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TEMPORAL TREND ANALYSIS OF HISTORICAL CLIMATIC DATA AT NORTH-EASTERN HILLY REGION OF BANGLADESH USING MANN-KENDALL TEST

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ABSTRACT

An attempt has been implemented to find out the temporal trend of climatic data of average temperature and total rainfall for the study period 1980-2016 at North-Eastern Hilly Region in Bangladesh. The non-parametric Mann-Kendall test is used to analyze the trend of climatic data. The objective of the study is to investigate the trend variation in the North-Eastern hilly region. Results show that in monsoon season, both Sylhet and Srimangal meteorological stations experience a positive tendency with a rate of 0.037 and 0.017^{0}C/year, respectively which are statistically significant at 99.9% level of significance. Monthly significant positive changes are found in all months except November, December and January for Sylhet while Srimangal indicates significant positive changes except July, September, October and November. The total rainfall at both the stations reveals decreasing trend during maximum seasons and months but the trend is not significant.

Keyword: *Hilly; Mann-Kendall; Trend; Temporal; Temperature; Rainfall.*

1. INTRODUCTION

Climate change issue is apprehensive throughout the world. A Scientific observational evident that the global mean temperature has increasing trend at about 0.3 to 0.6^{0}C over the last 100 years (WMO 1991). Bangladesh is the worst sufferer among the world for its bad impacts. Temperature and rainfall are the most important climatic parameters in atmospheric science. Temperature is increasing in an alarming rate and rainfall is fluctuating.The Climate of Bangladesh comprises four seasons: pre-monsoon, monsoon, post-monsoon and winter. Most of the rainfall are occurs during pre-monsoon and monsoon seasons in Bangladesh according to Bangladesh meteorological department (BMD). Ahmed (2012) has shown that the variability of rainfall amount was higher in the pre-monsoon season at north-eastern part of Bangladesh around Sylhet. Research was implemented on trend of climatic parameter leading to change the atmospheric conditions by Almazroui *et al.* (2014). Karmakar (1997) studied climatic change and its impacts on natural disasters and south-west monsoon in Bangladesh and the Bay of Bengal. They found that especially after 1961-1970 Bangladesh have experienced increasing tendency of decadal mean annual temperature. Mondal *et al.* (2018) found in a study that Dhaka division (Dhaka, Faridpur and Mymensingh stations) experience a positive trend of average temperature which is high populated-industrial area and situated at the center of the country compare to Khulna division. Alam *et al*. (2010) investigated temporal variation of rainfall over south-western part of Bangladesh and noticed positive tendency of seasonal rainfall. A study was implemented by Khatun et *al*. (2016) on climate change in Bangladesh which reported that southeastern part of Bangladesh experiences an extreme rainfall event while negative deviations are found at Dhaka, Chattogram and Sylhet regions during monsoon season. Rainfall anomaly of 1984-2016 showed an increasing trend over the south-west Bangladesh which is an indicator of changing spatial distribution of rainfall over the country (Gupta *et al.,* 2018). Reza *et al.* (2018) showed that excess value of rainfall observed in the fourth decade at North-Eastern part of Bangladesh during the study period 1948-2015. Mannan *et al.* (2015) indicated that total numbers of rainy days in monsoon season at Srimangal & Sylhet are 83.8 and 99.7 during 1980-2014 and their STDs are 8.5 and 5.7. And the trends of rainfall deviations are 0.05% and -0.04% respectively.

The primary objectives of this study are to find out temporal trend of climatic data, such as average temperature (T_{avg}) and total rainfall for the study period 1980-2016 at north-eastern hilly region in Bangladesh using Mann-Kendall test.

2. DATA USED AND METHODOLOGY

2.1 DATA USED

The temperature and rainfall data of northeastern part (Figure 1) in Bangladesh for the period 1980-2016 are used in this study. These data are collected from BMD which comply the World Meteorological Organization (WMO) terms and conditions in maintaining the data collection. Monthly data are obtained from the daily data.

