Trends of Climate Change in Bangladesh: Temperature and Rainfall Variability

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Master of Philosophy
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Letter of Approval

We hereby certify that this theses entitled " *Trends of Climate Change in Bangladesh: Temperature and Rainfall variability*" submitted to the Department of Geography and Environment, University of Dhaka, is a record of independent research work carried out by Md. Fazle Sobhan, an M.Phil student during the session 2017-2018, under our supervision and guidance. This research work fulfills the partial requirement for the degree of Master of Philosophy (M.Phil) and has not been previously submitted for the award of any degree, diploma, associateship or other similar title.

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Candidate's Declaration

I hereby declare that I have carried out the research work presented in this M. Phil thesis entitled "Trends of Climate Change in Bangladesh: Temperature and Rainfall Variability" under the joint guidance and supervision of Professor Md. Sofi ullah and Professor Dr. Md. Abdur Rob of the Department of Geography and Environment, University of Dhaka, in partial fulfillment of the requirement for the degree of Master of Philosophy (M. Phil).

Furthermore, I confirm that this research work is entirely my own work, including the design, arrangement, analysis, and manuscript preparation. I affirm that no part of this thesis has been submitted elsewhere in support of an application for a degree or qualification.

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Abstract

Climate change is a global issue that is affecting Bangladesh , a vulnerable country in the southeast region of the world.The Earth is experiencing rising temperatures and increasing average rainfall due to two critical climate parameters ,temperature and rainfall. Although Bangladesh's contribution to climate change is minimal, it is facing the consequences of this global issue.

This study focuses on the analysis of three climate parameters namely minimum temperature (Tmin), maximum temperature (Tmax) and rainfall in Bangladesh between 1968 and 2017. The study finds that the average minimum temperature in Bangladesh has increased at a rate of 0.19° C per decade, with an increase of 0.95° C between 1968 to 2017. The temperature is expected to rise by 0.63° C by 2050. Moreover, the average minimum temperature during the premonsoon season has increased at a rate of 0.21 ° C per decade and by 0.69 ° C in fifty years. During the monsoon season, the temperature has increased by 0.63 ° C over the past fifty years. Similarly, the average temperature during the post-monsoon has also risen, increasing by 0.1 °C over fifty years at a rate of 0.02 ° C.

This study also indicates that the average temperature during the dry season has risen by 0.84 °C over the past fifty years at a rate of 0.17 ° C. The minimum temperature in the climatic zonal has also increased, with the northeastern zone receiving the highest minimum temperature of 1.03 ° C over the past fifty years at a rare of 0.26 ° C. The western zone received the lowest average minimum temperature of 0.60 ° C at a rate of 0.12 ° C, while the southeastern zone received 0.78 ° C,the northern part of the northern region received 0.64 ° C, the southwestern zone received 0.65 ° C and south-central zone received 1.35 ° C.

During the last fifty years (1968-2017), the average maximum temperature of Bangladesh has been observed to be on the rise.This study revealed that the temperature has increased by 0.65 ° C, at a rate of 0.13 ° C per decade during that period. The temperature during the pre-monsoon period has increased by 0.58 ° C at

a rate of 0.12 ° C per decade, during monsoon by 1.43 ° C at a rate of 0.29 ° C per decade, during post-monsoon period by 1.16 ° C at a rate of 0.23 ° C and during the dry or winter season by 0.40 ° C at a rate of 0.08 ° C per decade.

Furthermore, the study found that the average maximum temperature of the south-eastern zone has increased by 0.33 ° C over the last fifty years at a rate of 0.067 ° C per decade. The north-eastern zone experienced an increase of 1.57 ° C at a rate of 0.31 ° C per decade while the north-western zone had an increase 0.78 ° C at a rate of 0.156 ° C per decade. The western zone had an increase of 0.43 ° C at a rate of 0.08 ° C per decade, the south-western zone had an increase of 0.75° C at a rate of 0.15° C per decade, and the south-central zone had an increase of 0.94 ° C at a rate of 0.19 ° C. The only exceptional was the northern part of the northern region, where the average maximum temperature was observed to be decreasing. Over the last fifty years,the temperature there decreased by -1.9 ° C at the rate of -0.38 ° C per decade.

The average total rainfall of Bangladesh has increased 5125 mm in the last fifty years at a rate of 1025 mm per decade. This increase has been observed in all seasons including premonsoon, monsoon, post-monsoon and dry. During premonsoon, the rainfall increased by 765 mm at a rate of 153 mm per decade, during monsoon it increased by 3595 mm at a rate of 719 mm per decade, during post-monsoon it increased by 780 mm at a rate of 156 mm, during dry/winter the average total rainfall increased by 150 mm at a rate of 30 mm per decade.

In terms of climatic zones, the south-western zone received the highest amount of rainfall at 12195 mm at a rate of 2439 mm per decade. The north-eastern zone received 5320 mm at a rate of 1064 mm per decade while the northern part of the northern region received 3115 mm at a rate of 623 mm per decade. However, the north-western received less rainfall of -4205 mm at a decreasing rate of -841 mm per decade.Similarly the western zone received less rainfall of -255 mm at a rate of -51 mm per decade. The South-western zone received 2210 mm of rainfall at a rate of 442 mm per decade, while the south-central zone received -756mm at a rate of -153 mm, per decade.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

Acronyms

AR4	fourth Assessment Report
AR5	fifth Assessment Report
AR6	sixth Assessment report
BAU	Business as usual
BBS	Bangladesh bureau of statistics
CRI	climate risk index
CV	coefficient of variance
CFC	cloro floro carbon
FAR	first Assessment Report
GCM	general circulation model
GDP	gross domestic products
GHG	green house gases
GOB	government of Bangladesh
IPCC	Intergovernmental panel on climate change
NAPA	national adaptation programme for action
NGOs	non government organizations
SAR	second assessment report
SPM	solid particulate matters
TAR	third Assessment report
UNEP	united nations environmental programme
UNICEF	united nations international children emergency fund
WTO	World Meteorological Organization

Chapter 1

INTRODUCTION

CHAPTER: 1

INTRODUCTION

1.1 Background of the study:

The Intergovernmental panel on climate change (IPCC) is an intergovernmental body of the United Nations located in Geneva Switzerland. Established by the World Meteorological Organization (WHO) in 1988 it consists of 195 member states and works on the impacts of antropogenic climate change including the natural, political and economic impacts and risk and possible response options. The organization is made up of thousands of scientists and other volunteers provide recommendations on climate change based on current research. The IPCC published five reports on current status of climate change of the world till to date. The first assessment report (FAR) was published in 1990, the second Assessment report (SAR) in 1995. the third Assessment Report (TAR) in 2001, the fourth Assessment Report (AR4) in 2007 and the fifth Assessment Report (AR5) in 2014. IPCC is currently preparing its sixth Assessment Report (AR6) which is expected to be completed in 2022. The first assessment report released that under a "business as usual" (BAU) scenario the global mean temperature would increase by about 0.3 ° C per decade during the 21st century and also judged that the global temperature had increased 0.3 to 0.6 ° C over the last one hundred years. On the other hand, the fifth assessment report (AR4) based on 9200 peer reviewed studies revealed that the world temperature had been increased by 0.85 ° C during the last hundred years and the magnitude of global warming have made the livelihood of severe, pervasive, and irreversible. This report also suggests an increase of 3.7 to 4.8 ° C temperature in 2100 relative to pre-industrial level. So, it is easily understandable to the severe impact of climate change in future.

Bangladesh, a South Asian country will no longer be spared from the worst consequence of climate change in future which will affect various sectors including development works.

Pressure of migration from the Coastal Area to big cities of the country will be strengthened. We are now realizing the impact of climate change which includes increasing trends of temperature and rainfall; various natural disasters are also seen as a common affair in each year. Germanwatch's 2021 Global Climate Risk Index (CRI) ranked Bangladesh seventh on the list of countries most vulnerable to climate devastation although Bangladesh produces only 0.56% of the global emissions. At present the average temperature of Bangladesh is around 26 ° C but range between 15 ° C and 34 ° C throughout the year. The average rise in temperature is 0.5 ° C between 1976 and 2019 ago and expected to rise by 1.0 ° C - 1.5 ° C by 2050. So, the trend of temperature rise is noteworthy which is consisted with the rise of global because it is difficult to differentiate the difference of temperature rise regionally. On the other hand, rainfall, a parameter of climate change is also increasing in Bangladesh and causes floods and devastation.

Bangladesh is less than 15 feet above sea level and rising seas due to climate change are going threat to all the people of Bangladesh. It has been estimated that by 2050, one in every seven people will be displaced in Bangladesh by the climate change. Due to the effect of climate change a projected 19.6inch rise of sea level may lose approximately 11% of the total land of Bangladesh. So, both the increase of temperature and rainfall will cause great devastation to the country. From this point of view the present study has been conducted.

1.2 Problem Statement:

As a south Asian country and in the perspective of worldwide climate change Bangladesh due to her geographical location is facing acute the climate change problem which include floods untimely or flash, tornado, tidal surge, drought and sea level rise etc. Experts opine that Bangladesh will be the worst sufferers to climate change in future. The symptoms of natural disasters due to climate change have already seen in Bangladesh. The losses due to the effect of climate change are very acute. Statistics show that from 2000 to 2019, Bangladesh suffered economic losses worth $ 3.72 billion and witnessed 185 extreme weather events due to climate change. It happened due to climate change worldwide and there is no exception in case of Bangladesh. Since climate change is greatly affecting Bangladesh especially due to the changes of temperature and rainfall it is a priority issue to see the trends of climate change for Bangladesh although climate change is a global issue and we cannot bound it regionally. This is because of due to the geographical location temperature increasing or rainfall increasing or decreasing do not remain constant on a specific geographic region. For this reason, greenhouse gas (the main gas culprit for climate change) emitted by the developed nations are mostly responsible for climate change whose affects are falling on many climates vulnerable countries of the world including Bangladesh. Experts opined that the coastal regions which constitute of the 19 southern districts of Bangladesh will be the worst sufferers in comparison to other districts. The people of the coastal district remain in high risk of climate affects.

1.3 Rationale and Relevance of the study:

We have already discussed that Bangladesh is a most vulnerable country to climate change. It is an established truth that if the average temperature increases at the global level a vast portion of the southern region will be submerged into sea causing a great damage and displacing 25 million people of the coastal region. We do not have enough influence over the emissions of greenhouse gases responsible for climate change for which the developed nations are responsible. Climate change is such an issue that every nation of the world will have to face the consequence of it. There is no exception in case of Bangladesh. It is a global issue and various types of research related to climate change are going on by researchers of almost all the countries of the world.

This is because of the consequence of the effect of climate change is very destructive. And that is why intensive research by the researchers of various fields related to climate change is done. From this research it has been tried to see the trends of climate change in Bangladesh although various types of research related to climate change are conducted. The study on the titled, “Trends of climate change in Bangladesh: Temperature and Rainfall Variability” chosen by me have an importance to see the change of temperature and rainfall is a time worthy research work. So, it is rationale to study such type of research. It will help the experts, policy makers, researchers and various departments who are working with climate change of Bangladesh. This study will help the policymakers and government to take steps how to tackle it and its consequences and save the large number of people from the hard-hit effect of climate change. So, the rationality of conducting of such type of research is rationale and relevant.

1.4 Aims and Objectives:

The primary objective of this proposed study is to examine the patterns of climate change in Bangladesh. The other specific objectives of this study are:

1. To analyze the characteristics and extent of climate change in Bangladesh, with a focus on changes in temperature and rainfall
2. To investigate the spatial and temporal distribution of temperature and rainfall changes throughout Bangladesh.
3. To demonstrate the trends of temperature and rainfall variability of Bangladesh in relation to climate change

By achieving these objectives, the study aims to provide a comprehensive understanding of The impacts of climate change in Bangladesh, which will be usefull for policymakers, researches, and other stakeholders working on climate change adaptation and mitigation strategies in the country.

1.5 Limitations of the Study:

In this study it has been tried to show the trends/ change of climate change in the perspective of two parameter of climate such as temperature and rainfall. For doing the work temperature and rainfall data of Bangladesh Meteorological station have been used. Temperature and rainfall data from 1968 to 2017 are used to analyze and to find out the trend / fluctuation of the temperature and rainfall. In Bangladesh there are 35 weather stations located in different districts of Bangladesh. Among them only 19 stations have shown the data required for the study. But the remaining stations have in many years no data record. But it is essential to find out all the data record of all the stations of the required time period for analysis. In this study there has been an exception. The missing or no data record have been adjusted through forecast method in excel. This is limitation of the study. For this limitation there may have been a difference between the results produced by IPPC or other study.

CHAPTER : TWO

LITARATURE REVIEW AND CONCEPTUAL FRAMEWORK

LITARATURE REVIEW AND CONCEPTUAL FRAMEWORK

2.1 **Introduction:**

The significance of climate cannot be overstated, as it is fundamental to the functioning of our planet (Pittock, 2009). All the landscape, plants and animals lied on this earth are determined to a large extent by the climate acting over long intervals of time. (Pittock, A Barrie 2009). From the historical records of Earth's climate it can be said that the climate of the Earth is unstable. The climate of the earth has changed greatly over geological time scales e.g. during several glacial and inter glacial periods in the Pleistocene period and it has changed within the historic period. The causes of such changes were 'natural'. The other causes include variations in solar radiation received on Earth's surface, volcanic activities , human actives which include emissions of the so-called 'greenhouse gases' carbon dioxide(CO2) , methane and nitrous oxides into the atmosphere associated with the burning of fuel in industrial, transport, domestic and agricultural activities and methane emissions from livestock and rice paddies.

The Earth is warmed by radiation received from the sun, and a balanced is maintained by outward radiation from the Earth into space.(Brammer, 2014). Most climate scientist believe that due to increase of greenhouse gases in the atmosphere the outward radiation of Earth's heat is reducing thereby causes increasing of global temperatures. They warn that continuous growing of world temperature level might cause change of rainfall pattern, increase the risk of flood, cycles and drought and raise global sea-level. That could reduce production of crops in many countries of the world, make part of the planet inhabitable, possibly leading to large scale famine, migration, conflict and death. On the other hand higher temperature could give opportunity for some of the temperate and mountain regions to produce agricultural crops while higher atmospheric CO2 level could increase plant growth and crop yield universally.

There is still uncertainty about the actual increase in global temperature. (Brammer,2014). There are two main reasons.

According to Brammer – one of the reasons is all the meteorological stations of the world are located in urban areas or airports where temperatures especially night temperature are inflated by heat absorption and retention by buildings and tarmac, and this influence has probably increased over time as urban areas have expanded. Therefore, temperature data from such sites do not properly represent the greater part of the land areas where natural vegetation and crops grow and the need to be adjusted to represent natural condition.

Secondly, the Earth's land masses cover about 25% of total globe and few temperature data are available for the globe's great ocean area. In future, greater reliance might be placed on temperature measurement made from satellite orbiting the earth, available since 1979 which cover all parts of the globe equally.

Despite these uncertainties it is generally accepted that the mean global temperature has risen by about 0.6 C in the past 50 years (IPCC, 2013). Changes have been particularly noticeable in the polar and north temperate regions because ice cap has been melting and milder winter has been experiencing in that regions including north Western Europe.

In the meantime, the large consensus of the scientific opinion says that greenhouses gases emitted by various human activities as well as vehicular movements and industrial works are doing a serious pose causing adverse changes in global climate that might affect many millions of people during the 21^{st} century and beyond. Bangladesh, also a south – Asian country has not been spared from the adverse consequences of the recent climate change which is harmful for her agricultural sectors as well as other sectors including fisheries. For example due to increase of winter temperature boro pady are planted earlier so that flood water cannot damage it. It can be stated that against the backdrop of increasing CO2 global wise, the increasing tendency of CO2 in Bangladesh is also occurring which is responsible for monsoon rainfall causing increase of crop yields throughout the year. The monsoon rainfall increases residual dry-season flow in rivers and make water available for irrigation in the dry season. Most recently it has been detected that the world mean temperature has risen by 0.6 C and Bangladesh is also the affected country whose mean annual temperature has also risen causing various problem in the countryOn the other hand mean global surface temperature has risen by approximately 1.1 ° C since the beginning of the industrial revolution. World Meteorological Organization (WMO) confirmed that 2016 was the warmest year since instrumental weather measurement began in 1880 directly following the previous records year 2014 and 2015 (WMO 2016). According to the Inter-Governmental Panel on Climate Change (IPCC) this warming is largely the result of greenhouse gas emissions from human activities into the atmosphere (IPCC, 2014).

2.2) What is climate change?

Climate change means the statistical distribution of weather pattern for a certain period of time such as decades to millions of years. It also refers to a change in weather condition. It refers to an increase in mean annual surface temperature of the earth's atmosphere due to increase in atmospheric concentrations of greenhouse gases. The climate change, thus ,is defined as variations and shift in weather conditions over space and time of different and magnitude resulting into change of climatic type for example, from warm and moist climate to warm and dry climate, from warm and moist climate to cool and moist climate etc.(Singh, 2005).

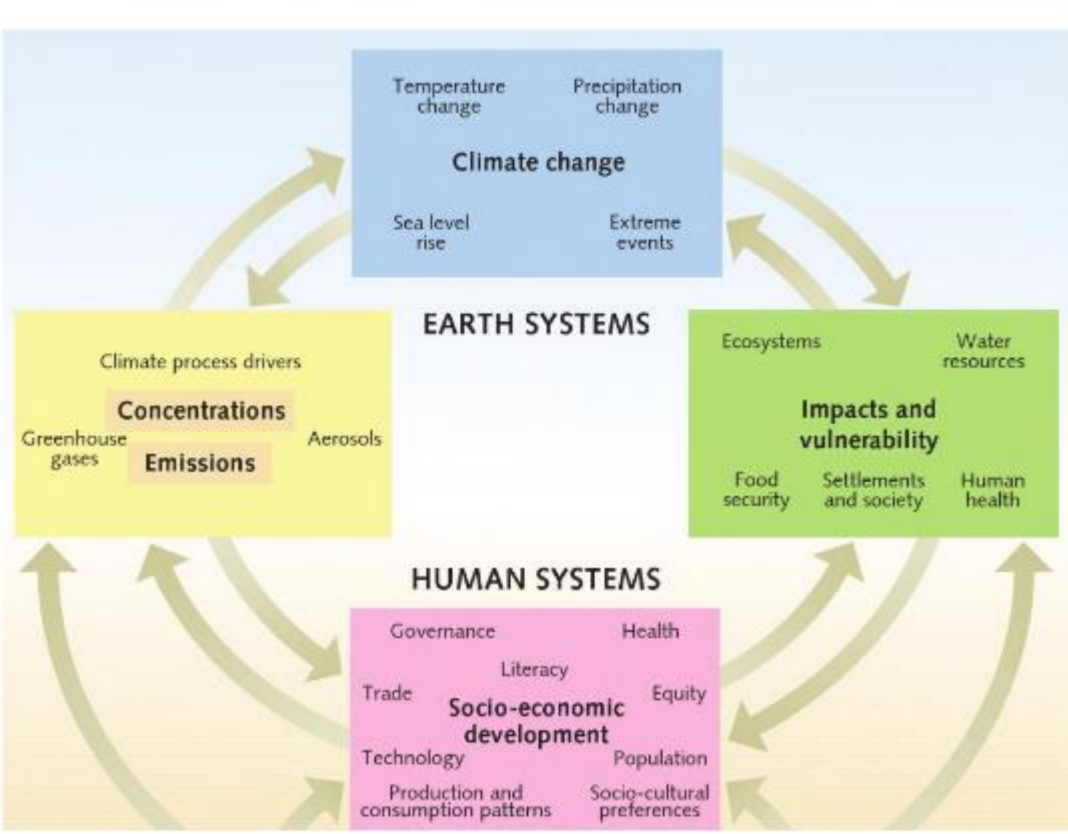

Figure. 2.1 Climate Change- An integrated framework. Source (Hughton, 2015)

To understand climate change the framework (refer in Figure 2.1) of the physical, social, economic, and political dimensions are most important.

