Rainfall-Temperature Nexus over the Mainland and Islands in Southeast Bangladesh

Syed Mustafizur Rahman[1]*, Md. Abdur Rahman[1], Razia Sultana[2] and Syed Mahbubur Rahman[3]

[1]Geophysics Lab, Department of Electrical and Electronic Engineering, University of Rajshahi, Rajshahi 6205, Bangladesh

[2]Bangladesh Meteorological Department, Dhaka 1207, Bangladesh

[3]BRAC Business School, BRAC University, Dhaka 1212, Bangladesh

**Corresponding author's Email: smrahman@ru.ac.bd*

Abstract

The southeast coastal area including a number of remote islands in Bangladesh is vulnerable to climate change, and the residents' living and livelihood are influenced by rainfall and temperature. This work has investigated the correlation between rainfall and temperature of the regions, and shown the deviation of estimated correlations in the mainland and islands. Correlations are estimated for various time lengths in daily recorded rainfall with minimum and maximum temperature, along with the difference between maximum and minimum temperature. Calculated correlations are very unstable for the time lengths employed less than a year. Use of four-year time length finds stable correlations but mean coefficients of correlation are poorly related as obtained respectively 0.2356, -0.2061 and 0.0930 for minimum, maximum and average temperature with rainfall. In contrast, association of rainfall with the difference between maximum and minimum temperature shows better relation with an average correlation coefficient of -0.4154. By employing smoothing of rainfall and temperature data, using moving average period, the magnitude of correlation coefficient increases further to 0.6 or more. After smoothing the estimated correlations of rainfall with difference between maximum and minimum temperature are mostly above 0.6. Variation in the estimated correlation has indicated stable climate in the mainland but variable in the islands as being experienced of accretion and erosion. Studied correlation pattern, from 0.5 to 0.03 to 0.5 or little more during 1997 to 2010, is well aligned with the land eroded in Sandwip island, similarly Hatiya island may lose land in the coming years. Pearson, Spearman and Kendall type estimations have interpreted similar facts for the study area.

Keywords: Rainfall; temperature; correlation; island; Bangladesh; vulnerability.

1. Introduction

Most of the regions of Bangladesh are under diverse threats due to the impacts of climate change (Rahman et al., 2016); and according to a long term climate risk assessment Bangladesh is among the top most affected countries hinge on death tolls and losses in gross domestic product caused by extreme weather events during the last twenty years (Eckstein et al., 2019).Northwest part of the country has been experiencing droughts of varied scales, riverine part is underlined for flood along with erosion, and the coastal south is prone to frequent cyclone, salinity and waterlogging along with climate change-induced sea level rise, one of the most devastating consequences of global warming (Abedin et al., 2019; Sovacool et al., 2012; MOEF, 2005). A 710 km long coastline of Bangladesh covers around 30-32% of the total land areas (Haque, 2006; MOWR, 2005). There are nineteen districts consisting 147 upazilas (sub-districts) in the coastal belt. Geo-morphologically the coastal areas are divided in three regions: western, central and eastern region. Fifty-one upazilas including a number of remote islands of twelve coastal districts have already started experiencing frequent cyclone with higher tide and more salinity (Dasgupta et al., 2014). Living and livelihood of coastal in a way depend on precipitation and temperature (Riha et al., 1996; Lobell and Field, 2007), while there is a link between temperature and the amount of precipitation (Buishand and Brandsma, 1999).

The relationship between temperature and precipitation is timescale-dependent (Rehfeld and Laepple, 2016), and is critical to agricultural productivity and other hydrological and meteorological phenomena (Pandey et al., 2018). The impact of rainfall and temperature alone has been a widely studied area of research; for instance, annual mean temperature plays an important role in agricultural production, while annual rainfall has little effect (Yang et al. 2020). Joint impact of rainfall and temperature has also attracted many researchers in wider array of investigation; for instance, on the incidence of dengue fever (Picardal and Elnar, 2017) and vegetation greenness (Lamchin et al., 2018).

However, research about the nexus between rainfall and temperature is relatively low in number; somehow neglected in the past (Buishand and Brandsma,1999). The efforts to explore any direct relationship with a particular concentration to space and time has attracted few researchers, for instance historically noticeable are the works of Hamrick and Martin (1941), Crutcher (1978), Zhao and Khalil (1993), and Subash and Sikka (2014). More recent works have also argued about the importance of studies about rainfall and temperature (Kreyling and Beier, 2013). In the USA the correlations of rainfall and temperature were variants at different regions over seasonal and monthly data. Regional positive and negative correlations were shown in winter and summer respectively (Hamrick and Martin, 1941). Zhao and Khalil (1993) had also shown no strong correlation at the coasts in the USA. There has also been found no direct relationship between increasing rainfall and increasing maximum temperature for monthly or seasonal data analysis in India (Subash and Sikka, 2014). However, sea surface temperature may have impact on seasonal rainfall as observed in Ethiopia (Alhamshry et al., 2020), the Philippines (Takahashi and Dado, 2018), and South Africa (Nkuna and Odiyo, 2016).

Buishand and Brandsma (1999), in case of Italy, found that although might be influenced by other factors there was a link between the amount of precipitation and temperature. Yang et al. (2006) has found precipitation and temperature well associated in Guliya ice cores. Yannick and Chae (2018) have found a level of correlation between temperature and rainfall in the Republic of Congo. The cumulative monthly average temperature is negatively correlated with cumulative monthly average rainfall; however, the relation is week in the equatorial fully humid region. The equatorial monsoonal region also shows the same relation, while the equatorial winter dry region shows a strong positive correlation (Yannick and Chae, 2018). It is apparent that precipitation influences erosion, groundwater recharge, water disposal, plant growth as well as slope instability, and understanding precipitation can result in disaster prediction and appropriate water management mechanisms (Aguado et al., 1992; L´opez-Moreno et al., 2009; Coscarelli and Caloiero, 2012). Temperature as well play similar role. It is also argued that making precipitation-temperature dependence visible is useful for climate change scenario development (Buishand and Brandsma, 1999). However, no substantial effort has been made to observe such relationship in Bangladesh. Hence, this research intends to investigate the rainfall-temperature nexus in the coastal south of Bangladesh. It also aims to explore the variation, if any, in the climate condition of the mainland and islands in the region.

