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Climate Change

To Cite:
Al-Munsur MAZ, Islam MS, Islam F, Biswas PK, Hasanuzzaman M, Hossain MI. Annual and seasonal variability of historical climatic parameters of Bangladesh. *Climate Change* 2025; 11: e3cc1057
doi: https://doi.org/10.54905/disssi.v11i29.e3cc1057

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Peer-Review History
Received: 09 September 2024
Reviewed & Revised: 13/September/2024 to 23/December/2024
Accepted: 26 December 2024
Published: 07 January 2025

Peer-Review Model
External peer-review was done through double-blind method.

Climate Change
pISSN 2394-8558; eISSN 2394-8566

URL: http://www.discoveryjournals.org/climate_change

DISCOVERY SCIENTIFIC SOCIETY

Annual and seasonal variability of historical climatic parameters of Bangladesh

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ABSTRACT

We analyzed the annual and seasonal variability of historical climatic parameters (temperature and rainfall) for eight divisions of Bangladesh. The linear trend of 40 years of data from 1981-to 2020 was analyzed for annual, pre-monsoon, monsoon, post-monsoon, and winter seasons. Annual maximum and minimum temperatures ranged from 29.1-32.6 °C and 19.0-23.1 °C, respectively, among the places. Pre-monsoons experienced the highest maximum temperatures, whereas monsoons received the highest minimum temperatures in the locations. Sylhet received the maximum (4113 mm) annual rainfall, whereas Rajshahi had the yearly minimum (1429 mm). Annual maximum and minimum temperatures showed an increasing trend in all locations. However, the rising maximum temperature rate was alarming (over one °C) in Sylhet, Chattogram, and Khulna. However, the minimum temperature increasing trend was critical (over one °C) in Sylhet, Rangpur, Dhaka, and Khulna. During the pre-monsoon season, the maximum temperature increased by 2.3 °C at Chattogram and the minimum 0.07 °C at Mymensingh. Annual rainfall is decreased in all locations except Chattogram. However, pre-monsoon rainfall increased in Rangpur, Sylhet, and Rajshahi, and monsoon rainfall decreased in all locations except Chattogram and Khulna. Since temperature and rainfall patterns have greatly influenced agriculture-based countries like Bangladesh, changing pattern analysis is necessary for crop planning. Moreover, these associated changes may threaten the significant achievements. Bangladesh has made so far over the last two decades in increasing incomes and reducing poverty. In this regard, it was necessary to regularly and systematically compile, monitor, and analyze the relevant climatic parameters for assessing the impacts of climate change.

Keywords: Annual and seasonal variability, historical, climatic parameters, Bangladesh, Rainfall, Temperature

1. INTRODUCTION

Increasing temperatures and shifting rainfall patterns hurt agricultural output, and climate variability is a significantly contributes to variations in the national crop yield (Zhao et al., 2017). Concerns over decreasing groundwater depth in some areas of the country, particularly in the northwest, have arisen as a result of the use of groundwater irrigation for dry season crops in recent decades, especially Boro rice (Kirby et al., 2015; Mojid et al., 2019). The majority of research, however, concurs that rainfall has reduced in central regions but increased in the south and maybe even in the north (Shahid and Khairulmaini, 2009; Mondal et al., 2013; Hossain et al., 2014; Kamruzzaman et al., 2018). It is essential to remember that some of the disparities between studies may have been caused by differences in the breadth of the periods and geographical areas studied, as well as the inherent unpredictability of rainfall data.

Rainfall and temperature have a vital role in crop output. Still non-climatic factors, including irrigated crop regions, new crop variety development, crop prices, labor availability, and market accessibility, also have a role in crop production. The effects of climate variability on rice production of Bangladesh have been evaluated in several studies (Mahmood and Hayes, 1995; Islam and Parveen, 2004; Karim et al., 2012; Sarker et al., 2012; Shahid et al., 2014; Haque et al., 2016; Hasan and Rahman, 2019; Mainuddin et al., 2022). Atmospheric temperature is the key environmental factor regulating plant growth and developmental processes. Both grain yield and growth duration of rice are affected due to air temperature. Crop growth mainly depends on accumulated growing degree days (GDD) and is derived from the mean daily temperature over the base temperature of the crop (Hossain et al., 2021).

The Intergovernmental Panel on Climate Change (IPCC) projected rising temperatures of 1.5 °C for RCP 4.5 and 2 °C for RCP 8.5 by the end of the 21st century, relative to the average from 1850 to 1900 (IPCC, 2014). The averaged combined land and ocean surface temperature throughout the planet shows a linear trend, indicating a warming of 0.85 (0.65 to 1.06) °C from 1880 to 2012 (IPCC, 2014). A historical (1990-2011) analysis showed a growing trend of daily average temperature in the Northwest hydrological region of Bangladesh (Mojid et al., 2015). The objective of the study was to assess possible climatic change, especially the variation of rainfall and temperature in eight regions of Bangladesh.

2. MATERIALS AND METHODS

Study Area

Eight locations in Bangladesh (Sylhet, Rangpur, Chattogram, Dhaka, Rajshahi, Mymensingh, Khulna, and Barishal) made up the study area. Each location had a meteorological station, and researchers collected data on meteorological parameters from 1981 to 2020.

Data Collection and Processing

This study collected daily data on maximum and minimum temperature and rainfall of all eight weather stations from the Bangladesh Meteorological Department (BMD). The present study has used forty years of data from 1981 to 2020. It should also be noted that there were some missing data for some months at some stations, which have been credited by taking the historical average data for the same parameter. Before doing that, data have been cleaned by checking the delicacy and range. The box plot technique was used to check the data outliers. All these activities were performed in a Microsoft spreadsheet.

