

## Recent Climatology of Thunderstorm Days over Bangladesh

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### Abstract

An attempt has been made to find out the monthly, seasonal and annual long term trend of average thunderstorm days over Bangladesh during 1981-2020. This trend is analyzed by using Mann-Kendal test and Sen's slope estimation. The time series shows that May is the highest thunderstorm occurring month and June and September are the second and third highest months respectively. The spatial distribution of annual and seasonal TS days goes from north-eastern part to mid-western part of the country and it ranges from 136.2 to 99.5. The highest number of TS days is spreading out from north-east to mid-western part of the country. The annual and seasonal TS analysis shows significant increasing trend except for winter which poses insignificant negative trend. The monthly trend analysis represents that the month of May, June and October exhibit only increasing trend.

**Keywords:** Categorical cyclonic disturbance, Trend, Mann-Kendal and

### 1. Introduction

Basically Thunderstorm (TS) is a part of Mesoscale Convective System (MCS) merely containing lightning and thunder, powerful gusty surface winds with heavy rain and hail, occasionally tornadoes. Usually, it starts to form with rising air in a conditionally unstable environment. As long as the rising air is warmer (less dense) than the air surrounding it, there is an upward directed buoyant force acting on it. The warmer the parcel is compared to its surroundings, the greater the buoyant force, and the stronger the convection. Severe TSs are usually defined as TSs having surface wind gust of at least 50 knots (58 mi/hr) or produce large hail with a diameter of at least 1 inch or a tornado. TSs (TS) are a very worldwide phenomenon and it is estimated that there are 16 million TSs each year and roughly 2,000 TSs are in progress at any given moment (<http://www.nssl.noaa.gov/education/svrwx101/TSs/>). According to Intergovernmental Panel on Climate Change, Bangladesh is one of the most disaster prone countries in the world due to its unique geographical location, i.e., Bay of Bengal to the south, Indian subcontinent to the west and the Meghalaya plateau in the northeast region make this country most vulnerable to severe local storms. Advection of warm and moist air from the Bay of Bengal and, cold and dry air from the north-eastern part of Bangladesh produce required instability in the mid-troposphere for the formation of severe TS [1]. This study showed that the passing of easterly lows across the southern peninsula of India, their subsequent movement towards north-east and westerly disturbance from north-west to south-west are resulting in higher frequency of TSs over Bangladesh. It has been found that high vertical wind shear in the lower troposphere is responsible for intense TS formation [2]. Not only that the low level jets with high intensity are also observed during pre-monsoon TS days [3]. TS are most likely occur in pre-monsoon season (March-May) peaking in May, though monsoon season faces highest number of TS days as compared to pre-monsoon but casualty is greater in pre-monsoon.

The highest frequency of TS is concentrated in the north-eastern part of Bangladesh. TSs in Pre-monsoon are known as "Nor'wester" because it comes Bangladesh from northwesterly direction and locally called "Kalbaishakhi" because of its intensive damage to life and property during the month of April-May. Earlier several studies have been done on physical characteristics for the formation and frequency distribution of TS days in India and Bangladesh [4, 5] Aside from those, a good number of investigations have been done in recent years on TS climatology around the world like India [6], Australia [7], Europe and in USA [8, 9]. The SWEAT index has been found very useful for determining TS intensity earlier. The value was below 195 on non-occurrence days and above 285 for occurrence days according to Das et al., 1994. (Ahasan et al., 2015) have shown in their study that the strong vertical wind shear (VWS) of the order of 15-20 ms<sup>-1</sup> may assist to develop multicell TSs in this region and subtropical jet stream at upper level provides necessary mechanism for this strong VWS [10]. A most recent study [11] also urged the impact of initial conditions and better physics options in forecasting of TS events. Previously an attempt was made to depict the climatology of Severe Local Convective Storms (SLCS) in Bangladesh from 1990 to 2005 which includes 2,324 events [12] but after that no reliable climatological study has not found for long period of time as it is needed for a disaster prone country like us. In this study, longer periods (40 years) are included than those of previous climatological studies. So it

may postulate a deep down thought of climatology for TSs in this area that would be a manuscript for all the people who wants to understand the climatological features of TSs over Bangladesh effortlessly. The present study includes monthly, seasonal and annual climatology of average TS days have been studied and trend analysis also has been studied with the data from 1981 to 2020.



