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An analysis of 50 years of seasonal rainfall and temperature pattern data in the Sylhet region of Bangladesh

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Abstract Climate variability, particularly due to rainfall and temperature, has a significant impact on the country's economy and has garnered significant global attention. The magnitude of climatic factor fluctuations varies according to geographic locations. Meteorological parameter analysis is critical in countries where rainfed agriculture predominates. The current study examined the monthly variations in rainfall and temperature (maximum and minimum) over a 50-year period (1967 to 2017) in Sylhet region of Bangladesh. The non-parametric Mann Kendall test was used to detect the trend, and the Sen's slope estimation method was used to identify the trend value. A thorough analysis of the data (1967 to 2017) reveals that the monthly rainfall occurs during the monsoon season (June to September). In terms of temperature, the maximum temperature was found from June to September, indicating the monsoon season. Mann Kendall trend analysis shows that the seasonal monthly rainfall and minimum temperature trends are not statistically significant, with Sen's slope values of <0.001 and 0.034, respectively. The maximum temperature trend is significant, with a p value of 0.042. As a result, the study concludes that Sylhet's climate is changing.

Keywords: climate change, trend analysis, Mann Kendall's test, Sen's slope estimator

1. Introduction

Bangladesh is one of the world's biggest deltas, making it especially susceptible to natural calamities due to its geographical location, population density, poverty, illiteracy, poorly constructed infrastructure, and so on (Biswas 2013). The average weather is commonly used to define climate. Climatic variables like temperature, rainfall, atmospheric pressure, humidity, and so on have recently received global attention (Panda and Sahu 2019). Considering the climate variables, Bangladesh can be classified as a three-season country: summer (March-May), monsoon (June-October), and winter (November-February) (Mondal and Hossain 2009). Climate change has an effect that is evident in rising temperatures as well as erratic rainfall (Asaduzzaman et al 2010; Hossain and Deb 2011). Hence, this unstable characteristic of rainfall results in water scarcity leading to a high risk of drought (Pal et al 2017). Climate change is a major threat to the world's food security and nutrition. Temperature and precipitation changes have already impacted agricultural output, and the cultivable land has shrunk considerably (Biswas 2013). Rajbhandari et al (2015) mentioned that, due to changes in the atmospheric condition, extreme temperature and rainfall changes might occur in the future.

Climatic parameters like rainfall and temperature determine the conditions of the environment of a specific area which influences crop output (Modarres and da Silva 2007; Kumar and Gautam 2014). The geography of a particular area depends on climatic parameters like heavy rainfall or drought (Rajbhandari et al 2015). From 1901 to 2015, 0.78 inches of precipitation change was recorded around the world, resulting in soil erosion (Zhang et al 2010). Agriculture has suffered as a result of precipitation anomalies, particularly in developing countries. It has a significant impact on cropland areas in addition to crop yields. It is evident that during the last 20 years, farmers expanded their farmland by 9% (approximately) in order to remunerate their financial losses (Zaveri et al 2010). Agricultural production has been vastly affected by rainfall characteristics. The variability and distribution of rainfall in a region are important and useful, especially for agricultural activities. Seasonal changes in rainfall, on the other hand, are more important for floods because maximum randomness could result in a widespread flood (Yuan et al 2019). Rainfall is a major factor in flood distribution and flood risk management in various regions (Wang et al 2011). Therefore, understanding the characteristics of rainfall variability is important for the mitigation of disaster loss. The analysis of temperature and rainfall trends is crucial for forecasting the upcoming climatic season (Meshram et al 2018; Partal and Kahya 2006; Arora et al 2005).

The climate of Sylhet is a tropical monsoon with hot summer and cool winter (Rashid 1991). Climate change is one of the burning issues at present times. Rainfall and temperature are two important parameters of climate change indicators. The change of these two variables is a major concern for a city like Sylhet, because of its geographical position, it is more vulnerable to climate change and natural hazards. For this reason, this study has been conducted to identify the changes in the rainfall and temperature pattern so as to reduce the impacts of climate change in Sylhet. In this context, the study assessed the variability of Sylhet's rainfall and temperature patterns in order to understand the uncertainties associated with these patterns. The aim of this study is to provide a foundation for better climate change management in agriculture and related industries.

