Original Research Article

Analysis of spatially distributed monthly rainfall and temperature over Bangladesh from 1989 to 2019

Abstract: In this study, based on the analysis of historical data on temperature and rainfall recorded at 34 meteorological stations, It is reveal Climate change and variability in Bangladesh from 1989-2019. Analysis of rainfall data showed that for most stations, the total rainfall showed an increasing trend for the monsoon and post-monsoon seasons. The average increase in monthly average maximum and minimum temperatures during the 31 years from 1989 to 2019 is quite significant. These changes will threaten Bangladesh's significant achievements over the last 31 years in increasing incomes and reducing poverty. Analysis of rainfall data showed a rising rainfall trend for most stations during the monsoon and post-monsoon seasons. Analysis of rainfall data showed that rain increased during and after the monsoon but decreased during the winter. Assessment of changes in maximum temperature, minimum temperature, and rainfall patterns. Bangladesh's annual maximum temperature was increasing on average by 34 stations. The greatest change in month-average maximum temperature was found in the Southeastern region of Bangladesh for maximum months.

Keywords: *Climate variability, Monthly Temperature, Monthly Rainfall, spatial distribution, SVM.*

1. INTRODUCTION:

"Climate is one of the key components in the earth system. It is the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months or millions of year (IPCC)" [6]. "The fourth Assessment report of (2007)[7] has observed that the 100-year linear trend (1906-2005) of global average surface temperature is 0.74 (0.56 to 0.92) and is longer that the corresponding trend of 0.6 (0.4 to 0.8) (1901-2000)". The trends of yearly average maximum and minimum temperatures have been found to be increasing at the rates of 0.025ºC and 0.018 ºC per year by Das & Zhang [2]. Warrick et al [14], Karmakar & Shrestha (2000)[9] and Debsarma (2003)[4] provided assessment of changes in temperature and rainfall over Bangladesh, while Chowdhury & Debsarma (1992)[1] and Mia (2003)[12] reported changes in temperature based on analysis of historical data of some selected weather stations in Bangladesh, Karmakar & Nessa (1997)[8] and Karmakar (2003)[10] provided "assessment of the effects of climate change on natural disasters". "The rainfall and temperatures (Singh et al. 2013) are the most important fundamental physical parameter among the climate as these parameter determine the environmental condition of the particular region which affects the agricultural productivity" (Modarses and da Silva) [11].

"In Bangladesh, different climate changes like recurring floods, river, bank erosion, and drought in dry season, salinity increase as a result of back water effect; downing ground water level, have been contributing to augment the vulnerability of many regions. Bangladesh is one of the top most nations vulnerable to climate change (Harmeling)" [5].

“Nevertheless, many regions of this country remain outside the ambit of climate change related actions” (Titumir & Basak) [13]. Das, Islam & Ghosh [3] showed that, “in Bangladesh January is the coldest month and April is the hottest month, where the average temperature is 18 ºC, and 28 ºC respectively”. Modeling studies by Haque et al (1992) calculated “the increasing temperature for the projected years of 2030 and 2075 would be 1.3 ºC and 2.6 ºC respectively”.

2. METHODOLOGY

The study was conveyed on 34 meteorological stations in Bangladesh for the period of 1989 to 2019 and their geographical locations are shown in figure 1. Among them Bogra, Dinajpur, Rangpur and sayedpur were selected for Nothern region, Chuadanga, Faridpur, Ishurdi and Rajshahi were sleeted for Northwestern region; Jessore, Khulna, Mongla, Patuakhali, Satkhira and Khepupara for North Southern region; Tangil, Dhaka and Mymensingh for central region; Barisal, Bhola, Chandpur, Comilla, Feni, Hatiya, M.Court, Madaripur for Sothern region; Chittagong, Cox’sbazar, Kutubdia, Rangamati, Shandwip, Sitakunda and Teknaf for Southeastern region and sylhet and Srimongal for Eastern region in Bangladesh.

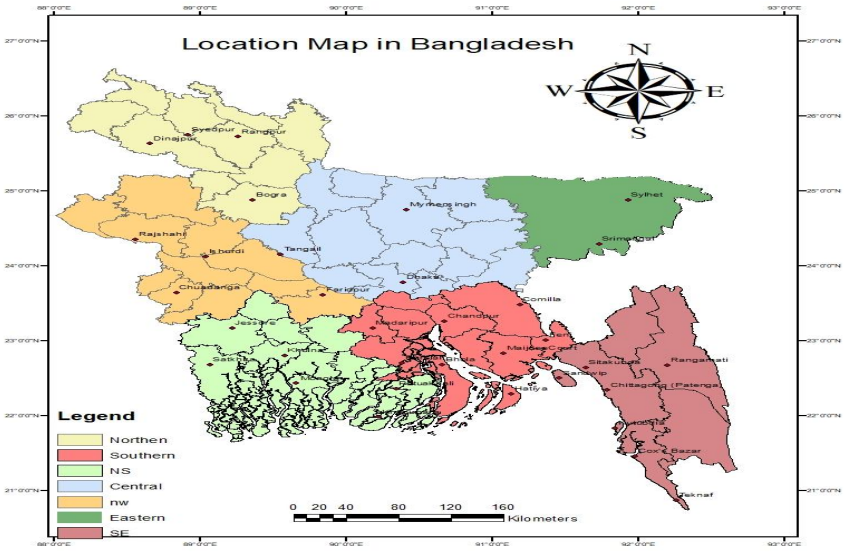

Fig-1 Location Map of the study area

It has been collected temperature and rainfall data of all 34 weather stations from Meteorological Department of Bangladesh. These data included daily, monthly average and annul mean for the period January 1989 to December 2019.

