A MACHINE LEARNING-BASED NUMERICAL MODEL TO ASSESS FUTURE EXTREME HEAT SCENARIOS IN BANGLADESH AND ITS IMPACT ON PUBLIC HEALTH

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STATEMENT OF ORIGINAL AUTHORSHIP

I, Tanvir Ehsan certify that the paper A MACHINE LEARNING-BASED NUMERICAL MODEL TO ASSESS FUTURE EXTREME HEAT SCENARIOS IN BANGLADESH AND ITS IMPACT ON PUBLIC HEALTH is my own work and that use of material from other sources in this paper has been properly and fully acknowledged in the text following the Jahangirnagar University referencing conventions. I am fully aware of the ethical behaviour in academic works, definition of plagiarism and the department's advice on good academic practice.

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LETTER OF ACCEPTANCE

This isto certify that the thesis on is done by TANVIR EHSAN “A MACHINE LEARNING-BASED NUMERICAL MODEL TO ASSESS FUTURE EXTREME HEAT SCENARIOS IN BANGLADESH AND ITS IMPACT ON PUBLIC HEALTH” as a partial fulfillment of the requirement of MSC I believe that the report has been prepared by him under my guidance and is a record of bona fide work carried out successfully.

I wish him success in every stage of life.

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ABSTRACT

Bangladesh is the most threatened and vulnerable on climate change issues. Because of its geographic location, it has already started experiencing the effects of climate change on public health. The objective of this study is to determine how public health of Bangladesh has been affected by climate change. In recent years, the rapid emergences of climate change in Bangladesh have been threatening public health along with poverty, inequity, infectious and non-communicable diseases. This study is based on relevant literature on climate change and public health issues. Climate is a paradigm of a complex system and its changes are global in nature. It is an exciting challenge to predict these changes over the period of different time scales. Timeseries analysis is one of the most important and major tools to analyze the climate time series data. Temperature is one of the most important climatic parameters. In this research, our main aim is to conduct a study across the country to forecast temperature through a method of forecasting approach named as time series. These forecasts were compared with the forecasts obtained from autoregressive integrated moving average (ARIMA) and exponential smoothing state-space (ETS) models, Double Exponential model.

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Keywords: Climate, Forecast, Forecast Accuracy, Climate Change, Public Health, Bangladesh

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CHAPTER-1

INTRODUCTION

1.1 Introduction

Extreme heat events are considered as a significant threat to public health, particularly in the context of climate change. Bangladesh, a densely populated country in South Asia, is highly vulnerable to the impacts of extreme heat due to its geographical location, socio-economic conditions, and rapid urbanization (Kabir et al., 2016). In view of the spatio-temporal variation of mean summer temperatures and their association with heat-related diseases, it is essential to develope effective mitigation and adaptation strategies.

1.2 Background of the Study

Climate change has resulted in an increase in the frequency, intensity, and duration of extreme heat events worldwide. The Intergovernmental Panel on Climate Change (IPCC) reports reveal that global temperatures have risen significantly over the past century, with projections indicating further increases. In Bangladesh, this trend is particularly concerning due to its tropical climate and already high baseline temperatures. Studies reveal that even a small increase in mean temperatures can have significant health impacts, particularly during the summer months when temperatures often exceed the threshold for human tolerance (Huang et al., 2011).

Rapid urbanization in Bangladesh has exacerbated the impact of extreme heat events. Urban areas, with their high density of buildings, asphalt roads, and limited green spaces, tend to experience higher temperatures than rural areas—a phenomenon known as the urban heat island effect. Dhaka, the capital city of Bangladesh, is one of the most densely populated cities in the world, making it particularly susceptible to this effect. The lack of adequate infrastructure and poor urban planning further contribute to the vulnerability of urban populations to extreme heat (Laaidi et al., 2012).

Extreme heat poses significant risks to public health, including heat-related illnesses such as heat exhaustion and heatstroke, as well as exacerbating pre-existing conditions like cardiovascular and respiratory diseases. Vulnerable populations, such as the elderly, children, and those with chronic illnesses, are particularly at risk. In

Bangladesh, the public health infrastructure is often ill-equipped to handle the surge in heat-related illnesses during extreme heat events. Studies have highlighted the need for early warning systems, public awareness campaigns, and improved healthcare services to mitigate the health impacts of extreme heat (McMichael et al., 2008).

Reports on extreme heat and public health in Bangladesh is growing, but gaps remain. Research has primarily focused on documenting the rise in temperatures and correlating them with health outcomes. However, there is a need for more comprehensive studies that integrate climate projections with health data to predict future scenarios and inform policy decisions. Kabir et al. (2016) emphasized the importance of such integrated approaches to develop effective mitigation and adaptation strategies.

Given the complexity of climate data and its interaction with public health outcomes, traditional statistical methods may fall short in accurately predicting future scenarios. Machine learning models offer a promising alternative by leveraging large datasets and uncovering complex patterns that may not be apparent through conventional analysis. By developing a machine learning-based numerical model, this study aims to provide a more accurate and reliable assessment of future extreme heat scenarios in Bangladesh and their potential impact on public health.

In summary, this study is grounded in the urgent need to address the growing threat of extreme heat in Bangladesh, driven by climate change and urbanization. By leveraging advanced machine learning techniques, the study aims to fill existing research gaps and provide actionable insights for policymakers and public health officials to protect vulnerable populations and enhance resilience against future extreme heat events.

This background section provides an overview of the existing literature on climate change, extreme heat, urbanization and their effects on public health, with focus on Bangladesh.

1.3 Problem Statement

Bangladesh, due to its tropical climate, dense population, and socio-economic conditions, is highly vulnerable to the effects of climate change, particularly extreme heat events. These events are expected to become more frequent and severe, posing significant risks to public health. Current predictive models lack the precision and granularity needed for effective planning and intervention. Thus, there is an urgent need for robust predictive tools that can aid in proactive public health management.

1.4 Research Objective

i. Develop an advanced machine learning-based numerical model
ii. Predict future extreme heat scenarios in Bangladesh
iii. Assess the potential impact of extreme heat on public health
iv. Provide actionable insights for policymakers and public health officials
v. Mitigate adverse effects of extreme heat events on public health
vi. The primary objectives of this study are as follows:
vii. Analyze spatio-temporal variations in mean summer temperatures in Bangladesh from 1971 to 2020.
viii. Develop a machine learning-based model to forecast temperatures at up to 2040.
ix. Correlate extreme heat events with heat-related diseases to predict future public health scenarios.
x. Formulate a best-fit equation to forecast heat-related disease incidence by 2040.

1.5 Research Questions

i. How can machine learning techniques be utilized to accurately predict future extreme heat events in Bangladesh?

ii. What are the most significant climatic and non-climatic factors influencing the occurrence and severity of extreme heat events?

iii. What is the projected impact of these extreme heat scenarios on public health, particularly heat-related illnesses?

iv. How can the insights derived from the model inform public health strategies and policies to mitigate the impacts of extreme heat?

1.6 Rationale and Significance of the Study

The study has significant implications for public health policy and urban planning in Bangladesh. By understanding the spatial-temporal variations of extreme heat and its association with heat-related diseases, policymakers and urban planners can develop targeted interventions to protect vulnerable populations, enhance healthcare infrastructure, and promote climate-resilient urban development. Additionally, the findings of this study can contribute to global efforts on public health mitigate the adverse impacts of climate change.

1.7 Conceptual Framework

The study would first attempt to assess the current scenario of in Bangladesh. Meanwhile, the researcher would gather necessary information from primary and secondary sources as well.

For clear understanding the conceptual framework is shown in the diagram below:

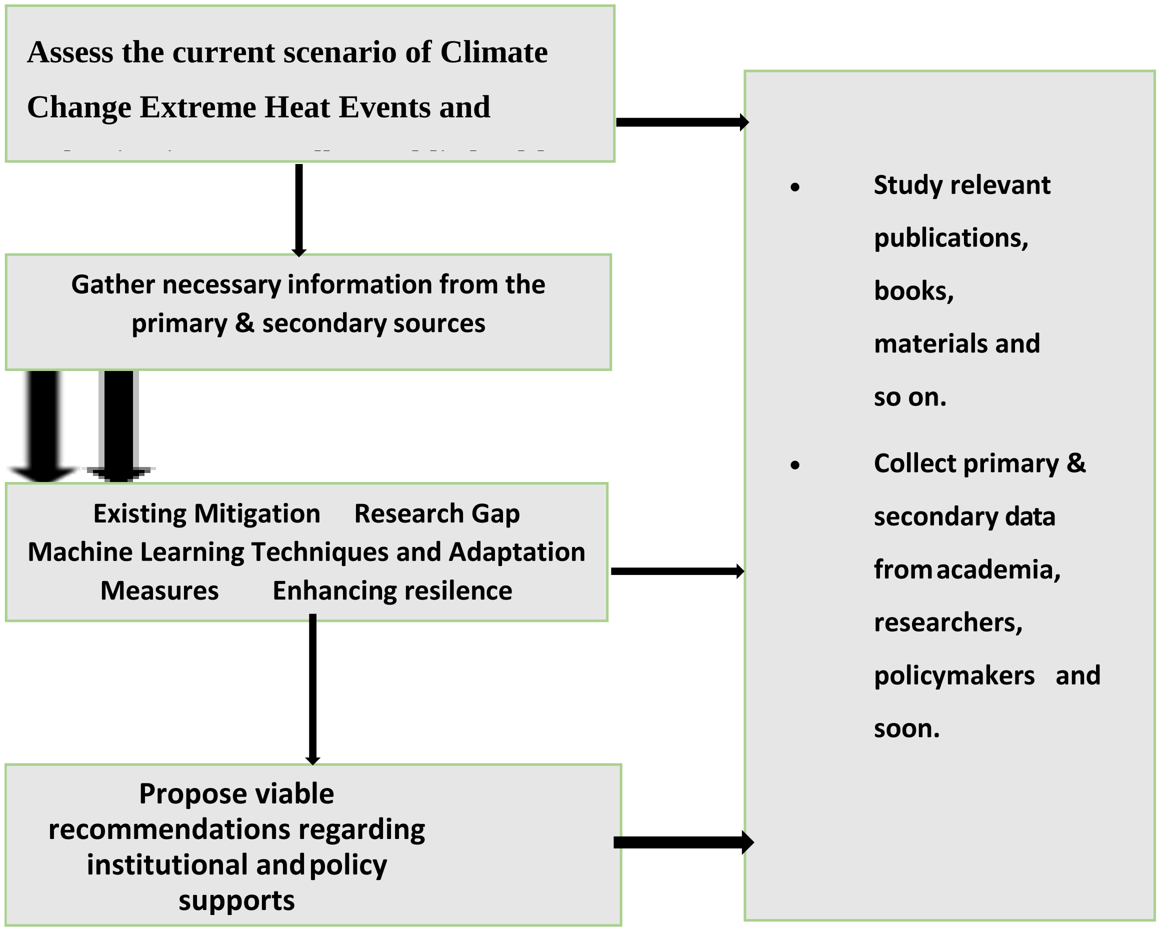


Figure 1.1: Conceptual framework

1.8 Structure of the thesis

The present thesis comprises five chapters. Chapter one titled '**Introduction**' gives an introduction of the study along with the objectives of the research work.

Chapter two titled '**Literature Review**' contains brief & selective review of the literature.

Chapter three titled '**Methodology**' presents a methodology for carrying out the work.

Chapter four titled '**Data Analysis and Findings'** studies and analyze the data collected through the primary as well as secondary sources.

Eventually, chapter five titled '**Conclusion** 'attempts to bring the major findings of the study together in the form of conclusion and outlines recommendations for the studies to be required in the future.

1.9 Hypothesis of the Study

The study has been conducted on the basis of the following hypothesis.

Null Hypothesis (H0)

There is no significant relationship between extreme heat events and the incidence of heat-related illnesses in Bangladesh.

Alternative Hypothesis (H1)

There is a significant relationship between extreme heat events and the incidence of heat-related illnesses in Bangladesh.

CHAPTER-2

LITERATURE REVIEW

2.1 Introduction

There are several research works regarding all across the world, however, no significant research has been published regarding challenges and prospects in Bangladesh. Relevant works of literature have been reviewed by the researchers.

No formal study on increase of heat waves in Bangladesh has been undertaken but the increasing trend of temperature has been found in Bangladesh in several studies. Increased temperature may result different types of complicacy for human health.

Rahman (2008)5 reported that the health impacts associated with heat waves are heat stroke, dehydration and aggravation of cardiovascular diseases in elderly.

Climatic conditions impact the epidemiology of infectious diseases. Furthermore, these climatic factors interact with additional factors such as behavioral, demographic, and socioeconomic ones that influence the incidence, emergence, and distribution of such infectious diseases (Watts et al. 2018). Climate suitability for climate-sensitive infectious diseases has increased globally (Watts et al. 2020). Vectorial capacity is increasing for a number of climate-sensitive diseases,[3] with exposures along a range of temperature and rainfall. These are most acutely experienced in low- and middle-income countries (Watts et al. 2019). The number of cases of dengue fever, which is spread by mosquitoes, recorded annually has doubled every decade since 1990, and one of the potential factors that contributed to this increase is climate change (Watts et al. 2020).(Mahmud & Raza, n.d.)

2.2 Research Gap and Rationale

While numerous studies have investigated the impacts of extreme heat on public health globally, there is a gap in research focusing on Bangladesh, particularly concerning the spatio-temporal variations in mean summer temperatures and their correlation with heat-related diseases (Kabir et al., 2016). Understanding these relationships is critical for developing targeted interventions and adaptation strategies to mitigate the adverse effects of extreme heat on public health in Bangladesh. Therefore, this study aims to address this gap by analyzing the spatio-temporal variation of mean summer temperatures in Bangladesh from 2000 to 2022 and developing a machine learning-based numerical model to forecast future temperatures and their impact on public health up to 2040.

2.3 Spatio-Temporal Variation of Mean Summer Temperatures in Bangladesh

In Bangladesh, the rise in mean summer temperatures is a significant issue, particularly in urban areas such as Dhaka. Rahman and Islam (2017) report that urbanization has significantly contributed to the increasing temperatures due to the UHI effect. Their study shows a marked rise in mean summer temperatures from 2000 to 2016, aligning with data from the Bangladesh Meteorological Department. This trend is consistent with global warming patterns observed by the Intergovernmental Panel on Climate Change (IPCC, 2018). The study by Shahid (2010) also indicates a significant warming trend in Bangladesh, with summer temperatures increasing at a rate of 0.016°C per year. The rapid urbanization and industrialization in Dhaka have further exacerbated the UHI effect, leading to higher temperatures in the city compared to rural areas. This increasing temperature trend has serious implications for public health, agriculture, and the overall economy of the country.

DHAKA, April 27, 2024 (BSS) - The met office today expressed fear that the country's highest temperature could break all-time record next month after witnessing the longest duration of a heatwave covering all corners of Bangladesh.

"Our mathematical model analysis suggests despite some expected rainfall in parts of the country in the first week of the coming month, the country may witness the all-time record temperature in May," meteorologist Kazi Zebunnesa told BSS.

She said the northeastern Sylhet region, parts of central Bangladesh and southeastern Chattogram region was likely to witness some welcome shower but it would unlikely reduce the much-expected heatwave throughout the country.

The country witnessed the longest duration of the heatwave for the past 25 days since April 1 and the met office warned the phenomenon would continue throughout the next month.

"But unlike the previous heatwaves, this year it spread all over the country," commented meteorologist Abul Kalam Mollik, who was supported by Zebunnesa as well.

Visibly for the first time the meteorologists acknowledged that the climate change phenomenon caused the erratic weather pattern with gradually expanding areas of hatwave, joining the voice with the climate experts and activists.

They said the heatwave also affected most parts of South Asia and partly East Asia with countries like India, Bangladesh, Pakistan, Afghanistan, Thailand the Philippines and Vietnam.According to the latest met office bulletin issued at 3 pm, the highest temperature was recorded at 42.6 degrees Celsius in Chuadanga, a day after Jashore recorded the year's highest temperature at 42.7 degrees Celsius.The temperature in Dhaka was recorded at 37.4 degrees Celsius but the high humidity has exposed the residents to massive discomfort."A very severe heat wave is sweeping over the districts of Rajshahi, Chuadanga & Pabna and severe heat wave is sweeping over the districts of Tangail, Bogura, Bagerhat, Jashore & Kushtia," the bulletin read.

It said mild to moderate heat wave is sweeping over rest parts of Dhaka, Rajshahi and Khulna divisions and the divisions of Rangpur, Mymensingh and Barishal and the districts of Moulvibazar, Rangamati, Chandpur, Noakhali, Feni and Bandarban and "it may continue".

April is typically hot in Bangladesh as it is in other South and Southeast Asian countries, but according to meteorologists, temperatures this month have been unusually high which was highlighted by international media outlets as well.

According to the New York Times, hundreds of millions of people in South and Southeast Asia were suffering from a grueling heatwave that has forced schools to close, disrupted agriculture, and raised the risk of heat strokes and other health complications.

The recent report also specially acknowledged the Bangladesh scenario saying temperature in some areas soared above 42 degrees Celsius but the "numbers don't quite capture how extreme humidity makes the heat feel even worse".

The schools across the country were closed due to the extreme weather but students are struggling to or doing anything at home as well.

The heatwave prompted thousands of people to gather in city mosques having air condition facilities and rural fields, praying for relief from the scorching heat.

The heatwave has forced the healthcare facilities to take emergency measures to provide medical services with higher number of patients reporting to hospitals with heat-related ailments since the beginning of April while the children and elderly people appeared as the most vulnerable during this prolonged hot weather.

"Large numbers of people are becoming ill with heatstroke, dehydration, exhaustion and breathing problems and they are suffering from other heat-related diseases as well," Director of Mugda Medical College and Hospital Dr Md Niatuzzaman told BSS.

The other hospitals and healthcare facilities including Shishu Hospital, Shaheed Suhrawardy Medical College Hospital and International Centre for Diarrheal Disease Research, Bangladesh (ICDDR, B) reported identical scenarios.

"Nearly, 500 diarrhoea patients have been admitted to the International Centre for Diarrheal Disease Research, Bangladesh (ICDDR, B). A significant number of patients are getting admission to ICDDRB daily," ICDDR'B spokesman AKM Tariful Islam Khan told BSS two days ago.

The health ministry issued a directive to take extra measures to face the crisis

HI = -42.379 + 2.04901523 T + 10.14333127 R - 0.22475541 TR - 6.83783x10-3T2-5.481717x10-2R2 + 1.22874x10-3T2R + 8.5282x10-4TR2 - 1.99x10-6T2R2

Where, T = ambient dry bulb temperature (°F), R = relative humidity. Because this equation is obtained by multiple regression analysis (Steadman 1979), the heat index value (HI) has an error of ±1.3°F. The formula is valid only when air temperature and relative humidity are higher than 27°C (80°F) and 40%, respectively.

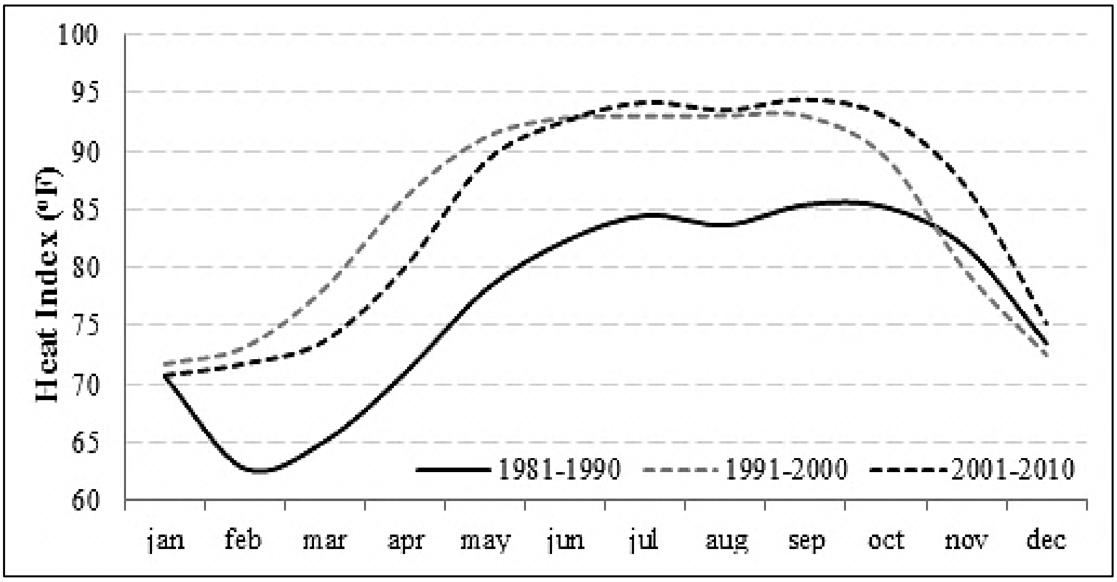


Figure 2.1: Temporal variation (1981-2010) of heat index in Bangladesh

Heat waves and exposure to high temperatures have negative impacts on human health, with morbidity and mortality caused by heat-related stress (Watts et al. 2020). Densely populated areas of the world are increasingly exposed to warmer climatic conditions, experiencing higher change in mean summer temperature compared to the global average (WMO 2020). Such extreme heat conditions are taking a toll on human health and overwhelming the health systems, with greater consequences for places where extreme heat occurs in the context of aging populations, urbanization, urban heat island effects, and health inequalities (WMO 2020). The elderly, people with disabilities or preexisting medical conditions or with both, and those exposed to heat from working outdoors or in noncooled environments are the worst affected by heat waves (Watts et al. 2020). Heat- related mortality among the elderly population—people more than 65 years of age—has increased by 53.7 percent in the past 20 years (Watts et al. 2020). Due to heat stress, people's productivity at work is impacted, and in Bangladesh an esti- mated 148 work hours per person was lost in 2019, which translates to 18.2 billion work hours lost in total for the country, compared to 13.3 billion work hours lost in 2013 (Watts et al. 2020).