Figure 1: Map showing 35 meteorological stations of Bangladesh

## 2. Data & Methodology

Daily TS frequency data during 1981-2020 for 35 meteorological stations of Bangladesh has been collected from Bangladesh Meteorological Department (BMD). Location of the stations are shown in figure 1. The number of TS recorded in one day is assumed as daily frequency of TS. Then monthly, seasonal and annual time series have also been calculated from this daily TS data for every individual station and this data has been used for estimating mean monthly, seasonal and annual climatology of TS days. Spatial distribution of average TS days has been depicted from station-wise time series data of average TS day, time series of annual average TS days is shown as well. Trend analysis of the time series of average TS days has been performed by Mann-Kandle test in R. All the map for spatial distribution has been created through ArcGIS and all the graph being constructed in R

## 3. Result and Discussion

### 3.1 Climatology of TS days over Bangladesh

Based on the data of 1981-2020, the country average monthly mean TS days of Bangladesh is shown in figure 3. It is seen that the high value of mean TS days is represented by the months of April-September, having highest value in the month of May (13), followed by June (12), September (11), August (9.3) and April (9.2).

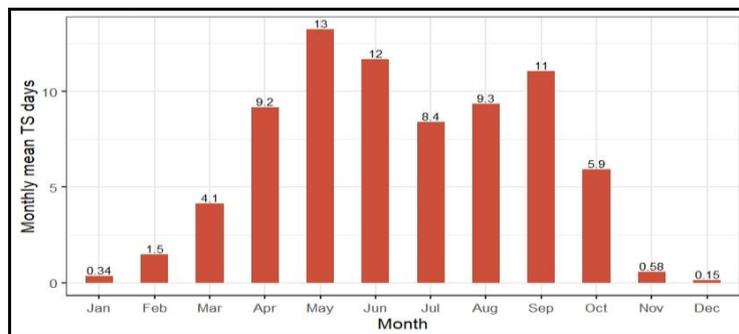


Figure 2: Monthly distribution of average TS days

Low value of mean TS days is observed in the months of November-February with the lowest mean value in December (0.15). Table 1 represents the country average seasonal and annual distribution of average TS days over Bangladesh. It shows that the Monsoon season is facing highest mean TS days (33.90), then Pre-monsoon and Post-monsoon are 24.54 and 5.74 respectively. The Lowest value of mean TS days is in Winter season (1.85). The annual average TS days over Bangladesh is 66.09.

