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ANALYSISOFCLIMATECHANGEINSUNDARBANSBANGLADESHPARTINTERMSOFTEMPERATUREANDRAINFALLVARIABILITY

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Analysis of Climate Change in Sundarbans (Bangladesh Part) in Terms of Temperature and Rainfall Variability

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Abstract- The Sundarbans, lies on the delta of the Ganges, Brahmaputra and Meghna rivers on the Bay of Bengal, is the largest contiguous mangrove forest in the world. Although the mangrove forests of the Sundarbans provide an important defense in limiting climate change impacts, the forest ecosystems have now become vulnerable due to the effects of climate change. The climate change of the region has been studied through statistical analysis of records of last thirty years of rainfall, temperature, sea level and sea surface temperature. Several statistical techniques such as Mann-Kendall/Modified Mann–Kendall tests, Theil and Sen's median slope analysis, simple linear regression method were applied for the study and data used from observed and gridded datasets. The annual rainfall has been decreased by 6.6% at a rate of 5.25 mm/yr. The atmospheric temperature has shown an increasing trend throughout the year except for the winter season which indicates that winter has become colder and summer has become warmer. Changes in temperature and rainfall pattern can have damaging results on biological diversity, physiological processes, ecological settings, agricultural productivity, and socioeconomic culture of the region. The greatest threat will come from the rising sea levels as it will lead to cause loss of habitats, salinity intrusion, extinction of important mangrove species, higher rate of coastal erosion and disappearance of forest land cover. Details study is required for better understanding of the climatic impacts and to developing sustainable mitigation action plan.

Keywords: climate, ecosystem, mangrove, significant, trend.

I. Introduction

Climate change is a contemporary burning issue for all around the world. Bangladesh is one of the fastest and severest affected countries of climate change due to its high population density, flat and low-lying topography, and adverse geographic location (Ali, 1999; Stern, 2007). The Sundarbans mangrove forest ecosystem, which is universally recognized as the largest mangrove forest formation in the world, lies to the downstream part of the Ganges-Brahmaputra-Meghna (GBM) Delta system at the point where it merges with the Bay of Bengal (Banerjee, 2013). The total area of Sundarbans estimated at 10,000 km^2 of which 60% area belongs to Bangladesh and the rest of the portion in India (Islam, 2019; Jahanara & Rahman, 2019). The Bangladesh part of Sundarbans is located in the southwestern part of the country, slightly south to the Tropic of Cancer between the latitudes 21°30'N and 22°30'N, and longitudes 89°00'E and 90°00'E (Figure 1).

The mangrove ecosystem of Sundarbans is one of the most biologically protective and taxonomically diverse ecosystems of the Indian Sub-continent (Mahadevia & Vikas, 2012). Several studies have indicated manifestations of climate changes in the Sundarban region in terms of temperature and rainfall variability. Atmospheric temperature has been increased significantly over the period of time. Surface air temperature anomaly data over the Sundarbans and adjoining portions of the Bay of Bengal indicates an increasing trend of 0.019°C per year between 1970 and 2000 (Hazra et al, 2002).

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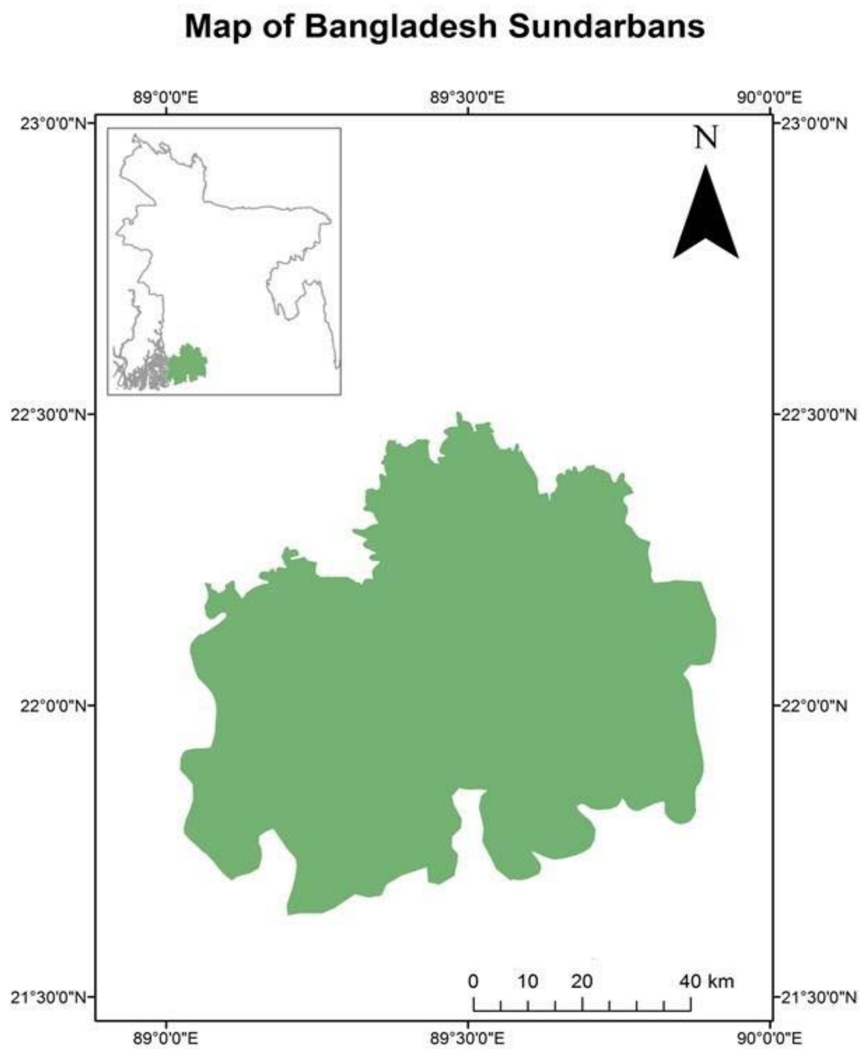