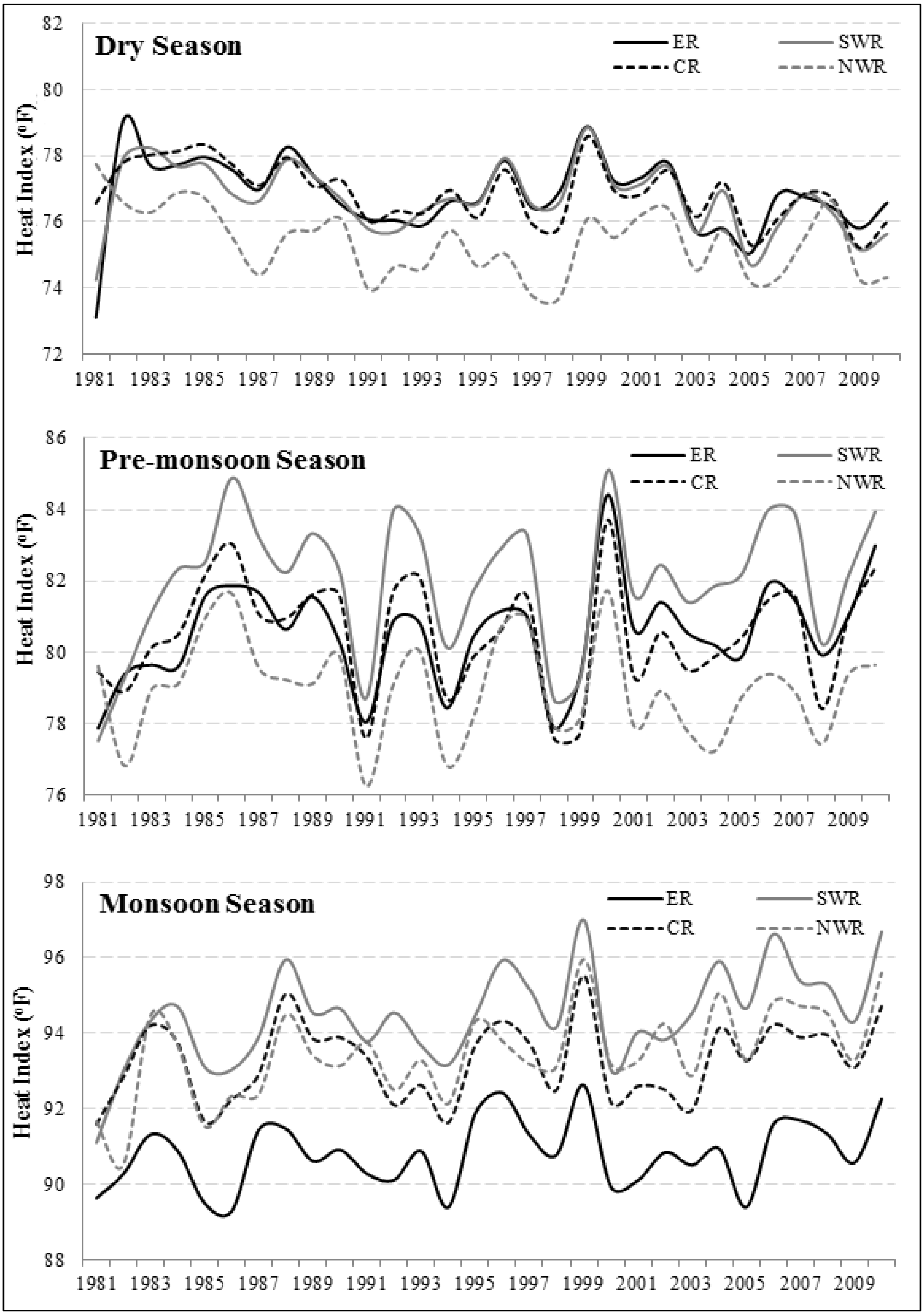


Figure 2.2: Temporal variation (1981-2009) Heat index for different seasons in Bangladesh

Heat waves and exposure to high temperatures have negative impacts on human health, with morbidity and mortality caused by heat-related stress (Watts et al. 2020). Densely populated areas of the world are increasingly exposed to warmer climatic conditions, experiencing higher change in mean summer temperature compared to the global average (WMO 2020). Such extreme heat conditions are taking a toll on human health and overwhelming the health systems, with greater consequences for places where extreme heat occurs in the context of aging pop- ulations, urbanization, urban heat island effects, and health inequalities (WMO 2020). The elderly, people with disabilities or preexisting medical conditions or with both, and those exposed to heat from working outdoors or in noncooled environments are the worst affected by heat waves (Watts et al. 2020). Heat- related mortality among the elderly population—people more than 65 years of age—has increased by 53.7 percent in the past 20 years (Watts et al. 2020). Due to heat stress, people's productivity at work is impacted, and in Bangladesh an esti- mated 148 work hours per person was lost in 2019, which translates to 18.2 billion work hours lost in total for the country, compared to 13.3 billion work hours lost in 2013 (Watts et al. 2020).

The change in heat index expressed in degrees Celsius for Dhaka and Chattogram cities is analyzed for the period 1976 to 2019 (figure 5.13) to provide an overview of how heat affected these cities. Heat index is a measure of real feel when relative humidity is factored in with the actual air temperature (United States, NWS 2020). The heat index was constructed using BMD's data for maxi- mum temperature and humidity to represent composite conditions using the Rothfusz (1990) equation. Overall, the heat indexes indicate a "danger" level during the months of April to October, with little variation over the years. A danger level of the heat index indicates that heat cramps and heat exhaustion are likely while heat stroke is probable with continued outdoor activity. The major differ- ence between Dhaka and Chattogram cities is noted in January, with Dhaka being relatively cooler than Chattogram, shown by more light blue cells in figure 5.13 (indicating a temperature range that will not adversely affect humans, with heat in normal limits of less than 27°C). A deeper look at the two indexes reveals differ- ences over time: for example, in 1976 there was a range of 40°C and

45°C for Dhaka and 40°C and 47°C for Chattogram; in 2018–19, the range increased to 45°C and 51°C for both the cities.

Dhaka	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
1976	27	31	40	38	45	42	42	41	44	41	36	27
1977	25	31	43	42	41	42	44	43	47	38	33	27
1978	25	28	35	44	43	44	44	44	43	44	35	29
1979	28	28	38	47	54	46	44	45	44	42	37	26
1980	25	29	38	51	44	45	42	43	43	39	34	28
1981	26	28	35	38	43	47	42	47	45	41	34	26
1982	28	29	35	43	50	45	46	42	46	43	31	27
1983	25	28	38	43	45	50	46	43	44	41	35	27
1984	25	29	42	48	43	42	43	43	43	43	34	28
1985	28	31	46	47	45	45	42	45	45	44	36	31
1986	28	31	43	47	49	51	46	49	43	42	35	30
1987	28	34	38	47	52	52	45	45	46	44	36	30
1988	29	35	41	53	49	46	47	45	49	46	37	30
1989	26	31	41	52	52	48	46	47	47	43	36	28
1990	26	29	33	42	42	46	44	46	46	37	36	28
1991	25	31	40	48	45	45	46	45	42	41	31	25
1992	24	26	39	56	47	50	44	44	45	43	34	27
1993	25	32	35	43	42	44	43	42	44	43	35	29
1994	28	28	40	44	48	44	44	44	46	45	36	30
1995	26	30	40	52	53	48	45	47	47	47	36	29
1996	27	33	46	49	53	47	49	45	53	44	37	29
1997	25	29	41	39	48	46	45	48	45	43	37	26
1998	23	31	35	44	48	53	46	45	48	49	39	32
1999	29	36	43	53	46	47	44	44	44	44	37	29
2000	25	26	35	44	44	45	43	44	44	41	35	28
2001	25	31	37	46	43	42	43	46	45	43	34	27
2002	26	30	36	41	44	45	45	43	45	40	33	27
2003	22	30	34	47	47	43	45	45	44	42	33	27
2004	24	30	39	43	49	46	43	44	41	39	33	29
2005	25	31	40	46	46	49	43	45	48	39	33	29
2006	26	37	38	44	47	46	46	45	44	43	34	28
2007	25	29	34	45	49	46	44	46	44	42	34	27
2008	25	31	38	45	49	46	45	45	47	41	34	27
2009	27	31	38	50	50	51	46	47	47	42	34	27
2010	24	30	42	50	48	48	47	48	46	43	35	27
2011	24	30	36	42	48	47	45	42	45	43	34	25
2012	24	29	39	45	49	47	46	45	47	42	32	24
2013	24	30	39	44	43	48	45	44	47	42	34	28
2014	25	28	36	47	50	48	46	46	46	42	35	25
2015	25	30	35	42	47	46	44	46	46	43	35	27
2016	25	33	39	52	47	49	46	47	48	45	35	30
2017	27	31	35	43	50	48	45	48	49	44	35	29
2018	24	32	40	43	45	51	48	50	51	41	35	27
2019	28	30	36	45	50	49	49	50	49	44		

Chatto-gram	Month										
	1	2	3	4	5	6	7	8	9	10	11
1976	27	30	40	46	47	40		43	46	40	36
1977	28	31	42	37	40	39	40	42	44	41	37
1978	25	31	36	43	45	42	44	46	42	44	37
1979	29	29	36	43	45	42	42	40	42	41	38
1980	26	29	36	44	43	43	42	41	46	38	33
1981	26	30	35	36	42	42	40	43	42	41	36
1982	28	30	35	41	46	41	42	40	41	41	32
1983	26	28	34	41	43	45	43	42	44	42	35
1984	26	29	36	42	45	43	42	43	45	46	36
1985	28	30	37	44	44	44	40	44	44	43	33
1986	27	32	39	41	45	45	42	45	42	43	35
1987	28	32	36	41	45	45	42	42	45	45	38
1988	29	33	39	44	45	43	44	44	45	44	38
1989	25	31	37	42	46	44	42	44	43	38	35
1990	27	32	33	40	45	44	39	45	46	41	38
1991	26	33	43		44	40	43	46	43	42	32
1992	25	27	37	45	45	45	43	45	45	42	35
1993	27	30	35	44	45	42	43	42	43	43	35
1994	29	30	37	43	47	45	44	46	47	44	37
1995	27	30	39	46	48	47	43	45	45	47	36
1996	28	32	39	44	49	47	46	42	47	45	40
1997	27	30	39	38	46	46	44	48	46	45	41
1998	26	31	36	43	49	53	45	45	49	52	46
1999	31	38	43	50	46	48	46	44	46	46	40
2000	29	31	39	46	45	47	46	46	47	46	40
2001	28	35	42	47	42	39	41	44	45	44	37
2002	31	38	42	40	41	42	39	42	44	44	37
2003	27	36	39	46	47	40	47	46	46	50	39
2004	28	33	40	42	50	45	42	45	44	46	39
2005	29	35	39	47	48	48	44	43	50	51	40
2006	32	39	44	47	48	51	45	46	47	48	41
2007	29	33	39	45	49	47	43	47	45	47	42
2008	30	30	42	49	49	44	42	44	47	46	39
2009	28	32	40	44	46	45	40	42	44	42	36
2010	25	31	39	43	44	44	44	45	45	45	36
2011	25	32	36	40	42	41	43	41	41	41	33
2012	26	32	37	42	46	43	41	44	43	43	33
2013	25	32	40	43	40	45	43	40	43	39	34
2014	26	30	36	47	45	43	43	41	42	41	37
2015	28	32	39	44	49	47	43	46	48	43	36
2016	27	34	42	46	47	48	43	45	48	46	35
2017	29	34	36	43	49	48	45	48	46	43	39
2018	25	32	41	46	47	47	46	48	49	39	37
2019	29	33	38	45	50	49	46	44	48	44	

27–32°C	Caution	Fatigue is possible with prolonged exposure and activity. Continuing activity could result in heat cramps.
33–40°C	Extreme caution	Heat cramps and heat exhaustion are possible. Continuing activity could result in heat stroke.
41–54°C	Danger	Heat cramps and heat exhaustion are likely; heat stroke is probable with continued activity.
Over 54°C	Extreme danger	Heat stroke is imminent.

Source: Original figure for this publication.
Note: Heat index is a measure of "real feel" that combines relative humidity and actual air temperature (United States, NWS 2020).
Empty cells indicate no data were available.

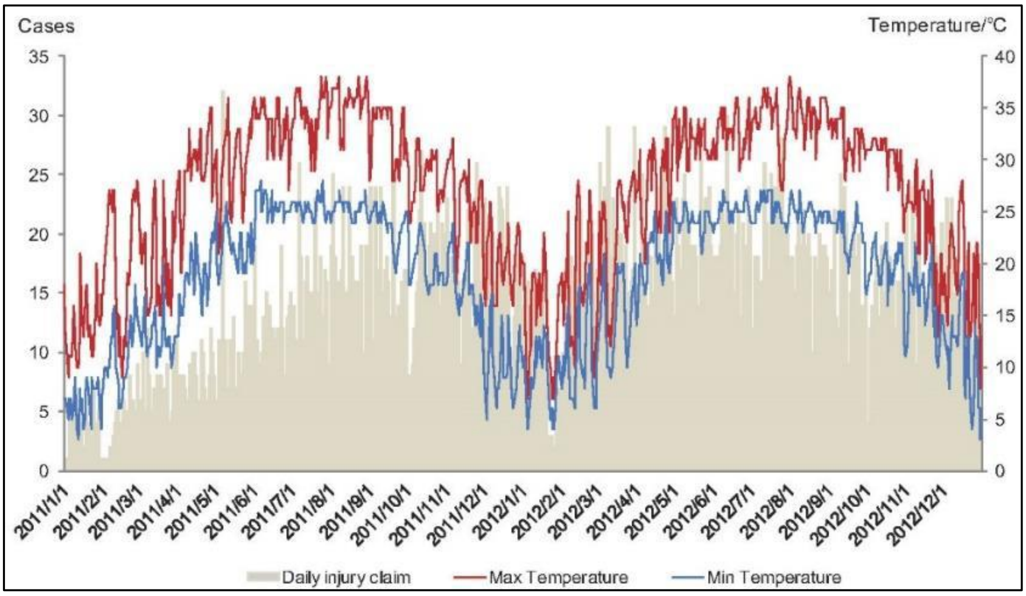
Figure 2.3: Heat Index for cities of Dhaka and Chattogram for each month between 1976 to 2019

Table1: Table showing Heat Index, Classification & Notes on heat effect

Heat Index		Classification	Notes
27–32°C	80–90 °F	Very Warm	Caution — fatigue is possible with prolonged exposure and activity. Continuing activity could result in heat cramps
32–41°C	90–105 °F	Hot	Extreme caution — heat cramps and heat exhaustion are possible. Continuing activity could result in heat stroke
41–54°C	105–130 °F	Very Hot	Danger — heat cramps and heat exhaustion are likely; heat stroke is probable with continued activity
over 54°C	over 130 °F	Extremely Hot	Extreme danger — heat stroke is imminent

2.4 Asia

In Asia, numerous studies have documented the increasing trend of summer temperatures. In India, for instance, Murari et al. (2015) observed a significant rise in the frequency and intensity of heatwaves over recent decades. Their research indicates that the number of heatwave days has increased by over 25% since the 1950s, with significant public health impacts. Similarly, in China, Sun et al. (2019) found that mean summer temperatures have increased substantially, particularly in urban areas. Their study highlights the role of rapid urbanization and industrialization in driving these temperature increases. Moreover, research by Tan et al. (2010) emphasizes that the rising temperatures in Asia are linked to broader global climate change patterns, with urban areas experiencing the most significant impacts due to the UHI effect.*Figure*



2.4: Temperature induced public health impacts for different timeline

Overall, a total of 9,550 workers’ compensation claims were identified in Guangzhou between 2011-2012, and 5,418 work-related injuries were included for analysis over the period of warm seasons. As shown in Table 1, the majority of claimants were male (77.2%) and aged 25-44 years (63.0%). About half (53.6%) of all injury claims occurred in the small enterprises. The percentage of injury claims for workers in manufacturing was 47%. The daily average minimum and maximum temperatures during the study period were 24 °C and 32 °C, respectively. Figure 1 demonstrates the distribution of daily injury claims and outdoor temperatures for Guangzhou.

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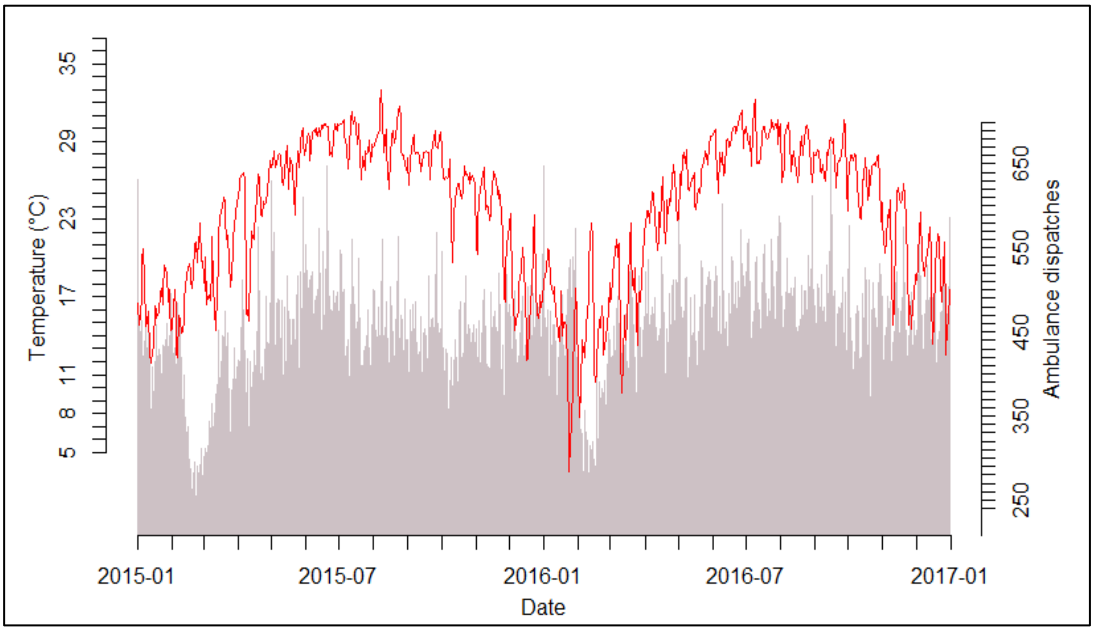


Figure 2.5: Time-series distribution of daily ambulance dispatches and mean temperature (°C) in Shenzhen, 2015-2016. Red line represents daily mean temperature, and grey regions represent daily ambulance dispatches.

2.5 Middle East

The Middle East is also experiencing extreme heat conditions. Lelieveld et al. (2016) highlight that the region is becoming increasingly inhospitable due to rising temperatures and prolonged heatwaves. This study emphasizes that cities like Riyadh and Tehran have recorded unprecedented temperature increases, severely impacting public health and infrastructure. Alghamdi et al. (2020) further discuss the implications of rising temperatures in the Middle East, noting the increased strain on water resources and public health systems. The extreme temperatures in the region are not only a result of global climate change but also local factors such as extensive urbanization and the UHI effect.

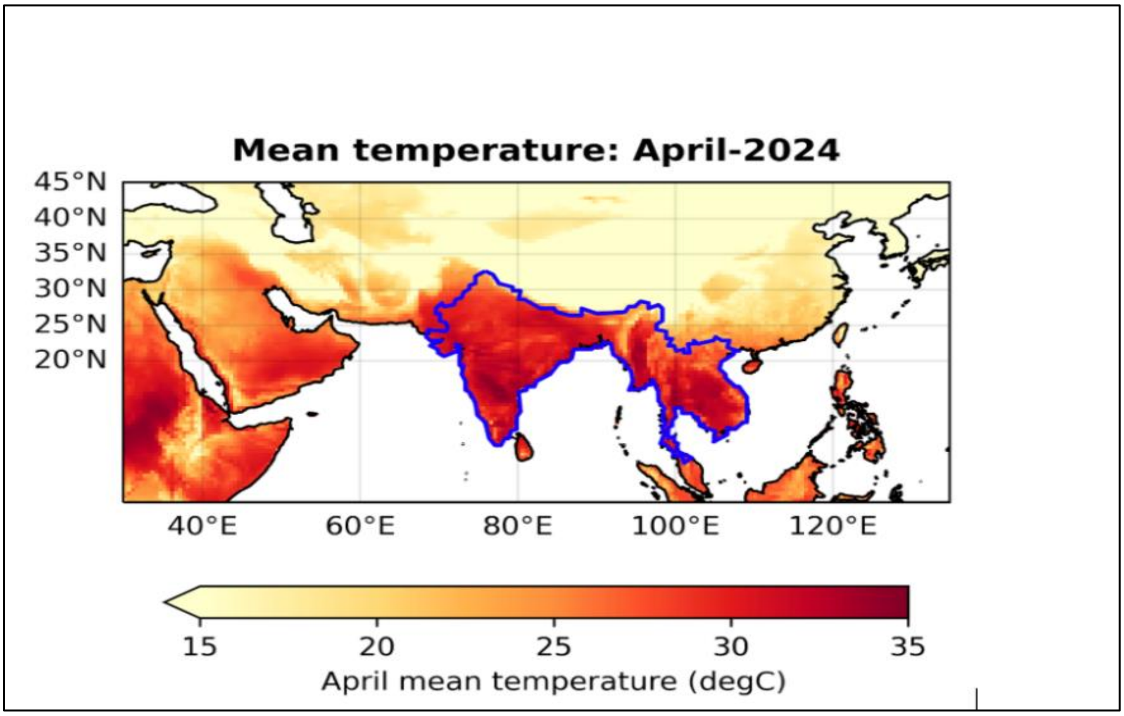


Figure 2.6: April mean temperature 2024. The blue outline shows the region with the most extreme heat in South Asia.

Renowned analyst Frederic Wehrey warns, “Climate change in the Middle East will amplify pre-existing vulnerabilities stemming from conflict, displacement, marginalization, and corruption while also creating new risks. Governments in the region will need to adopt more inclusive reforms as part of their climate adaptation strategies.”

Heatwaves, droughts, sandstorms, floods, and rising sea levels are some of the challenges that the region faces. The Middle East, particularly Arabic-speaking countries, is highly exposed to these impacts. The effects will be felt differently across the region, with resource-poor countries being more severely affected due to limited adaptive capacities and inadequate infrastructure. Inequities in water and land management will worsen, exacerbating existing social and political issues.