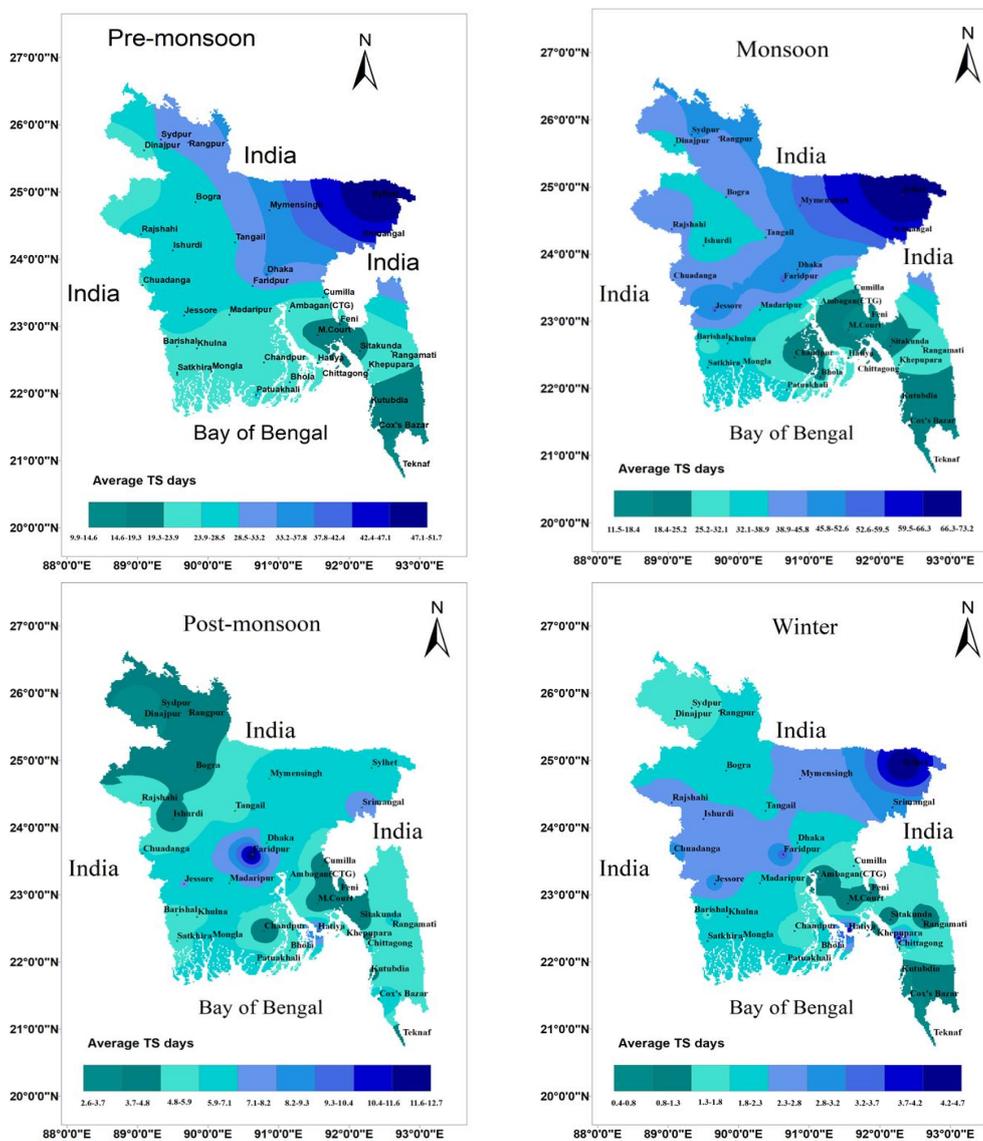
**Table 1:** Seasonal and Annual average TS days in Bangladesh

Season	Mean TS days
Winter	1.85
Pre-monsoon	24.54
Monsoon	33.90
Post-monsoon	5.76
Annual	66.09

### 3.1.1 Spatial Distribution of TS

#### 3.1.1.1 Seasonal

TS (TS) activity increases over all parts of Bangladesh in the Pre-monsoon season. North-eastern part of Bangladesh is facing highest TS activity that is (47.1-51.7) days per year and south-eastern part is having the lowest value ranges from 9.9-14.6. All other parts of the country records almost moderate TS activity in this



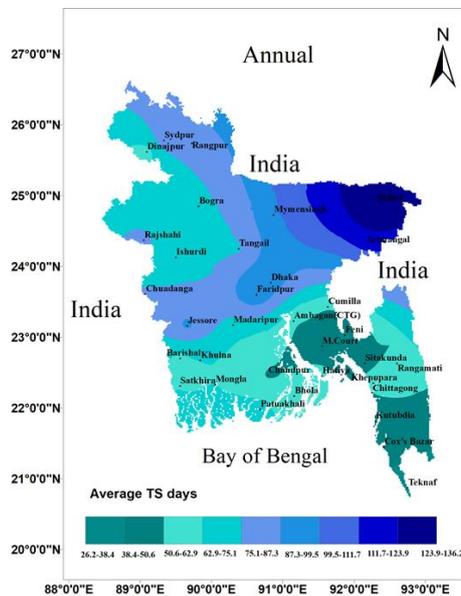
**Figure 3:** spatial distribution of Seasonal average TS days in Bangladesh

season. The monsoon season experiences highest average TS days, ranging from 66.3- 73.2 over the north-eastern part of Bangladesh. Western and north-western part of Bangladesh also experience high TS activity on average 38.9-52.6 days per year.