2. Materials and Methods

2.1. Study area

The latitudes and longitudes of Sylhet lie between 24.89^{o} N and 91. 87^{o} E (Figure 1). The figure of the study area is obtained from (Ishaque et al 2020). It is bordered by Meghalaya to the north, Moulvibazar to the south, Assam to the east, and Sunamganj and Habiganj to the west. Sylhet has a land area of 3490.40 Km^2. The climate of Sylhet is primarily hot, wet, and humid tropical. On average 4200 mm (170 inches) of rainfall is recorded from May to September. The geological formation of the region is mainly from the Pleistocene era with high topography. The physiographic covers are mostly hill soils, with a large depressed area known locally as "beels" (BMD 2009). On the ridges, the soils are grey, heavy silty clay loams, while in the basins, the soils are clays. Soil organic matter content is moderate. Soils react in a variety of ways, ranging from strongly acidic to neutral (Brammer 2002).

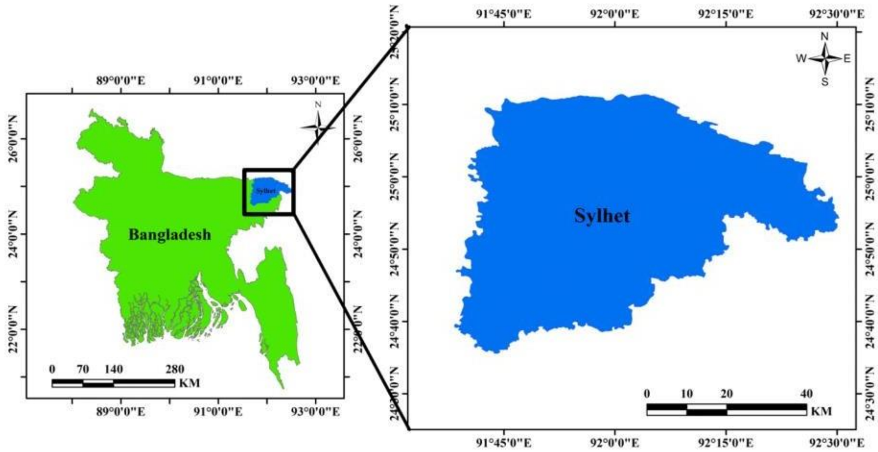

Figure 1 Study area.

2.2. Data collection

Temperature and rainfall data for the study period of 1967 to 2017 were obtained from the Bangladesh Meteorological Department (BMD). To fill the missing data, a statistical method called the imputation (most frequent) method was used. Implementation of imputation methods for missing data is one of the reassuring methods. The most commonly used method for filling missing observations is imputation (Ramli et al 2013).

2.3. Statistical analysis

2.3.1. Trend analysis

Trend was determined by analyzing climatic factors like temperature and rainfall (Panda and Sahu 2019). Statistical methods like the coefficient of variation and regression analysis are used in the current study. This method justifies the significance of temperature and rainfall trends. Mann-Kendall test is used for the determination of the test (increasing or decreasing). The mean, standard deviation (SD), and coefficient of variation (CV) of rainfall and temperatures were calculated to investigate the relationship.

2.3.2. Mann- Kendall trend test

The Mann- Kendall (MK) test does not require normally distributed data (Tabari et al 2011). Mann–Kendall trend test (Mann 1945) and (Kendall 1976); was used to evaluate Tmax, Tmin, and rainfall trends. This trend test is based on the null (H_o)

and alternative (H_a) hypotheses. In the case of the null hypothesis, there is no trend, while the alternative hypothesis indicates a trend (Koudahe et al 2018).

The M–K statistic is computed as follows:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn\,(xj - xk)$$

Here, k = 1,2,3……. n-1, j = i+1, i+2, i+3 ....n, xj is taken as the reference point for each of the data.

$$sgn\,(xj - xk) = 1 \quad if\ xj - xk > 0$$

$$= 0\ if\ xj - xk = 0$$

$$= -1\ if\ xj - xk < 0$$

XLSTAT software is used for the MK test. There is an upward and downward trend, which is indicated by the very high and low values of S. The Z value comprises a statistically significant trend.