In a disturbing milestone, the first week of July 2023 marked the hottest week on Earth ever recorded. The Middle East has been particularly hard hit by the heatwave, which is expected to worsen as August approaches. The scorching temperatures not only broke records but also brought severe consequences to the region.

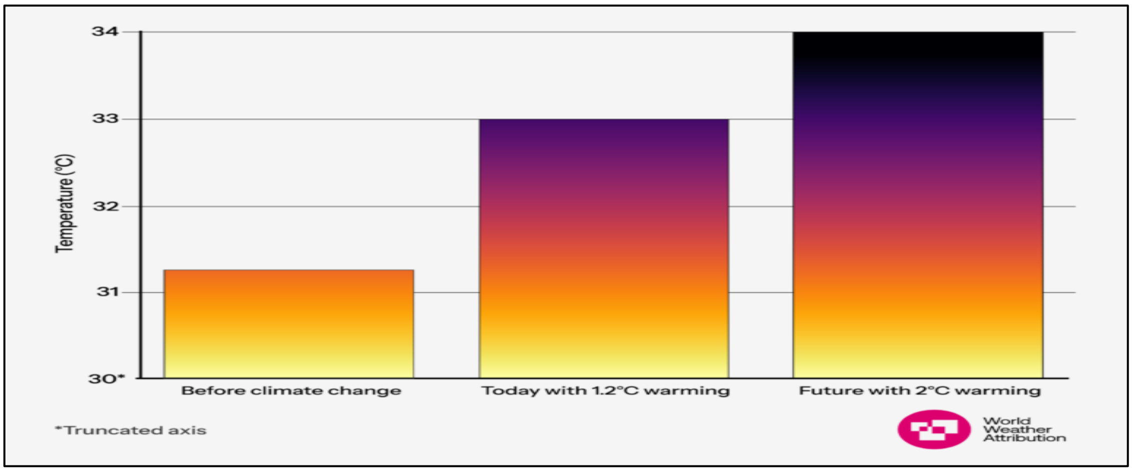


Figure 2.7: how has climate change influenced the most intense three days heatwaves in Palestine, Israel, Syria, Lebanon and Jordan

The Middle East, already warming twice as fast as the global average, is experiencing a rapidly changing climate that threatens the livelihoods, well-being, and stability of its communities.

A study published in The Lancet sheds light on the gravity of the situation. If global warming continues, the number of heat-related deaths in the Middle East and North Africa is projected to rise significantly. By the last two decades of the century, heat-related deaths in the region could increase from an average of about two deaths per 100,000 people to about 123 per 100,000 people.

Without immediate action, some areas may experience an average temperature increase of four degrees by 2050. The goal of limiting global warming to 1.5 degrees, as laid out in the Paris Agreement, seems increasingly unachievable in the region.

According to research by the German Max Planck Institute of Chemistry and the Cyprus Institute, the situation is critical. Based on a 'business-as-usual pathway' where no climate action is taken, the Middle East will face unprecedented heat waves that will make life in some areas impossible. The coolest summers by the end of the century will be as hot as the hottest summer peaks between 1981 and 2010.

2.6 Europe

In Europe, the summer of 2003 is a notable example of extreme heat, which resulted in significant mortality across the continent. According to Robine et al. (2008), this heatwave caused over 70,000 deaths. More recent studies, such as those by Vautard et al. (2020), indicate that Europe continues to experience increasing summer temperatures, with heatwaves becoming more frequent and severe. In Southern Europe, López-Bueno et al. (2021) have documented an increase in the length and intensity of heatwaves, posing serious challenges for public health and urban planning.

It appears that about 125 million people are currently exposed to heat waves in different parts of the world. This heat wave killed more than 70,000 people in Europe in 2003. In the last week of July 2019, heat wave killed 2964 people in Netherlands.

In 2018, heat wave killed 700 people in Sweden and more than 250 in Denmark. In 2010, 56,000 people died in Russia because of heat wave (Stephen Leahy, National Geography, 28 June 2019.

2.7 America

Heat waves can cause a wide range of health problems (Figure 3). A rise of 1 °C above the local unusually hot threshold may account for 1-3% increase in all-cause mortality. The increased mortality is mainly attributed to the cardio-cerebrovascular system, central nervous system and respiratory system, which are highly sensitive to heat . Compared with mortality, heat-related morbidity is less well studied for that death data are easier to access around the world. Research so far has also shown inconsistent findings on morbidity. For example, 9 during heat waves, increased in ischemic heart disease and stroke were found in California while the rising number of respiratory and renal diseases were illustrated in London. In general, the rising number of emergency hospitalization are mostly attributed to heat-related illnesses, such as heat stroke, dehydration and electrolyte disturbances, as well as pre-existing diseases with other International Classification of Diseases (ICD) chapters but actually related with heat, such as cardio-cerebrovascular diseases, respiratory illness, chronic renal diseases, reduced function of central nervous, and mental disorders.

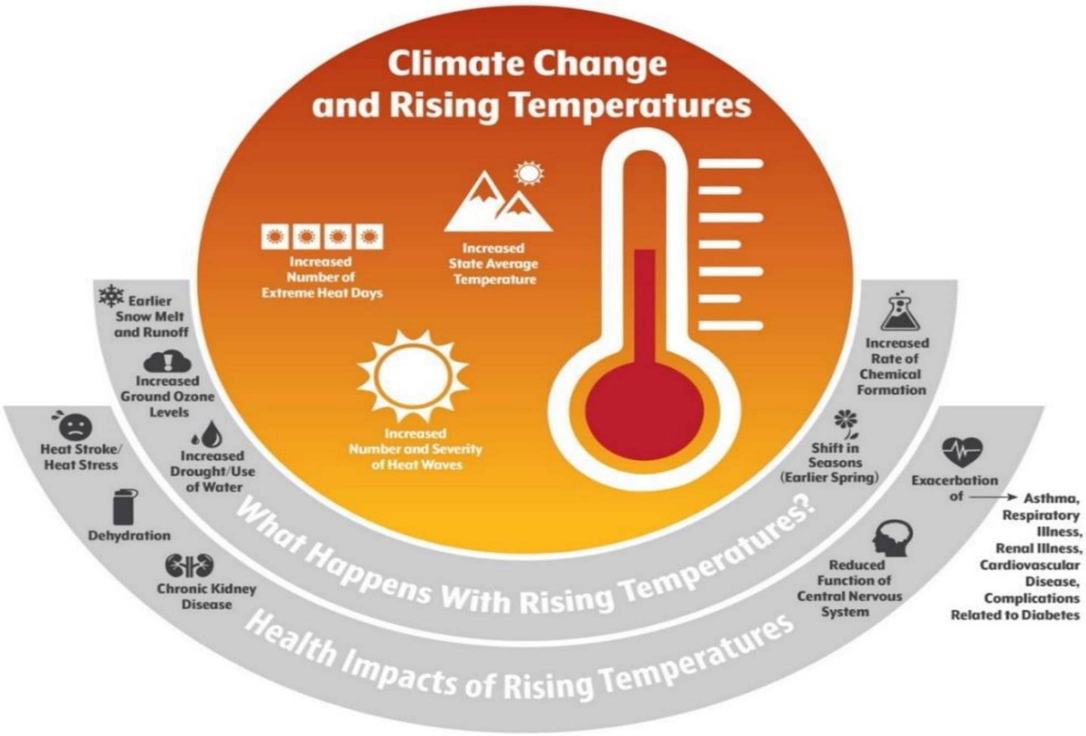
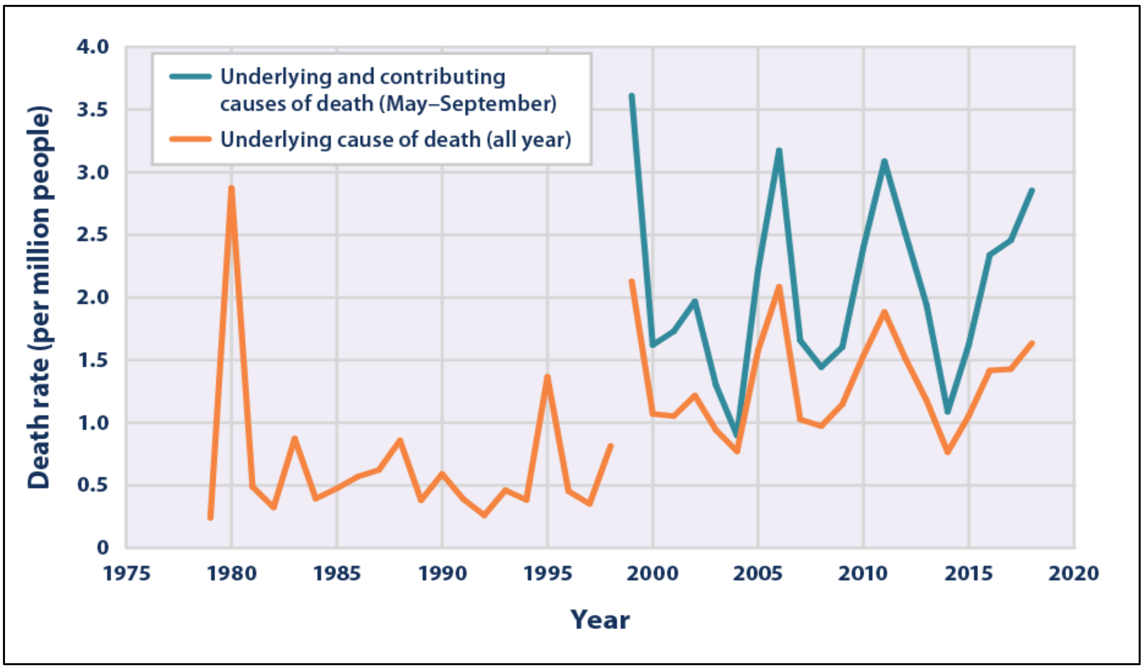


Figure 2.8: Rising temperature and its health impacts.

In North America, cities such as Los Angeles and New York have also experienced significant increases in summer temperatures. Heatwaves in the United States have been extensively studied, with Sheridan et al. (2012) documenting the increasing frequency and intensity of these events. Their research highlights the role of both global climate change and local urbanization in driving temperature increases. Similarly, research in Canada by Cheng et al. (2014) shows rising summer temperatures, particularly in southern regions, with significant implications for public health and energy consumption.



Source(2000)

Figure 2.9: Death rate of people due to excessive heat condition

The figure 2.9 shows the annual rates for deaths classified as “heat-related” by medical professionals in the 50 states and the District of Columbia. The orange line shows deaths for which heat was listed as the main (underlying) cause. The blue line shows deaths for which heat was listed as either the underlying or contributing cause of death during the months from May to September, based on a broader set of data that became available in 1999.

2.8 Urban Heat Island (UHI) Effect

2.8.1 Causes and Mechanisms

The UHI effect is a significant factor contributing to higher temperatures in urban areas compared to their rural surroundings. According to Oke (1982), this phenomenon is primarily driven by the replacement of natural surfaces with impervious materials such as asphalt and concrete, which absorb and retain heat. Urban structures also limit airflow, reducing the cooling effects of wind. Furthermore, human activities, including transportation and industrial processes, generate additional heat. These factors combine to create higher temperatures in cities, particularly during the summer months.

2.9 Impacts in Bangladesh

In Bangladesh, the UHI effect is particularly pronounced in cities like Dhaka. Ahmed and Hasan (2014) provide a detailed analysis of the UHI effect in Dhaka, showing significant temperature differences between urban and rural areas. Their study highlights the role of rapid urbanization and lack of green spaces in exacerbating the UHI effect. The increased temperatures in urban areas have severe implications for public health, as they can lead to heat stress and other heat-related illnesses. Life expectancy in Bangladesh is only 61 years, and 61% of children are malnourished.29 Perhaps more

illustrative of this point, though, is the low expenditure of US$ 12 per person per year that the Bangladesh government makes on health, well below the US$ 21 spent in low income countries in general (World Bank,

2002). With increased climate variability and change, high summer temperatures could result in a greater number of deaths due to heat stress, but the extent of such impacts has not been quantitatively assessed yet. However, the combination of higher temperatures and potential increases in summer precipitation could create favorable conditions for greater intensity or spread of many infectious diseases. Global burden (mortality and morbidity) of climate-change-attributable diarrhea and malnutrition are already the largest in South-East Asian countries, including Bangladesh.30 Still, the perceived risk to human health is low relative to those in other sectors (such as water resources), mainly because of the higher uncertainty about many of the possible health outcomes. Increased risk to human health from increased flooding and cyclones seems most likely. Changes in infectious disease are less certain as the causes of outbreaks of infectious disease are quite

complex and often do not have a simple relationship with increasing temperature or change in precipitation. Coupled with its poor public health infrastructure and land transport system, which is fragmented by numerous ferry crossings and extensive river systems, health care accessibility will be further curtailed in the

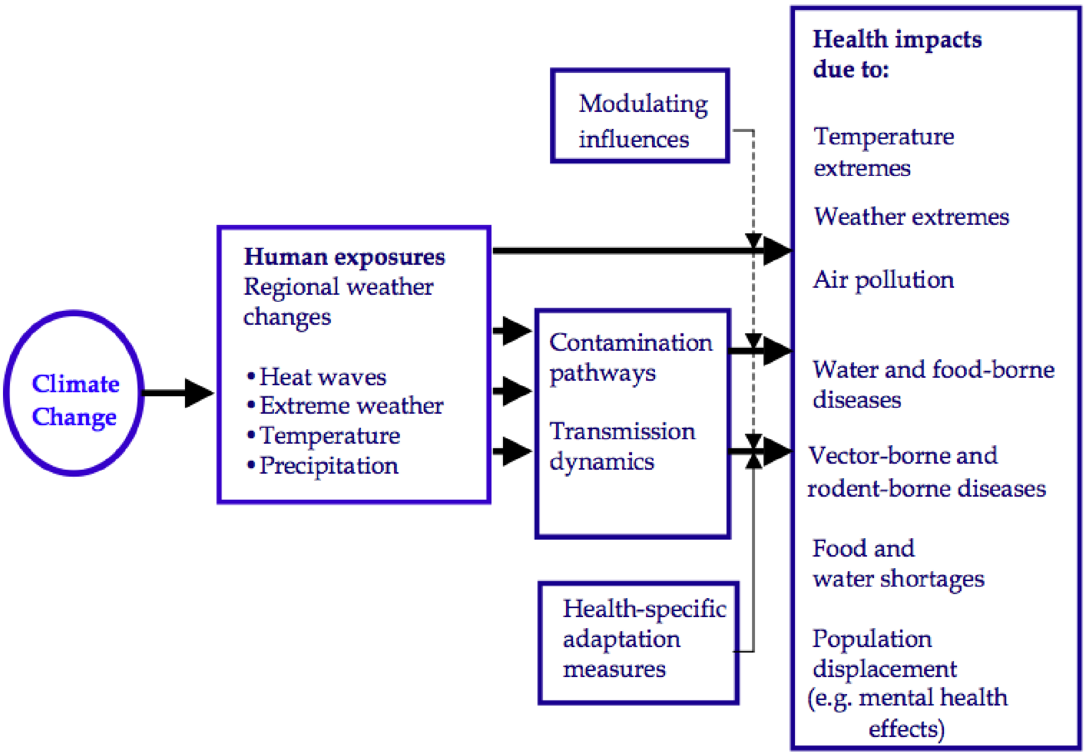


Figure 2.10: Pathways by which climate change affects human health, including local modulating influences and the feedback influence of adaptation measures (Patz et al. 2000)

2.10 Bangladesh (national averages)

Bangladesh has gotten warmer over the past 44 years (figure 5.1), with an increase in annual mean temperature by 0.5°C between 1980 and 2019, based on three-year averages.1

Figure 5.2 provides a more detailed representation of the pattern of maximum temperature recorded on a monthly basis between 1976 and 2019.

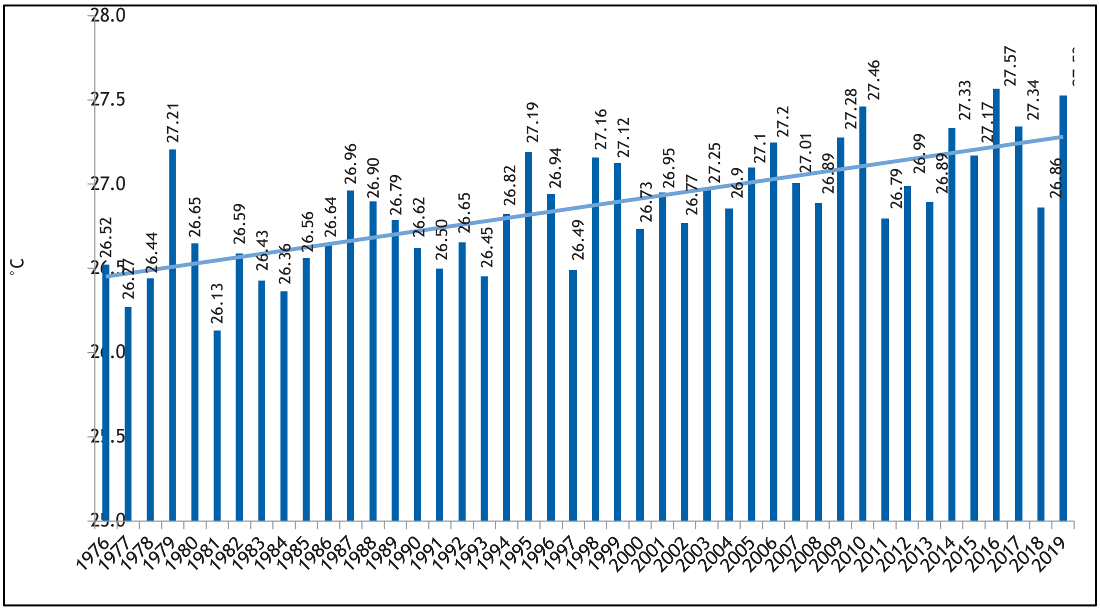
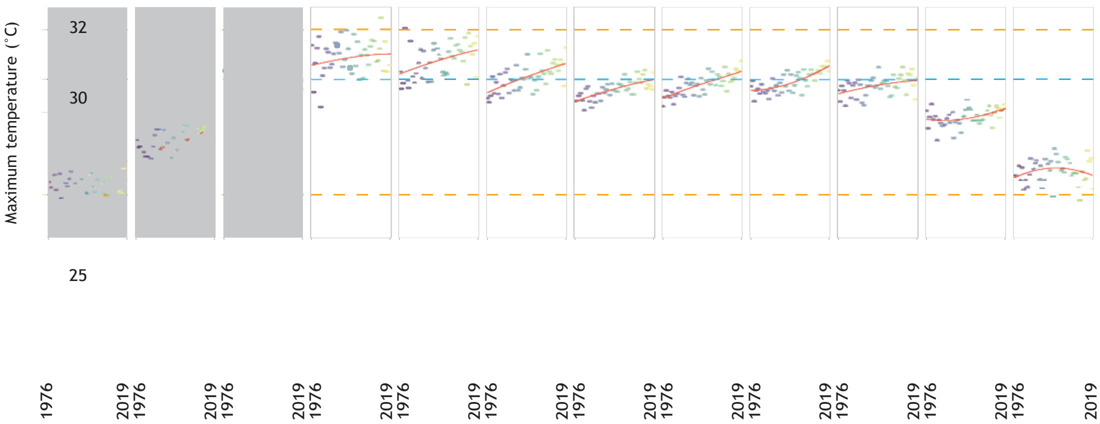


Figure 2.11: Annual mean temperature for Bangladesh (1976-2019) Source (BMD)



Source: Original figure for this publication.
Note: The figure shows monthly average maximum temperature for every year between 1976 and 2019. The trend lines across the years for each month (in red) are represented by a fitted Lowess curve, which is based on the scatterplot for each month. Horizontal dotted lines at 25°C, 32°C, and 35°C indicate the range of maximum temperature that is conducive to the spread of dengue cases. Between 25°C and 35°C (orange line) the spread increases with a peak at 32°C (blue line). At temperatures higher than 35°C, mosquitoes cannot survive.

Figure 2.12: National maximum temperature for Bangladesh (1976-2019)

The figure shows monthly average maximum temperature for every year between 1976 and 2019. The trend lines across the years for each month (in red) are represented by a fitted Lowest curve, which is based on the scatterplot for each month. Horizontal dotted lines at 25°C, 32°C, and 35°C indicate the range of maximum temperature that is conducive to the spread of dengue cases. Between 25°C and 35°C (orange line) the spread increases with a peak at 32°C (blue line). At temperatures higher than 35°C, mosquitoes cannot survive.

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The above provides a more detailed representation of the pattern of maximum temperature recorded on a monthly basis between 1976 and 2019.

2.11 Machine Learning Models for Temperature Forecasting

2.11.1 Overview

Machine learning models have become increasingly important tools for predicting future temperature trends. These models can process large datasets and identify patterns that traditional statistical methods might miss.

2.12 Applications in Bangladesh

In Bangladesh, machine learning models have been used to forecast future temperatures and assess the impacts of climate change. Islam et al. (2020) developed a machine learning-based model to predict temperature trends in Dhaka, using historical temperature data and socio-economic factors. Their model shows a significant increase in future summer temperatures, which is consistent with global warming trends. This model is particularly useful for urban planners and public health officials in developing strategies to mitigate the impacts of extreme heat.

2.13 Correlation Between Extreme Heat and Health Outcomes

2.13.1 Health Impacts

Extreme heat has been linked to various adverse health outcomes, including heat exhaustion, heatstroke, and increased mortality rates. Watts et al. (2015) discuss the broad health impacts of climate change, emphasizing the risks posed by increasing temperatures. Their study highlights the vulnerability of certain populations, such as the elderly and those with pre-existing health conditions, to extreme heat. In Bangladesh, Shahid et al. (2016) found a strong correlation between high temperatures and the incidence of heat-related illnesses, particularly in urban areas like Dhaka.

