

Detection to Climate Change Characteristics in the Coastal Regions of Bangladesh: An Integrated Case Study in the Noakhali District

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Abstract: Climate change is a crucial issue and raises significant challenges in the coastal region of Bangladesh. This study examines the spatial distribution of climatic variables (temperature and rainfall) and detects the trends in the coastal district Noakhali using climatic data from 1970 to 2020 collected at M. Court and Hatiya stations, incorporating three neighboring weather stations (Sandwip, Bhola, and Feni) to enhance the spatial analysis. Trend analysis was conducted using the Mann-Kendall test and linear trend analysis methods. Spatial distribution was carried out using the interpolation method. In M. Court station, both annual minimum and maximum temperatures are increased significantly by 0.036°C and 0.057°C/year, respectively, resulting in a gradual increase of annual mean temperature (0.032°C/year). In contrast, at Hatiya station annual minimum decreased by -0.037°C/year and maximum temperatures increased by 0.027°C/year, and annual mean temperature is raised by 0.010°C per year at the 5% significant level. Linear trend analysis depicts the up warding and down warding lines of temperature and rainfall over time. There is no significant trend except July, August and October in the monthly rainfall trend analysis and annual rainfall is increasing at Hatiya. Spatial analysis shows low variability in mean temperature but an apparent variation in monthly rainfall throughout the study area. Hatiya station and surrounding areas receive more rainfall than the M. Court station area. The gradual increase of mean temperature indicates the future warmer climate in the coastal area of Bangladesh. This research would contribute to the comprehension of regional climate dynamics and facilitate planning in agricultural sector, water management and the local level.

Keywords: Temperature, Rainfall, Trends, Mann-Kendall's Test, Interpolation, Noakhali

1. Introduction

Low-income and developing countries are facing the most challenges to adverse impact of climate change. Bangladesh is a riverine country and Sothern part of this country is the coastal region. Due to its geographical location and developing economic condition, this country is disposed to climate change impact extremely on a global scale. Several studies

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focused the increased number of extreme events of climate emphasizing the distinction of inland and coastal climatic responses (Abdullah et al., 2022; Islam et al., 2019). Moreover, the monsoon precipitation pattern has been found to depend strongly on sea-surface temperature and regional topography (Fahad et al., 2022). In recent years, studies on climate change have gathered significant interest from researchers and decision-makers (Rakib, and Islam, 2017; Mondol, et al., 2019). This study aimed to analyze the distributions and variability of rainfall and temperature parameters. Examining the fluctuations in temperature and precipitation is of utmost importance for scholars and policymakers. Numerous research on the probability distribution and trends of several meteorological indicators has been conducted in Bangladesh and around the world in the past. Distribution and trend analysis are critical issues for a nation like Bangladesh that has limited resources. Similar to crop production forecasting, trend analysis, and probability distribution studies help estimate framework factors for water-based systems. (Sarker et. al., 2012), forecasting both favorable and unfavorable weather conditions, a priceless tool for helping decision-makers assess the return period and risk of most-affecting weather events like floods, droughts, cyclones, and other natural disasters so that future infrastructure needs can be fixed.

Trend analysis helps us understand how climate phenomena, such as global warming, global dimming, wetter summers, drier winters, etc., are gradually changing. (Olusina et. al. 2012; Rakib, et al., 2018). A consistent method for predicting the magnitude of frequency connections for point rainfall extremes (EP) has become more crucial due to planning in large-scale for enhanced management of land and water and growing the development of water resources (Akhter 1992). Unpredictability in the climate and changes in its parameters directly affect the ecosystem and the survival of humans. Every unfavorable shift in the climate is always accompanied by dysfunctional effects on the environment and on humans, whether locally or worldwide. Some of the disastrous repercussions of severe climate change include flooding, low agricultural output, starvation, and even death. For the purpose of evaluating environmental studies and making appropriate plans, information and knowledge regarding the parameters of variation of climate in an ecosystem are essential. As a result, it is crucial to understand the parameters of future climate variation (Olusina et. al. 2012).

For these researches, BMD and BARC data were primarily employed to measure rainfall and temperature parameters. The trend analysis and distribution patterns of several climatic indicators in the numerous weather stations of the Noakhali District were the main objectives of this extensive study. There has been statistical study of the current trend in climate change as well as future climate change scenario projection, or interpretation of climate change. This study uses BARC and BMD data from several weather station for the two climatological parameters—temperature and rainfall. By using the current rainfall and temperature data from the Bangladesh Meteorological Department (BMD) and the High Resolution Atmospheric-Ocean General Circulation Model (AOGCM), the past, present, and future climatic patterns (temperature and rainfall) of the northwest and southwest regions of the country were evaluated (Rouf et al., 2011). According to an overall analysis, Bangladesh's mean temperature has slightly increased from the previous years, but in the near and distant future Long-term trends and changes in meteorological variables,

including temperature, sunshine length, rainfall, and evaporation, were studied in a study (CCC, 2009).

Noakhali is a coastal district of Bangladesh and like other coastal district it is also highly vulnerable to climate change. Cyclone and coastal flood is the common hazard in that area. There is enormous work regarding trend analysis and spatial distribution of climatic variables in coastal area and national level. But there is no precise work for trend analysis and spatial distribution of Noakhali district precisely. The lack of understanding localized climate dynamics obstruct effective planning in agriculture, water resource and climate adaptation in that area. Besides, coastal area of Bangladesh undergone massive destruction in cyclone which intensified in climate change specially temperature raises. This study also identifies the contribution of temperature raises in coastal area. Therefore, a comprehensive study focusing the climatic variables trends in the Noakhali district to fulfillment of this gap. This study aims to identify trends and understand the distribution patterns and of climatic parameters, specifically temperature, and rainfall, in the Noakhali district. Analyzing the spatial and temporal variations of climatic data will contribute to determining the local climate dynamics in the region. The specific objectives are following below:

- a) To identify the long-term (1970 to 2020) trends and patterns in temperature, and rainfall in the Noakhali district.
- b) To analyze the spatial distribution of temperature and rainfall throughout the Noakhali.

2. Data and Methods

2.1 Study Area

Noakhali District is situated in the southeastern region of Bangladesh inside the Chittagong division. It spans a land area of approximately 4202.70 square kilometers. The district is bordered by Cumilla and Chandpur districts to the north, the Meghna estuary and the Bay of Bengal to the south, Feni and Chittagong districts to the east, and Lakshmipur and Bhola districts to the west. The absolute location of the Noakhali district: Latitude: 22.8724° N, Longitude: 91.0973° E. Noakhali is among the coastal districts of Bangladesh. It is enclosed by Comilla district to the north, the Bay of Bengal and the Meghna estuary to the south, Feni and Chittagong districts to the east, and Lakshmipur and Bhola districts to the west. The area consists of a vast expanse of flat, coastal, and deltaic regions situated on floodplain of the Meghna River delta, and is distinguished by flat ground and low relief. Diurnal tidal cycles, and tidal changes' seasonal fluctuations influence the area, being most noticeable during the monsoon season. Noakhali has a tropical climate with heavy rains most of the year and a short dry season. The average annual temperature in Noakhali is 25.6 °C (78.1 °F), and the average annual precipitation is 3,302 mm (130.0 in). May is the month with the highest temperature of the year, with an average temperature of 35.6 °C (96.08 °F). January is the month with the lowest temperature, with an average temperature of 19.5°C (67.1°F). January is the driest month, with only 8 mm (0.31 in) of precipitation. The average rainfall in July is 671 mm (26.4 in). The location of the stations is: M. Court (22°51'47.15"N, 91° 6'17.38"E) located in northern part, and Hatiya Island

(22°17'42.08"N, 91° 8'47.05"E) located in southern part of the district.