2. Materials and Method

The correlations may occur for the changes in precipitation and heat balance of the regions (Zhao and Khalil, 1993). However, inclusion of the changes in heat flow rather than minimum, maximum and average temperature seems more realistic, which this study has employed. Changing temperature in a climate system refers to gaining or loosing energy in the form of heat. If the mass and specific heat capacity of the system are known the amount of heat energy transferred can be determined. In the daily temperature time series of climate data, the difference between maximum and minimum temperature can lead to learn the rate of the total amount of heat changes in the day.

2.1 Materials

Daily minimum and maximum temperature, and rainfall data recorded at Teknaf, Cox'sbazar, Kutubdia, Ambagan, Sandwip, Hatya, Shitakundu and Feni stations in the costal belt of the southeastern Bangladesh for the duration of 33 years from 1985 to 2017 have been obtained from Bangladesh Meteorological Department (BMD) (Figure 1). The missing data have been filled up using cubic spline interpolation technique. The areas are the coastal plains or offshore islands of the Bay of Bengal under Chattogram division.

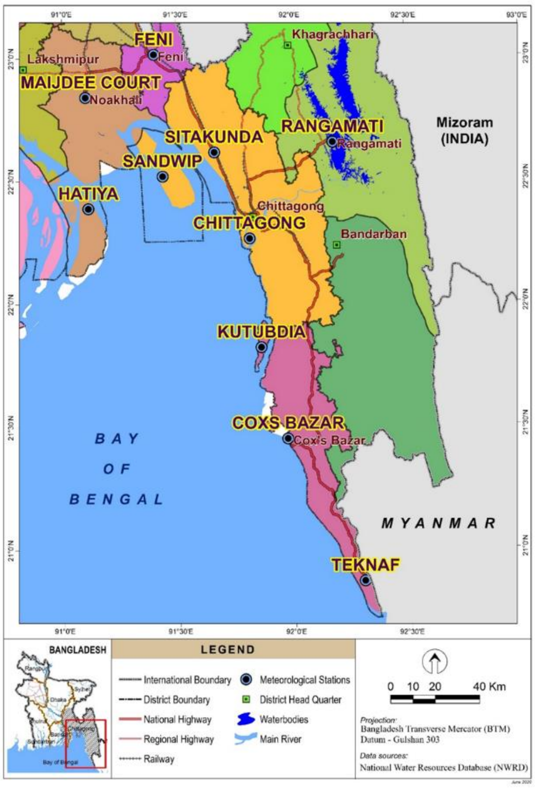

Figure 1. Location map and meteorological recording stations of the study area.

2.2 Methods

2.2.1 Correlation

Mathematically correlations defined as the ability to quantify a measure of linear relationship between two variables. If no relation exists, one variable cannot influence the other to increase or decrease in tandem. Linear correlation can investigate the relationship between two variables without having to assume or to fit a specific model. However, no or small linear correlation does not necessarily mean no relation at all; a strong nonlinear relationship may exist. Correlation is the standardized covariance, which determines the strength of the variances giving a dimension-less quantity the degree of a linear relationship known as coefficient of correlation. Pearson, Kendall and Spearman type correlations are bivariate analyses that determine the strength of linear relation between two variables and a value of ± 1 indicates the degree of association between the two variables.

Pearson's correlation coefficient, $\rho_{X,Y}$ between two random variables X and Y,with mean values of μ_X and μ_Y, and standard deviations σ_X and σ_Y is defined as (Rodgers and Nicewander, 1988):

$$\rho_{X,Y} = corr(X,Y) = \frac{cov(X,Y)}{\sigma_X \sigma_Y}$$

$$= \frac{E[(X-\mu_X)(Y-\mu_Y)]}{\sigma_X \sigma_Y} \tag{1}$$

where, E is the expected value operator, cov means covariance, and corr is correlation coefficient. The Pearson correlation is defined further only if both standard deviations are finite and positive can be written as:

$$\rho_{X,Y} = \frac{E(XY)-E(X)E(Y)}{\sqrt{E(X^2)-E(X)^2}.\sqrt{E(Y^2-E(Y)^2}} \tag{2}$$

On other hand, Spearman's and Kendall's correlation coefficients known as rank correlation coefficient (τ) represented by a linear relationship are alternatives to Pearson's coefficient (Kendall, 1955). The Spearman’s correlation coefficient can be defined as:

$$r_s = 1 - \frac{6\sum d_i^2}{n(n^2-1)} \tag{3}$$

where, $d_i = rg(X_i) - rg(Y_i)$ and n is the number of observations.

And Kandall’s rank correlation coefficient can be shown as written (Kruskal, 1958) below.

$$\tau = \frac{2}{n(n-1)} \sum_{i<j} sgn(x_i - x_j) sgn(y_i - y_j) \tag{4}$$

2.2.2 Moving Average

Moving average technique is one of the important and widely used techniques in climate time series data analysis. This work likes to employ moving average technique to enhance the correlation of rainfall and temperature which determined the summer and winter correlations using seasonal total precipitation and mean temperature (Madden and Willimas, 1978). Van den Dool (1989) has the estimated correlations using monthly data of total precipitation and mean temperature. Smoothing is frequently used technique to cancel the effect due to random variation in climate data analysis. It reveals better understanding of trend, seasonal and cyclic components when properly applied. The general expression for the moving average can be written as:

$$M_t = [X_t + X_{t-1} + X_{t-2} + \cdots + X_{t-N+1}]/N \tag{5}$$

where, $N$is the period.

2.2.3 Correlation in between Rainfall and Temperature

Since a meaningful relation between rainfall and temperature is undefined (Hamrick and Martin, 1941; Subash and Sikka, 2014), this work likes to introduce a relationship between rainfall and temperature. To visualize such relation the meteorological data recorded at Teknaf station for various time lengths have been analyzed. Pearson type coefficient of correlation has been studied for rainfall with minimum, maximum and average, as well as difference between maximum and minimum temperature for a length of four years from 1985 to 1989as shown in Figure 2. Here, the length is used as for example, 30 days length: for the data starting from 1stJanuary 1985 to 31st December 1989, analyses to be made as correlation coefficient on the 1st, 2nd and 3rdJanuary 1985 according to data for 1st to 30th January, 2nd to 31st January and 3rdto 1st February1985, respectively, and so on up to 2nd December of 1989.