2.14 Case Studies

In Europe, the 2003 heatwave provides a stark example of the health impacts of extreme heat. Robine et al. (2008) reported over 70,000 excess deaths due to the heatwave, highlighting the need for effective heat action plans. In the United States, Sheridan et al. (2012) documented the variability in heat-related mortality across different regions, with urban areas experiencing higher mortality rates due to the UHI effect. In Asia, Honda et al. (2014) developed a heat-related mortality risk model to project the impacts of climate change on public health, finding that the risk of heat-related deaths is expected to increase significantly in the coming decades.

2.15 Mitigation and Adaptation Strategies

Effective mitigation and adaptation strategies are essential to reduce the health impacts of extreme heat. The IPCC (2018) highlights the importance of integrating heat action plans into urban planning to protect vulnerable populations. In Bangladesh, Hossain et al. (2019) discuss various adaptation strategies, including the development of heat-resistant infrastructure and the implementation of early warning systems. Globally, Watts et al. (2015) emphasize the need for comprehensive policies that address the health impacts of climate change, including the development of public health interventions to reduce heat-related morbidity and mortality.

CHAPTER-3

METHODOLOGY

3.1 Introduction

This study has been initiated by collecting primary data from Researchers and government and private employee from relevant sectors and associated organization reviewing previous research reports, newspaper articles, and online document reports from the various Health Organization of Bangladesh.

3.2 Research Approach and Types of Data

This study has been initiated by reviewing previous research reports, newspaper articles, online documents, reports of Government.

Mixed-method research methodology has been used which includes both quantitative and qualitative approaches.

Quantitative data shows the numerical presentation of data along with necessary tables & charts. On the other hand, qualitative data has been illustrated through the descriptive presentation. Information has been collected from secondary sources and also has been collected from cross-sectional data from the primary sources as well.

3.2.1 Primary Data

Primary source information has been gathered from the relevant Professionals from the selected regions. Researchers, Private and govt. officers of relevant sectors and associated organizations have also been consulted for their expert opinion.

3.2.2 Secondary Data

Secondary data of the related issues have been collected from various books, policies, journal articles, newspaper articles and presentations. Relevant content will be analyzed to critically and objectively review published and printed facts, opinions and observations too.

3.3 Data Collection Period

The data collection period for the study has been considered from January to May 2024.

3.4 Selection of Target Group

The target group was the professionals engaged in the various sector, Government, Private organizations, Academia, Business, research and so on.

3.5 Data Collection

Sampling is a statistical technique that involves selecting a limited number of elements from a larger population in order to make inferences about that population. Probability sampling operates on the principle of random selection, employing a carefully controlled process to ensure that every element in the population has a discernible, non-zero likelihood of being chosen. Random Sampling has been used for data collection. Both primary and secondary data have been used in this study and findings would have been developed on the basis of collected data. Primary cross-sectional data would have been collected in different sampling methods, including- direct/telephonic interview, emailing by using semi-structured questionnaire, FGDs. Qualitative data have been gathered by informal discussion/interview conducted on farmers, govt. officers, researchers, and so on.

3.6 Questionnaire Design

The questionnaire for the survey is comprised of two parts; the first part includes name, designation and organization about respondents' age and profession. All the questions are multiple-choice and close-ended questions. Because of being closed- ended and multiple-choice in nature. The results of the questions are easy to compare, tabulate and analyze. In the questions, 5-point Likert-scale was used where the respondents are asked to select the most appropriate number those correspondents to extent to which they agree with a statement. The scales in our survey questions are 1 to 5 with "1" denoting "strongly disagree" and "5" denoting "strongly agree". A five-point Likert scale is used to determine the importance and acceptance of each question.

3.7 Processing and Analysis of Data

Data collected from primary as well as secondary sources will be analyzed to understand the present condition, Different figures, tables will be produced through various analytical tools, techniques. Furthermore, statistic softwaresuch as R, Minitab, Python software has been used to analyses the data.

3.8 Data Collection:

3.8.1 Climate Data:

Gather historical and projected climate data, including temperature, from sources such as BMD, NASA, NOAA, and the IPCC.

3.8.2 Health Data:

Collect data on heat-related illnesses, hospital admissions, emergency call records, and mortality rates from health agencies and hospitals.

3.8.3 Socioeconomic Data:

Obtain data on population density, age distribution, socioeconomic status, and urbanization from government databases and surveys.

3.9 Data Preprocessing:

Clean and normalize the data to handle missing values and ensure consistency.

Perform feature engineering to create relevant variables such as heatwave duration, intensity, and frequency.

3.10 Data Processing and Analysis

3.10.1 Data Preprocessing:

The temperature data is cleaned and formatted to ensure consistency and accuracy. This involves removing any outliers, handling missing values, and ensuring uniformity in the units of measurement. The health data is also standardized to facilitate comparative analysis.

3.10.2 Geographic Information System (GIS) Integration:

The preprocessed temperature data is imported into a GIS environment for spatial analysis. Each data point is geo-referenced according to its corresponding division in

Bangladesh. GIS software such as ArcGIS or QGIS is used to map the spatial distribution of the average maximum temperatures for the selected years (Esri, 2020).

3.11 Spatio-Temporal Analysis:

The interpolated temperature surfaces are analyzed to identify spatio-temporal patterns of extreme heat across different divisions of Bangladesh. Statistical methods such as trend analysis and spatial autocorrelation are used to detect significant changes and hotspots of extreme heat over the selected time periods.

3.12 Forecasting Future Temperatures:

Using the historical temperature data from 2004, 2014, and 2024, future temperatures for the year 2040are forecasted. Time-series analysis techniques, including autoregressive integrated moving average (ARIMA) models, are employed to predict the maximum temperatures. The forecast considers both linear and non-linear trends to enhance prediction accuracy (Box, Jenkins).

3.13 Public Health Impact Assessment

3.13.1 Correlation Analysis:

Correlation analysis is a statistical tool used to quantify the relationship between two variables. It measures the degree to which one variable is associated with another. The correlation coefficient, which ranges from -1 to 1, expresses the strength and direction of this relationship. A correlation coefficient of -1 indicates a perfect negative correlation, 0 indicates no correlation, and 1 indicates a perfect positive correlation.

A correlation analysis is conducted to examine the relationship between extreme heat conditions and public health outcomes. Statistical tests, such as Pearson correlation coefficients, measure the strength and significance of associations between temperature variations and health data.

Pearson’s Correlation Coefficient

The Pearson correlation coefficient is a statistical measure used to assess the strength and direction of the linear relationship between two continuous variables.

Formula:

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}}$$

r = correlation coefficient

x_i = values of the x-variable in a sample

$\bar{x}$ = mean of the values of the x-variable

y_i = values of the y-variable in a sample

$\bar{y}$ = mean of the values of the y-variable

3.13.2 Regression Modeling:

Multiple regression models are developed to quantify the impact of extreme heat on health indicators, controlling for potential confounding factors such as population density, socioeconomic status, and access to healthcare services. These models help isolate the effect of temperature on health outcomes and predict future health risks based on projected temperatures (Kleinbaum, Kupper, & Muller, 1988).

3.14 Significance of the Study

This study will contribute to the body of knowledge on climate change and public health by providing a data-driven approach to predicting and managing the impacts of extreme heat events. The insights generated from this model will help policymakers and public health officials implement effective strategies to protect vulnerable populations and enhance resilience against climate change-induced heat stress. By addressing the growing threat of extreme heat, this research aims to improve public health outcomes and ensure sustainable development in Bangladesh.

3.15 Climate Change and Extreme Heat

Climate change, driven by human activities such as burning fossil fuels and deforestation, is leading to global warming and altering weather patterns (IPCC, 2018). Extreme heat events, characterized by abnormally high temperatures and prolonged periods of heat, are becoming more frequent and intense as a result (Field et al., 2014). The Intergovernmental Panel on Climate Change (IPCC) has highlighted the significant impacts of global warming, including heatwaves, heat-related illnesses, and mortality (IPCC, 2018).

3.16 Urbanization and Urban Heat Islands

Rapid urbanization and unplanned urban development contribute to the urban heat island (UHI) effect, where urban areas experience higher temperatures than surrounding rural areas (Santamouris, 2015). Factors such as the abundance of concrete and asphalt, reduced green spaces, and increased human activities contribute to elevated temperatures in urban environments (Oke, 1982). In Bangladesh, rapid urbanization, particularly in cities like Dhaka, exacerbates the UHI effect and increases the vulnerability of urban populations to extreme heat events (Rahman & Islam, 2017).

3.17 Health Impacts of Extreme Heat

Extreme heat events have various adverse health effects, including heat exhaustion, heatstroke, dehydration, and exacerbation of cardiovascular and respiratory conditions (Hajat et al., 2010). Vulnerable populations, such as the elderly, children, pregnant women, and individuals with pre-existing health conditions, are particularly susceptible to heat-related illnesses and mortality (Basu, 2009). In Bangladesh, where access to healthcare and adaptive infrastructure may be limited, extreme heat events pose a significant public health challenge, especially during the summer months (Hossain et al., 2018).

CHAPTER-4

ANALYSIS AND FINDINGS

4.1 Data Analysis and Findings:

Table 1: Maximum and Mean temperature of Bangladesh in the past years from 1971 to 2020

Year	Maximum temperature(°C)	Mean temperature(°C)
1971	29.59	25.1
1972	29.6	25.6
1973	29.61	25.4
1974	29.62	25.6
1975	29.63	25.4
1976	29.64	25.6
1977	29.63	25.3
1978	29.7	25.3
1979	29.75	26.1
1980	29.08	25.8
1981	30.8	25.4
1982	30.8	25.6
1983	30.8	25.45
1984	30.8	25.6
1985	30.79	25.5
1986	30.99	25.9
1987	31.19	25.8
1988	31.39	25.9
1989	31.59	25.3
1990	31.5	25.3
1991	30.75	25.3
1992	30.7	25.3
1993	30.76	25.4
1994	30.77	25.45
1995	30.78	25.5
1996	30.79	25.55
1997	30.8	25
1998	30.8	25.6
1999	30.81	25.6
2000	30.82	25.25
2001	30.83	25.4
2002	30.84	25.35
2003	30.85	25.3
2004	30.86	25.5
2005	30.87	25.4
2006	30.88	25.6
2007	30.9	25.5
2008	31	25.7
2009	31.1	25.9
2010	31.2	26
2011	31.3	25.4
2012	31.3	25.8
2013	31.4	25.4
2014	31.4	25.6
2015	31.4	25.8
2016	31.4	26.1
2017	31.5	25.6
2018	31.5	25.8
2019	31.5	25.7
2020	31.85	26.8

Source (BMD)

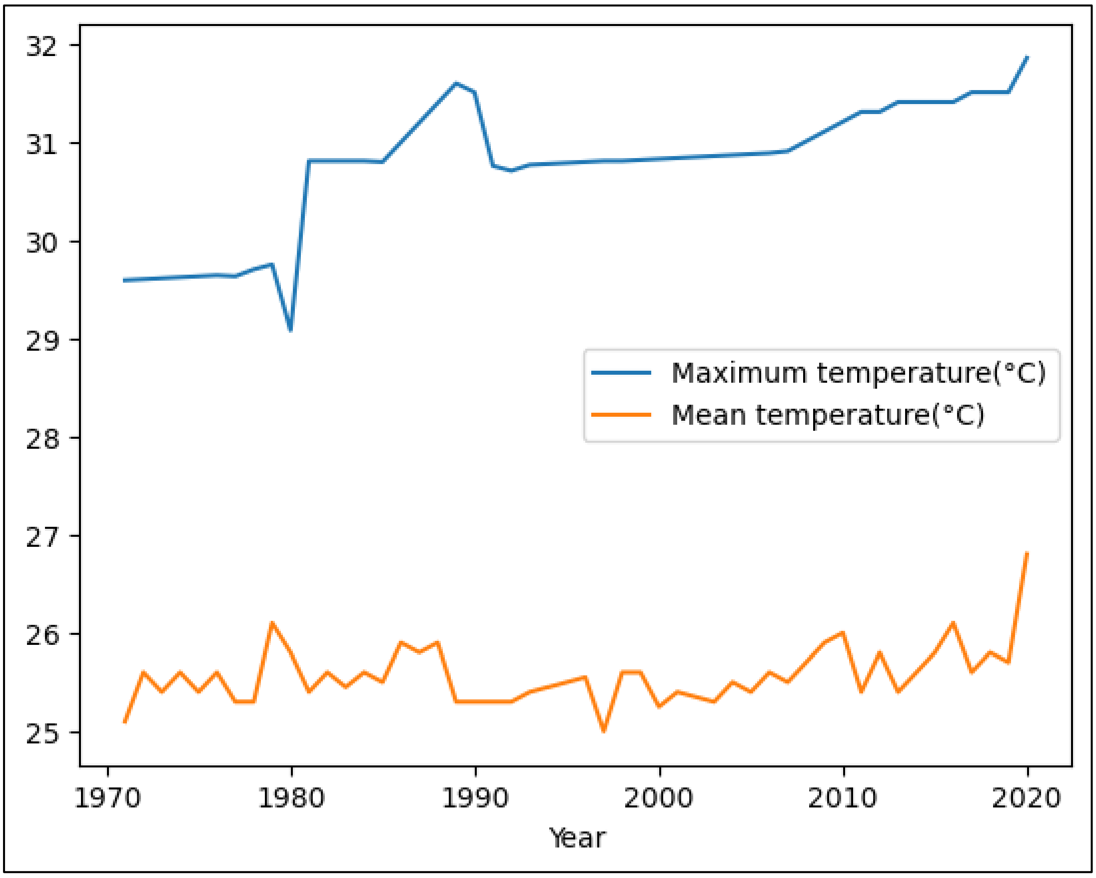

Figure 4.1:Variation in maximum and mean temperature (1971-2020)

The above time series plot exhibits maximum and mean temperature from 1971 to 2020. In 2020, maximum temperature was 31.5 °C which was the highest temperature from 1971 to 2020. On the other hand, in 1971, maximum temperature was 29.59°C which was the lowest maximum temperature from 1971 to 2020. In the event of mean temperature, maximum mean temperature was 26.8 °C in 2020 which was the highest mean temperature from 1971 to 2020. However, in 1971, mean temperature was 25.1°C which was the lowest mean temperature from 1971 to 2020.

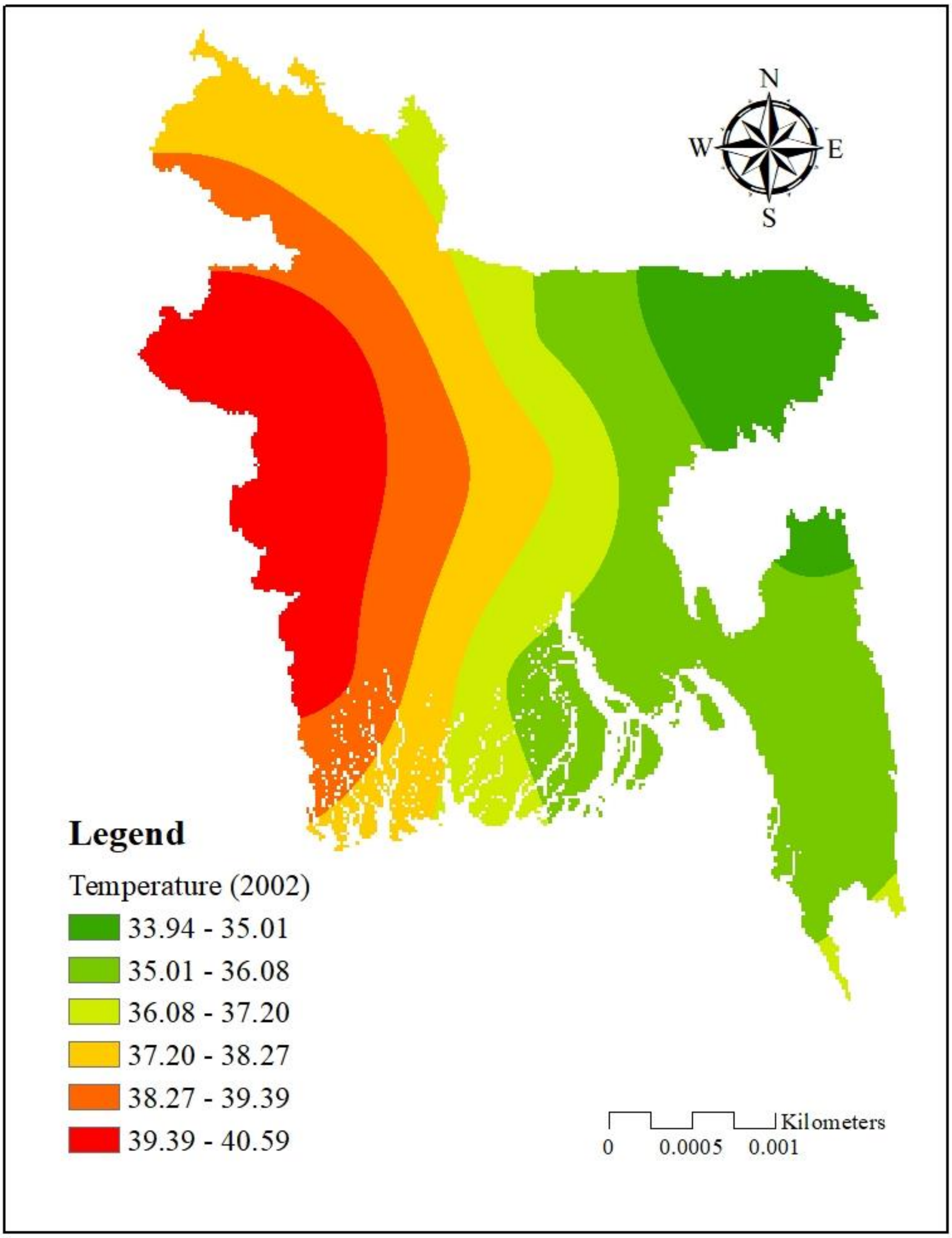

Figure 4.2 : Spatial variation of extreme temperature for Summer season in Bangladesh (2002)

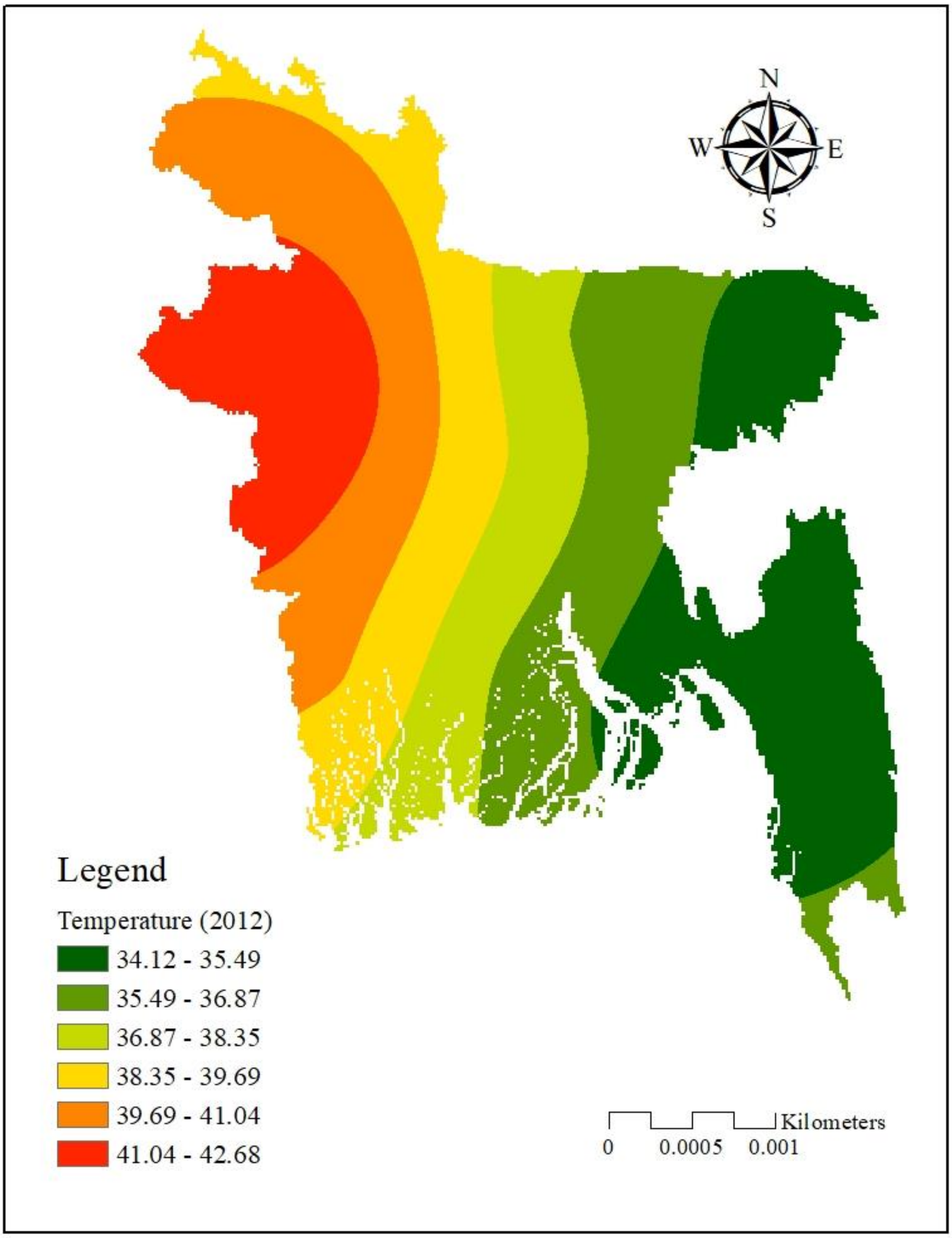

Figure 4.3: Spatial variation of extreme temperature for Summer season in Bangladesh (2012)