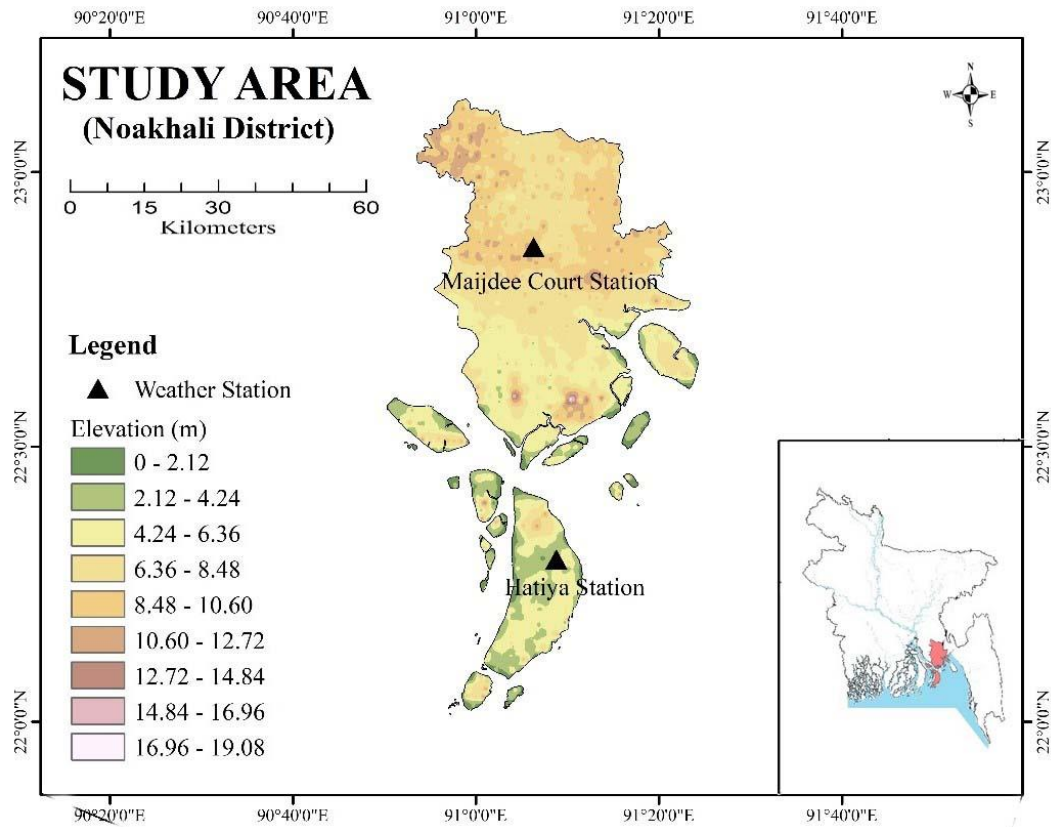


Figure 1: Study Area (Noakhali District) [Source: SRTM DEM, Prepared by Author, 2024]

2.2 Data

This study is mainly based on secondary sources of data. Monthly maximum, minimum, and mean temperature and rainfall data were collected from the Bangladesh Meteorological Station (BMD) and Bangladesh Agricultural Research Council (BARC). These data were collected from the available weather stations Maijdee Court (Station ID 41953) and Hatiya (Station ID 41963) of Noakhali district in Bangladesh with their geographical locations.

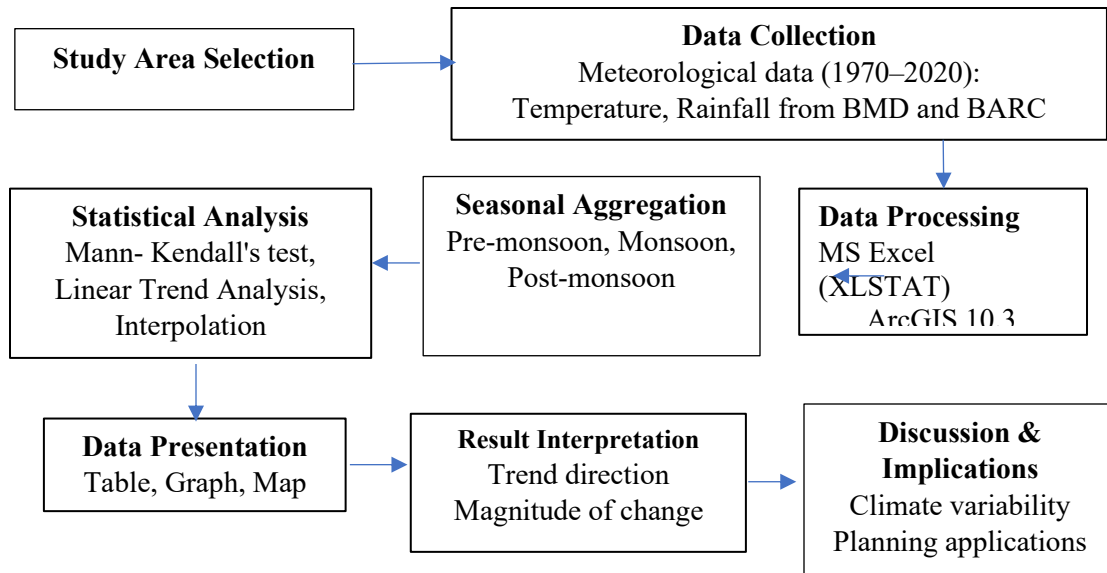


Figure 2: Methodological flow chart of this study.

Source: Compiled by Author, 2024

2.3 Methods

After collecting the climatic data, data were processed for statistical analysis to find out the climatic variability and trends in the Noakhali district. Mann Kendall Test, linear trend analysis was adopted in this study for assessing the climatic trends of the study area (Fig. 2). Similar methodological approaches were adopted by Monir et al. (2023) and Kamruzzaman et al. (2023), who applied MAKESENS, CMIP6, and other statistical models to assess rainfall and temperature trends across Bangladesh, validating the suitability of these techniques for spatio-temporal climatic analysis. Temperature and rainfall parameters both were summarized for graphing according to the categories of monthly, annually, mean, minimum, and maximum. Rainfall graphs also classified based on seasonal variations of Bangladesh. Finally, spatiotemporal distribution of the climatic conditions of the Noakhali district were mapping by interpolation method by using ArcGIS 10.3.

2.3.1 Mann Kendall Test

In this study, Mann Kendall test is used to demonstrate the significant trend denoting increase, decrease or insignificant trend of climatic variables (rainfall, temperature). To determine the importance of the trend, the absolute value of τ is compared to a critical value obtained from the standard normal distribution. The critical value is often set at $\alpha = 0.05$, which represents the chosen threshold of significance.