Figures 2(a-c) show that the correlations are unstable with shorter (<year) length of data and the coefficient of correlation with 12 months length are found to stable but very poorly correlated mostly less than |0.4|. Where, relation of rainfall with the difference of maximum to minimum temperature is found stronger among others with a value, $\rho \cong 0.4$. But this relation is seemingly not adequate enough. In order to find a better relation moving average technique has been applied to smooth the data as moving average is appeared (Mohorji et al., 2017) playing important role in climate data analysis. Correlation has been investigated further with moving average period to see the influences. Before applying moving average Figure2(d) has been extended for the time length from 1985 to 2017 taking the four-year based progressive correlation, where it shows once again the correlation of rainfall

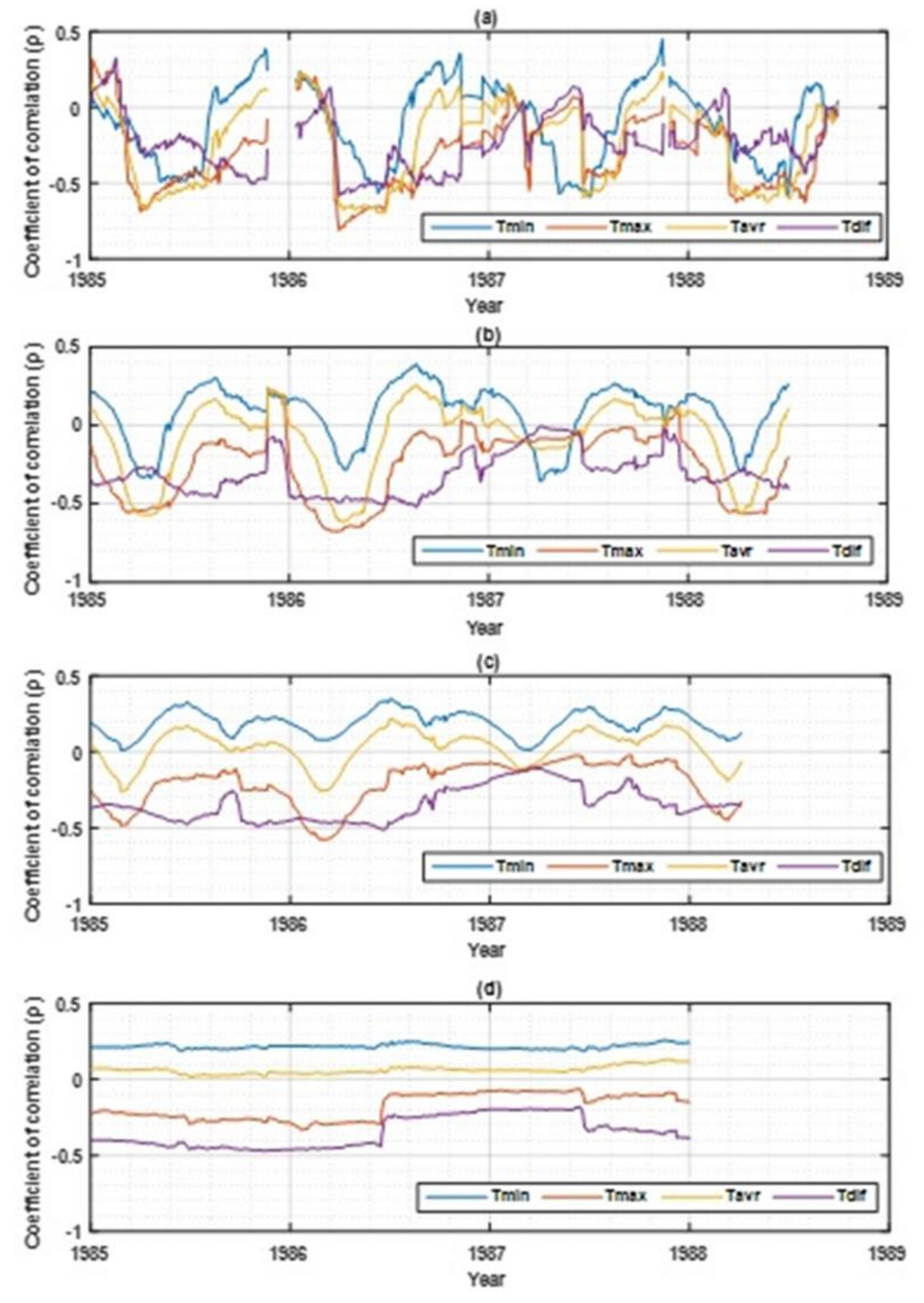

Figure 2. Correlation of daily rainfall with temperature recorded at Teknaf station for various time lengths a) 3 months, b) 6 months, c) 9 months and d) 12 months.

with temperatures and the relation is little stronger with difference temperature of maximum to minimum (Figure 3). Figure 4 shows how correlation coefficient varies with moving average period. It also shows that the relation is highly influenced by the moving average period, and correlation gets higher with moving average period. If the moving average period increases, correlation on a day seems loosely related. In contrast, if moving average period decreases coefficient of correlation becomes lower. In order to find the minimum moving average period, second order derivative is also shown in Figure 4, and the analysis suggests that maximum changes in correlation occurs from 5 to 50 days. This work has arbitrarily selected moving average period of seven days keeping moving average period close to minimum days but comfortably in the estimated range.