The root cause of climate change is the accumulation of greenhouse gases emission and accumulation in the atmosphere. The greenhouse gases leads to the warming of the planet. On the other hand, human activities such as burning fossil fuels, forest destruction, and industrilization are the main force behind climate change. To address climate change, a holistic approach that covers both mitigation and adaptation is necessary. Mitigation focuses on reducing greenhouse gas emissions, while adaptation prepares for and responds to the impacts of climate change. Policy, technological, and behavioral changes at the individual, community, and national levels are critical for both mitigation and adaptation strategies.

In addition to the physical aspects, the social and economic dimensions of climate change must also be considered. Vulnerable populations such as low-income communities, indigenous peoples, and small island states are disproportionately affected by climate change. A just transition that emphasizes social equity, environmental justice, and human rights is essential to tackle climate change.

Lastly, the political dimensions of climate change must also be taken into account. It's a global problem that requires collective action and cooperation across national borders. The United Nations Framework Convention on Climate Change (UNFCCC) serves as a platform for international cooperation and negotiations on climate change.

In fact integrated framework for climate change should consider the physical, social, economic, and political dimensions of the issue and prioritize a just transition that promotes environmental justice and human rights.

Climate change refers to significant changes in the balance of heat, moisture, cloudiness, and precipitation in the earth-atmosphere system. These changes can be caused by internal or external factors such as variations in the earth's orbital characteristics, solar fluctuations, tectonic processes, vulcanicity, and changes in atmospheric composition. It can occur at the local, regional, and global levels (Singh, 2005). It is important to note that short-term fluctuations in weather conditions such as El Nino do not represent climate change. While human activities can contribute to climate change, it can also result from natural processes. In the context of environmental policy, climate change has become synonymous with anthropogenic global warming, which refers to the increase of surface temperature due to the rise of greenhouse gas levels. Scientific journals often use the term global warming to refer to surface temperature increase, while climate change encompasses all factors that affect greenhouse gas levels.

The concentration of greenhouse gases such as carbon dioxide, methane, CFCs, and nitrous oxide has increased significantly since 1750, primarily due to human activities like fossil fuel combustion, according to the IPCC (Houghton et al., 2002). While climate change is often thought of as quick and rapid, it can occur both gradually and suddenly. For example, the sudden onset of cold climate during the Jurassic period led to the mass extinction of dinosaurs. The causal factors responsible for climate change vary, as in the case of the Jurassic climate change which occurred due to the collision of the earth and a giant meteor, resulting in the release of a significant amount of dust into the atmosphere. Present-day climatic conditions cannot accurately predict the nature of long-term climate. Additionally, the cool periods in the earth's history are associated with greater than normal climatic instability (J.E. Hoobs, 1980). The study of climate change is dependent on the temporal and spatial scale of the research purpose and is a pressing issue of our times.

2.3 Climate Change Scenario over the world:

While the climate system is global, its effects are regional or local, with atmospheric processes, ocean circulation, bioclimatic zones, daily weather, and long-term climate trends all contributing to this phenomenon. Climate change is an ongoing process that is expected to continue at unprecedented rates in human history. It is believed to be one of the most persistent threats to global stability in the coming century. The IPCC has acknowledged the existence of human-induced climate change, which is now considered an undeniable fact. Although differentiating between human-induced changes and natural climate variation at small scales is challenging, evidence of long-term geophysical and biological changes, such as the retreat of mountain glaciers, earlier arrival of spring, and changes in primary productivity, is apparent in many parts of the world. Global warming is already happening at an unprecedented rate in the past 1000 years and is inevitably affecting local and regional weather around the world. The fact that the global climate is changing is beyond dispute, with a nearly 1°C globally averaged change in the past century, concurrent with changes in some extreme event regions, as summarized in Table 1 based on IPCC reports (2000a).

According to the UNEP Global Environmental Outlook, the warming of the planet has resulted in environmental issues. Although verifying global warming was challenging until the late 1990s, the increasing temperature of several years in recent decades has provided evidence that the earth is slowly warming. Temperature records from thermometers in the past 130 years and evidence from tree rings and ice cores indicate that the earth is currently at its warmest since at least the Middle Ages. It is beyond doubt that the primary cause of global warming is the increase in greenhouse gas emissions, including carbon dioxide, carbon monoxide, methane, chlorofluorocarbons, and nitrous oxide, which trap heat. Chlorofluorocarbons, in particular, are a potent greenhouse gas, trapping 1000 times more heat than carbon dioxide. It is concerning that chlorofluorocarbon emissions into the atmosphere are increasing at a rate of 5% per year. The following are potential sources of carbon dioxide emissions.

2.4 Regional Scenario:

Asia: Asia is indeed the largest continent in the world, and is home to a vast array of cultures, languages, and ecosystems. According to the United Nations Department of Economic and Social Affairs Population Division (UN DESA), as of 2013, Asia's population was estimated to be around 4.3 billion, accounting for approximately 60% of the world's population. Moreover, Asia's population density was about 134 people per square kilometer in 2012, according to the Population Reference Bureau (PRB).

Asia spans four climatic zones, including boreal, arid, tropical, and temperate, and has experienced a variety of natural hazards, including devastating events such as the 2004 Indian Ocean Tsunami, the 2005 Pakistan Earthquake, and the 2006 landslides in the Philippines. Additionally, research has shown that Asia has experienced an increase in the intensity and/or frequency of many extreme weather events, including heat waves, tropical cyclones, prolonged dry spells, intense rainfall, tornadoes, snow avalanches, thunderstorms, and severe dust storms (Cruz et al., 2007).

Climate change is predicted to increase rainfall over most of Asia, particularly during the summer monsoon, resulting in an increased risk of flooding in East Asia, South Asia, and Southeast Asia, according to the Intergovernmental Panel on Climate Change (IPCC, 2014). Furthermore, climate change has been linked to a drop in crop yields of up to 30%, posing a significant risk of hunger in several countries.

The increase in temperature, caused by global warming, has resulted in the melting of glaciers in the Himalayas, leading to flooding, erosion, mudslides, and glacial lake outburst floods (GLOFs) in Nepal, Bangladesh, Pakistan, and North India during the wet season (IPCC, 2014).

Africa: The African continent is facing increasing climate stress due to the impact of climate change. Many areas of Africa are already recognized as vulnerable to climate changes on seasonal and decadal time scales, with reports from the Intergovernmental Panel on Climate Change (IPCC) indicating that 220 million Africans are exposed to drought each year. In addition, the continent is facing both temperature and rainfall change stress, with average temperatures in Africa being higher than the global average. Near surface temperatures have increased by 0.50 C or more during the last 50 to 100 years over most parts of Africa, with minimum temperatures warming more rapidly than maximum temperatures (Hulme et. al 2001; Jones and Moberg, 2003).

According to Collins (2011), near surface air temperature anomalies in Africa were significantly higher for the period 1995-2010 compared to the period 1979-1994. It is very likely that mean annual temperature has increased over the past century over most of the African Continent, with the exception of areas where the data coverage has been determined to be insufficient to draw conclusions about temperature trends.

However, most areas of the African Continent lack sufficient observational data to draw conclusions about trends in annual precipitation over the past century. Discrepancies also exist between different observed precipitation data sets in many regions of the continent. There are very likely decreases in annual precipitation over the past century over parts of the western and eastern Sahel region in northern Africa, along with very likely increases over parts of eastern and Southern Africa (IPCC, 2014).

Latin America: Latin America has already been experiencing intensity of extreme events associated with the ENSO phenomenon which include torrential rains and floods caused by cyclone. Due to climate change in Latin America Andean glaciers disappear this century. Besides climate change causes shortage of rainfall in arid and semi-arid areas which will receive less rainfall causing degradation of agricultural land and impacting food security. Climate change threatens to substantially affect the Amazan region which is in turn expected to alter global climate and increase the risk of biodiversity loss (WWF2006). By 2050 it is projected that the temperature of this region will increase 20C causing severe sepsis loss which will affect the bio-diversity of this region.

North America: The third largest continent of the world, North America, covering an area of 24,230,000 square kilometers, is also experiencing the impact of climate change. Being a developed region, it is contributing a significant amount of greenhouse gas emissions and playing a major role in climate change. This continent is composed of three countries, namely the United States of America, Canada, and Mexico, which are some of the largest countries in the world.

According to the Fourth National Climate Assessment (NCA4) report published by the United States Global Change Research Program (USGCRP) in 2018, North America is already experiencing the impacts of climate change, including more frequent and intense heatwaves, increased frequency of heavy precipitation events, and more severe droughts, among others. These changes are affecting the continent's ecosystems, water resources, agricultural productivity, and human health, among others.

Moreover, North America is projected to face significant climate change impacts in the future, including sea-level rise, ocean acidification, and more frequent and intense extreme weather events, which could cause severe damage to infrastructure, buildings, and other vital systems. Therefore, urgent action is needed to reduce greenhouse gas emissions and adapt to the unavoidable impacts of climate change in North America.

2.5 Bangladesh Scenario:

Bangladesh, with a population of over 165 million people, is one of the most climate-vulnerable countries in the world. The country is experiencing significant temperature and rainfall variability, leading to severe impacts on agriculture, water resources, and infrastructure. The annual mean temperature in Bangladesh has increased by 1.1°C from 1951 to 2018, and the rate of warming is higher than the global average. The number of hot days and warm nights has increased significantly, and heatwaves have become more frequent and intense in recent years. The annual rainfall has increased significantly by 29 mm per decade from 1960 to 2017, mainly due to the intensification of extreme rainfall events. However, there is a decreasing trend of rainfall in the central region of the country. The trends in temperature and rainfall vary across different regions of Bangladesh. The increasing temperature trend could have significant impacts on agriculture, water resources, and human health in Bangladesh, and suggested the need for adaptation strategies to cope with the changing climate patterns.

Temperature variability is a significant indicator of climate change in Bangladesh. The country is experiencing a rising trend of temperature over the past few decades. According to Rahman et al. (2021), the annual mean temperature in Bangladesh has increased by 1.1°C from 1951 to 2018. The study also revealed that the rate of warming in Bangladesh is higher than the global average.

Another study by Rahman et al. (2020) examined the trends of temperature and heatwaves in Bangladesh. The study found that the number of hot days and warm nights has increased significantly, and heatwaves have become more frequent and intense in recent years.

Rainfall variability is another critical indicator of climate change in Bangladesh. The country is experiencing both excessive and deficient rainfall events, leading to severe impacts on agriculture, water resources, and infrastructure.

According to Islam et al. (2020), the annual rainfall in Bangladesh has increased significantly over the past few decades. The study found that the annual rainfall has increased by 29 mm per decade from 1960 to 2017. The increase in rainfall is mainly due to the intensification of extreme rainfall events.

Another study by Hossain et al. (2021) examined the spatiotemporal variability of rainfall in Bangladesh. The study revealed that rainfall variability is increasing in the northern and southern regions of Bangladesh. The study also found that there is a decreasing trend of rainfall in the central region of the country.

The study by Akanda, Hasan, and Islam (2020) analyzed the trends of temperature and rainfall in Bangladesh over a period of 38 years (1981-2018) using the Mann-Kendall trend test and Sen's slope estimator. The results indicated a significant increasing trend in temperature, particularly during the winter and pre-monsoon seasons, while rainfall showed no significant trend. The authors also found that the trends in temperature and rainfall varied across different regions of Bangladesh. The study concluded that the increasing temperature trend could have significant impacts on agriculture, water resources, and human health in Bangladesh.

The study by Chowdhury and Rahman (2020) examined the trends of temperature and rainfall in Dhaka city, Bangladesh, over a period of 34 years (1985-2018). The authors used the Mann-Kendall trend test and Sen's slope estimator to analyze the data. The results indicated a significant increasing trend in temperature, particularly during the winter and pre-monsoon seasons, while rainfall showed no significant trend. The study also found that the trends in temperature and rainfall varied across different seasons and locations within Dhaka city. The authors concluded that the increasing temperature trend could have significant impacts on the urban environment, public health, and economy in Dhaka city.

The study by Das and Nasrin (2019) analyzed the rainfall trends and variability in the western region of Bangladesh over a period of 30 years (1986-2015). The authors used the Mann-Kendall trend test and Sen's slope estimator to analyze the data. The results indicated a decreasing trend in rainfall in the study area, particularly during the monsoon season. The study also found that the inter-annual variability of rainfall was high, indicating a high degree of uncertainty in rainfall patterns. The authors concluded that the decreasing trend in rainfall could have significant impacts on agriculture, water resources, and human livelihoods in the western region of Bangladesh.

The study by Hasan, Akanda, Islam, and Roy (2020) investigated the impact of climate change on rainfall variability in Bangladesh using observed rainfall data from 64 stations across the country over a period of 38 years (1981-2018). The authors used the coefficient of variation and the inter-annual standard deviation to analyze the variability of rainfall. The study found that the variability of rainfall had increased significantly over the study period, indicating a higher degree of uncertainty in rainfall patterns. The authors also found that the increasing trend in temperature could be a key driver of the increased rainfall variability. The study concluded that the increasing variability of rainfall could have significant impacts on agriculture, water resources, and human livelihoods in Bangladesh.

The study by Islam, Rahman, and Roy (2020) examined the spatiotemporal variability of temperature and rainfall in Bangladesh over the last three decades (1990-2019). The authors used the Mann-Kendall trend test and Sen's slope estimator to analyze the data. The study found that temperature had increased significantly across the country, particularly during the winter and pre-monsoon seasons. The authors also found that rainfall had decreased significantly in some parts of the country, particularly in the western region. The study concluded that the increasing temperature trend and decreasing rainfall trend could have significant impacts on agriculture, water resources, and human health in Bangladesh, and suggested the need for adaptation strategies to cope with the changing climate patterns.

The study by Haque, Islam, and Hoque (2018) analyzed the trends of temperature and rainfall in the southeastern coastal region of Bangladesh over a period of 30 years (1984-2013). The authors used the Mann-Kendall trend test and Sen's slope estimator to analyze the data. The study found that temperature had increased significantly in the study area, particularly during the pre-monsoon season. The authors also found that rainfall had decreased significantly in the area, particularly during the monsoon season. The study concluded that the increasing temperature trend and decreasing rainfall trend could have significant impacts on agriculture, water resources, and human health in the southeastern coastal region of Bangladesh, and suggested the need for adaptation strategies to cope with the changing climate patterns.

The study by Mia, Ahsan, and Islam (2019) assessed the impact of climate change on rainfall variability in the northeastern region of Bangladesh using observed rainfall data from 10 stations over a period of 33 years (1985-2017). The authors used the Mann-Kendall trend test and Sen's slope estimator to analyze the data. The study found that the variability of rainfall had increased significantly in the study area, indicating a higher degree of uncertainty in rainfall patterns. The authors also found that the increasing temperature trend could be a key driver of the increased rainfall variability. The study concluded that the increasing variability of rainfall could have significant impacts on agriculture, water resources, and human livelihoods in the northeastern region of Bangladesh, and suggested the need for adaptation strategies to cope with the changing climate patterns.

The study by Kabir, Hoque, and Biswas (2019) analyzed the trends of rainfall and temperature in Rangpur district, Bangladesh, over a period of 30 years (1985-2014). The authors used the Mann-Kendall trend test and Sen's slope estimator to analyze the data. The study found that temperature had increased significantly in the study area, particularly during the winter and pre-monsoon seasons. The authors also found that rainfall had decreased significantly in the area, particularly during the post-monsoon season. The study concluded that the increasing temperature trend and decreasing rainfall trend could have significant impacts on agriculture, water resources, and human health in Rangpur district, and suggested the need for adaptation strategies to cope with the changing climate patterns.

The study by Kibria, Rahman, and Alam (2020) investigated the spatiotemporal variation of temperature in Bangladesh over a period of 50 years (1961-2010) using observed temperature data from 35 stations across the country. The authors used the Mann-Kendall trend test and Sen's slope estimator to analyze the data. The study found that temperature had increased significantly across the country, particularly during the pre-monsoon and post-monsoon seasons. The authors also found that the rate of temperature increase was higher in the northern and northeastern regions of Bangladesh compared to the southern and southwestern regions. The study concluded that the increasing temperature trend could have significant impacts on agriculture, water resources, and human health in Bangladesh, and suggested the need for adaptation strategies to cope with the changing climate patterns.

The study by Rahman and Islam (2020) analyzed the trends and variability of temperature and precipitation in Bangladesh using observed data from 35 stations over a period of 50 years (1961-2010). The authors used the Mann-Kendall trend test and Sen's slope estimator to analyze the data. The study found that temperature had increased significantly across the country, particularly during the pre-monsoon and post-monsoon seasons, while precipitation had decreased significantly in some parts of the country, particularly in the northwest and central regions. The authors also found that the decreasing precipitation trend could have significant impacts on agriculture, water resources, and human livelihoods in Bangladesh. The study concluded that the changing climate patterns in Bangladesh require immediate attention and adaptation strategies to minimize the potential impacts on the country's economy and society.

The study by Uddin and Akter (2020) analyzed the trends of rainfall and temperature in the southern region of Bangladesh using observed data from six stations over a period of 30 years (1985-2014). The authors used the Mann-Kendall trend test and Sen's slope estimator to analyze the data. The study found that rainfall had decreased significantly in the region, particularly during the pre-monsoon and post-monsoon seasons, while temperature had increased significantly throughout the year. The authors also found that the decreasing rainfall trend could have significant impacts on agriculture and water resources in the region. The study concluded that the changing climate patterns in the southern region of Bangladesh require immediate attention and adaptation strategies to minimize the potential impacts on the region's economy and society.

The study by Hossain and Islam (2019) investigated the trends of rainfall variability in Bangladesh using observed data from 10 stations over a period of 34 years (1982-2015). The authors used the Mann-Kendall trend test and Sen's slope estimator to analyze the data. The study found that rainfall had become more variable in Bangladesh, with a higher occurrence of both extreme wet and dry events. The authors also found that the increasing variability of rainfall could have significant impacts on agricultural production in Bangladesh. The study concluded that the changing climate patterns in Bangladesh require immediate attention and adaptation strategies to minimize the potential impacts on the country's agriculture and food security.

The study by Haque, Kabir, and Ghosh (2020) analyzed the trends of temperature and rainfall in Bangladesh using observed data from 35 stations over a period of 60 years (1960-2019). The authors used the Mann-Kendall trend test and Sen's slope estimator to analyze the data. The study found that temperature had increased significantly across the country, particularly in the pre-monsoon and post-monsoon seasons, while rainfall had decreased significantly in some parts of the country. The authors also found that the decreasing rainfall trend could have significant impacts on water resources and agriculture in Bangladesh. The study concluded that the changing climate patterns in Bangladesh require immediate attention and adaptation strategies to minimize the potential impacts on the country's economy and society.

The review by Islam and Al-Mamun (2021) focused on the impacts of climate change on agriculture in Bangladesh, which is the main source of livelihood for millions of people in the country. The review highlighted the significant changes in temperature, rainfall, and other climatic variables that have occurred in Bangladesh in recent decades and their impacts on crop production, livestock rearing, and fisheries. The review also discussed various adaptation strategies that have been implemented in Bangladesh to cope with the changing climate patterns, including crop diversification, adoption of new crop varieties, irrigation management, and climate-smart agriculture. The review concluded that more efforts are needed to develop and implement effective adaptation strategies to ensure the sustainability of agriculture and food security in Bangladesh under changing climate conditions.