Normal Temperature, Rainfall, and Trend Analysis

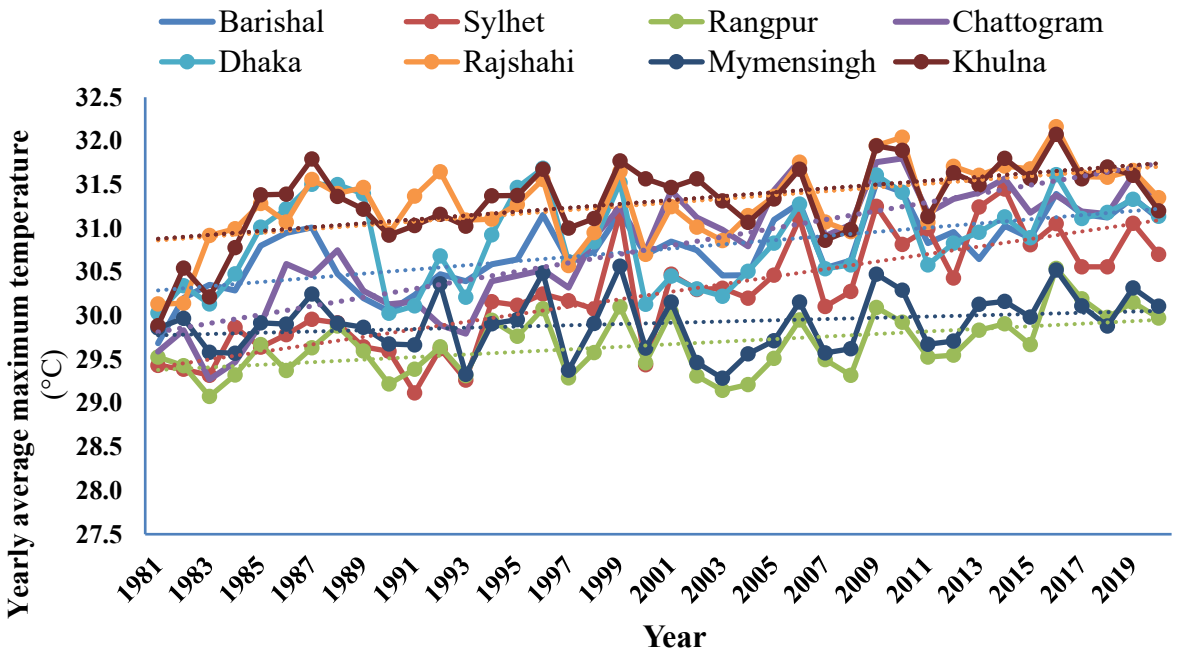
Normal temperature implies the historical average temperature. This study considered the 40-year average data to be normal temperature and normal rainfall. From the daily, we calculated yearly and seasonal temperature and precipitation using the pivot table function in an Excel spreadsheet. This study considered four climatological seasons pre-monsoon, monsoon, post-monsoon, and winter (Hossain et al., 2021). The pre-monsoon season starts in March and goes up to May.

Usually, it is the summer period in Bangladesh. In Bangladesh, the monsoon season, which lasts from July to September, is the rainy season. October and November are considered the post-monsoon period in the country. The dry period of December, January, and February is the winter season in Bangladesh. For each season, only a linear trend was assessed for the period from 1981-2020, and the nature of either increasing or decreasing trend was determined by the sign of linear trend line slope and the significance of the trend was estimated from the R2 value of the fit.

3. RESULTS AND DISCUSSION

Average Maximum and Minimum Temperature

Among the locations, the annual maximum temperature ranged from 29.1 to 32.6°C (Figure 1). The forty years (1981-2020) the average highest maximum temperature was found in Rajshahi and Khulna, followed by Barishal, Dhaka, Chattogram, and Sylhet, and the lowest minimum temperature was found in Rangpur (Figure 1). In all studied locations, an increasing trend of annual average temperature found (Figure 1). Mondal et al., (2017) discovered that while the annual maximum temperature (Tmax) is trending downward in Rangpur and Mymensingh divisions, it is trending upward in Khulna, Dhaka, Rajshahi, Sylhet, Barisal, and Chittagong divisions. Considering all seasons, pre-monsoon is the hottest period of the year in all locations in Chattogram, Dhaka, Rajshahi, Khulna, and Barishal.



	Barishal	Sylhet	Rangpur	Chattogram	Dhaka	Rajshahi	Mymensingh	Khulna
Equation	y = 0.0239x + 30.266	y = 0.0431x + 29.37	y = 0.0147x + 29.365	y = 0.0495x + 29.764	y = 0.0136x + 30.58	y = 0.0216x + 30.841	y = 0.0071x + 29.77	y = 0.0221x + 30.858
R2	R^2 = 0.4552	R^2 = 0.6401	R^2 = 0.2514	R^2 = 0.717	R^2 = 0.0976	R^2 = 0.3135	R^2 = 0.0602	R^2 = 0.3288

Figure 1 Annual average maximum temperature (1981 to 2020) of Sylhet, Rangpur, Chattogram, Dhaka, Rajshahi, Mymensingh, Khulna, and Barishal.

In the other three locations, Sylhet, Rangpur, and Mymensingh, monsoons showed the highest maximum temperature. The three coastal locations (Chattogram, Barishal, and Khulna) experienced the highest average winter temperature ranging from 26.9 to 27.9 °C. However, Rangpur received the lowest average maximum temperature of 24.8°C in winter (Figure 2). Temperature fluctuation was calculated in the base year 1981 to 2020. Results showed that all locations pre-monsoon, monsoon, post-monsoon, and winter average maximum temperatures rose except Dhaka and Mymensingh winter temperature (Figure 3). Basak et al., (2013) found that the rates of change minimum temperature were 0.032 °C, 0.023 °C, 0.011 °C, 0.003 °C, 0.020 °C, 0.001 °C, and 0.016 °C per year for northern, northwestern, northsouthern, central, southern, southeastern and eastern region respectively.

