DOI: 10.21120/LE/18/2/5

Acta Geographica Debrecina
Landscape & Environment series 18 (2) 2024. 63-76

TREND ANALYSIS OF TEMPERATURE OVER THE MEGHALAYA PLATEAU: A CASE STUDY OF RI BHOI DISTRICT

ANDY T.G LYNGDOH*, SUBRATA PURKAYASTHA

Department of Geography, North Eastern Hill University, Shillong, Meghalaya. India
*Email: andygaland86@gmail.com

Received 24 February 2024, accepted in revised form 13 May 2024

Abstract
Temperature is an important element of climate, and its trend analysis helps the scientific community assess the phenomena of climate change as experienced by the world at present. The present paper attempts to assess the change in temperature on the northern slopes of the Meghalaya plateau by taking up the Ri Bhoi district as an area of study. This district, located in the north, connects the highest part of the Meghalaya plateau to the Brahmaputra plains. It also has two separate peneplain surfaces, one from Jorhat to Khanapara and the other from Nongpoh to Byrnihat, both at different elevations. Hence, this paper is attempting to analyze the trend and magnitude of the minimum temperature (T-min) and maximum temperature (T-max) over the Highland and Lowland zones of Ri Bhoi from 1999 to 2019 using the Mann-Kendall test and Sen slope estimate to see how they changed over time. The results suggest a significant trend of change in T-min and T-max for the months of January, February, and October. Further, the Sen's slope values for the average monthly T-min indicate a cooler and warmer condition, while the slope values for the average monthly T-max reveal a warmer climatic condition in both zones. The results suggest that no significant trend in the average seasonal T-min and T-max time series has been detected in both the Highland and Lowland of Ri Bhoi, but the average T-max post-monsoon and winter seasons in the Highland zone show a significant trend. Further, results also reveal that the magnitude of the average seasonal Tmax trend shows an increasing slope indicating a warmer condition, while the magnitude of the average seasonal T-min trend reveals a decreasing slope suggesting cold or cooler conditions, especially during the pre-monsoon, monsoon, and post-monsoon seasons.

Keywords: Trend analysis, Minimum Temperature, Maximum Temperature, Mann-Kendall test, Sen's Slope estimate, Ri Bhoi District

1. Introduction

Global climate change is evident by an increase in surface and ocean water temperatures, the melting of the iceberg, a rise in sea level, and the erratic behavior of rainfall from time to time. Human activities such as clearing forest land for farming activities and land use changes significantly distort the phenomenon of climate change (Seneviratne et al., 2012), and the alteration in the climate will have a serious impact on the world.

Surface temperature (maximum and minimum temperature) is a significant climatic parameter. Studies indicate that temperatures have increased significantly, primarily due to global warming, heat waves, and drought conditions that have become more frequent. The soaring temperature and changes in the frequency and severity of extreme climate events, particularly in terms of the increase in temperature, will have significant consequences on the agriculture and agro-based sectors, the availability of water resources, human well-being, and society as a whole (Seneviratne et al., 2012; Deshmukh and Lunge, 2013).

Using a non-parametric test, like the Mann-Kendall test and Sen's slope estimate, to look at the temperature trend over time is more acceptable and reliable. This is because these statistical methods can handle time series data that doesn't have a random statistical distribution (Mohammed & Santhanakrishnan, 2021).

Ghasemi (2015), while assessing the changes and trend in temperature in Iran with the help of the Mann-Kendall test and Sen's Slope Estimate from 1961 to 2010, found out that the minimum temperature (T-min) shows a warming trend across all clusters, with an average rate of 0.32 °C, 0.42 °C, 0.36 °C, and 0.32 °C per decade for winter, spring, summer, and autumn, respectively. On the other hand, the maximum temperature (T-max) shows an increase of 0.22º C, 0.21º C, 0.17º C, and 0.07º C per decade for winter, spring, summer, and autumn, respectively. The above values suggest that T-min trends increase more than T-max trends in all seasons. It's also interesting to note that the most significant trend is recorded in summer and spring as compared to winter and autumn in all clusters. In addition, the most significant trends are more prevalent in warm-climate regions than in cold-climate ones. Despite the fact that the maximum temperature change rates do not show a significant difference between regions with warm and cold climates, averaging over regions with warm climates yields a significant warming of 0.61º C per decade in T-min, whereas averaging over regions with cold climates yields a warming of only 0.39º C per decade in T-min. This suggests that the regions with warm climates in Iran are warming at a much faster rate than the regions with cold climates.

While analyzing the temperature trend using the Mann-Kendall test and Sen's slope estimate at the 5 percent level of significance in the Ghotki district of Sindh from 2000 to 2020, Shah & Kiran (2021) found out that the annual average temperature showed an increasing trend, and the slope is 0.012, suggesting an increasing trend in the magnitude of temperature. Further, the seasonal average temperature of the summer and autumn depicts a sharply increasing trend, with an estimated slope of 0.025 and 0.028, respectively, suggesting an increasing trend in magnitude of temperature. Similarly, the winter and spring seasons show an increasing trend, along with an increasing trend in the magnitude of temperature and the slope, which were determined to be 0.010 and 0.005, respectively, from 2000 to 2022.

India is a developing country affected by climate change and global warming. Numerous scientific studies for the Indian subcontinent have been conducted, and the results reveal that the mean annual temperature has risen by 0.51 ºC from 1901 to 2005 all over India (Fulekar and Kale, 2010).

While employing the Mann-Kendall Test and Sen's Slope Estimate to investigate the minimum temperature and maximum temperature trend on a yearly, seasonal, and monthly average from 1901 to 2002 in the Ranchi and Lohardaga districts of Jharkhand, Kerketta and Singh (2020) found out that the majority of the months revealed a statistically insignificant positive minimum and maximum temperature trend; however, significant positive trends were seen in February, October, November, and December. A statistically significant increasing minimum temperature trend is seen only in the post-monsoon season in Ranchi and Lohardaga. On the other hand, a statistically significant increasing maximum temperature trend is depicted in the post-monsoon and winter seasons in both districts. Further, while examining the yearly average minimum temperature and maximum temperature trend, results reveal a significant positive trend in both Ranchi and Lohardaga districts. Conversely, while analyzing the trend variation in the maximum and minimum temperature pattern in Uttarakhand from 1990–2019 by using the Mann-Kendall Test and Sen's Slope Estimate at a 95 percent confidence level, Bhardwaj et al. (2020) found out that the average annual minimum temperature p-value is 0.002 °C, suggesting a statistically significant positive trend, while the p-value of the average maximum temperature is 0.748 °C, depicting a statistically insignificant positive trend as the p-value is greater or equal to the alpha value (0.05 °C). Further, while analyzing the magnitude of the trends with the help of Sen's Slope Estimate, results reveal an increasing magnitude in the maximum temperature and minimum temperature trends, indicating a slightly warming period and a cooling period, respectively.

Studying the spatio-temporal distribution of maximum temperature (T-max) and minimum temperature (T-min) in India is necessary, as it will enable a better understanding and provide valuable information regarding water availability. It will also be useful for flood forecasting, hydrological process modeling, water balance components, crop production, and water management resources. The maximum temperature (T-max) and minimum temperature (T-min) at the international, national, and local levels have been the subject of several studies and research projects (Rao et al., 2005).

The northern slope of the Meghalaya plateau, which covers Ri Bhoi district, is an important physiographic zone because it connects the plateau with the Brahmaputra plains. Although a lot of research has been conducted on rainfall in Meghalaya and Ri Bhoi district in particular (Lyngdoh and Purkayastha, 2024), studies on temperature, which is another important climatic parameter, have rarely been investigated. The rising temperature as a result of climate change over the Meghalaya plateau and Ri Bhoi District, in particular, is a reality, and Roy et al. (2022) suggest that the Ri-Bhoi District has recorded the maximum variability in the average monthly temperature from 2009 to 2013 and is the most vulnerable district to climate change among the other districts in Meghalaya. An alternation in temperature can have a significant impact on crop yield and increase pest and disease outbreaks, which can hamper the livelihood of the farmers and the economy of Meghalaya (Finance Department, Government of Meghalaya, 2024). Consequently, the review of the literature indicates that the trend analysis pertaining to the average monthly, seasonal, and annual maximum temperature (T-max) and minimum temperature (T-min) has not yet been investigated at a micro-level.

2. Objective

The present work aims to analyze the minimum temperature (T-min) and maximum temperature (T-max) trend and its magnitude on an average monthly, average seasonal, and average annual basis in the Highland and Lowland zones of Ri Bhoi district, Meghalaya from 1999 to 2019.

3. Location of the Study Area

The study area spans between 91°20′30″ to 92°17′00″ east longitude and 25°40′ to 26°20′ north latitude, with an elevation ranging from 100 to 1300 meters above mean sea level (Kharkongor, 2012), as shown in Fig1. Attributed to complex climatic conditions that range from hot and humid summers and cool winters in areas bordering Assam to pleasant and humid summers and cold winters in areas closer to Shillong, which is the central part of the Meghalaya plateau.

Ri Bhoi district is comparatively drier than other districts in Meghalaya due to the rain shadow effect (Diamari, 2013) and experiences erratic rainfall behavior (Chowdhury et al., 2012). The temperature

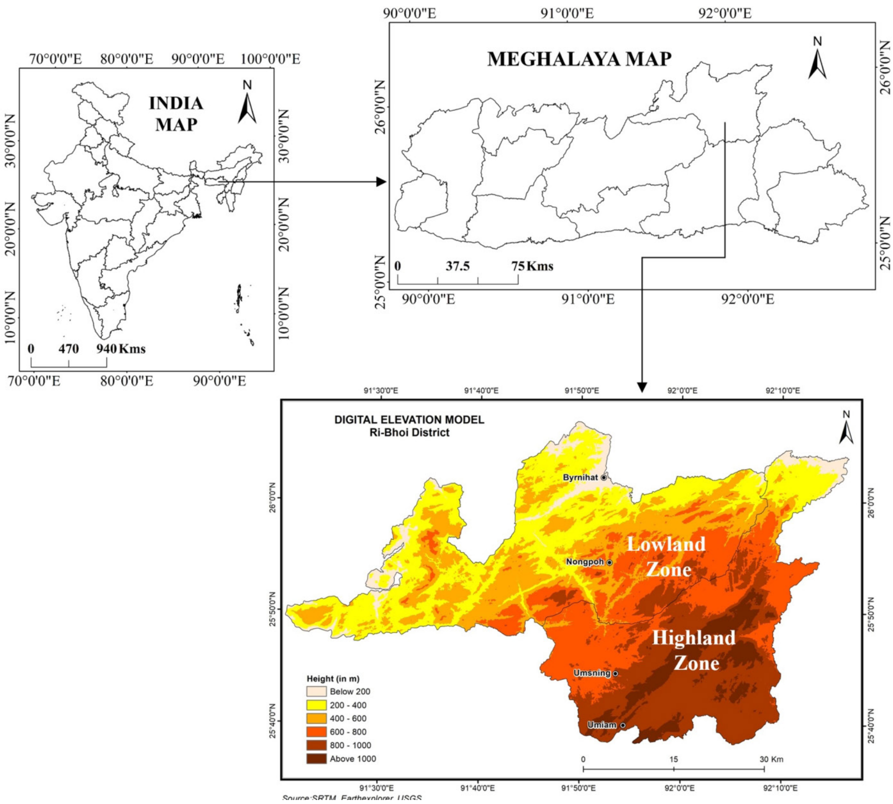

Fig. 1. Location of the study area

of the area averages between 18 and 30 °C, and rainfall averages between 1245 and 1500 millimeters (Lyngdoh and Purkayastha, 2024). The region is basically a rural area dominated by the Bhoi's (tribal communities) who live close to nature, deriving their livelihood mainly from various agricultural activities.

4. Materials and Methodology

To examine the minimum temperature (T-min) and maximum temperature (T-max) trends of Ri Bhoi district, firstly, the district has been divided into two altitudinal zones, namely the Highland zone and the Lowland zone. The Highland zone is marked by the contour of above 700 meters, located closer to the Shillong plateau; on the other hand, the Lowland zone is marked by the contour of below 700 meters, lying closer to the Brahmaputra plain, as different climatic conditions prevail over these two zones. The Highland zone experiences a pleasant summer and cold winter; on the other hand, the Lowland zone experiences a hot and humid summer and cool winter.

The monthly T-min and T-max data has been collected from four stations, namely Umiam and Umsning stations, representing the Highland zone, and Nongpoh and Byrnihat stations, representing the Lowland zone. Besides this, the monthly T-min and T-max data has also been retrieved from the Indian Meteorological Department, the Department of Agriculture, the Government of Meghalaya, and NASA Data Access Viewer from 1999–2019 (Stackhouse, n.d.).

Finally, the T-min and T-max trends of the two elevation zones were computed and analyzed on average monthly, seasonal, and yearly levels using the non-parametric statistical technique that is the Mann-Kendall test and Sen Slope Estimate with a 95% confidence level. The Mann-Kendall test and Sen Slope Estimate are used as they deal with irregular and abnormally distributed temperature data in the time series. The Mann-Kendall test is used to check the null hypothesis (Ho) of no trend against the alternative hypothesis (Ha) of the existence of an increasing or decreasing trend in the time series data. Equation 1 shows how to calculate the statistic.

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}\left(x_j - x_i\right) \qquad \text{Eq. 1.}$$

Where,

x_j and x_i are the annual values in years *j* and *i*, *j > i* respectively, n is the data points number, while $\operatorname{sgn}(x_j - x_i)$ is calculated by applying equation 2.

$$\operatorname{sgn}\left(x_j - x_i\right) = \begin{cases} 1 & \text{if } x_j - x_i > 0 \\ 0 & \text{if } x_j - x_i = 0 \\ -1 & \text{if } x_j - x_i < 0 \end{cases} \qquad \text{Eq. 2}$$

An increase or decrease trend indicates a positive or negative value of the S-statistic, respectively. To obtain the Z-value, the calculation of the variance of the rainfall is important. The calculation of the variance (S) is as follows:

$$\operatorname{Var}(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{n} t_i(t_i-1)(2t_i+5)}{18} \qquad \text{Eq. 3}$$

Where,

The symbol *n* in equation 3 represents the number of tied (zero difference between compared values) groups, and t_i is the data points number in the i^{th} tied group.

Using equation 4, the standard normal distribution (Z-statistics) is computed using the following formula:

$$Z = \begin{cases} \frac{S-1}{\sqrt{\operatorname{Var}(S)}} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \frac{S+1}{\sqrt{\operatorname{Var}(S)}} & \text{if } S < 0 \end{cases} \qquad \text{Eq. 4}$$

The Z-value is a statistical measure used to determine the significance of a trend. While a negative value of Z indicates a decreasing trend, a positive value of Z suggests an increasing trend. Consequently, in a two-sided trend test, if the computed value of Z > 1.96, the null hypothesis (of no trend) is rejected; on the other hand, if the value of Z < -1.96, the null hypothesis (of no trend) is accepted in the time series (Jaswal et al., 2015).

Another non-parametric method for trend analysis of the hydrological and hydrometeorological data sets is Sen's Slope Estimate (Alemu &Dioha, 2020). Sen's estimator tends to determine the magnitude of the trend, and this test calculates the slope and intercept of the linear rate of change (Sen, 1968). The formula for finding the Sen's slope of all the data pairs is as follows:

$$T_i = \frac{x_j - x_k}{j-k} \text{ for } i = 1,2,3, \ldots n \qquad \text{Eq. 5}$$

Where,

x_j and x_i are the values of the data at times *j* and *k (j > k)* separately. Sen's Slope Estimate represents the median of the n values of T_i, and the formula for calculating it is as follows:

$$Q_i = \begin{cases} T_{n+1} & \text{for } n \text{ is odd} \\ \frac{1}{2}\left(T_{\frac{n}{2}} + T_{\frac{n+2}{2}}\right) & \text{for } n \text{ is even} \end{cases} \qquad \text{Eq. 6}$$

Further, all the calculations are being computed with the help R Software version 4.2.1 (R: The R Project for Statistical Computing, June 2022) and XLSTAT version 2022.5.1.(Addinsoft, 2022)

5. Results

Trend analysis of the average monthly, seasonal, and annual minimum temperature (T-min) and maximum temperature (T-max) from 1999–2019 in the Highland Zone

Analysing the average monthly T-min trend in the Highland zone with the Mann-Kendall test, Table 1 shows that only October has a

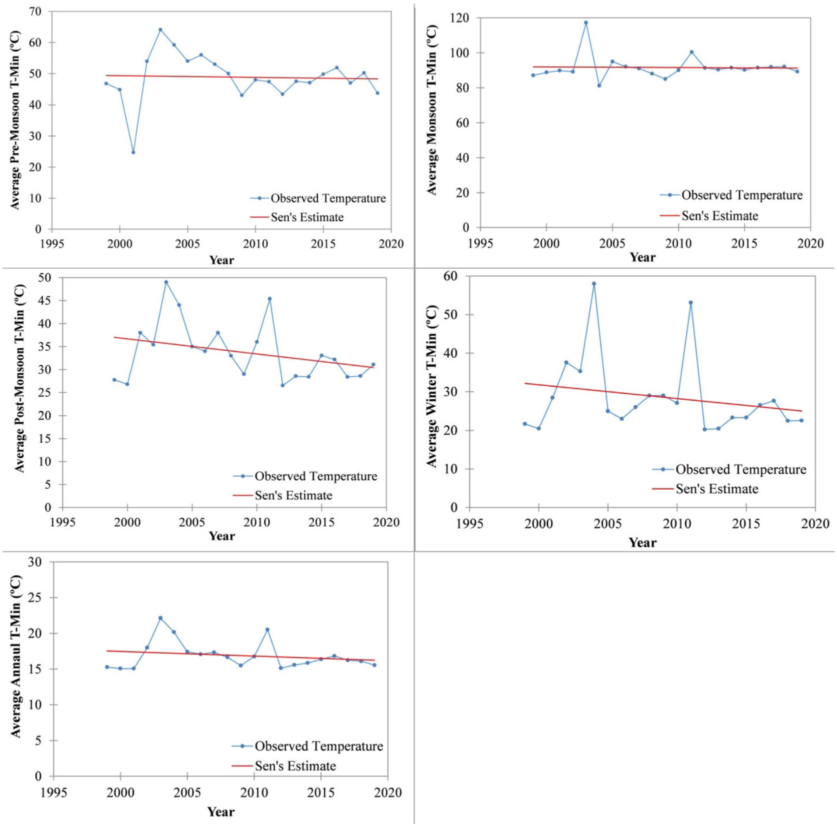

Fig. 2. Observed average seasonal and annual minimum temperature of the Highland zone, Ri Bhoi District (1999-2019)

statistically significant decreasing trend. This is because the P-value ≤ α at a 95% confidence level supports the alternative hypothesis (Ha), which means there is a monotonic trend. On the other hand, January, February, and October reveal a statistically significant increasing trend in the average monthly T-max time series, accepting the alternative hypothesis (Ha), as shown in Table 2. Also, the test results show that most of the months have a statistically insignificant rising and falling trend, as shown in Tables 1 and 2. This supports the null hypothesis (Ho) that the T-min and T-max times series have not changed significantly. Similarly, using Sen's slope estimate to look at the magnitude of the average monthly temperature trend from 1999 to 2019, the results from Tables 1 and 2 show that the average monthly T-min trend is both falling and rising by -0.03 to 0.06 °C per year, while the average monthly T-max trend is going up by 0.16 to 0.51 °C per year.

The data from Table 1 shows that the average seasonal T-min trend has an insignificant downward trend in all seasons except the monsoon season, which is represented by an insignificant upward trend. This means that the average seasonal T-min time series has not changed significantly over the last twenty years (1999–2019), thereby accepting the null hypothesis (Ho). In contrast, Table 2 shows a statistically significant upward trend during the average winter and post-monsoon seasons. This suggests that the average seasonal T-max time series in the Highland zone has a monotonic trend during the average winter and post-monsoon seasons, supporting the alternative hypothesis (Ha). By looking at the magnitude of the temperature trend from

Table 1. Mann-Kendall and Sen's Slope Estimate Trend of Minimum Temperature (1999-2019) in the Highland zone

Months	MK Statistic	Kendall Tau	Var (S)	P- value (two tailed test)	Alpha Value	Z Statistic	Sen's Slope
January	11.00	0.05	1093.00	0.76	0.05	0.30	0.02
February	-27.00	-0.13	1093.67	0.43	0.05	-0.79	-0.12
March	-54.00	-0.26	1092.00	0.11	0.05	-1.60	-0.20
April	2.00	0.01	1094.67	0.98	0.05	0.03	0.00
May	-32.00	-0.15	1094.67	0.35	0.05	-0.94	-0.05
June	48.00	0.23	1092.00	0.16	0.05	1.42	0.04
July	11.00	0.05	1093.67	0.76	0.05	0.30	0.01
August	52.00	0.25	1088.00	0.12	0.05	1.55	0.06
September	-20.00	-0.10	1094.67	0.57	0.05	-0.57	-0.03
October	-67.00	-0.32	1093.67	0.046*	0.05	-2.00	-0.25
November	-42.00	-0.20	1092.00	0.22	0.05	-1.24	-0.11
December	-43.00	-0.21	1095.67	0.20	0.05	-1.27	-0.16
Annual	-24.00	-0.11	1095.67	0.49	0.05	-0.69	-0.08
Winter	-29.00	-0.14	1093.67	0.40	0.05	-0.85	-0.71
Pre-Monsoon	-34.00	-0.16	1093.67	0.33	0.05	-1.00	-0.24
Monsoon	48.00	0.23	1093.67	0.16	0.05	1.42	0.12
Post-Monsoon	-51.00	-0.24	1095.67	0.13	0.05	-1.51	-0.37

*Value is statistically significant at 95% confidence level.
+ Sign indicates increasing trend whereas –sign indicates decreasing trend.

Table 2. Mann-Kendall and Sen's Slope Estimate Trend of Maximum Temperature (1999-2019) in the Highland zone

Months	MK Statistic (S)	Kendall Tau	Var (S)	P- value (two tailed test)	Alpha Value	Z Statistic	Sen's Slope
January	80.00	0.39	1090.00	0.02*	0.05	2.39	0.35
February	68.00	0.33	1094.67	0.04*	0.05	2.03	0.32
March	65.00	0.31	1095.67	0.057	0.05	1.93	0.51
April	64.00	0.31	1094.67	0.06	0.05	1.90	0.50
May	51.00	0.25	1093.67	0.13	0.05	1.51	0.49
June	51.00	0.25	1091.00	0.13	0.05	1.51	0.36
July	40.00	0.19	1094.67	0.24	0.05	1.18	0.32
August	60.00	0.29	1094.67	0.08	0.05	1.78	0.22
September	53.00	0.25	1093.00	0.12	0.05	1.57	0.17
October	87.00	0.42	1093.67	0.01*	0.05	2.60	0.44
November	56.00	0.27	1092.00	0.10	0.05	1.66	0.31
December	62.00	0.30	1092.00	0.07	0.05	1.85	0.16
Annual	64.00	0.31	1092.00	0.06	0.05	1.91	0.39
Winter	79.00	0.38	1095.67	0.02*	0.05	2.36	1.00
Pre-Monsoon	63.00	0.30	1095.67	0.06	0.05	1.87	1.67
Monsoon	37.00	0.18	1095.67	0.28	0.05	1.09	0.92
Post-Monsoon	76.00	0.37	1092.00	0.02*	0.05	2.27	0.59

*Value is statistically significant at 95% confidence level.
+ Sign indicates increasing trend whereas –sign indicates decreasing trend.

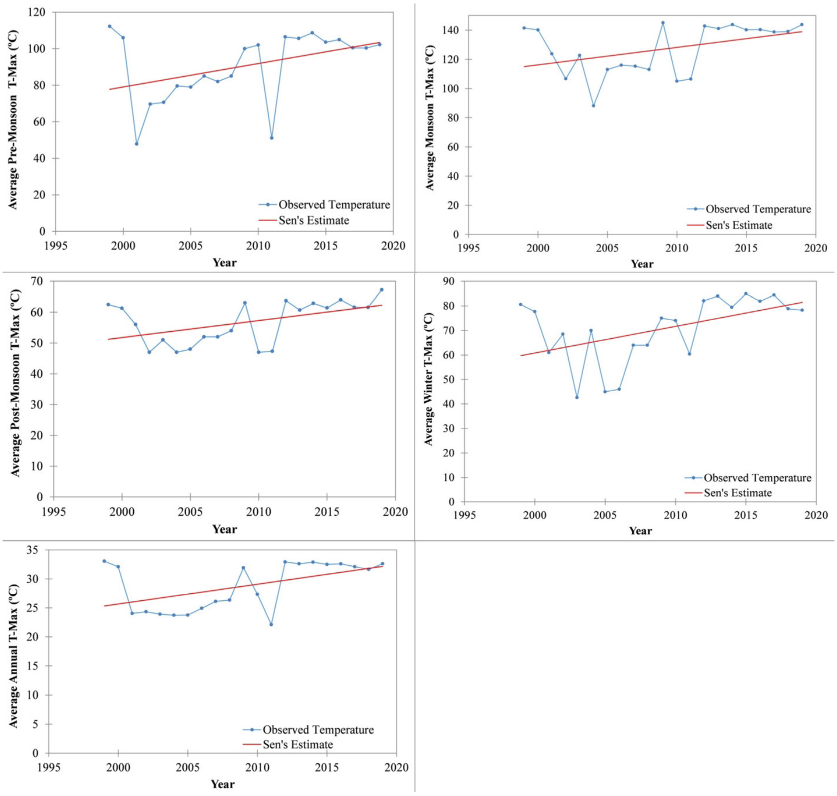

Fig. 3. Observed average seasonal and annual maximum temperature of the Highland zone, Ri Bhoi District (1999-2019)

Table 1 and Fig. 2, the result indicates that the average seasonal T-min trend is declining by -0.05 to -0.71 °C per year, except during the average monsoon season, which highlights a positive trend. On the other hand, the magnitude of the average seasonal T-max trend is increasing by 0.59 to 1.67 °C per year, as shown in Table 2 and Fig. 3.

The results from Tables 1 and 2 reveal an insignificant T-min and T-max trend, and no marked changes are observed in the average annual T-min and T-max time series in the Highland zone. Further from Tables 1 and 2, the results reveal that the magnitude of the average annual T-min is declining by -0.08 °C per year (Fig. 2), and that of the average annual T-max is increasing by 0.39 °C per year (Fig. 3) from 1999 to 2019. Another thing that can be seen is that the Z-statistic values match the Kandell Tau values when looking at the T-min and T-max trends on a monthly, seasonal, and yearly average.

Trend analysis of the average monthly, seasonal, and annual minimum temperature (T-min) and maximum temperature (T-max) from 1999–2019 in the Lowland Zone

In the Lowland zone, the average monthly T-min depicts both positive and negative values that are not statistically significant, as shown in Table 3, accepting the null hypothesis (Ho). Furthermore, the result from Table 4 indicates that the average monthly T-max shows a positive, insignificant trend, except for October, as the P-value ≤ α at a 95% confidence level. This supports the alternative hypothesis (Ha) that there has been a monotonic trend in October over the past 20 years. According to Sen's slope estimate, the test results in Table 3 reveal that the magnitude of the average monthly T-min is both decreasing and increasing by -0.01 to 0.05 °C per year, while that of the average monthly T-max is decreasing and increasing by -0.05 to 0.19 °C per year, as

Table 3. Mann-Kendall and Sen's Slope Estimate Trend of Minimum Temperature (1999-2019) in the Lowland zone

Months	MK Statistic (S)	Kendall Tau	Var (S)	P- value (two tailed test)	Alpha value	Z Statistic	Sen's Slope
January	10	0.05	1094.67	0.79	0.05	0.27	0.04
February	-24	-0.11	1094.67	0.49	0.05	-0.70	-0.20
March	-16	-0.08	1094.67	0.66	0.05	-0.45	-0.07
April	5	0.02	1095.67	0.90	0.05	0.12	0.01
May	24	0.11	1095.67	0.49	0.05	0.69	0.05
June	20	0.10	1094.67	0.57	0.05	0.57	0.04
July	-9	-0.04	1095.67	0.81	0.05	-0.24	-0.02
August	27	0.13	1093.00	0.43	0.05	0.79	0.03
September	-7	-0.03	1095.67	0.86	0.05	-0.18	-0.01
October	-28	-0.14	1092.00	0.41	0.05	-0.82	-0.10
November	-8	-0.04	1092.00	0.84	0.05	-0.21	-0.04
December	-11	-0.05	1095.67	0.76	0.05	-0.21	-0.04
Annual	-12	-0.06	1095.67	0.74	0.05	-0.33	-0.07
Winter	-8	-0.04	1095.67	0.84	0.05	-0.21	-0.05
Pre-Monsoon	-12	-0.06	1095.67	0.74	0.05	-0.33	-0.09
Monsoon	16	0.08	1095.67	0.66	0.05	0.45	0.07
Post-Monsoon	-14	-0.07	1095.67	0.70	0.05	-0.39	-0.17

*Value is statistically significant at 95% confidence level.
+ Sign indicates increasing trend whereas –sign indicates decreasing trend.

Table 4. Mann-Kendall and Sen's Slope Estimate Trend of Maximum Temperature (1999-2019) in the Lowland zone

Months	MK Statistic (S)	Kendall Tau	Var (S)	P- value (two tailed test)	Alpha Value	Z Statistic	Sen's Slope
January	39.00	0.19	1095.67	0.25	0.05	1.15	0.11
February	16.00	0.08	1095.67	0.66	0.05	0.45	0.04
March	14.00	0.07	1095.67	0.70	0.05	0.39	0.03
April	31.00	0.15	1095.67	0.37	0.05	0.91	0.11
May	3.00	0.01	1095.67	0.95	0.05	0.06	0.01
June	37.00	0.18	1095.67	0.28	0.05	1.09	0.13
July	32.00	0.15	1095.67	0.36	0.05	0.94	0.07
August	-32.00	-0.15	1095.67	0.36	0.05	-0.94	-0.05
September	38.00	0.18	1095.67	0.27	0.05	1.12	0.07
October	71.00	0.34	1095.67	0.03*	0.05	2.11	0.19
November	40.00	0.19	1095.67	0.24	0.05	1.18	0.11
December	39.00	0.19	1095.67	0.25	0.05	1.15	0.10
Annual	28.00	0.13	1095.67	0.42	0.05	0.82	0.05
Winter	48.00	0.23	1095.67	0.16	0.05	1.42	0.29
Pre-Monsoon	4.00	0.02	1095.67	0.93	0.05	0.09	0.05
Monsoon	20.00	0.10	1095.67	0.57	0.05	0.57	0.19
Post-Monsoon	58.00	0.28	1095.67	0.09	0.05	1.72	0.23

*Value is statistically significant at 95% confidence level.
+ Sign indicates increasing trend whereas –sign indicates decreasing trend.

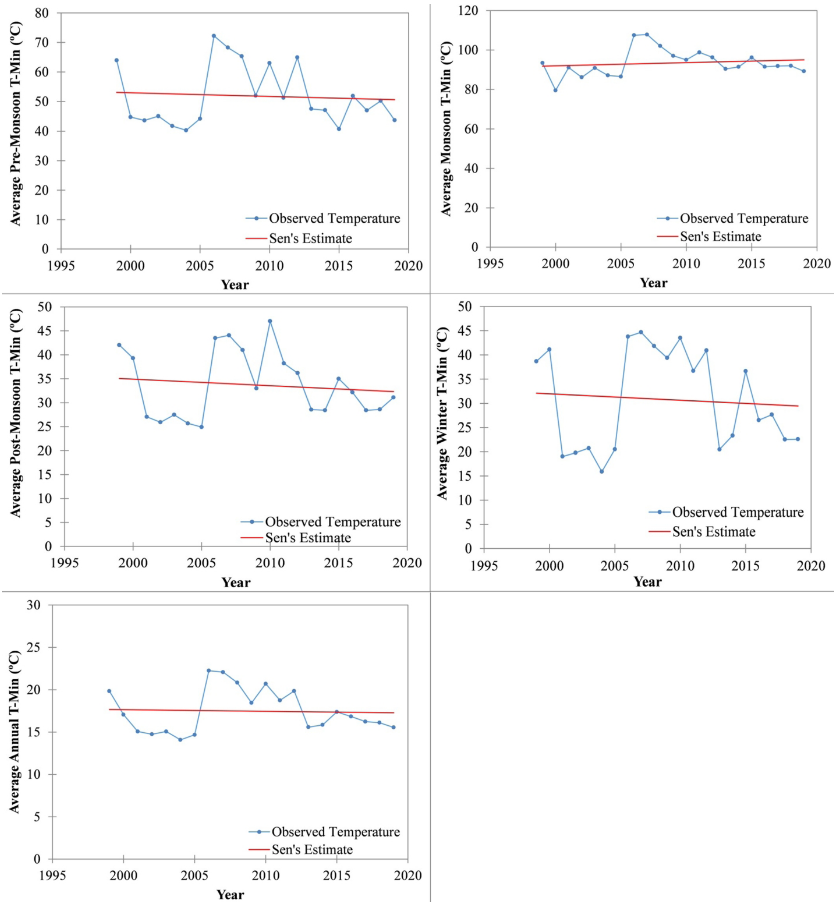

Fig. 4. Observed average seasonal and annual minimum temperature of the Lowland zone, Ri Bhoi District (1999-2019)

shown in Table 4.

When analysing the average seasonal temperature trend, Tables 3 and 4 show a trend that is statistically not significant and rises and falls while accessing the T-min and T-max. This supports the null hypothesis (Ho), and there were no noticeable changes in temperature from 1999 to 2019. While examining the magnitude of the average T-max trend, the results suggest that the average winter, pre-monsoon, and post-monsoon seasons have declined by -0.05 to -0.17 °C per year, while the average monsoon season has increased by 0.07 °C per year, as shown in Table 3 and Fig. 4. Conversely, the magnitude of the average seasonal T-max has increased by 0.05 to 0.29 °C per year in all the seasons, as shown in Table 4 and Fig. 5.

The average annual temperature trend in the Lowland zones can be seen in Tables 3 and 4. The Mann-Kendall test and Sen's slope estimate show a statistically insignificant negative T-min trend and a positive T-max trend, respectively. This means that there aren't any changes in the T-min and T-max time series from 1999 to 2019. Also, Tables 3 and Fig. 4 show that the average annual T-min is going down at a rate of -0.07 °C per year, while the average annual T-max is going up at a rate of 0.05 °C per year, as shown in Table 4 and Fig. 5. Additionally, Tables 3 and 4 show that the Z-statistic values match the

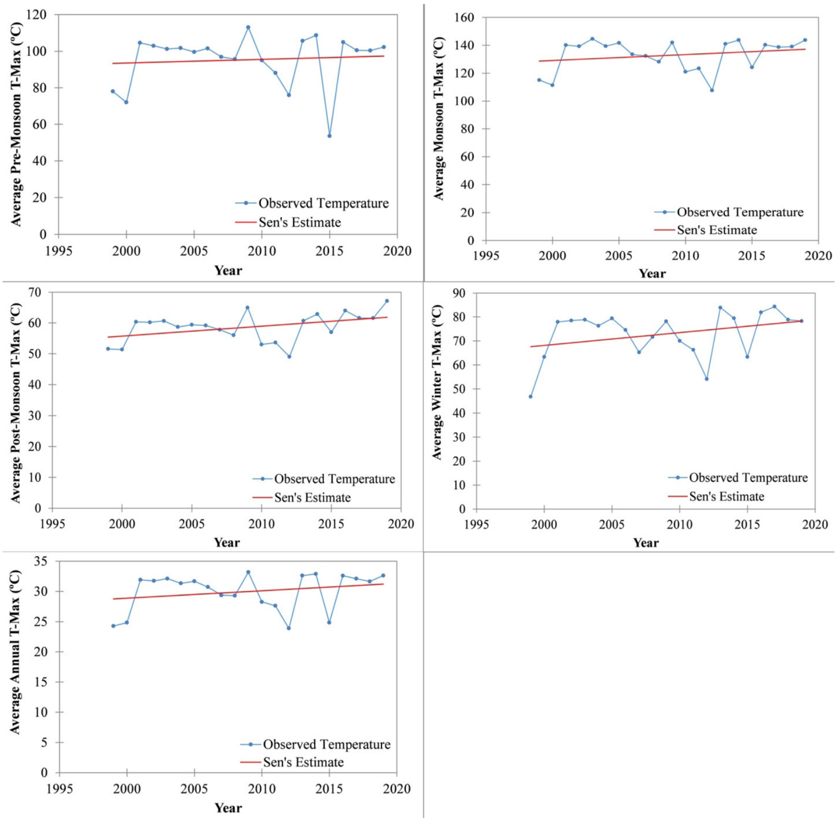

Fig. 5. Observed average seasonal and annual maximum temperature of the Lowland zone, Ri Bhoi District (1999-2019)

Kandell Tau values for both the T-min and T-max trends in the Lowland zone over a twenty-year period.

6. Discussion

Surface temperature, be it monthly, seasonally, or yearly, is greatly affected by altitude, vegetational cover, and the location of a place (Kalita et al., 2020). If the temperature (minimum and maximum) increases or decreases over a longer period of time than normal, it can alter the hydrological and other biogeochemical cycles. This can lead to rapid evaporation and evapotranspiration (Dai et al., 2018; Kalita et al., 2020), which can impact soil fertility, crop productivity, water resources, and the agro-based livelihood of people in general (Lyngdoh, 2018).

This study reveals that the average monthly T-min trend is significant only in October and not at all in the other months. The Sen slope was decreasing (-0.03 to -0.25 °C per year) and rising (0.01 to 0.06 °C per year). The average monthly T-max trend was significant in January, February, and October, but not at all significant in the other months. The Sen slope was increasing. These results are similar to those found by Kalita et al. (2020). In the Lowland zone, no significant trend is seen in the average monthly T-min with a declining Sen's slope (-0.01 to -0.20 °C per year) and a rising slope (0.01 to 0.05 °C per year); however, a significant trend is reported only in October in the average monthly T-max time series with an increasing Sen's slope. Therefore, this study's results agree with those of Bhardwaj et al. (2020), showing that the most significant trend is seen in the average monthly T-max compared to the average monthly T-min. A recoded negative or no trend in the Sen's slope in the study area means that the region experiences a cold or cooler climate, while an increasing trend in the Sen's slope indicates a warmer climatic condition.

There is no significant trend in the average seasonal T-min in the Highland zone nor in the average seasonal T-min and T-max in the Lowland zone. However, the average seasonal T-max time series in the Highland zone shows a significant trend during the post-monsoon and winter seasons. This finding is in line with what Chakraborty et al. (2014) and Kerketta and Singh (2020) found, which suggests that the seasonal changes in the T-min and T-max are mostly caused by the south-west and north-east monsoons over the high hills of the Meghalaya plateau.

Further, Sen's slope reveals an increasing slope in the average pre-monsoon, post-monsoon, and winter seasons in the T-max trend in both zones. Such findings bear a similar result to Chakraborty et al. (2014), which suggest that the decrease in rainfall during the pre-monsoon, post-monsoon, and winter seasons has resulted in warmer climatic conditions, especially during the daytime. However, the average seasonal T-min trend in the Highland and Lowland zones reveals a warmer and cooler climatic condition.

The average annual T-min and T-max show a statistically insignificant positive and negative trend in both zones of the Ri Bhoi district. These results agree with those of Kalita et al. (2020), who found that temperatures in Meghalaya are rising by between 0.2 and 1.4 °C every 100 years. However, the Sen's slope estimates reveal that the magnitude of the average annual T-min trend is falling while that of the average annual T-max is rising in the Highland and Lowland zones. Between 1999 and 2019, the trend and magnitude of the average annual T-min and T-max changed in both zones. This could be due to more or less rain, pollution, forest fires, global warming, changes in air flow, new factories, and more exposure to sunlight (Kalita et al., 2020; Gocic and Trajkovic, 2013), all of which affected crop growth, crop yield, and the rural livelihood of the people of the Ri Bhoi district.

7. Conclusion

Located on the northern slopes of the Meghalaya plateau, the Highland and Lowland zones of Ri Bhoi district are characterized by distinct climatic attributes that are greatly influenced by the south-west monsoon, altitude, and latitude. The trend analysis of different climatic parameters, especially T-min and T-max, is significant because they influence agricultural productivity, rural livelihoods, and the wellbeing of people residing in these zones.

The main goal of this study is to look at the T-min and T-max trend and its magnitude on a monthly, seasonal, and annual average in the Highland and Lowland zones of Ri Bhoi district from 1999 to 2019. This will be done using non-parametric statistical methods like the Mann-Kendall test and Sen's slope estimate with a 95% confidence level.

The time series data on the average temperature (T-min and T-max) trends and their magnitude in the Highland and Lowland zones of Ri Bhoi district from 1999 to 2019 reveals no significant changes except for January, February, and October, which show a significant trend. Further, the Sen's slope values for the average monthly T-min indicate a cooler and warmer condition, while the slope values for the average monthly T-max reveal a warmer climatic condition in both zones. Similarly, no significant trend has been detected in the average seasonal T-min and T-max time series in the Highland and Lowland except for the average T-max post-monsoon and winter season in the Highland zone that reveals a significant trend. The dynamics of the monsoon, changes in global atmospheric circulation, deforestation, pollution, and so on that happen over the Meghalaya plateau have a significant effect on the T-min and T-max in the study area. In both zones, the T-max trend shows an increasing Sen's slope, while the T-min trend shows a decreasing slope, indicating warmer and cooler climatic conditions, respectively.

The average annual T-min and T-max time series in both zones show no significant trends or changes. Further, the Sen's slopes indicate that the T-min and T-max are characterized by a cold or cooler and warmer climatic condition, respectively, in the Highland and Lowland zones of the Ri Bhoi district from 1999–2019.

The rationale behind identifying T-min and T-max trends on a monthly, seasonal, and annual scale for the Highland and Lowland zones in the Ri Bhoi district is that this can help create awareness among the population to reduce the adverse effects of climate change, the risk of drought, degrading water resources, and crop failure. Furthermore, these small-scale studies, especially in places where farming is still the primary source of livelihood, will help people, policymakers, and stakeholders understand the pattern and trend of T-min and T-max over the years. This will assist them in devising a robust strategy to combat climate change and cultivate newer crop varieties that can endure the fluctuating patterns and levels of T-min and T-max. This will protect the farmers and their primary livelihood practices, thereby enhancing the overall advancement, particularly in Ri Bhoi district.

Acknowledgement

We, the authors, would like to express our humble thanks to God and our family, who have given us the physical and mental strength to complete this paper. Appreciation also goes to the Indian Meteorological Department, Department of Agriculture, Government of Meghalaya, and NASA Data Access Viewer for providing important data. We would also like to express our gratitude to Mrs. Beltimai Lyngdoh, who has lent us a helping hand in completing this research paper. This research paper is an original research work and part of the researcher's Ph.D. thesis and was not funded by any agency whatsoever.

8. Reference

Addinsoft. (1st May, 2022). XLSTAT statistical and data analysis solution. https://www.xlstat.com.

Alemu, Z. A., and Dioha, M. O. (2020). Climate change and trend analysis of temperature: the case of Addis Ababa, Ethiopia. Environmental Systems Research, 9(1). https://doi.org/10.1186/s40068-020-00190-5Retrieved on 16th January 2024.

Bhardwaj, S.B., Raghav, M., and Bhatt, R. (2020). An Analysis of Trend Variation in Minimum and Maximum Temperature Pattern in Uttarakhand. International Journal of Current Microbiology and Applied Sciences.11, 1292-1301.

https://www.ijcmas.com/special/11/S.B.%20Bhardwaj,%20et%20al.pdfRetrieved on 18th January 2024.

Chakraborty, D., Singh, R, K., Saha, S., Roy, A., Sethy, B., Kumar, A., and Ngachan, S.V. (2014). Increase in extreme day temperature in hills of Meghalaya: its possible ecological & bio-meteorological effect. Journal of agrometeorology, 16(1), 147-152.

https://www.researchgate.net/publication/316239901_Increase_in_extreme_day_temperature_in_hills_of_Meghalaya_its_possible_ecological_bio-meteorological_effect

Retrieved on 18th January 2024.

Choudhury, U.B., Das, A., Ngachan, V.S., Slong, A., Bordoloi, J.L., and Chowdhury, P. (2012). Trend analysis of long-term weather variables in mid-altitude Meghalaya, North-East India. Journal of Agricultural Physics, 12(1), 15-16.

https://www.researchgate.net/publication/298105131_Trend_analysis_of_long-term_weather_variables_in_mid-altitude_Meghalaya Retrieved on 26th January 2024.

Dai, A., Zhao, T., and Chen, J. (2018). Climate Change and Drought: A Precipitation and Evaporation Perspective. Current Climate Change Reports, 4(3), 301–312. https://doi.org/10.1007/s40641-018-0101-6 Retrieved on 6th November 2023.

Daimari, M.C. (2013). Livelihood Pattern in Ri Bhoi District of Meghalaya (Unpublished PhD thesis). North Eastern Hill University, Meghalaya, India, 77-90.

Deshmukh, D. T. D., and Lunge, H. S. (2012). Trend Detection of the Rainfall, Rainy Days and Temperature Data of Akola District in Vidarbha, India. International Journal of Scientific Research, 2(2), 404–407. https://doi.org/10.15373/22778179/feb2013/138 Retrieved on 17th December 2023.

Finance Department, Government of Meghalaya (2024). Climate Action Budget 2023-2024, 1-4. https://megfinance.gov.in/budget_documents/2023-2024/others/climate_action.pdf . Retrieved on 17th June 2024.

Fulekar, M.H., and Kale, R.K. (2010). Impact of climate change: Indian Scenario, University News, 48(24), 15-23.

Ghasemi, A. (2015). Changes and trends in maximum, minimum and mean temperature series in Iran. Atmospheric Science Letters, 16(3), 366–372. https://doi.org/10.1002/asl2.569

Gocic, M., and Trajkovic, S. (2013). Analysis of changes in meteorological variables using Mann-Kendall and Sen's slope estimator statistical tests in Serbia. Global and Planetary Change, 100, 172–182. https://doi.org/10.1016/j.gloplacha.2012.10.014 Retrieved on 17th December 2023.

Kalita, R., Kalita, D., Sharma, Y., Walia, D., and Saxena, A. (2020). Long-term trend analysis of temperature in Meghalaya. Hill Geographer, 36(1), 31-40.

https://www.researchgate.net/publication/350075446_Long-term_trend_analysis_of_temperature_in_Meghalaya#:~:text=The%20annual%20mean%2C%20maximum%20and,is%20observed%20among%20the%20zones. Retrieved on 6th January 2024.

Jaswal, A. K., Karandikar, A., Gujar, M. K., and Bhan, S. C. (2015). Seasonal and annual rainfall trends in Himachal Pradesh during 1951-2005. Mausam, 66(2), 247–264. https://doi.org/10.54302/mausam.v66i2.534Retrieved on 6th January 2024.

Kerketta, J., and Singh, A. K. (2020). Temporal Trend Analysis of Temperature Data Using Mann-Kendall Test and Sen's Slope Estimator. Journal of Water Engineering and Management,1(1), 31-43.https://doi.org/10.47884/jweam.v1i1pp31-43Retrieved on 12thFebruary 2024.

Kharkongor, S.B. (2012). Road network and socio-economic development in Ri Bhoi district, Meghalaya, (Unpublished Ph.D. thesis). North Eastern Hill University, Meghalaya, India.50-59.

Lyngdoh, Andy. T. G. (2018). Impact of Seasonal Variation of Rainfall on Livelihood in Pynursla Area, Meghalaya. (Unpublished M.Phil. dissertation). North Eastern Hill University, Meghalaya, India.

Lyngdoh, A. T. G., and Purkayastha, S. (2024). Rainfall Trend Analysis of the Meghalaya Plateau: A Case Study of Ri Bhoi District. International Journal of Ecology and Environmental Sciences, 50(3), 405–411. https://doi.org/10.55863/ijees.2024.0038 Retrieved on 6th April 2024.

Mohammed, J.N., and SanthanaKrishnan, P, T. (2021). Rainfall Trend Analysis by Mann-Kendall Test and Sen's Slope Estimator: A Case Study of Gummidipoondi Sub-basin, Tamil Nadu, India. International Journal of Scientific & Engineering Research, 12(6), 575-580.https://www.ijser.org/researchpaper/Rainfall-Trend-Analysis-by-Mann-Kendall-Test-and-Sens-Slope-Estimator-A-Case-Study-of-Gummidipoondi-Sub-basin-Tamil-Nadu-India.pdf Retrieved on 6th January 2024.

Panda, A., and Sahu, N. (2019). Trend analysis of seasonal rainfall and temperature pattern in Kalahandi, Bolangir and Koraput districts of Odisha, India. Atmospheric Science Letters, 20(10). https://doi.org/10.1002/asl.932Retrieved on 16hFebruary 2024.

R: The R Project for Statistical Computing. (June, 2022). https://www.r-project.org/ Retrieved on 30th July 2022

Rao, G. S., Murty, M. S. N., Joshi, U., and Thapliyal, V. (2005). Climate change over India as revealed by critical extreme temperature analysis. Mausam, 56(3), 601- 608.

https://doi.org/10.54302/mausam.v56i3.990Retrieved on 6thDecember 2023.

Roy, A., Kolady, D., Singh, N.U., Chakraborty, D., Feroze, S.M., and Yumnam, A. (2022). Impact of climate change on agriculture in north-east India: A case study in Meghalaya. The Pharma Innovation Journal, 11(2), 282-286. https://www.thepharmajournal.com/archives/2022/vol11issue2S/PartD/S-11-1-333-111.pdfRetrieved on 6thNovember 2023.

Saikia, N. U. S., Satapathy, N. K. K., Goswami, N. B., Singh, N. R., and Rao, N. B. K. (2007). Trend of rainfall and temperature change at umiam, Meghalaya. Journal of Agrometeorology, 9(2), 203–208. https://doi.org/10.54386/jam.v9i2.1129 Retrieved on 6th November 2023.

Sen, P. K. (1968). Estimates of the Regression Coefficient Based on Kendall's Tau. Journal of the American Statistical Association, 63(324), 1379–1389. https://pacificclimate.org/~wernera/zyp/Sen%201968%20JASA.pdf Retrieved on 18th January 2024.

Shah, S. A., and Kiran, M. (2021). Mann-Kendall Test: Trend Analysis of Temperature, Rainfall and Discharge of Ghotki Feeder Canal in District Ghotki, Sindh, Pakistan. Environment & Ecosystem Science, 5(2), 137–142. https://doi.org/10.26480/ees.02.2021.137.142Retrieved on 26th January 2024.

Stackhouse, P. (n.d.). POWER | DAVe. https://power.larc.nasa.gov/data-access-viewer/ . Retrieved on 18th December 2021.