2.3.3. Sen's slope estimator method

For the determination of a magnitude of a trend in a time series, Sen's estimator was used (Sen 1968). This method evaluates changes in the slope of a trend. The positive and negative value of Sen's slope indicates ascending and descending trend.

3. Results and discussion

Jain and Kumar (2012) indicate that for trend analysis, the MK test is the finest. 50 years (1967 to 2017) data of monthly temperature and rainfall for Sylhet has been analyzed using XLSTAT software.

3.1. Rainfall pattern in Sylhet

Rainfall data from 1967 to 2017 were analyzed over a 50-year period. The statistical analysis of rainfall which includes means, SD, CV, skewness, and kurtosis, is deliberate in (Table 1). By studying the statistical information on rainfall, it was observed that the maximum rainfall was found in the month of June-July. The value of mean monthly rainfall is 29.08 mm in June and 0.42mm in January (Table 1). This variation happens because of the climatic condition of Sylhet. In the month of December highest skewness (2.75) and kurtosis (8.13) were found.

Table 1 Statistical information of rainfall in Sylhet.

Months	Maximum	Minimum	Mean	SD	CV (%)	Skewness	Kurtosis
January	2.60	0.00	0.42	0.65	155.13	2.01	3.71
February	8.40	0.00	1.70	1.78	104.92	2.07	5.33
March	19.51	0.54	5.23	4.02	76.89	1.66	2.90
April	36.56	0.00	14.72	8.01	54.43	0.61	0.04
May	38.12	2.33	20.79	8.02	38.60	0.23	-0.37
June	46.31	0.00	29.08	9.57	32.90	-0.46	0.37
July	48.93	11.21	27.38	9.39	34.30	0.56	-0.20
August	43.09	10.06	22.75	7.42	32.62	0.35	0.03
September	39.43	3.96	18.94	8.76	46.26	0.46	-0.38
October	25.09	1.33	9.52	6.08	63.84	0.79	-0.17
November	7.37	0.00	1.48	2.05	138.95	1.49	1.29
December	4.84	0.00	0.50	1.00	200.76	2.75	8.13

The outcome of a monthly rainfall analysis describing an overall increasing trend is shown in (Figure 2). Positive value of 0.0004 is depicted by the linear regression equation. This model described the availability of seasonal rainfall.

3.2. Maximum temperature pattern in Sylhet.

50 years (1967 to 2017) data of maximum temperature have been analyzed in (Table 2). As compared to (Table 1), the maximum temperature (Table 2) shows variation in results because the climate of Sylhet is tropical monsoon, which includes hot and humid summer and relatively cool winter (Rashid 1991). In Table 2, it was observed that in the month of June-July, the temperature was maximum (39.6^{o}C), and the minimum temperature was found in the month of December (2.6^{o} C). According to LGED (2015), in Sylhet, from August to October, the average highest annual temperature was found 23^{o} C, and in the month

of January, the value was the lowest (7° C). The variation in the value of skewness and kurtosis was observed to be greater than rainfall because of the changing conditions of temperature in the Sylhet region. From that trend of seasonal maximum temperature (Figure 3), it was found that the temperature is increasing over time.