The Mann-Kendall test, denoted by τ , is calculated as follows:

$$\tau = \frac{\Sigma S}{n(n-1)} \quad \text{where, } \Sigma S \text{ is the sum of the signed ranks and } n \text{ is the number of data points.}$$

The signed rank: $s = \text{sign}(x_i - x_j)$

where, x_i and x_j are the values of the data points at times i and j , respectively and $\text{sign}(x)$ is the sign function, which is +1 for positive values of x , 0 for zero values of x , and -1 for negative values of x (Table 1).

Table 1: Interpreting the Mann-Kendall Test Statistic

Kendall's τ	Significant or not	Trend
$\tau > 0$	Statistically significant	Upward trend
$\tau < 0$	Statistically significant	Downward trend
τ is close to 0	Not significant	No trend

Source: Compiled by Author, 2024

p-value: It indicates the detected trend is significant or no significant trend. If $p \leq 0.05$ the trend is significant and $p > 0.05$ the trend is not significant.

Sen's Slope: It measures the changing rate (magnitude) in per unit time. Like, yearly increase or decrease of temperature.

2.3.2 Linear Trend Analysis

Linear trend analysis is used to identify the inclination or reduction of annual and monthly temperature and rainfall for each year and also denotes whether these changes are significant or not. In linear trend analysis, the line showing the relationship between the dependent variable (year) in the x-axis and the independent variable (temperature and rainfall) crosses the y-axis. The formula $Y = mx + c$ calculates the intercept and slope of climatic data. Where 'm' denotes the fluctuation rate in the climatic variable (y-axis) when the year (x-axis) is incremented by one unit and 'c' is the intercept of the independent variable it takes when the independent variable is set to zero.

2.3.4 Interpolation

In the Noakhali district, there are only two stations that are located in M. Court and Hatiya. But for spatial distribution, there needs to be at least 3 points to demark the area. For more accuracy, there are 3 nearest stations from outside these are located in the Bhola, Feni, and Sandwip added for spatial distribution. These 3 stations show more accurate data for our study area and proper data was found to analyze the spatial distribution of the study area. This method is known as interpolation where for achieving the accurate data of the study area, the data from outside are taken in grant by the IDW (Inverse distance weighting)

method of ArcGIS. The interpolation method IDW is denoted by a spatial autocorrelation test.

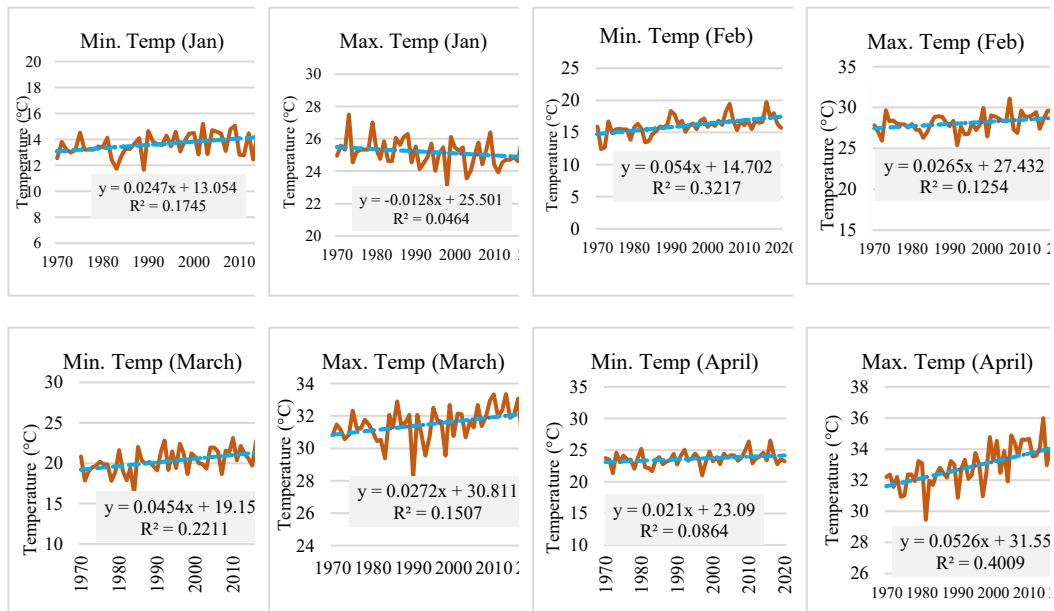
3. Results

3.1 Trend Analysis of Temperature

To assess long-term patterns and variability in temperature across the Noakhali District, a Mann-Kendall trend analyses were conducted on monthly and annual minimum, maximum, and mean temperatures using data from 1970 to 2020.

At M. Court Station: In the figure 3, linear trend analysis depicts statistically significant upward trends of monthly minimum and maximum temperatures for most of the months at M. Court station. In December and January, the maximum temperature is remained in downward movement.

In The Table 2, January maximum, April minimum and December maximum temperature has no significant trend. In minimum temperature, the Sen's slope calculation also calculates the significantly rising rate of minimum temperature which is observed in February ($0.045^{\circ}\text{C}/\text{year}$), March ($0.043^{\circ}\text{C}/\text{year}$), December ($0.043^{\circ}\text{C}/\text{year}$), and July ($0.33^{\circ}\text{C}/\text{year}$) are mentionable. Robust increasing trends is identified by low p-values ($p < 0.0001$) and Positive Kendall's τ values. From the overall trend analysis, it is underscored that statistically temperature increasing pattern is revealed significantly over the M. Court station of Noakhali which means the evidence of longer-term climatic variability's changes.