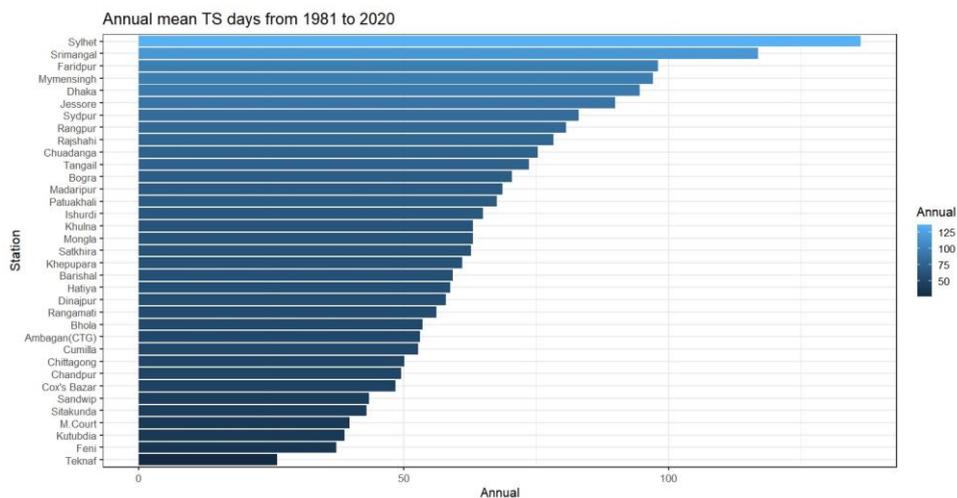
The lowest activity is observed in the eastern and south-eastern part of Bangladesh that is 11.5-25.2 days per year as shown in the figure 3, With the withdrawn of monsoon period, TS activity gradually decreases in the Post-monsoon season. Still central part of the country is experiencing highest TS activity of 11.6-12.7 days per year, followed by mid-western and north-eastern part. Whereas the lowest activity is recorded in the north-western, central eastern and mid-southern parts of Bangladesh as depicted in the figure 3. Due to stable atmospheric condition of the country, winter season experiences lowest average TS days per year. The highest value is concentrated on the north-eastern part ranges from 4.2 to 4.7 and upper south-eastern part with the average value of 3.7-4.2. The lowest value is observed in the south-eastern and central eastern part of Bangladesh which ranges from 0.4 to 1.3 as shown in the figure 3.

**3.1.1.2 Annual**

Annually the highest average value of TS days goes from north-eastern part to mid-western part of the country and it ranges from 136.2 to 99.5. The south-eastern and mid-eastern part is having the lowest average value of 26.2-50.6 days per year. North-western and south-western part experiences on average 50.6-75.1 TS days per year as it is seen in the figure.



**Figure 4:** Spatial distribution of annual average TS days in Bangladesh



**Figure 5:** Station-wise Annual mean TS days

From the figure of station-wise average TS days distribution, Sylhet and Srimangal experience highest annual mean TS days of 136.28 and 116.92 respectively. Teknaf is experiencing the lowest mean value of 26.15 TS days annually and almost 24 stations are having the mean value between (50-100) TS days.