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Monthly data of average temperature are evaluated from monthly maximum and minimum temperatures. Again, from the monthly data, seasonal mean values are computed for the four seasons such as pre-monsoon (March-May), monsoon (June-September), post-monsoon (October-November) and winter (December-February). The missing data are filled up by the time mean values of the existing years. The trend of the dataset is analyzed using Mann-Kendall test.

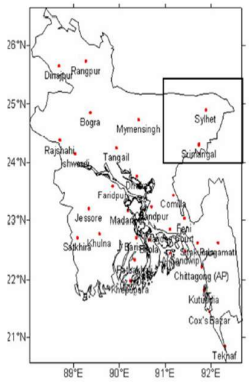

Figure 1: Selected area of Bangladesh used under this study (Mannan *et al.,* 2015)

2.2 METHODOLOGY

Mann-Kendall test is used to find out the temporal variation of climatic data. The following subsections are written for Mann-Kendall analysis and Sen's Slope estimator.

2.2.1 Mann-Kendall Analysis

The Mann-Kendall test was commonly applied where the data do not identical to a normal distribution. This test evaluates a nonparametric form of monotonic trend regression analysis of y values tend to increase or decrease over time. WMO has been extensively recommended this test for public use to evaluate trends. The nonparametric Mann-Kendall (1945) test is commonly used for hydrologic data analysis; can be used to detect that are monotonic but not necessarily linear. The null hypothesis in the Mann-Kendall is that the data are independent and randomly ordered. The Mann-Kendall test does not require the assumption of normality, and not only indicates the direction but not the magnitude of significant trends. The Mann-Kendall test measured values, (x_j–x_k), where j>k, and test statistics S is computed exerting the formula;

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(x_j - x_k) \quad (1)$$

Where x_j and x_k are the annual values in years j and k, j>k, respectively, and

$$sgn(x_j - x_k) = \begin{cases} 1 & if\ x_j - x_k > 0 \\ 0 & if\ x_j - x_k = 0 \\ -1 & if\ x_j - x_k < 0 \end{cases} \quad (2)$$

The test statistics τ can be computed as;

$$\tau = \frac{S}{n-(n-1)/2} \quad (3)$$

It is necessary to compute the probability associated with S and the sample size n, to statistically quantify the significance of the trend. The calculating formula of variance S is denominate as;

$$VAR\ (S) = \frac{1}{18}[(n-1)\ (2n+5)\sum_{p=1}^{q} t_p\ (t_p - 1)\ (2t_p + 5)] \quad (4)$$

Where q is defined as the number of tied groups and t_p is the number of data in the p^{th} group. The values of S and VAR(S) are accustomed to calculate the test statistics Z which is following as;

$$Z = \begin{cases} \frac{S-1}{\sqrt{VAR(S)}} & if\ S > 0 \\ 0 & if\ S = 0 \\ \frac{S+1}{\sqrt{VAR(S)}} & if\ S < 0 \end{cases} \quad (5)$$

Z score follows a normal distribution. At a choice of α=0.05 (95% confidence interval) and two sided alternative, the critical values of $Z_{0.025}$ are equal to -1.96 to 1.96. The trend is said to be decreasing if Z is negative and the absolute value is greater than the level of significance, while it is increasing if Z is positive and greater than the level of significance. If n≤10 the normal approximation test is used and a statistically significance trend is computed exerting the Z score. Mann-Kendall & Sen's slope estimator tested the Z score significance level at α: 0.001, 0.01, 0.05 and 0.1.

2.2.2 Sen's Slope Estimator

The Sen's slope estimator is a method of nonparametric that was employed to exhibit the linear patterns in this study. This method is most effective than regression equation. If a linear aptitude present in a time series, then the true slope can be calculated by exerting a simple nonparametric procedure. In the case of linear model f(t) can be denominate as

$$f\,(t) = Qt + B \tag{6}$$

Where Q is representing slope, B is a constant value and t is time. To derive an estimate of the slope Q, the slopes of all data pairs are calculated exert the equation;

$$Q_i = \frac{x_j - x_k}{j-k}\ ,\ i = 1,2,3,\ldots\ldots N, j > k \tag{7}$$

If there are n values x_j in the time series there will be as many as N = n(n-1)/2 slope estimates Q_i. To estimates of B in equation the n values of differences $x_i – Qt_1$ are calculated. An estimate of B isobtained from the given mean values. Data were processed using an Excel macro names MAKESENS created by Salmi *et al*. (2002).

