Quantifying the Trend of Climatic Variables in the Jessore Region of Bangladesh

ABSTRACT

The main goal of this study was to track the trend of various significant meteorological variables in the Jessore region of Bangladesh. The secondary data for monthly maximum temperature, monthly rainfall, and monthly cloud coverage were collected from the Bangladesh Meteorological Department (BMD) during 1983–2015. As a result, there are 365 samples, and no missing values have been identified. The research variables' general trends are shown on the time series plots for each variable. The LOWESS curve demonstrated that the temperature was moving up while rainfall and cloud coverage were moving down. The Mann-Kendall trend test was executed to determine the trend of each variable. The monthly rainfall and cloud coverage both showed a decreasing trend (-0.131 and -0.581, respectively), whereas the monthly maximum temperature demonstrated an upward trend (0.396).

***Keywords**: Climatic variables, LOWESS curve, Mann-Kendall test, Trend*

1. INTRODUCTION

One of the most affected countries in terms of climate change is Bangladesh. The greater part of her territory is not elevated above sea level, and a large portion of the country is flooded on an annual basis. Natural calamities like floods, tsunamis, cyclones, storms, and droughts occur regularly. A large number of people who live in rural areas are seriously affected. That is why the study of climate-related variables is badly needed in Bangladesh.

The temperature of the earth has increased by 0.3–1°C since the beginning of the 20th century as a consequence of increased CO_2 in the atmosphere. Computer simulations of global temperature change show that if the CO_2 concentration of the atmosphere doubles from its present-day value, then the global temperature would increase by 1.3–4 °C. On the other hand, temperature increases would be much higher in the middle and high latitude regions (5–9°C). Moreover, there will be a differential temperature increase in summer and winter; the temperature increase in the winter season will be higher than that in the summer (Banglapedia, 2021).

The trending behavior of climatic variables would lead to a catastrophic phenomenon in Bangladesh. Variables like temperature, rainfall, and cloud coverage are part and parcel of the atmosphere. If one of the variables is changed, surely other variables will be altered. Natural hazards that come from increased rainfall, rising sea levels, and tropical cyclones are expected to increase as the climate changes, seriously affecting agriculture, water and food security, human health, and shelter (The World Bank, 2021). The southern and northern regions of Bangladesh are vivid signs of the ill impacts of global warming and climate change.

Global surface temperature has been increasing day by day since the last few decades of the 19^{th} century as a result of increasing emissions of greenhouse gases caused by worldwide urbanization, large-scale combustion of fossil fuels, human intervention, and land use changes (IPCC, 2018). Bangladesh has already experienced, and generally we are facing, some of the impacts of climate change, such as summer becoming warmer, irregular monsoons, untimely rainfall, bulky amounts of rainfall during short periods causing landslides, small amounts of rainfall in dry periods, increased river flow during monsoons, monsoon floods, drought due to a shortage of potable water, extreme heat and extreme cold causing diarrhea, typhoid, malaria, cholera, dysentery, outbreaks of dengue, etc.

Numerous research have been carried out to quantify the trend of meteorological variables both domestically and internationally; however, for the Jessore region, parameters like rainfall, temperature, and cloud coverage are not emphasized. Most of the country's territory lies in flood plains, and 60 percent of it is vulnerable to extremely high floods. Up to 30 percent of the country floods annually during the monsoon season (UNESCAP, 2013). Detection of changes and trends in climatic variables in Bangladesh during 1988–2017(Khan et al., 2019; (Ali, 1999; Shahid, 2011).Exploring the Behavior and Changing Trends of Rainfall and Temperature Using Statistical Computing TechniquesClimate Change in Bangladesh (Azad et al., 2104). A Historical Analysis of Temperature and Rainfall Data (Basak, 2013). The variation of mean annual temperature over Bangladesh follows closely to that of the Northern Hemisphere land temperature: a warming trend during 1910-1940, a slight cooling trend until the mid -1970s, and resumed warming there after (Folland *etal.*, 1992). For the period 1979-1991, 12 out of the 13 years were warmer than the reference period. Karmakar and Nessa (1997) reported on climate change's effects on natural disasters, the south-west monsoon, and the Bay of Bengal in Bangladesh. The mean annual temperature over Bangladesh has shown increasing tendency especially after 1961-1970. Chowdhury and Debsarma (1992) observed the increasing tendency of the lowest minimum temperature over Bangladesh. Ahmed & Karmakar (1993) noted arrival and withdrawal date of the summer monsoon in Bangladesh. Ferdous & Baten (2011) explore climatic variables of 50 years and their trends over Rajshshi and Rangpur division.