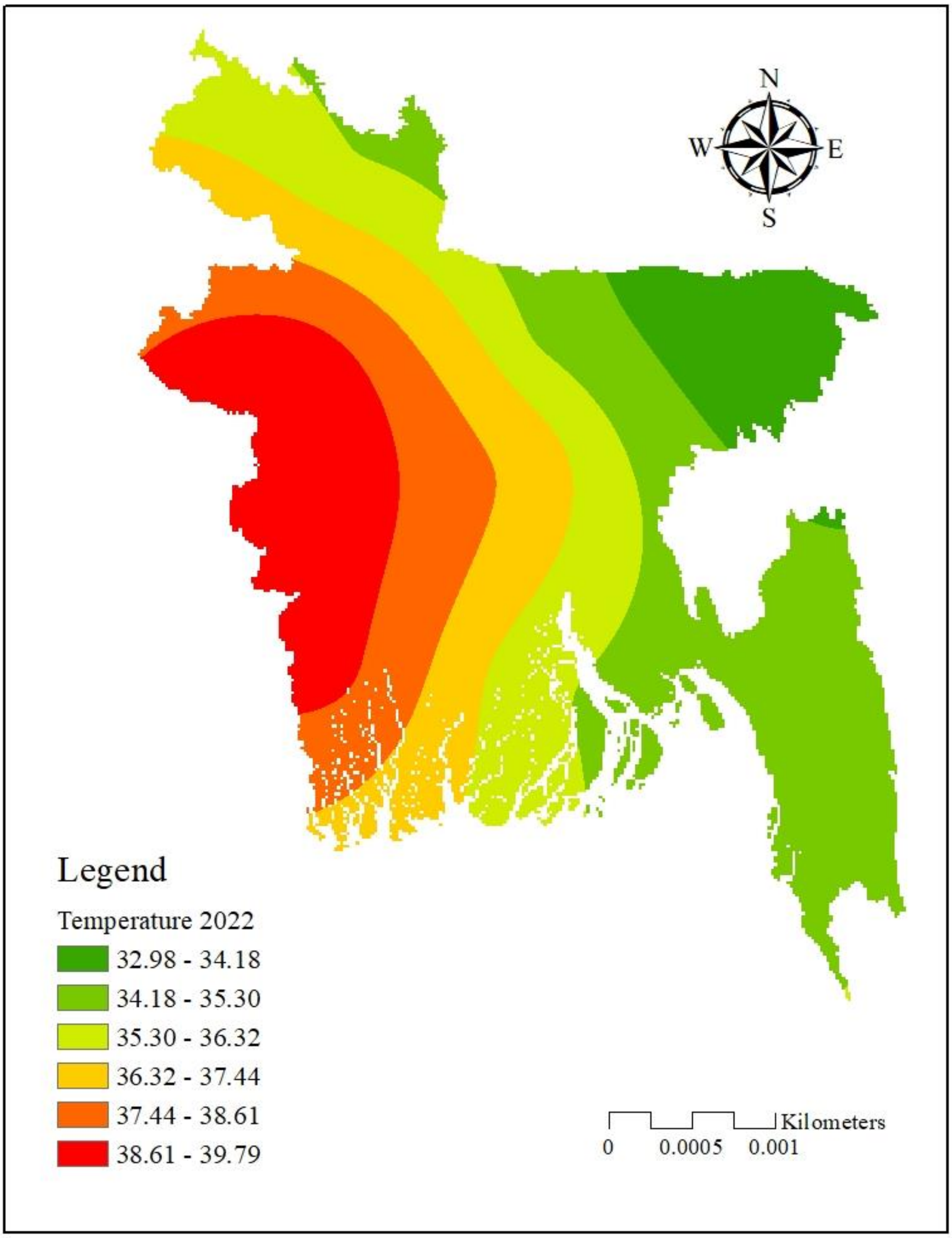

Figure 4.4: Spatial variation of extreme temperature for Summer season in Bangladesh (2022)

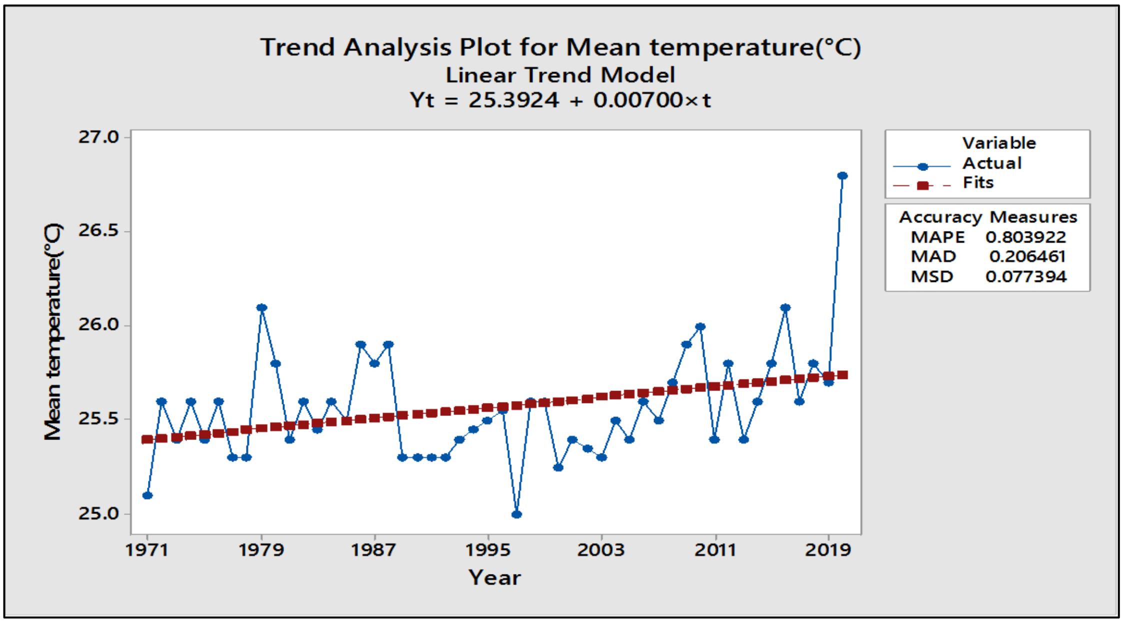

Figure 4.5:Trend Analysis plot for Mean temperature(°C)

The above trend analysis of time series plot shows fluctuation in temperature from the mean and exhibits a clear increasing trend in the temperature of Bangladesh from 1971 to 2019.

Figure 4.6:Forcasting Analysis plot for Mean temperature(°C)

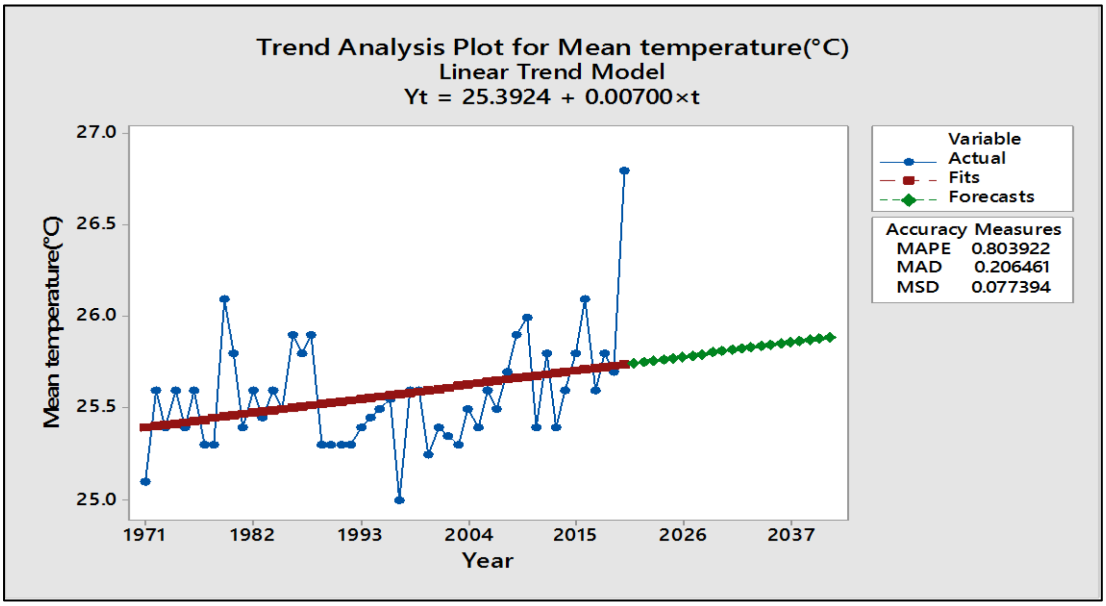

Table 2:Forecasts of Mean temperature

Year	Forecasts of Mean temperature
2021	25.7496
2022	25.7566
2023	25.7636
2024	25.7706
2025	25.7776
2026	25.7846
2027	25.7916
2028	25.7986
2029	25.8056
2030	25.8126
2031	25.8196
2032	25.8266
2033	25.8336
2034	25.8406
2035	25.8476
2036	25.8546
2037	25.8616
2038	25.8687
2039	25.8757
2040	25.8827

The temperature data shown above reveals that there is more than 1-degree temperature rise on an average in the last century.

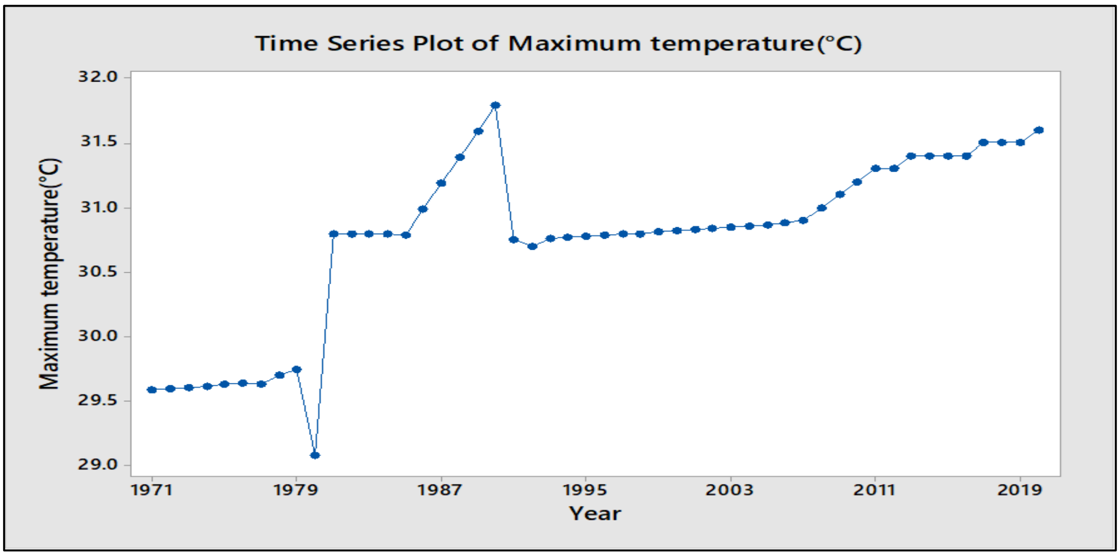

Figure 4.7:Time series plot for maximum temperature(°C)

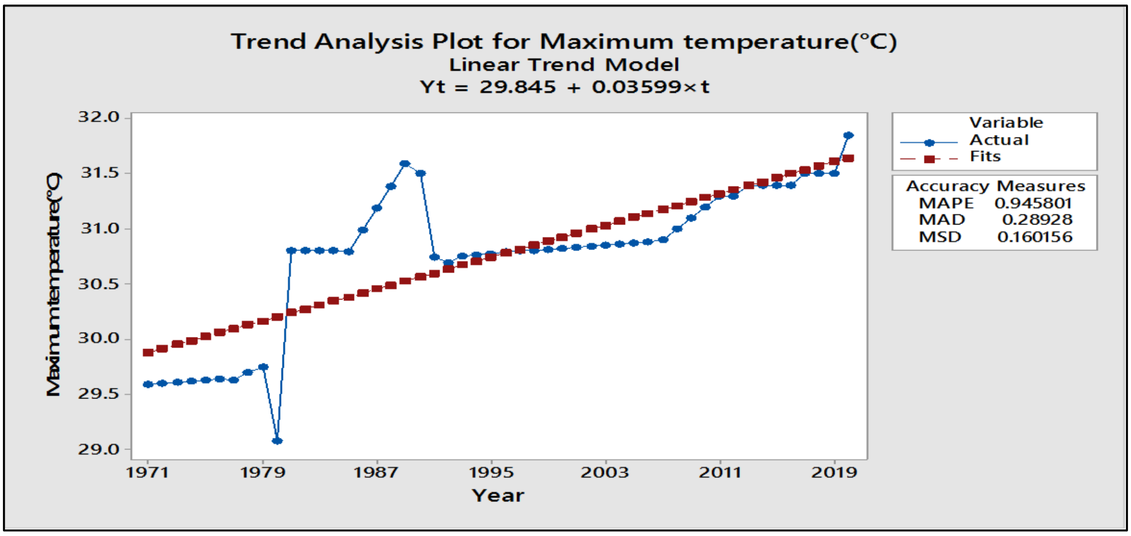

Figure 4.8:Trend Analysis plot for maximum temperature(°C)

The above time series analysis for maximum temperature from the past years indicate a clear upward trend in the temperature of Bangladesh.

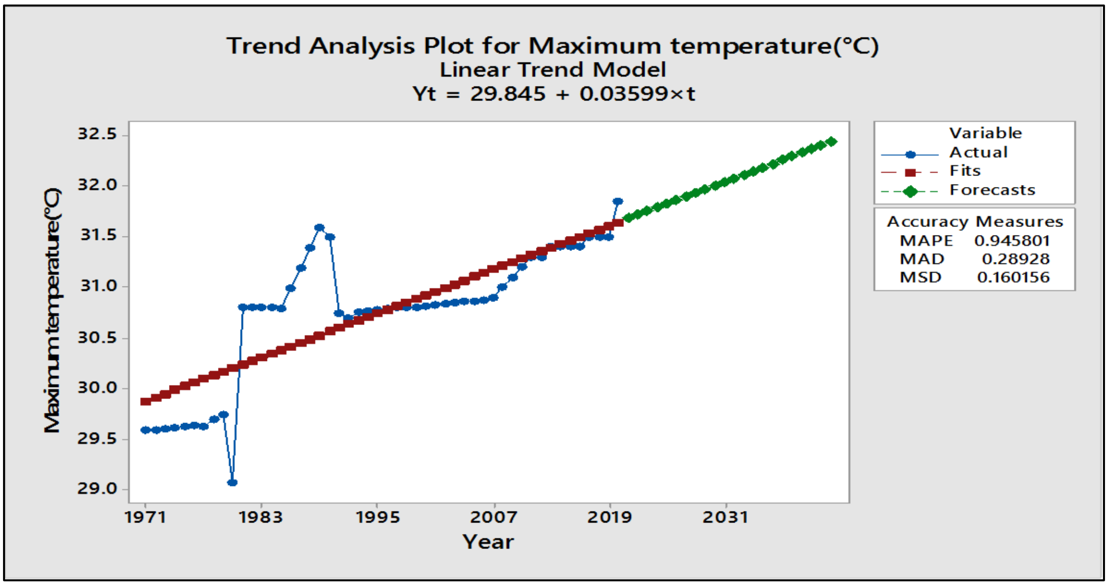

Figure 4.9:Forcasting Analysis plot for Maximum temperature(°C)

Table 3:Forecasts for Maximum temperature(°C)

Year	**Forecasts for Maximum temperature(°C)**
2021	31.6811
2022	31.7170
2023	31.7530
2024	31.7890
2025	31.8250
2026	31.8610
2027	31.8970
2028	31.9330
2029	31.9690
2030	32.0050
2031	32.0410
2032	32.0770
2033	32.1130
2034	32.1490
2035	32.1850
2036	32.2210
2037	32.2570
2038	32.2930
2039	32.3289
2040	32.3649

The above time series analysis shows increasing trend of temperature in the upcoming years.

Figure 4.10:ETS forecasting Analysis plot for Maximum temperature(°C)

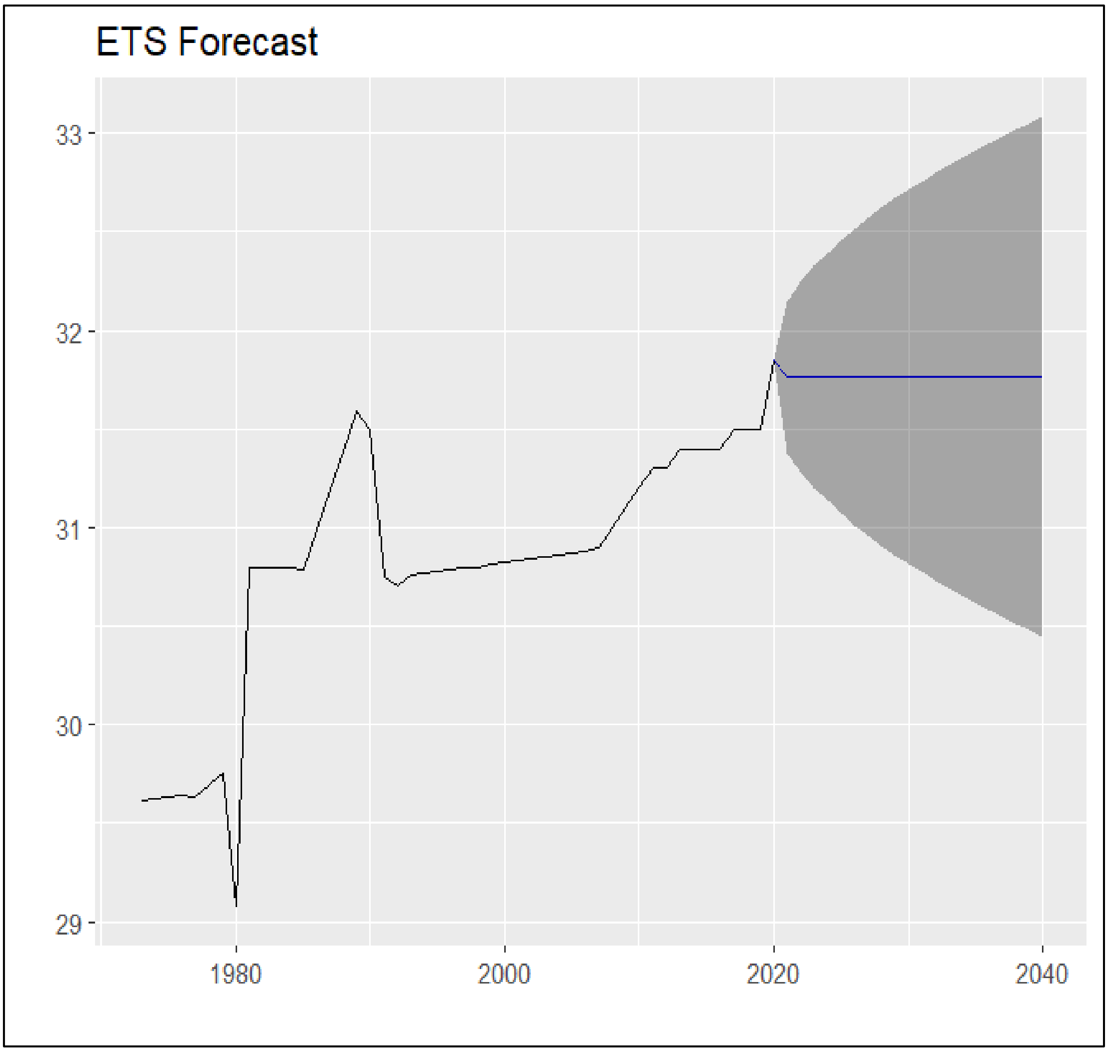

Table 4:ETS forecasting for Maximum temperature(°C)

Point Forecast	Lo 80	Hi 80	Lo 95	Hi 95
2021 31.76394	31.38114	32.14674	31.17850	32.34938
2022 31.76394	31.28426	32.24362	31.03033	32.49755
2023 31.76394	31.20389	32.32399	30.90742	32.62046
2024 31.76394	31.13369	32.39419	30.80006	32.72782
2025 31.76394	31.07056	32.45732	30.70351	32.82437
2026 31.76394	31.01272	32.51516	30.61504	32.91283
2027 31.76394	30.95902	32.56886	30.53292	32.99496
2028 31.76394	30.90869	32.61919	30.45595	33.07193
2029 31.76394	30.86116	32.66672	30.38325	33.14463
2030 31.76394	30.81601	32.71187	30.31420	33.21368
2031 31.76394	30.77291	32.75497	30.24829	33.27959
2032 31.76394	30.73161	32.79626	30.18513	33.34274
2033 31.76394	30.69191	32.83597	30.12441	33.40347
2034 31.76394	30.65362	32.87426	30.06585	33.46203
2035 31.76394	30.61661	32.91127	30.00924	33.51864
2036 31.76394	30.58075	32.94713	29.95441	33.57347
2037 31.76394	30.54595	32.98193	29.90119	33.62669
2038 31.76394	30.51212	33.01576	29.84945	33.67843
2039 31.76394	30.47918	33.04870	29.79906	33.72881
2040 31.76394	30.44706	33.08082	29.74994	33.77794

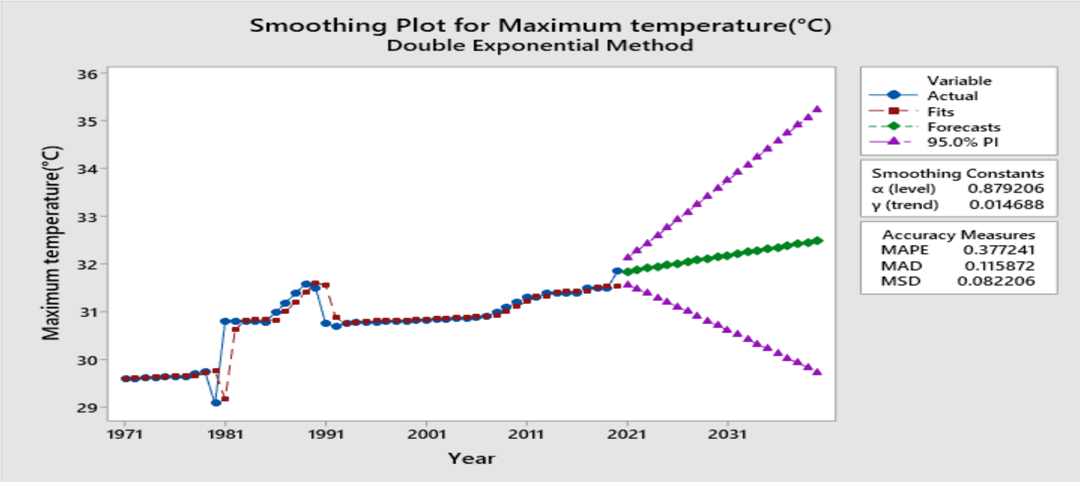

Figure 4.11:Forecasts for Maximum temperature(°C) Double Exponential Method

Table 5:Forecasts for Maximum temperature(°C) Double Exponential Method

Year	Forecast	Lower	Upper
2021	31.8455	31.5617	32.1294
2022	31.8793	31.4788	32.2799
2023	31.9131	31.3883	32.4378
2024	31.9468	31.2946	32.5991
2025	31.9806	31.1992	32.7620
2026	32.0144	31.1029	32.9258
2027	32.0481	31.0059	33.0903
2028	32.0819	30.9086	33.2552
2029	32.1156	30.8110	33.4203
2030	32.1494	30.7131	33.5857
2031	32.1832	30.6152	33.7511
2032	32.2169	30.5171	33.9168
2033	32.2507	30.4189	34.0824
2034	32.2844	30.3207	34.2482
2035	32.3182	30.2224	34.4141
2036	32.3520	30.1240	34.5799
2037	32.3857	30.0256	34.7459
2038	32.4195	29.9272	34.9118
2039	32.4533	29.8287	35.0778
2040	32.4870	29.7302	35.2438

The above time series analysis using double exponential method shows maximum temperature(°C) rise considerably in the future years.