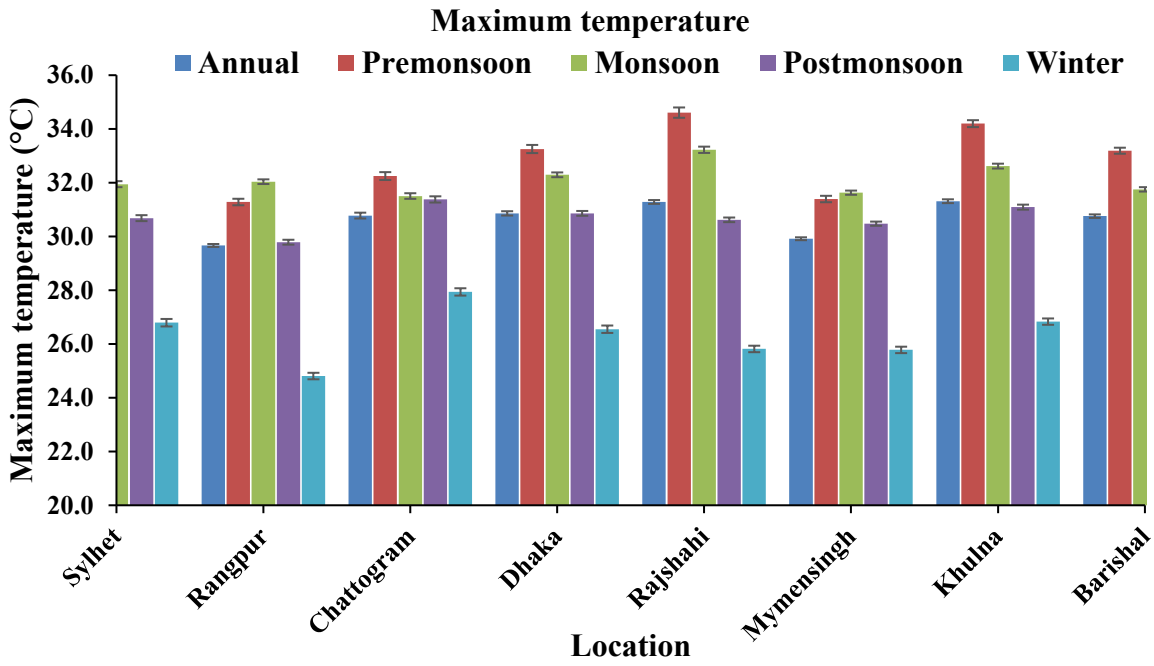


Figure 2 Season-wise average maximum temperature (1981 to 2020) of Sylhet, Rangpur, Chattogram, Dhaka, Rajshahi, Mymensingh, Khulna, and Barishal. The error bar indicates standard error.

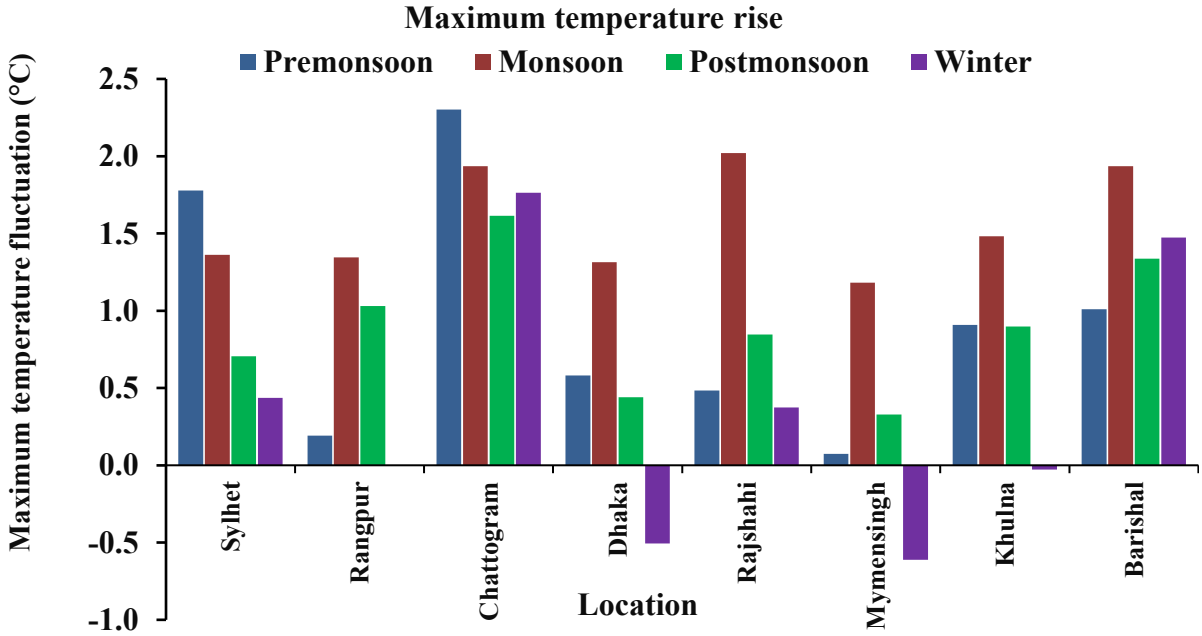
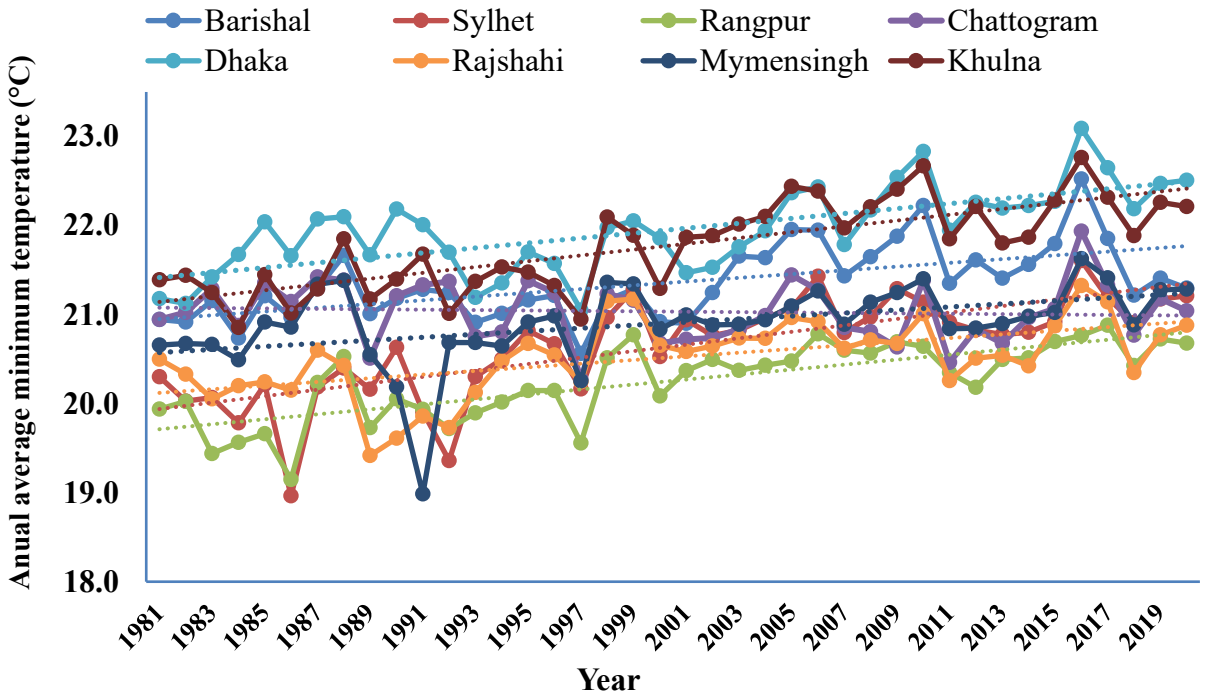