2.1 RMSE, MAE, and MAPE: Using RMSE, MAE, and MAPE metrics, the LSTM model's performance in predicting temperature was assessed. The following equation can be used to determine the RMSE, which is a measure of the,

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}$$

The MAE (mean absolute error) is a measurement of the discrepancies between predictions and actual observations.

$$MAE = \frac{1}{n}\sum_{i=1}^{n}|y_i - \hat{y}_i|$$

The following equation can be used to calculate MAPE, which expresses the error as a percentage between expected and observed data.

$$MAPE = \left(\frac{1}{n}\sum_{i=1}^{n}\left|\frac{y_i - \hat{y}_i}{y_i}\right|\right) \times 100\%$$

The discrepancy between actual observations and the model's projected results is measured by the assessment metrics mentioned above. As a result, the model's accuracy rises as the RMSE, MAE, and MAPE values fall. These numbers are computed using the test set predictions.

3. RESULT AND DISCUSSION

"Trend is defined as the general movement of a series over an extended period of time it is the long term change in the dependent variable over a long period of time" (Webber and Hawkins, 15]. Trend is determined by the relationship between the two variables of temperatures rainfall and their temporal resolution. The statistical method such as regression analysis and coefficient of determination R^2 are used for the significance of trend of temperature and rainfall.

3.1 Rainfall pattern: The whole year divided into four seasons to assessed changes in rainfall pattern by analyzing changes in total rainfall for the period of 1989 to 2019. The hot season start from March to May which is called pre-monsoon, June to September is Monsoon, October and November constitute the post-monsoon season. The cold season is from December to February which is winter. In this study, observed the significant change in trends of rainfall. In winter season of Bangladesh among the 34 stations, 2 stations showed increasing trend while 32 showed decreasing trends in total rainfall. On the other hand, for

monsoon season showed rising trend in 31 stations; 30 stations showed increasing trend of total rainfall for post monsoon and 20 stations for pre-monsoon among 34 weather stations. Moreover, the observed trends were not statistically significant in most cases. Nevertheless, majority of stations showed increasing trend of rainfall during monsoon and post-monsoon season while significant number of stations showed decreasing trend of total rainfall during winter. From analysis of total rainfall observed that the results are consistent with the general climate change predictions that day periods would become drier and wet periods would become wetter. In Bangladesh during the period of 1989–2019, the yearly average rainfall increased in the southern and southeastern region. while the yearly average rainfall decreased at the remaining regions for the northern, northwestern, north southern, central and eastern regions, respectively.

Table-1: Amount of Rainfall (mm per year) in four Seasons during 1989-2019

Region	Winter	Pre-monsoon	Monsoon	Post-monsoon
Northern	0.293	3.463	10.857	2.313
North Western	0.407	2.867	8.651	2.401
North Southern	0.509	3.455	11.900	3.584
Central	0.408	4.802	10.787	3.150
Southern	0.421	4.736	16.122	4.458
South Eastern	0.449	5.484	18.882	4.664
Eastern	0.602	9.777	16.263	3.461

Observed that the highest change of the rainfall was recorded for monsoon season in Bangladesh for maximum months and the lowest changes for winter season during the period of 1989-2019. Analysis of changes in total rainfall was made separately for each weather station. The southwest monsoon is the source of rainfall in Bangladesh. About 80% of the total rainfall is received during the monsoon. The variation in the annual rainfall and temperature from year to year is not very large.

3.2 Rainfall Prediction:

We practiced Linear Regression, used Test & Score to assess how well they performed. By building a learner or predictor from its input data, the linear regression widget creates a linear function.

The history of decision trees and how they're trained, many forecasters regression trees to accurately anticipate load demand. The training data is separated into sub-units of data in a decision tree.

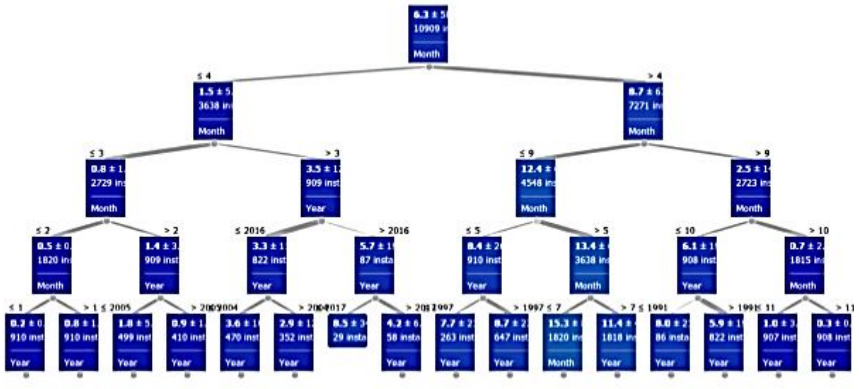

Fig 2: Rainfall forecast result using DT compared with observed value.

Patterns

The study's utilization of temperature data from 34 meteorological stations is described.

Table 2: Lists the 34 meteorological stations temperature data

No	Station Name	Climate Region	latitude (N)	longitude (E)	Minimum (Temperature)	Maximum (Temperature)	Period of Record used
1	Bogura,	Northern	24°51	89°22'	21.984	31.591	1989-2019
2	Dinajpur,	Northern	25°33'	88°43'	20.689	30.966	1989-2019
3	Rangpur	Northern	25°42'	89°22'	20.878	30.542	1989-2019
4	Sayedpur	Northern	25°48'	89°0'	20.737	30.672	1989-2019
5	Chuadanga	Northwestern	23°64'	88°85'	21.406	32.448	1989-2019
6	Faridpur	Northwestern	23°15'	89°55'	22.141	31.936	1989-2019
7	Ishurdi	Northwestern	24°12'	89°06'	21.478	31.920	1989-2019

8	Rajshahi	Northwestern	24°22'	88°39'	21.339	32.184	1989-2019
9	Jessore,	North Southern	23°10'	89°10'	21.712	32.920	1989-2019
10	Khulna,	North Southern	22°25'	89°35'	22.763	31.943	1989-2019
11	Mongla,	North Southern	22°49'	89°60'	23.205	31.768	1989-2019
12	Patuakhali,	North Southern	22°20'	90°25'	22.897	31.661	1989-2019
13	Satkhira	North Southern	22°31'	89°11'	22.485	31.996	1989-2019
14	Khepupara	North Southern	22°00'	90°22'	22.815	31.672	1989-2019
15	Tangil,	Central	24°40'	90°00'	21.385	31.661	1989-2019
16	Mymensingh	Central	24°45'	90°24'	21.645	30.489	1989-2019