Agarwala et al. (2003) developed a Global Climate Model (GCM) projection using the Hadley Centre Coupled Model version 2 (HadCM2). The study aimed to assess the potential impacts of climate change on global water availability and agriculture, taking into account changes in temperature, precipitation, and carbon dioxide (CO2) concentrations.

The GCM projection suggested that, by the year 2080, global mean temperature could increase by approximately 2.8°C, and precipitation could increase by around 3.7%. However, these changes were not uniform across the globe, with some regions experiencing significant decreases in precipitation.

The study also found that the increase in atmospheric CO2 concentrations could lead to a significant increase in agricultural productivity, with some regions benefiting more than others. However, the overall impact of climate change on agriculture was likely to be negative due to the adverse effects of rising temperatures and changes in precipitation patterns.

Overall, the Agarwala et al. (2003) GCM projection highlights the potential impacts of climate change on water resources and agriculture, and underscores the need for effective adaptation measures to minimize the negative consequences of these changes.

Bangladesh is among the countries that are highly vulnerable to the impact of climate change. The changing climate is affecting the country's precipitation patterns, annual mean temperature, and sea level rise. From 1961 to 1990, the annual mean temperature in Bangladesh increased at a rate of 0.0037 degree Celsius, but from 1961 to 2000, the rate increased to 0.0072 (Hossain et al., 2012). This increase in mean annual temperature was twice as high as in previous years.

The Intergovernmental Panel on Climate Change (IPCC) has identified Bangladesh as one of the most vulnerable countries to climate change. Climate change is expected to cause a steady increase in temperature and changes in rainfall patterns, which could have significant implications for agriculture, water resources, and public health (Karim et al., 1999; Fung et al., n.d.; Shahid, 2009). The temperature in Bangladesh has been increasing since the 1900s, as shown in Figure 2.2, which displays the mean annual temperature change in Bangladesh between 1870 and 1991.

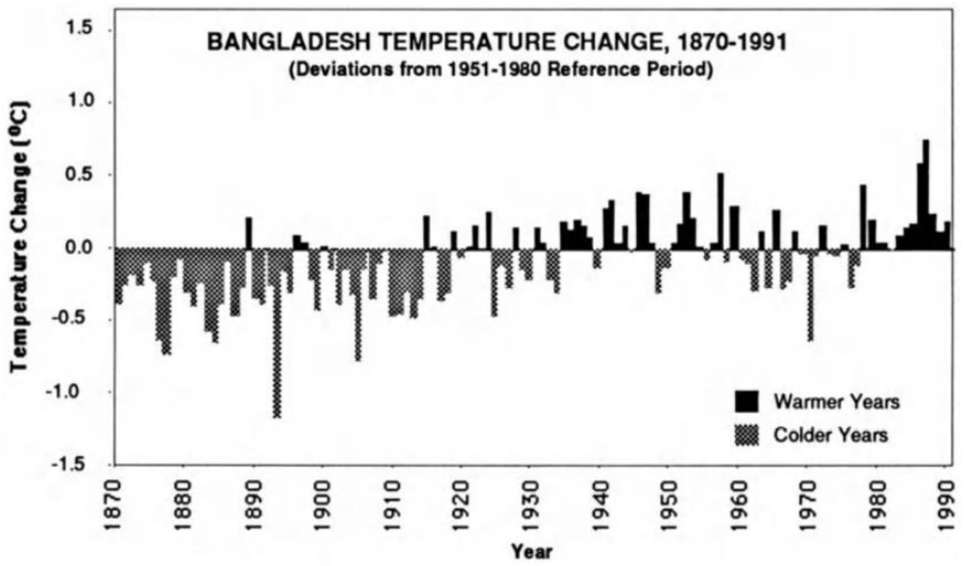

Figure 2.2: Temperature Change in Bangladesh

Source: Karim et al. 1999

According to research, the temperature in Bangladesh has been steadily increasing since the 1900s. From 1961 to 1990, the annual mean temperature increased at a rate of 0.0037 degrees Celsius, but during the period from 1961 to 2000, the rate of increase was higher at 0.0072 degrees Celsius (IPCC). This means that the annual temperature rise doubled during the later period compared to the earlier one.

Figures also show that the mean-annual temperature change in Bangladesh during the time period of 1870-1991 has been increasing (Karim et al. 1999). Climate change is predicted to result in a steady increase in temperature and a change in rainfall patterns, which could have significant implications for agriculture, water resources, and public health (Fung et al.; Shahid 2009). Due to these changes, Bangladesh has been identified as one of the most vulnerable countries in the world by the IPCC (2007).

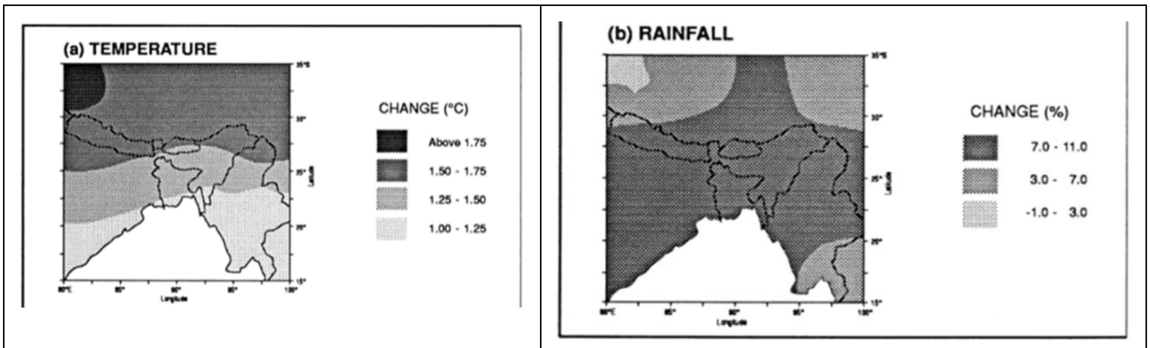

Figure 2.3: The projected best-estimate 1990-2030 climate changes for the monsoon (June to October) : (a) temperature (b) rainfall.

Source: Ahmad QK et. al (1996)

Ahmad QK et al. (1996) provided a figure showing the projected best-estimate 1990-2030 climate changes for the monsoon season (June to October) in terms of temperature and rainfall. The figure (Figue 2.3) has two panels: (a) shows the projected temperature changes and (b) shows the projected rainfall changes. The temperature panel (a) shows that the projected temperature changes during the monsoon season are expected to be higher in the northern and western parts of India and lower in the southern parts of India. The maximum temperature increase is projected to be around 2-3 °C in the northwest region of India. The rainfall panel (b) shows that the projected rainfall changes during the monsoon season are expected to be higher in the central and northern parts of India and lower in the southern parts of India. The maximum rainfall increase is projected to be around 15-20% in the central parts of India. The figure suggests that climate change is likely to have a significant impact on the monsoon season in India, with both temperature and rainfall changes expected to occur.

In 1990's it has been tried to generate climate change scenarios for Bangladesh by the use of General Circulation Model (GCM) . The BUP-CEARS-CRU (1994) study reported that the temperature of Bangladesh would rise 0.5 to 2.0 degree Celsius by the year2030 under 'business as usual' scenario of IPCC. According to the estimation of same model average monsoon rainfall rise would be 10 to 15% by the year 2030.

By applying the GFLD 1% transient model, Ahmed and Alam (1998) reproduced the climate change scenarios, which were largely used for a number of subsequent national assessment. It reported that the average increase in temperature would be 1.3 °c to 2.6 °c for the two projection year, 2030 and 2075, respectively. It was noticed that the variation of changed temperature for winter was 1.4 °C and 0.7 °C for the monsoon months in 2030 while the variation would be 2.1 °C and 1.7 °C for the winter and monsoon months respectively. The report revealed that the decreases of winter rainfall would be a negligible rate in 2030, while there would be no appreciable rainfall in 2075. On the other hand monsoon precipitation would increase at the rate of 12 and 27 percent respectively for the two projection years. The following table summaries the climate change scenarios developed by Ahmed and Alam (1998).

In the 1990s, attempts were made to generate climate change scenarios for Bangladesh using General Circulation Models (GCMs). The BUP-CEARS-CRU (1994) study predicted that under the "business as usual" scenario of the IPCC, the temperature of Bangladesh would rise by 0.5 to 2.0 degrees Celsius by the year 2030, while average monsoon rainfall would rise by 10 to 15%.

Ahmed and Alam (1998) reproduced the climate change scenarios using the GFLD 1% transient model, which was widely used for subsequent national assessments. They estimated that the average temperature would increase by 1.3°C to 2.6°C for the two projection years, 2030 and 2075, respectively. The temperature change for winter was projected to be 1.4°C and 0.7°C for the monsoon months in 2030, while the variation would be 2.1°C and 1.7°C for the winter and monsoon months, respectively.

The report also suggested that there would be a negligible decrease in winter rainfall in 2030, while there would be no appreciable rainfall in 2075. However, monsoon precipitation was predicted to increase by 12% and 27% respectively for the two projection years. Ahmed and Alam (1998) created various scenarios of climate change, which are outlined in the table below:

Table 2.1 Output of GCM exercise using GFD 01 transient model

Variable	**2030**	**2075**
Temperature	1.3-2.6°C	1.8-4.6°C
Winter rainfall	Negligible decrease	No appreciable rainfall
Monsoon rainfall	12% increase	27% increase

Source: Ahmed and Alam (1998)

In the 1990s, climate change scenarios were developed for Bangladesh using General Circulation Models (GCMs). Mirza (1997) used an ensemble technique with multiple GCMs and developed climate change scenarios that were later used for a World Bank study (WB, 2000). The study predicted a rise in temperature of 0.7°C during the monsoon season and 1.3°C during the winter season by the year 2030. These findings were similar to the results of Ahmed and Alam's (1998) study.

Mirza (2005) conducted another modelling exercise where three different temperature change scenarios were considered with average temperature changes of 2°C, 4°C, and 6°C. The response of rainfall changes over the South Asian subcontinent, particularly in Bangladesh, was then computed. The output results showed huge variations, with mean annual rainfall increasing from 0.8% to 13.5% for the Ganges basin and changing from -0.03% to 6.4% for the Brahmaputra basin for a 2°C temperature change scenario.

Agarwala et al. (2003) used an ensemble of a dozen GCMs driven by the MAGICC model using the SCENGEN database to generate climate change scenarios for Bangladesh. The study projected an increase in mean annual temperature ranging from 1.4 °C to 3.4 °C by the 2080s, depending on the emissions scenario used. For precipitation, the study projected an increase of up to 18% during the monsoon season, while the dry season could see a reduction of up to 8%.

The study also identified a range of uncertainties and limitations in the GCMs, including uncertainties in modeling regional and local climate, difficulties in modeling extreme events, and uncertainties related to model parameterization and data input.

The National Adaptation programme for Action (NAPA) for Bangladesh has developed the latest climate change scenarios by adopting the results obtained by Agrawala et. al. (2003) regarding changes in temperature and precipitation.

The Bangladesh NAPA (National Adaptation Programme of Action) document, published by the Government of Bangladesh in 2005, presents a comprehensive overview of the potential impacts of climate change on the country, as well as proposed adaptation measures.

According to the report, the average temperature in Bangladesh has been increasing over the past century, and the rate of increase has been accelerating in recent decades. It is projected that the annual mean temperature will continue to increase by 1.5°C to 2.0°C by the year 2050, compared to the baseline period of 1961-1990. This increase in temperature is likely to result in changes in the frequency and intensity of extreme weather events, including heatwaves, floods, and cyclones.

In terms of rainfall, the report notes that Bangladesh receives over 80% of its annual precipitation during the monsoon season, which runs from June to September. Climate change is expected to alter the timing and intensity of monsoon rainfall, leading to more frequent and severe flooding in some areas and more prolonged droughts in others. The report projects an increase in mean annual rainfall of up to 10% by 2050, with more intense and erratic rainfall patterns.

Overall, the report emphasizes the urgent need for adaptation measures to address the impacts of climate change in Bangladesh, particularly in vulnerable sectors such as agriculture, water resources, and coastal communities. Proposed measures include the construction of flood shelters, the promotion of climate-resilient crop varieties, and the development of early warning systems for extreme weather events.

Bangladesh's climate action plan (GOB, 2008) was based on the IPCC (2007) temperature and rainfall projections for the South Asia region, which were derived from an amalgam of 16 General Circulation Models (GCMs) (Brammar, 2014). The predicted seasonal changes in mean temperature and rainfall by 2030, 2070, and 2100 under the highest (A1F1) and lowest (B1) greenhouse gas emission scenarios are summarized in Table 2.7 (temperature) and Table 2.8 (rainfall).

The table 2.7 shows the predicted changes in mean temperature (in degrees Celsius) for the four seasons (December-February, March-May, June-August, September-November) in Bangladesh under two greenhouse gas emission scenarios (A1F1 and B1) for three time periods (2010-2039, 2040-2069, 2070-2099) based on 16 General Circulation Models (GCMs). The IPCC (2010-2039) projections indicate that the mean temperature in Bangladesh is expected to increase by 1.17-5.44°C under the A1F1 scenario and 1.11-2.93°C under the B1 scenario, depending on the season and time period.

The table 2.7 also shows the predicted changes in mean rainfall (in millimeters per month) for the four seasons in Bangladesh under the same greenhouse gas emission scenarios and time periods. The predicted changes in rainfall are not shown in the description as they are missing in the given table.

Additionally, the table includes the mean temperature values (in degrees Celsius) for the four seasons in Dhaka for the period of 1953-2008. The mean temperature during December-February was 18.7°C, during March-May was 28.9°C, during June-August was 28.7°C, and during September-November was 27.4°C.

The table shows the predicted changes in mean temperature (in degrees Celsius) for the four seasons (December-February, March-May, June-August, September-November) in Bangladesh under two greenhouse gas emission scenarios (A1F1 and B1) for three time periods (2010-2039, 2040-2069, 2070-2099) based on 16 General Circulation Models (GCMs). The IPCC (2010-2039) projections indicate that the mean temperature in Bangladesh is expected to increase by 1.17-5.44°C under the A1F1 scenario and 1.11-2.93°C under the B1 scenario, depending on the season and time period.

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Table 2.2: IPCC projections of seasonal changes in surface air temperatures in the South Asia sub-region for the 21st century

Period	December- February		March-May		June-August		September-November	
	A1F1 °C	B1 °C	A1F1 °C	B1 °C	A1F1 °C	B1 °C	A1F1 °C	B1 °C
IPCC								
2010-2039	+1.17	+1.11	+1.18	+1.07	+0.54	+0.55	+0.78	+0.83
2040-2069	+3.16	+1.97	+2.97	+1.81	+1.71	+0.88	+2.41	+1.49
2070-2099	+5.44	+2.93	+5.22	+2.71	+3.14	+1.56	+4.19	+2.17
Dhaka 1953-2008	18.7		28.9		28.7		27.4	
Notes: The values in the tables represent the change in mean temperature and mean rainfall from the baseline period of 1961-1990. The "+" sign denotes an increase, while the "-" sign denotes a decrease.								

1. IPPC source: IPPC (2007). 2. A1F1= highest future emissions scenerios. B1= lowest future emissions scenarios. 3. Dhaka temperature are the means for January,May, and October. (Source: Brammar, 2014)

Table 2.3: Predicted Seasonal Changes in Mean Rainfall (%) by 2030, 2070, and 2100 under A1F1 and B1 Emission Scenarios

	December-February		March-May		June-August		September-November	
Period	A1F1	B1	A1F1	B1	A1F1	B1	A1F1	B1
2010-2039	3.3	2.7	-7.9	-6.6	5.5	4.5	11.6	9.5
2040-2069	5.2	4	-13.2	-10.3	10.1	7.5	18.9	14.6
2070-2099	5.5	4.1	-15.8	-11.7	15.4	10.3	27.4	19.8

Note: The values in the tables represent the change in mean temperature and mean rainfall from the baseline period of 1961-1990. The "+" sign denotes an increase, while the "-" sign denotes a decrease.

The literature review provides strong evidence that Bangladesh is currently undergoing significant changes in its climate patterns, particularly in terms of rainfall and temperature. A consistent increase in temperature has been observed across all studies, particularly during the winter and pre-monsoon seasons. However, there are variations in rainfall patterns depending on the region and the time of the year. While some areas in Bangladesh have experienced an increase in extreme rainfall events, others have seen a decreasing trend, particularly during the monsoon season. These changes in climate patterns could have severe impacts on agriculture, water resources, human health, and the economy of Bangladesh. Therefore, it is crucial to develop and implement adaptation strategies to cope with these changes and mitigate their adverse effects. As a result, further research is necessary to investigate the dimensions of these changes and update our understanding of the situation.

2.6 Study Area Profile:

2.6.1 Location and General Geographic Background:

Bangladesh which emerged as a sovereign state in 1971, is a tropical climatic region in South Asia, lies between 20^0 $34^/$ N to 26^0 $38^/$ N latitude and 88^0 $01^/$ E to 92^0 $41^/$ E longitude having an area of 1,47,570 sq. Kilometers(BBS,2005) is vulnerable to climatic change. This country is bounded by West Bengal (India) on the west, Assam and Meghalaya (India) on the north, and Assam, Tripura and Mizoram on the north-east and Mayanmar on the south-east and the Bay of Bengal on the south (Rashid,1991). The Bay of Bengal lies on the south with 177 kilometers length is the largest sea beach in the world. Most of the country is low-lying land comprising the delta of the Ganges and Brahmaputra rivers (Agarwala,et al,2003). Floodplain occupy 80% of the country (Agarwala, et al,2003) . Mean elevations range from less than 1 meter in the tidal floodplains, 1 to 3 meters on the main river and estuarine floodplain and up to 6 meters in Sylhet basin in the north-east (Rashid, 1991).

The total area of Bangladesh is approximately 147000 sq. kilometers is a large alluvial basin floored with sediments deposited by three major rivers of this region the Ganges, the Brahmaputra and the Meghna and their numerous associated streams, tributaries, and dis tributaries. Of the total area 138000 sq. kilometers comprises the land surface and 9400 sq. kilometers cover rivers and other inland water-bodies. There are 7 climatic regions according to Rashid (1991).

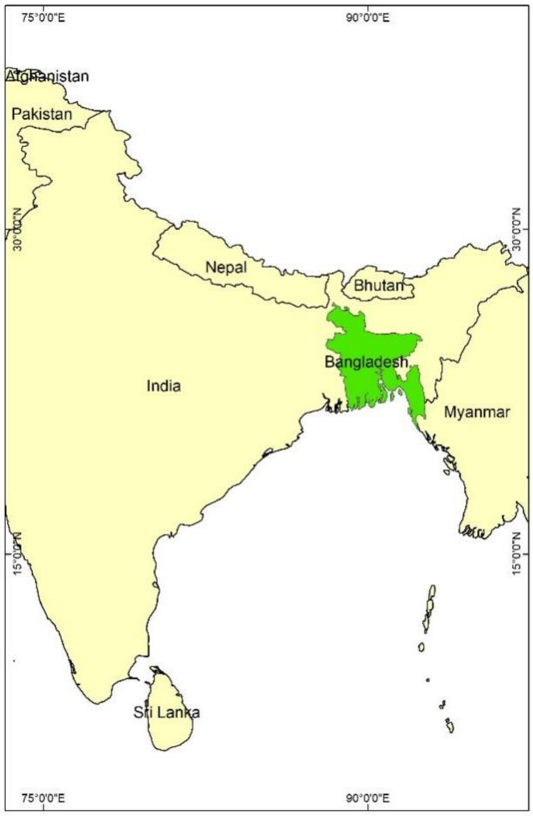


Figure 2.4: Location of Bangladesh

From the environmental point of view and meteorological consideration, four distinct seasons can be acknowledged in Bangladesh (Bhuyan et al., 2010). According to the article, the four distinct seasons in Bangladesh are:

1. Winter (December to February): This season is characterized by relatively cool and dry weather, with temperatures ranging from 12°C to 26°C. The air is generally clean and pollution levels are low.

