EVALUATING DECADAL SHIFTS AND FLUCTUATION IN MEAN TEMPERATURE: A STUDY ON BANGLADESH'S CHANGING CLIMATE BY USING GIS TECHNOLOGY

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Abstract

The climate is changing because of global warming. It is crucial to assess how much change has occurred during a certain period. Based on quantitative data, this study shows the decadal change in mean temperature of Bangladesh. The study focuses on spatial distribution of numerical temperature changes. Atmospheric temperature data have been collected from Bangladesh Meteorological Department (BMD). Mean is calculated from daily observed temperature data with MS Excel. Later mean data have been taken to ArcGIS 10.8 software for interpolation to understand the spatial distribution with IDW tool. Using the 42-year mean value and the latest year's mean value, the percentage is calculated to know about the fluctuation. From the findings, in every station the mean maximum and minimum temperatures increased by 0.5°C and 0.39°C respectively, within four decades. The maximum mean temperature increased by 4.62%, which was the highest change around Kutubdia and Sandwip. Apart from Chuadanga, Satkhira, and Madaripur, practically every region's maximum temperature is rising at a different rate. Increase in decadal mean maximum temperature is found in hilly (Chittagong, Sitakundo) and coastal (Cox's Bazar, Patuakhali, Shundarbans) regions almost 2.75% which is an indicator of climate change. In comparison to nearby areas, the maximum temperature is significantly higher in northern areas such as Rangpur, Saidpur about 3.75%. With a projected 2.5% increase in mean maximum temperature and a 5.28% increase in mean minimum temperature, Dhaka has the highest increase in minimum temperature. Dinajpur, and Chittagong's mean minimum temperatures are also rising and range from 3.46% to 4.5%. Near the coastal areas, it is found that there is a decrease in maximum mean temperature (Patuakhali, Mongla, Hatiya, Bhola, Kutubdiya) but an increase in minimum mean temperature. This 42-year period decadal study on temperatures change can significantly contribute to our country's climate change policies.

***Keywords**: Climate change; Decadal; Spatial distribution; Temperature; GIS; Bangladesh.*

1 Introduction

Climate change refers to long-term shifts and alterations in temperature, precipitation patterns, and other aspects of the Earth's climate system. The term is often used to describe the recent and ongoing trends in global warming and related changes. Climate is the average state of the atmosphere over a period of 30 to 40 years, considering factors such as temperature, precipitation, humidity, wind, cloud cover, and barometric pressure (Rashid, 2019). So, climate change refers to significant and lasting changes in the average temperature and weather patterns of the Earth over extended periods, typically decades to millennia. It encompasses both natural variations and human-induced changes. A warming globe has ramifications for weather systems, hydrology, ecosystems, and the environment (Rahman & Lateh, 2016). Changes primarily resulting from activities such as burning fossil fuels, deforestation, and industrial processes, leading to increased levels of greenhouse gases in the atmosphere. This is often associated with global warming and impacts such as rising sea levels, more frequent extreme weather events, and shifts in ecosystems. Variations in climate that occur due to natural processes, such as volcanic eruptions, changes in solar radiation, or natural climate cycles like El Niño and La

Niña. Climate change is being caused by humans, which is already having a large impact on our daily lives (Easterling, et al., 2000). Although there are many aspects to the subject of climate change, at least one of them, the shifting patterns of temperature around the world, needs urgent and methodical consideration (Dore, 2005). Heat-trapping greenhouse gas concentrations are rising in the Earth's atmosphere (Islam, Almazroui, Dambul, Jones, & Alamoudi, 2015). As a result, average Earth surface temperatures are rising, and this trend is anticipated to continue (Fei Ji, Huang, & Chassignet, 2014). The global average surface temperature has risen by approximately 0.6° over the 20th century, and there is evidence that the warming in the second half of the 20th century is mostly due to human activity (Qian & Qin, 2006). As of 2023, the global average surface temperature has risen by approximately 1.2°C (about 2.2°F) above pre-industrial levels, which are typically considered to be the late 19th century baseline, around 1850-1900. This warming is primarily attributed to human activities, particularly the emission of greenhouse gases such as carbon dioxide (CO_2) and methane (CH_4), which trap heat in the atmosphere. The 1.2°C increase reflects a significant and ongoing trend in global warming, with 2023 being one of the warmer years on record. The rise in temperature has been associated with a range of impacts, including more frequent and intense heatwaves, changing precipitation patterns, and accelerated melting of ice and glaciers. Temperature affects humidity, which in turn affects the potential for precipitation (YIN & SUN, 2018). The supply of freshwater for agriculture and energy is immediately impacted by climatic changes in glacier-fed stream flow regimes (Sorg, Bolch, Stoffel, Solomina, & Beniston, 2012).