Figure 3 Annual average maximum temperature (1981 to 2020) fluctuation of Sylhet, Rangpur, Chattogram, Dhaka, Rajshahi, Mymensingh, Khulna, and Barishal

Moreover, average minimum temperature of Bangladesh has been found to increase 0.015 °C per year. Bhuyan et al., (2018) discovered that, according to BMD data, the annual average temperature peaked in 1999 at 30.9˚C and fell to 29.6˚C in 1981. The MPI-ESM-LR (CMIP5) model data showed that the highest average maximum temperature occurred in 2007 at 41˚C, while the lowest was recorded in 1985 at 37.1˚C. These findings were similar to the present study. Annual and seasonal normal (1981-2020) minimum temperatures of eight study locations were analyzed and presented in (Figure 4). Among the locations, the yearly minimum

temperature ranged from 19.0 to 23.1°C. The forty years (1981-2020) average yearly highest minimum temperature of 23.1 °C was recorded in Dhaka (2016), whereas the lowest minimum (19.0 °C) was observed in Sylhet (1986) and Mymensingh (1991) (Figure 4).



	Barishal	Sylhet	Rangpur	Chattogram	Dhaka	Rajshahi	Mymensingh	Khulna
Equation	y = 0.021x + 20.929	y = 0.0361x + 19.903	y = 0.0279x + 19.685	y = -0.0023x + 21.08	y = 0.0276x + 21.389	y = 0.0205x + 20.10	y = 0.0171x + 20.557	y = 0.0326x + 21.11
R2	R^2 = 0.3569	R^2 = 0.5731	R^2 = 0.5826	R^2 = 0.0063	R^2 = 0.4662	R^2 = 0.3194	R^2 = 0.1997	R^2 = 0.5937

Figure 4 Annual average minimum temperature (1981 to 2020) of Sylhet, Rangpur, Chattogram, Dhaka, Rajshahi, Mymensingh, Khulna, and Barishal.

Monsoons experienced the highest minimum temperature, ranging from 25.1- 26.3°C among all locations (Figure 5). The Dhaka, Sylhet, and Khulna regions experienced comparatively higher minimum temperatures than the other parts of the country. The coldest winter was experienced in Rajshahi (12.1 °C), followed by Rangpur (12.5 °C). Minimum temperature fluctuation (increasing or decreasing) is shown in (Figure 6). Temperature fluctuation was calculated in the base year 1981 to 2020. Results showed that pre-monsoon, monsoon, post-monsoon, and winter average minimum temperature was rise except in the winter temperature of the Chattogram (Figure 6).

Basak et al., (2013) found that the yearly average maximum temperature increased in all regions in Bangladesh from 1976-2008. The rates of change in temperature were 0.014 °C, 0.007 °C, 0.024 °C, 0.003 °C, 0.014 °C, 0.039 °C, and 0.022 °C per year for northern, northwestern, northsouthern, central, southern, southeastern, and eastern region respectively. On average (i.e., average of 34 stations), the average maximum temperature of Bangladesh is increasing at a rate of 0.018 °C per year. These findings were similar to the present study.

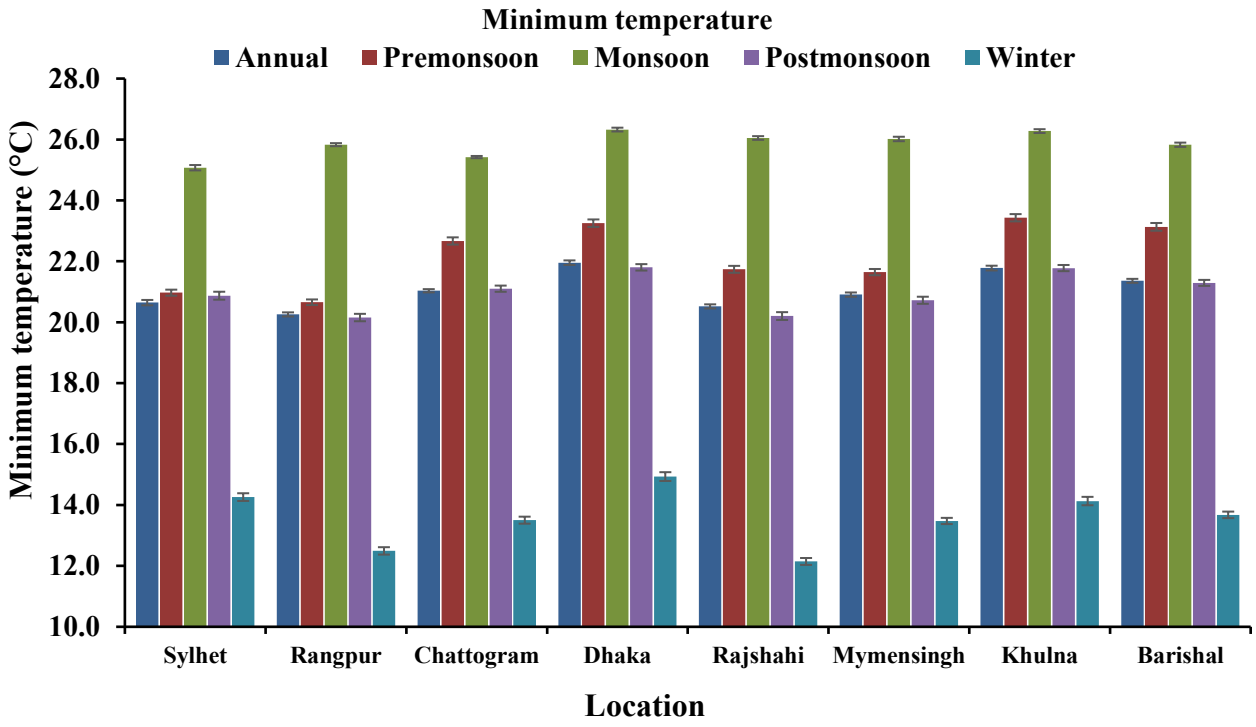


Figure 5 Season-wise average minimum temperature (1981 to 2020) of Sylhet, Rangpur, Chattogram, Dhaka, Rajshahi, Mymensingh, Khulna, and Barishal. The error bar indicates standard error.