17	Dhaka	Central	25°46'	89°42'	23.111	31.892	1989-2019
18	Barisal	Southern	22°45'	90°20'	22.521	31.523	1989-2019
19	Bhola,	Southern	22°45'	90°35'	22.421	31.400	1989-2019
20	Chandpur,	Southern	23°08'	90°45'	22.726	31.627	1989-2019
21	Comilla,	Southern	23°28'	91°10'	22.502	32.154	1989-2019
22	Feni,	Southern	23°01'	91°40'	22.106	31.547	1989-2019
23	Hatiya	Southern	22°29'	91°14'	22.716	30.930	1989-2019
24	M. Court	Southern	22°88'	91°09'	23.289	32.295	1989-2019
25	Madaripur	Southern	23°19'	90°15'	21.666	30.266	1989-2019

26	Chittagong	Southeastern	22°19'	91°48'	23.088	31.373	1989-2019
27	Cox’sbazar,	Southeastern	21°26'	91°59'	23.305	31.705	1989-2019
28	Kutubdia,	Southeastern	21°81'	91°85'	23.164	30.850	1989-2019
29	Rangamati	Southeastern	22°65'	92°18'	21.969	31.927	1989-2019
30	Shandwip,	Southeastern	22°59'	91°50'	23.054	31.636	1989-2019
31	Sitakunda	Southeastern	22°62'	91°68'	21.936	32.529	1989-2019
32	Teknaf	Southeastern	20°86'	92°30'	22.860	31.339	1989-2019
33	Sylhet	Eastern	24°54'	91°52'	21.613	31.450	1989-2019

34	Srimongal	Eastern	24°31'	91°73'	20.486	31.63	1989-2019

Maximum high and low temperature:

The period 1989-2019 of all 34 meteorological stations of Bangladesh the temperature data have been analyzed. Analysis of temperature data and rainfall data of all stations showed that most of the stations have increasing trends of the yearly average maximum and minimum temperature. Prior to analysis, the station data were checked for any potential temporal discontinuities and inconsistencies. To determine the changes of maximum and minimum temperature from monthly and yearly average maximum temperature data for the period January, 1989 to December, 2019. The yearly average maximum high temperature were 30.943ºC, 32.122ºC, 31.993ºC, 31.3480ºC, 31.464ºC, 27.670ºC and 31.545ºC yearly and average maximum low temperature were 29.546ºC, 30.245ºC, 30.545ºC, 29.721ºC, 29.844ºC, 29.600ºC, 29.497ºC, for Northern, North-Western, North-southern, Central, Southern, Southeastern and Eastern region respectively high and maximum low temperature were 32.122ºC and 29.497ºC.

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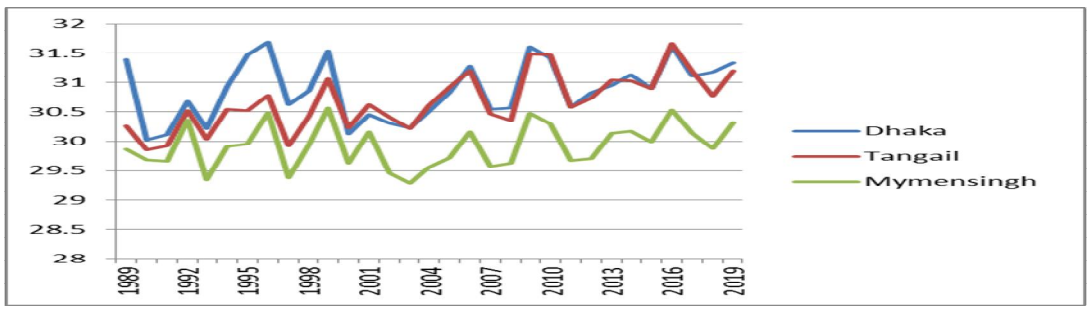