Bangladesh is a country highly susceptible to climate variability due to its geographic location, low-lying topography, and high population density. With a population of over 160 million people and extensive agricultural and coastal communities, even minor fluctuations in climate can have profound effects on livelihoods, economic stability, and environmental health. Over recent decades, there has been growing concern about how climate patterns are shifting on a decadal scale and what these changes mean for Bangladesh's future. Despite various studies on climate change, there is a need for a focused examination of decadal changes in climate variability specific to Bangladesh. Many studies provide snapshots of climate data without a comprehensive analysis of how variability has evolved over the past decades. Understanding decadal trends requires detailed, long-term datasets to identify significant shifts in climate patterns. There is limited research on how decadal climate variability affects in Bangladesh. Bangladesh experiences diverse climatic conditions across its regions, from the coastal areas to the northwestern and northeastern highlands. Understanding how decadal climate variability affects different regions differently is crucial for targeted interventions. The study uses a combination of historical climate data analysis. Data has been sourced from meteorological stations, satellite observations, and existing research. Statistical and computational tools, and GIS (Geographic Information System) have been employed to identify trends and develop predictive maps. By addressing these problems, the study aims to provide a comprehensive understanding of decadal climate variability in Bangladesh and its implications for the country's future.

Bangladesh is expected to be among the most vulnerable countries to climate change (Ali, Climate change impacts and adaptation assessment in Bangladesh, 1999). Over the previous three decades, Bangladesh has seen greater temperatures and more frequent droughts (Sarker, Alam, & Gow, 2012). The rise in minimum temperature relative to maximum temperature is insufficient to make a major shift in Bangladesh's average diurnal temperature range (Shahid, Harun, & Katimon, 2012). Has the temperature over the Bangladesh region changed as a result of climate change? Such a question is crucial today because the area has been dealing with various environmental problems over the past few decades. Bangladesh is one of the most climate-vulnerable countries in the world due to its geographic location, low-lying deltaic terrain, and high population density. Research has long demonstrated that climate change has accelerated the hydrological cycle (Djamil, 2008). Understanding decadal changes in climate variability helps in addressing this vulnerability by providing insights into how climate patterns are shifting over time. Agriculture is a cornerstone of Bangladesh's economy and a major source of livelihood for millions. Decadal changes in temperature can significantly impact crop yields and food production (Viner, 2022) . Research can help farmers adapt to these changes, ensuring food security and stabilizing agricultural output. Water resources are crucial for agriculture, industry, and daily life. Understanding long-term climate variability allows for better forecasting and management of water resources,

helping to mitigate the impacts of droughts, floods, and changing precipitation patterns (IPCC, 2022). Bangladesh's extensive coastline is particularly vulnerable to sea-level rise and coastal erosion. By studying decadal climate trends, the research can improve the design and implementation of coastal protection measures, reducing the risk of flooding and protecting coastal communities. Bangladesh frequently faces extreme weather events such as cyclones and floods (Ahmed, Hasan, Pongsiri, & Szabo, 2020). A deeper understanding of decadal climate variability can enhance early warning systems and disaster preparedness, enabling quicker and more effective responses to climate-related emergencies. Different regions of Bangladesh experience climate impacts differently. This research can provide detailed insights into regional climate patterns, allowing for more targeted and effective adaptation strategies that address local needs and conditions. Effective adaptation and management strategies informed by decadal climate variability can reduce the economic costs associated with climate change, including damage to infrastructure, loss of agricultural productivity, and increased disaster recovery expenses. Policymakers require reliable data to create effective climate policies and strategies (WMO, 2023). Research on decadal climate changes provides the evidence needed to develop robust policies that address both current and future climate challenges. By understanding long-term climate trends, communities can be better prepared and equipped to adapt to changing conditions. This strengthens overall community resilience, improves livelihoods, and reduces vulnerability. The research contributes to the broader body of climate science, improving understanding and predictive capabilities. It also builds local scientific and technical capacity, enabling better climate research and adaptation planning in the future.

2 Aim and objectives

The main aim is to assess how much global climate change has affected the decadal shift in mean temperature. This study can show how one of the major climatic components such as temperature is changed over the last 42 years.

Objectives

i. To analyze the decadal mean temperature shifts from 1981 to 2022.
ii. To calculate the fluctuation of temperature over a 42-year period.

3 Materials and methods

This study is supported by secondary data. Atmospheric temperature data were collected from the Bangladesh Meteorological Department (BMD). To investigate decadal shift in the mean of maximum and minimum temperature, the data were analyzed in MS Excel.

$$\text{Mean} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

n = number of values

x = data set values

Daily observed data were averaged to generate decadal, or 10 years mean temperature. Both maximum and minimum values were analyzed separately. To identify the overall fluctuation, 42 years data were averaged and then it was compared with latest year (2022).

$$\text{Fluctuation} = \left(\frac{2022's\ \text{data} - 42\ \text{years mean data}}{42\ \text{years mean data}} \times 100\right)\ \%$$

Later these values were taken to Arc GIS 10.8 to create an interpolation with the help of the inverse distance weighting (IDW) tool. IDW calculates the result using the equation given below.

$$Z_p = \frac{\sum_{i=1}^{n}(\frac{Z_i}{d_i^p})}{\sum_{i=1}^{n}(\frac{1}{d_i^p})}$$

The isotherm line is drawn in ArcGIS software to understand the temperature variation better. The study area map is shown in Figure 1, and weather stations are indicated in Table 1.