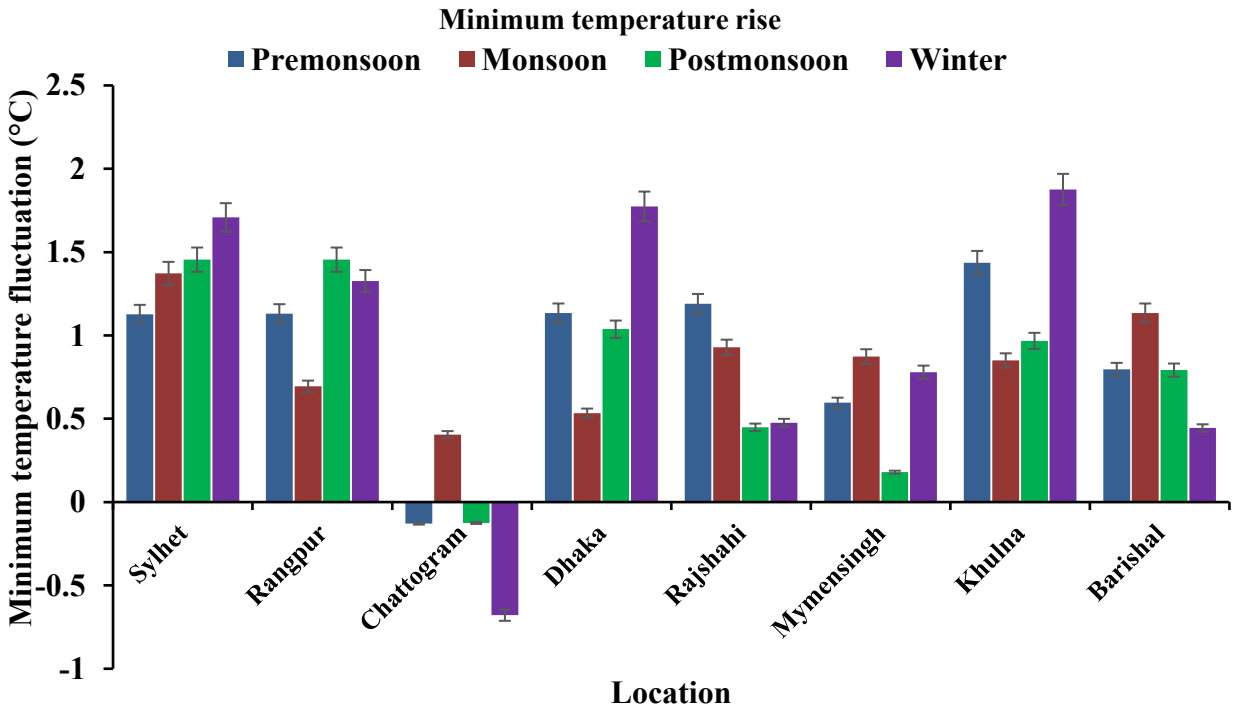
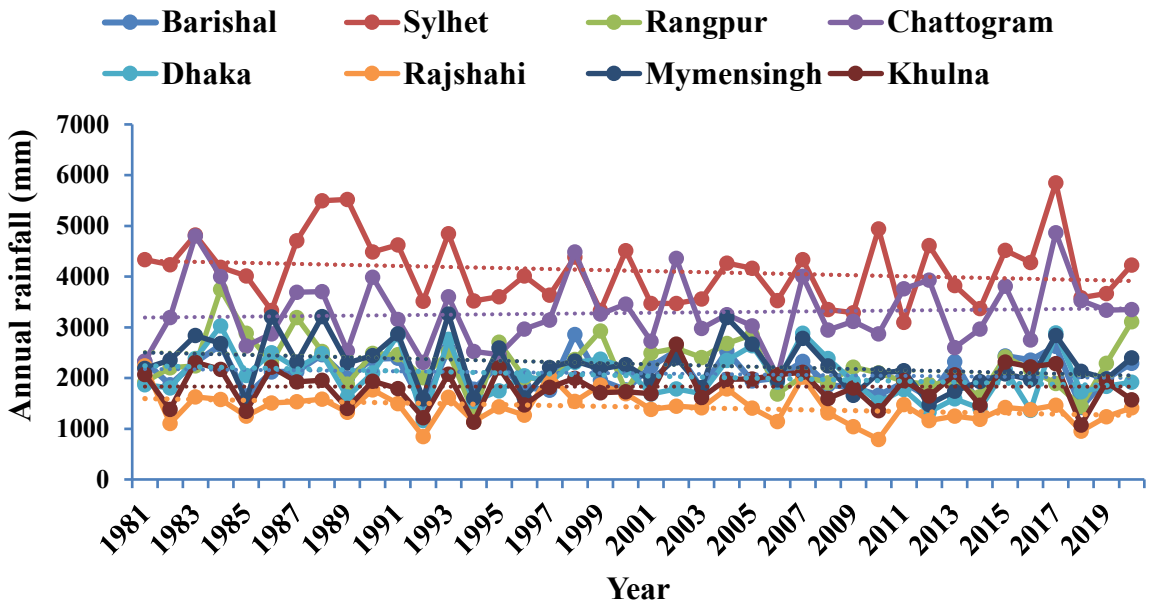


Figure 6 Season-wise minimum temperature (1981 to 2020) fluctuation of Sylhet, Rangpur, Chattogram, Dhaka, Rajshahi, Mymensingh, Khulna, and Barishal. The error bar indicates standard error.

Normal Annual and Seasonal Rainfall

Figure 7 shows Sylhet received the highest annual rainfall (4113 mm) among the locations. Chattogram received the second highest 3283 mm rainfall. Mymensingh (2277 mm) and Rangpur (2276 mm) experienced almost the same annual rainfall. Among the locations, Rajshahi received the lowest 1429 mm, followed by 1931 mm rainfall in Khulna (Figure 8). Ahasan et al., (2010) found that the mean summer monsoon rainfall is 1769.14 mm, the standard deviation is 209.16 mm (coefficient of variance 11.82 %), and the annual country average rainfall is 2456.38 mm. Ahmed and Kim, (2013) discovered that tropical depressions in the Bay of Bengal are the primary cause of rainfall in Bangladesh during the monsoon season. Mondol et al., (2018) and Rahman et al., (2020) observed that the divisional rainfall trends show a large variability. During the pre-monsoon season, Sylhet received a maximum of 1119 mm, whereas Rajshahi had only 237 mm of rainfall.



	Barishal	Sylhet	Rangpur	Chattogram	Dhaka	Rajshahi	Mymensingh	Khulna
Equation	y = -4.5333x + 2182.6	y = -10.162x + 4321.3	y = -12.11x + 2523.9	y = 4.6422x + 3187.8	y = -10.136x + 2251.4	y = -8.4621x + 1602.5	y = -11.558x + 2513.5	y = -0.0198x + 1831.1
R2	R^2 = 0.0209	R^2 = 0.0314	R^2 = 0.0815	R^2 = 0.0064	R^2 = 0.0627	R^2 = 0.102	R^2 = 0.0765	R^2 = 4E-07

Figure 7 Spatio-temporal rainfall variation in Sylhet, Rangpur, Chattogram, Dhaka, Rajshahi, Mymensingh, Khulna, and Barishal.

Monsoons showed the highest rainfall in all the locations as they were in the wet period of the year (Figure 8). Post-monsoon season received comparatively less rainfall than pre-monsoon in every area. Winter received the lowest amount of rainfall. Khulna and Sylhet accounted for 50 mm of rainfall, and the rest of the locations experienced around 30 mm of rainfall in winter. Rahman and Abdullah, (2022) also observed a similar trend of rainfall. The temporal variation of rainfall distribution was analyzed and presented in (Figure 9). It illustrated that monsoon accounted for more than 60% of total rainfall in all locations. Among the places, the highest 72% rainfall is in Rangpur, Chattogram, and Rajshahi, whereas the lowest 65% rainfall is estimated during monsoon in Dhaka. The vast amount of rainfall and higher river flow during the monsoon season often create waterlogging and floods in Bangladesh.

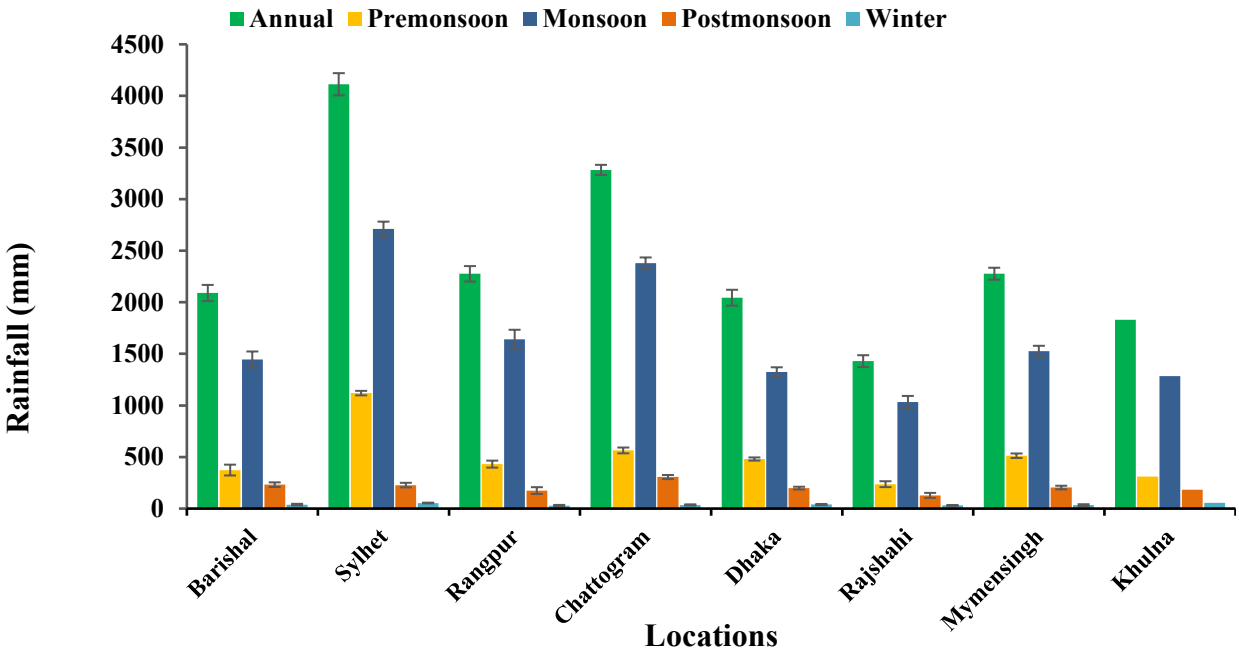


Figure 8 Spatio-temporal average total rainfall (1981-2020) variation in Sylhet, Rangpur, Chattogram, Dhaka, Rajshahi, Mymensingh, Khulna and Barishal. The error bar indicates standard deviation.

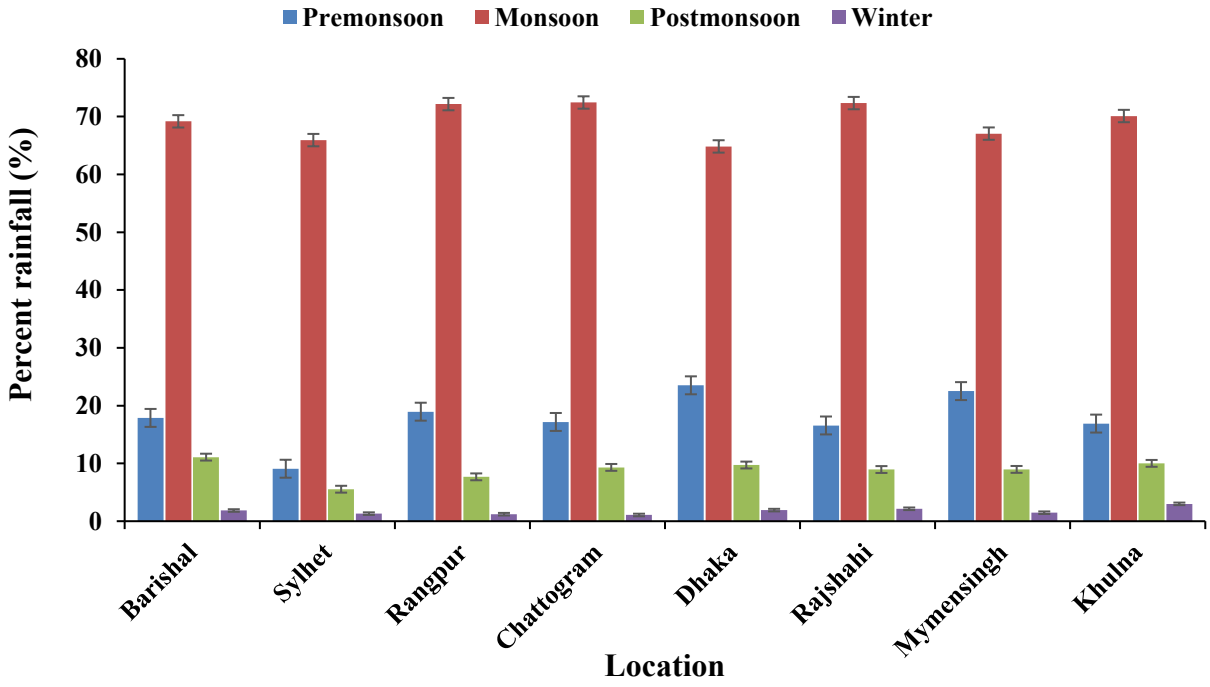


Figure 9 Percent of average total rainfall (1981-2020) distribution in Sylhet, Rangpur, Chattogram, Dhaka, Rajshahi, Mymensingh, Khulna, and Barishal. The error bar indicates standard deviation.

Following monsoon, pre-monsoon estimated the second highest rainfall, ranging from 17-27% of total rainfall. The considerable rainfall during pre-monsoon is enough to meet the wasteful use of crops. However, consecutive rainfall during the period sometimes damaged rabi and kharif-1 crops. However, the later stage of Boro rice showed less irrigation due to the rainfall. Post-monsoon estimated only 6 to 11% of total rainfall during the season. Many times, T. Aman crops suffered from terminal drought due to

insufficient rainfall in the post-monsoon season. Only 1-3% of rainfall is accounted for in winter, considered the driest period of the year in Bangladesh. Irrigation must provide sufficient soil moisture for rabi crops in this period. Bhuyan et al., (2018) found that for the north-western region, 63.58%, and 63.80% of total rainfall occurred in monsoon.

Trend Analysis of Maximum and Minimum Temperature

The spatial variation of maximum and minimum temperature trends (1981-2020) was analyzed and presented in (Figure 1 and Table 1). It found that both maximum and minimum temperatures showed an increasing linear trend in all the locations (Figure 1). Among the locations, the maximum temperature increased at the highest rate of 0.0495 °C at Chattagram followed by 0.0431 °C per year at Sylhet. On the contrary, Mymensingh showed the lowest increasing rate of 0.0071 °C per year (Table 1). Following the same maximum temperature trend, the minimum temperature trend showed rising in nature in all locations except Chattogram. Sylhet showed the maximum increasing rate (0.0361 °C year-1), and Mymensingh showed the lowest increasing rate @ 0.0171 °C. Nonetheless, the annual lowest temperature in Chattogram decreased at a rate of 0.0023 °C year-1.

Table 1 Spatio-temporal variation of maximum temperature changing rate (1981-2020) at the study areas

Season	Annual rate of change of maximum temperature in the study locations (°C year-1)							
	Barishal	Sylhet	Rangpur	Chattogram	Dhaka	Rajshahi	Mymensingh	Khulna
Pre-monsoon	0.026	0.046	0.005	0.059	0.015	0.012	0.020	0.023
Monsoon	0.035	0.050	0.035	0.050	0.034	0.052	0.031	0.038
Post-monsoon	0.018	0.034	0.026	0.041	0.011	0.022	0.008	0.023
Winter	0.011	0.038	0.000	0.045	-0.013	-0.010	-0.016	-0.001

State that the outcome, however, is consistent with the patterns of the Indian subcontinent's average mean minimum and mean maximum temperatures. Climate change has occurred in all the study locations in the last 40 years (1981-2020). Figures 1 and 4 illustrate the maximum and minimum temperature increasing rate over the last 40 years. It showed that annual maximum air temperature increased by 1.68, 0.57, 1.93, 0.53, 0.84, 0.27, 0.86, and 0.93 °C over the four decades for Sylhet, Rangpur, Chattogram, Dhaka, Rajshahi, Mymensingh, Khulna, and Barishal, respectively. The rising maximum temperature rate is alarming (over one °C) in Sylhet, Chattogram, and Khulna (Figure 3). However, the trend of minimum temperature increase was critical (over one °C) in Sylhet, Rangpur, Dhaka, and Khulna.

The rising temperature trend was negative, indicating that the temperature is decreasing in Chattogram. Shahid, (2010) found that the maximum temperature increased at Cox's Bazar station, located in the southeastern coastal zone of Bangladesh, by 0.36 °C per decade at a 99% level of confidence, and a significant decrease in mean temperature was observed in Rangamati station. Changes in areal averaged temperature over Bangladesh assessed by OCDE in 2003 based upon over a dozen general circulation models reveal an average temperature rise of 1.3 °C by 2030 for Bangladesh, with more warming for winter (1.1 °C) than for summer (0.8 °C) (Shahid et al., 2016). A transient model by the Geophysical Fluid Dynamics Laboratory also estimated more winter warming than summer warming in Bangladesh (Manabe et al., 1991). Over the past 50 years, temperatures of Bangladesh have risen dramatically, with the lowest temperatures rising more than maximum temperatures.

According to a seasonal study, Temperatures of Bangladesh worm more in the winter than in the summer (Shahid, 2010; Shahid, 2011). Peng et al., (2004) investigated how the diurnal temperature range affected rice yield and discovered that higher nighttime temperatures or a smaller diurnal temperature range resulted in lower rice yields. Human discomfort may result from decreased DTR. According to the results, mean minimum and mean maximum temperatures of Bangladesh have increased noticeably, by 0.15°C and 0.11°C per decade, respectively. However, the average diurnal temperature of Bangladesh range is not significantly altered by the increase in minimum temperature relative to maximum temperature (Shahid et al., 2012). Trend analysis of spatio-temporal variation of maximum and minimum temperature was shown in (Tables 1 and 2).

Table 2 Spatio-temporal variation of minimum temperature changing rate (1981-2020) at the study areas

Season	Annual rate of change of maximum temperature in the study locations (°C year-1)							
	Barishal	Sylhet	Rangpur	Chattogram	Dhaka	Rajshahi	Mymensingh	Khulna
Pre-monsoon	0.020	0.029	0.029	-0.003	0.029	0.031	0.015	0.037
Monsoon	0.029	0.035	0.018	0.010	0.014	0.024	0.022	0.022
Post-monsoon	0.020	0.037	0.037	-0.003	0.027	0.012	0.001	0.025
Winter	0.011	0.044	0.034	-0.015	0.046	0.012	0.020	0.048

In Barishal, Sylhet, Rangpur, and Chattogram, maximum temperature showed an increasing linear trend in pre-monsoon, monsoon, post-monsoon, and the winter seasons. However, in the other four locations (Dhaka, Rajshahi, Mymensingh, and Khulna), maximum temperature decreased during the winter season (Table 1). In the pre-monsoon season, a maximum temperature changing rate of 0.059 °C was observed in Chattogram. In contrast, that rate was 0.052 °C in Rajshahi during monsoon, 0.041 °C and 0.045 °C per year in Chattogram during post-monsoon and winter, respectively. Minimum temperature also showed an increasing trend during all the seasons at all the locations except Chattogram (Table 2). In Chattogram, the minimum temperature decreased over time during pre-monsoon, post-monsoon, and winter. Figure 2 analyzed season-wise maximum temperature rise in the last 40 years from 1981 in all eight study locations.

It was observed that during the pre-monsoon season, the highest maximum temperature increased by 2.3 °C at Chattogram and minimum 0.07 °C at Mymensingh. In the monsoon season, the highest minimum temperature rise was 2.02°C at Rajshahi, and the lowest maximum temperature rise in Dhaka was 1.31 °C (Figure 6). Winter maximum temperature decreased in Dhaka, Mymensingh, and Khulna. The cold period got colder over time (Figure 6). The minimum temperature increased over time in all locations except Chattogram, which decreased during pre-monsoon, post-monsoon, and winter (Figure 6). Using the GCM for Bangladesh, Ahmed and Alam, (1999) reported that there would be an increase of 1.3° in the temperatures by 2030. They also found a seasonal variation in the temperature of +1.4 °C in the winter and +0.7 °C in the monsoon by 2030. Yu et al., (2010) projected a median temperature rise of 1.1 °C by 2030.

Trend Analysis of Rainfall Trend

Annual rainfall patterns showed positive and negative changes among the study locations (Figure 7). Only in Chattogram has yearly rainfall increased by 6% over the last 40 years. However, annual rainfall remained unchanged in Khulna (Figure 9). Other than these two locations, decreased rainfall ranged from 8-21%. Of which, the maximum of 21% was reduced in Rajshahi and a minimum of 8% in Barishal. In the pre-monsoon season, rainfall showed an increasing trend at Sylhet (1%), Rangpur (15%), and Rajshahi (14%). Rainfall in pre-monsoon decreased by a maximum of 37% at Dhaka and a minimum at Mymensingh (10%). Monsoon rainfall decreased in all locations except Chattogram and Khulna (Table 3). Table 3 showed increased rainfall during post-monsoon in Sylhet (43%), Khulna (23%), and Barishal (44%).

Table 3 Annual and seasonal rainfall change (%) from 1981 to 2020

Location	Rainfall changed (%) over the last 40 years from 1981				
	Annual	Pre-monsoon	Monsoon	Post-monsoon	Winter
Sylhet	-9	1	-15	43	-17
Rangpur	-19	15	-25	-27	-30
Chattogram	6	-24	21	-134	23
Dhaka	-18	-37	-9	-31	-19
Rajshahi	-21	14	-26	-19	-32
Mymensingh	-18	-10	-17	-92	-27
Khulna	0	-30	8	23	-15
Barishal	-8	-19	-8	44	-19

(-) sign indicates a decreasing trend.

However, the maximum 134% rainfall decreased at Chattogram during post-monsoon. On the other hand, winter rainfall was reduced in all locations except Chattogram (Table 3). The time series plot of average summer monsoon rainfall in Bangladesh reveals inter-annual variability in 2-3 years and 4-6 years by (Ahasan et al., 2010). They found that the eastern region shows decreasing trends of about -2 to -7 mm/year, with the highest (-6 to -7 mm year-1) in the east-central part. Shahid, (2010) demonstrated that monsoon rainfall only rose significantly in western region of Bangladesh. At the 99% confidence level, the northern part of Bangladesh experiences the most significant rise in rainfall, 11.15 mm year-1.

Rahman and Lateh, (2017) claim that the monsoon rainfall in Bangladesh has stayed the same, which is inconsistent with the regional pattern of monsoon rainfall, in contrast to the current findings, which mostly recorded changes in the stations in the southeast hill region of Bangladesh. Rahman and Lateh, (2017) a shifting pattern of monsoon rainfall in the stations in this area. However, the outcome agrees with the findings of the Indian study by (Kumar et al., 2003). In northeast India (east of Bangladesh), they observed a statistically significant decline in monsoon rainfall at a rate of -6% to -8% of standard/100 years, while in central India (west of Bangladesh), they observed a statistically significant increase at a rate of +10% to +12% of normal 100 years-1. According to Ahmed and Alam, (1999), rainfall will decrease to a negligible level by 2030. By 2030, Yu et al., (2010) predicted a 1% increase in median yearly rain.

4. CONCLUSION

The pre-monsoon experienced the highest maximum temperature, whereas the monsoon received the highest minimum temperature among the locations. However, the rising maximum temperature rate is alarming (over one °C) in Sylhet, Chattogram, and Khulna. Annual rainfall is decreased in all locations except Chattogram. However, the pre-monsoon rainfall increased in Rangpur, Sylhet, and Rajshahi, and monsoon rainfall decreased in all locations except Chattogram and Khulna.

Acknowledgement

The author expresses his heartfelt gratitude to Director, National Agricultural Technology Project (A World Bank Funded Project), Department of Agricultural Extension for financial support by offering scholarship and research cost during the research period.

Informed consent

Not applicable.

Ethical approval

Not applicable.

Conflicts of interests

The authors declare that there are no conflicts of interests.

Funding

The study has not received any external funding.

Data and materials availability

All data associated with this study are present in the paper.

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