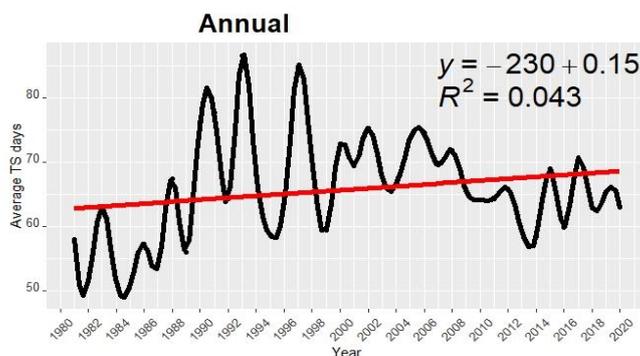
### 3.2 Country average TS variability and trends

The time series plot of Annual average (avg) TS days shows that avg TS days increases gradually up to 1988, after that it's increased rapidly and reach the peak value at 1993 (Figure 6). After 1993, the value is decreased rapidly up to 1995 and at 1997 it almost touches the peak again. But during 2000-2009, it follows almost steady variation of avg TS days and no trend is observed at that time.

**Table 2:** Seasonal and annual trends of average TS days in Bangladesh during (1981-2020)

Season/Annual	Trend	P-value
Winter	-0.04	0.029
Pre-monsoon	0.07	0.387
Monsoon	0.08	0.2003
Post-monsoon	0.03	0.087
Annual	0.13	0.291

Trend analysis shows increasing trend of annual avg TS days (0.13 per year). Seasonal trend analysis exhibits increasing trend for all seasons except for winter, when the trend value is -0.04 (Table-2). The time series plot of seasonal avg TS days also demonstrate the increasing trend for all seasons but for winter its showing significant decreasing trend (Figure7). Monsoon is experiencing high trend (0.08 per year) value (Table-2), then pre-monsoon and post-monsoon as follows.



**Figure 6:** Annual trend of average TS over Bangladesh

From monthly trend analysis, it is observed that the month of May, June and October exhibit only increasing trend with the highest value in June. Apart from that, all other months show decreasing trend value. The p-value for the month December is showing very significant decreasing trend.

**Table 3:** The trends of monthly mean TS days of Bangladesh

Month	Z value	S	Sen's slope	P-value
January	-1.57624543	-136.000	-0.00351724	0.11496925
February	-1.70116651	-147.000	-0.02541486	0.08891172
March	-1.13015035	-98.000	-0.03912604	0.25841288
April	-0.74571683	-65.000	-0.02366154	0.45583849
May	0.41946572	37.000	0.01912972	0.67487581
June	1.25839715	109.000	0.03404262	0.20824816
July	-1.03708287	-90.000	-0.03055451	0.29969724
August	-0.96716717	-84.000	-0.03285256	0.33346047
September	-0.33788000	-30.000	-0.01118240	0.73545362
October	0.87382759	76.000	0.01961076	0.38221215
November	-0.32625111	-29.000	-0.00165271	0.74423437
December	-2.673536320	-230.000	-0.003361285	0.007505615

#### 3.2.1 Distribution of station-wise trends of average TS days

Station wise annual trend for average TS days illustrates that overall 15 stations out of 35 exhibits increasing trend and rest of 20 stations show decreasing trend. Spatial distribution of annual trend of average TS days is also displayed as shown in figure which shows that only north-eastern and mid-western part of the country possess negative trend. Otherwise all other parts having positive high trend value in the range 1.9-3.9.