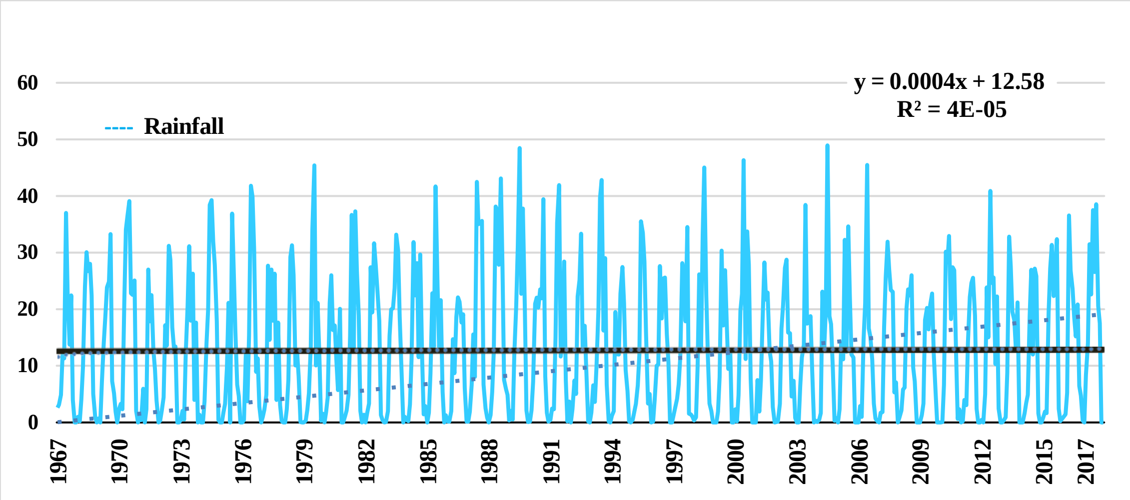

Figure 2 Trend of seasonal rainfall of Sylhet from 1967 to 2017.

Table 2 Statistical information of maximum temperature of Sylhet.

Months	Maximum	Minimum	Mean	SD	CV (%)	Skewness	Kurtosis
January	34.50	25.90	28.52	1.59	5.57	1.26	2.84
February	35.00	26.80	31.31	1.54	4.93	-0.27	0.56
March	38.80	31.80	34.61	1.58	4.58	0.33	-0.33
April	39.20	32.10	35.24	1.32	3.74	0.34	0.96
May	38.20	32.80	35.45	1.13	3.20	-0.20	0.40
June	39.60	32.50	35.39	1.23	3.47	0.41	1.63
July	38.40	32.50	35.34	1.17	3.31	-0.00	0.14
August	37.60	33.30	35.43	1.07	3.03	-0.04	-0.66
September	37.80	33.30	35.30	1.17	3.32	0.49	-0.34
October	37.00	32.20	34.44	1.16	3.37	-0.06	-0.48
November	35.00	29.70	32.36	1.10	3.40	-0.07	-0.21
December	31.30	26.70	29.32	1.20	4.11	-0.29	-0.59

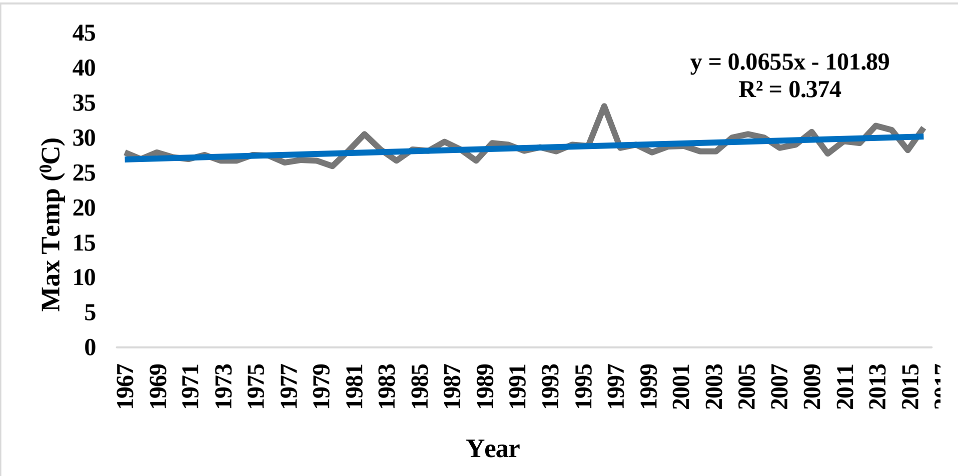

Figure 3 Trend of seasonal maximum temperature (^{0}C) of Sylhet from 1967 to 2017

3.3. Minimum temperature pattern

Like maximum temperature, minimum temperature data have been analyzed in this research (Table 3) for 50 years (1967 to 2017). The value of SD varies from 1.067 to 2.188. Whereas the CV (%) ranges from 5.11 to 18.02. Similarly to the maximum temperature, the skewness value fluctuates, but on the other hand, the kurtosis value is on the constant side. The lowest temperature was observed in January. From the trend of seasonal minimum temperature (Figure 4), it was noticed that the trend is increasing but not like seasonal maximum temperature (Figure 3).