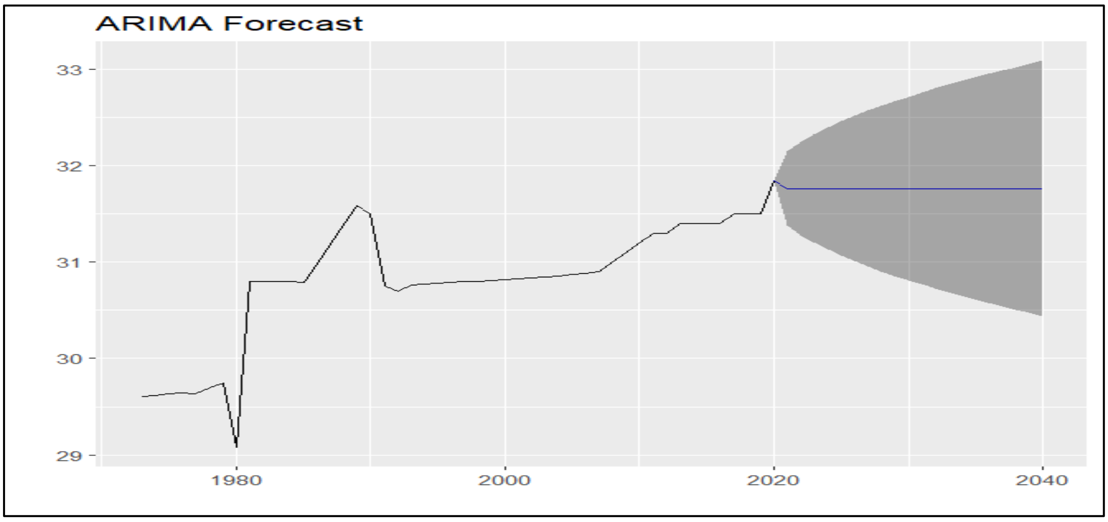

Figure 4.12:ARIMA Forecasting Analysis plot for Maximum temperature(°C)

Table 6:ARIMA Forecasting Analysis plot for Maximum temperature(°C)

	Point Forecast	Lo 80	Hi 80	Lo 95	Hi 95
2021	**31.76587**	**31.38303**	**32.14872**	**31.18036**	**32.35138**
2022	**31.76587**	**31.28488**	**32.24687**	**31.03025**	**32.50149**
2023	**31.76587**	**31.20361**	**32.32814**	**30.90596**	**32.62578**
2024	**31.76587**	**31.13268**	**32.39906**	**30.79749**	**32.73425**
2025	**31.76587**	**31.06894**	**32.46281**	**30.70000**	**32.83174**
2026	**31.76587**	**31.01055**	**32.52119**	**30.61071**	**32.92103**
2027	**31.76587**	**30.95637**	**32.57537**	**30.52785**	**33.00390**
2028	**31.76587**	**30.90559**	**32.62615**	**30.45019**	**33.08155**
2029	**31.76587**	**30.85765**	**32.67409**	**30.37687**	**33.15488**
2030	**31.76587**	**30.81211**	**32.71963**	**30.30723**	**33.22452**
2031	**31.76587**	**30.76866**	**32.76309**	**30.24076**	**33.29098**
2032	**31.76587**	**30.72701**	**32.80473**	**30.17708**	**33.35467**
2033	**31.76587**	**30.68698**	**32.84477**	**30.11585**	**33.41590**
2034	**31.76587**	**30.64837**	**32.88337**	**30.05681**	**33.47494**
2035	**31.76587**	**30.61106**	**32.92068**	**29.99974**	**33.53200**
2036	**31.76587**	**30.57492**	**32.95683**	**29.94446**	**33.58728**
2037	**31.76587**	**30.53984**	**32.99191**	**29.89081**	**33.64093**
2038	**31.76587**	**30.50573**	**33.02601**	**29.83866**	**33.69309**
2039	**31.76587**	**30.47253**	**33.05921**	**29.78788**	**33.74387**
2040	**31.76587**	**30.44016**	**33.09159**	**29.73836**	**33.7933**

Table 7:Diarriah Cases in the Past **Source** (DG Health, 2015-17)

Year	Diarriah
2000	1556
2001	1866
2002	2599
2003	2287
2004	2246
2005	2152
2006	1962
2007	2335
2008	2295
2009	2619
2010	2427
2011	2268
2012	2631
2013	2641

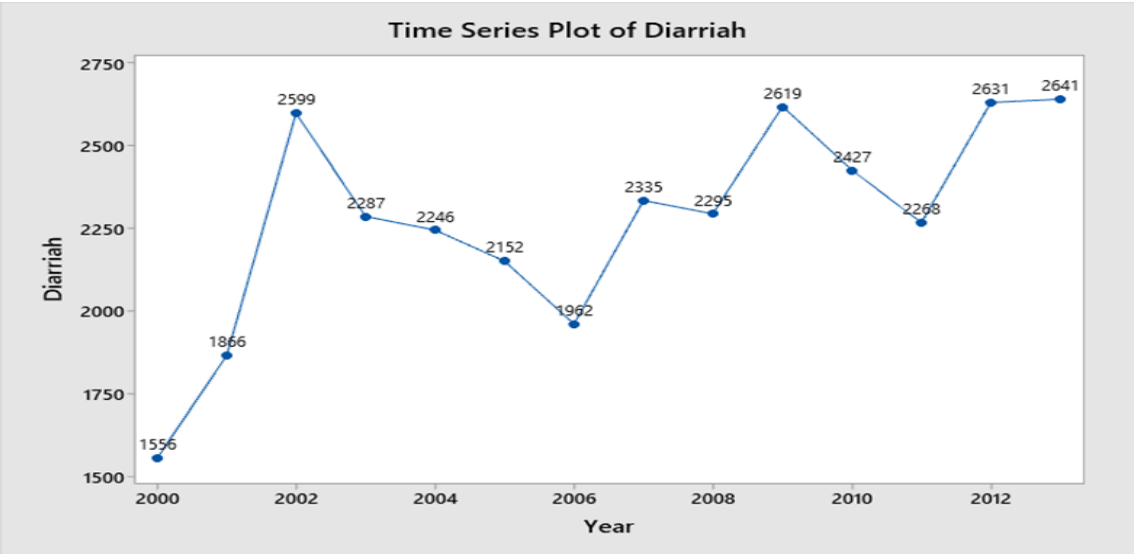

Figure 4.13:Time Series plot for Diarriah in the past

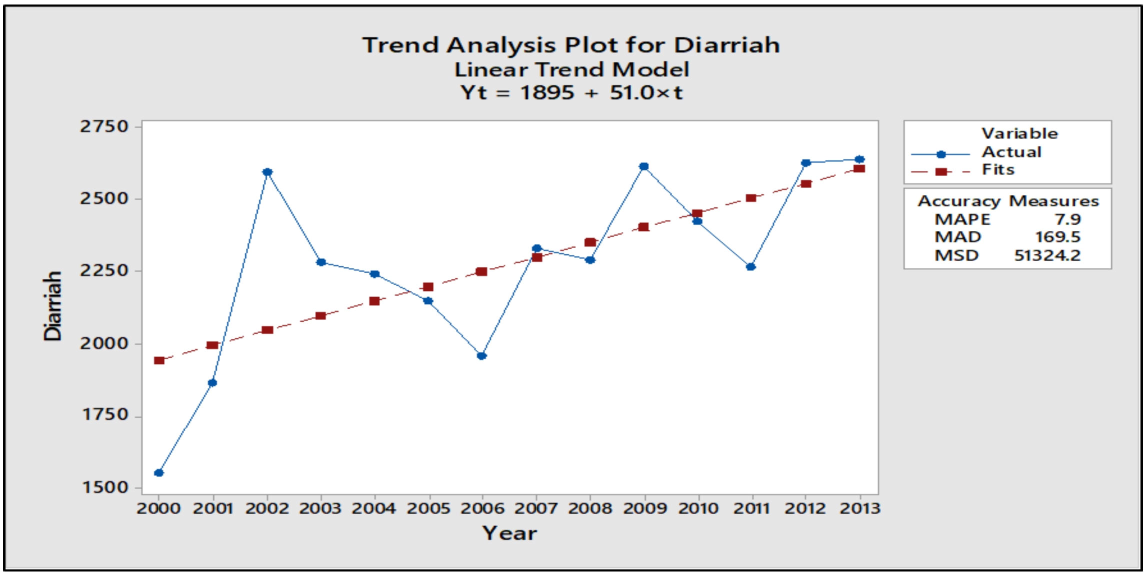

Figure 4.14:Trend Analysis plot for Diarriah in the past

The above time series plot for diarrhea cases show lowest number of diarrhea cases that was 1556 during 2000 to 2013. On the other hand, in 2013, it was rocketed which was 2641number of diarrhea cases.So, the above time series plot exhibits a clear upward trend regarding the diarrhea cases of Bangladesh during 2000 to 2013.

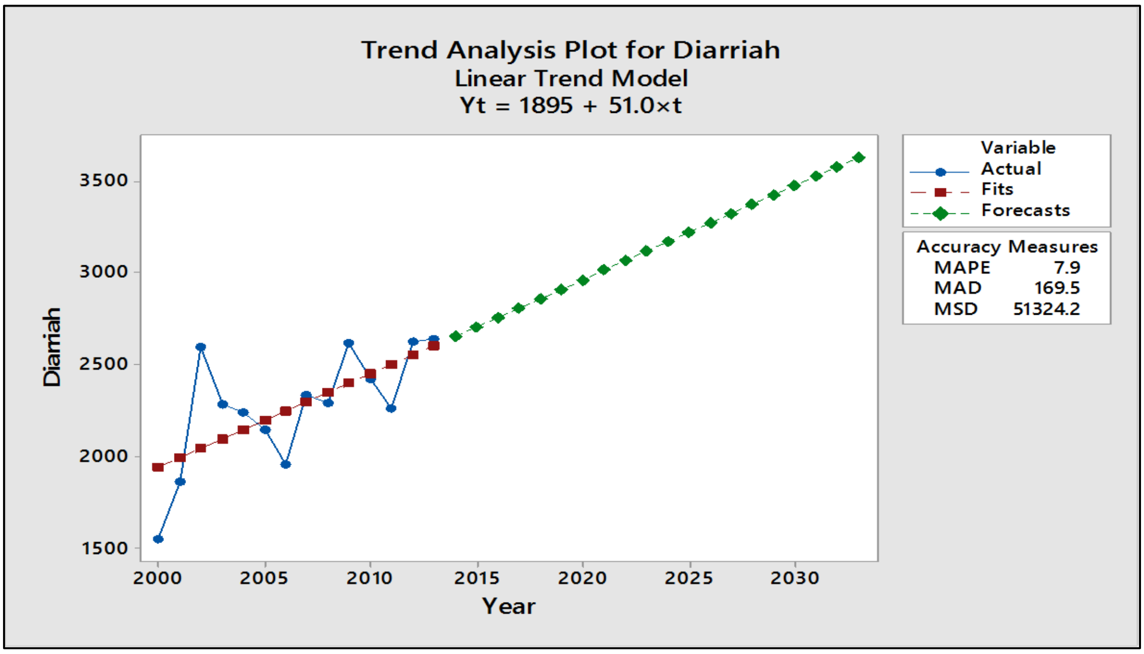

Figure 4.15:Forecasted Diarriah Cases

Table9: Forecasted Diarriah Cases

Year	Forecasted Diarriah Cases
2014	2659.65
2015	2710.61
2016	2761.57
2017	2812.54
2018	2863.50
2019	2914.46
2020	2965.42
2021	3016.39
2022	3067.35
2023	3118.31
2024	3169.27
2025	3220.24
2026	3271.20
2027	3322.16
2028	3373.13
2029	3424.09
2030	3475.05
2031	3526.01
2032	3576.98
2033	3627.94
2034	3678.90
2035	3729.86
2036	3780.83
2037	3831.79
2038	3882.75
2039	3933.71
2040	3984.68

From the above time series plot, it is anticipated that Diarriah cases will increase significantly in the future.

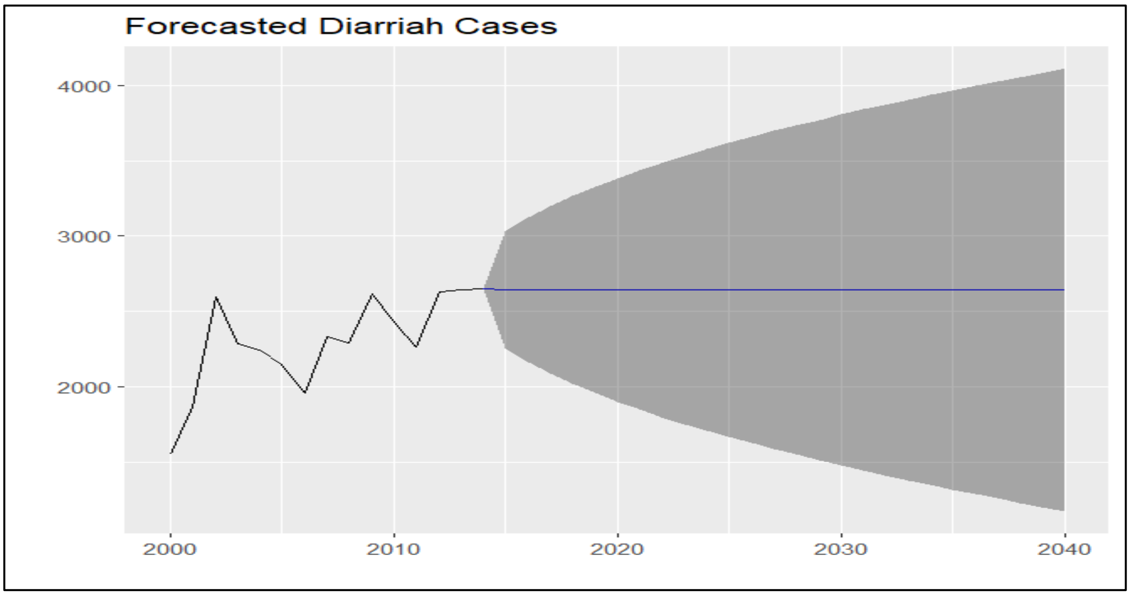

Figure 4.16:Forecasted Diarriah Cases ETS model

Table 10: Forecasted Diarriah Cases ETS model

	Point Forecast	Lo 80	Hi 80	Lo 95	Hi 95
2015	2642.98	2256.112	3029.847	2051.3167	3234.642
2016	2642.98	2163.710	3122.249	1909.9998	3375.959
2017	2642.98	2086.443	3199.516	1791.8311	3494.128
2018	2642.98	2018.668	3267.291	1688.1769	3597.782
2019	2642.98	1957.561	3328.398	1594.7227	3691.236
2020	2642.98	1901.473	3384.486	1508.9439	3777.015
2021	2642.98	1849.340	3436.619	1429.2122	3856.747
2022	2642.98	1800.426	3485.533	1354.4045	3931.555
2023	2642.98	1754.199	3531.760	1283.7077	4002.251
2024	2642.98	1710.261	3575.698	1216.5103	4069.449
2025	2642.98	1668.302	3617.657	1152.3391	4133.620
2026	2642.98	1628.076	3657.883	1090.8187	4195.140
2027	2642.98	1589.385	3696.574	1031.6454	4254.314
2028	2642.98	1552.065	3733.894	974.5695	4311.389
2029	2642.98	1515.980	3769.979	919.3826	4366.576
2030	2642.98	1481.015	3804.944	865.9087	4420.050
2031	2642.98	1447.072	3838.887	813.9975	4471.961
2032	2642.98	1414.067	3871.892	763.5196	4522.439
2033	2642.98	1381.925	3904.034	714.3624	4571.597
2034	2642.98	1350.582	3935.377	666.4274	4619.532
2035	2642.98	1319.981	3965.978	619.6277	4666.331
2036	2642.98	1290.072	3995.887	573.8862	4712.073
2037	2642.98	1260.810	4025.149	529.1343	4756.825
2038	2642.98	1232.156	4053.803	485.3104	4800.649
2039	2642.98	1204.071	4081.888	442.3591	4843.600
2040	2642.98	1176.525	4109.434	400.2302	4885.729

ARIMA (2,1,2) with drift : Inf

ARIMA (0,1,0) with drift : 203.0181

ARIMA (1,1,0) with drift : 205.8053

ARIMA (0,1,1) with drift : Inf

ARIMA (0,1,0) : 201.2859

ARIMA (1,1,1) with drift : Inf

Best model: ARIMA (0,1,0)

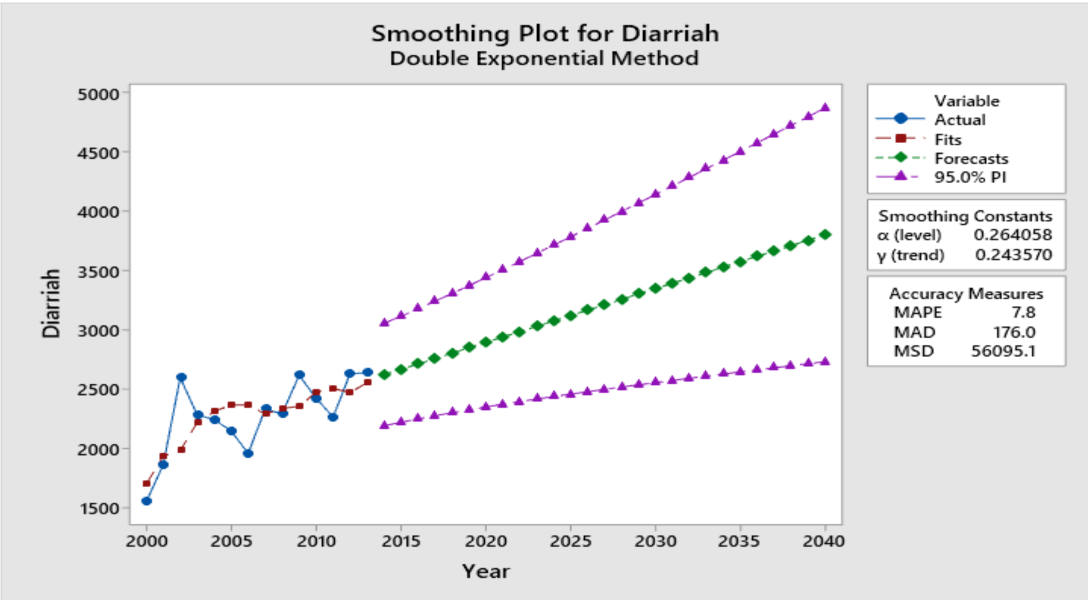

Figure 4.17:Forecasted Diarriah Cases Double Exponential model

Table 11: Forecasted Diarriah Cases Double Exponential model

Year	Forecasted Diarriah Cases Double Exponential model	Lower	Upper
2014	2623.45	2192.20	3054.70
2015	2668.74	2221.68	3115.80
2016	2714.04	2249.73	3178.34
2017	2759.33	2276.49	3242.16
2018	2804.62	2302.11	3307.13
2019	2849.91	2326.72	3373.11
2020	2895.21	2350.43	3439.98
2021	2940.50	2373.34	3507.65
2022	2985.79	2395.55	3576.03
2023	3031.08	2417.14	3645.03
2024	3076.37	2438.17	3714.58
2025	3121.67	2458.70	3784.63
2026	3166.96	2478.79	3855.13
2027	3212.25	2498.49	3926.01
2028	3257.54	2517.83	3997.25
2029	3302.84	2536.86	4068.81
2030	3348.13	2555.60	4140.65
2031	3393.42	2574.08	4212.76
2032	3438.71	2592.33	4285.09
2033	3484.00	2610.37	4357.64
2034	3529.30	2628.21	4430.38
2035	3574.59	2645.88	4503.30
2036	3619.88	2663.39	4576.37
2037	3665.17	2680.75	4649.60
2038	3710.47	2697.97	4722.96
2039	3755.76	2715.08	4796.44
2040	3801.05	2732.06	4870.03

Table12: Dengue cases of Bangladesh in the past **Source** (DG Health, 2015-17)

Year	Dengue(Cases in 1000)
2000	5.55
2001	2.43
2002	6.23
2003	3.93
2004	1.05
2005	2.2
2006	0.47
2007	0.41
2008	1.15
2009	0.47
2010	0.41
2011	1.36
2012	0.67
2013	1.75
2014	0.38
2015	3.16
2016	6.06
2017	2.77
2018	10.15
2019	101.35