Figure 1: Location map of Sundarbans in Bangladesh

The post monsoon rainfalls in Sundarbans had slightly increased during the period of 1990-99 (Chand et al, 2012). There is also a trend of delayed monsoon and heavy rains at the beginning as well as late recession and sometimes heavy precipitation during August and September (Khosla, 2010). As it is evident that the climatic pattern of Sundarbans is changing gradually which can ultimately affect it diverse ecosystem. Considering the issue, the study will focus trend analysis of the climatic parameters of temperature and rainfall through statistical analysis.

II. Data and Method

a) *Data*

Temperature and precipitation are two basic components of climate. The study focuses on trend detection of seasonal and annual precipitation along with monthly and annual temperature. Both observed and gridded datasets have been used to operate the trend analysis. The observed series are collected from the Bangladesh Meteorological Department (BMD) for the station Mongla which is closest BMD station to Sundarbans. As the BMD inaugurated the station in 1989, the temperature and rainfall data are available from 1989 and 1991 respectively. On the other hand, precipitation and temperature data have also been extracted from CRU TS (Climatic Research Unit gridded Time Series) 3.23 dataset for the period of 1985–2014 at 0.5° X 0.5° resolution for gridded time series. The study area belongs to the range of latitude 21°30'0" N to 22°30'0" N and longitude 89°0'0" E to 90°0'0" E comprising four adjacent grid areas cover the whole Sundarbans (Bangladesh part) as seen in Figure 2.

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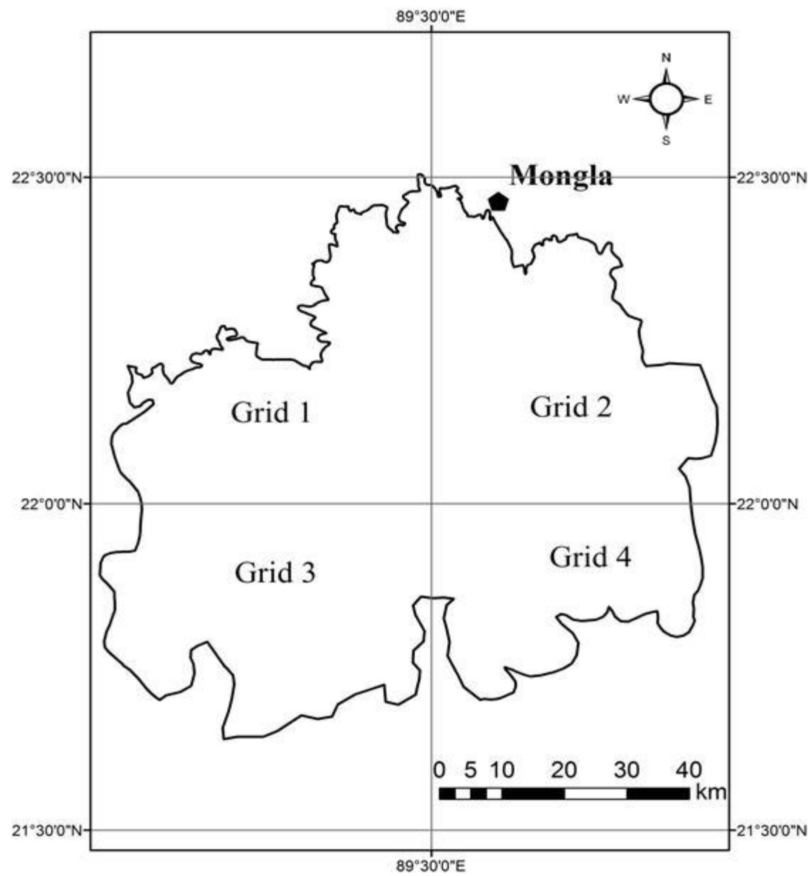