Table 3 Statistical information of minimum temperature of Sylhet.

Months	Maximum	Minimum	Mean	SD	CV (%)	Skewness	Kurtosis
January	14.20	3.40	9.48	1.70	18.02	-0.42	2.68
February	15.50	6.40	10.81	1.81	16.81	-0.17	0.41
March	18.40	10.00	14.30	1.81	12.67	-0.03	0.15
April	19.40	14.00	17.35	1.06	6.15	-0.59	0.77
May	22.80	10.30	19.19	1.63	8.49	-3.11	17.56
June	23.60	11.10	21.36	1.86	8.73	-3.48	17.97
July	25.20	18.30	23.18	1.24	5.38	-1.84	4.96
August	24.70	16.70	23.34	1.25	5.38	-3.21	15.11
September	24.00	18.30	22.45	1.14	5.11	-1.75	4.05
October	24.40	16.50	19.58	1.52	7.79	0.46	0.92
November	23.60	10.90	15.48	2.18	14.13	1.64	5.72
December	18.80	8.00	11.41	1.95	17.15	0.89	2.96

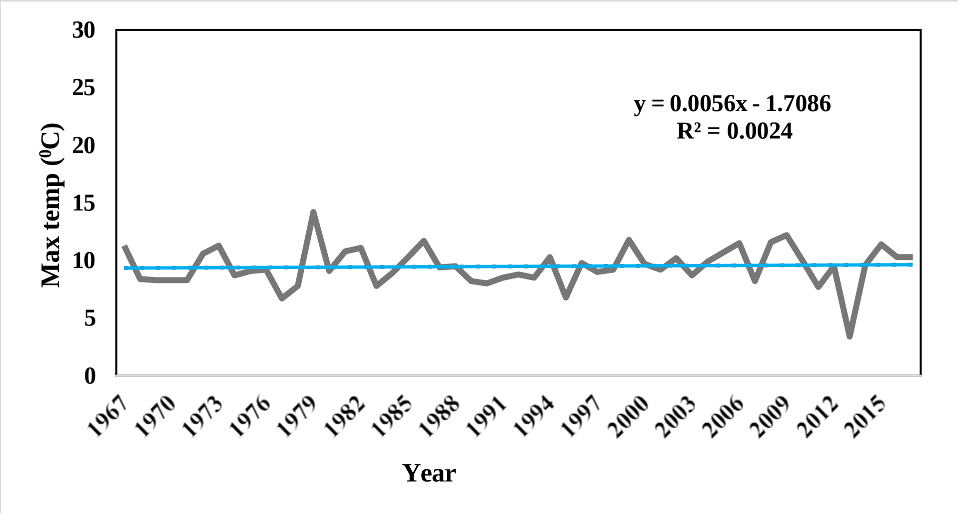

Figure 4 Trend of seasonal minimum temperature (⁰C) of Sylhet from 1967 to 2017.

3.4. Mann- Kendall (MK) trend analysis of monthly rainfall, maximum, and minimum temperature

MK test is also used for trend testing of seasonal rainfall and temperature (maximum and minimum) for the period 1967 to 2017 (Table 4). The MK method is used to determine whether a variable has a monotonic positive or negative trend over time. From the observation (Table 4), it was clear that rainfall showed a slightly decreasing trend (Sen's slope = <0.001). For the observed period, both T_{max} and T_{min} depicted a minimal increasing trend (Table 4). In a nutshell, with a 95% level of significance, both seasonal rainfall and minimum temperature trend are not statistically significant, whereas the maximum temperature trend is significant.

Table 4 Mann-Kendall trend analysis.