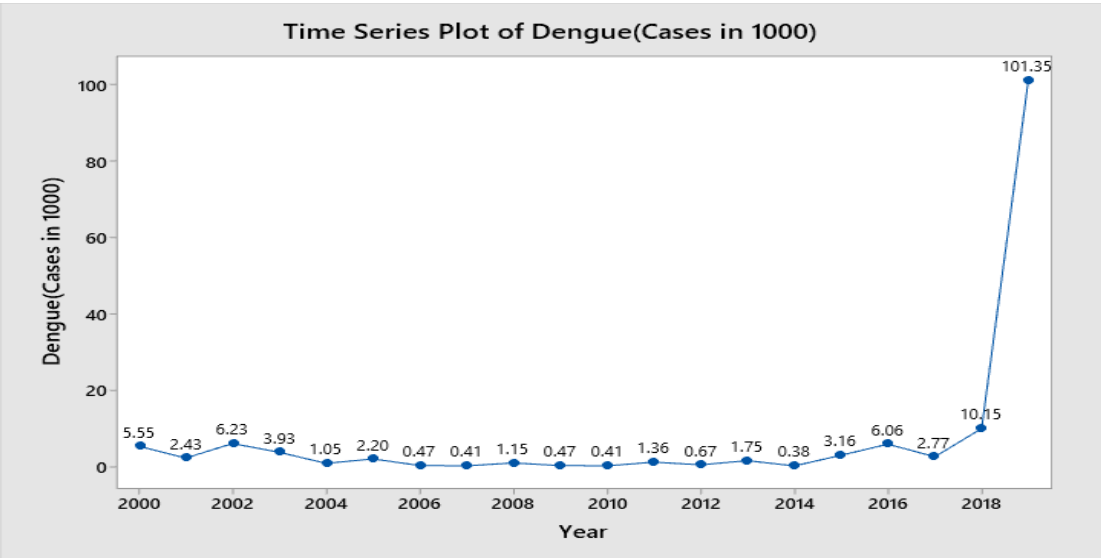

Figure 4.18:Time Series plot for Dengue Cases in the past

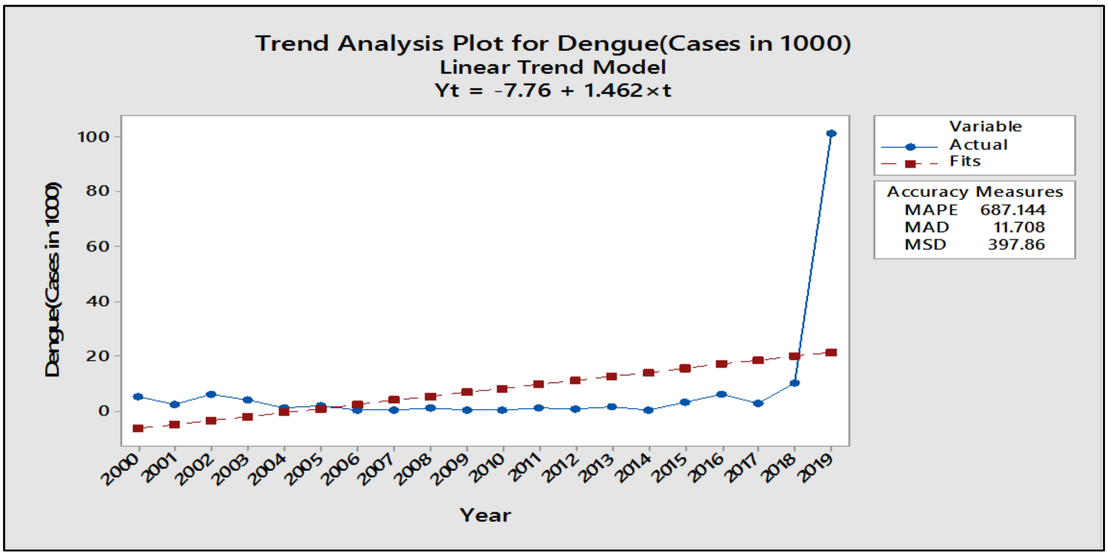

Figure 4.19:Trend Analyses Plot for Dengue cases of Bangladesh in the past

The above time series plot shows a clear upward trend regarding the Dengue (Cases in 1000) of Bangladesh during 2000 to 2013.

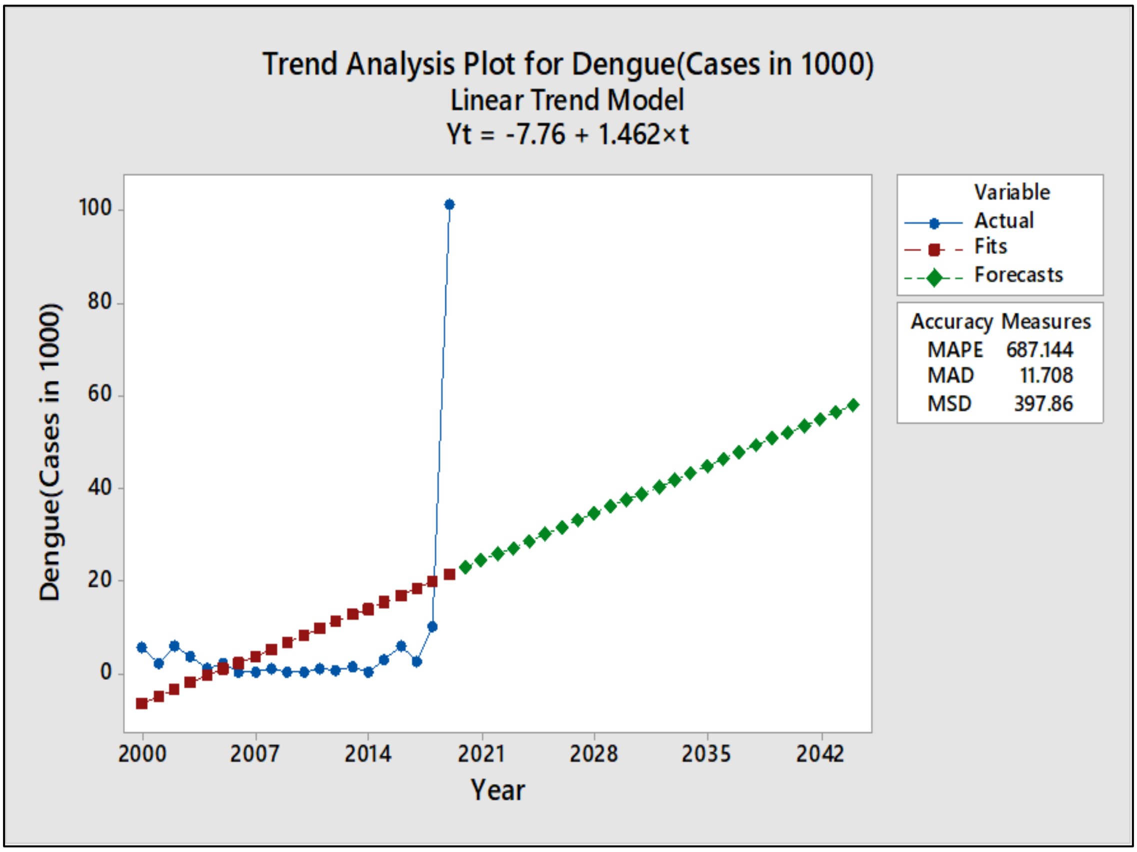

Figure 4.20:Forecasted Dengue Cases

Table 13: Forecasted Dengue Cases

Year	**Forecasted Dengue Cases**
2020	22.9519
2021	24.4142
2022	25.8765
2023	27.3389
2024	28.8012
2025	30.2635
2026	31.7258
2027	33.1882
2028	34.6505
2029	36.1128
2030	37.5751
2031	39.0375
2032	40.4998
2033	41.9621
2034	43.4244
2035	44.8867
2036	46.3491
2037	47.8114
2038	49.2737
2039	50.7360
2040	52.1984

From the above time series plot, it is expected that Dengue Cases will rise considerably in the future.

Table 14: Heat index in Dhaka in the past

Year	Average Heat Index	Max Heat Index	Minimum Heat Index
1976	37.83333333	45	27
1977	38	47	25
1978	38.16666667	44	25
1979	39.91666667	54	26
1980	38.41666667	51	25
1981	37.66666667	47	26
1982	38.75	50	27
1983	38.75	50	25
1984	38.58333333	48	25
1985	40.41666667	47	28
1986	41.16666667	51	28
1987	41.41666667	52	28
1988	42.25	53	29
1989	41.41666667	52	26
1990	37.91666667	46	26
1991	38.66666667	48	25
1992	39.91666667	56	24
1993	38.08333333	44	25
1994	39.75	48	28
1995	41.66666667	53	26
1996	42.66666667	53	27
1997	39.33333333	48	25
1998	41.08333333	53	23
1999	41.33333333	53	29
2000	37.83333333	45	25
2001	38.5	46	25
2002	37.91666667	45	26
2003	38.25	47	22
2004	38.33333333	49	24
2005	39.5	49	25
2006	39.83333333	47	26
2007	38.75	49	25
2008	39.41666667	49	25
2009	40.83333333	51	27
2010	40.66666667	50	24
2011	38.41666667	48	24
2012	39.08333333	49	24
2013	39	48	24
2014	39.5	50	25
2015	38.83333333	47	25
2016	41.33333333	52	25
2017	40.33333333	50	27
2018	40.58333333	51	24

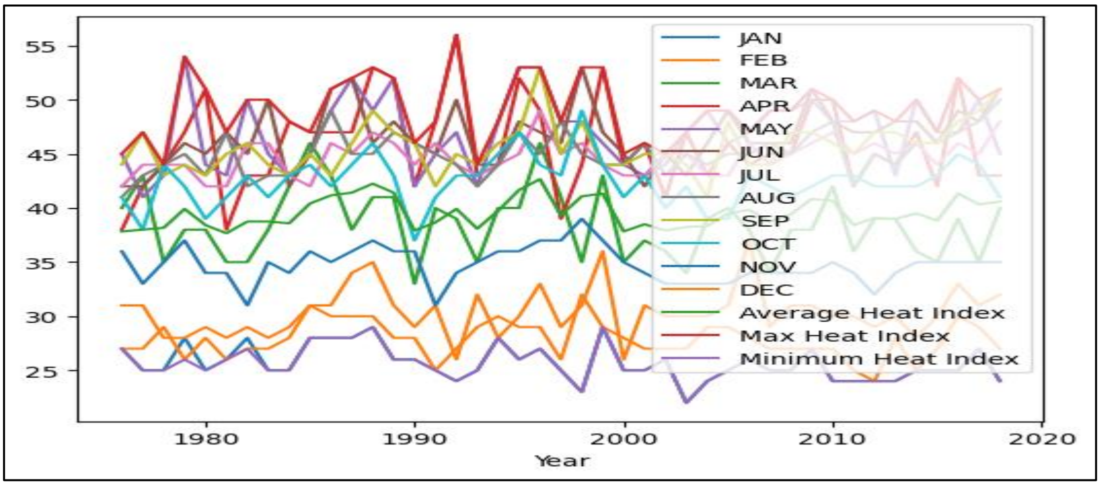

Figure 4.21:Time series Analyses of Heat index in Dhaka in the past

The above timeseries graph shows the Heat index during the period from the year 1976 to 2018. In the year 1992 Maximum Heat index was 54. On the other hand, In the year 1993 it was lowest which was 44. In the event Of Average Heat index,

it was around 43in the year 1996 which was highest.

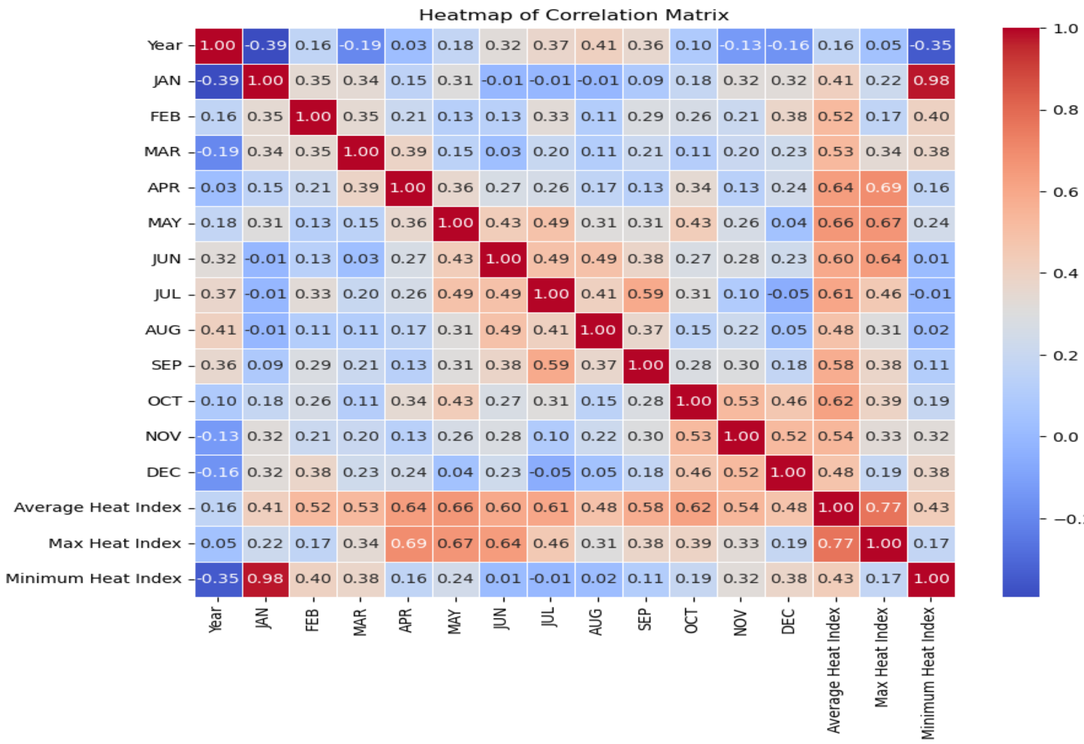

Figure 4.22:Heatmap of Correlation Matrix of Heat Index

Correlation plot heatmap representing the correlation between sixteen pairs of variables during the period.

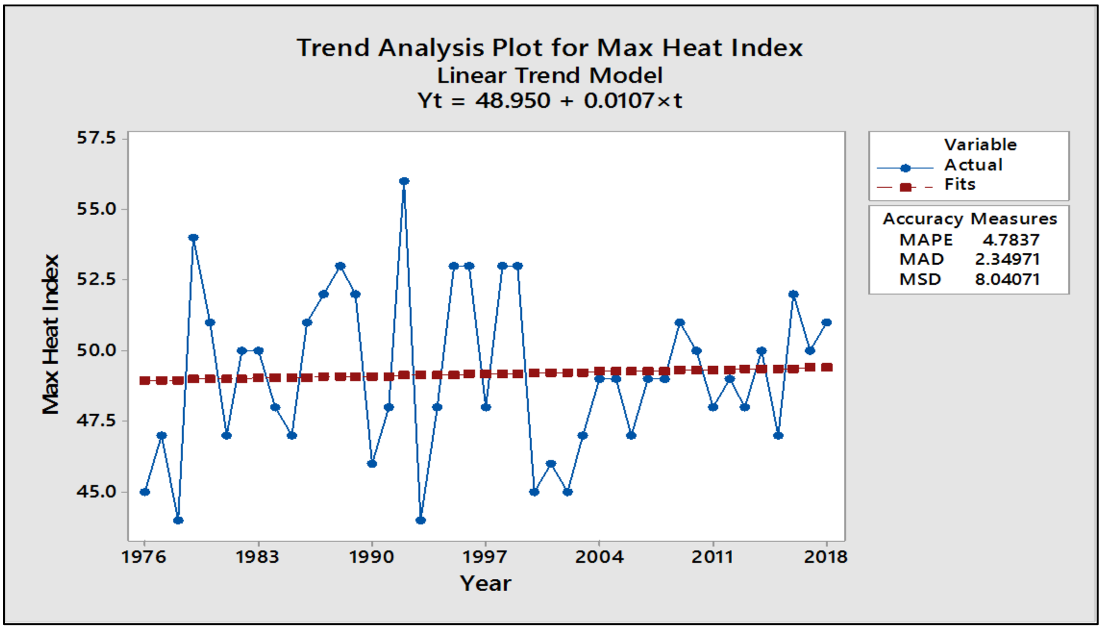

Figure 4.23:Trend Analyses Plot for Max Heat index in Dhaka Trend Analyses Plot for Max Heat index in Dhaka

4.2 Impact of temperature on Diarriah in Bangladesh

Table15: Maximum temperature VS Diarriah cases in Bangladesh

Year	Maximum temperature(°C)	Diarriah
2000	30.82	1556
2001	30.83	1866
2002	30.84	2599
2003	30.85	2287
2004	30.86	2246
2005	30.87	2152
2006	30.88	1962
2007	30.9	2335
2008	31	2295
2009	31.1	2619
2010	31.2	2427
2011	31.3	2268
2012	31.3	2631
2013	31.4	2641

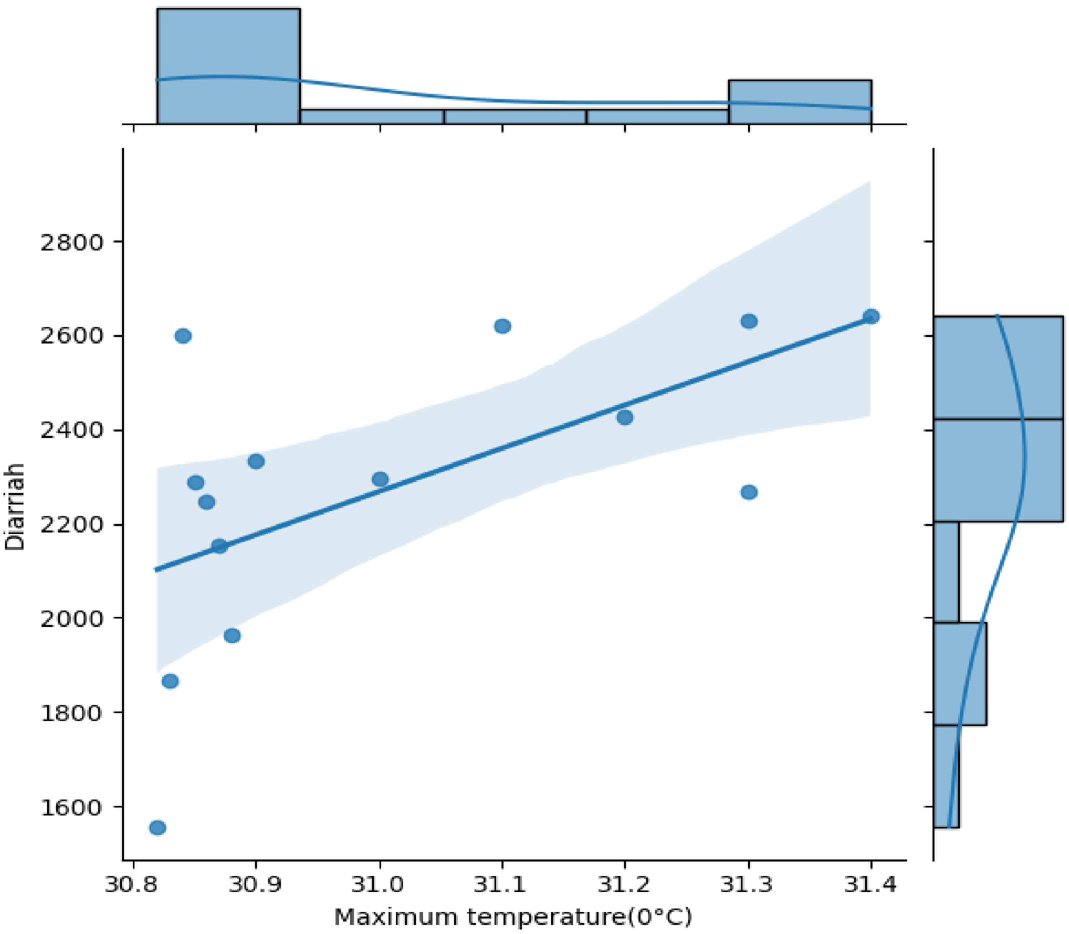

Figure 4.24: Joint plot showing the relationship between maximum temperature (in °C) and cases of diarrhea.

Here is the joint plot showing the relationship between maximum temperature (in °C) and cases of diarrhea. The scatter plot in the center visualizes this relationship, while the histograms along the margins display the distributions of each variable individually.

From the plot, it appears that as the temperature increases, the number of diarrhea cases increases, suggesting a potential positive relationship between these variables.

The joint plot displays the relationship between maximum temperature (in °C) and cases of diarrhea. As the maximum temperature increases, the number of diarrhea cases increases. This is evident from the upward slope in the scatter plot, indicating a positive correlation between these two variables.

The histogram along the x-axis shows that the maximum temperatures are fairly evenly distributed across the observed range (30.8°C to 31.4°C). The histogram along the y-axis indicates that the number of diarrhea cases ranges from 1600 to 2800, with a relatively even spread across these values.

The positive relationship might suggest that higher temperatures could be associated with factors that increases the incidence of diarrhea. This could be due to a variety of reasons, such as changes in environmental conditions.

Overall, the joint plot provides a clear visual representation of the positive correlation between maximum temperature and diarrhea cases, highlighting a potential area for further investigation. In the Joint plot, we find evidence of outlier.