3 RESULTS AND DISCUSSION

Temporal trend variation of climatic data, average temperature (T_{avg}) and total rainfall for the study period 1980-2016 at north- eastern hilly region of Bangladesh are discussed in the following subsection.

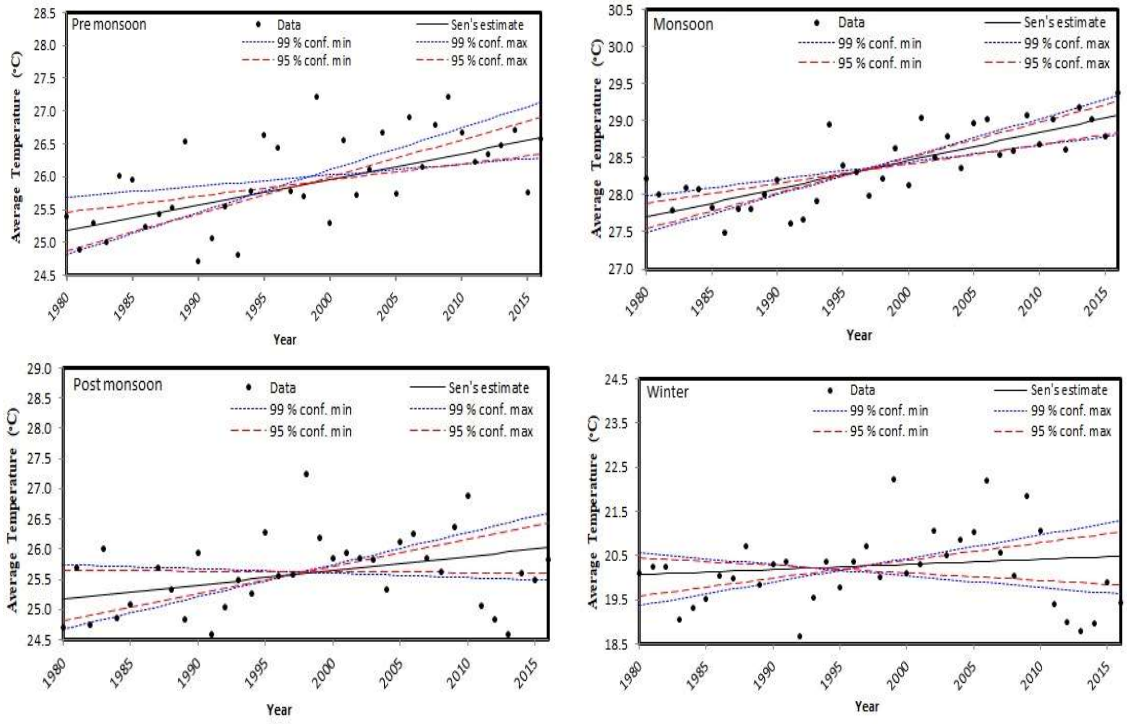

Figure 2: Seasonal change of average temperature at Sylhet during the period 1980-2016

3.1 Temporal trend of average temperature at Sylhet

Using Mann Kendall test seasonal and monthly trends considering T_{avg} is evaluated at Sylhet for the study period 1980-2016 and shown in Figure 2. Calculated values of Sen's slope and Z with its significance level using Mann-Kendall & Sen's slope estimator is tabulated in Table 1. It indicates that except winter season the

other three seasons are experiencing significant positive tendency. Sen's slope values of Pre-monsoon and monsoon seasons are 0.036 and 0.037 ^{0}C/year, respectively. According to Z values these trends are statistically significant at level of 99.9% interval. Subsequently the post-monsoon season observed a positive trend with a rate of 0.023 ^{0}C/year that is statistically significant at 90% confidence level.