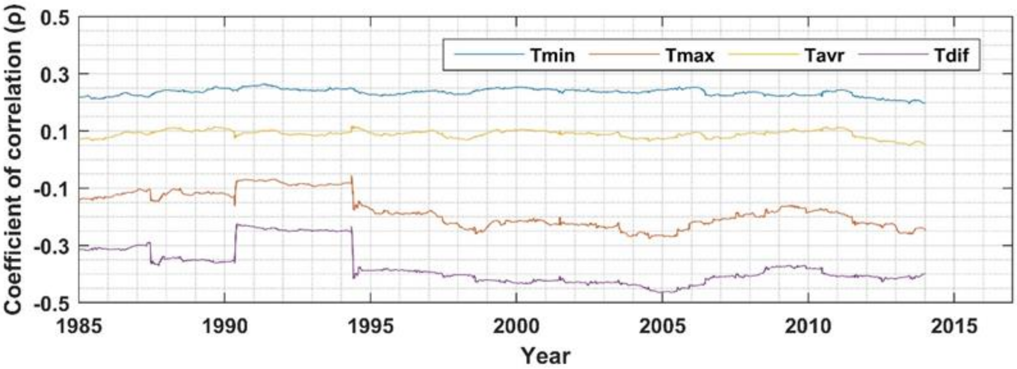

Figure 3. Correlation of daily rainfall with minimum temperature, maximum temperature, average temperature and difference of maximum to minimum temperature for four yearly time lengths from 1985 to 2017 recorded at Teknaf station.

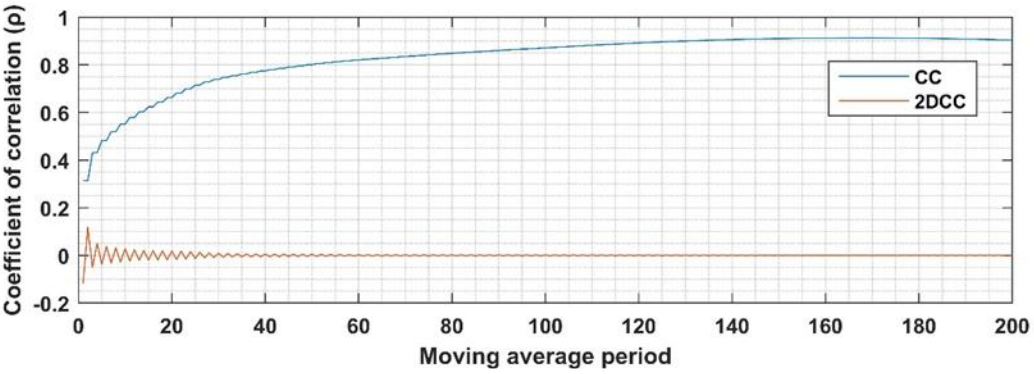

Figure 4. Influence of correlation of rainfall and difference of maximum to minimum temperature with moving average period.

The correlation analysis of one station climate data suggests that there is little stronger correlation of rainfall with the difference between maximum and minimum temperature. As shown that the correlation is influenced by the moving average period, using 7 days as moving average period the correlation of rainfall with the difference of maximum to minimum temperature for the whole study area has investigated and shown in the following section.

3. Result and Discussions

Correlations of daily rainfall with the difference between maximum and minimum temperature recorded at various meteorological stations of the southeastern costal part of Chattogram division using Pearson, Spearman and Kendall technique are show in Figures 5-12. Estimated correlations are for the stations: Teknaf, Cox’s bazar, Kutubdia, Ambagan, Sandwip, Hatya, Shitakundu and Feni. Overall correlations are almost similar since most of the stations present above 0.5 or close to 0.6, except Ambagan that shows below 0.4. Slightly different picture has been obtained from the Kutubdia, Sandwip and Hatya stations showing mean correlation above 0.5 (Figures 7, 9-10). Interestingly, all of these are island based stations in the Bay of Bangle. Correlations in island stations also show that Kutubdia, Sandwip and Hatya did have different climate in 1992, 2000-2002, and 1994, respectively, as the calculated correlation coefficients explain (Figures 7, 9-10). Correlations obtained from the remaining land based stations are found to be similar, and may be interpreted as the mainland of the coastal area shares unique climate. This work has intentionally excluded explanation of the estimations obtained for Ambagan station, because this station has produced many missing data.

The analysis of data collected from the Sandwip station shows different scenario where calculated correlation was 0.6 from the year 2012, while the same for the duration 1997-2010 has shown initially decreasing and later increasing significantly. The climate of Sandwip may not be judged as ideal climate for the duration from 1997 to 2010. This argument agrees with status of the island. Sandwip, the offshore island of Meghna estuary, has gone significant morphological change, e.g. 40% of the land eroded, in last 200 years (Brammer, 2014 and Roy and Mahmood, 2016) because of active coastal dynamics, which continues till date. Using the precipitation concentration index, Mondol et al. (2018) have also shown the irregularities in the northwest and southeast regions of Bangladesh during 2000 to 2011.

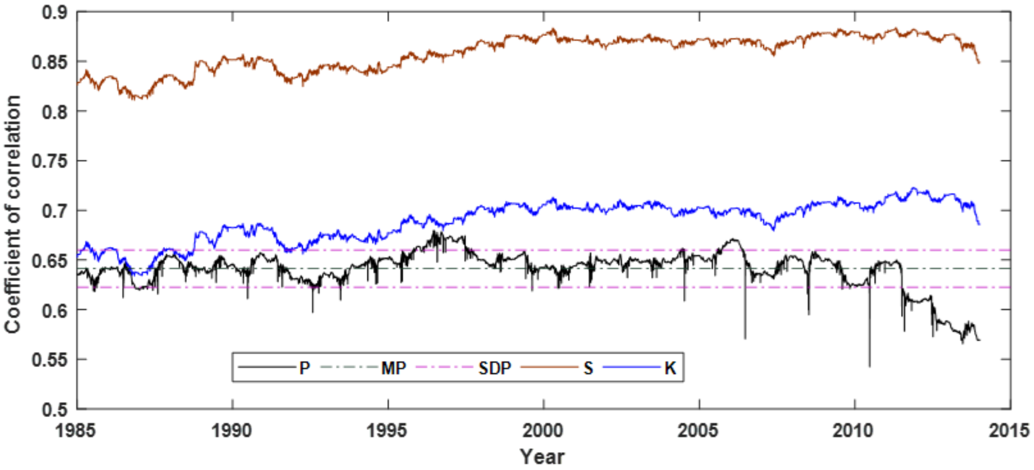

Figure 5. Correlation of rainfall with difference of maximum to minimum temperature at Teknaf station. P-Pearson, S-Spearman, K-Kendall, MP-mean Pearson and SDP-standard deviation of Pearson type correlations.