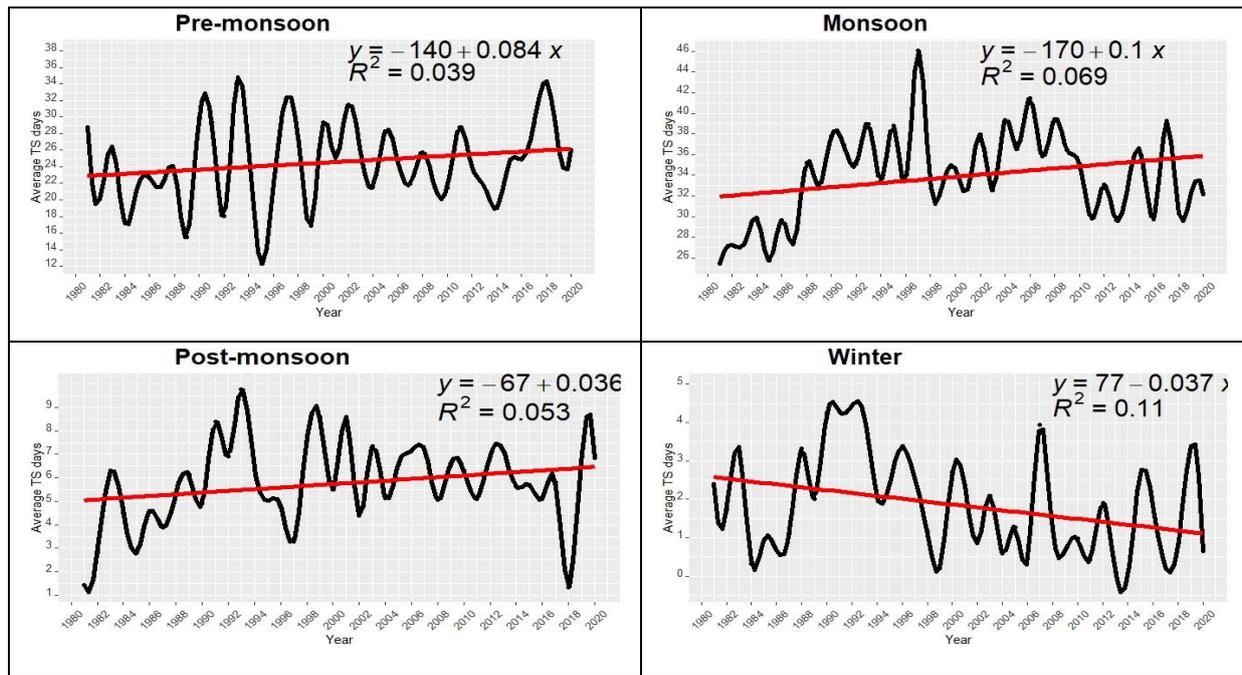