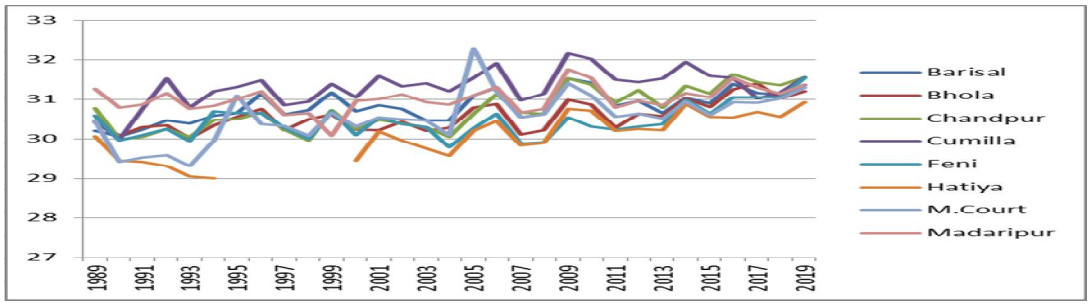
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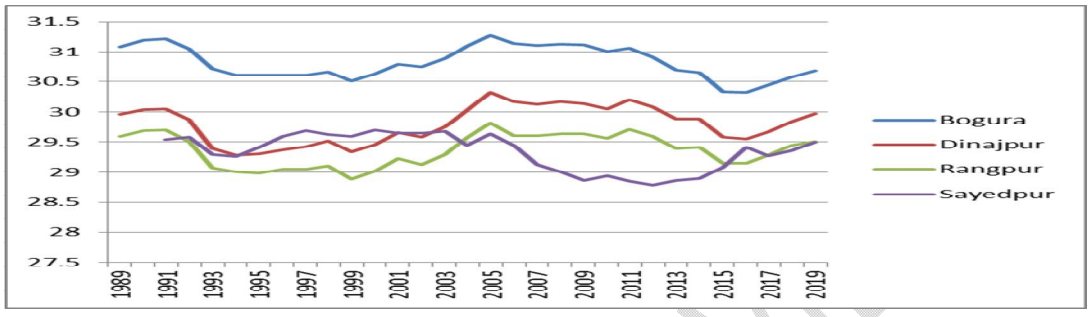
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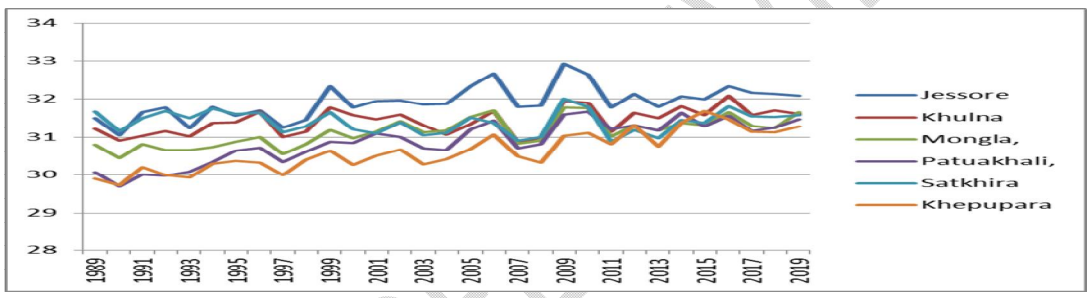
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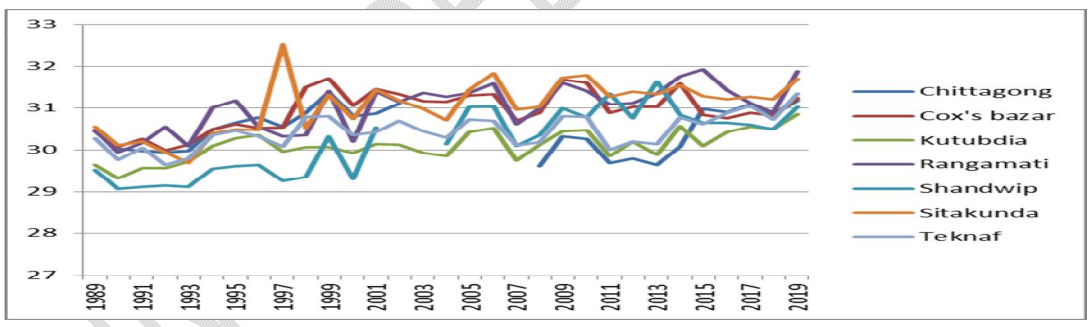
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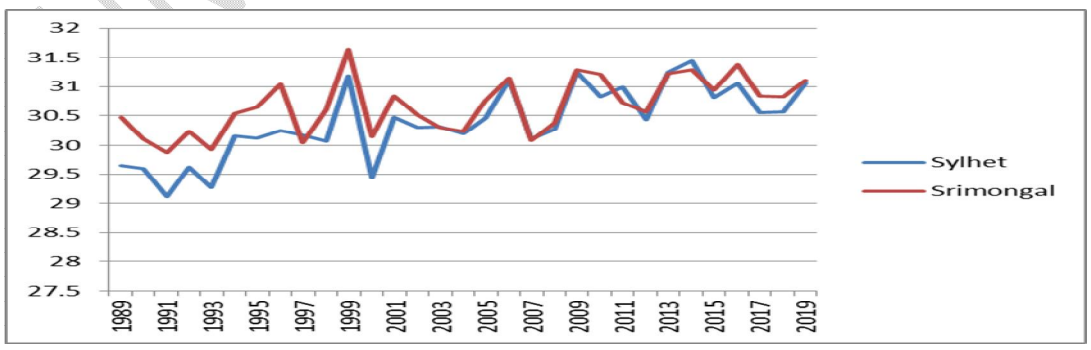
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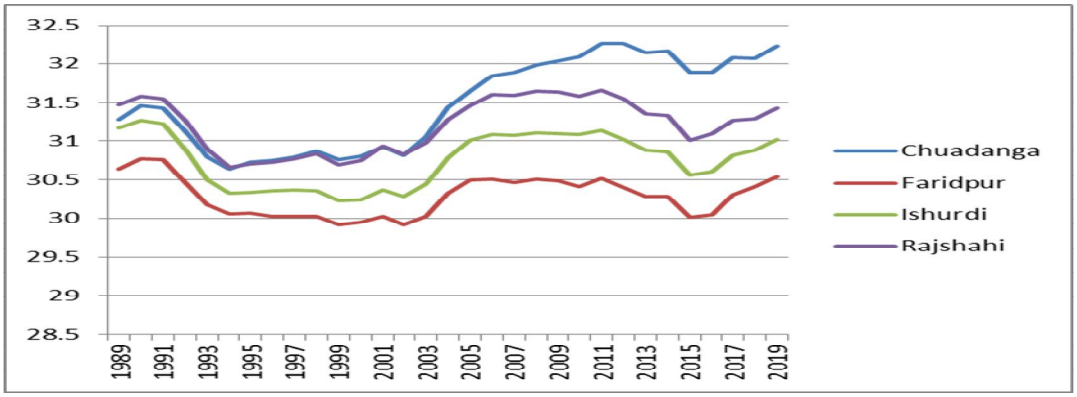
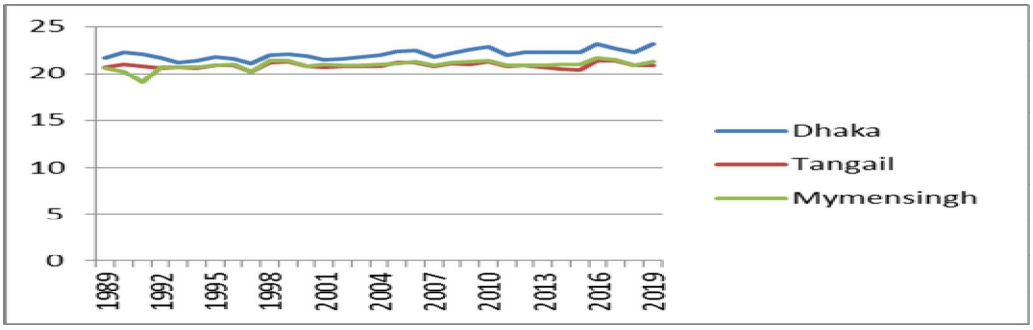


Fig-3: Yearly average maximum high and low temperature changed at different region in Bangladesh.