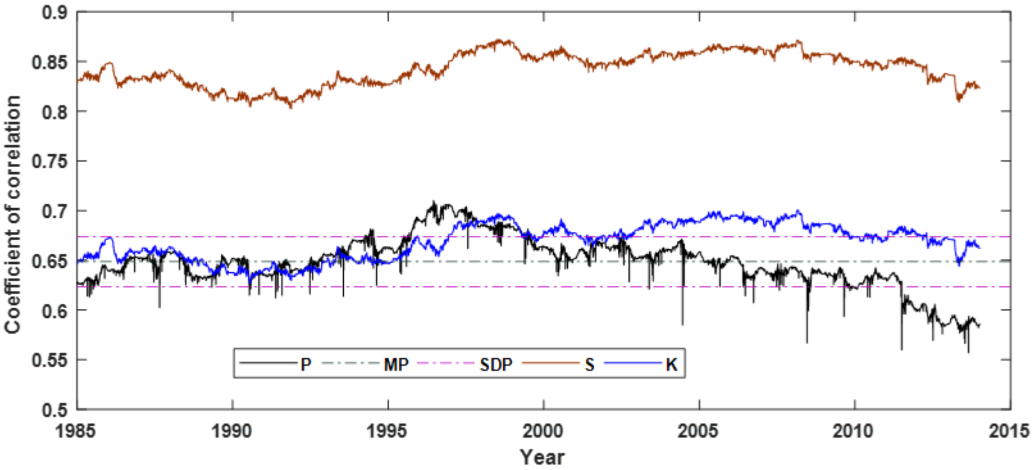

Figure 6. Correlation of rainfall with difference of maximum to minimum temperature at Cox's bazar station. P-Pearson, S-Spearman, K-Kendall, MP-mean Pearson and SDP-standard deviation of Pearson type correlations.

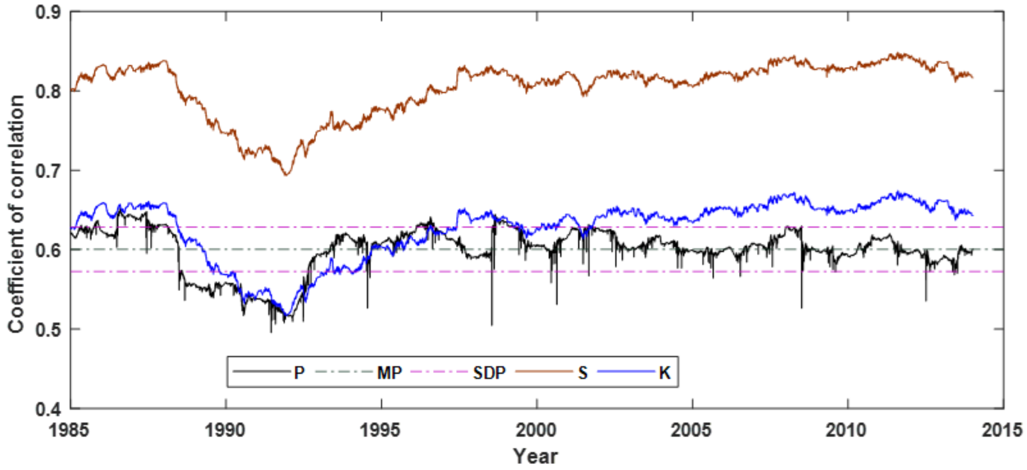

Figure 7. Correlation of rainfall with difference of maximum to minimum temperature at Kutubdia station. P-Pearson, S-Spearman, K-Kendall, MP-mean Pearson and SDP-standard deviation of Pearson type correlations.

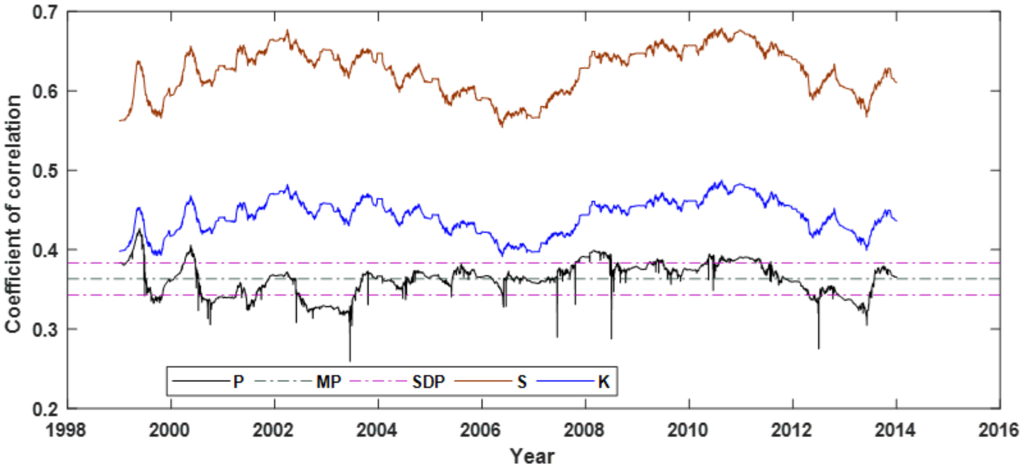

Figure 8. Correlation of rainfall with difference of maximum to minimum temperature at Ambagan station. P-Pearson, S-Spearman, K-Kendall, MP-mean Pearson and SDP-standard deviation of Pearson type correlations.