Figure 2: Location of BMD Station and CRU TS Grids of Temperature and Rainfall Data Series

The daily series of the datasets were collected for the both parameters. The rainfall records were converted to monthly scale from the daily series which were in turn converted to seasonal and annual analysis. Three seasonal variations have been considered for rainfall data analysis: pre-monsoon season (January to May), monsoon season (June to September), and post-monsoon season (October and December). The temperature data is processed as average figure from daily maximum and minimum records.

b) Methods

All the climate data series have been processed for trend analysis through several statistical methods. First, student's t test at lag-1 is functioned at 10% significant level to check the significance of autocorrelation. The test result indicates level of significance of the correlated data series. Modified Mann-Kendall (MMK) test at 10% significant level is conducted for the autocorrelated series, Mann-Kendall (MK) test is performed for the rest of the analysis at same significant level (Basistha et al., 2009). The presence of positive or negative trend has been determined from the Z_S value of the MK and MMK test of the series. Linear trend analyses for the climate parameters have also been carried out and the scale of the trend have been calculated by the Theil-Sen's slope method. The magnitude percentage change of the parameters has calculated through applying the Sen's slope value. Trend of linearity of variables has also calculated by simple linear regression method at 95% confidence interval. The regression method was applied to explore the magnitude of the climate variables.

i. *Student's 't' test for autocorrelation*

The detection of trend in a series is influenced by the presence of positive or negative autocorrelation (Anderson & Anderson, 1941; Taxak et al., 2014). There are more odds of a series being found as having trend with a positively autocorrelated series while there may be essentially nothing (Basistha et al., 2009). The case is opposite for negatively auto-correlated series, where a trend fails to get identified. The autocorrelation coefficient ρ_k of a discrete time series for lag-k is calculated as

$$\rho_k = \frac{\sum_{t=1}^{n-k}\left(x_t-\bar{x}_t\right)\left(x_{t+k}-\bar{x}_{t+k}\right)}{\left[\sum_{t=1}^{n-k}\left(x_t-\bar{x}_t\right)^2 \times \sum_{t=1}^{n-k}\left(x_{t+k}-\bar{x}_{t+k}\right)^2\right]^{\frac{1}{2}}} \quad (1)$$

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where, $\overline{x}_t$ and *Var* (X_t) are the sample mean and sample variance of first *(n-k)* terms, and xt+k and *Var* $(\overline{X}_{t+k})$ are the sample mean and sample variance of the last *(n-k)* terms. The hypothesis of serial independence is then tested by the lag-1 autocorrelation coefficient as H_0: $\rho_1 = 0$ against H_1: $|\rho_1| > 0$ using

$$t = |\rho_1| \sqrt{\frac{n-2}{1-\rho_1^2}} \tag{2}$$

where the test statistic *t* has a Student's *t* –distribution with *(n-2)* degrees of freedom (Cunderlik and Burn, 2004). If $|t| \geq t_{\frac{\alpha}{2}}$, the null hypothesis about serial independence is discarded at the significance level (α = 10%).

ii. *Mann-Kendall trend test*

Mann Kendall test is a statistical trial broadly exercised for the trend analysis in climatologic and in hydrologic time series (Yue & Wang, 2004). Using the test provides two important benefits. Firstly, it is a non-parametric test and does not necessitate the data to be normally distributed. Secondly, the test has low sensitivity to abrupt breaks due to inhomogeneous time series (Tabari et al., 2011).