2. Pre-monsoon or summer (March to May): This season is characterized by hot and humid weather, with temperatures ranging from 20°C to 38°C. Dust and particulate matter levels in the air increase during this season due to dry weather conditions and winds from the northwest.

3. Monsoon (June to September): This season is characterized by heavy rainfall and high humidity, with temperatures ranging from 25°C to 33°C. Wet weather conditions and stagnant air can lead to an increase in air pollution levels, particularly in urban areas.

4. Post-monsoon or autumn (October to November): This season is characterized by cool and dry weather, with temperatures ranging from 15°C to 28°C. The air is generally clean and pollution levels are low.

Again, Rashid (1991) has divided Bangladesh into seven climatic sub-zones (Fig-). These are as described by Islam and Neelim (2010) mentioned bellow-

A) South-eastern: Comprises greater Chittagong and Chittagong Hill Tracts and a coastal strip extending from south-west Sundarban to the south of cumilla. Climatic characteristics: Small range of mean temperature and heavy rainfall.

B) North- eastern: Includes greater Sylhet district. Climatic characteristics : Milder summer , heavy rainfall, cloudy cool winter.

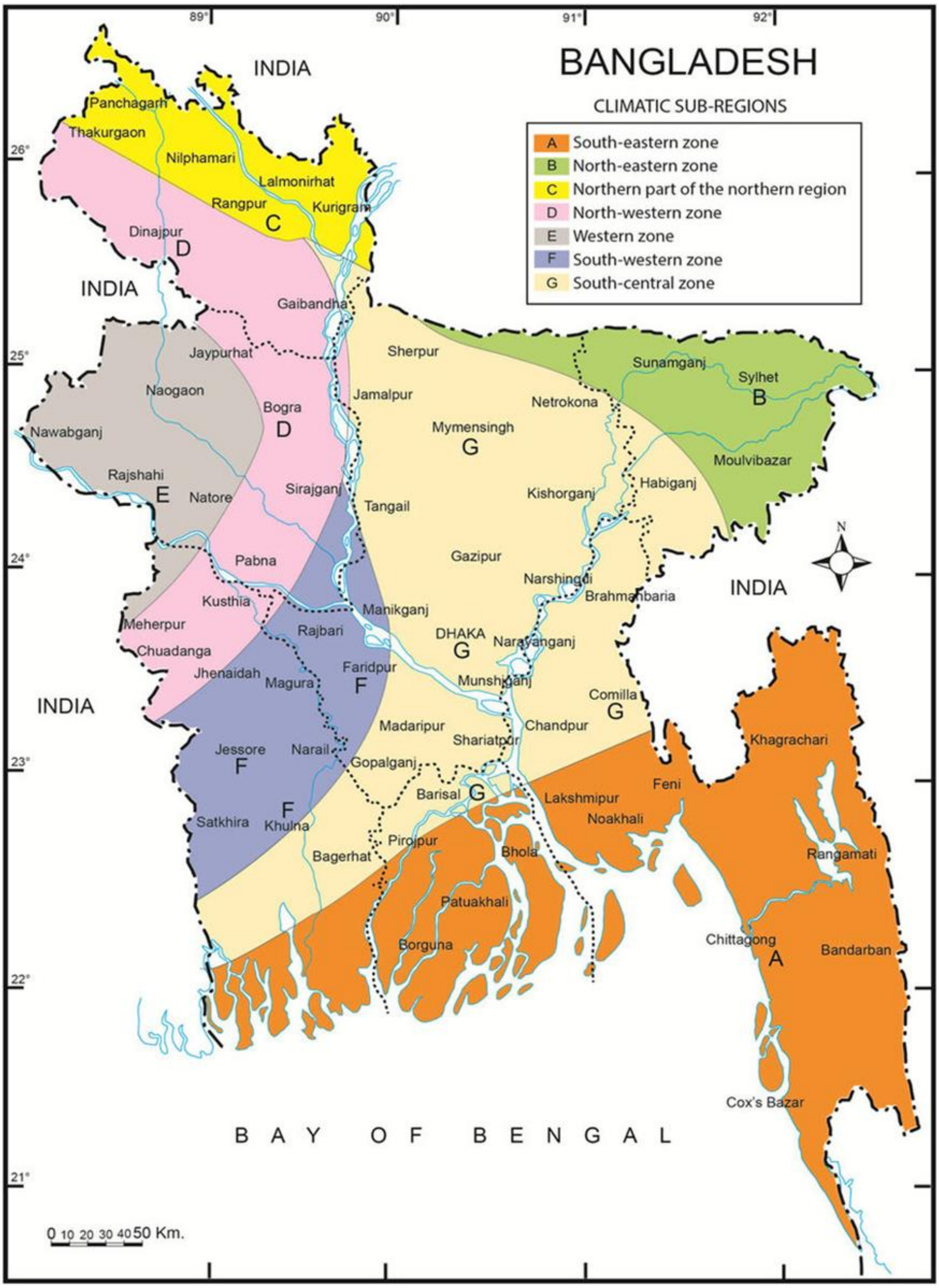
C) Northern part of the Northern Region: Area of extreames . Climatic characteristics: Heavy rainfall, hot summer and cool winter.

D) North-western: Similar to sub-zone C , except that extremes are less. Climatic characteristics: Hot summer and moderate rainfall.

E) Western: Greater Rajshahi and parts of adjoining districts. Climatic characteristics:The hottest and driest of all sub-zones.

F) South-western: Less extremes than the sub-zones E and D. Climatic characteristics:Hot summer and fairly heavy rainfall.

G) South-central: Climatic characteristics:Mild summer and fairly heavy rainfall.



Source: Banglapedia (2006)

CHAPTER: THREE

METHODOLOGY

METHODOLOGY

3.1 Climatic Data over Bangladesh:

Monthly climatic datasets, including surface air temperature and rainfall, were collected from the Bangladesh Meteorological Department for the period 1968 to 2017. The Meteorological Department of the University of Dhaka facilitated the collection. There are 35 weather stations situated across different climatic regions of Bangladesh. As per Haroun-er Rashid (1991), the country is divided into seven climatic regions, namely: southeastern, northeastern, northern part of the northern region, northwestern, western, southwestern, and south-central.

Table 3.1: Climatic regions of Bangladesh

Regions	Name of the Stations
South-eastern	Chattagram (City), Chattagram (Ambagan), Cox's Bazar, Kutubdia, Rangamati, Sandwip, Teknaf, Hatiya, M. Court, Bhola, Patuakhali, Khepupara, Feni, Sitakunda.
North-eastern	Sylhet, Srimongal.
Northern part of the northern region	Rangpur, Syedpur.
North-western	Bogra, Dinajpur, Chuadanga.
Western	Rajshahi, Ishurdi
South-western	Faridpur, Jessore, Satkhira, Khulna
South-central	Tangail, Chandpur, Dhaka, Moymonsing, Madaripur, Kumilla, Mongla, Barishal

Source: Adaped from (Rashid, 1991)

The monthly data were sorted into meteorological seasons, and separate tables were generated for each season. These tables were arranged according to the climatic division number and year. To calculate the seasonal averages of Tmax and Tmin, we considered the number of days in each month, using the following formulas. For each formula, the name of the month indicates whether it represents the average Tmax or Tmin for that month.

Winter/Dry= $\frac{31Dec + 31Jan + 28.25Feb}{90.25}$

Summer/Pre-monsoon= $\frac{31March + 30April + 31May}{92}$

Rainy/Monsoon= $\frac{30June + 31July + 31Aug + 30Sep}{102}$

Autumn/Post monsoon= $\frac{31Oct + 30Nov}{61}$

To simplify calculations, a uniform number of days in February was used. In leap years, which occur once every four years, February has 29 days, and winter has 91 days instead of 90. The average temperature was calculated as the average of T max and T min. Seasonal rainfall was calculated as the sum of monthly rainfall values within each meteorological season. The annual averages for each temperature variable were calculated based on the number of days in each season.

Annual= $\frac{90.25Winter + 92Premonsoon + 102Monsoon + 61Postmonsoon}{365.25}$

The data collected covers a period from 1968 to 2017, spanning 50 years. For the analysis in this study, the 50-year period was divided into five decades, each consisting of 10 years. The temperature and rainfall data were analyzed on a decadal basis.

3.2 Analyzing Air Temperature:

The annual T max, T min, and T avg temperature values were calculated for each station using the following equation:

AT = ΣT/I

where T is the monthly temperature amount for each station, I is the month of the year, and AT is the annual temperature amount at that station.

The mean decadal temperature amount for each station over a period of ten years was calculated using the following equation:

TT = ΣAT/10

where TT represents the decadal amount of temperature.

3.3 Analyzing Rainfall:

The mean annual rainfall values were computed for each station from the monthly rainfall amount using the following equation:

$Ar = \Sigma R/I$

where R is the monthly rainfall amount at each station, I is the month of the year, and Ar is the annual rainfall amount at that station.

The mean decadal rainfall amount for each station over a period of ten years was computed using the following equation:

$RD = \Sigma Ar/10$

where RD represents the mean decadal rainfall amount for each station over a 10-year period, and j is the decade index.

3.4 Statistical Techniques:

Trend analysis is a method used to identify patterns in historical data and make predictions about future outcomes. To analyze the trends of temperature and rainfall, linear regression using the least squares method was applied (Moore and McCabe, 2003), and the least squares were calculated by Eq. 2.1: $y = ax + b$ (2.1)

where x and y represent the independent and dependent values, respectively; a is the coefficient of each x value; b denotes the constant value; and $\bar{x}$ and $\bar{y}$ are the sample means.

The coefficient a was calculated using Eq. 2.2: $a = \Sigma[(x - \bar{x}) * (y - \bar{y})] / \Sigma(x - \bar{x})^2$ (2.2)

The constant value b was calculated using Eq. 2.3: $b = \bar{y} - a\,\bar{x}$ (2.3)

3.5 Geographic Information system:

A GIS is a computer-based system for acquiring, storing, manipulating, editing, interpreting, analyzing and representing spatial data along with non-spatial data. Geographical variables such as temperature and rainfall cannot be measured in all parts of space; therefore, point observation data and spatial interpolation techniques are used to obtain spatial coverage of the variable. We analyzed the changes in temperature and rainfall based on spatiotemporal analysis. Therefore, the spatial distribution patterns of temperature and rainfall in different time periods were represented using GIS. Kriging interpolation was applied to present and analyze the findings spatially.

3.6 Variability Analysis:

The variability analysis was conducted by calculating the standard deviation and the coefficient of variation (CV) of the mean annual temperatures and rainfalls at 35 stations for the time period from 1968 to 2017, and for each decade. The spatial variation was assessed using the Kriging method of interpolation in GIS, specifically in ArcGIS data analysis.

3.7 Methodology Process and Techniques:

To complete the research work, the following methods and techniques will be followed:

1) Secondary sources were used, such as the Bangladesh Meteorological Department (BMD), which is the national agency responsible for collecting, analyzing, and disseminating meteorological information in the country. The BMD maintains a network of weather stations throughout the country, which collect meteorological data on a regular basis. The data is available in both raw and processed formats and can be accessed through the BMD website or through other online sources such as the Global Historical Climatology Network (GHCN) or the National Centers for Environmental Information (NCEI). Necessary information about the two important elements of climate, i.e., temperature and rainfall, was collected.
2) Decadal variations in the major climatic parameters, i.e., rainfall and temperature, were examined using appropriate statistical methods, and relevant climatic maps of the country were prepared.
3) GIS and cartographic techniques were applied to show the temperature and rainfall variability, and relevant climatic maps of the country were prepared.

CHAPTER: FOUR

TEMPERATURE TRENDS AND VARIABILITY OF BANGLADESH

4.1 Minimum Temperature (T_{min})Trends and Variability:

4.1.1 Introduction

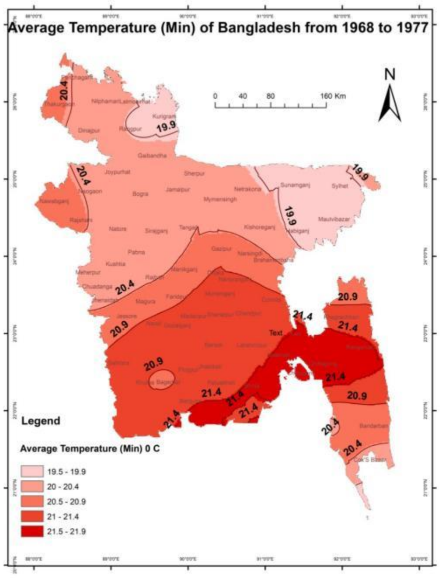
Current global debate on climate change is widely quoted with the predictions and models results produced by Intergovernmental Panel on Climate Change (IPCC). According to the latest IPCC assessment report (AR5), the global temperature has been increased by 0.85 ^{0} C during the last hundred years, where this value was predicted as 0.6 degree in their third assessment report. IPCC use General Circulation Model (GCM) to arrive at prediction results, where they used data from weather stations located in different parts of the world which were able to fulfil specific criteria preset by IPCC (Houghton, 2004). The discussion and argument that take place in Bangladesh are also based on IPCC prediction results, though IPCC clearly mentioned in AR5 that the model results are appropriate for global scale (Islam, T and Neelim, A, 2010). In response, Climate Change Cell (CCC) has conducted some works on climate change in Bangladesh. The discussion and action plans about Bangladesh in regards to climate change undertaken by the UNFCC and IPCC produced estimates results and prediction about climate change by focusing global scale and have local level interventions they gather data by declaring clearly that they are produced at global scale (IPCC, 2007). In this case they gathered data from different weather stations of the world (and ocean-going vessels) which were able to meet specific criteria set by the IPCC among which the most important ones that the station should have been engaged in gathering data at least for 130 years. Bangladesh weather station could not fulfill this criterion. So, in this study, temperature and rainfall data from 35 weather stations were obtained over the time period of 1968 to 2017 among which only 19 stations fulfill the whole time series data requirement. The missing data of the remaining stations over that time series were assessed based on either on the neighbouring stations or the missing data of the year were also assessed by applying forecast method in Excel data format. As a result, there might have been a little intervention over the temperature and rainfall data set causing a little bit intervention since there was no alternative to prepare maps without considering the input data sets of all the stations over all the considered years. As a result, in some case of the output of the results might have been a little bit different against other studies conducted by local level by considering local data. In Bangladesh most of the weather stations were established during twentieth century and data recording procedure (especially during earlier time) were non scientifically. And there remains heavy missing data and no data record. It indicates that General Circulation Model did not receive climatic data from Bangladesh that scientifically represent the country (Islam and Neelim, 2010). This study tried to establish local scale trends of climate change since the fifty years (1968-2017) when the temperature and rainfall data were recorded digitally in case of most of the weather stations.

This chapter focuses on presenting temperature and rainfall maps with interpretations covering the period of fifty years (1968-2017), divided into five decades. The temperature and rainfall data were analyzed to show yearly, decadal, seasonal, and climatic-zonal trends. The temperature data were analyzed in terms of minimum average, maximum average, and mean temperature. The temperature data were further analyzed for four seasons of Bangladesh, namely, pre-monsoon, monsoon, post-monsoon, and dry/winter seasons. Additionally, temperature data were analyzed considering seven climatic sub-divisions as grouped by Haroon er Rashid (1991), and temperature trend/fluctuation was detected in the map. On the other hand, rainfall data trends were also shown on the map, displaying decadal, seasonal, and climatic zonal-wise trends.

However, it should be noted that the BMD datasets used in this study contain many missing data over the last 50 years, which were adjusted using the forecast method in Excel. Therefore, there may be slight differences in the temperature trend compared to the results of other studies, particularly at the global scale conducted by the IPCC.

4.1.2 Description of Decadal Trends and Variability of Minimum Temperature (T_{min})

The trend of minimum temperature (Tmin) in Bangladesh has been categorized into average (Mean), average minimum, average maximum, and standard deviation for the time period of 1968 to 2017, showing five decades. Temperature trends and variability analysis have been carried out for four seasons of Bangladesh, namely, pre-monsoon, monsoon, post-monsoon, and dry/winter. Additionally, temperature trends in different climatic sub-regions of Bangladesh have also been discussed. The temperature trend series are presented in Figure 4.1.



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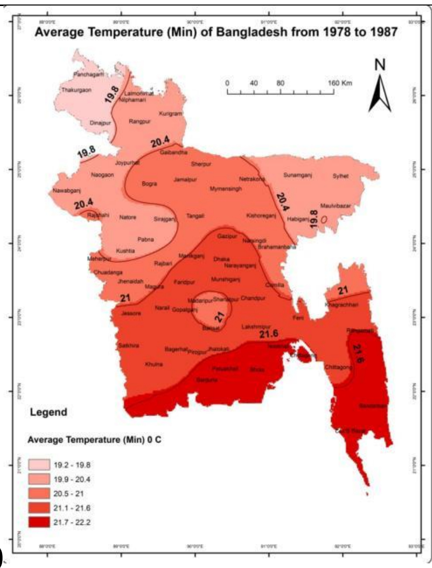

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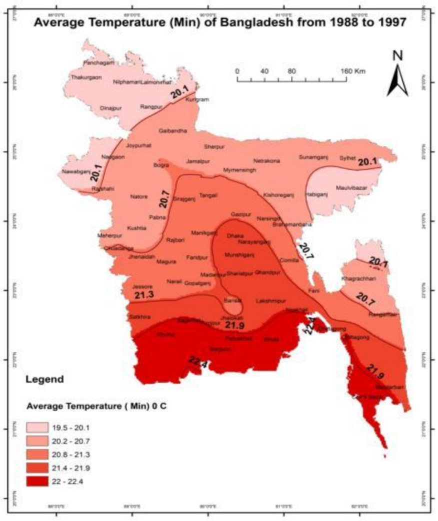

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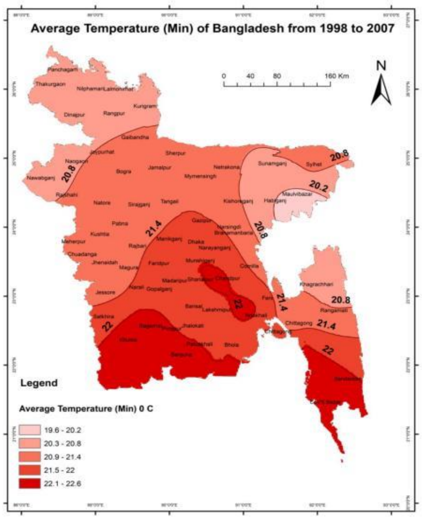

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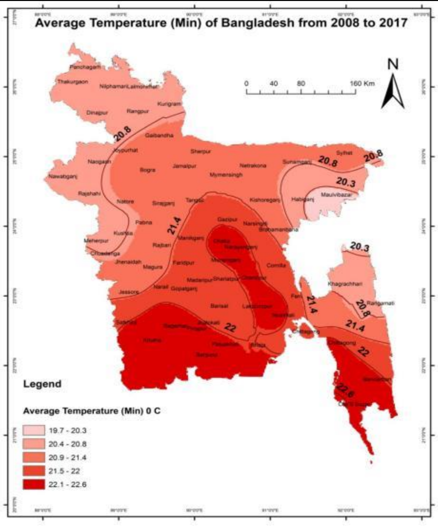


e)

Figure 4.1 a) Map of average temperature (T_{min}) of Bangladesh from 1968 to 1977. b) Map of average temperature (T_{min}) of Bangladesh from 1978 to 1987. c) Map of average temperature (T_{min}) of Bangladesh from 1988 to 1997. d) Map of average temperature of Bangladesh from 1998 to 2007 (T_{min}) e) Map of average temperature (T_{min}) of Bangladesh from 2008 to 2017.