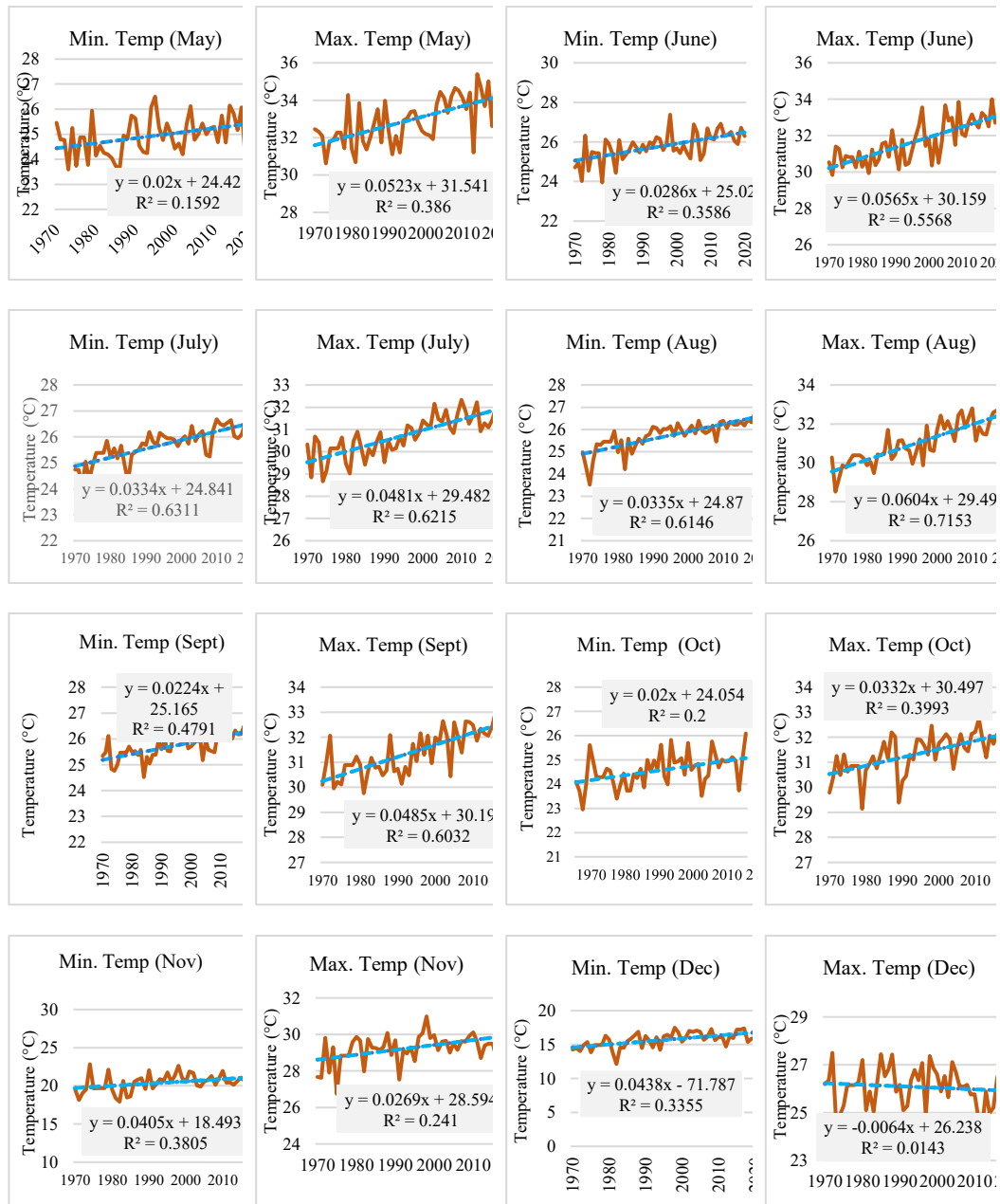


Figure 3: Linear trend for monthly minimum and maximum temperature at M. Court station.

Source: BARC, Compiled by Author, 2024

Table 2: Mann Kendall's test statistics of the monthly minimum and maximum temperature of M. Court station.

Month	Kendall's τ		Scores (S)		p-value (Two-tailed)		Sen's Slope		Trend	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Jan	0.305	-0.155	388	-197	0.002	0.111	0.03	-0.012	Increasing	No significant
Feb	0.411	0.235	523	299	<0.0001	0.015	0.045	0.235	Increasing	Increasing
March	0.303	0.298	386	379	0.002	0.002	0.043	0.026	Increasing	Increasing
April	0.168	0.468	214	596	0.084	<0.0001	0.015	0.05	No significant	Increasing
May	0.265	0.428	337	545	0.006	<0.0001	0.022	0.057	Increasing	Increasing
June	0.406	0.542	517	691	<0.0001	<0.0001	0.027	0.056	Increasing	Increasing
July	0.628	0.606	799	771	<0.0001	<0.0001	0.033	0.049	Increasing	Increasing
Aug	0.676	0.667	856	847	<0.0001	<0.0001	0.028	0.059	Increasing	Increasing
Sept	0.549	0.55	696	699	<0.0001	<0.0001	0.023	0.05	Increasing	Increasing
Oct	0.344	0.458	437	583	0	<0.0001	0.02	0.032	Increasing	Increasing
Nov	0.286	0.309	364	393	0.003	0.001	0.031	0.023	Increasing	Increasing
Dec	0.394	-0.091	502	-116	<0.0001	0.35	0.043	-0.006	Increasing	No significant

Source: BARC, Compiled by Author, 2024

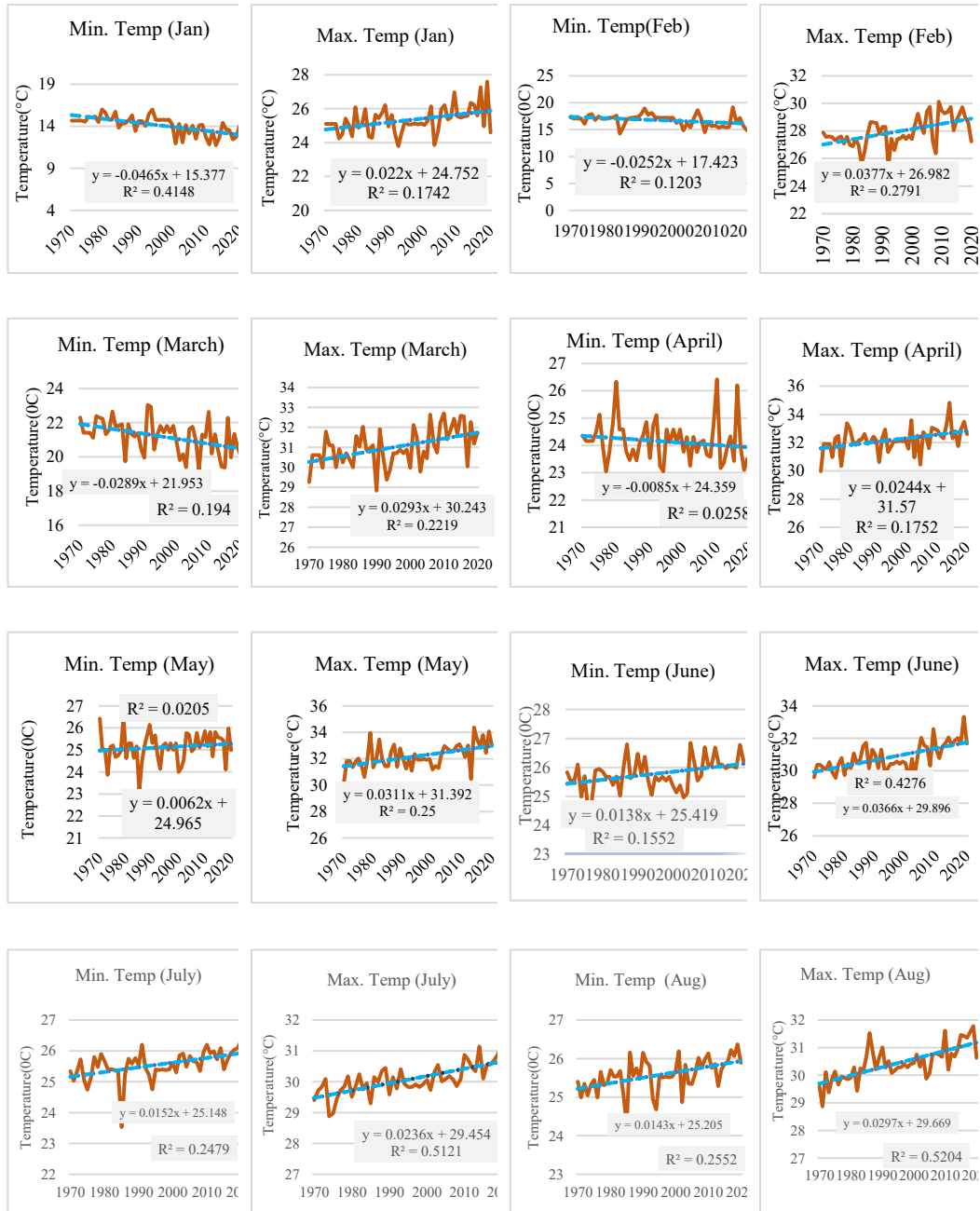
At Hatiya Station: In the figure 4, linear trend analysis depicts a significant increasing trend of monthly maximum temperatures of the months at Hatiya station. Besides, From October to April has down ward trend in minimum temperature. That's denotes the decrease of minimum temperature at Hatiya station.