3.3 Average minimum high and low temperature:

Yearly average minimum temperature also has been increased in all regions of Bangladesh during the past 31-years period. The yearly average minimum high temperature was 21.073ºC, 21.591ºC, 22.468ºC, 22.047ºC, 22.494ºC, 22.768ºC, 21.049ºC yearly. And average minimum low temperatures were 19.581ºC, 19.804ºC, 21.132ºC, 20.103ºC, 21.078ºC, 20.861ºC, 18.821ºC, for Northern, North-Western, North-southern, Central, Southern, Southeastern and Eastern region word respectively here minimum low temperature was 18.821ºC, minimum high temperature was 22.768ºC.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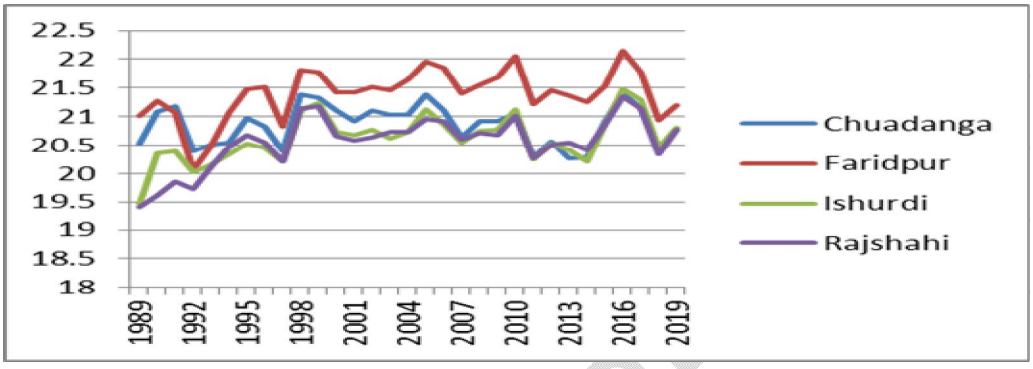
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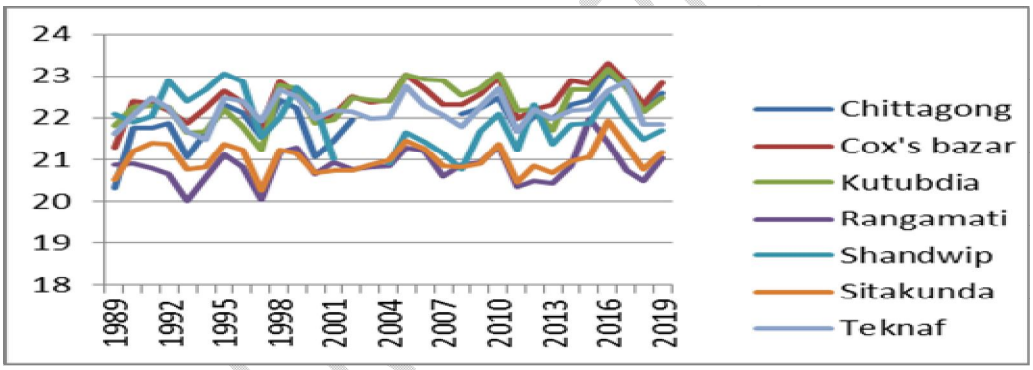
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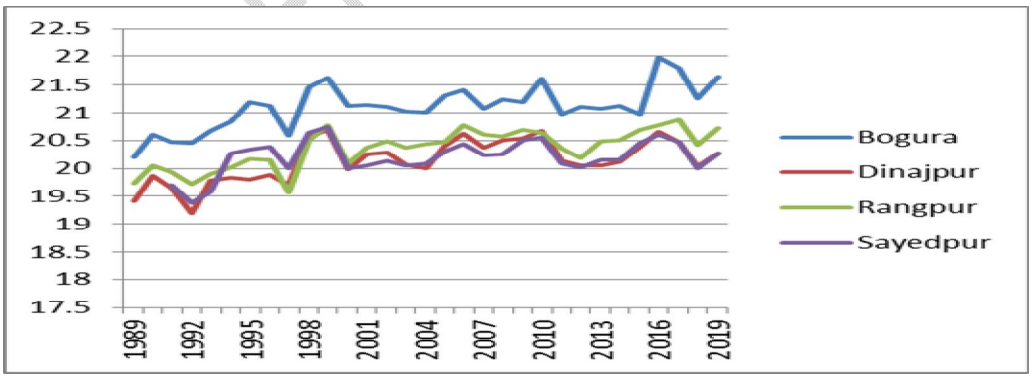
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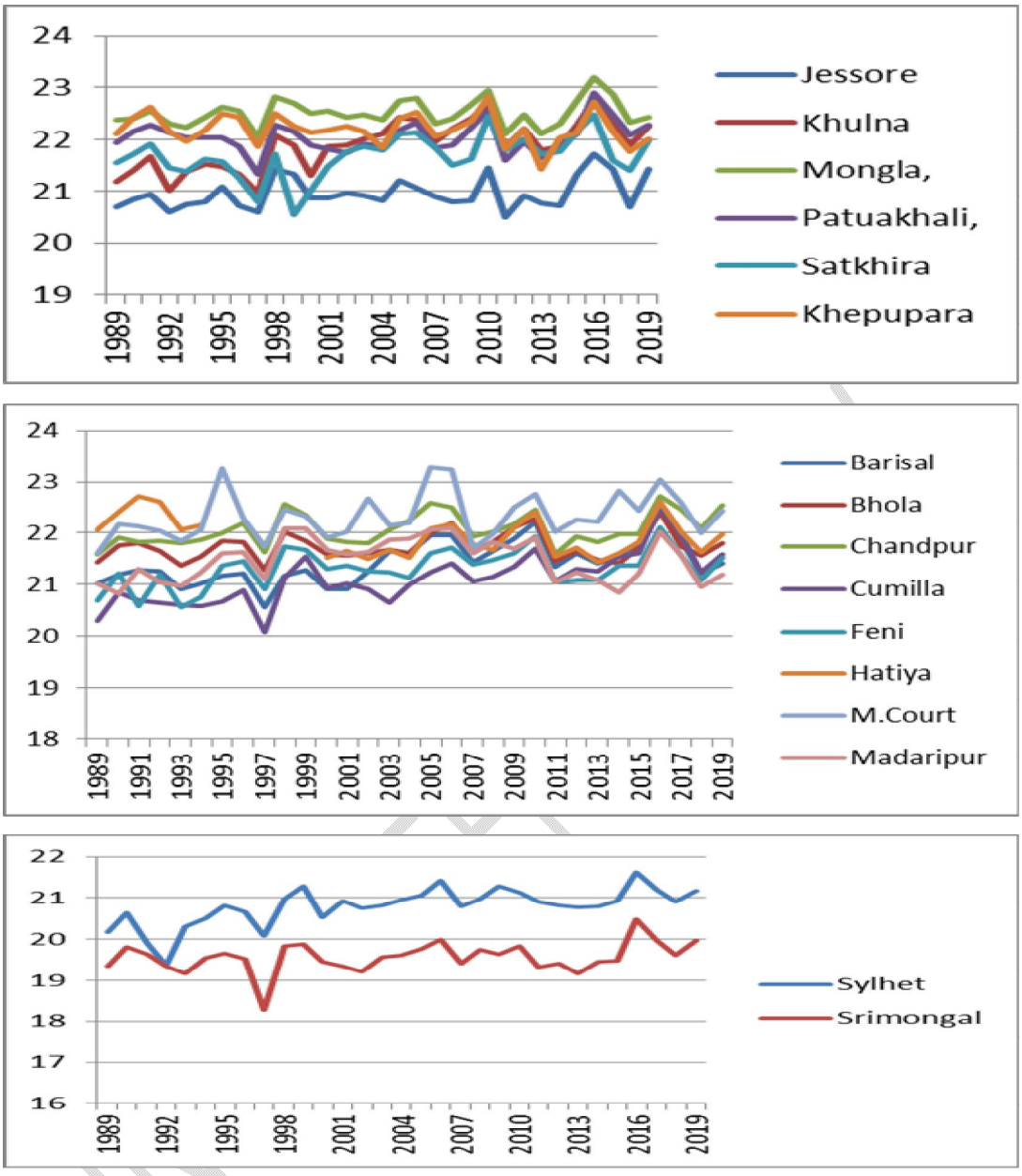