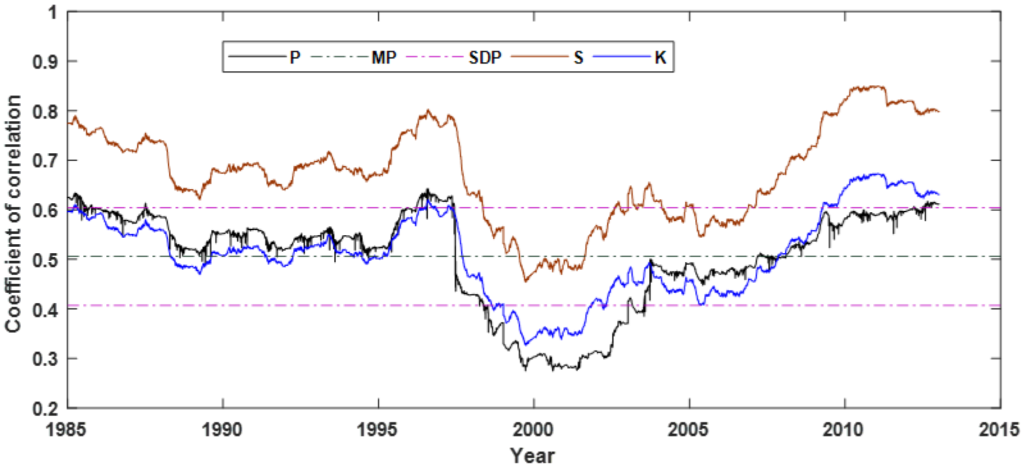

Figure 9. Correlation of rainfall with difference of maximum to minimum temperature at Sandwip station. P-Pearson, S-Spearman, K-Kendall, MP-mean Pearson and SDP-standard deviation of Pearson type correlations.

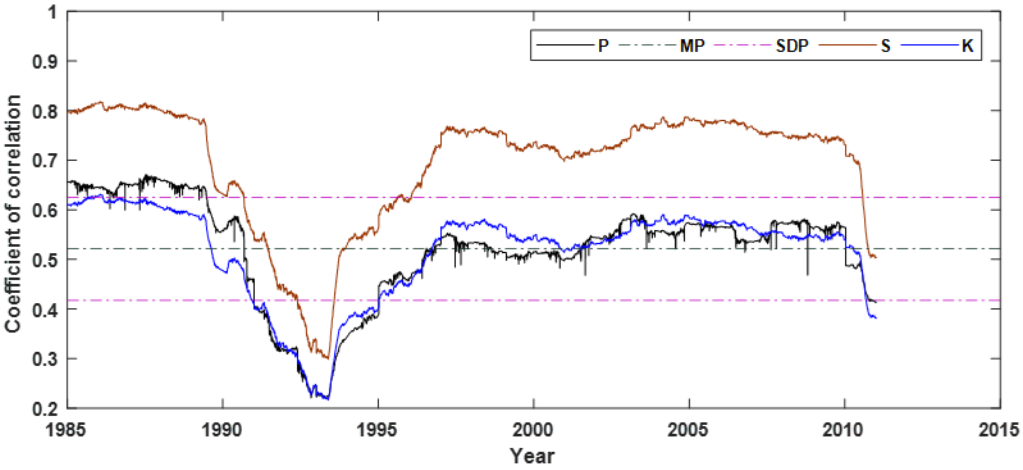

Figure 10. Correlation of rainfall with difference of maximum to minimum temperature at Hatya station. P-Pearson, S-Spearman, K-Kendall, MP-mean Pearson and SDP-standard deviation of Pearson type correlations.

The correlation obtained from the Sandwip station also indicates costal dynamics as active, since the correlation is increasing continuously. During 1974-2014 only 17.48 km^2 of land accreted, while 90.35 km^2 of stable land disappeared. The maximum loss, 33.75 km^2, the island experienced during 2001 to 2011 (Roy and Mahmood, 2016). This work also shows the similar picture particularly for the islands of southeastern region, since it has shown very poor correlation of rainfall with difference between maximum and minimum temperatures during 1997-2010 within the time frame of 1985-2014. The study also finds alignment of the poor correlations during 1997-2010 is highly correlated with the highest loss of land. Climate time series analysis as well has depicted different climate pattern of Sandwip. Although not significant, slightly similar effects are also visible in the estimations in data from the Kutubdia and Hatiya stations in the year 1992 and 1994. Hence, this research assumes that disappearance of land surface is possible, even if not substantial. It can also be argued that in terms of land loss Hatiya is more vulnerable compared with Kutubdia. Kutubdia has been found to be stable, while Haiya may experience land loss further since the correlation started to fall after 2010. While the analyses of data collected from the main land stations: Teknaf, Cox'sbazar, Shitakunda and Feni show almost the similar climate.

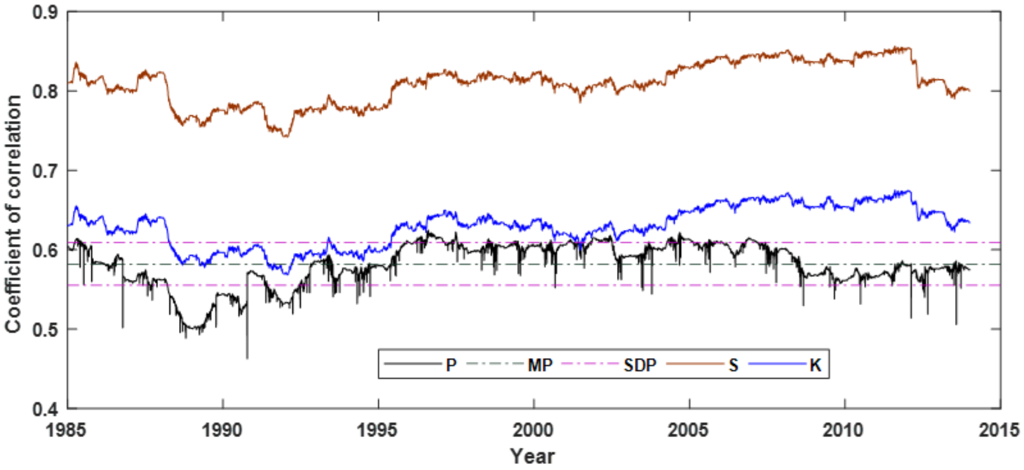

Figure 11. Correlation of rainfall with difference of maximum to minimum temperature at Sitakundu station. P-Pearson, S-Spearman, K-Kendall, MP-mean Pearson and SDP-standard deviation of Pearson type correlations.