Parameters	Seasonal Rainfall	Seasonal maximum temperature	Seasonal minimum temperature
Kendall's tau	-0.03	0.35	0.29
Sen's slope	<0.0001	0.04	0.03
S	-39	451	366
P value	0.51	0.008	0.15
Significance	Not Significant	Significant	Not Significant

Bangladesh is frequently referred to as one of the most susceptible countries to climate change, and the Sylhet district is no exception. Changing climatic parameters (temperature and rainfall) are a common occurrence in the study area. The economy of Bangladesh, as well as Sylhet, is vastly reliant on agriculture. On the other hand, the agricultural sector is mainly dependent on climate variability. The analysis of metrological parameters like rainfall and temperature is essential for a city like Sylhet because the temperature of Sylhet has an increasing trend (Chowdhury et al 2012). The box and whisker plots (Tukey 1977) facilitates parallel comparisons between various sets of data, which can be tough to depict using more comprehensive depictions like histogram (Banacos 2011). There is a horizontal line in the plots. The central line represents the median, while the top and bottom horizontal lines depict the interquartile range. The percentiles (25^{th} and 75^{th}) are shown by bottom and top horizontal lines. In the case of whiskers, the vertical line delineates the outer ranges. When the median line is moved from the center, then skewness happens. The interquartile range determines the relative dispersion of a dataset's middle by 50%. On the other hand, the whisker measures the outer range (10th to 25th percentiles and 75th to 90th percentiles) (Banacos 2011).

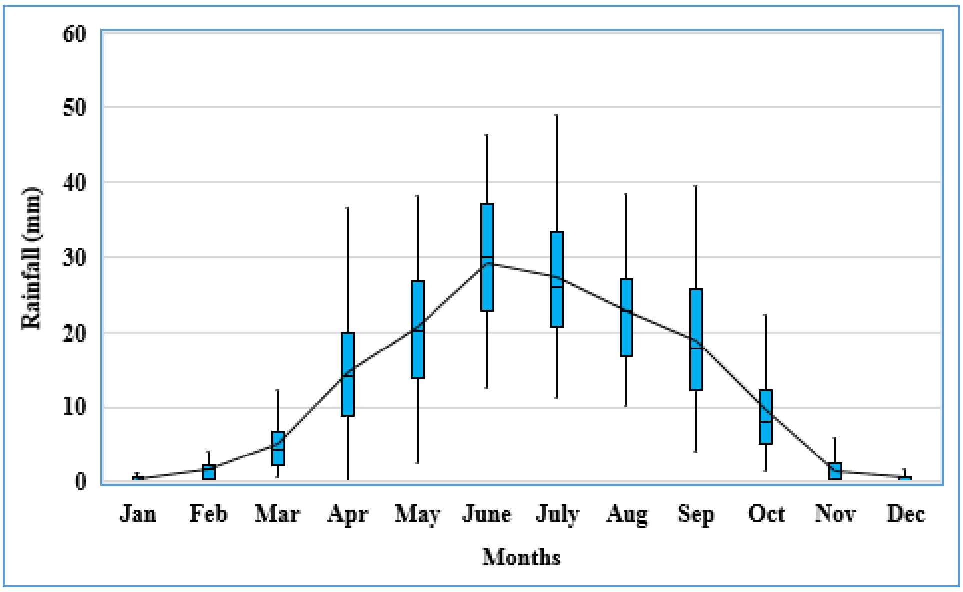

Figure 5 Box and whisker plot of monthly rainfall (mm) for Sylhet from 1967 to 2017.

The fluctuation of rainfall is shown in (Figure 5). From the skewness and kurtosis value (Table 1), it was observed that from the month of May to October, the value was on the lower side, and after that, the values increased. By analyzing the values, it was clear that the rainfall was at its peak in the month of June to September (monsoon period), and minimum rainfall was found during winter.

Weather prediction is greatly dependent on temperature characteristics. A study on surface air temperature helps in interpreting a clear idea of climate-changing at various levels (Ghasemi 2015). Although enormous proof of rising temperature around the globe, precise forecasting of time series trends remains a challenge (Gil-Alana 2018).