From Table 3, Mann-kendall's test result shows only October has no significant trend in minimum temperature, others have statistically significant upward or down ward trend. Minimum temperature decreases ranges from $-0.013^{\circ}\text{C}/\text{year}$ to $-0.406^{\circ}\text{C}/\text{year}$. The notable temperature decreases in November ($-406^{\circ}\text{C}/\text{year}$) and March ($-313^{\circ}\text{C}/\text{year}$). MK Test results also confirming these warming scenarios where 0.037°C , 0.037°C , 0.036°C and 0.033°C temperature has increasing rate observed in February, September, June, and May respectively in maximum temperature. Overall, it is notable that at the Hatiya station climatic trend has shift scenario where minimum temperature decreasing but maximum temperature trend is up warding sharply. These results reflect a slightly warming trends of temperature in the district.

Table 3: Mann-Kendall's test statistics of monthly minimum and maximum temperature of Hatiya station.

Month	Kendall's τ		Scores (S)		p-value (Two-tailed)		Sen's Slope		Trend	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Jan	-0.455	0.307	-576	389	<0.0001	0.002	-0.039	0.024	Decreasing	Increasing
Feb	-0.256	0.326	-324	414	0.009	0.001	-0.025	0.037	Decreasing	Increasing
March	-0.313	0.316	-397	401	0.001	0.001	-0.313	0.029	Decreasing	Increasing
April	-0.191	0.337	-242	428	0.05	0.001	-0.013	0.021	Decreasing	Increasing
May	0.153	0.382	194	485	0.117	<0.0001	0.009	0.033	Increasing	Increasing
June	0.238	0.466	302	590	0.014	<0.0001	0.011	0.036	Increasing	Increasing
July	0.416	0.536	526	680	<0.0001	<0.0001	0.014	0.023	Increasing	Increasing
Aug	0.404	0.569	512	721	<0.0001	<0.0001	0.014	0.029	Increasing	Increasing
Sept	0.341	0.521	429	661	0	<0.0001	0.012	0.037	Increasing	Increasing
Oct	-0.076	0.385	-96	488	0.44	<0.0001	-0.005	0.024	No Significant	Increasing
Nov	-0.406	0.414	-514	525	<0.0001	<0.0001	-0.406	0.031	Decreasing	Increasing
Dec	-0.374	0.378	-472	479	0	0	-0.034	0.03	Decreasing	Increasing

Source: BARC, Compiled by Author, 2024



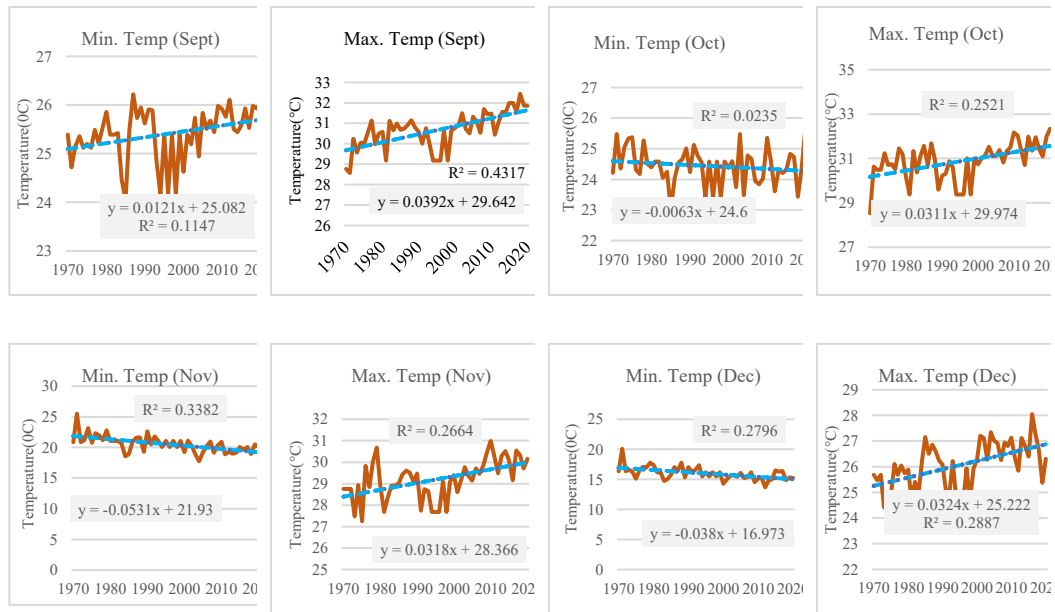


Figure 4: Linear trend for monthly minimum and maximum temperature at Hatiyastation.

Source: BARC, Compiled by Author, 2024

Figure 5 concisely present the linear trends observed in the yearly minimum, maximum, and mean temperatures for the M. Court and Hatiya station. All three temperature variables show statistically significant variations at a significance level of 5%. All the temperature figure has upward movement excluding Minimum temperature of Hatiya station, it is gradually decreasing $-0.0454^{\circ}\text{C}/\text{year}$.