According to this test, it is assumed that the there is no trend for the null hypothesis H0 (the data is independent and randomly ordered) and this is tested against the alternative hypothesis H1, which supposes that there is a trend (Onoz & Bayazit, 2012). The rank correlation test (Kendall, 1955) for two sets of observations X = x_1, x_2… x_n and Y = y_1, y_2,…y_n is expressed as follows. The statistic S is calculated as in the following equation:

$$S = \sum_{i<j} a_{ij} b_{ij} \tag{3}$$

and b_{ij} is correspondingly defined for the observations in Y. Under the null hypothesis that X and Y are independent and randomly ordered, the statistic S tends to normality for large n, with mean and variance given by:

$$E(S) = 0 \tag{4}$$

$$V(S) = n\,(n-1)\,(2n+5)/18 \tag{5}$$

If the values in Y are substituted with the order of the time series X, i.e. 1, 2,...n the test can be used as a trend test. In this circumstance, the statistic S decreases as

$$S = \sum_{i<j} a_{ij} = \sum_{i<j} sgn\,(x_j - x_i) \tag{6}$$

$$Sign(x_j - x_i) = \{1 \; if \; x_j - x_i > 0 \; 0 \; if \; x_j - x_i = 0 \; -1 \; if \; x_j - x_i < 0 \tag{7}$$

with the same mean and variance as in equations, and x_j and x_i are the annual values in years j and i, j > i, respectively. The standard test statistic Z_s is calculated as follows:

$$Z_s = \{\frac{s-1}{\sigma} \; for \; S > 0 \;\; 0 \; for \; S = 0 \; \frac{s-1}{\sigma} \; for \; S < 0 \tag{8}$$

where V(S) is from Equation (5). The rest is as in the MK test.

iii. *Modified Mann–Kendall (MMK) test*

Pre-whitening has been used to reveal a trend in a time series in presence of autocorrelation (Cunderlik and Burn, 2004; Basistha et al., 2009). In spite of this, pre-whitening is reported to decrease the detection rate of significant trend in the MK test (Yue et al., 2003). Hence, the MMK test has been applied for trend detection of an auto-correlated series (Basistha et al., 2009). In this, the autocorrelation between ranks of the observations ρ_k are evaluated after deducting a non-parametric trend estimate such as Theil and Sen's median slope from the data. Only significant values of ρ_k are applied to calculate the variance correction factor n/ns*, as the variance of S is undervalued when the data are positively auto-correlated:

$$\frac{n}{n_s^*} = 1 + \frac{2}{n(n-1)(n-2)} \times \sum_{k=1}^{n-1} (n-k)(n-k-1)\,(n-k-2)\rho_k \tag{9}$$

where n is the actual number of observations, ns* is considered as an 'effective' number of observations to account for autocorrelation in the data and is the autocorrelation function of the ranks of the observations. To account only for significant autocorrelation in data, number of lags can be limited to 3 (Rao et al., 2003). The corrected variance is then computed as

$$V^*(S) = V(S) \times \frac{n}{n_s^*} \tag{10}$$

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iv. *Theil and Sen's median slope*

When a monotonic trend is determined using the Mann-Kendall test and the trend seems to be linear, we can use a Theil-Sen line to estimate the slope of the trend. The slope line is a nonparametric substitute to the parametric ordinary least square regression line. The slope of N pairs of data is estimated by Theil and Sen's estimators (Theil, 1950; Sen, 1968) using the following formula

$$Qi = (x_j - x_k)/(j-k) \text{ for } i=1,...N \tag{11}$$

where x_j and x_k represent values at times j and k (j > k), respectively. The median of these N values of Q_i is considered as the Sen's estimator of slope. If there is a single data in each time period, then

$$N = \frac{n(n-1)}{2} \tag{12}$$

where n is the number of time periods. The median of the N assessed slopes is obtained in the normal way, i.e., the N values of Q_i are ranked by $Q_1 \le Q_2 \le ... \le Q_{n-1} \le Q_n$ and

$$\text{Sen's estimator} = \{Q_{\frac{(N+1)}{2}} \; if\ N\ is\ odd \left(\frac{1}{2}\right)\left(Q_{\frac{N}{2}} + Q_{\frac{(N+2)}{2}}\right) \; if\ N\ is\ even \tag{13}$$

v. *Change magnitude as percentage of mean*

Some trends may not be assessed to be statistically significant while they might be of practical interest, and vice versa (Yue and Hashino, 2003, Basistha et al., 2009). For the current study, change percentages have been figured by approaching it with a linear trend, calculate approximately its magnitude by Theil and Sen's median slope and assessing the change over the period as percentage of mean of the period concerned, following (Yue & Hashino, 2003).

$$\text{Percentage change } (\%) = \frac{\beta \times Length\ of\ year}{Mean} \times 100 \tag{14}$$

That is, the change of percentage equates median slope (β) multiplied by the length of study period divided by the corresponding mean, expressed as percentage. The significance level has been established to be 10%, the same as the level for statistical signi ficance.

vi. *Confidence interval for linear regression slope*

The equation of simple linear regression is expressed as

$$Y_i = \alpha + \beta X_i + \varepsilon_i \tag{15}$$

The dependent variable Y has a linear relationship to the independent variable X, whereas α and β are fixed quantities for the parameters of the model. Here, α act as a constant or intercept which determines the value where the regression line intersects the y-axis; β is called coefficient or slope, and measures the gradient of the regression line; the random component ε_i is called disturbance or error in observation i.