Source: Analyzed by Author, based on BMD data set, 2022.

From Figure 4.1a) it can be observed that the average minimum temperature (Tmin) of Bangladesh from 1968 to 1977 ranged from 19.5-21.9 °C. The highest temperature range of 21.5-21.9 °C was observed in the southeastern zone, including the districts of Patuakhali, Bhola, Noakhali, Feni, parts of Chattogram, and Rangamati. The lowest temperature range of 19.5-19.9 °C prevailed in the northeastern zone, including parts of Sylhet, Moulobibazar, Sunamgonj, Hobigonj, part of Kurigram, and Rangpur district. The south-central zone, which is the largest climatic zone of Bangladesh, experienced temperatures ranging from 20-20.4 °C, 20.5-20.9 °C, and 21-21.4 °C, respectively. Dhaka, which falls under this zone, experienced a temperature range of 21-21.4 °C in this decade. The northern part of the northern region, northwestern zone, western zone, and southwestern zone also experienced varying temperatures during this decade. The northern part of the northern region had an average temperature range of 19.5-19.9 °C, 20-20.4 °C, and 20.5-20.9 °C. In the western zone, the district of Naogaon and Natore experienced an average temperature range of 20-20.4 °C, while Rajshahi and Nawabganj had a range of 20.5-20.9 °C. The northwestern zone mostly had an average temperature range of 20-20.4 °C, while in the southwestern zone, Rajbari had an average temperature range of 20-20.4 °C, and the districts of Magura, Faridpur, and Jessore had a range of 20.5-20.9 °C. Narail and Satkhira district had an average temperature range of 21-21.4 °C.

Figure 4.1 b) shows the average temperature of Bangladesh from 1978 to 1987, and it can be observed that the average temperature ranges from 19.2-22.2 °C. The highest temperature range of 21.7-22.2 °C was prevalent in most parts of the southeastern zone, which includes the districts of Patuakhali, Borguna, Chittagong, Bhola, Noakhali, Feni, Cox’s Bazar, Rangamati, and Bandarban. The lowest temperature range of 19.2-19.8 °C was prevalent in most parts of the northeastern zone, which includes the districts of Sylhet, Moulibazar, Sunamgonj, and Hobigonj. In this decade, Dhaka experienced an average temperature range of 21.1-21.6 °C.

Figure 4.1 c) indicates the average temperature of Bangladesh from 1988 to 1997, and in this decade, the temperature range of 19.5-22.4 °C was prevalent throughout the country. The highest temperature range of 22-22.4 °C was prevalent in parts of the southeastern zone, which includes the districts of Patuakhali, Borguna, Bhola, and Cox’s Bazar. The lowest temperature range of 19.5-20.1 °C was prevalent in Moulibazar and Hobigonj districts. Dhaka experienced a temperature range of 21.4-21.9 °C in this decade.

Figure 4.2 d) shows the average temperature of Bangladesh from 1998 to 2007, and in this decade, the temperature range of 19.6-22.6 °C was prevalent throughout the country. The highest temperature range of 22.1-22.6 °C was prevalent in parts of the southeastern zone, which includes the districts of Borguna, Patuakhali, Bandarban, and Cox’s Bazar. The lowest temperature range of 19.6-20.2 °C was prevalent in parts of the northeastern zone, which includes the districts of Moulibazar and Hobigonj. In this decade, Dhaka experienced a temperature range of 21.5-22.0 °C.

Figure 4.2 e) indicates the average temperature of Bangladesh from 2008 to 2017, and it shows that the temperature range of 19.7-22.6 °C was prevalent in this decade. The highest temperature range of 22.1-22.6 °C was prevalent in parts of the southeastern zone, which includes the districts of Patuakhali, Barguna, Bandarban, and Cox's Bazar. The lowest temperature range of 19.7-20.3 °C was prevalent in parts of the northeastern zone, which includes the districts of Moulvibazar and Hobigonj, as well as a part of the south-central zone. In this decade, Dhaka experienced a temperature range of 21.5-22.0 °C.

Table 4.1 Decadal Average Temperature Range

Decades	Temperature Range (Average) ^{0} C
1968-1977	20.78
1978-1987	21.04
1988-1997	21.18
1998-2007	21.45
2008-2017	21.53

Source: By Author calculated from BMD datasets

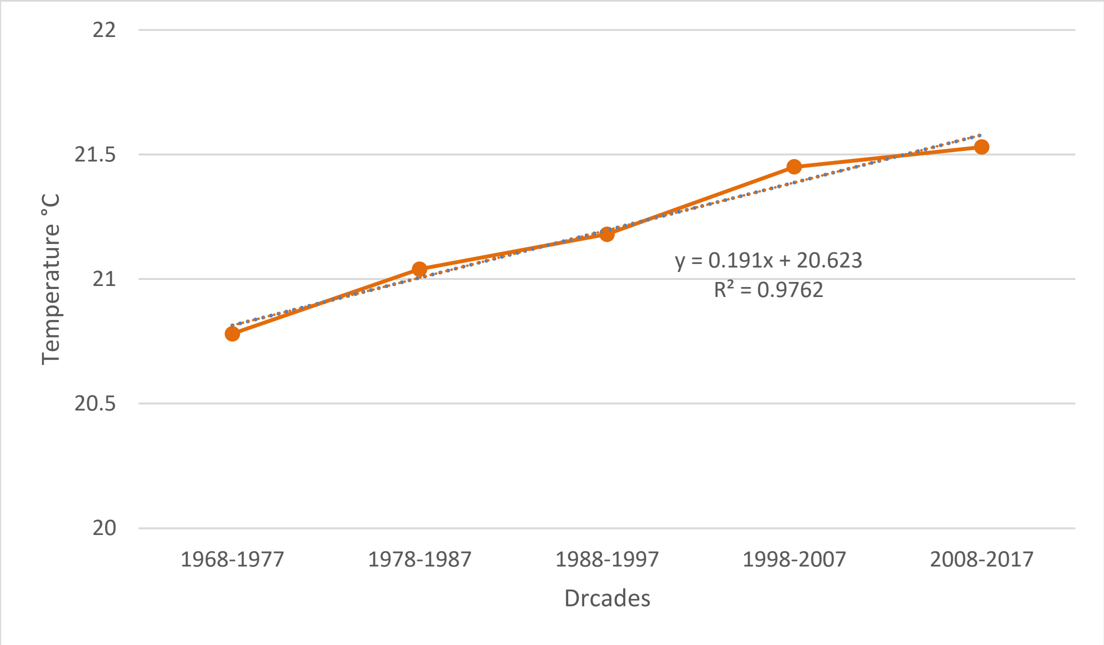


Figure 4.2: Trends in Average Temperature of Bangladesh from 1968 to 2017

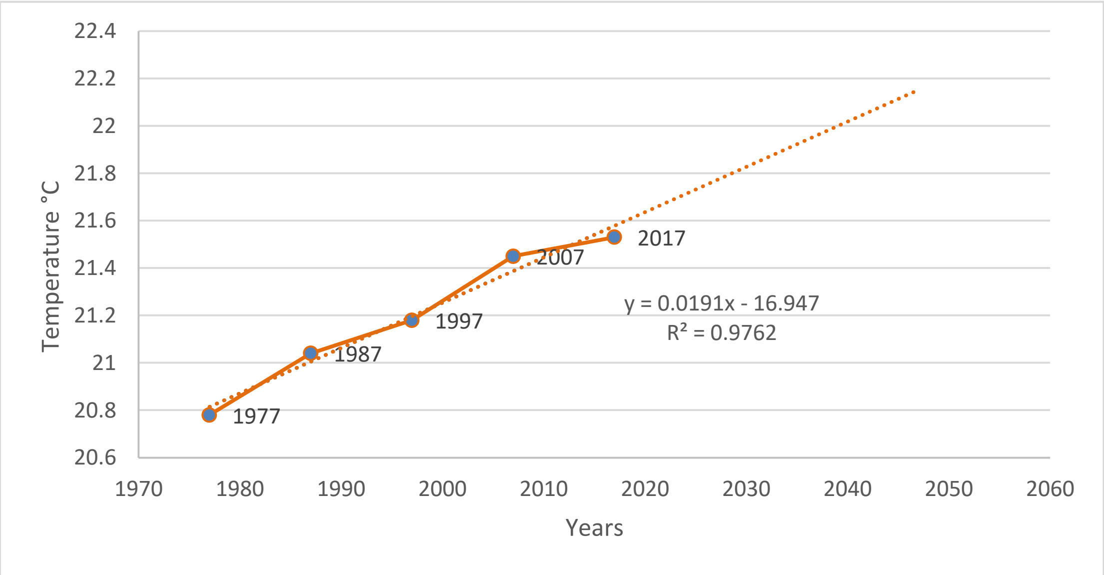


Figure 4.3: Projected Trends of Average temperature of Bangladesh

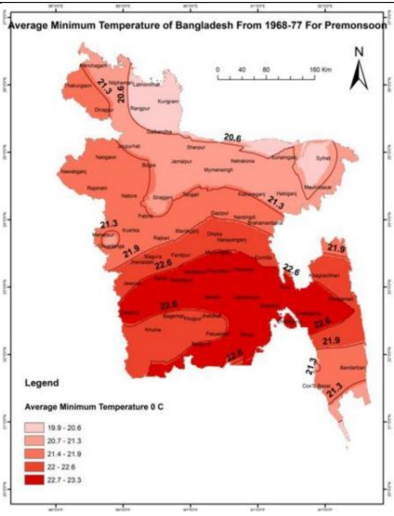
From Figure 4.2, it is observed that the average temperature of Bangladesh has increased at a rate of 0.19°C per decade, and in a fifty-year time period, the average temperature has increased by 0.96°C, which is consistent with the prediction of the IPCC, which shows that in the last fifty years, the world average has increased by 0.85°C. From Figure 4.3, it is also observed that the yearly increase in the average temperature is 0.019°C, and after 33 years, in 2050, the average temperature of Bangladesh will increase by 0.627°C. And after 83 years, in 2100, the average temperature of Bangladesh will increase by 1.577°C.

4.1.3 Description of Seasonal Trends and Variability of Minimum Temperature:

In our country, four seasons are recognized and the minimum temperature of those seasons varies from one to another. During the winter or dry season, the minimum temperature fluctuates the lowest in the northern region. This year, the lowest temperature was recorded in Tetulia at 6.7 degrees Celsius (The Financial Express, 14 January 2023).

4.1.3.1 Pre-monsoon Temperature: This season consists of the months of March, April, and May. The minimum temperature of this season ranges from 19-23 0 C. Figure 4.4 (a-e) presents the decade-wise seasonal trends and variability of minimum temperature.

From Figure 4.4 a), it is indicated that the map shows the average minimum temperature of Bangladesh from 1968 to 1977 during pre-monsoon. The temperature range during this decade was observed to be between 19.9°C to 23.3°C. The highest temperature range of 22.7°C to 23.3°C was observed in the south-central zone, including districts like Sariatpur, Madaripur, Chandpur, Gopalgonj, and parts of Khulna, Barishal, and the south-eastern zone, including districts like Bhola, Noakhali, Feni, Luxmipur, Chittagonj, and parts of Patuakhali, Barguna, Khulna, and Bagerhat. The lowest temperature range of 19.9°C to 20.6°C was observed in the northern part of the northern region, including districts like Kurigram, Rangpur, Lalmonirhat, Gaibandha, and the north-eastern zone, including districts like Sylhet, Sunamgonj, and part of Teknaf.



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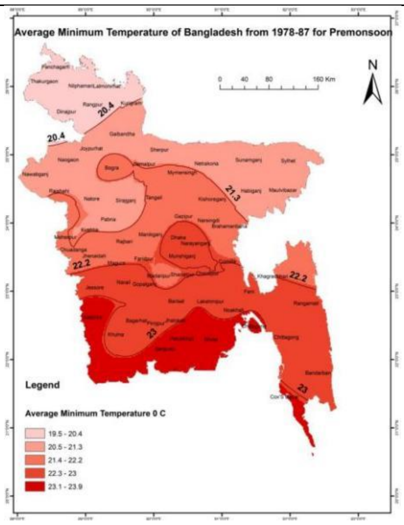

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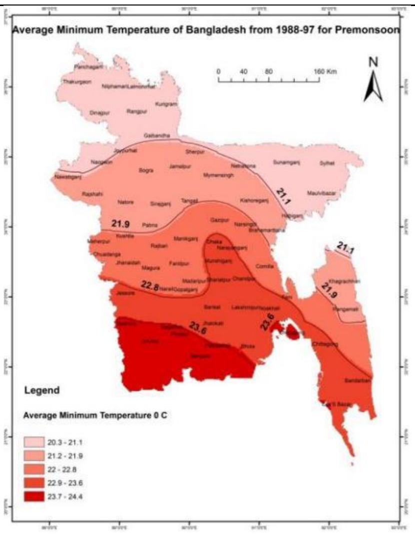

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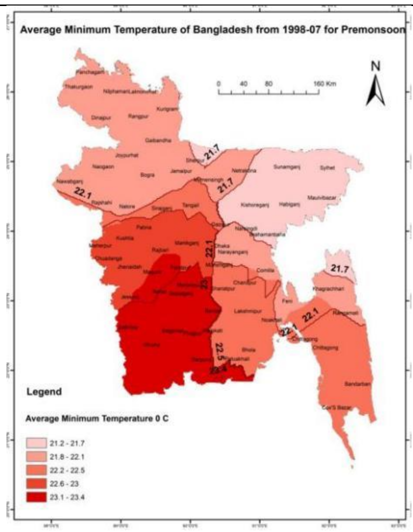

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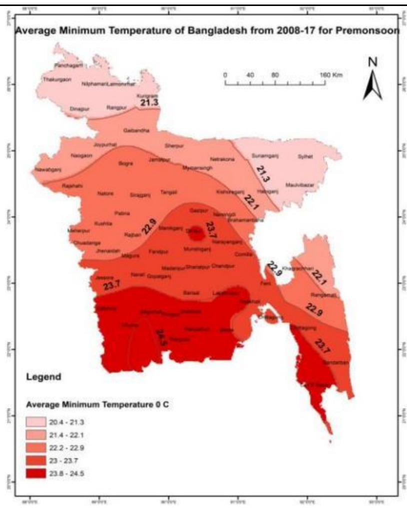

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Figure 4.4 a) Map of average minimum temperature of Bangladesh from 1968 to 1977 for Premonsoon b) Map of average minimum temperature of Bangladesh from 1978 to 1987 for Premonsoon c) Map of average minimum temperature of Bangladesh from 1988 to 1997 for Premonsoon d) Map of average minimum temperature of Bangladesh from 1998 to 2007 for Premonsoon e) Map of average minimum temperature of Bangladesh from 2008 to 2017 for Premonson

Source: Analyzed by Author, based on BMD data set, 2022.

From Figure 4.4 b), it is indicated that the map shows the average minimum temperature of Bangladesh from 1978 to 1987 during pre-monsoon. The temperature range during this decade was observed to be between 19.5°C to 23.9°C. The highest temperature range of

23.1°C to 23.9°C was observed in the south-eastern zone, including districts like Patuakhali, Bhola, Noakhali, Borguna, Bagerhat, Khulna, Satkhira, and Cox's Bazar, and parts of the south-western zone, including the Satkhira district. The lowest temperature range of 19.5°C to 20.4°C was observed in most parts of the northern region, including districts like Panchagar, Nilphamary, Lalmonirhat, Rangpur, and most parts of the north-western zone, including districts like Thakurgaon and Dinajpur.

From Figure 4.4 c), it is indicated that the map shows the average minimum temperature of Bangladesh from 1988 to 1997 during pre-monsoon. The temperature range during this decade was observed to be between 20.3°C to 24.4°C. The highest temperature range of 23.7°C to 24.4°C was observed in the south-eastern zone, including districts like Barguna, Patuakhali, Khulna, Bagerhat, Satkhira, and Chittagong. The lowest temperature range of 20.3°C to 21.1°C was observed in the north-eastern zone, including districts like Sunamgonj, Sylhet, Moulvibazar, part of the south-central zone, including districts like Hobigong and Netrokona, and the northern part of the northern region, including districts like Panchagar, Nilphamary, Lalmonirhat, Rangpur, and parts of the north-western zone, including districts like Dinajpur, Gaibandha, Noagaon, and Nababgonj situated in the western zone.

Figure 4.4 d) shows the average minimum temperature of Bangladesh during the pre-monsoon period from 1998 to 2007. The map indicates a temperature range of 21.2-23.4°C during this period. The highest temperature range of 23.1-23.4°C was observed in the southeastern zone, which includes the districts of Pirojpur, Jhalokhati, Borgona, parts of Patuakhali, Bhola, Bagerhat, Khulna, Satkhira, and parts of the south-central zone, which includes the districts of parts of Khulna, Bagerhat, Satkhira, Madaripur, Gopalgong, Barishal, and parts of the southwestern zone, which include the districts of parts of Faridpur, Narail, Magura, Jessore, and Satkhira. The lowest temperature range of 21.2-21.7°C was observed in most parts of the northeastern zone, which includes the districts of Sylhet, Sunamgonj, Moulvibazar, parts of the south-central zone, which includes the districts of parts of Hobigonj, Kishoregonj, Netrokona, Brahmonbaria, Gazipur, Narshindi, Mymensingh, and parts of the south-central zone, which include the district of parts of Khagrachari, Rangamati.

Figure 4.4 e) shows the average minimum temperature of Bangladesh during the pre-monsoon period from 2008 to 2017. The map indicates a temperature range of 20.4-24.5°C during this period. The highest temperature range of 23.8-24.5°C was observed in the southeastern region, which includes the districts of Patuakhali, Borguna, parts of Bagerhat, Khulna, Satkhira, Bhola, parts of the south-central zone, which includes the districts of parts of Khulna, Satkhira, and parts of the western zone, which includes parts of Satkhira. The lowest temperature range of 20.4-21.3°C was observed in most parts of the southeastern zone, which includes the districts of Sylhet, Sunamgonj, Moulvibazar, and parts of Hobigonj district of the south-central zone. The lowest temperature range was also observed in the northern part of the northern region, which includes the districts of Panchagar, Nilphamari, Lalmonirhat, Rangpur, parts of Kurigram, and parts of the northwestern zone, which includes the districts of Takhurgaon, parts of Rangpur, and Dinajpur.