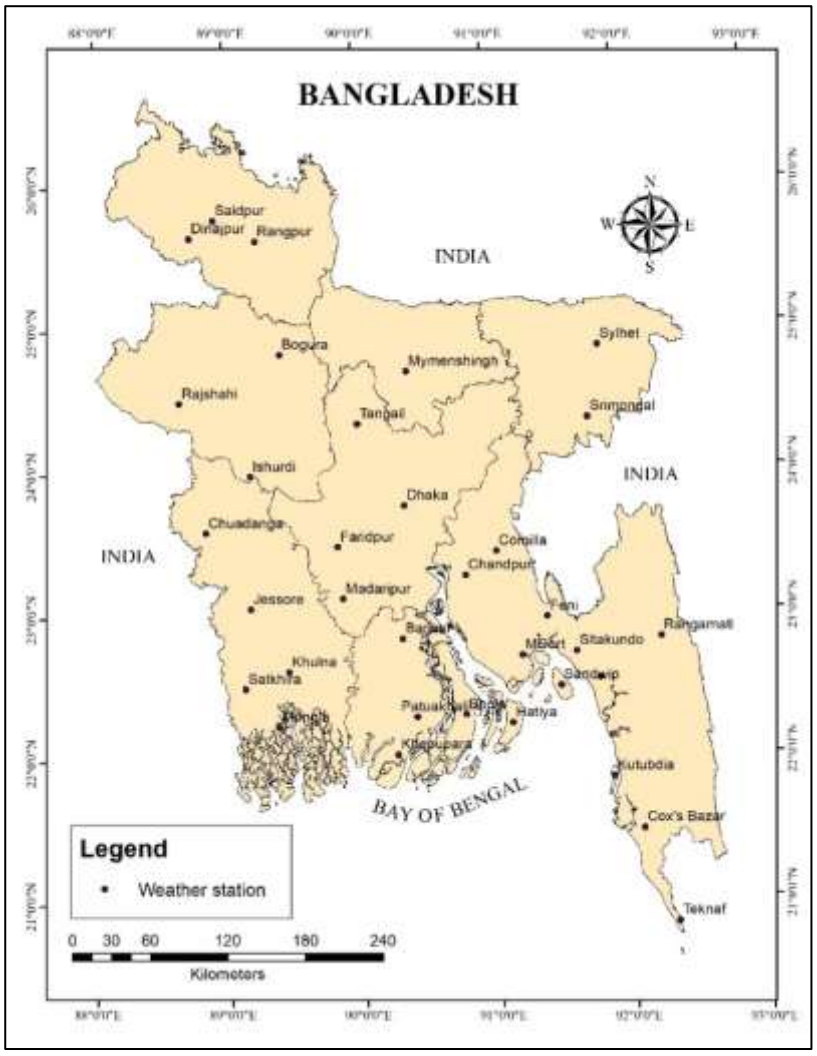

Fig. 1 Study area

Table 1 Weather stations in the study area

Station	Station ID	Longitude	Latitude
Barisal	11704	90.37	22.72
Bhola	11706	90.65	22.68
Bogra	10408	89.37	24.85
Chandpur	11316	90.7	23.23
Chittagong	11921	91.82	22.35
Chuadanga	41926	88.82	23.65
Comilla	11313	91.18	23.43
CoxsBazar	11927	91.97	21.45
Dhaka	11111	90.38	23.78
Dinajpur	10120	88.68	25.65
Faridpur	11505	89.85	23.93
Feni	11805	91.42	23.03
Hatiya	11814	91.1	22.45
Ishurdi	10910	89.03	24.15
Jessore	11407	89.33	23.2
Khepupara	12110	90.23	21.98
Khulna	11604	89.53	22.78
Kutubdia	11925	91.85	21.82
Madaripur	11513	90.18	23.17
Maijdeecourt	11809	91.1	22.87
Mongla	41958	89.6	22.47
Mymensing	10609	90.42	24.73
Patuakhali	12103	90.33	22.33
Rajshahi	10320	88.7	24.37
Rangamati	12007	92.15	22.63
Rangpur	10208	89.27	25.73
Sandwip	11916	91.43	22.48
Satkhira	11610	89.08	22.72
Sayedpur	41858	88.92	25.75
Sitakunda	11912	91.7	22.63
Srimongal	10724	91.73	24.3
Sylhet	10705	91.88	24.9
Tangail	41909	89.93	24.25
Teknaf	11929	92.3	20.87

Source: BMD, 2024

4 Results and discussion

4.1 Decadal mean shifts in maximum temperature

Figure 2 shows the maximum temperature trend analysis. The study demonstrates that in 1981's decade, Bangladesh's western region, with a maximum average temperature of 31.25°C to 31.54°C, had the greatest temperature. The lowest temperature, between 29.21°C and 29.50°C, was recorded in the eastern mountainous regions. The variation in the mean maximum temperature over the entire research area is 2.33°C. The lowest value between 1981 and 1990 was also recorded in the coastal southeast regions.