2. MATERIAL AND METHODS

2.1 Data

The monthly data of the climatic variables temperature, rainfall, and cloud coverage of the Jessore region for the period January 1983 to December 2015 are used in this research, and the data were collected from the Bangladesh Meteorological Department (BMD). That is why the sample size is 365. The data has been organized, and no missing value has been found. We have arranged, furnished, and tabulated the original raw data to pursue our objective of the study. The units of measurement of the considered variables are Celsius, mm, and octas respectively. Software like MS Office and the various R packages have been used to arrange this data set as time series data, and subsequent analysis has been conducted by R code.

2.2 Temperature:

Temperature is an objective comparative measurement of whether something is hot or cold.Average maximum and minimum temperatures in winter are 29^0C and11^0C, respectively, and34^0C and 22^0 in summer over Bangladesh (BBS, 2002). Bangladesh has a tropical monsoon-type climate, with a hot and rainy summer and a pronounced dry season in the cooler months. January is the coolest month of the year, with the temperature ranging from 13.5^0C to 26^0C, and April is the warmest month, with the temperature ranging from 33^0C and 36 36^0C.

2.3 Rainfall

Water that is condensed from the aqueous vapor in the atmosphere and falls in drops from the sky to the earth is called rain, and the total amount of rain that falls in a particular area within a certain time is called rainfall. The rainfall in Bangladesh varies seasonally and from place to place. About 70.6% of the country's average rainfall occurs in the monsoon season, and 18.8% occurs per monsoon season. The winter and post-monsoon contribute to 1.6 and 9.0% of annual rainfall, respectively. The area-weighted country average annual rainfall of Bangladesh is 2315.7 mm, and monsoon rainfall is 1635.4 mm, as obtained from the data of 57 years from 1948–2004. A study by (Choudhury, *et al.* 1997) has reported that the precipitation in Bangladesh has been increasing in recent decades.

2.4 **Cloud Coverage**

A visible collection of particles of water or ice suspended in the air, usually at an elevation above the earth's surface. In Bangladesh, the cloud cover has two opposing seasonal patterns, coinciding with the winter monsoon and the summer monsoon. As a result of the flow of cold, dry winds from the northwestern part of India during the winter season, the cloud cover is at a minimum. On average, the cloud cover in this season is about 10%, almost all over the country. With the progression of the season, the cloud cover increases, reaching 50–60% by the end of the pre-monsoon hot season. During the summer monsoon season, which is also the rainy season, the cloud cover is very widespread. In the months of July and August, which are the middle of the rainy season, the cloud cover varies from 75 to 90% all over the country. However, it is more extensive in the southern and eastern parts (90%) than in the northwestern part (75%). After the withdrawal of the summer monsoon, the cloud cover decreases rapidly, dropping to 25% in the northern and western parts and 40–50% in the southern and eastern parts.

2.5 LOWESS Curve

A very popular technique for curve fitting complicated data sets is called LOWESS (Locally Weighted Smoothing Scatter Plots). LOWESS, originally proposed by Cleveland (1979) and further developed by Cleveland and Devlin (1988), specifically denotes a method that is known as locally weighted scatter plot Smoothing. In LOWESS, the data is modeled locally by a polynomial-weighted least squares regression, with the weights giving more importance to the local data points. This method of approximating data sets is called locally weighted polynomial regression.

2.6 The LOWESS Method

The Lowess method requires the use of a weighted least squares linear regression fit. For this weighted fit, the data points each have associated with them a weight, so you are given a set of points and weights. The difference between weighted least squares and regular least squares is that the function that is minimized as

$$F(\alpha_1, \alpha_2, \dots, \alpha_N) = \sum_{i=1}^{N} w_i \left(\frac{y_i - f(t_i;\ \alpha_1, \alpha_2, \dots, \alpha_M)}{\sigma_i} \right)^2$$

The lowess fit is calculated at each data point in the data set. At each point, a local polynomial is fitted to a local region of the data using linear least squares regression. The method has two inputs: the smoothing parameter (usually between 0 and 1) and the degree of the local polynomial (usually 1 or 2).

Let's work out how Lowess fits into the data points.
First, we need the weights for the neighboring data points. Here is how these weights can be calculated: The user supplies two parameters: a smoothing parameter and the degree of the local polynomial that is to be fitted to the data.

Then, the following distances are calculated:

$$d_i = (t_k - t_i)\,, i = 1, 2, \ldots, N$$

which are sorted into ascending order.