Table 4.2: Decadal Average Minimum Temperature of Bangladesh for Premonsoon Period from 1968-2017

Decades	Temperature Range (Average)°C
1968-1977	22.04
1978-1987	22.14
1988-1997	22.53
1998-2007	22.33
2008-2017	22.99

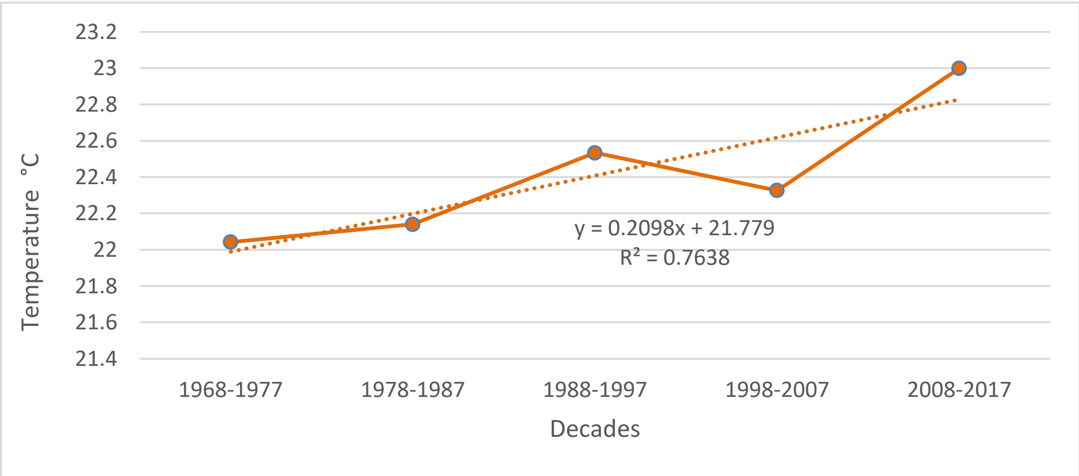


Figure 4.5: Trends of Average minimum temperature of Bangladesh from 1968 to 2017 for Premonsoon

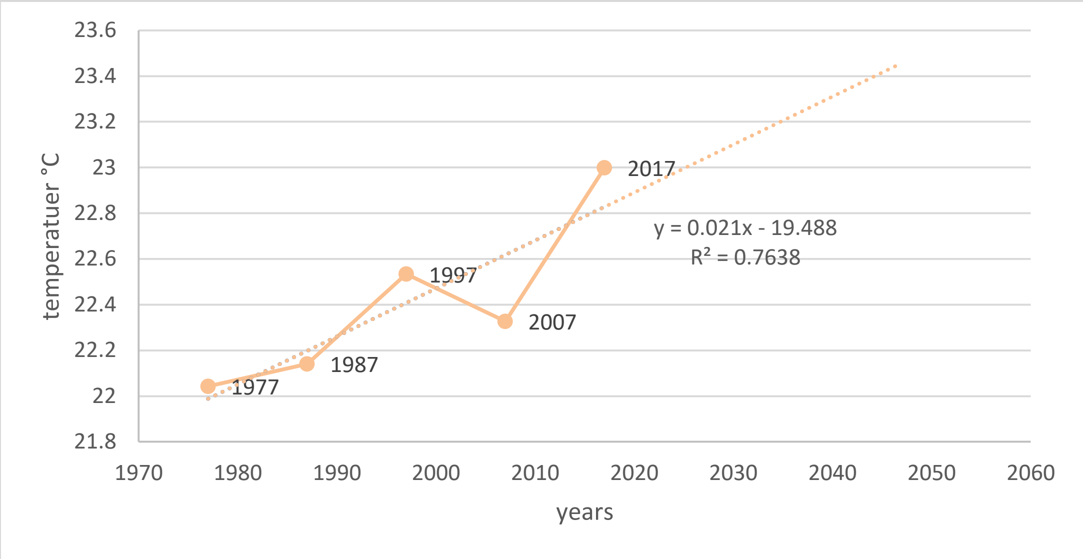


Figure 4.6: Projected Trends of Average minimum temperature of Bangladesh for Premonsoon

From Figure 4.5, it is noticed that the average minimum temperature of Bangladesh from 1968 to 2017 for pre-monsoon has increased by 1.049°C at a rate of 0.2098°C per decade. From Figure 4.6, it is observed that the trend of average minimum temperature is 0.021°C per year. At this rate, the projected temperature after 33 years in 2050 will be 0.693°C and in 2100, the temperature will be 1.743°C.

4.1.3.2 Monsoon Temperature:

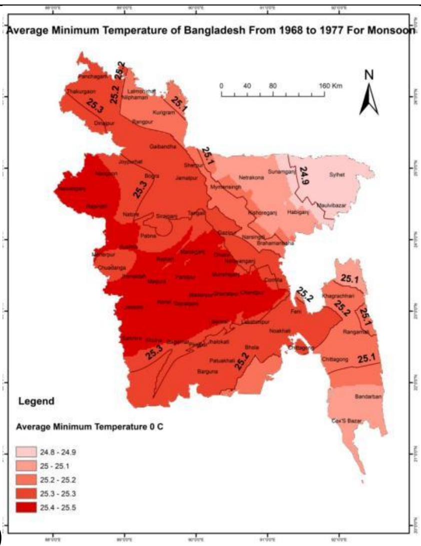
Monsoon is the season when the maximum rainfall occurs, and the average temperature remains comparatively lower than other seasons of the year. Figure 4.7 shows the average minimum temperature of Bangladesh from 1968 to 2017 for the monsoon season. Figure 4.7a) shows the average minimum temperature of Bangladesh from 1968 to 1977 for the monsoon season. In this decade, the average minimum temperature range was 24.8-25.5°C. The highest temperature range of 25.4-25.5°C was observed in most parts of the south-central zone, which includes the districts of Dhaka, Manikgonj, Munshigonj, Chadpur, Sariatpur, Madaripur, Gopalgonj, part of Khulna, Barishal, Faridpur, Narayangonj, part of the southwestern zone, which includes the districts of Jessore, Magura, Rajbari, part of Faridpur, Narail, Khulna, Satkhira, Jhenaidah, part of the northwestern zone, which includes the districts of part of Kustia, part of Pabna, and part of the western zone, which includes the districts of Rajshahi, Nawabgonj, and part of Nawgaon. Again, the lowest temperature range of 24.8-24.9°C was noticed in most parts of the northeastern zone, which includes the districts of Sylhet, Moulvibazar, part of Sunamgonj, and part of Hobigonj of the south-central zone.

Figure 4.7b) shows the average minimum temperature of Bangladesh from 1978 to 1987 for the monsoon season. In this decade, the temperature range was 24.7-25.8°C. The highest temperature range of 25.9-26.0°C was noticed in parts of the south-central zone, which includes the districts of Dhaka, Gazipur, Jamalpur, part of Manikgonj, Munshigonj, Narayangonj, Faridpur, Mymensingh, Sherpur, most parts of the northern part of the northern zone, which includes the districts of Nilphamari, Lalmonirhat, Kurigram, part of Rangpur, part of the northwestern zone, which includes the districts of Gaibandha, part of Rangpur and Bogra, and part of the southwestern zone, which includes the districts of part of Khulna, Satkhira, and Narail. Again, the lowest temperature range of 24.7-25.0°C was observed in parts of the southeastern zone, which includes the districts of Cox's Bazar, Bandarban, part of Chittagong, Rangamati, and part of northeastern zone, which includes the districts of Sylhet and Moulvibazar.

Figure 4.7c) indicates the average minimum temperature of Bangladesh during the monsoon season from 1988 to 1997. Based on this map, it was observed that the average minimum temperature of Bangladesh ranged from 24.7-26.2 °C during this decade. The highest temperature range of 26-26.2 °C was observed in parts of the south-central zone, which includes the districts of Dhaka, Narayangonj, Munshigonj, Gazipur, part of Sariatpur, Manikgonj, Khulna, Barishal, Satkhira, part of the southeastern zone, which includes the districts of Barguna, part of Patuakhali, Pirojpur, Bagerhat, Khulna, Satkhira, part of the southwestern zone, which includes part of Jessore, Satkhira, and part of the northwestern zone, which includes the districts of Chuadanga and part of Meherpur. The lowest temperature range during this season was observed in part of the northeastern zone, which includes the districts of Sylhet, Moulvibazar, part of Sunamgonj, and part of the southeastern zone, which includes the districts of Rangamati and Khagrachari. The lowest temperature range observed during this season was 24.7-25 °C.

Figure 4.7 d) indicates the average minimum temperature of Bangladesh during the monsoon season from 1998 to 2007. From this map, it was observed that the temperature ranged from 24.9-26.3°C during this decade. The highest temperature range of 26.2-26.3°C was observed in parts of the south-central zone, which includes the districts of Madaripur, Shariatpur, Gopalgonj, part of Khulna, Bagerhat, Satkhira, Munshigonj, and Faridpur. It was also observed in parts of the south-eastern zone, including parts of Borguna, Bagerhat, Khulna, and Satkhira, parts of the south-western zone, including the districts of Magura, Narail, part of Faridpur, Jhenaida, Jessore, and Satkhira, parts of the north-western zone, including the districts of Bogra, Kustia, Chuadanga, Meherpur, part of Natore, Pabna, and part of the western zone, including the districts of Rajshahi, Naogaon, Nawabganj, and part of Natore. The lowest temperature range of 24.9-25.2°C was observed in parts of the north-eastern zone, including the district of Maulvibazar, and parts of the south-eastern zone, including the districts of Khagrachari and Rangamati.

Figure 4.7 e) indicates the average minimum temperature of Bangladesh during the monsoon season from 2008 to 2017. From this map, it can be observed that the temperature ranged from 24.7-26.6 °C during this decade. The highest temperature range of 26.3-26.6 °C was observed in parts of the south-central zone, which include the districts of Dhaka, Narayangonj, Gazipur, Munshigonj, Manikgonj, Tangail, part of Mymensingh, Jamalpur, Sherpur, Faridpur,



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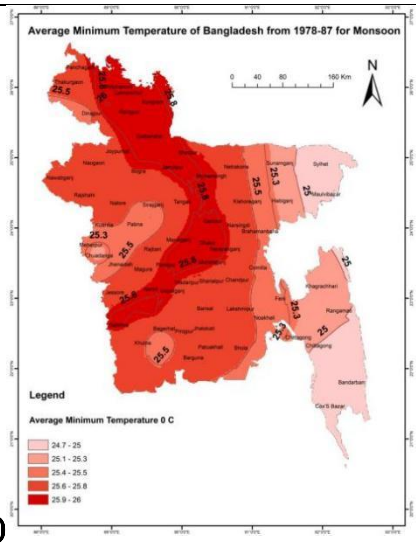

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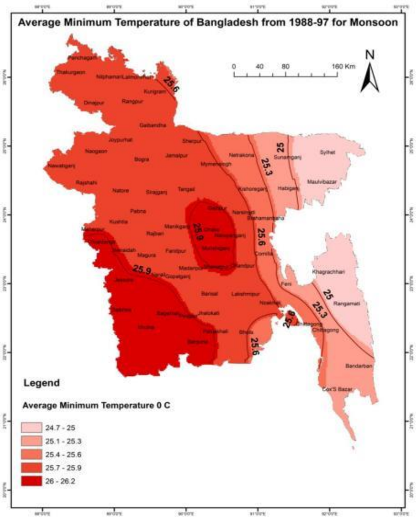

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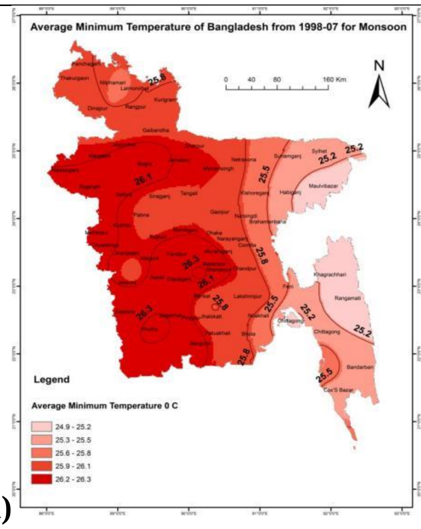
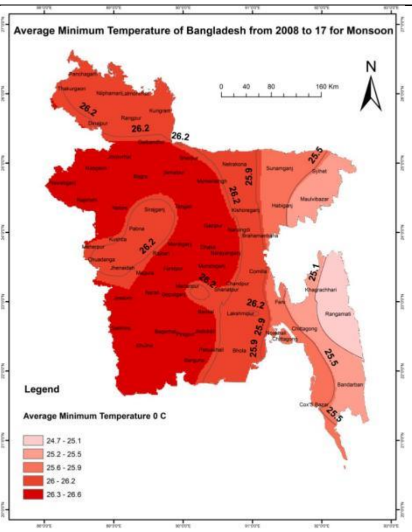


d)



e)

Figure 4.7 includes maps of average minimum temperature of Bangladesh for Monsoon during different time periods: a) 1968 to 1977 b) 1978 to 1987 c) 1988 to 1997 d) 1998 to 2007 e) 2008 to 2017

Source: Analyzed by Author, based on BMD data set, 2022.

Gopalgonj, Khulna, Bagerhat, Satkhira, part of the south-eastern zone which include the districts of Barguna, Jhalokhati, part of Barishal, Patuakhali, Khulna, Bagerhat, Pirojpur, Satkhira, part of the south-western zone which include the districts of Faridpur, Magura, Narail, Jessore, Satkhira, part of the north-western zone which include the districts of Bogra, Joypurhat, Gaibandha, and western zone which include the districts of Naogaon, Rajshahi, Nawabgonj, and part of Natore. The lowest temperature range of 24.7-25.1 °C was observed in part of the south-central zone, which includes the districts of Rangamati and part of Khagrachari.

Table 4.3: Decadal Average Minimum Temperature of Bangladesh for Monsoon period from 1968 to 2017

Decades	Temperature Range (Average) ° C
1968-1977	25.21
1978-1987	25.45
1988-1997	25.60
1998-2007	25.79
2008-2017	26.01

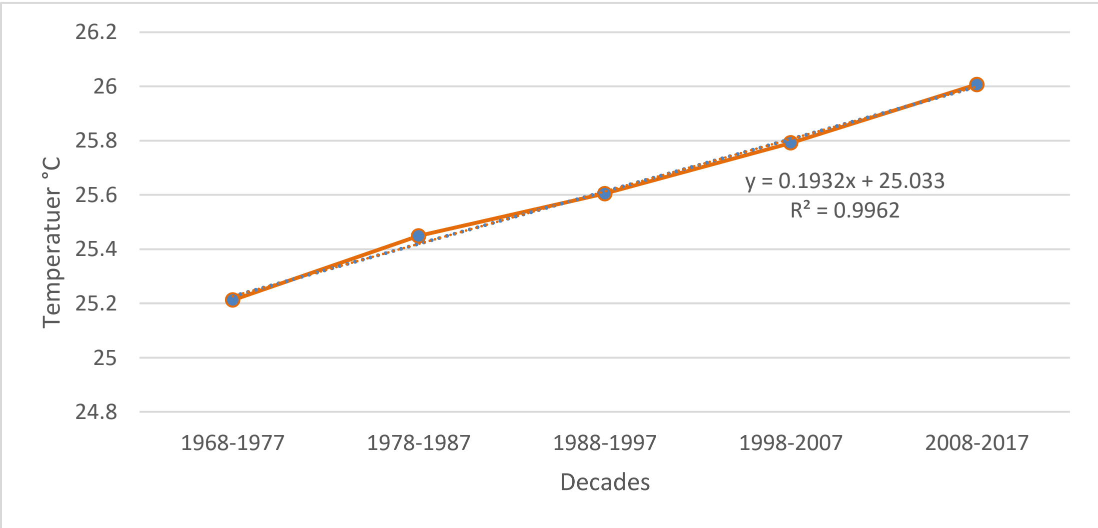


Figure 4.8: Trends of Average Minimum Temperature of Bangladesh from 1968 to 2017 for Monsoon.

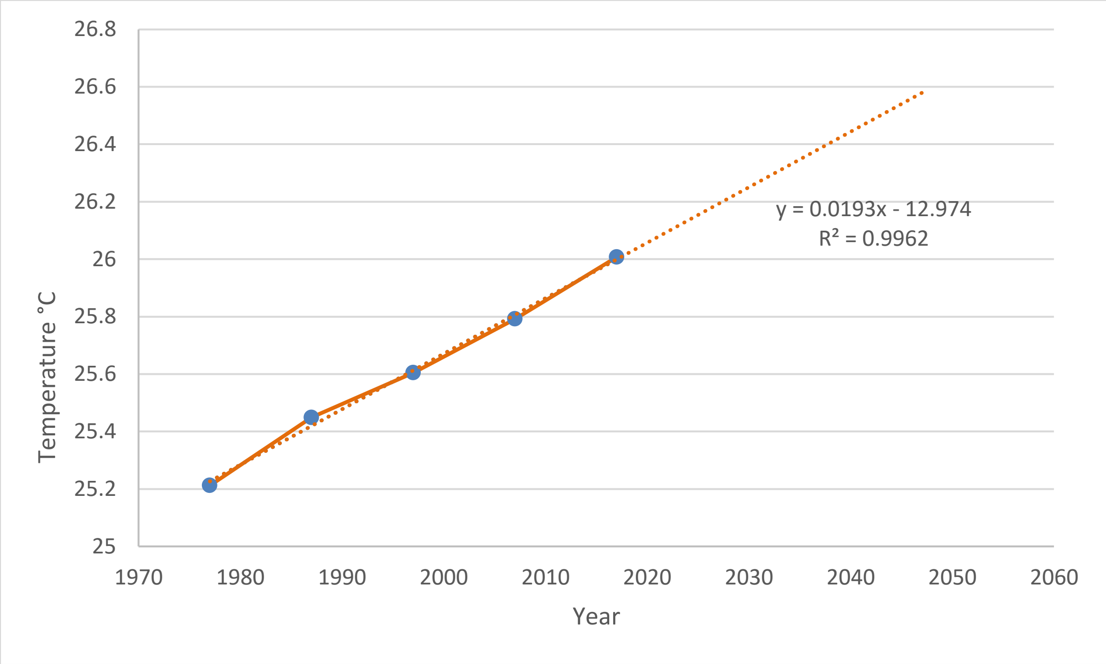
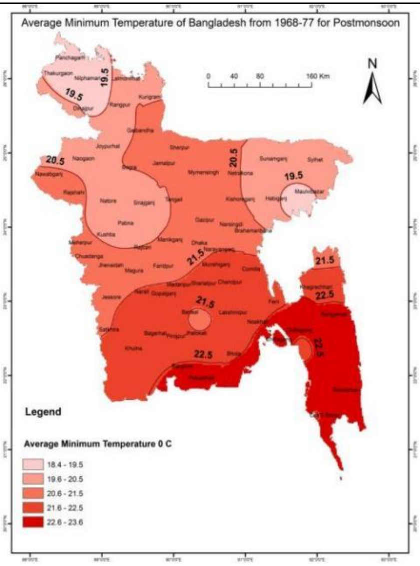


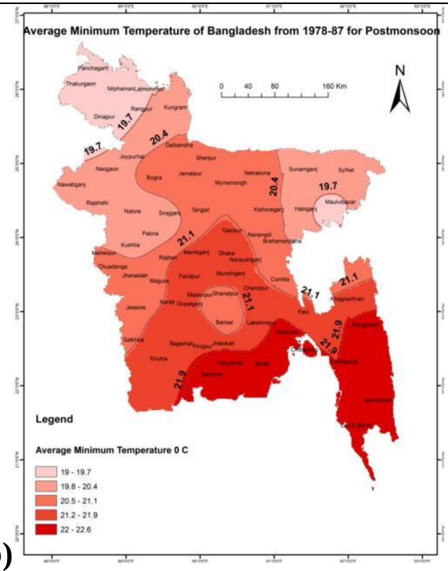
Figure 4.9: Projected Trends of Average Minimum Temperature of Bangladesh for Monsoon.

From Figure 4.8, it is observed that the trend of the average minimum temperature of Bangladesh during the monsoon season has been increasing from 1968 to 2017, with an overall increase of 0.966 °C at a rate of 0.1932 °C per decade. From Figure 4.9, it is noted that the increasing rate of temperature is 0.0193 °C per year, and at this rate, the temperature will increase by 0.7335 °C after 33 years in 2050, and by 1.6019 °C in 2100.

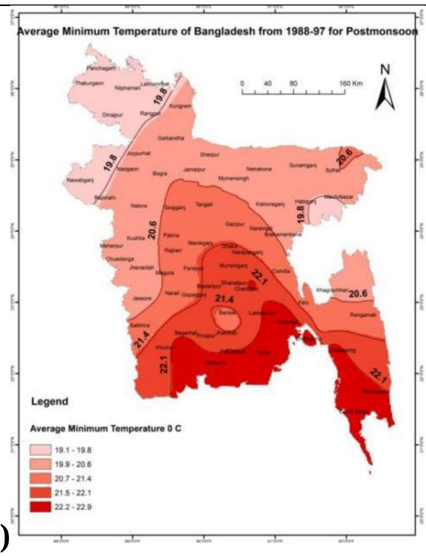
4.1.3.3 Post-monsoon Temperature:



a)



b)



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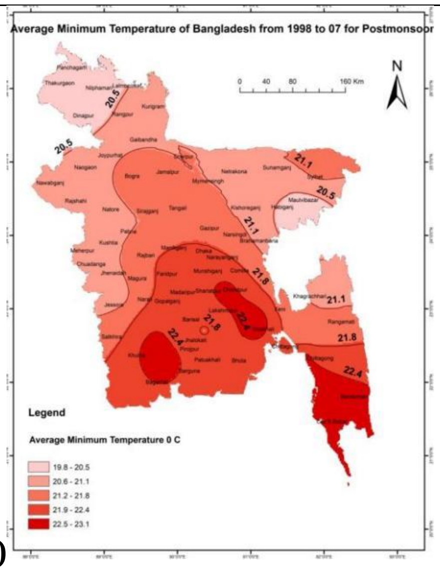
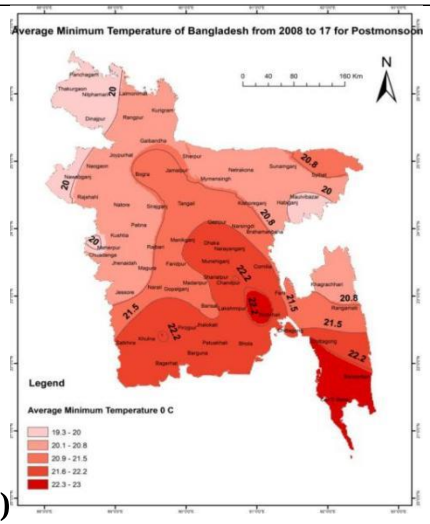


d)



e)

Figure 4.10 a) Map of average minimum temperature of Bangladesh from 1968 to 1977 for post-monsoon b) Map of average minimum temperature of Bangladesh from 1978 to 1987 for post-monsoon c) Map of average minimum temperature of Bangladesh from 1988 to 1997 for post-monsoon d) Map of average minimum temperature of Bangladesh from 1998 to 2007 for post-monsoon e) Map of average minimum temperature of Bangladesh from 2008 to 2017 for post-monsoon.

Source: Analyzed by Author, based on BMD data set, 2022.

Figure 4.10 a) shows the average minimum temperature of Bangladesh from 1968 to 1977 for Postmonsoon. From this map, it was observed that the range of average minimum temperature during this decade was 18.4-23.6 °C. The highest temperature range 22.6-23.6 °C was observed in the south-eastern zone which includes the districts of Chittagong, Cox's Bazar, Bandarban, part of Rangamati, Khagrachari, Noakhali, Bhola, and Patuakhali. The lowest temperature range 18.4-19.5 °C was observed in part of the northern region which includes the districts Panchagar, Nilphamary, part of the north-western zone which includes the districts part of Thakurgaon, Dinajpur, and part of the south-eastern zone which includes the districts of part of Moulvibazar and Habiganj which is the part of south-central zone.

Figure 4.10 b) indicates the average minimum temperature of Bangladesh from 1978 to 1987 for Postmonsoon. In this decade, the temperature range was 19.0-22.6 °C. From this map, it was also noticed that the highest temperature range 22-22.6 °C was observed in part of the south-central zone. The lowest temperature range 19-19.7 °C was also observed in part of the northern region which includes the districts Panchagar, Nilphamary, part of Rangpur, Lalmonirhat part of the north-western zone which includes the districts part of Thakurgaon, Dinajpur.

Figure 4.10 c) indicates the average minimum temperature of Bangladesh from 1988 to 1997 for post-monsoon. From this map, it was observed that the minimum temperature range of 19.1-22.9 °C existed during this decade. The highest temperature range of 22.2-22.9 °C was observed in parts of the south-eastern zone which includes the districts of Cox's Bazar, part of Chittagong, Bandarban, Noakhali, Bhola, Patuakhali, Barguna, and Bagerhat. On the other hand, the lowest temperature range of 19.1-19.8 °C was observed in parts of the northern region which includes the districts of Panchagar, Nilphamari, part of Rangpur, Lalmonirhat, part of the north-western zone which includes the districts of Thakurgaon, Dinajpur, Rangpur, part of the western zone which includes the districts of Nawabganj, part of Naogaon and Rajshahi, part of the north-eastern zone which includes part of the district of Moulvibazar, and part of Hobigonj which is the part of the south-central zone.

Figure 4.10 d) indicates the average minimum temperature of Bangladesh from 1998 to 2007 for post-monsoon. During this period, the range of the average minimum temperature of Bangladesh was 19.8-23.1 °C. The maximum temperature range of 22.5-23.1 °C was observed in parts of the south-eastern region which includes the districts of Cox's Bazar, part of Bandarban, Chattagram, Luxmipur, Khulna districts, and part of the south-central region which includes Bagerhat and Chandpur. On the other hand, the lowest temperature range of

19.8-20.5 °C was observed in parts of the northern region which includes the districts of Panchagar, Nilphamari, and part of the north-western zone which includes the districts of Thakurgaon and part of Dinajpur.

Figure 4.10 e) indicates the average minimum temperature of Bangladesh from 2008 to 2017 for post-monsoon. The temperature range observed during this decade was 19.3-23.0 °C. The highest temperature range of 22.3-23.0 °C was observed in the part of the south-eastern zone which includes Cox's Bazar, part of Chittagong, Bandarban, and Noakhali districts. The lowest temperature range of 19.3-20.0 °C was observed in part of the northern part of the northern region which includes the districts of Panchagar, Nilphamari, and part of the north-western zone which includes the districts of Thakurgaon and Dinajpur. The lowest range of temperature was also observed in part of the north-eastern zone which includes part of the district of Moulvibazar, Hobigonj which is part of the south-central zone and also part of the western zone which includes the districts of Nawabganj and part of Naogaon districts and Meherpur of the north-western zone.

Table 4.4: Decadal Average Minimum Temperature of Bangladesh for Postmonsoon Period from 1968 to 2017

Decades	Temperature Range (Average) °C
1968-1977	21.52
1978-1987	21.17
1988-1997	21.23
1998-2007	21.7
2008-2017	21.34

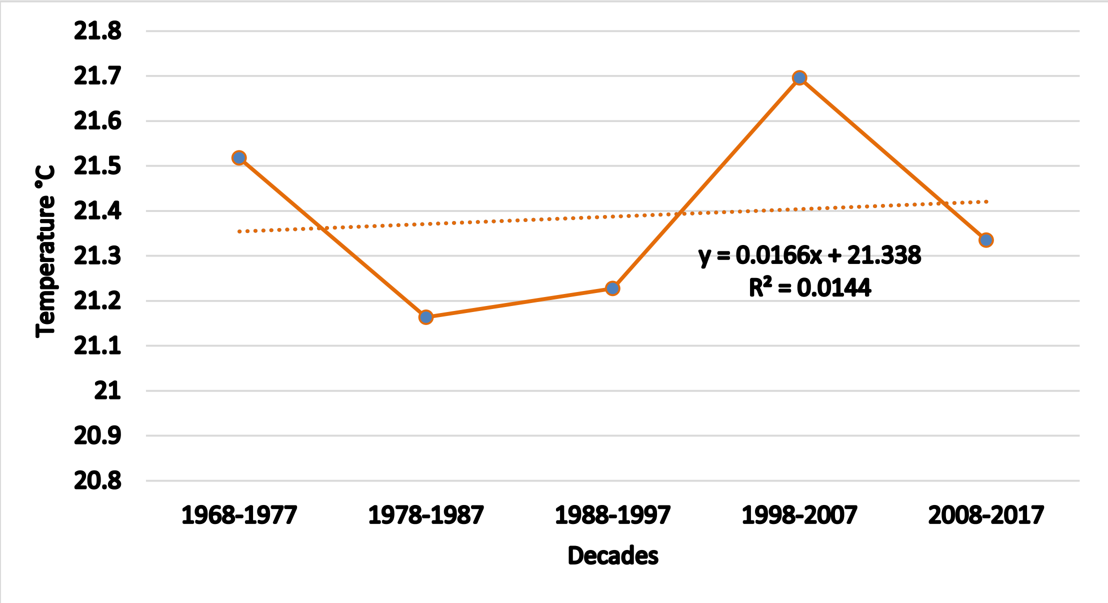


Figure 4.11: Trends of average minimum temperature of Bangladesh from 1968 to 2017 for Postmonsoon.

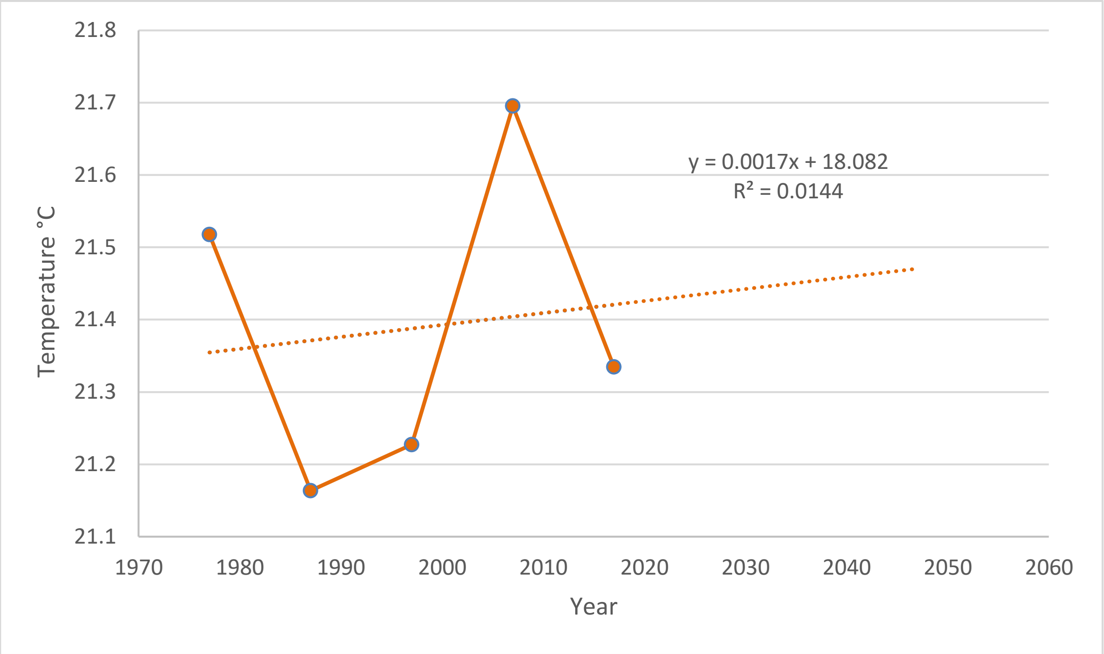
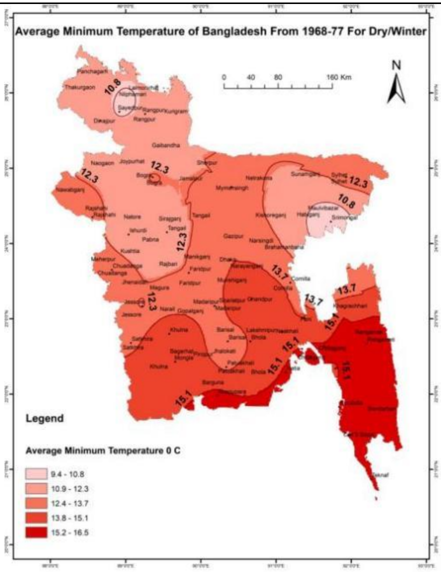


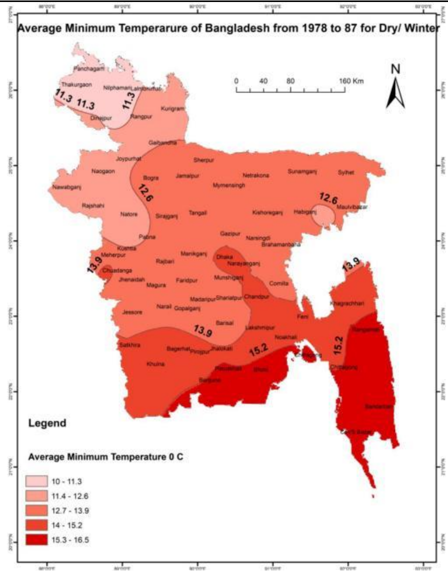
Figure 4.12: Projected Trends of average minimum temperature of Bangladesh for Postmonsoon.

From Figure 4.11, it can be observed that the post-monsoon temperatures have increased by 0.083°C between 1968 and 2017, which corresponds to a rate of 0.0166°C per decade. Similarly, from Figure 4.12, it can be observed that the projected temperature will increase by 0.0561°C in 2050 at an increasing rate of 0.0017°C per year, and by 0.141°C in 2100.

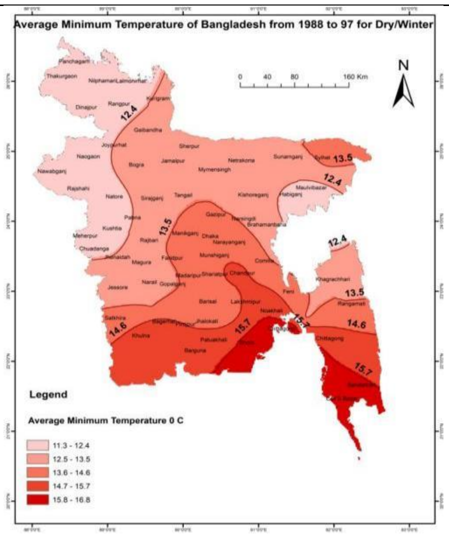
4.1.3.4 Dry/ Winter Temperature:



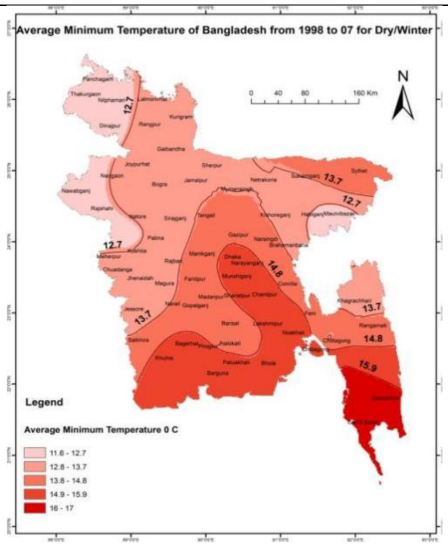
a)



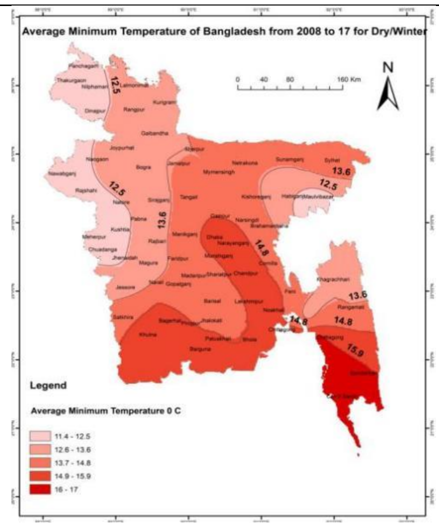
b)



c)



d)



e)

Figure 4.13 shows five maps of Bangladesh, each displaying the average minimum temperature during the Dry/Winter season for a specific time period. Figure (a) shows the period from 1968 to 1977, Figure (b) shows the period from 1978 to 1987, Figure (c) shows the period from 1988 to 1997, Figure (d) shows the period from 1998 to 2007, and Figure (e) shows the period from 2008 to 2017.

Source: Analyzed by Author, based on BMD data set, 2022.

Figure 4.13 shows the average minimum temperature of Bangladesh during the Dry/Winter season from 1968 to 2017. Figure 4.13a indicates the average minimum temperature from 1968 to 1977 for the Dry/Winter season. During this decade, the temperature range was 9.4-16.5 °C. The highest temperature range of 25.2-16.5 °C was observed in the southeastern zone, including the districts of Cox's Bazar, Bandarban, part of Chittagong, Rangamati, Bhola, and Patuakhali. The lowest temperature range of 9.4-10.8 °C was observed in the northeastern zone, including parts of Moulvibazar and Hobigonj, as well as the southern-central zone. The lowest temperature range was also observed in part of Nilphamari in the northern zone.

Figure 4.13b indicates the average minimum temperature from 1978 to 1987 for the Dry/Winter season. During this decade, the average minimum temperature range was 10-16.5 °C. The highest temperature range of 15.3-16.5 °C was observed in the southeastern zone, including the districts of Cox's Bazar, Bandarban, part of Chittagong, Rangamati, Bhola, Patuakhali, and Barguna. The lowest temperature range of 10-10.3 °C was observed in the northern part of the northern zone, including the districts of Panchagar, Nilphamari, and parts of the northwestern zone, including the districts of Thakurgaon and part of Dinajpur.

Figure 4.13c indicates the average minimum temperature of Bangladesh from 1988 to 1997 for the Dry/Winter season. During this period, the temperature range was 11.3-16.8 °C. The highest temperature range of 15.8-16.8 °C was observed in the southeastern region, including the districts of Cox's Bazar, part of Chittagong, Bandarban, and Bhola. The lowest temperature range of 11.3-12.4 °C was observed in the northern part of the northern region, including the districts of Panchagar, Nilphamari, Rangpur, Lalmonirhat, parts of the northwestern zone including the districts of Thakurgaon, Dinajpur, and Rangpur, parts of the western zone including the districts of Nowabgonj, Rajshahi, Naogaon, and parts of the northwestern zone including the districts of Meherpur, Kustia, Chuadanga, and parts of Pabna.

Figure 4.13d indicates the average minimum temperature of Bangladesh from 1998 to 2007 for the Dry/Winter season. During this decade, the minimum temperature range was from 11.6-17.0 °C. The highest temperature range of 16-17 °C was observed in the southeastern zone, including the districts of Cox's Bazar, part of Chittagong, and Bandarban. The lowest temperature range of 11.6-12.7 °C was noticed in the northern part of the northern zone, including the districts of Panchagar and Nilphamari, part of the northwestern zone including the districts of Thakurgaon and part of Dinajpur, and part of the western zone including the districts of Nawabgonj, and part of Rajshahi and Naogaon.

Figure 4.13 e) shows the average minimum temperature of Bangladesh from 2008 to 2017 for the Dry/Winter season. During this period, the average minimum temperature range was from 14.4-17.0 °C. The highest temperature range of 16-17 °C was observed in the southeastern zone which includes the districts of Cox's Bazar and part of Chittagong. The lowest temperature range of 11.4-12.5 °C was noticed in the northern part of the northern zone which includes the districts of Panchagar, part of Nilphamari, part of the northwestern zone which includes the districts of Thakurgaon and part of Dinajpur, and also part of the western zone which includes Nawabgonj, part of Rajshahi, Naogaon, and part of the northwestern zone which includes the districts of Meherpur, Chuadanga, and Kustia.