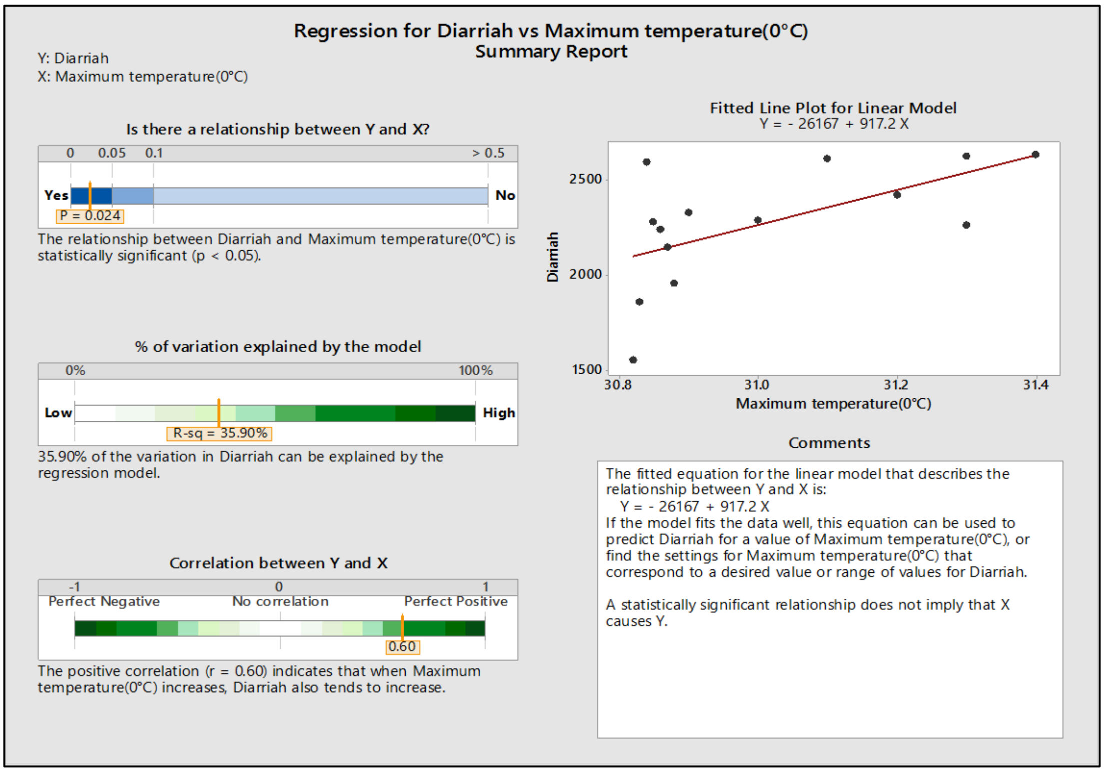

Figure 4.25:Regression analysis for Diarriah vs Maximum temperature

From figure 4.29, Pearson correlation coefficient of 0.599 indicates a moderately positive linear relationship between two variables. The correlation coefficient (r) ranges from -1 to 1. A value of 0.599 suggests that there is a moderate positive correlation between the two variables. This means that as one variable increases, the other tends to increase as well, though not perfectly. The positive sign indicates that as one variable increases, the other also tends to increase. In contrast, a negative correlation coefficient would indicate that as one variable increases, the other tends to decrease. While 0.599 is not a perfect correlation (which would be 1 or -1), it still indicates a noticeable tendency for the variables to move together. This can be useful in understanding how changes in one variable might predict changes in the other, though it does not imply causation.

To determine if this correlation is statistically significant (i.e., not likely due to random chance), one would typically look at the p-value associated with the correlation coefficient. If the p-value is sufficiently low (often less than 0.05), the correlation is considered statistically significant.

To recapitulate, a Pearson correlation coefficient of 0.599 indicates a moderate positive linear relationship between two variables, suggesting that they tend to move together in a positive direction, but not perfectly so.

4.3 Impact of temperature on Dengue in Bangladesh

Table 16: Maximum temperature VS Dengue cases in Bangladesh

Year	Maximum temperature(°C)	Dengue (Cases in 1000)
2000	30.82	5.55
2001	30.83	2.43
2002	30.84	6.23
2003	30.85	3.93
2004	30.86	1.05
2005	30.87	2.2
2006	30.88	0.47
2007	30.9	0.41
2008	31	1.15
2009	31.1	0.47
2010	31.2	0.41
2011	31.3	1.36
2012	31.3	0.67
2013	31.4	1.75
2014	31.4	0.38
2015	31.4	3.16
2016	31.4	6.06
2017	31.5	2.77
2018	31.5	10.15
2019	31.5	101.35

Pearson correlation coefficient: 0.33

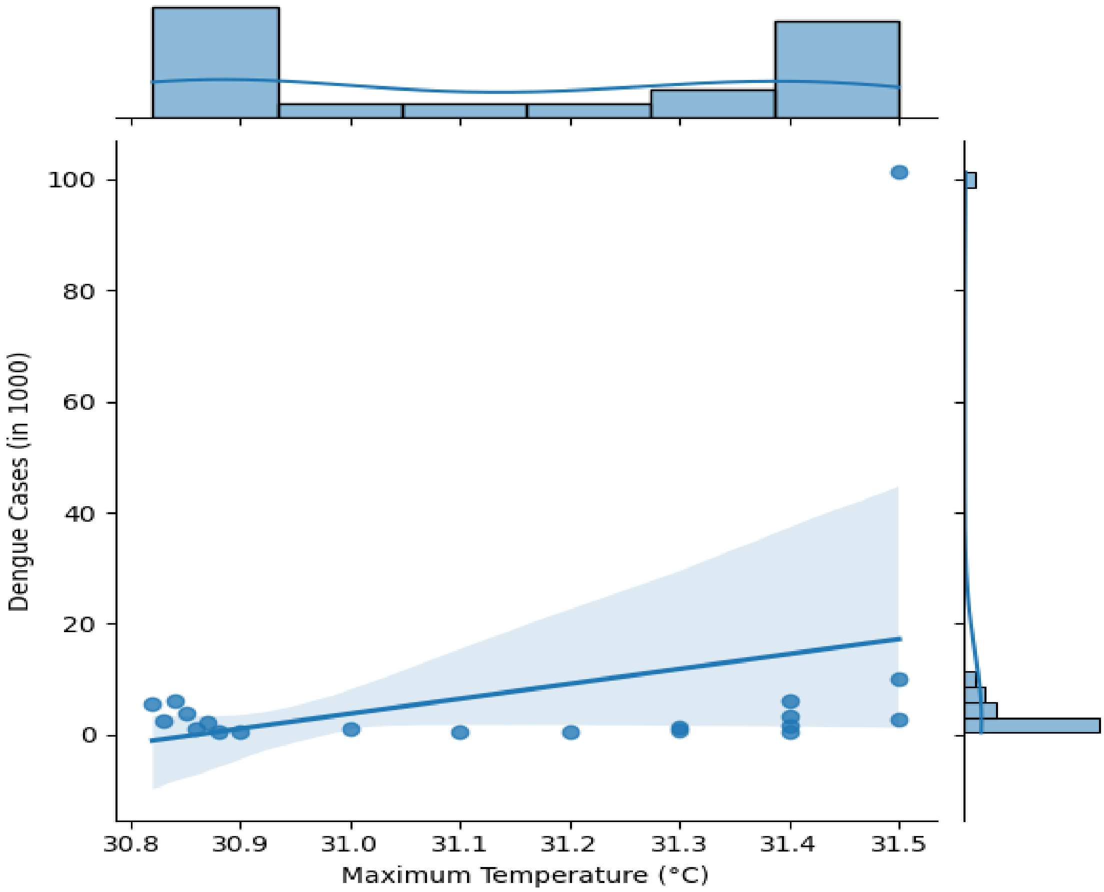

Figure 4.26: joint plot showing the relationship between maximum temperature (in °C) and cases of Dengue Cases(in1000)

Here is the joint plot showing the relationship between maximum temperature (in °C) and cases of Dengue Cases (in1000). The scatter plot in the center visualizes this relationship, while the histograms along the margins display the distributions of each variable individually.

The joint plot displays the relationship between maximum temperature (in °C) and cases of diarrhea. As the maximum temperature increases, the number Dengue cases increases. This is evident from the upward slope in the scatter plot, indicating a positive correlation between these two variables.

The histogram along the x-axis shows that the maximum temperatures are fairly evenly distributed across the observed range (30.8°C to 31.4°C). The histogram along the y-axis indicates that the number of cases ranges from 0 to 100 Dengue cases (in thousands), with a relatively even spread across these values. Higher temperatures might create conditions that are more conductive for the spread of Dengue, perhaps affecting mosquito populations or their activity. In the Joint plot, we find evidence of outlier.

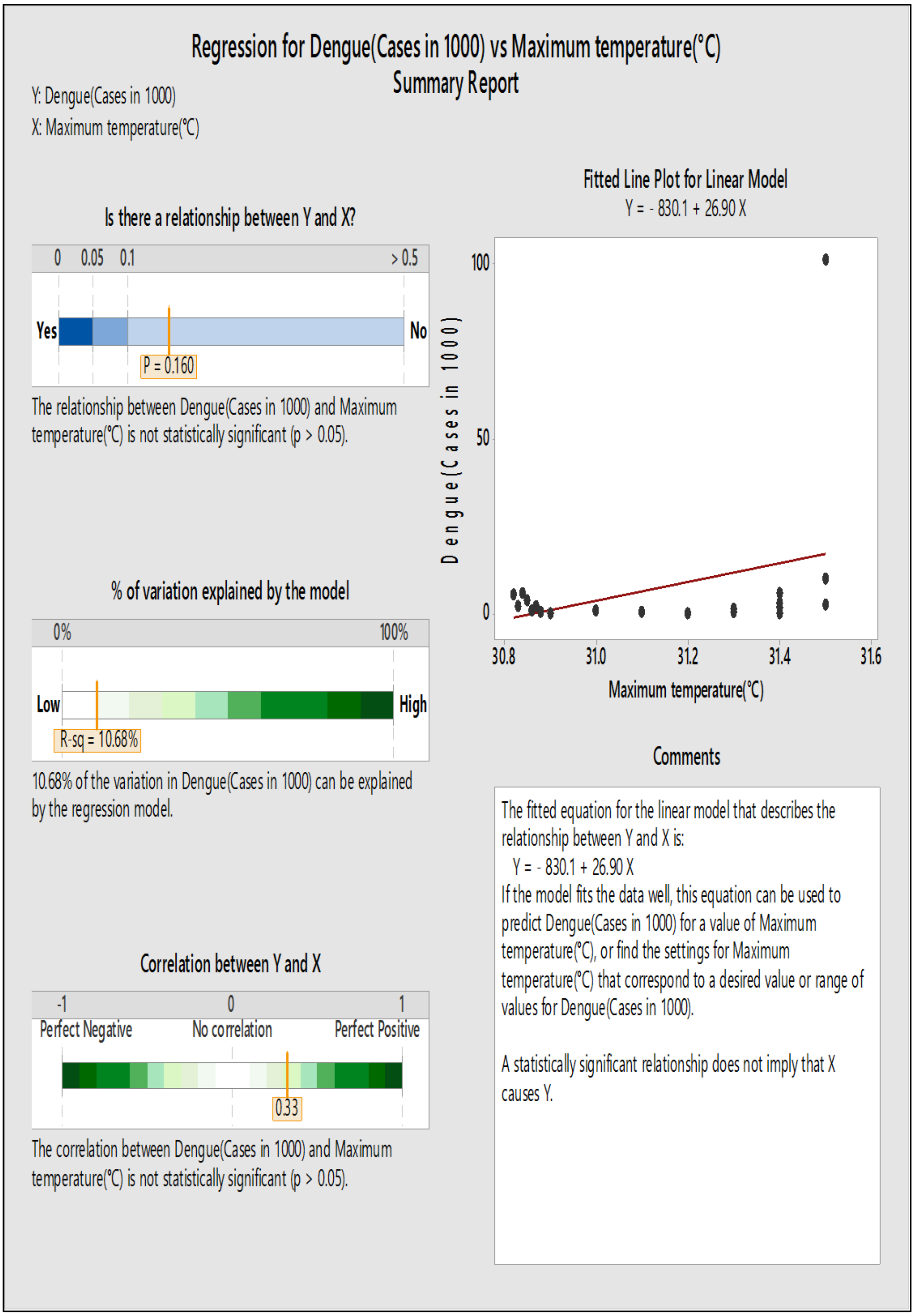

Figure 4.27:Regression analyses for Dengue (Cases in 1000) vs Maximum temperature(°C)

In figure 4.31, Pearson correlation coefficient of 0.33 indicates a moderate positive linear relationship between two variables. Here are some key points to consider about this correlation coefficient: The positive sign indicates that as one variable increases, the other variable tends to increase as well**.** A correlation of 0.33 suggests a weak to moderate strength of association. This means that there is a noticeable relationship, however it's not very strong.

In practical terms, this could imply that about 11% (0.33^2) of the variability in one variable can be explained by the variability in the other variable. The remaining 89% is influenced by other factors or random variation.

The significance and practical importance of a correlation coefficient depend heavily on the context. In some fields, a correlation of 0.33 might be considered quite meaningful, while in others, it might be seen as relatively weak.

CHAPTER-5

CONCLUSION

5.1 Conclusion

The findings of this study underscore the urgent need for proactive measures to mitigate and adapt to the increasing threat of extreme heat in Bangladesh. Utilizing a machine learning-based model, this research provides precise predictions that can guide public health interventions and policymaking, ultimately helping to protect vulnerable populations and enhance community resilience in the face of climate change.

This study demonstrates the efficacy of machine learning models in predicting extreme heat scenarios and their health impacts. The insights gained can guide public health policies and climate adaptation strategies in Bangladesh, ultimately reducing the adverse effects of climate change on human health.

Findings of this study

- Considerable changes to the climate have already occurred in Bangladesh. Over the past 44 years, Bangladesh has become hotter, with a more than 1°C increase in mean temperature recorded between 1976 and 2019. Trend analyses indicate that the maximum temperature continues to rise for all months except December and has already substantially increased from February to November. Overall, summers are becoming hotter and longer with the monsoon period being extended from February and October, while winters are becoming warmer. Bangladesh appears to be losing its distinct seasonality.
- The projected changes in climate will have considerable ramifications on the health of the population. With further climatic changes predicted across Bangladesh, including increase of temperature by approximately 1.4°C in the year 2040 causes deleterious effects on human physical as well as mental health that are likely to escalate.
- Heat impacts on certain groups such as construction workers, transport drivers, farmers, fishermen and so on disproportionately. In addition, heat impacts on women as well as children in all ages. Therefore, heat impacts affect livelihood

of the general people reducing income significantly, and causes personal health risks.

- The recurrent heat events and associated impacts every year in these regions in the past few years have enabled heatwaves to be recognized as a serious concern in most countries. At the same time, cross-sectoral as well as comprehensive collaborative strategies that focus on providing immediate relief during the hot days are needed to eradicate this huge problem.

5.2 Implications for Public Health

Increased Healthcare Demand: The projected rise in heat-related illnesses will likely lead to increased demand for healthcare services, straining existing infrastructure.

Emergency Preparedness: Improved emergency response plans will be necessary to handle the surge in heat-related health issues during extreme heat events.

5.3 Challenges

Data Availability and Quality: Reliable and comprehensive climate and health data are often difficult to obtain, which can hinder accurate modeling and analysis.

Integration of Diverse Datasets: Combining different types of data, such as climate, health, and socio-economic data, poses significant challenges due to differences in formats, scales, and collection methods.

Limited Focus on Indirect Effects: The study primarily focused on direct health impacts of heat, potentially overlooking important indirect effects such as economic and social consequences.

Resource Constraints: Implementing the recommended mitigation and adaptation strategies requires substantial financial and human resources, which may be limited.

Public Awareness and Engagement: Raising public awareness and changing behavior regarding heat risks and protective measures can be challenging, especially in rural and underserved communities.

Infrastructure Limitations: Existing healthcare and emergency response infrastructure may be inadequate to handle the projected increase in heat-related health issues.

Policy and Governance: Developing and enforcing effective policies for heat mitigation and adaptation requires strong governance and coordination among various stakeholders.

5.3.1 Recommendations

5.3.1.1 Mitigation Strategies:

- Urban Greening: Implementing green roofs, parks, and trees in urban areas to reduce the urban heat island effect.
- Building Designs: Encouraging the use of heat-resistant building materials and designs that enhance ventilation and cooling.

5.3.1.2 Adaptation Measures:

- Public Awareness Campaigns: Educating the public about heat risks and protective measures.
- Early Warning Systems: Developing and implementing early warning systems to alert communities regarding impending heat waves. Record more accurate weather data with localized information. The Bangladesh Meteorological Department (BMD) needs to expand the number of weather stations geographically to be able to collect more localized and granular information on the various weather variables.
- Healthcare System Strengthening: Investing in healthcare infrastructure and training to improve capacity and response to heat-related health issues.

- Individual and community measures to cope with extreme heat: Using fans, staying indoors during peak heat, increasing hydration, and using shaded areas. Some communities may use traditional cooling methods such as cool baths and wet clothing.

- Local policies or programs in place to help communities adapt to extreme heat: The government and NGOs often run awareness campaigns, establish cooling centers, and distribute water during severe heatwaves. There are also efforts to ameliorate urban planning to include more green spaces and better ventilation in crowded areas.

5.3.1.3 Limitations of the Study and Scope of the Further Research:

The study had several limitations and areas for improvement. Firstly, it lacked a dedicated semester for research, which may have restricted the depth of analysis. Additionally, the difficulty in obtaining reliable secondary data impacted the accuracy of the models. The integration of diverse datasets posed significant challenges, leading to potential biases. As a result, the models may not generalize well to other regions or conditions without further validation. Furthermore, the study primarily focused on direct heat-related health impacts, neglecting indirect effects. Finally, correlations with different health outcomes is not evaluated. This is particularly significant for malnutrition, which is related to the occurrence of diseases. To address these limitations and ameliorate future research, the following steps are recommended:

- **Collaborate with Universities and Industry Partners**: Engage with academic and industry experts to conduct comprehensive studies. This collaboration can provide additional resources and expertise, enhancing the quality of research.

- **Conduct Field Studies**: Undertake field studies to gather accurate, localized data on heat impacts. Field studies can provide valuable primary data, improving the reliability of the models.
- **Leverage IoT and Remote Sensing**: Utilize Internet of Things (IoT) devices and remote sensing technologies to collect better climate data. These technologies can enhance data integration techniques, providing a more comprehensive dataset.
- **Broaden Analysis Scope**: Include factors such as air pollution and urban heat islands in the analysis for a broader understanding of heat impacts. Considering these additional variables can provide a more holistic view of the issue.
- **Monitor Long-term Trends**: Establish mechanisms to monitor long-term trends to understand the effects of heat over time. Longitudinal data can reveal patterns and trends that short-term studies might miss.
- **Evaluate Public Health Interventions**: Assess the effectiveness of public health interventions to develop effective heat mitigation strategies. Evaluating existing interventions can provide insights into best practices and areas for improvement.
- **Compare Findings with Other Regions**: Compare the study's findings with results from other regions to identify common risks and successful adaptations. Cross-regional comparisons can highlight universal challenges and effective solutions.
- **Refine Models with Granular Data**: Future research should focus on refining the models with more granular data. Detailed data can improve model accuracy and applicability.
- **Explore Additional Climate Variables**: Investigate the impact of other climate variables, such as air pollution, on heat-related health impacts. Expanding the scope of variables can provide a more comprehensive understanding of the issue.

- **Extend Analysis to Other Regions**: Expand the research to include other regions to test the models' generalizability. This extension can validate the models across diverse geographic and climatic conditions.
- **Collaborate Internationally**: Work with international climate and health organizations to enhance the robustness and applicability of the models. International collaboration can provide access to additional data, resources, and expertise.
- By addressing these recommendations, future research can overcome current limitations and provide more robust and generalizable insights into heat-related health impacts.

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APPENDIX

QUESTIONNAIRE

SURVEY QUESTIONNAIRE

The questionnaire has been formed to collect opinion of the respondents regarding MACHINE LEARNING-BASED NUMERICAL MODEL TO ASSESS FUTURE EXTREME HEAT SCENARIOS IN BANGLADESH AND ITS IMPACT ON PUBLIC HEALTH. The information collected through interview will be analyzed to conduct the research on 'MACHINE LEARNING-BASED NUMERICAL MODEL TO ASSESS FUTURE EXTREME HEAT SCENARIOS IN BANGLADESH AND ITS IMPACT ON PUBLIC HEALTH' for the partial fulfilment of the curriculum of Master of Professional Studies (MPS) in Applied Statistics and Data Science (ASDS) under the Department of Statistics and Data Science, It is expected that the research would be able to motivate the academicians, researchers, relevant policy makers and respective stakeholders to undertake further necessary actions.

Respectfully

Tanvir Ehan

Roll No: 20231063

Department of Statistics and Data Science

Jahangirnagar University

Questionnaire:

Respondent's Information and Opinion

1. Name:
2. Designation & Organization:

3. Cell No. & Email:

4. Gender:

a) Male b) Female

5. Age:

a) 01-25 Years b) 26-50 Years

c) 51-75 Years d) Above 75 Years

6. Profession:

a) Govt Service

b) Academia

c) Private Service

d) Business

e) Other…………………….

7.Highest level of education you have completed?

a) Primary-Intermediate Degree b) Undergraduate Degree

c) Postgraduate Degree d) PhD Degree

8. Are general people aware of heatwaves? Yes/No.Provide additional details if necessary?

a) Yes b) No

9. How many years of temperature data are available for your location?

10. What are the typical temperature ranges during summer months (June-August)?

11.Have you observed any significant changes in temperature patterns over the past decades?

12.How often do heatwaves occur in your region?

13.What is the average duration of a heatwave event?

14.What were the highest recorded temperatures during recent heatwaves?

15.Have you or anyone in your household experienced heat-related illnesses (e.g., heat exhaustion, diarrhea) in the past five years?

16.How frequently do heat-related health issues occur in your community during heatwaves?

17.How many cases of heat-related illnesses have been reported at your local healthcare facilities in the past five years?

18.What are the most common symptoms observed in patients during heatwaves?

19.Can you provide data on mortality rates during heatwave periods compared to non-heatwave periods?

20.What age groups are most affected by heat-related health issues?

21. Which groups in your community are most vulnerable to extreme heat (e.g., elderly,Women, children, outdoor workers)?

22.What factors contribute to their vulnerability?

23.What measures do individuals and communities take to cope with extreme heat (e.g., using fans/air conditioning, staying indoors)?

24.Are there any local policies or programs in place to help communities adapt to extreme heat?

25. Are there any local policies or programs in place to help communities adapt to extreme heat Policy of Bangladesh is user friendly.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

26.Do you think Govt incentive and policy support may minimize extreme heat in Bangladesh?

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree