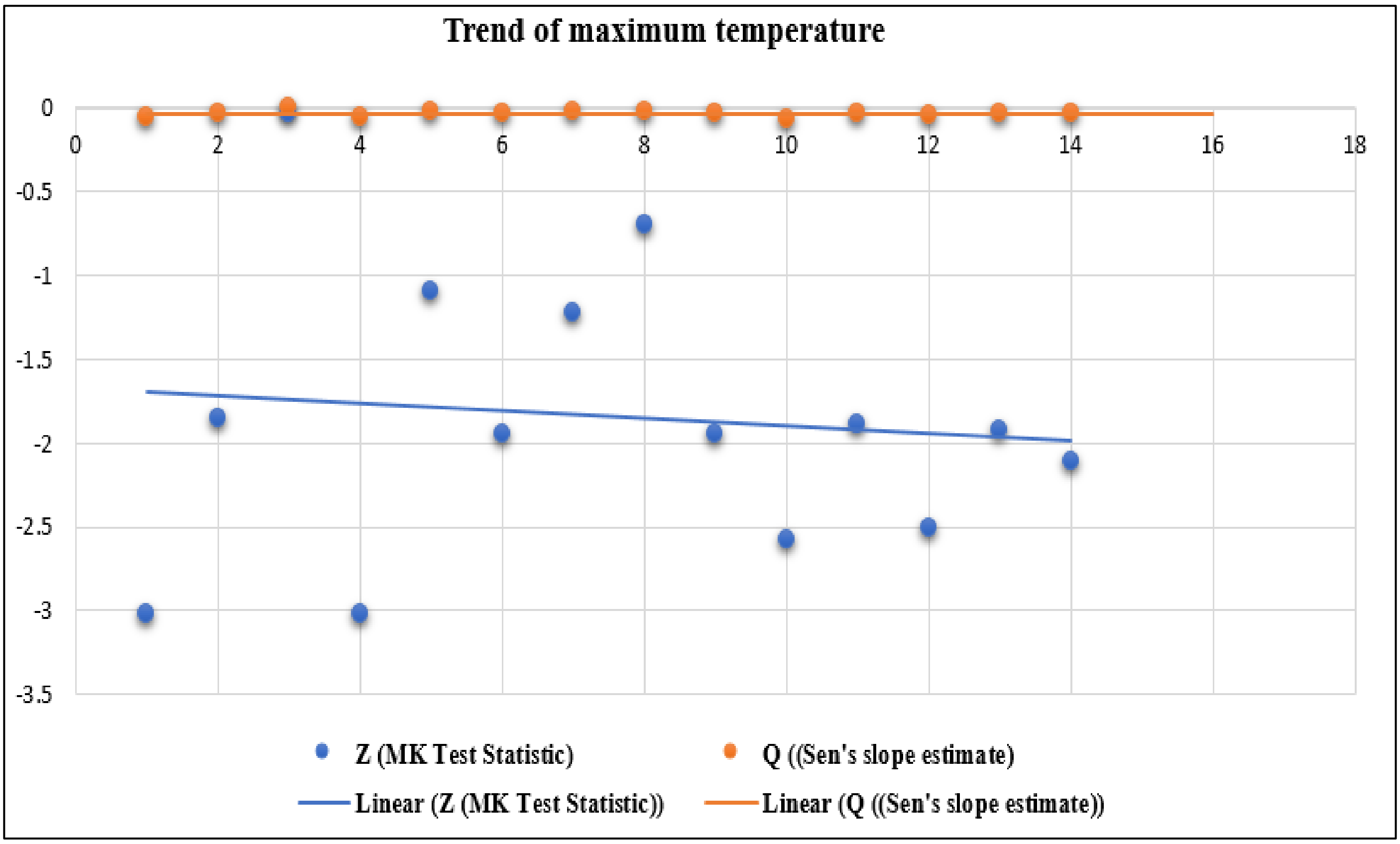

Fig 2 MK Statistics and Sen's Slope for Maximum Temperature (2001-2021)

➢ *Minimum Temperature*

Table 3 displays the MK test and Sen's slope estimator results. The trend analysis's Sen's slope (Q value) and MK statistics (Z value) are shown graphically in Figure 3. All districts showed an upward trend, according to Table 3's results. At the 1% level, East Kameng, Lower Subansiri, Upper Dibang Valley, Upper Siang, Upper Subansiri, and West Siang showed significant increasing trends, while Changlang, Longding, Lower Dibang Valley, Papumpare, Siang, and Tirap showed significant increasing trends at the 5% level of significance. On the other hand, Anjaw and East Kameng displayed a noteworthy negative trend at the 10% significance level. A rising minimum temperature will contribute to climatic change brought on by global warming (Kharmeshu N. 2012). This suggests that temperature trend shows rising and due to this rising temperature, other climatic variables may experience affected in the hydrologic processes and surrounding environment (Rao, P.G.,1993).

Table 3 Results of Minimum Temperature Trend analysis using MK Test and Sen's Slope Estimator

Districts	**Z**	**Q**
Anjaw	2.08*	0.023
changlang	2.71**	0.03
East kameng	**3.44**	0.063
Lohit	2.07*	0.025
Longding	2.68**	0.058
Lower dibang valley	3.07**	0.042
Lower subansiri	**3.83**	0.082
Paumpare	2.89**	0.073
Siang	3.07**	0.042
Tirap	2.63**	0.04
Dibang valley	**3.87**	0.05
Upper siang	**3.68**	0.075
Upper subansiri	**3.38**	0.081
West siang	**3.8**	0.088

Significant trends at 1 % indicated by bold numbers, significant trends at 5 % indicated by **, significant trends at 10 % indicated by *, significant trends at 15% indicated by +

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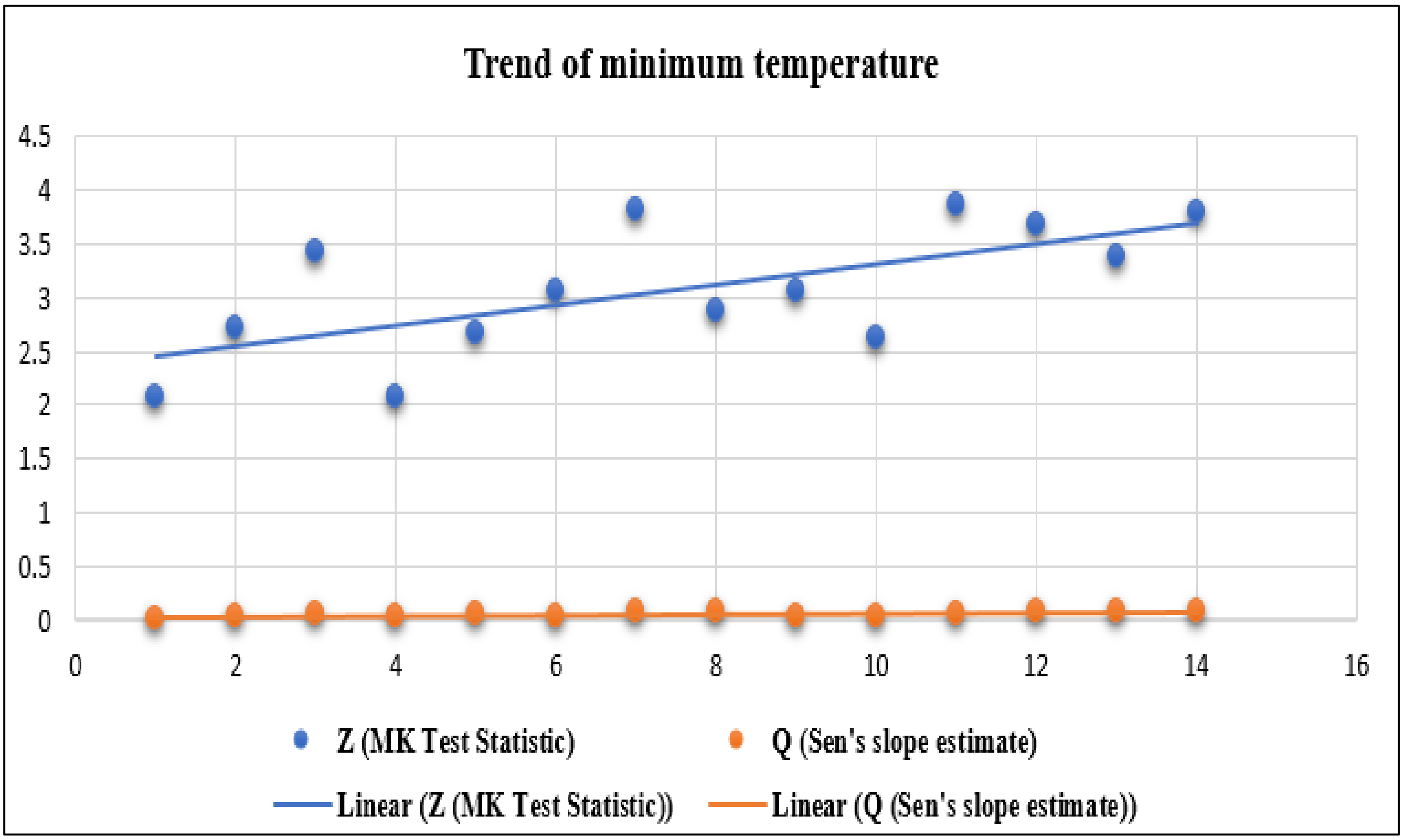

Fig 3 MK Statistics and Sen's Slope for Minimum Temperature (2001-2021)

B. Trend analysis of Rainfall

Table 4 displays the MK test and Sen's slope estimator results. The trend analysis's Sen's slope (Q value) and MK statistics (Z value) are shown graphically in Figure 4. All of the districts showed an increased trend, according to the results in Table 4. Significant increasing trends were observed in Longding, Lower Subansiri, Papumpare, Tirap, Dibang Valley, Upper Siang, and West Siang, whereas East Kameng, Anjaw, Lohit, Lower Dibang Valley, Siang, and Upper Subansiri exhibited significant at the 1% level. Changlang, on the other hand, displayed a noteworthy increasing trend at the 15% significance level. There will be more water available for the crops when rainfall increases.

Table 4 Results of Rainfall Trend analysis using MK Test and Sen's Slope Estimator

Districts	Z	Q
Anjaw	**4.14**	91.569
Changlang	1.66+	21.026
East kameng	0.57	5.702
Lohit	**4.20**	96.029
Longding	3.23**	50.722
Lower dibang valley	**3.77**	73.417
Lower subansiri	3.05**	37.807
Paumpare	2.63**	30.037
Siang	**3.77**	73.417
Tirap	3.05**	70.03
Dibang valley	2.99**	35.101
Upper siang	2.93**	45.371
Upper subansiri	**3.41**	45.318
West siang	2.93**	49.296

Significant trends at 1 % indicated by bold numbers, significant trends at 5 % indicated by **, significant trends at 10 % indicated by *, significant trends at 15% indicated by +

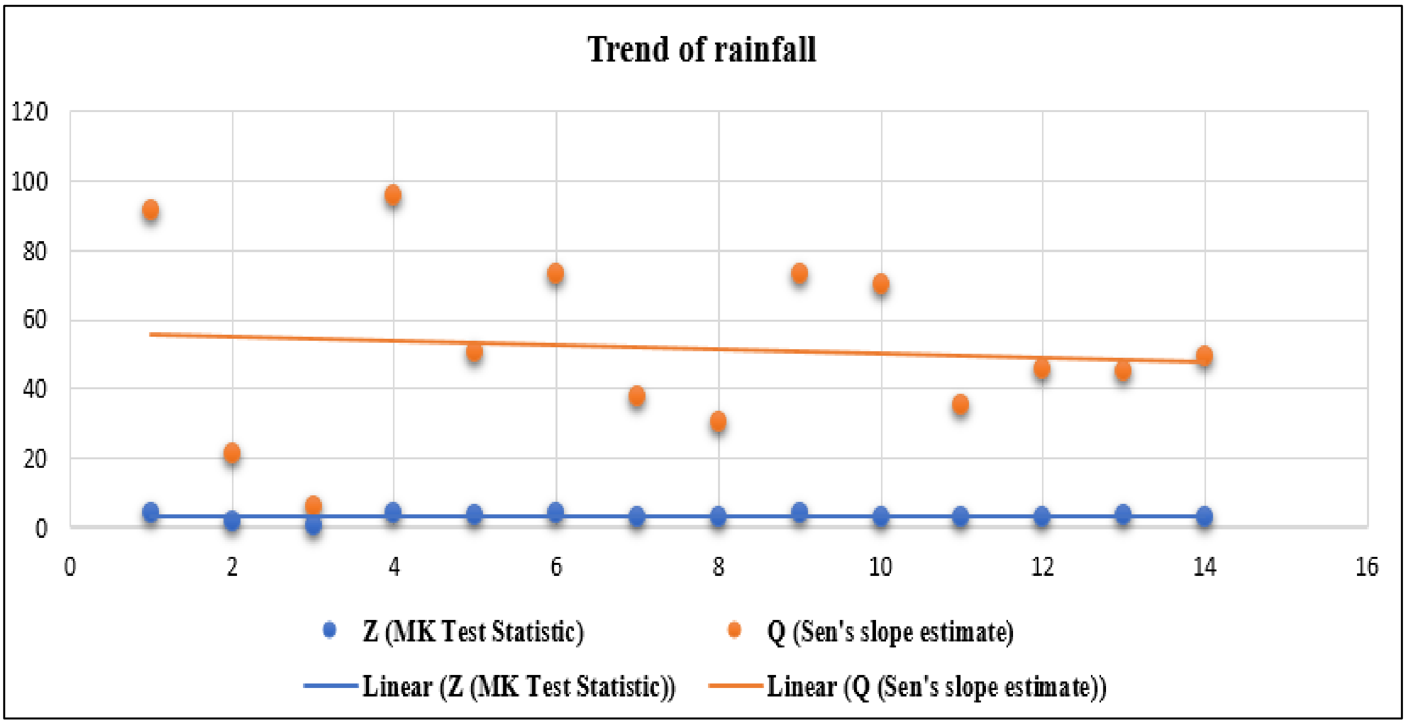

Fig 4 MK Statistics and Sen's Slope for Rainfall (2001-2021)

IV. CONCLUSION

I conclude from my study's findings that the Sen Slope estimator and the Mann-Kendall test offer outstanding outcomes in presenting the region's climatic variables' progression. I have observed an unpredictability in the weather; we have also observed a clear increase tendency in rainfall and minimum temperature. However, there was a declining tendency in the maximum temperature. The region may experience a series of extreme occurrences, including floods, as a result of this trend. Since floods are unavoidable, it is wise to track and analyse variations in rainfall and temperature to prevent potentially disastrous outcomes. Along with predicting and looking for new metrics to adjust to and attenuate these more common undesirable events. In the end, we may suggest that mapping be used to identify the overflow zones for floods with varying return times. This is a crucial component to increase awareness, protect lives, prevent damage, and assist in decision-making and action.

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