The quantity q is calculated,

$$q = \max(Truncated(\alpha N), 1).$$

This is used to calculate the distance scale

$$D = \begin{cases} d_q & , \quad \alpha \leq 1 \\ \alpha d_N & , \alpha > 1 \end{cases}$$

The weight function for the data points is defined as

$$T(u) = \begin{cases} (1 - |u|^3)^3 & |u| \leq 1 \\ 0 & |u| \geq 1 \end{cases}$$

The weights for the data points are then given by

$$w_i = T\left(\frac{t_i}{D}\right)$$

Once the weights have been found, the weighted polynomial fit on the points (t_i, y_i) with weights w_i is performed. This fit function is then used to determine the lowess fit at t_k.
This entire procedure is repeated for each data point (t_k, y_k), $k = 1, 2, \ldots, N$. The effect of the weight function is to make LOWESS a local polynomial fit, taking into account the neighboring points of the point (t_k, y_k). Typically, the smoothing makes only a few neighboring points contribute; the weights for points far away from (t_k, y_k) are going to be zero.

2.7 Mann-Kendall Trend Test

A non-parametric test for monotonic trend detection is known as the Mann-Kendall test. A monotonic trend can be either an upward trend or a downward trend. In the Mann-Kendall test (Mann, 1945; Kendall, 1975), the data are evaluated as an ordered time series. Each data point is compared to all subsequent data points. The initial value of the Mann-Kendall statistic, S, is assumed to be 0 (e.g., no trend). If data from a later time period is higher than data from an earlier time period, S is incremented by 1. On the other hand, if the data from a later time period is lower than the data sampled earlier, S is decremented by 1. The net result of all such increments and decrements yields the final value of S.If $x_1, x_2, \ldots, x_i$ represent *n* data points where x_i represents the data point at time *j*, then *S* is given by:

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

Where,

$$sign(x_j - x_k) = \begin{cases} 1 if\,(x_j - x_k) > 0 \\ 0 if\,(x_j - x_k) = 0 \\ -1 if\,(x_j - x_k) < 0 \end{cases}$$

The probability associated with *S* and the sample size, *n*, are then computed to statistically quantify the significance of the trend.

Mann-Kendall statistics computed as follows

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{VAR(S)}} if S > 0 \\ 0 if S = 0 \\ \dfrac{S-1}{\sqrt{VAR(S)}} if S < 0 \end{cases}$$

In Mann-Kendall trend test assume that under following hypothesis.

H_0 : There is no trend in entire data set

H_1 : There is a monotonic trend in the data set (upward or downward)

3. RESULTS AND DISCUSSION

3.1 Original Scenario of climatic variables

Before detecting trend, we should visualize the series of our study variable.

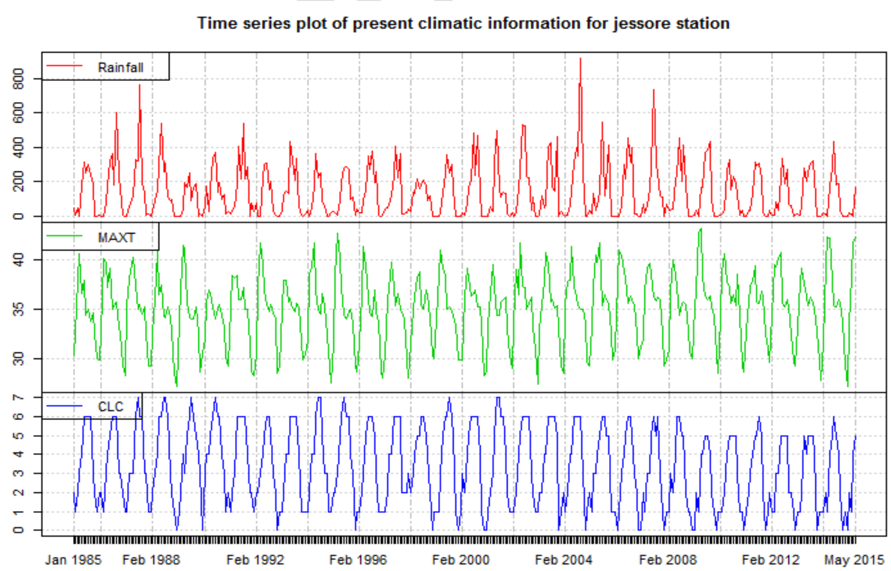

Fig. 1. Time series plot of the study variables for the interest period

Comment: While the temperature is rising over the course of time, it is evident from the time series plot above that rainfall and cloud coverage are both slowly but surely decreasing.

3.2 Lowess Curve for Rainfall

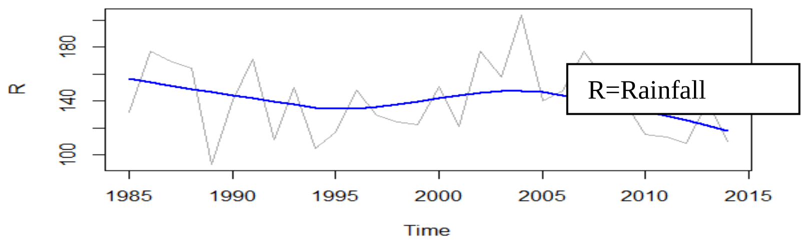

Fig. 2. Lowess curve for Rainfall

Comments: From the aforementioned graph, it can be seen that the monthly rainfall is monotonically falling from 1985 to 1995; it then slightly increases from 1996 to 2004; and finally, it decreases monotonically from 2005 to 2014. Therefore, it may be concluded that rainfall throughout our research period has been progressively declining.