Fig-4: Yearly average minimum high and low temperature changed at different region in Bangla

Average Maximum Temperature

Table 3: Monthly Average Maximum Temperature from 1989-2019

Month	Jan	Feb	Mar	Apr	May	June	July	August	Sep	Oct	Nov	Dec
Northern	22.7988	26.444	30.3593	31.7433	32.2226	32.146	31.785	32.1311	31.722	30.924	28.893	25.097
Northwestern	24.0889	28.153	32.961	35.454	34.945	33.826	32.603	32.825	32.497	31.694	29.384	25.522
North Southern	25.4388	29.046	32.812	34.459	34.638	33.125	31.949	31.896	32.343	31.909	29.972	26.687
Central	24.2622	27.714	31.564	33.215	30.011	32.483	31.923	32.229	32.172	31.736	29.614	25.944
Southern	25.193	28.340	31.549	32.965	33.140	31.993	31.400	31.703	31.867	31.681	30.048	26.539
South Eastern	26.765	28.891	31.534	32.426	32.699	31.572	30.794	31.233	31.718	31.666	30.243	27.336
Eastern	25.369	28.249	31.395	32.120	31.912	31.946	32.291	32.656	32.379	31.716	29.702	28.254

Changes in Monthly Average Maximum Temperature per year during 1989-2019

Observed that the highest change of monthly average maximum temperature was found for eastern region in Bangladesh, whereas the lowest change was found for Southern region in Bangladesh during the period of 1989-2019. In the similar way of monthly average maximum temperature, got changes of monthly average minimum temperature.

Average Minimum Temperature

Table 4: Monthly Average Minimum Temperature from 1989-2019

Region	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Northern	10.695	13.638	17.681	21.188	23.314	25.174	25.852	25.998	24.994	22.295	17.136	12.698
North Western	10.743	14.111	18.822	23.278	24.777	25.997	26.195	26.305	25.779	23.338	17.941	12.994
North Southern	12.564	16.161	20.8222	24.328	25.606	26.412	26.286	26.289	25.928	23.980	19.221	14.257
Central	12.113	15.395	19.652	23.003	24.307	25.901	26.289	26.374	25.847	23.598	18.657	13.876
Southern	12.732	16.103	20.570	23.746	24.980	25.905	25.852	2.804	25.534	23.978	19.432	14.671
South Eastern	13.853	16.470	20.463	23.798	25.033	25.444	25.249	25.278	25.022	24.057	19.962	15.739