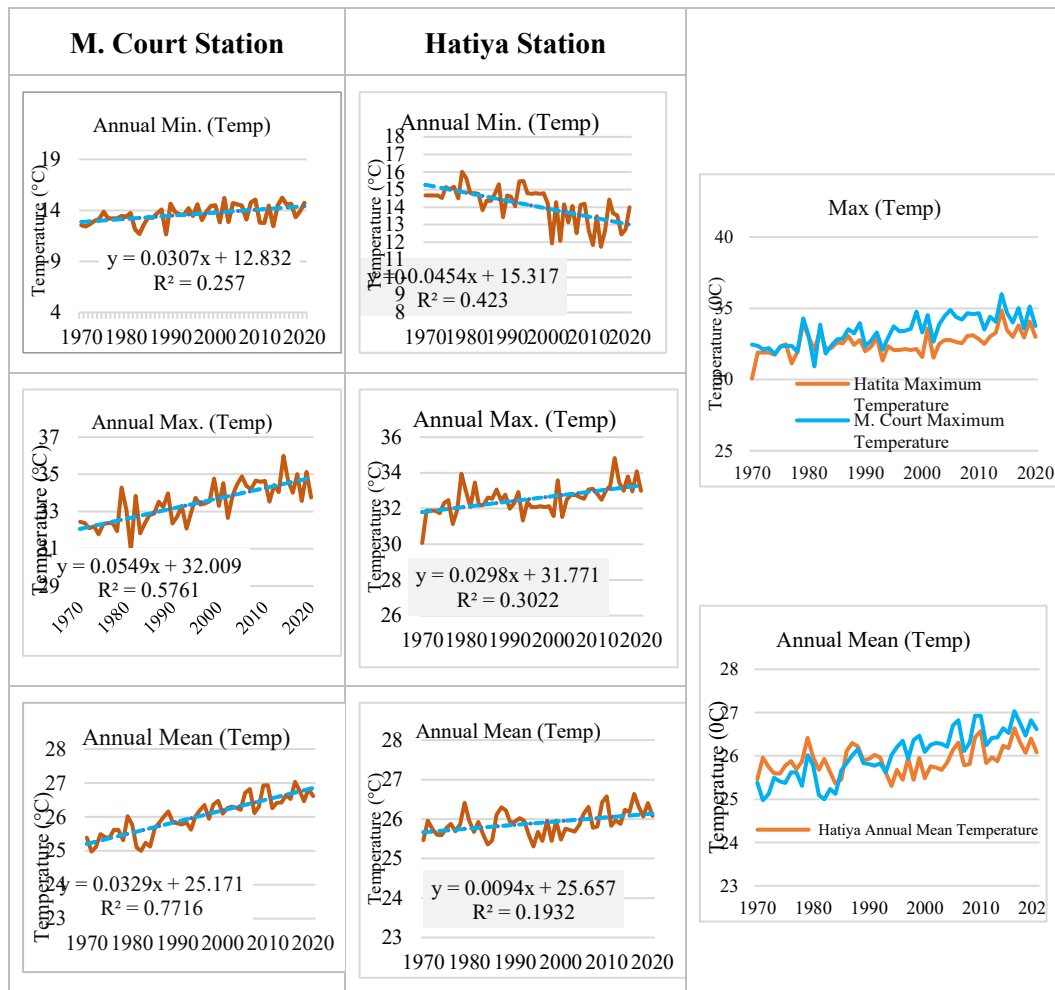


Figure 5: Linear trend for annual minimum, maximum, and mean temperature at M. Court and Hatiya station and comparison between both stations' annual temperature.

Source: BARC, Compiled by Author, 2024

3.2 Trend Analysis of Rainfall

From 1970 to 2020 rainfall data analysis, most of the months do not exhibit statistically significant trends in precipitation at the M. Court and Hatiya station (Figure 6). However, July, August and October show notable upward trends while October records the most substantial increase with a Sen's slope 4.05 mm/year, July increased by 3.643 mm/year, and August 3.42 mm/year. June also suggests a potential increasing trend with a Sen's slope of 2.174 mm/year, although it is not statistically significant. Overall, rainfall pattern is shown a declining trend with a complex pattern which indicate localized climatic variability over long-term and within two area Hatiya received more rainfall than M. court.

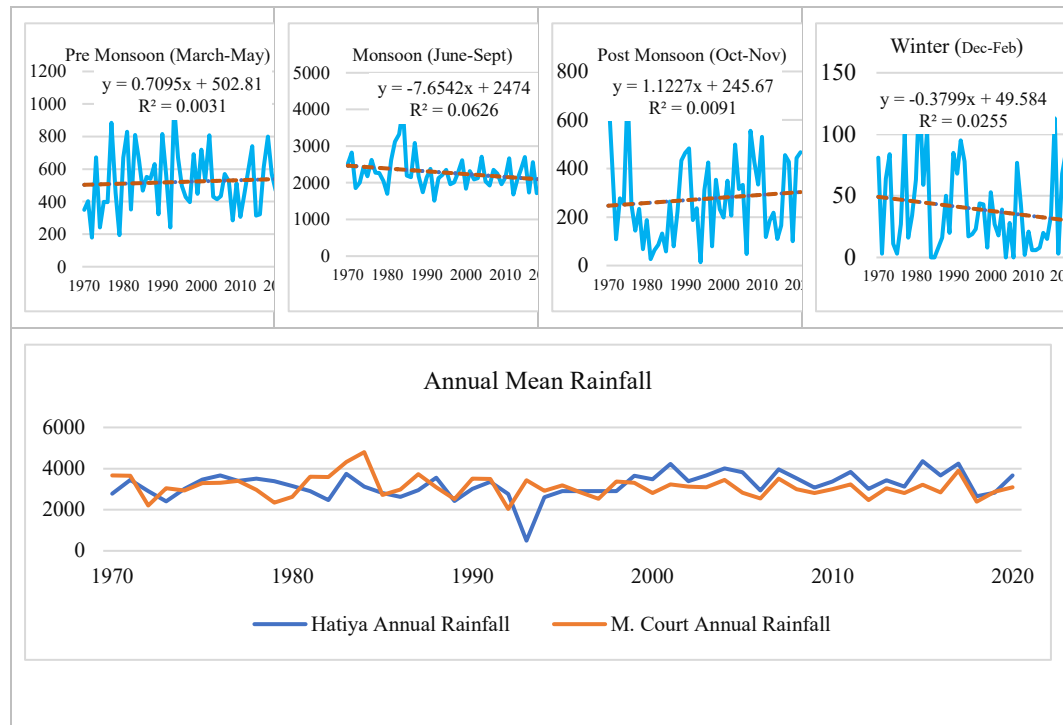


Figure 6: Trend for seasonal rainfall in Hatiya station and M. Court.

Source: BARC, Compiled by Author, 2024

Table 4: MK TEST for Monthly Rainfall (M. Court Station and Hatiya Station)

Month	Kendall's tau		Scores (S)		p-value (Two-tailed)		Sen's slope		Trend	
	M. Court	Hatiya	M. Court	Hatiya	M. Court	Hatiya	M. Court	Hatiya	M. Court	Hatiya
Jan	-0.109	0.009	-117	8	0.945	0.306	0	0	No significant	No significant
Feb	-0.076	-0.144	-94	-173	0.156	0.447	-0.057	-0.04	No significant	No significant
March	0.025	-0.058	32	-72	0.563	0.801	-0.045	0.053	No significant	No significant
April	0.003	-0.041	4	-51	0.684	0.981	-0.079	0.065	No significant	No significant
May	0.044	0.014	56	18	0.89	0.655	0	0.581	No significant	No significant
June	-0.052	0.11	-66	139	0.262	0.598	2.174	-1.038	No significant	No significant
July	-0.11	0.214	-140	270	0.029	0.259	3.643	-2.136	Increasing	No significant
Aug	-0.195	0.011	-249	14	0.916	0.044	0	3.423	No significant	Increasing
Sept	-0.003	0.078	-4	99	0.425	0.981	0.75	-0.027	No significant	No significant
Oct	0.156	0.274	199	345	0.005	0.108	4.056	2.421	Increasing	No significant
Nov	-0.18	-0.136	-223	-168	0.172	0.069	-0.344	-0.4	No significant	No significant
Dec	-0.051	-0.087	-53	-97	0.411	0.639	0	0	No significant	No significant

Source: BARC Data, Compiled by Author, 2024

4. Spatiotemporal Distribution of Temperature and Rainfall

From the figure 7, it is seen that the spatio-temporal distribution of temperatures varies monthly in both M. Court and Hatiya areas. This interpolation method (IDW) used the mean temperature of every month of five weather stations. Thus, the spatial distribution depicts the mean monthly temperature. Higher temperature is visible in the southern part of the study areas and comparatively lower temperature recorded in the northern to the central part of this region. Overall, temperature variation is comparatively moderate across the region. In summer season northern part of the district remains warmer than southern part. In winter season southern part remains warmer than northern part.