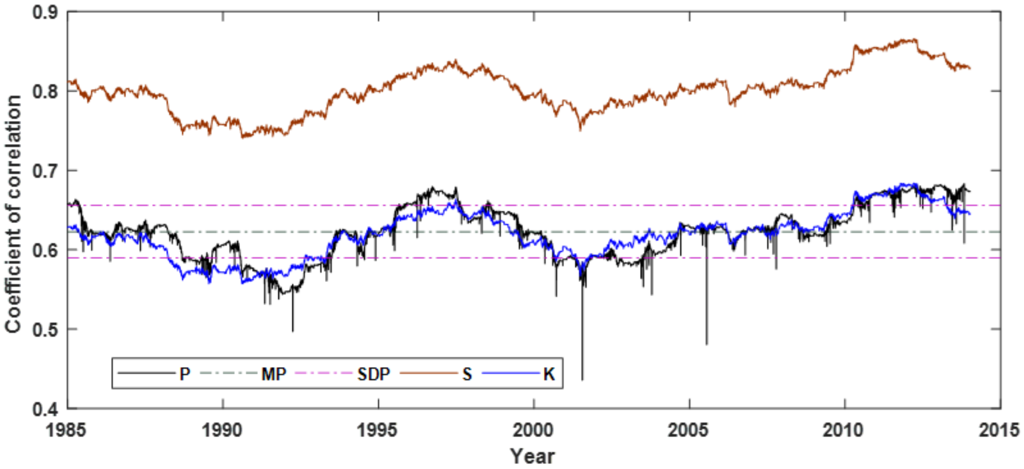

Figure 12. Correlation of rainfall with difference of maximum to minimum temperature at Feni station. P-Pearson, S-Spearman, K-Kendall, MP-mean Pearson and SDP-standard deviation of Pearson type correlations.

Estimated direct correlations of daily recorded rainfall with minimum and maximum temperature have been calculated as approximately +0.2 and -0.2, respectively, a poorly correlated factors. With average temperature the value remains close to less than 0.1. Besides, correlation of rainfall with the difference between maximum and minimum temperature has been obtained close to -0.4, which seems to be more realistic, since increase in rainfall causes decreases in temperature, and vice-versa. The rate of heat flow is proportional to the difference between maximum and minimum temperature. Though the value $\rho = -0.4$ is not significant, this research has been extended through applying moving average technique, which has shown that addition of a period of only seven days can improve the relation of rainfall with the difference between maximum and minimum temperature.

Comprehension of the direct relation between precipitation and temperature in a global scale is absent as of yet, and most of the available contributions have shown regional analysis which are not significantly correlated. The maximum positive and negative correlation of 0.40 and -0.36, respectively have been observed at Teknaf and

Sitakundu. While, Khalil and Jhao (1993) have shown positive and negative correlation close to ±0.2 or ±0.3 or less between monthly mean temperature and rainfall, and have shown negative significant relation, -0.75, during summer in the central United States. This work also supports the above mentioned results that have shown similar poor correlation between minimum, maximum and average temperature with rainfall as close to ±0.25 or less in the study area. Result shows positive and negative correlations with minimum and maximum daily recorded rainfall and temperature. While the results have shown very poor correlation with average temperature, the correlation is slightly stronger, i.e. -0.4 or above, with the difference between maximum and minimum temperature and this correlation is uniform all over the study area. Addition of moving average period has also increased the correlations as shown in Figure 4.

4. Conclusion

It has not been evident any significant correlation between rainfall and maximum, minimum and average temperature in southeastern costal region in Bangladesh. Significant positive or negative correlation may occur with time and space, however has not been found in this present analysis. Approximately uniform and poor correlation less than ±0.35 is obtained all over the study area. A correlation of -0.4 or greater magnitude has been obtained for rainfall with the difference between maximum and minimum temperature. The difference between maximum and minimum temperature in a day is the rate of heat flow in a day. Result confirms that the correlation of rainfall with heat flow in the study area is to be greater. This work has also shown that the correlation can be gained more with smoothing climate data with moving average technique. Application of seven-day moving average period in data for smoothing has increased the correlation over 0.6.Estimated correlations of the study area have shown that the mainland is experiencing almost similar climate, however the islands: Kutubdia, Sandwip and Hatiya are experiencing different climates. This research has shown that the major land losses in Sandwip during 1997 to 2011 are well associated with the estimated correlations of rainfall with the difference between maximum and minimum temperature. The island Hatiya is also highlighted as vulnerable of losing of land in the coming years. The results have revealed similar facts in Pearson, Spearman and Kendall type correlation estimations; thus the work can be extended for other islands to study the erosion and accretion dynamics of the land.

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References

Abedin, M. A., Collins, A. E., Habiba, U. & Shaw, R. (2019). Climate change, water scarcity, and health adaptation in southwestern coastal Bangladesh. *International Journal of Disaster Risk Science*, 10(1), 28-42.

Agbazo, M., Koto N'gobi, G., Alamou, E., Kounouhewa, B., Afouda, A., and Kounkonnou, N. (2019). Multifractal Behaviors of Daily Temperature Time Series Observed over Benin Synoptic Stations (West Africa), *Earth Sci. Res. J.*, 23(4), 365-370.

Aguado, E., Cayan, D., Riddle, L. & Roos, M. (1992). Climatic fluctuations and the timing of west coast streamflow. *Journal of Climate*, 5(12), 1468-1483.

Buishand, T. A. & Brandsma, T. (1999). Dependence of precipitation on temperature at Florence and Livorno (Italy). *Climate research*, 12(1), 53-63.

Coscarelli, R. & Caloiero, T. (2012). Analysis of daily and monthly rainfall concentration in Southern Italy (Calabria region). *Journal of Hydrology*, 416-417, 145–156.

Crutcher, H. L. (1978). Temperature and precipitation correlations within the United States. *NOAA Tech. Rep.* EDS 26 NOAA.

Eckstein, D., Künzel, V., Schäfer, L. & Winges, M. (2019). Global Climate Risk Index 2020. *Bonn: Germanwatch eV*, 44pp.