The results for the next ten years (1991–2000) indicate no discernible change. The eastern mountain regions have the lowest value, while the western region has the highest. Coastal regions were becoming warmer than in the previous decade. However, there is a 2.36°C difference in the maximum mean temperature. A noticeable change is noted from 2001 to 2010. The increase in the mean maximum temperature was 0.63°C. The northern region had the lowest value. The eastern hilly regions of Bangladesh clearly show an increase in the maximum temperature. There is a 2.53°C difference across all weather stations. The maximum mean temperature in the coastal region rises by 0.321°C. Analyzing data from the last 12 years (2011-2022). This demonstrates that the difference in the maximum mean temperature was 2.011°C throughout all stations. A significant portion of the study area is warmer than 31°C. Bangladesh's western parts are becoming warmer. However, the highest temperature decreased 0.119°C from the previous decade. The lowest maximum temperature is only present in the northern portion.

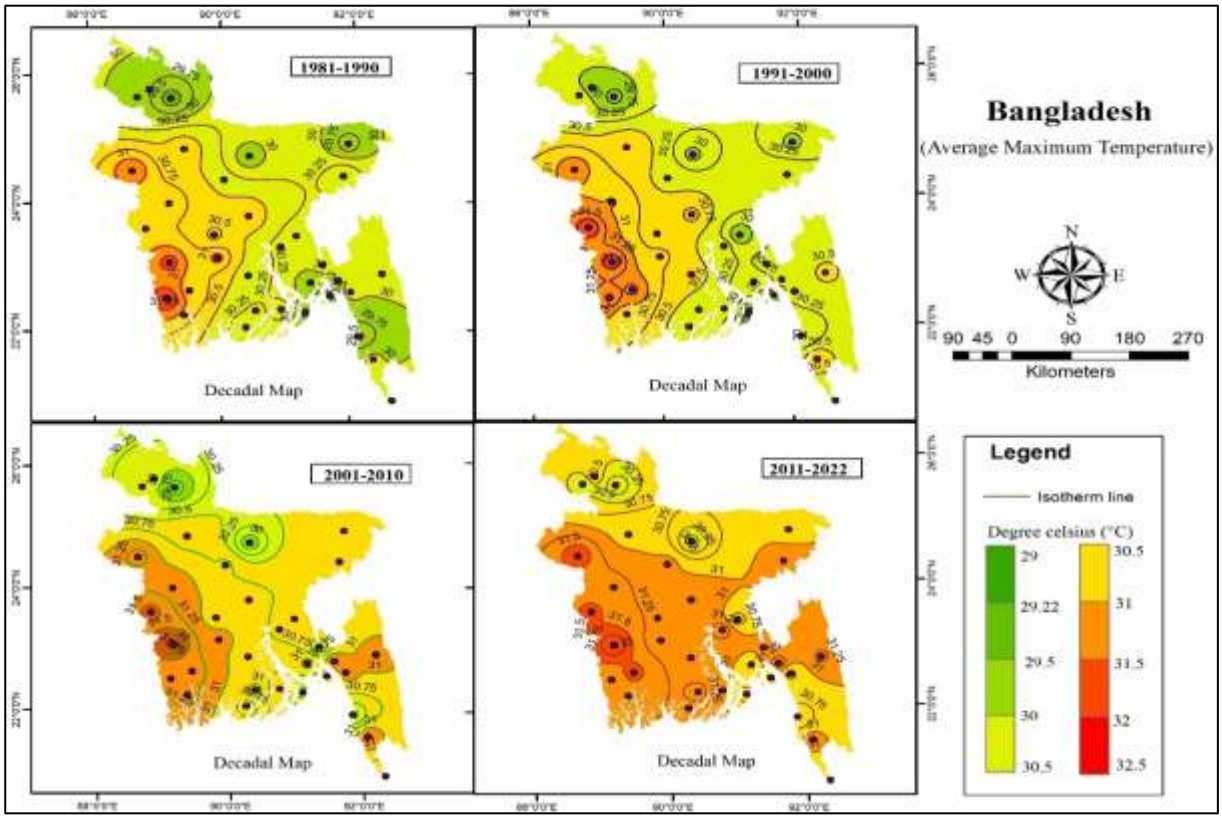

Fig. 2 Shifts in Average Maximum temperature map

4.1.1 Decadal mean shifts in minimum temperature

Figure 3 illustrates the minimum temperature trend analysis maps. The minimum average temperature follows a distinct trend from the maximum average temperature. Studying the analyzed data from 1981 to 1990, the highest minimum mean temperature ever recorded was between 21.92°C and 22.27°C in coastal areas and Dhaka. The lowest minimum mean temperature was recorded in the northern and eastern hilly regions (Sylhet, Srimongal), which ranged from 19.43°C to 19.79°C. Across all stations, the decadal mean minimum temperature difference is 2.84°C.

The mean lowest temperature increased 0.2°C over the following ten years, from 1991 to 2000. The area near the shore was relatively warmer, and Bangladesh's northern region experienced low mean minimum temperatures. However, there was a 3.04°C temperature difference across the entire station. The minimum mean temperature situation was comparable to the previous one in the decade from 2001 to 2010. However, the highest mean value of 0.336°C was raised. Although the minimum average temperature was 19.43°C in 1981, it increased to 20.08°C during this decade. The temperature variation is comparable to that in the past ten years. The mean lowest temperature climbed 0.07°C from the previous decade and 0.41°C from 1981 to 1990 in the ten-year period from 2011 to 2022. The minimum temperature trend is consistent with the preceding ten years. The cities along the coast and Dhaka, the capital, have the highest average low temperatures. Srimongal, Saidpur, and Dinajpur have the lowest values. From the study, the mean minimum temperature rises as each decade passes.

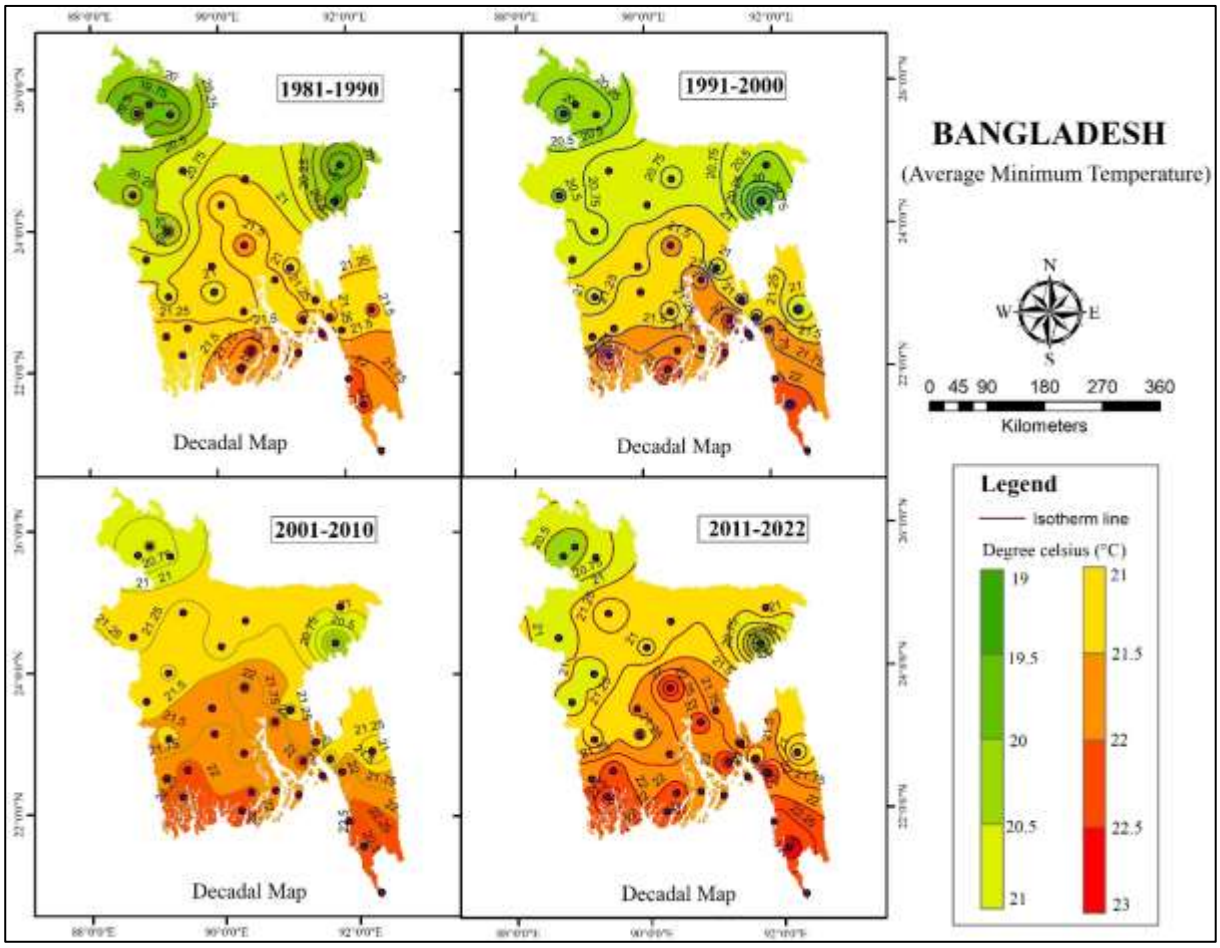

Fig. 3 Shifts in Average Minimum temperature map

4.2 The change in temperature over a 42-year period

The highest mean maximum temperature climbed 4.62%. Around Kutubdia, Sandwip station, the temperature change has been distinct during the course of the past 42 years, which is evidence of the study area's changing climate (Figure 4**)**. Almost every research area's maximum mean temperature is rising at a different rate, except for Chuadanga, Satkhira, and Madaripur, which have decreasing rates. This alteration becomes noticeable after 42 years. The rate of growth in hilly (Chittagong, Sitakundo), coastal (Cox's Bazar, Patuakhali), and northern (Rangpur, Saidpur) areas is substantially higher than that in neighboring areas (Figure 5**)**. In the northern region (Rangpur, Saidpur), the value has increased by 3.75%.

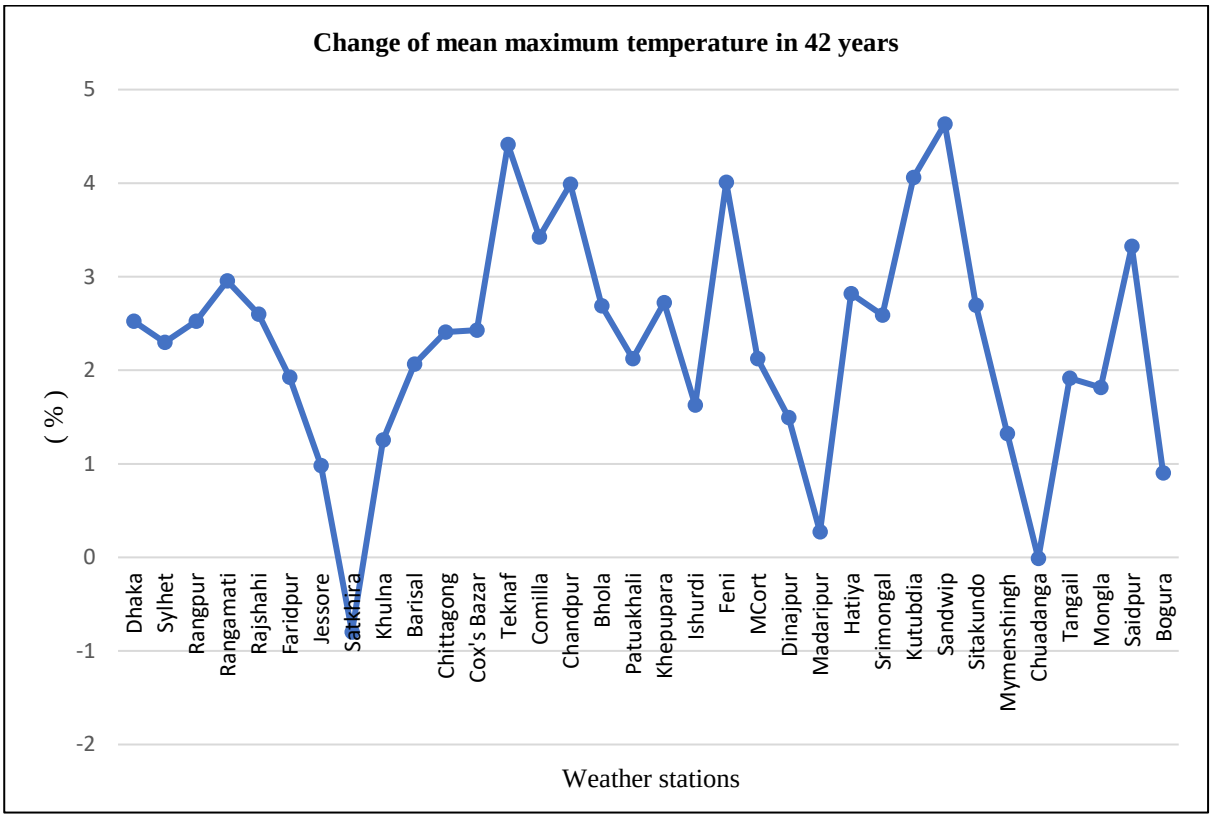

Fig. 4 Change of mean maximum temperature

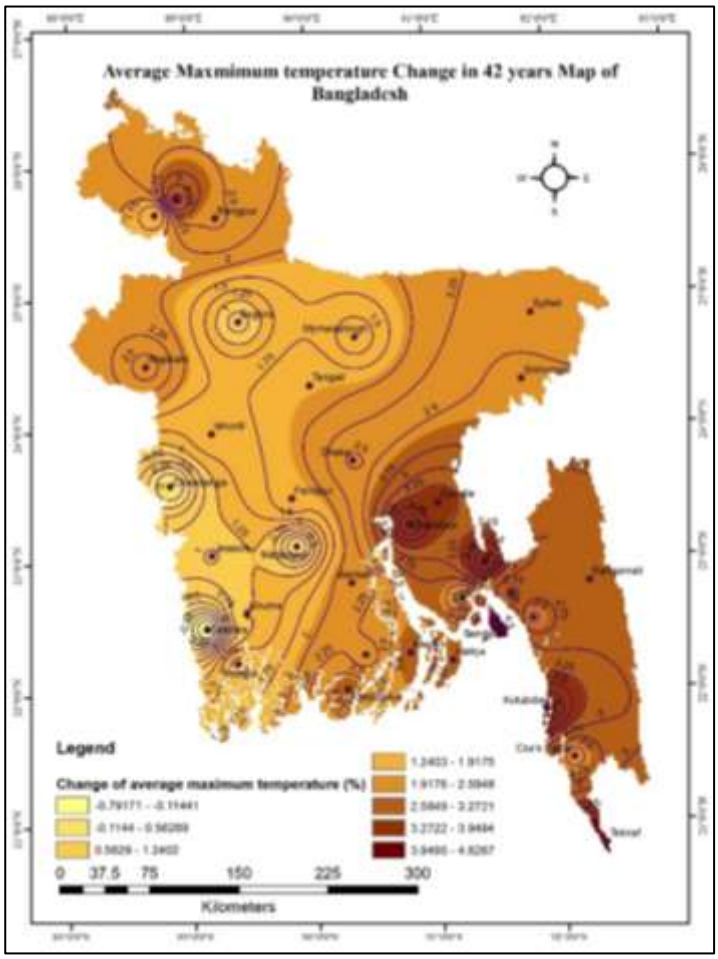

Fig. 5 Change in the mean maximum temperature map

The study shows a difference between the minimum temperature average during the previous 42 years and last year (Figure 6**)**. The mean minimum temperature of Dhaka, Dinajpur, and Chittagong is rising and ranges from 3.46% to 5.28%. The city with the highest minimum temperature increase is Dhaka. Areas close to the coast trend downward (Patuakhali, Mongla, Hatiya, Kutubdiya) (Figure 7**)**. In summary, the fluctuating rates in city areas are higher than those in other locations. Around the northern region (Rangpur, Saidpur), the minimum temperature also increased by 4.5%.

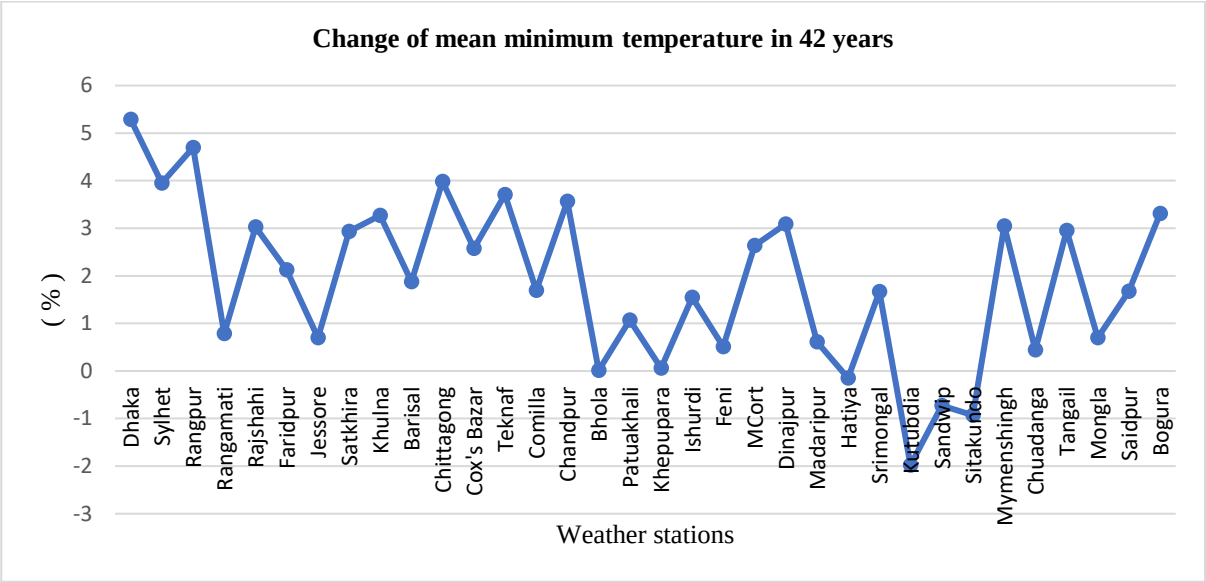

Fig. 6 Change of mean minimum temperature

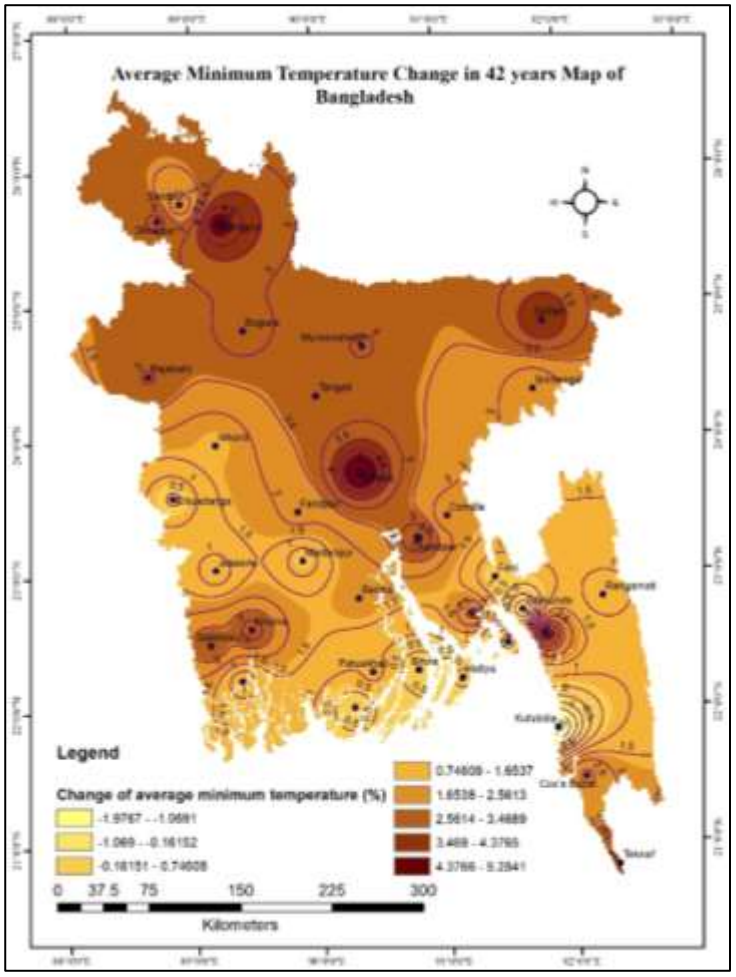

Fig. 7 Change in the mean minimum temperature map

5 Conclusion

Bangladesh lies in the tropical monsoon belt. Environmental instability is becoming more common in Bangladesh. High temperatures, a large amount of rain, often too much humidity, and pronounced seasonal fluctuations characterize Bangladesh's climate. Its economy is heavily reliant on agriculture, and agriculture is inextricably linked to climate. This study attempted to conduct an analysis of Bangladesh's temperature and an appropriate map to understand the effect on temperature due to climate change. The study focuses on spatial distribution of numerical temperature changes. The monthly maximum and minimum daily atmospheric temperature data of 34 weather stations from 1981 to 2022 were collected from the Bangladesh Meteorological Department to examine the analysis of temperature map. To investigate the exploratory statistical analysis of the study site, MS Word, MS Excel, and ArcGIS 10.8 software were employed. The temperature change is examined by comparing the observed value from the previous year to the mean value over the previous 42 years. Findings revealed that temperatures are rising with every decade. The mean maximum and minimum temperatures increased by 0.5°C and 0.39°C, respectively, within four decades. As a developing country this change will cost a lot. If this trend continues, drought will be a major issue around the northwestern region. This change in temperature might not be aware of us, but the fluctuation percentage with 42 years of data and the last year of data deserves our attention. Evaluating all the results, it is possible to conclude that a necessary plan is required to protect the vulnerable regions such as coastal and northwestern regions. These findings will be useful for policymakers in developing a national mitigation policy for climate change problems and adaptive planning in Bangladesh. Additionally, coordination between governmental agencies, NGOs (non-governmental organizations), and community groups need to enhance to ensure cohesive and effective climate adaptation strategies. It will help to build the capacity of local researchers, policymakers, and practitioners through training and education in climate science and adaptation strategies.

Statements and Declarations

The authors certify that this manuscript is original, has not been published before, and is not being considered for publication anywhere.

Funding

The writers claim that they did not take any grants or other funding to assist them in authoring this publication.

Availability of data and materials

Data that is used in this study will be available upon request to the corresponding author.

Competing interest

The authors declare that they have no relevant financial or nonfinancial interests to report for this publication and no competing interests.

Author contribution

All authors contributed to the study's conception and design. The final paper was read and approved by all authors, and no other individuals who matched the criteria for authorship but were not identified were included. We have all agreed on the order of the authors listed in the manuscript. The authors' individual contributions are listed as follows: introduction, literature review, data collection and analysis, findings, formatting tables and figures, conclusion [Jubied Alam[1]], conceptualization, literature, methodology, data analysis, conclusion, critical revision, review, and editing of the work [Towfiqul Islam Khan[1*]].

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