3.2 Temporal trend of average temperature at Srimangal station

Using Mann Kendall test seasonal and monthly trends considering of T_{avg} are evaluated at Srimangal for the study period 1980-2016 and the results are shown in Figure 3. Calculated values of Sen's slope and Z with its significance level using Mann-Kendall & Sen's slope estimator is tabulated in Table 1. It indicates that according to Z value trend at the winter season for both stations is statistically insignificance but that at the monsoon and post-monsoon seasons for both stations is statistically significant whereas the trend at pre-monsoon season is significant only at Sylhet station. Monsoon and post-monsoon seasons show a positive tendency with a value of Sen's slope 0.017 and 0.023 ^{0}C/year respectively which is statistically significant at level of 99.9% confidence interval. Whereas the pre-monsoon and winter seasons imply that the trends are insignificant.

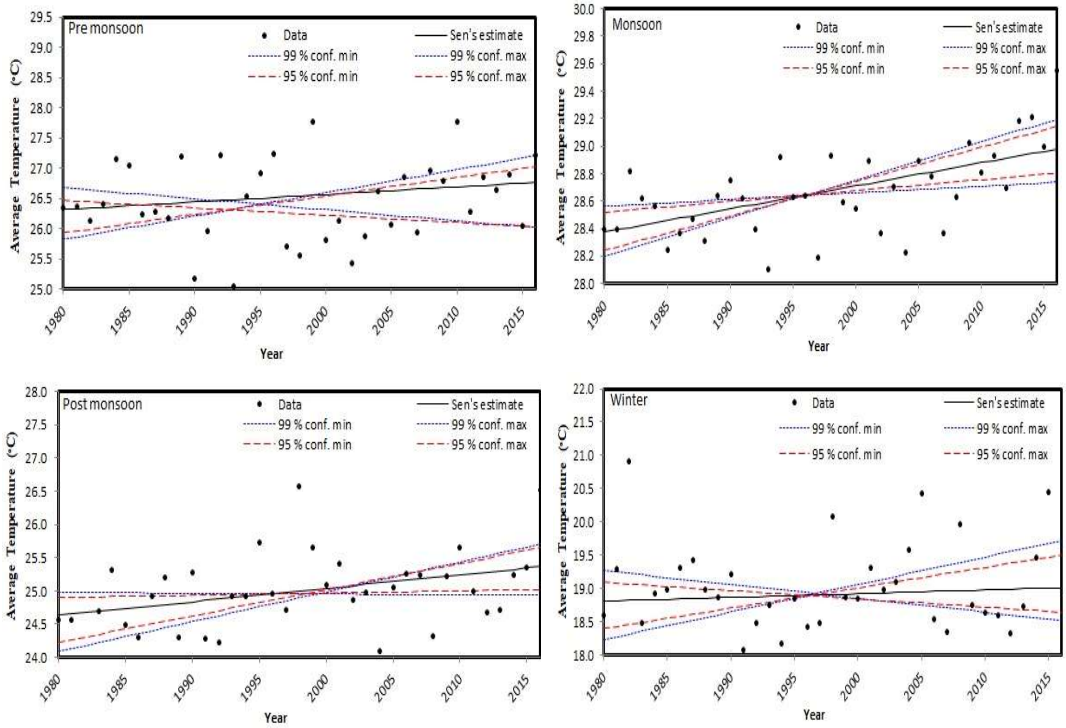

Figure 3: Seasonal change of average temperature at Srimangal during the period 1980-2016

Monthly trend analysis reveals that T_{avg} rising for all of the months except April. But the values dominate significantly only in July and September to November. The Sen's slope estimates for July, September, October and November are 0.024, 0.027, 0.024 and 0.025 ^{0}C/year respectively. All of these values indicate the increasing rate of temperature. Again the Z values are extending the critical values for all these months but it varies for different level of significance. 99.9% significant are found for the month of July and September. And the trend of temperature in November is significant at level of 90% confidence interval whereas the trend in October is 95% confidence interval according to Z value. The Sen's slope estimates for January to June, August and December are 0.008, 0.020, 0.012, -0.003, 0.015, 0.004, 0.008 and 0.010 ^{0}C/year respectively. Here January, February, March, May, June, August and December are express positive trend whereas the April is negative trend. According to Z statistics all of these trends are insignificant.

3.3 Temporal trend of total rainfall at Sylhet

Using Mann Kendall test seasonal and monthly trends considering total rainfall is evaluated at Sylhet of Bangladesh for the study period 1980-2016 and the results are shown in Figure 4. Calculated values of Sen's slope and Z with its significance level using Mann-Kendall & Sen's slope estimator is tabulated in Table 2. It indicates that all seasons experience negative tendency where all seasons except winter, the trends are

statistically insignificant. The winter season observed trend to decrease with a value -0.871 mm/year that is significant at 90% confidence level according to Z value.

Table1: Monthly and seasonal Sen's slope estimates for T_{avg} with Z test value at Sylhet and Srimangal.

Season/Month	Sen's slope Q		Z value		Significance Level	
	Sylhet	Srimangal	Sylhet	Srimangal	Sylhet	Srimangal
Pre- monsoon	0.036	0.008	3.55	0.53	***	-
Monsoon	0.037	0.017	5.18	3.77	***	***
Post-monsoon	0.023	0.023	1.84	2.79	+	**
Winter	0.010	0.004	0.78	0.28	-	-
January	-0.003	0.008	-0.23	0.33	-	-
February	0.028	0.020	1.66	1.46	+	-
March	0.031	0.012	1.65	0.48	+	-
April	0.030	-0.003	2.49	-0.20	*	-
May	0.037	0.015	2.54	1.21	*	-
June	0.018	0.004	1.95	0.55	+	-
July	0.049	0.024	4.93	3.37	***	***
August	0.025	0.008	3.44	1.41	***	-
September	0.043	0.027	3.32	3.99	***	***
October	0.035	0.024	3.51	2.54	***	*
November	0.004	0.025	0.30	1.94	-	+
December	0.018	0.010	0.98	0.50	-	-

Note: *** significant at the 99.9% confidence level; ** significant at the 99% confidence level; * significant at the 95% confidence level and $^{+}$ significant at the 90% confidence level.

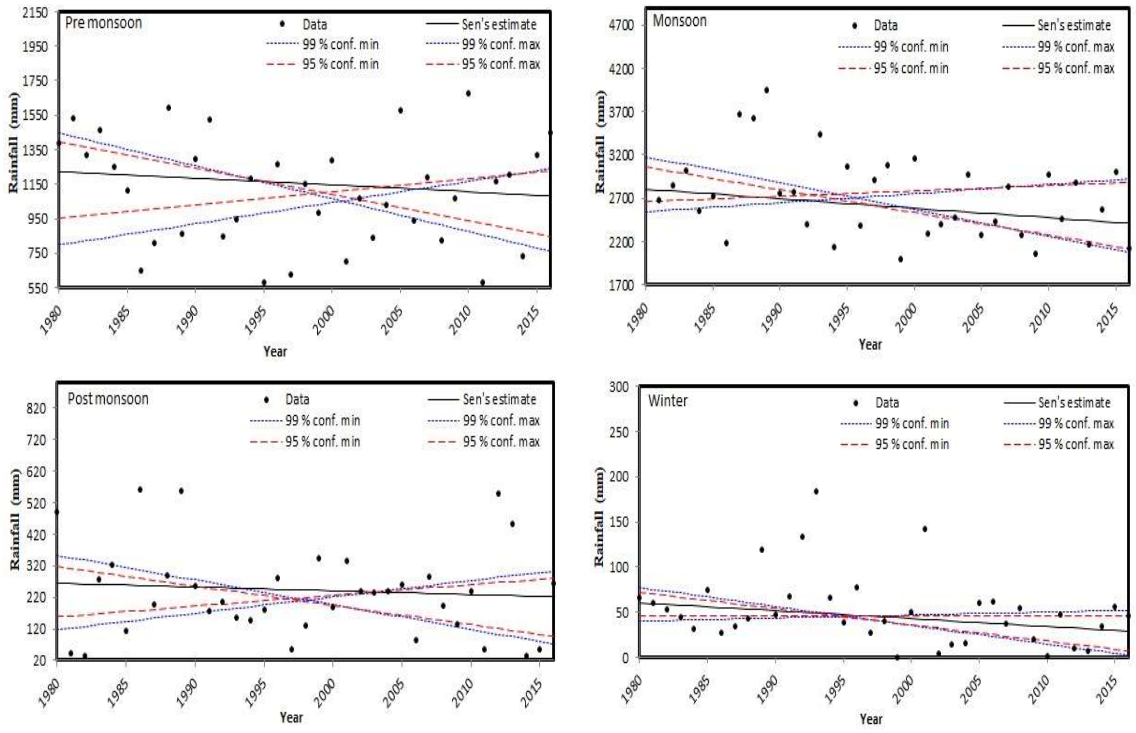

Figure 4: Seasonal change of total rainfall at Sylhet during the period 1980-2016

Monthly trend analysis reveals that total rainfall has the trend of rising for of the months of January, June, August, November and December. Other months are shows negative tendency of rainfall. But the trend in rainfall in March, July and December has only significant values. The Sen's slope estimates for July and December are -8.707 and 0.001 mm/year, respectively. And the trend of December is significant at level of 90% confidence interval whereas July is 95% confidence interval. In Sylhet station the rainfall shows negative trends

for February, March, April, May, July, September and October while positive trends are shows for January, June, August, November and December those are statistically insignificant.

3.4 Temporal trend of total rainfall at Srimangal

Using Mann Kendall test seasonal and monthly trends considering total rainfall is evaluated at Srimangal of Bangladesh for the study period 1980-2016 and shown in Figure 5. Calculated values of Sen's slope and Z with its significance level using Mann-Kendall & Sen's slope estimator is tabulated in Table 2. It indicates that the rainfall trend in pre-monsoon and monsoon seasons experiences positive tendency while the trends in post-monsoon and winter seasons are negative and are statistically insignificant. Monthly trend analysis reveals that total rainfall has rising trends for of the months of January, May-August and December.

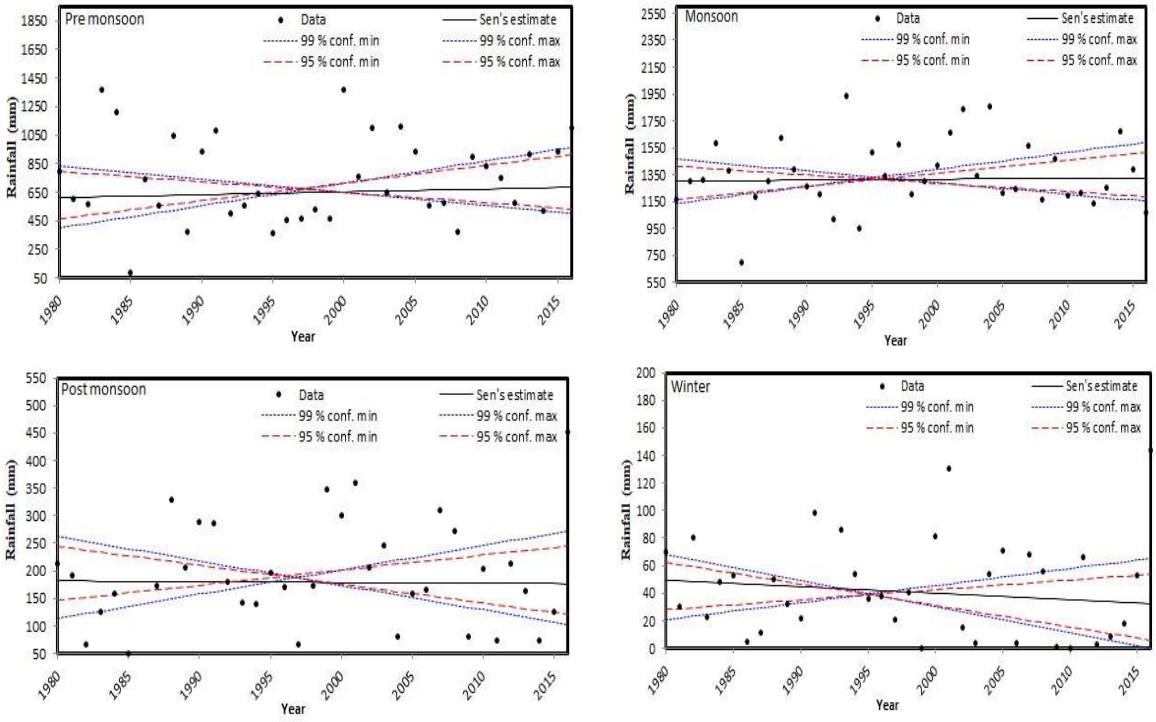

Figure 5: Seasonal change of total rainfall at Srimangal during the period1980-2016

Table 2: Monthly and seasonal Sen's slope estimates for total rainfall with Z test value at Sylhet and Srimangal

Season/Month	Sen's slope Q		Z value		Significance Level	
	Sylhet	Srimangal	Sylhet	Srimangal	Sylhet	Srimangal
Pre-monsoon	-3.893	2.038	-0.77	0.52	-	-
Monsoon	-11.026	0.662	-1.12	0.17	-	-
Post-monsoon	-1.211	-0.143	-0.47	-0.10	-	-
Winter	-0.871	-0.479	-1.91	-0.80	+	-
January	0.000	0.000	-0.67	-0.10	-	-
February	-0.267	-0.085	-1.00	-0.51	-	-
March	-1.971	-0.485	-2.00	-0.67	*	-
April	-2.506	-0.020	-0.59	-0.03	-	-
May	-0.154	4.994	-0.07	1.54	-	-
June	2.056	1.351	0.46	0.72	-	-
July	-8.707	1.279	-2.21	0.78	*	-
August	3.923	1.000	1.10	0.37	-	-
September	-5.750	-2.458	-1.45	-1.96	-	*
October	-1.793	-0.389	-0.78	-0.18	-	-
November	0.000	-0.023	-0.34	-0.65	-	-
December	0.001	0.000	-1.88	-1.20	+	-

The trends in other months have negative tendency. But only the trend in September has significant value. The Sen's slope estimates for September is -2.458 mm that significant at level of 95% confidence interval according to Z value. In Srimongal the rainfall experiences negative trends for February, March, April, September, October and November while positive trends are shown in January, May, June, July, August and December those are statistically insignificant.

3.5 Temporal variations of T_{avg} & total rainfall at Sylhet and Srimangal

For average temperature 99.9% significant value complies in pre-monsoon at Sylhet, whereas it complies in post-monsoon season at Srimongal. Monthly significant positive changes of average temperature are found in Srimangal except July, September, October and November while Sylhet except November, December and January. All seasons in Sylhet experiences negative trends whereas only post-monsoon and winter seasons experiences negative trends in Srimongal. The both stations are perceived positive trends in January, June, August and December and negative trends in February, March, April and September. The trends of average temperature & rainfall in Sylhet are mostly significant than that of Srimangal.

4 CONCLUSIONS

The following conclusions can be made from studies:

- In Monsoon season the temperature in both Sylhet and Srimangal experiences a positive tendency with a rate 0.037 and 0.017 ^{0}C/year, respectively which are significant at 99.9% level of significance.
- Monthly significant positive changes of average temperature are found in all months except November, December and January for Sylhet while Srimangal indicates significant positive changes except July, September, October and November.
- Monthly negative changes of average temperature are found in January and August in Sylhet and Srimangal respectively which are not statistically significant.
- The total rainfall in most seasons and months at both stations reveals decreasing tendency dramatically.
- There is a clear indication that the trends of Sylhet for average temperature & rainfall are mostly significant than that of Srimangal station.

More investigations are needed to completely identify if there is any climatic change occurred.

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