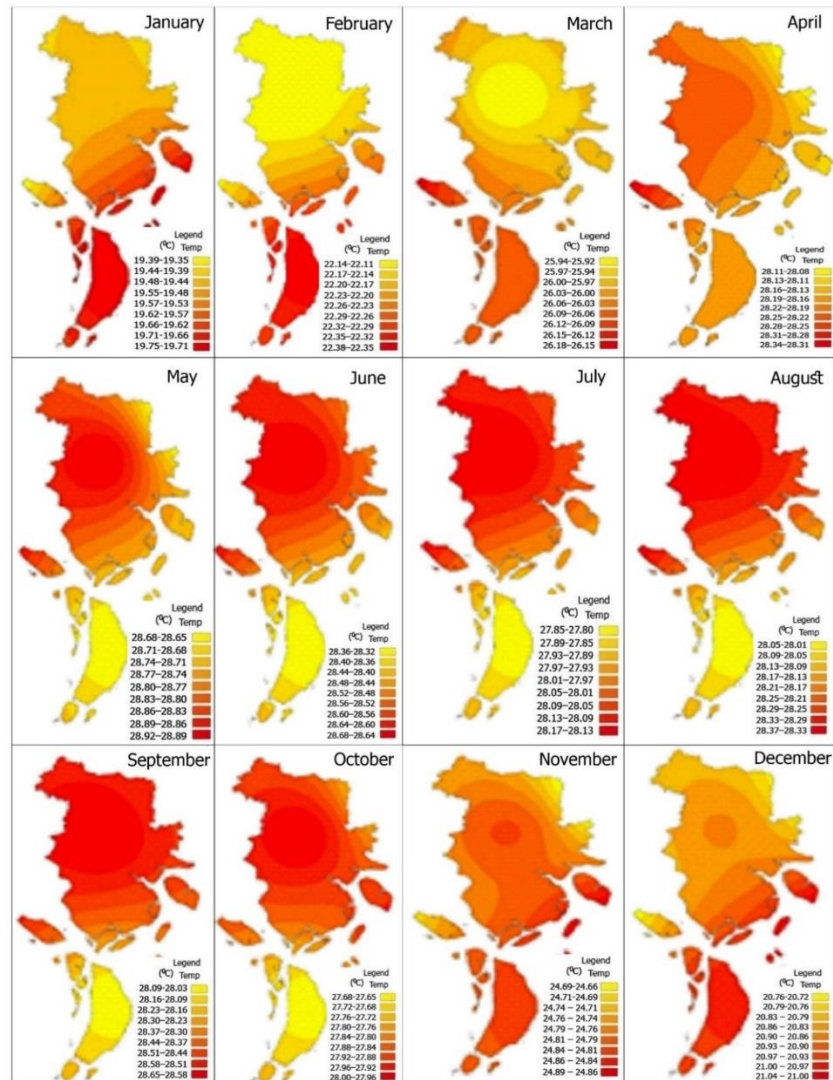


Figure 7: Spatiotemporal distribution of temperature.

Source: BARC, Compiled by Author, 2024

In case of rainfall, the average monthly rainfall of multi-year recorded and measured in millimeters which demonstrates a distinct seasonal pattern in the study area. The figure 8 demonstrates the detailed spatio-temporal analysis of rainfall pattern and confirming the changing scenario of rainfall across the study area. Rainfall in this study area depicted a distinct variation seasonally over the years and concentrated high in the south and southeastern areas with a major shift. Rainfall is higher during the monsoon season rather to pre-monsoon and post-monsoon period while even distribution of rainfall is experienced during the monsoon.

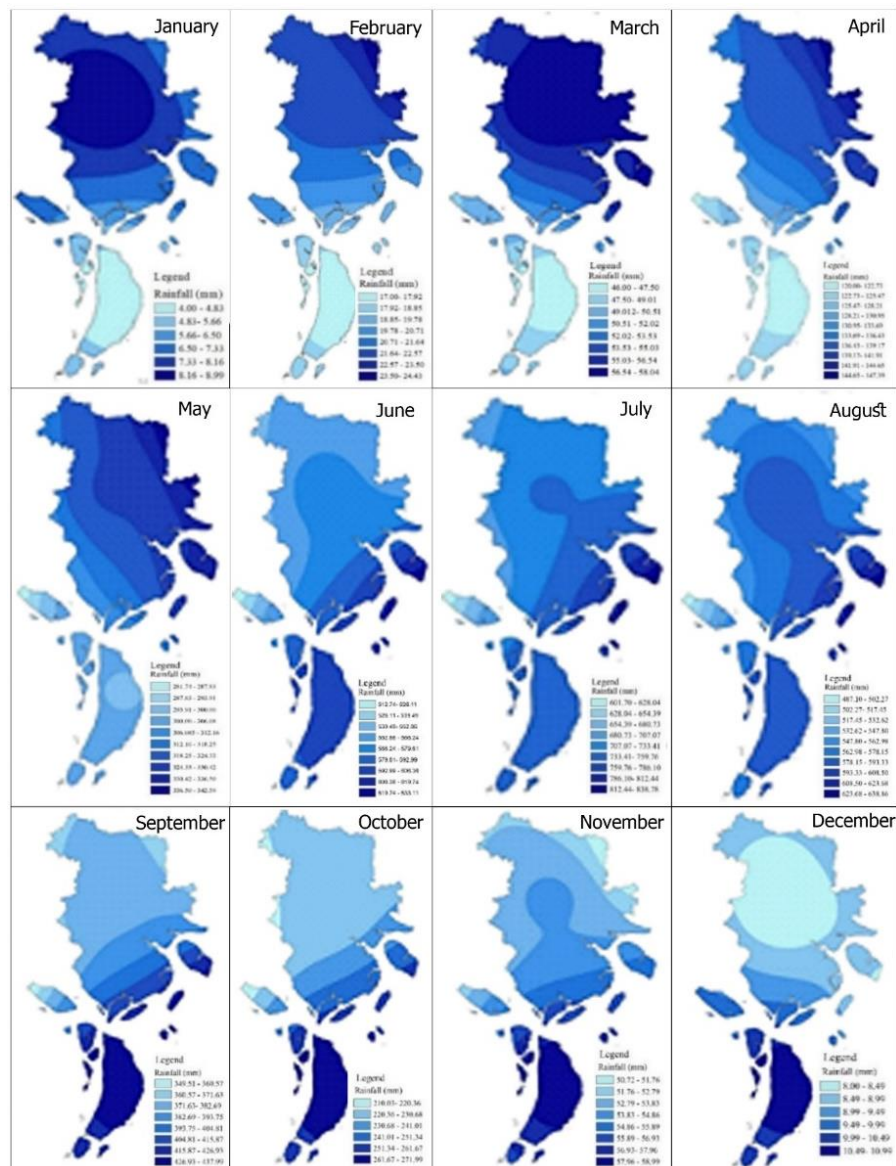


Figure 8: Spatiotemporal distribution of rainfall. Source: BARC, Compiled by Author, 2024

4. Discussion

Climatic trend analysis from 1981 to 2020 of Noakhali district demonstrate that temperature has increasing trend significantly both in M. Court and Hatiya station (Table 5 & 6). Sharply increasing rate is found at M. Court station while Hatiya station also exhibits mean annual upward trend. Mann-Kendall test and Sen's slope result confirming the up-warding trends of temperature. Thus, trend analysis confirming significant spatio-temporal variation of temperatures and long-term changes (Fig. 9). Similarly, annual rainfall trend also shows increasing pattern in Hatiya. Rainfall varies across individual moths and seasons. During the monsoon rainfall evenly distributed across the region whereas higher rainfall concentration recorded during the pre-monsoon season. Contrast to M. Court station, Hatiya receives a comparatively higher rainfall concentration and annual precipitation ranges vary from 2700mm to 3,430mm.