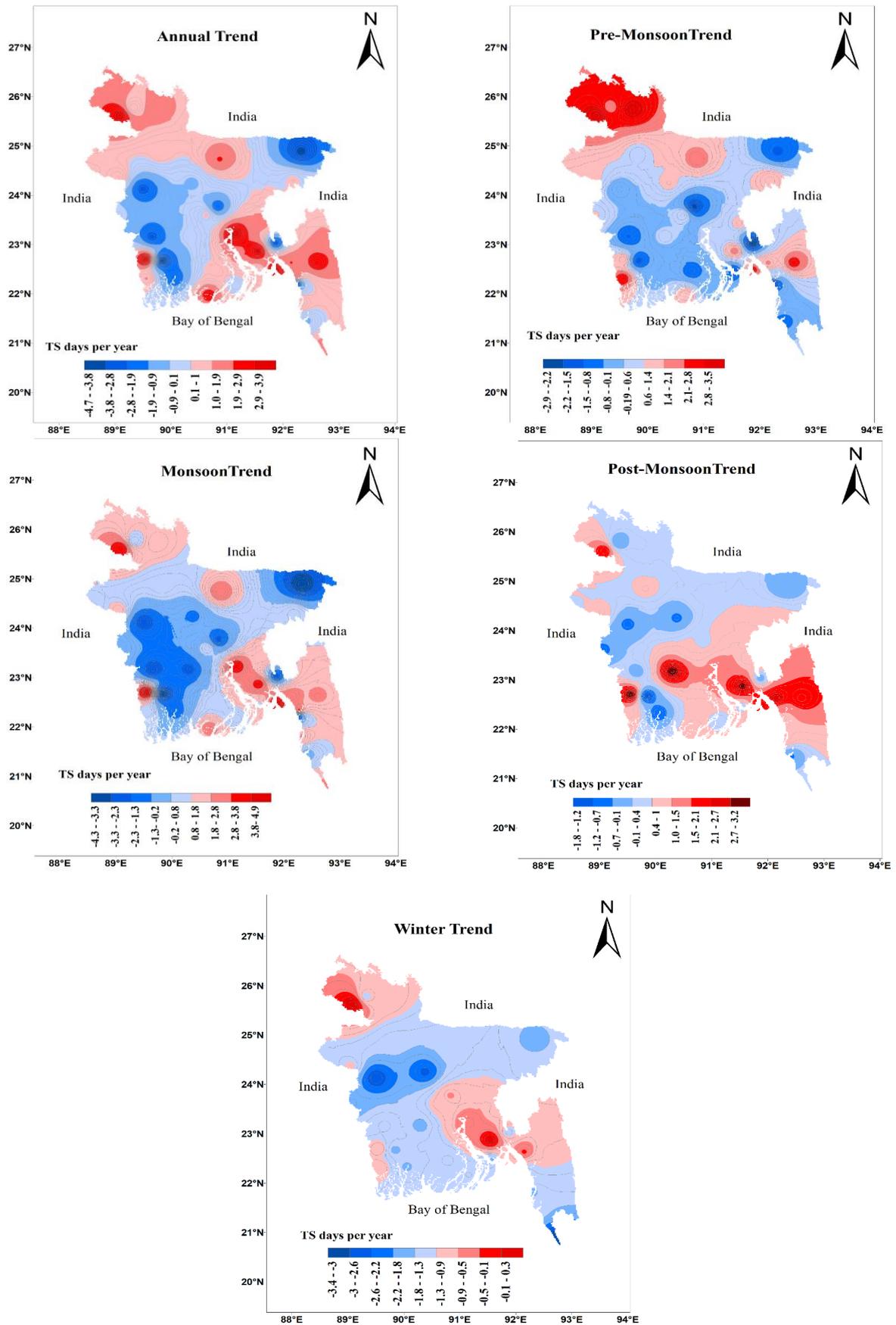