One intuitive criterion would be to estimate α and β by a and b so as to minimize the deviation ε_i between the observed values of Y, Y_i, and the predicted values of Y, $\hat{Y}_i$. In this way values for a and b would be sought that minimize the sum

$$\sum(Y_i - \hat{Y}_i) = \sum \varepsilon_i = \sum\left(Y_i - \hat{\alpha} - \hat{\beta} X_i\right) = \sum (Y_i - a - bX_i) \tag{16}$$

Thus it is desired to estimate α and β by a and b such $\sum \varepsilon_i^2$ is minimum. Denoting the sum by M, we have

$$M = \sum \varepsilon_i^2 = \sum(Y_i - \hat{Y}_i)^2 = \sum (Y_i - a - bX_i) \tag{17}$$

The solution of normal equations in terms of a and b is

$$b = \frac{\left[\sum X_i Y_i - \frac{\sum X_i \sum Y_i}{n}\right]}{\left[\sum X_i^2 - \frac{\left(\sum X_i\right)^2}{n}\right]} = \sum x_i y_i / \sum x_i^2 \tag{18}$$

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$$a = \frac{\Sigma Y_i - b\Sigma X_i}{n} = (\overline{Y} - b\overline{X}) \quad (19)$$

An unbiased estimate is S^2 calculated from

$$S^2 = \frac{\Sigma e_i^2}{n-2} = \frac{\Sigma (Y_i - \hat{Y}_i)^2}{n-2} \quad (20)$$

Confidence limits of regression line are given by

$$U = a = bX + S[\frac{1}{n} + (X - \frac{\overline{X})^2}{\Sigma X_i}]^{\frac{1}{2}} t_{1-\frac{\alpha}{2},\, n-2} \quad (21)$$

$$L = a = bX - S[\frac{1}{n} + (X - \frac{\overline{X})^2}{\Sigma X_i}]^{\frac{1}{2}} t_{1-\frac{\alpha}{2},\, n-2} \quad (22)$$

U and L represent the upper and lower limits of the regression line respectively.

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III. Results and Discussions

a) *Rainfall Analyses*

i. *Observed Data*

The rainfall pattern of Mongla station has been studied to understand the precipitation scenario of the study area. The results of statistical analysis for the period of 1991–2014 are presented in Table 1. Percentage changes over mean values have also been shown in the table. Out of the three seasons only the pre-monsoon season is showing a decreasing trend, while monsoon and post-monsoon have an increasing trend. The rainfall has decreased at annual scale, though it is not statistically significant. However, significant increase (at the 10% significance level) has occurred only in post-monsoon season.

Table 1: Results of MK (MMK) test (at 10% level), Theil & Sen's Slope analysis and percent change of observed rainfall over 1991–2014 of Mongla station.

	Pre-Monsoon	Monsoon	Post-Monsoon	Annual
Mean	311	1380	218	1908
Z	-1.61	0.02	0.32*	-0.57
Theil & Sen's Slope	-4.34	1.06	0.79	-5.25
Percentage Change	-33.49	1.84	8.66	-6.60

**marked value indication of auto-correlated series*

The statistical analyses of the single observed station indicate that the pre-monsoon rainfall decreased considerably (33.5%), whereas the monsoon rainfall has been increased slightly (1.8%) and post-monsoon rainfall has been increased significantly (8.7%). The analysis of the annual rainfall shows that rainfall has decreased by (6.6%) at a rate of 5.25 mm/yr.

The highest annual rainfall in the Mongla Station has been observed in 2002 which was peaked to 2786 mm, whereas the annual average is 1908 mm. Generally, the monsoon season contributes about 60-80% of total annual rainfall. It is noticeable that monsoon rainfall is almost proportional to the annual rainfall, which indicates that annual rainfall pattern predominantly determined by the rainfall received during monsoon season.

The annual rainfall in the observed station has also been analyzed by simple regression method at 95% confidence interval (Figure 3). The trend line appears as horizontally parallel straight line which is an indication of almost unchanging magnitude of total annual rainfall. The maximum and minimum edges of the regression trend are exhibited by upper limit and lower limits in the graph respectively.