3.3 Lowess Curve for Temperature

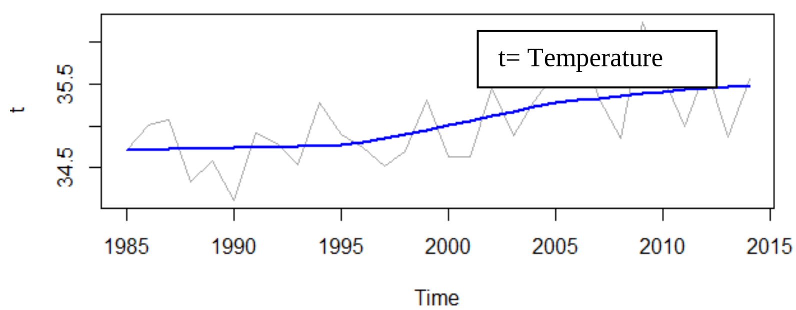

Fig. 3. Lowess curve for monthly maximum Temperature

Comments: It is obvious from the aforementioned LOWESS curve that over the study period, the monthly maximum temperature is increasing gradually.

3.4 LOWESS Curve for Cloud Coverage

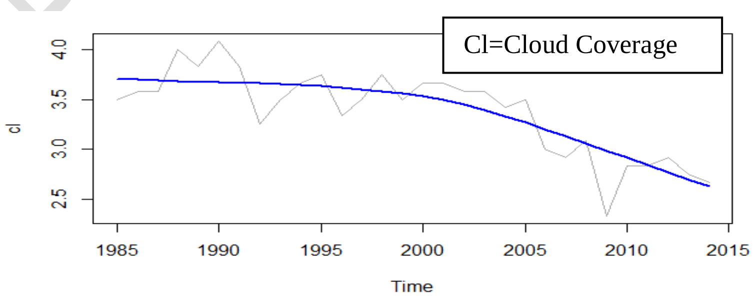

Fig.4. Lowess curve for Cloud coverage

Comment: As seen in the Lowess curve above, the yearly mean cloud coverage has been trending somewhat lower from 1985 to 2000. But the trend of declining cloud covering has been clearly seen since the year 2000.

3.5 Mann Kendall Trend Test

Table 1. Mann-Kendall trend test for the selected variables

Variables	Tau (τ)-statistics	Two-sided p-value
Rainfall	-0.131	0.31775
Temperature	0.396	0.0022785
Cloud coverage	-0.581	0.000011

Test of Hypothesis for the Mann-Kendall Trend Test of Rainfall

H_0 : There is no trend in entire data set

H_1 : There is a monotonic trend in the data set (upward or downward)

Comments: The tau statistic shows that the monthly rainfall level has been declining for the whole time. However, the Mann-Kendall test's p-value is greater than 0.05, which suggests that there is a statistically insignificant decrease trend in the rainfall levels.

3.6 Test of Hypothesis for the Mann-Kendall Trend Test of Maximum Temperature

H_0 : There is no trend in entire data set

H_1 : There is a monotonic trend in the data set (upward or downward)

Comments: The test statistic indicates that there is a positive trend in the monthly maximum temperature. As it is seen that the Mann-Kendall test's p-value is less than the level of significance (0.05), it may be concluded that there is a statistically significant upward trend in temperature.

3.7Mann-Kendall Trend Test for Cloud coverage

H_0 : There is no trend in entire data set

H_1 : There is a monotonic trend in the data set (upward or downward)

Comments: The test statistic indicates that there is a negative trend in the cloud overage. As it is seen that the Mann-Kendall test's p-value is less than the level of significance (0.05), it may be concluded that there is a statistically significant downward trend in monthly cloud coverage.

4. CONCLUSION

This study was conducted to evaluate the trends in several meteorological variables in the country's Jessore region from 1985 to 2015. The LOWESS curves show that there is an upward trend in monthly average maximum temperature but a diminishing trend for rainfall and cloud coverage, respectively. The Mann-Kendal trend test quantifies the trend at -0.131 for monthly average rainfall, which supports the declining character of rainfall for the region. A similar decreasing trend of -0.581 has been traced for monthly average cloud coverage over the time span. On the other hand, an increasing trend of 0.396 was found for the monthly maximum temperature. The original time series plot of the variables also satisfies the result of the LOWESS curve as well as the Mann-Kendal tau-test. In one word, it can be said that the usual pattern of the study variables has been altering gradually, which may be alarming signs for the climatic component of the study region.

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