Figure 7: Seasonal trend of average TS over Bangladesh

Table 4: Station wise Seasonal and Annual trend of average TS days in Bangladesh during 1981-2020

Stations	Winter		Pre-monsoon		Monsoon		Post-monsoon		Annual	
	Z-value	P-value	Z-value	P-value	Z-value	P-value	Z-value	P-value	Z-value	P-value
Dhaka	-0.860	0.3897	-2.370	0.0177	-2.557	0.0105	0.235	0.813	-2.589	0.009
Tangail	-2.704	0.0068	0.817	0.4140	-1.485	0.1373	-0.825	0.409	-1.010	0.312
Madaripur	-1.156	0.2474	0.455	0.6487	0.303	0.7617	0.596	0.550	0.221	0.824
Faridpur	-1.921	0.0546	0.101	0.9196	-2.638	0.0083	3.043	0.002	-0.745	0.455
Mymensingh	-1.6126	0.1068	1.799	0.0720	2.579	0.0098	0.258	0.795	1.949	0.051
Srimangal	-1.758	0.0786	1.283	0.1995	0.504	0.6136	0.508	0.611	0.204	0.837
Sylhet	-1.930	0.0535	-1.601	0.1092	-4.107	0.000	-0.552	0.580	-3.975	0.000
Bogura	-1.691	0.0909	0.269	0.7881	0.339	0.7345	0.623	0.533	0.373	0.709
Rajshahi	-1.244	0.2133	0.701	0.483	1.169	0.2423	0.623	0.533	1.002	0.315
Ishurdi	-2.9807	0.0028	-0.642	0.5205	-2.965	0.0030	-0.875	0.381	-3.148	0.001
Dinajpur	0.3151	0.7526	3.469	0.0005	3.607	0.0003	1.932	0.053	3.276	0.001
Rangpur	-1.0784	0.2808	3.231	0.0012	1.400	0.1612	-0.023	0.981	1.482	0.138
Chuadanga	-1.391	0.1641	1.882	0.0598	0.206	0.8362	-0.570	0.568	0.225	0.821
Sydpur	-2.015	0.0439	0.635	0.5252	-0.486	0.6264	-0.836	0.402	-0.786	0.431
Jessore	-1.347	0.1778	-1.529	0.1261	-3.067	0.0021	-0.351	0.725	-3.125	0.001
Khulna	-1.892	0.0585	-1.763	0.0778	-4.351	0.0000	-1.771	0.076	-4.723	0.000
Mongla	-1.850	0.0642	-0.508	0.6111	-1.906	0.0566	-1.208	0.226	-2.806	0.005
Satkhira	-1.007	0.3139	2.702	0.0068	0.781	0.4344	0.849	0.395	1.026	0.304
Barishal	-1.036	0.3001	1.144	0.2527	4.887	0.0000	3.217	0.001	3.884	0.000
Bhola	-1.613	0.1067	-0.783	0.433	0.023	0.9813	0.000	1.000	-0.582	0.559
Khepupara	-1.313	0.1893	0.228	0.8194	2.930	0.0033	1.057	0.290	1.776	0.075
Patuakhali	-1.502	0.1332	1.225	0.2206	2.242	0.0249	0.743	0.457	2.323	0.020
Chandpur	-1.637	0.1016	-1.261	0.2072	0.502	0.6156	0.508	0.610	0.116	0.907
Chittagong	-1.483	0.1379	-2.378	0.0173	-2.921	0.0034	0.371	0.710	-3.599	0.000
Ambagan	-0.514	0.6073	0.335	0.7377	3.571	0.0003	1.341	0.179	3.637	0.000
Cumilla	-1.024	0.3055	0.852	0.3941	1.800	0.0718	0.706	0.480	1.189	0.234
Cox's Bazar	-1.705	0.0881	-1.111	0.267	-0.537	0.5907	-0.774	0.438	-1.061	0.288
Feni	-1.469	0.1418	-2.874	0.0040	-2.788	0.0052	-0.365	0.714	-3.219	0.001
Hatiya	-1.908	0.0563	-1.934	0.0530	0.604	0.5456	0.113	0.909	0.075	0.939
Kutubdia	-1.854	0.0638	0.014	0.9890	1.869	1.8698	0.905	0.365	0.968	0.332
M.court	0.1696	0.8653	1.717	0.0859	3.337	0.0008	2.916	0.003	3.383	0.000
Rangamati	-1.251	0.2109	2.544	0.0109	2.053	0.0400	2.099	0.035	2.739	0.006
Sandwip	-0.998	0.3183	2.652	0.0079	4.261	0.0000	2.230	0.025	3.604	0.000
Sitakunda	-0.433	0.6651	1.484	0.1379	2.369	0.0178	2.574	0.010	1.923	0.054
Teknaf	-3.417	0.0006	0.138	0.1827	1.881	0.0599	0.010	0.204	1.645	0.099



**Figure 8:** Spatial distribution of annual and Seasonal trend of average TS over Bangladesh

#### 4. Conclusions

It can be concluded from the analysis of recent (1981-2020) climatology of TS days over Bangladesh:

- a) The time series plot shows that the year 1993 is highly affected by highest no of TS event till now, not only that the monthly distribution plot reveals the month of May occupies highest no of TS days (12) per year and the month June and September ranked as second and third position. That means the pre-monsoon and monsoon are the dominant season for TSs.
- b) The spatial distribution of annual and seasonal TS days goes from north-eastern part to mid-western part of the country and for annual, it ranges from 136.2 to 99.5 .The highest value is spreading out from north-east to mid-western part of the country.
- c) From the seasonal time series plot, it is clearly seen that all the three season approaching increasing trend but only winter is showing decreasing trend. Station-wise distribution of annual average TS days reveals that Sylhet and Srimangal experience highest annual mean TS days of 136.28 and 116.92 respectively, while Teknaf is experiencing the lowest mean value of 26.15 TS days annually.
- d) The annual and seasonal trend analysis shows significant increasing trend except for winter which poses insignificant negative trend value. The monthly trend analysis represents that the month of May, June and October exhibit only increasing trend with the highest value in June.

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