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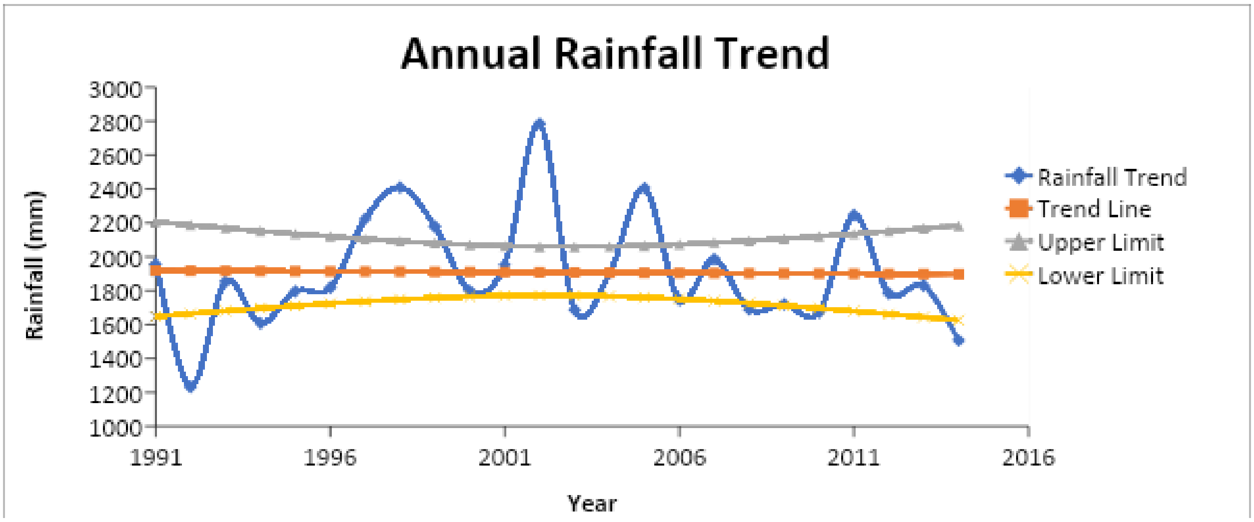

Figure 3: Annual Rainfall Trend at 95% Confidence Interval of Mongla Station from the year 1991 to 2014

ii. *Gridded data*

Precipitation data has also been collected from CRU TS 3.23 datasets for further analysis. The assessment is carried out for seasonal and annual series for the data sets of four grids. The analysis figure indicates that there is overall an insignificant change throughout the study period except for the annual level of grid 2. The annual rainfall has decreased for every grid, whereas seasonal rainfall has also decreased for most of the grids apart from the pre-monsoon and monsoon seasons of grid 4. The results of the autocorrelation analysis for 1985–2014 are presented in Table 1.

Table 1: Results of MK (MMK) test (at 10% level), Theil & Sen's Slope analysis and percent change of CRU TS 3.23 gridded rainfall between 1985 and 2014.

	Grid 1				Grid 2			
	Z Value	Mean	Sen's Slope	Change of Percentage	Z Value	Mean	Sen's Slope	Change of Percentage
Pre-Monsoon	-0.14	293.96	-0.58	-5.87	-0.32	363.16	-0.75	-6.20
Monsoon	-0.54	1452.33	-2.20	-4.54	-0.50	1526.51	-3.06	-6.02
Post Monsoon	-1.28	234.27	-3.21	-41.15	-1.00	238.12	-2.12	-26.75
Annual	-1.07	1980.56	-8.67	-13.13	-2.34*	2127.79	-8.45	-11.92
	Grid 3				Grid 4			
	Z Value	Mean	Sen's Slope	Change of Percentage	Z Value	Mean	Sen's Slope	Change of Percentage
Pre-Monsoon	-0.14	292.66	-0.29	-2.92	0.04	448.06	0.02	0.15
Monsoon	0.43	1591.82	1.28	2.42	0.00	2204.26	0.11	0.14
Post Monsoon	-1.25	268.49	-3.27	-36.50	-1.61	281.73	-3.65	-38.87
Annual	-0.43	2152.97	-3.23	-4.50	-0.61	2934.05	-5.18	-5.30

**marked value indication of auto-correlated*

b) *Atmospheric Temperature Analyses*

i. *Observed data*

The air temperature records of Mongla station has been studied for the period of 1989-2014. Monthly temperature records indicate that May is the hottest month of the year and January is the coolest month of the Sundarbans. The warmest (29.6°C) year was observed in 2010 and coolest (28.4°C) year was 1997, whereas the annual average temperature was 28.9°C during the 26 year study duration. The statistics shows that a significant rising trend of mean annual temperature at 95% confidence interval (Figure 4). The upper and lower confidence limits of the regression line are also displayed for the increasing trend of observed atmospheric temperature.