Table 5: Mann Kendall's test of the annual temperature of M. Court and Hatiya station.

Variable	Kendall's τ		Scores (S)		p-value		Sen's Slope		Trend	
	M court	Hatiya	M court	Hatiya	M court	Hatiya	M court	Hatiya	M court	Hatiya
Min Temp	0.374	-0.456	476	-577	0.000	<0.0001	0.036	-0.037	Increasing	Decreasing
Max Temp	0.569	0.423	724	536	<0.0001	<0.0001	0.057	0.027	Increasing	Increasing
Mean Temp	0.708	0.304	903	387	<0.0001	0.002	0.032	0.010	Increasing	Increasing

Source: BARC, Compiled by Author, 2024

Table 6: MK TEST for Seasonal and annual Rainfall

{	Kendall's τ		Scores (S)		p-value		Sen's slope		Trend	
	M court	Hatiya	M court	Hatiya	M court	Hatiya	M court	Hatiya	M court	Hatiya
Pre-Monsoon	0.046	-0.006	59	-8	0.638	0.955	1.071	0.000	No sign.	No sign.
Monsoon	-0.166	0.187	-211	237	0.088	0.055	-6.279	10.538	No sign.	No Sign
Post Monsoon	0.105	-0.146	134	-184	0.280	0.136	1.900	-0.837	No sign.	No sign.
Annual	-0.139	0.210	-177	266	0.153	0.031	-7.091	10.379	No sign.	Increasing

Source: BARC, Compiled by Author, 2024

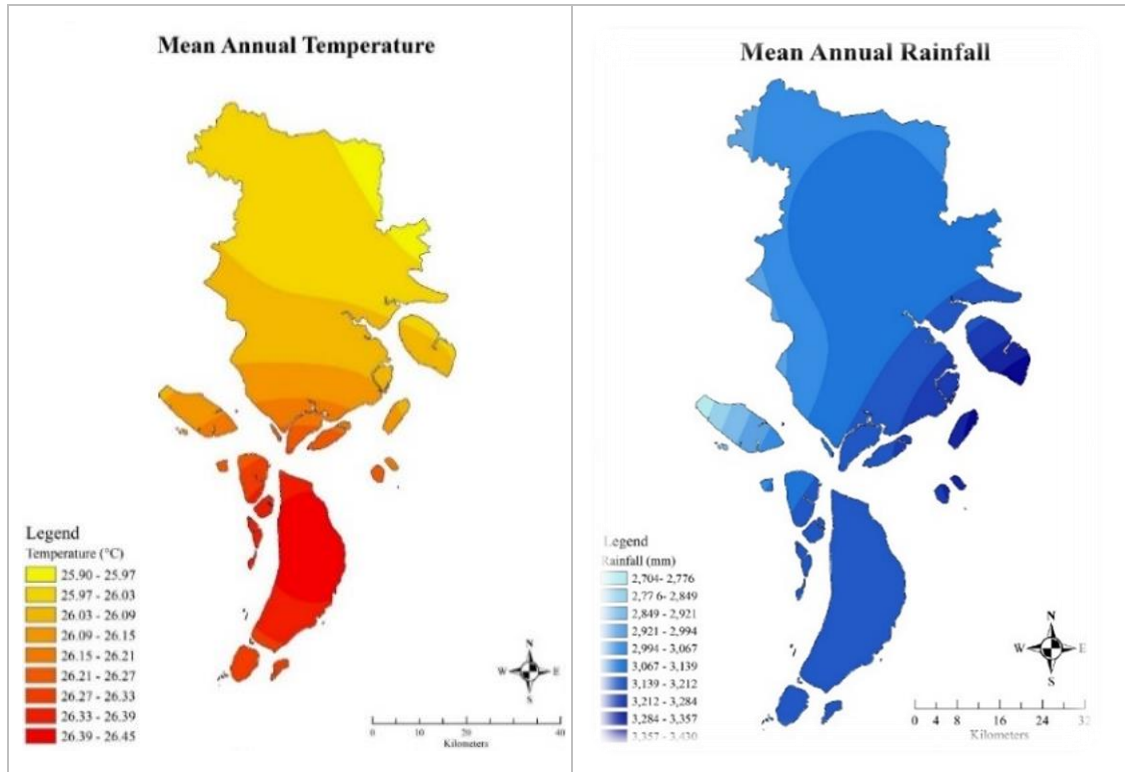


Figure 9: Spatiotemporal distribution of mean annual temperature and rainfall.

Source: BARC, Compiled by Author, 2024

This study result of maximum temperature increasing trend of the pre-monsoon and post-monsoon seasons has similar patterns in other regions of South Asia which aligns with global and regional temperature trends of the IPCC report 2021 (Basak et al., 2010; Klein Tank et al., 2006; Turner and Annamalai, 2012). This finding also aligns with high-resolution projections under CMIP6 which forecast that summer monsoon temperature and rainfall intensity in Bangladesh is significantly increasing (Bhattacharjee et al., 2023). The seasonal analysis that changing temperature and precipitation are sensitive to agricultural regions (Alam et al. 2023; Rahman et al., 2012). Moreover, climatic variability has diverse impact on agricultural activities, sub-climatic zone and spatio-temporal climatic variation is found across the Bangladesh (Bari et al., 2016; Rahman et al., 2023; Sheikh et al., 2015; Saha et al., 2020). Overall, the study findings recommend that localized climate adaptation strategies are essential for long-term climatic variability and warming patterns particularly during non-monsoon seasons, because irrigation demands could increase and alter crop calendars which can elevate the risk of heat waves.

5. Conclusion

This study investigated the trend of climatic elements like temperature and rainfall in the Noakhali District of Bangladesh over a span of 50 years. The overall analysis revealed that this study found distinct climatic variability in both stations. Statistical analysis, the Mann-Kendall test, Sen's slope, and linear trend analysis with spatial distribution indicate a significant upward trend of the annual maximum and mean temperature in M. Court and Hatiya. Although there was a downward trend of minimum temperature in Hatiya. This significant up warding mean temperature marks the gradual warming situation in the coastal area of Bangladesh. Relatively, the absence of a significant trend of rainfall intensity is observed in the M. Court station, in contrast to the Hatiya station, and its surrounding area received higher rainfall than the M. Court station. Moreover, monthly temperature and rainfall have different scenarios where almost every month in temperature has significant changes, but in rainfall, most months exhibit no significant changes.

As the study region is evolving to spatio-temporal climatic variability, there should be effective planning in agricultural activities, water management, and climatic resilience. Though this study is based on small coastal area and monthly temperature basis, this methodology provides an applicable framework for the entire coastal regions of Bangladesh, and for further studies, long term daily additional climatic data would be preferable for the comprehensive observation of climate change as well as to assess and mitigate the future impacts.

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