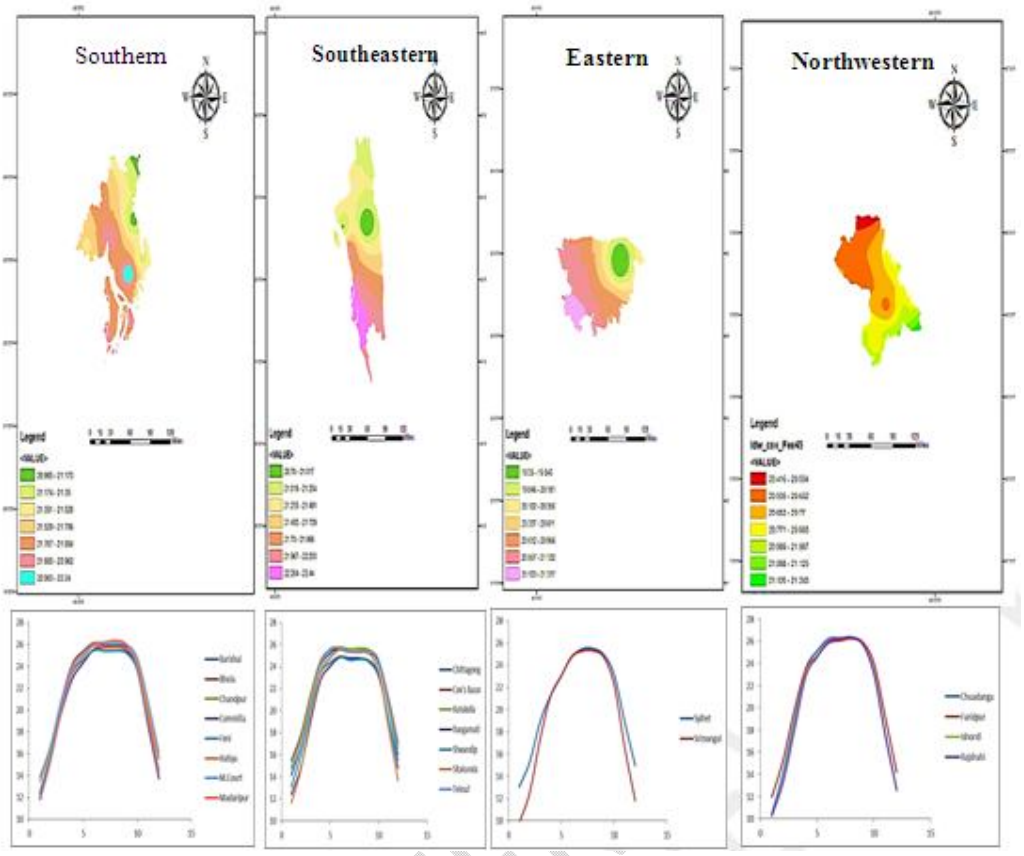
Eastern	11.426	13.914	18.179	21.291	23.054	24.789	25.391	25.013	24.875	22.737	17.795	13.393

Changes in Monthly Average Minimum Temperature per year during 1989-2019.

It is also noticed that the highest change of the monthly average minimum temperature was recorded for eastern region in Bangladesh for maximum months and the lowest changes for northern region during the period of 1989-2019.

3.4 Visualization of average maximum and minimum temperatures for all regions

Two indications of the state of the climate are temperature and rainfall. In this article, It has been displayed the mean monthly maximum and minimum temperatures as well as the typical rainfall in various parts of Bangladesh (Fig. 5(a), 5(b)). From figure 5(a), In this study period, Rajshahi, Sylhet and Dhaka all had an increase in the maximum temperature for July, and August months. In the months between September and March, the highest temperatures were in Sylhet and Chittagong. This reveals that the maximum temperatures in Sylhet, and Chittagong recent fall and winter seasons were higher. From figure 5(b), for the months of July to August, the minimum temperature in Rajshahi and Dhaka climbed. It should be noted that, with the exception of May, all other months, Sylhet minimum temperatures increased. In Chittagong, the minimum temperature rose in January, April, October, and December.



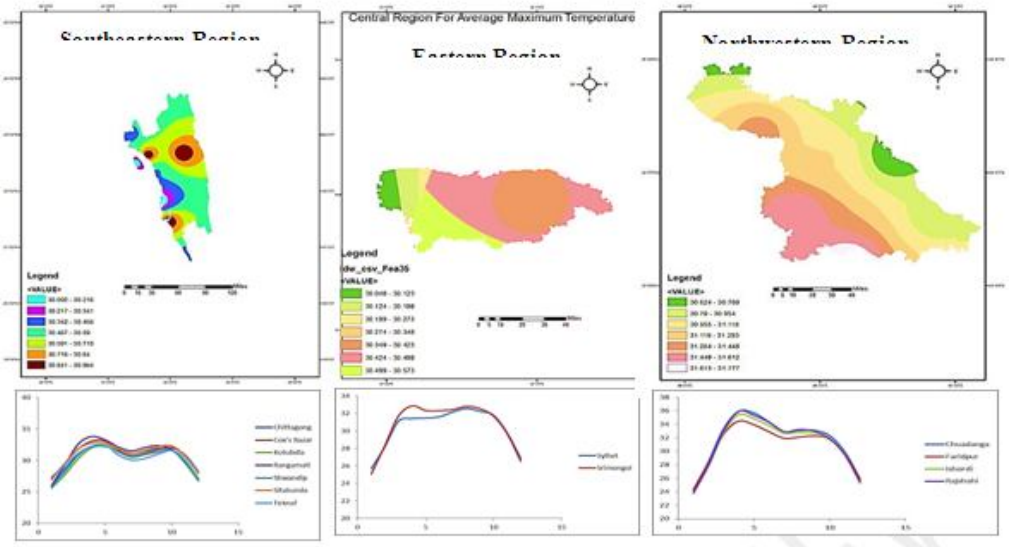
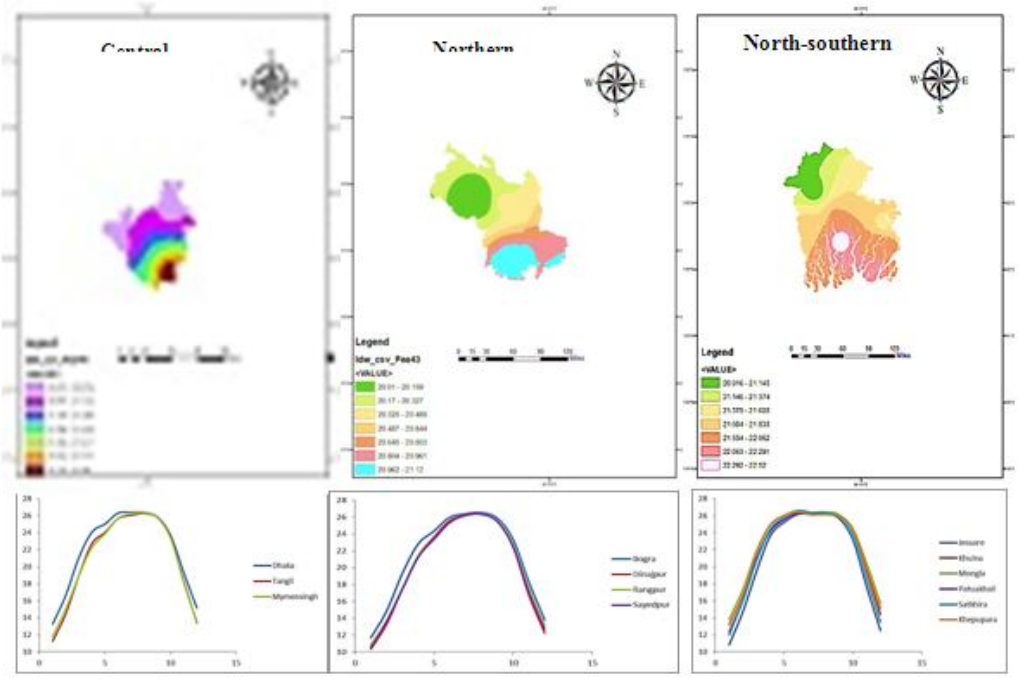
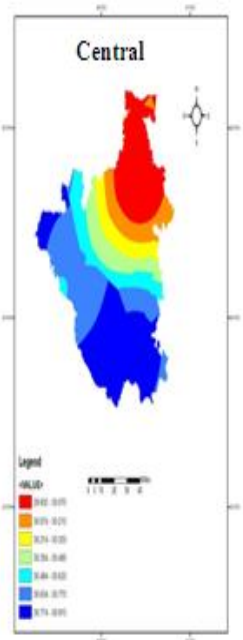