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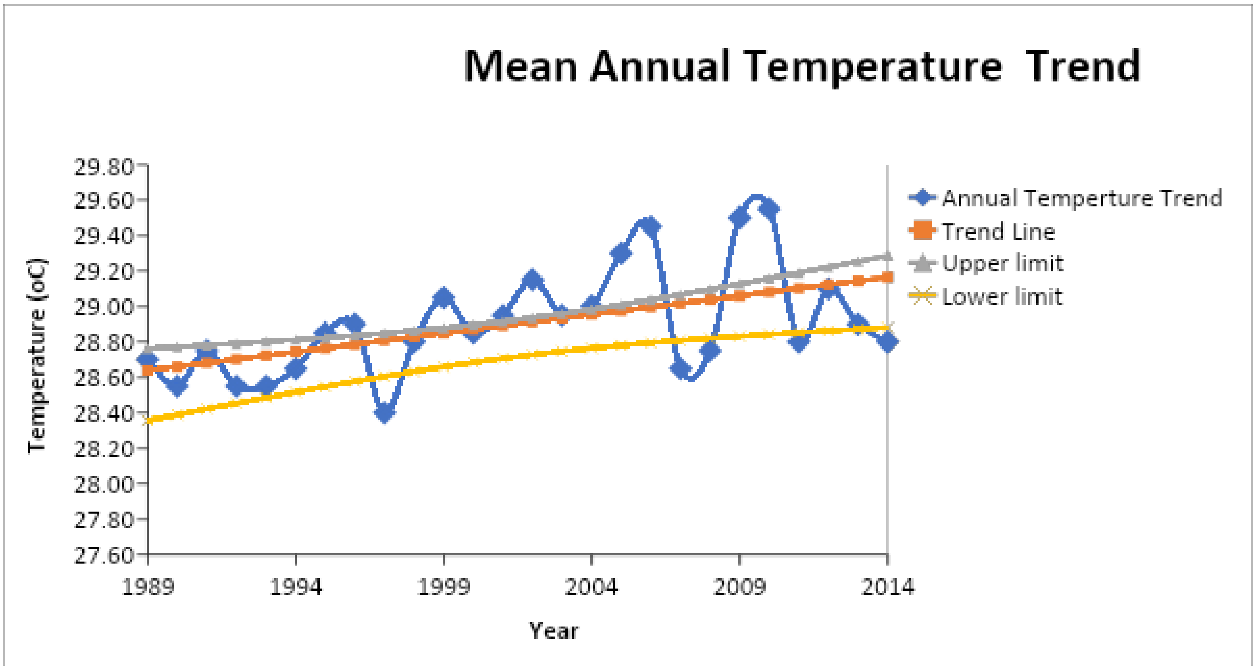

Figure 4: Annual Mean Temperature Trend at 95% Confidence Interval of Mongla Station from 1989 to 2014

The results of statistical analysis monthly and annual air temperature datasets are shown in the Table 2. The autocorrelation tests reveal that the datasets are statistically not auto-correlated. However, the temperature has increased for all months except for December, January and February. The maximum increase is observed in the month of April, May and June which belongs to the summer season. This can be interpreted as summers getting warmer and winters getting colder, thus increasing the range of temperature. Such change can have catastrophic effects on the delicate wetland/mangrove ecology.

Table 2: Results of MK (MMK) test (at 10% level), Theil & Sen's Slope analysis and percent change of atmospheric temperature over 1989–2014 of Mongla station.

	Mean	Z	Sen's Slope	Change of Percentage
Jan	19.6	-0.86	-0.02	-2.21
Feb	23.1	-0.33	0.00	-0.56
Mar	27.4	0.99	0.02	1.90
Apr	29.9	1.83*	0.05	4.09
May	30.3	1.97*	0.03	2.86
Jun	29.8	2.08*	0.03	2.84
Jul	29.1	1.70*	0.02	1.84
Aug	29.1	1.35	0.01	1.28
Sep	29.0	2.19*	0.02	1.99
Oct	28.1	1.59*	0.02	1.54
Nov	25.0	0.00	0.00	0.00
Dec	21.0	-0.55	-0.01	-1.24
Annual	28.9	2.98*	0.025	2.25

**marked value indication of auto-correlated series*

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ii. *Gridded data*

Air temperature data of CRU TS 3.23 datasets have been utilized for climatic study of Bangladesh Sundarbans. Although there is largely a rising trend observed for monthly temperature series except for the months of January, August and December, the trends are not statistically significant (Table 3). The highest temperature increase is observed for the month of June with for all grids, January shows the lowest temperature reduction for the same. As for the gridded datasets temperatures are mostly showing decrease in winter, the changing patterns are almost identical with the observed data point.