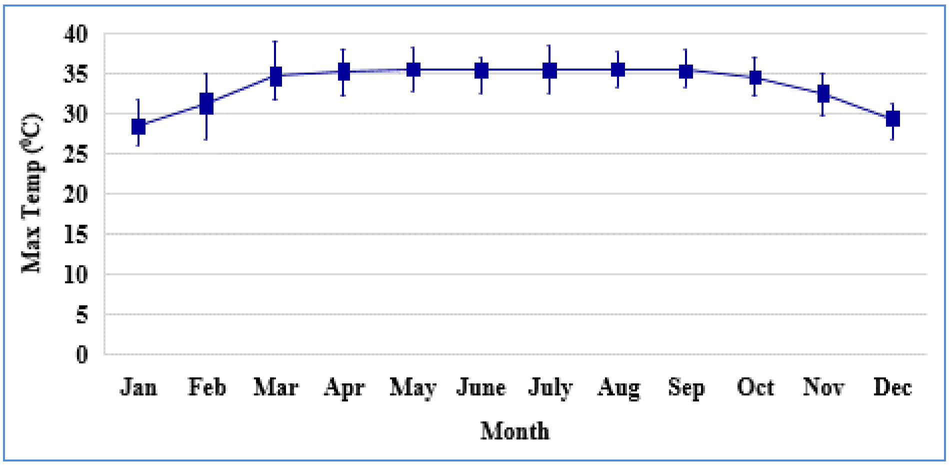

Figure 6 Box and whisker plot of monthly maximum temperature (^{0}C) of Sylhet from 1967 to 2017.

Figure 6 shows the value of monthly temperature (maximum) is constant from the month of June to September. The minimum temperature was found in the month of December and January. In the case of minimum temperature (Figure 7), the peak was detected in July and August. From January to June, it increases in nature, and after the peak period, it decreases (September to December).

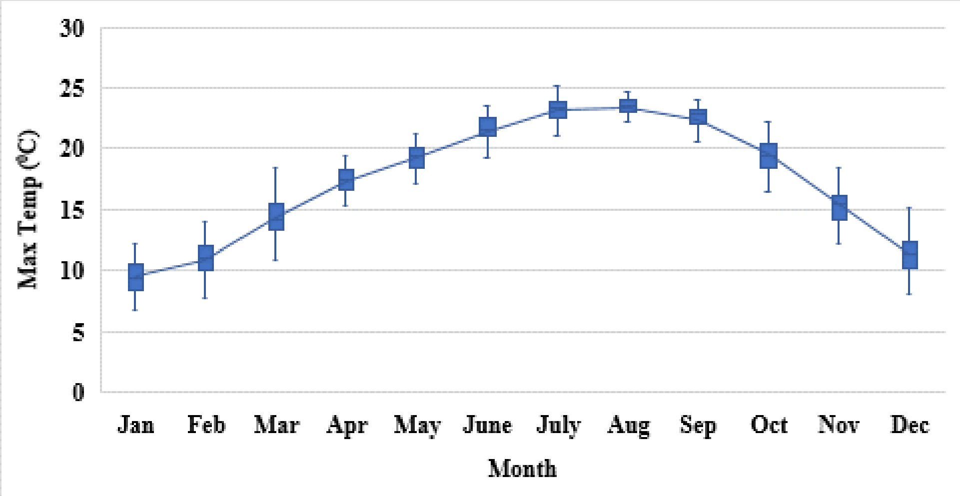

Figure 7 Box and whisker plot of monthly minimum temperature (^{0}C) of Sylhet from 1967 to 2017.

The distribution of temperature and rainfall of Sylhet is demonstrated in this research article. The distributing patterns of these two parameters are made using XLSTAT software. The study shows the highest maximum temperature is found during the monsoon season, and minimum temperature is observed during the winter period. The founding of this research work is consistent with (Wahiduzzaman and Luo 2021). They discovered that during the monsoon season, both temperature and rainfall (68% of the annual sum) are maximum, while minimal rainfall (1.6%) and the lowest temperature has found during winter. It is also clearer in the fact that in both cases, the monsoon rainfall varies widely.

4. Conclusions

The temperature of Sylhet is much more consistent throughout the study period (1967 to 2017) compared to rainfall. The current study examined meteorological data from Bangladesh's Sylhet district. The non-parametric MK test and the Sen's slope estimator were used to study time series, both commonly used tests for trend analysis. The analysis of rainfall and temperature is done using the box and whisker plot. The plots show in the monsoon month, June to September, the maximum monthly rainfall occurs. For maximum temperature, the value is roughly similar to rainfall. In the case of minimum temperature, the maximum results were found in the month of July to September. Now from the study, it was clearer that rainfall variability plays a much more significant role than the temperature in the case of agricultural productivity. As a result, the concerned stakeholders should consider the variability in temperature and rainfall while proposing a climate change adaptation policy.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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