Fig 5(a): Changes in Monthly Average Maximum Temperature in 7 different regions

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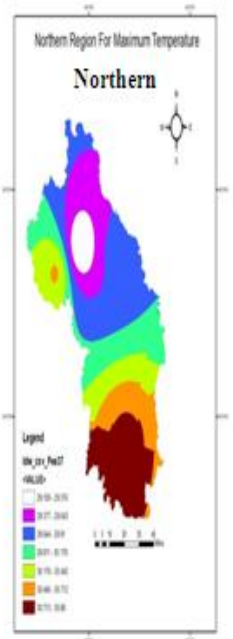
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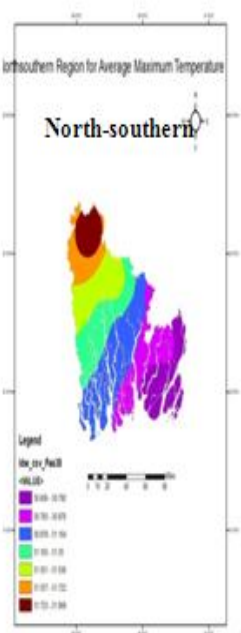
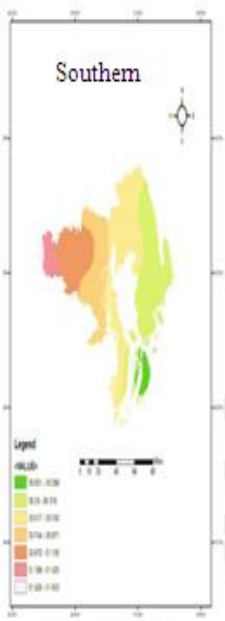
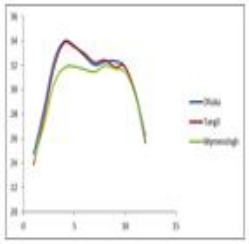
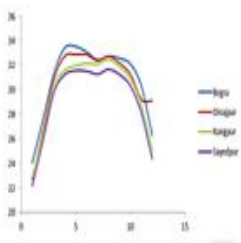
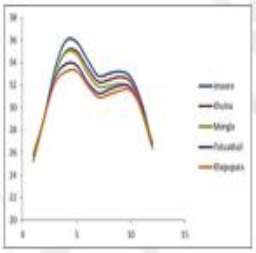

orthsouthern Region for Average Maximum Temperature
North-southern


Southern







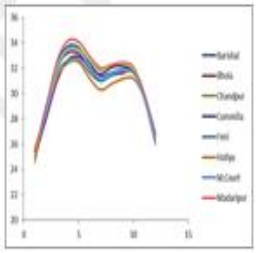


Fig 5(b): Changes in Monthly Average Minimum Temperature in 7 different regionsFrom figure 5(a, b), it is observed that the changes of average Maximum and minimum temperature in every region and the graphical visualization shows the little changes of every meteorological station of each region. It's calculates monthly average data for maximum and minimum temperature.

4. CONCLUSION: The period 1989-2019 of all 34 meteorological stations of Bangladesh the temperature and rainfall data have been analyzed. Analysis of temperature data of all stations showed that most of the stations have increasing trends of the yearly average maximum and minimum temperature. The trends of yearly average maximum and minimum temperatures have been found to be increasing year-on-year. Also showed increasing trend for all months except January, April and December; the increasing trend was particularly significant for the months February, March and June to September. Moreover, significant increase of maximum temperature was observed at eastern region for both yearly and monthly average data and northern region for minimum temperature. Analysis of rainfall data showed increasing trend of rainfall for majority of stations during monsoon and post-monsoon seasons, while decreasing trend of total rainfall during winter, pre-monsoon period did not show any significant change in total rainfall. In general, these trends are consistent with the general climate change predictions. In view of these changes, it is necessary to regularly and systematically compile, monitor and analyze the relevant climate parameters for assessing the impacts of climate change.

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