Table 3: Results of MK (MMK) test (at 10% level), Theil & Sen's Slope analysis and percent change of CRU TS 3.23 gridded temperature data between 1985 and 2014.

	Mean				Z values			
	Grid 1	Grid 2	Grid 3	Grid 4	Grid 1	Grid 2	Grid 3	Grid 4
Jan	19.77	19.59	20.21	20.53	-1.32	-1.56	-1.70*	-1.93*
Feb	23.15	22.79	23.35	23.16	-0.07	-0.25	0.00	-0.11
Mar	27.52	27.26	27.25	26.84	0.79	0.64	0.88	0.91
Apr	29.46	29.12	29.02	29.13	0.91	0.70	0.97	0.98
May	30.01	29.56	29.69	29.68	1.49	1.24	1.54	1.11
Jun	29.77	29.37	29.45	29.16	1.70*	1.20	1.94*	1.86*
Jul	28.93	28.67	28.75	28.23	1.45	1.36	1.80*	1.23
Aug	28.96	28.66	28.69	28.29	-0.23	-0.67	-0.07	-0.65
Sep	29.09	28.84	28.82	28.50	0.88	0.86	1.29	1.15
Oct	28.14	27.99	28.05	27.74	0.57	0.30	0.99	0.95
Nov	25.10	24.99	25.21	25.18	0.54	0.68	1.10	0.77
Dec	21.24	21.03	21.51	21.92	-1.27	-0.86	-0.74	-0.74
Annual	26.76	26.49	26.67	26.53	0.95	0.38	0.95	0.62
	Sen's Slope				Change of Percentage			
	Grid 1	Grid 2	Grid 3	Grid 4	Grid 1	Grid 2	Grid 3	Grid 4
Jan	-0.025	-0.026	-0.024	-0.029	-3.79	-4.03	-3.49	-4.17
Feb	0.000	-0.007	0.000	0.000	0.00	-0.98	0.00	0.00
Mar	0.013	0.012	0.017	0.014	1.36	1.38	1.83	1.52
Apr	0.017	0.011	0.014	0.017	1.70	1.08	1.48	1.72
May	0.020	0.011	0.020	0.012	2.00	1.07	2.02	1.26
Jun	0.027	0.020	0.030	0.032	2.75	2.04	3.06	3.27
Jul	0.013	0.011	0.013	0.007	1.30	1.16	1.39	0.71
Aug	0.000	-0.004	0.000	-0.004	0.00	-0.39	0.00	-0.38
Sep	0.009	0.005	0.010	0.009	0.90	0.55	1.04	0.92
Oct	0.006	0.004	0.010	0.011	0.63	0.41	1.07	1.20
Nov	0.004	0.011	0.014	0.010	0.43	1.33	1.62	1.19
Dec	-0.019	-0.011	-0.011	-0.009	-2.65	-1.58	-1.55	-1.24
Annual	0.004	0.002	0.004	0.003	0.40	0.19	0.47	0.30

**marked value indication of auto-correlated series*

IV. Conclusions

Because of its geographical settings the Sundarbans of Bangladesh is vulnerable from various perspectives of climate variability and climate change-related phenomenon. The fluctuation of seasonal rainfall is an indication changing rainfall pattern. Although the monsoon rainfall increased slightly, it delayed to befall in

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usual monsoon period. The overall analysis suggests that the annual rainfall has been decreased and the seasonal monsoon rainfall has shifted to post-monsoon season. Mangrove growth and its spatial distribution are supposed to be affected by changing rainfall pattern of Sundarbans. Furthermore, decrease of rainfall can increase salinity, which consequently reduces diversity, productivity, growing and seedling existence, hence moving competition among mangrove species. Changes in rainfall generally can have undesirable impacts to the biodiversity, ecological settings, agricultural practices, local livelihood as well as the socio-economic systems of the Sundarbans.

The temperature analysis reveals increase of average annual temperature of Sundarbans locality. The temperature has shown an increasing trend throughout the year except for the winter season that indicates that winter has become colder and summer turned into warmer. Temperature has an effect on basic physiological processes and mangrove reproduction and distributions. Increasing temperature can result altering species composition (extinction) and changing phenological patterns (timing of flowering and fruiting) of plants (Gilman et al., 2008). On the other hand, reproduction system of Sundarbans can be restricted by low temperatures (Duke 1990).

There are several climate induced impacts such as tropical cyclones, sea level rise, scarcity of fresh water, salinity intrusion which have already been observed in the region and the outcomes are severe in most cases. Climatic vulnerability can further endanger a wide range of floral and faunal species in the forest. A comprehensive study is required in a greater quantitative scale to understand the threats of climate change on biodiversity and mangrove ecosystem of Sundarbans.

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