Dasgupta, S., Kamal, F. A., Khan, Z. H., Choudhury, S. & Nishat, A. (2014). River salinity and climate change: evidence from coastal Bangladesh. *Environment and Energy Team, The World Bank*. Retrieved 10 January 2015,

http://documents.worldbank.org/curated/en/522091468209055387/pdf/WPS6817.pdf

Hamrick, A. M. & Martijn, H. H. (1941). Fifty years' weather in Kansas, MO, 1889-1983. *Mon. Wea Rev.*, 44(Suppl.), 53.

Kendall, M. G. (1955). Rank Correlation Methods. *Charles Griffin & Co*.

Kreyling, J. & Beier, C. (2013). Complexity in climate change manipulation experiments. *Bioscience*, 63(9), 763-767.

Kruskal, W.H. (1958). Ordinal Measures of Association. *Journal of the American Statistical Association*, 53(284), 814-861.

Lobell, D. B. & Field, C. B. (2007). Global scale climate–crop yield relationships and the impacts of recent warming. *Environmental Research Letters*, *2*(1), 014002.

L´opez-Moreno, J. I., Vicente-Serrano, S. M., Gimeno, L.& Nieto, R. (2009). Stability of the seasonal distribution of precipitation in the Mediterranean region: observations since 1950 and projections for the 21st century. *Geophysical Research Letters*, 36(10), 1-6.

Madden, R. A. & Williams, J.(1978). The correlation between temperature and precipitation in United States and Europe. *Mon. Wea Rev.*, 106, 142-147.

MOEF, (2005). National Adaptation Programme of Action. *The Ministry of Environment and Forest*, Dhaka: The Government of Bangladesh.

Mohorji, A. M.,Sen, Z. & Almazroui, M.(2017). Trend Analyses Revision and Global Monthly Temperature Innovative Multi-Duration Analysis.*Earth Syst Environ*, 1, 1-13.

Mondol, M. A. H., Al-Mamun Iqbal, M. & Jang, D. (2018). Precipitation Concentration in Bangladesh over Different Temporal Periods. *Hindawi Advances in Meteorology,* ID 1849050, 1-18.

MOWR. (2005). Coastal Zone Policy 2005. Ministry of Water Resources, Government of the People’s Republic of Bangladesh, 14pp.

Myers, J. L.& Well, A. D. (2003). Research Design and Statistical Analysis (2nd ed.). *Lawrence Erlbaum*, 508pp.

Nkuna, T. R. & Odiyo, J. O. (2016). The relationship between temperature and rainfall variability in the Levubu sub-catchment, South Africa. *International Journal of Education and Learning Systems*, 1, 66-75.

Pandey, P. K., Das, L., Jhajharia, D., & Pandey, V. (2018). Modelling of interdependence between rainfall and temperature using copula. *Modeling Earth Systems and Environment*, *4*(2), 867-879.

Picardal, J. P. & Elnar, A. R. B. (2017). Rainfall, temperature and the incidence of dengue in Central Visayas, Philippines are not correlated. *CNU Journal of Higher Education*, *6*, 61-70.

Rahman, S. M., Ahmad, M. M. & Alam, M. S. (2016). From strategy to execution: the case of local climate fund in Bangladesh. *International Journal of Environmental Policy and Decision Making*, *2*(1), 1-18.

Haque, A. (2006). Review article salinity problems and crop production in coastal regions of Bangladesh. *Pak. J. Bot.*, 38(5) 1359-1365.

Rehfeld, K. & Laepple, T. (2016). Warmer and wetter or warmer and dryer? Observed versus simulated covariability of Holocene temperature and rainfall in Asia. *Earth and Planetary Science Letters*, 436, 1-9.

Riha, S. J., Wilks, D. S. & Simoens, P. (1996). Impact of temperature and precipitation variability on crop model predictions. *Clim Change*, 32(3), 293-311.

Rodgers, J. L.& Nicewander, W. A. (1988). Thirteen ways to look at the correlation coefficient. *The American Statistician,* 42 (1), 59-66.

Ruigar, H. & Golian, S. (2015). Assessing the correlation between climate signals and monthly mean and extreme precipitation and discharge of Golestan Dam Watershed. *Earth Sci. Res. J.*, 19(1), 65-72.

Sovacool, B. K., D’Agostino, A. L., Rawlani, A. & Meenawat, H. (2012). Improving climate change adaptation in least developed Asia. *Environmental Science and Policy,* 21, 112-125.

Subash N.& Sikka, A. K. (2014). Trend analysis of rainfall and temperature and its relationship over India. *Theor Appl Climatol*, 117, 449-462.

Takahashi, H. G. & Dado, J. M. B. (2018). Relationship between sea surface temperature and rainfall in the Philippines during the Asian summer monsoon. *Journal of the Meteorological Society of Japan*, 96, 283-290.

Van den Dool, H. M. (1988). A utilitarian atlas of monthly and seasonal precipitation-temperature relations, the United States, 1931-1987. *Department of Meteor., University of Maryland*, College Park, MD 20742, SR-88-17.

Van den Dool, H. M. (1989). Monthly precipitation-temperature relations, the United States, 1931-1987. *Proc., 13th Annula Climate Diagnostics Workshop. Cambridge, US Dept of Commerce*, 210-213.

Yang, M., Yao, T., Wang, H. & Gou, X. (2006). Correlation between precipitation and temperature variations in the past 300 years recorded in Guliya ice core, China. *Annals of Glaciology*, 43, 137-141.

Yang, Q., Zheng, J. & Zhu, H. (2020). Influence of spatiotemporal change of temperature and rainfall on major grain yields in southern Jiangsu Province, China. *Global Ecology and Conservation*, 21, e00818.

Yannick, B. K.& Chae, J. (2018). Relationship between temperature and rainfall in the Democratic Republic of the Congo. *Proceedings of the Korean Meteorological Society Conference 2018, Korean Meteorological Society Fall Conference 3-6 October 2018*, COEX, Seoul, Korea.

Zhao W. & Khalil, M. A. K. (1993). The Relationship between Precipitation and Temperature over the Contiguous United States. *Journal of Climate,* 6(6), 1232-1236.