Table 4.5: Decadal Average Minimum Temperature of Bangladesh for Dry/Winter

Decades	Temperature Range (Average) ^{0} C
1968-1977	13.57
1978-1987	13.96
1988-1997	13.94
1998-2007	14.34
2008-2017	14.22

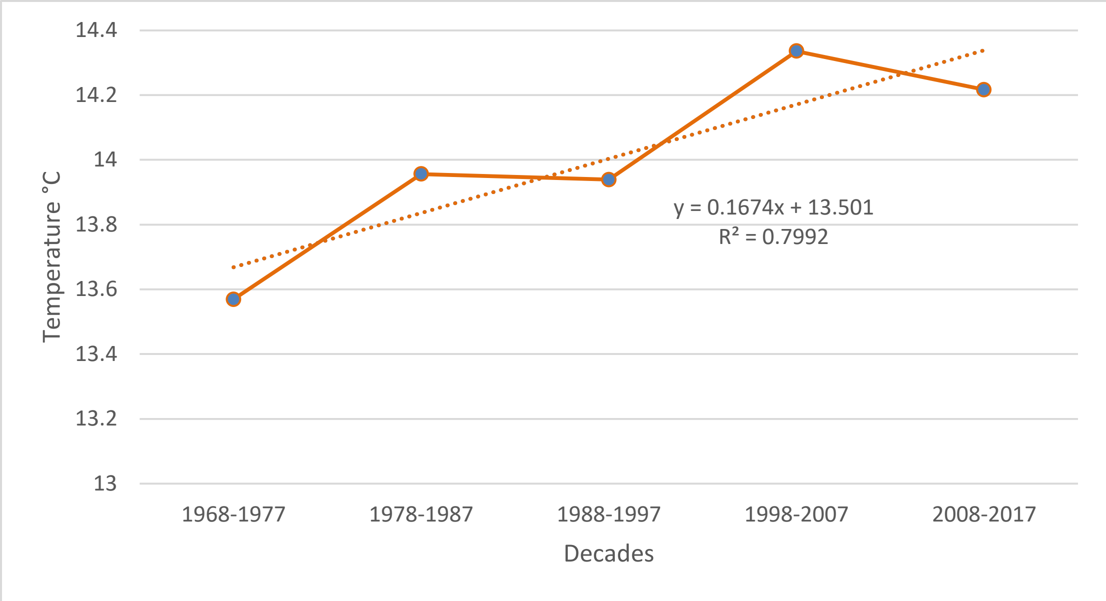


Figure 4.14: Trends of average minimum temperature of Bangladesh from 1968 to 2017 for Dry/ Winter

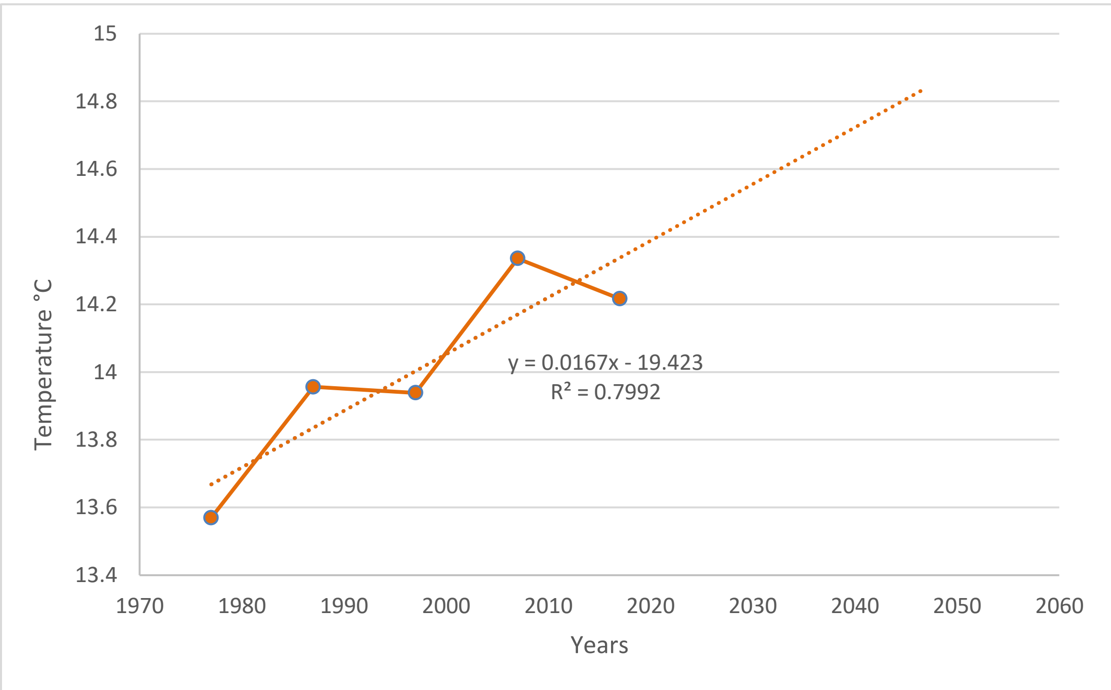


Figure 4.15: Projected Trends of average minimum temperature (T_{min}) for Dry/ Winter

From Figure 4.14, it can be observed that the average minimum temperature of Bangladesh during the dry/winter season has increased by 0.837°C over a period of 50 years, from 1968 to 2017, at an average rate of 0.167°C per decade.

From Figure 4.15, it can be seen that if the average temperature continues to increase at the same rate of 0.0167°C per year, then by 2050 the temperature is expected to increase by 0.551°C, and by 2100 it is expected to increase by 1.38°C.

4.1.4 Description of Climatic Zonal Trends and Variability of Minimum Temperature

4.1.4.1 Introduction:

The average minimum temperature (Tmin) in Bangladesh varies across different climatic regions and seasons due to their location and surrounding environment. However, this study found that there is only a little fluctuation in the average minimum temperature records across different climatic regions and seasons, as mentioned earlier.

4.1.4.2 Average Minimum Temperature (Tmin):

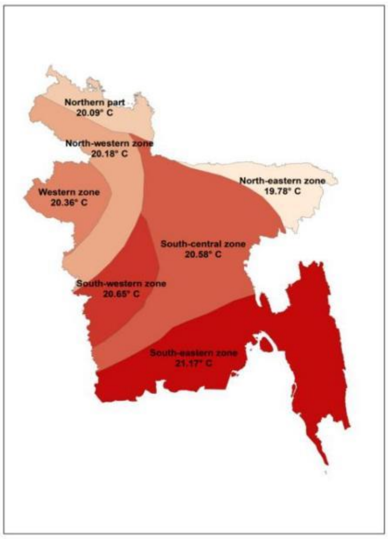
Figure 4.16 a) shows that the highest average minimum temperature during the period of 1968 to 1977 was recorded in the south-eastern zone at 21.17°C, followed by the south-western zone at 20.65°C, south-central zone at 20.58°C, western zone at 20.36°C, north-western zone at 20.18°C, northern part of the northern region at 20.09°C, and north-eastern zone at 19.78°C.

Figure 4.16 b) shows that during the period of 1978 to 1987, the highest average minimum temperature was recorded in the south-eastern zone at 21.58°C, followed by the south-western zone at 20.98°C, south-central zone at 20.86°C, western zone at 20.22°C, north-western zone at 20.15°C, northern part of the northern region at 20.01°C, and north-eastern zone at 19.82°C.

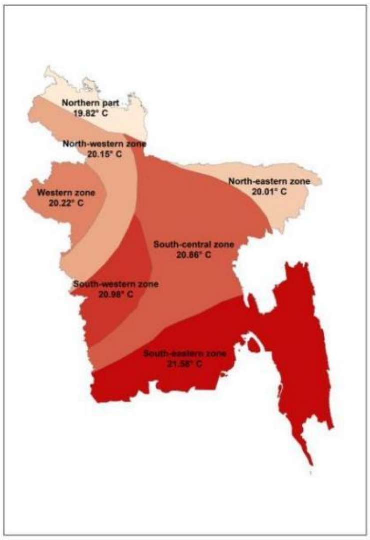
Figure 4.16 c) shows that during the period of 1988 to 1997, the highest average minimum temperature was recorded in the south-eastern zone at 21.6°C, followed by the south-western zone at 20.99°C, south-central zone at 20.98°C, north-western zone at 20.32°C, western zone at 20.17°C, north-eastern zone at 20.1°C, and northern part of the northern region at 19.94°C.

From Figure 4.16 d) it was observed that during the decade of 1998 to 2007, the highest average minimum temperature was recorded in the south-eastern zone which was 21.78°C followed by the south-central zone recorded a temperature of 21.36°C, the south-western zone recorded a temperature of 21.34°C, the western zone recorded a temperature of 20.8°C, the north-eastern zone recorded a temperature of 20.63°C, and the northern part of the northern region recorded a temperature of 20.41°C.

From Figure 4.16 e) it was noticed that the highest average minimum temperature was recorded in the south-eastern zone during the decade of 2008-2017 which was 21.81°C followed by the south-central zone recorded a temperature of 21.51°C, the south-western zone recorded a temperature of 21.36°C, the north-western zone recorded a temperature of 20.78°C, the western zone recorded a temperature of 20.77°C, the north-eastern zone recorded a temperature of 20.71°C and the northern part of the northern region recorded a temperature of 20.49°C.



a)



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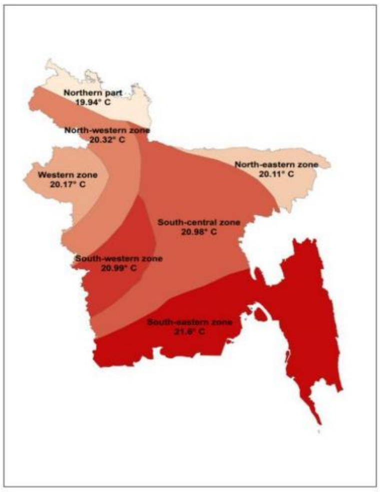
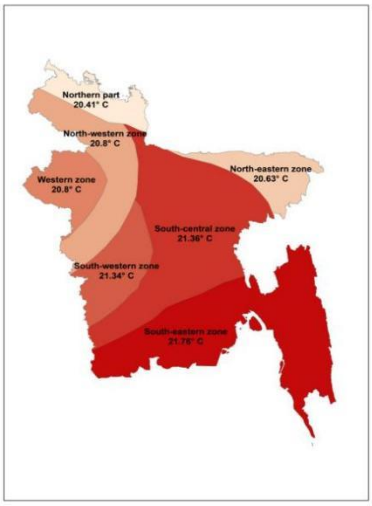
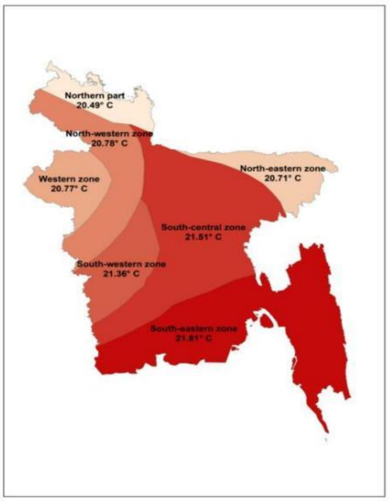


C)



d)



e)

Figure 4.16 a) Climatic zonal average minimum temperature of Bangladesh from 1968 to 1977. b) Climatic zonal average minimum temperature of Bangladesh from 1978 to 1987 c) Climatic zonal average minimum temperature of Bangladesh from 1988 to 1997 d) Climatic zonal average minimum temperature of Bangladesh from 1978 to 1987 e) Climatic zonal average minimum temperature of Bangladesh from 1978 to 1987

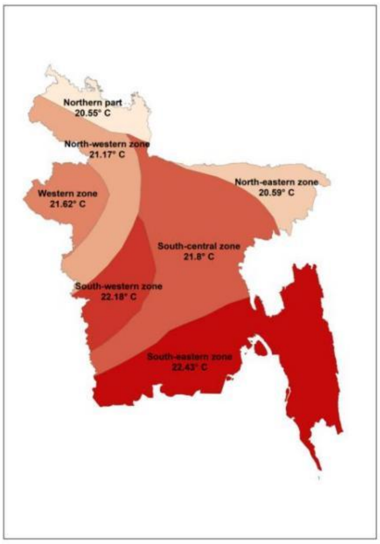
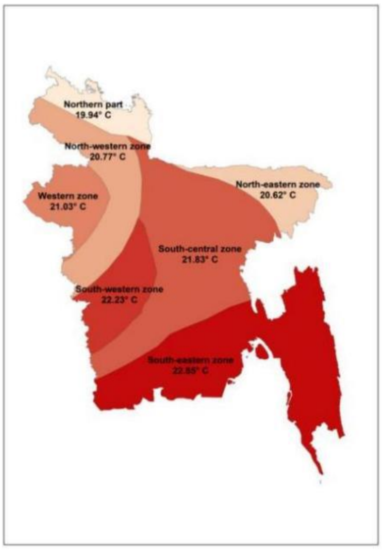
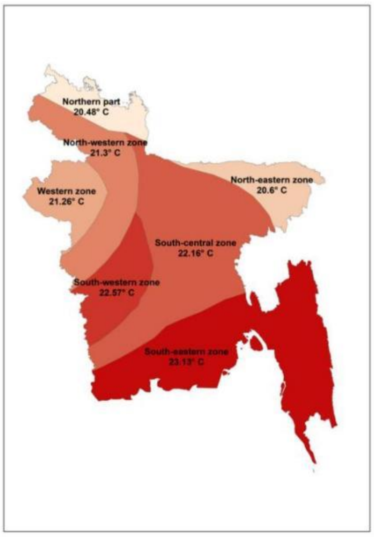
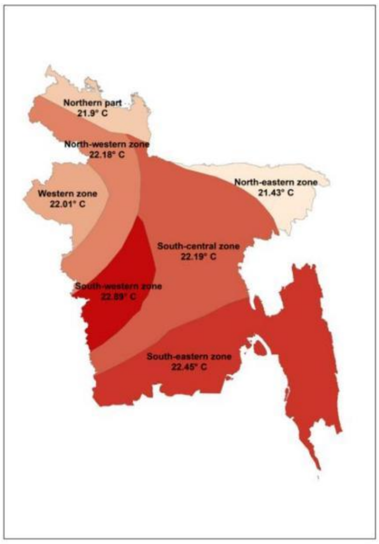
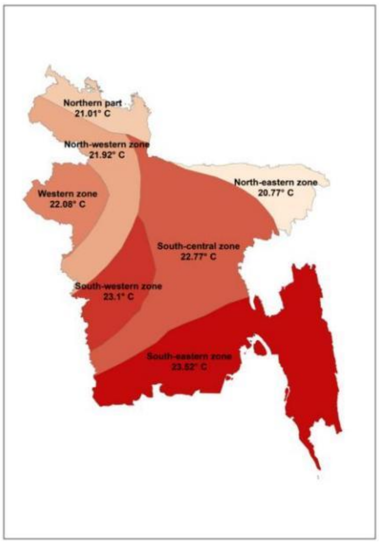
Source: Analyzed by Author, based on BMD data set, 2022.

4.1.4.3 Premonsoon Temperature:

In Bangladesh climate premonsoon consisting of the month of March, April and May experiences the hotter temperature gradually following the season winter. From Figure 4.17 a) it was observed that the highest average minimum temperature for premonsoon during the period of 1968 to 1977 was recorded in the south-eastern zone which was 22.43 °C followed by south-western zone temperature recorded 22.18 °C , south-central zone temperature recorded 21.8 °C , western zone temperature recorded 21.62 °C, north-western zone temperature recorded 21.17 °C, north-eastern zone temperature recorded 20.59 °C and northern part of the northern region recorded temperature 20.55 °C.

From Figure 4.17 b) it was noticed that the highest average minimum temperature for premonsoon during the decade of 1978 to 1987 was recorded in the south-eastern zone which was 22.85 °C followed by south-western zone temperature recorded 22.23 °C, south-central zone temperature recorded 21.83 °C, western zone temperature recorded 21.03 °C, north-western zone temperature recorded 20.77 °C, north-eastern zone temperature recorded 20.62 °C and northern part of the northern region temperature recorded 19.94 °C.

From Figure 4.17 c) it was observed that during the decade of 1988 to 1997, the highest average minimum temperature for premonsoon recorded was 23.13 °C in the south-eastern zone followed by south-western zone temperature recorded 22.57 °C, south-central zone temperature recorded 22.16 °C, western zone temperature recorded 21.62 °C, north-western zone temperature recorded 21.3 °C, north-eastern zone temperature recorded 20.6 °C and northern part of the northern region temperature recorded 20.48 °C.

 a)	 b)
 c)	 d)
 e)	Figure 4.17 a) Climatic zonal average minimum temperature of Bangladesh from 1968 to 1977 for pre-monsoon. b) Climatic zonal average minimum temperature of Bangladesh from 1978 to 1987 for premonsoon c) Climatic zonal average minimum temperature of Bangladesh from 1988 to 1997 for premonsoon d) Climatic zonal average minimum temperature of Bangladesh from 1998 to 2007 for premonsoon e) Climatic zonal average minimum temperature of Bangladesh from 2008 to 2017 for premonsoon. Source: Analyzed by Author, based on BMD data set, 2022.

From Figure 4.17 d) it was observed that the highest average temperature for premonsoon during the period of 1998 to 2007 was observed in the south-western zone which was

22.89 °C followed by south-eastern zone temperature recorded 22.45 °C , south-central zone temperature recorded 22.19 °C, north-western zone temperature recorded 22.18 °C, western zone 22.01 °C, northern part of the northern region 21.9 °C and north-eastern zone 21.43 °C. Again, from Figure 4.17 e) it was also observed that the highest average minimum temperature 23.52 °C was recorded in the south-eastern zone followed by south-western zone temperature recorded 23.1 °C, south-central 22.77 °C, western zone 22.08 °C, north-western 21.92 °C, northern part of the northern region 21.01 °C and north-eastern zone 20.77 °C.

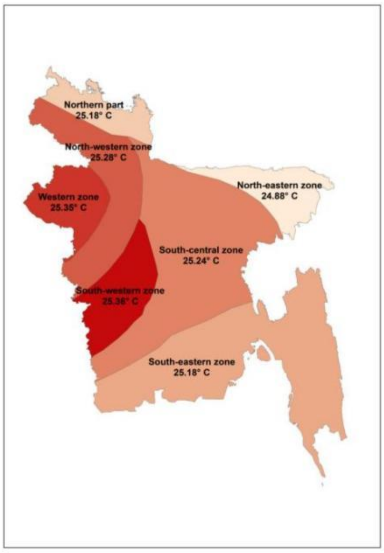
4.1.4.4 Monsoon Temperature: The season monsoon comprising of the month of June, July, August and September is usually the hotter season although the season receives the highest rainfall than any other season of Bangladesh. From Figure 4.18 a) it was observed that the highest average minimum temperature for monsoon during the period of 1968 to 1977 was recorded in the south-western zone temperature recorded 25.36 °C followed by western zone temperature recorded 25.35 °C, north-western zone temperature recorded 25.28 °C, south-central zone temperature recorded 25.24 °C , northern part of the northern region temperature recorded 25.18 °C, south-eastern zone temperature recorded 25.18 °C and north-eastern zone temperature recorded 24.88 °C.

From Figure 4.18 b) it was noticed that the highest average minimum temperature for monsoon for the time period from 1978 to 1988 was recorded in the northern part of the northern region which was 25.83 °C followed by south-western zone recorded temperature 25.67 °C, south-central zone recorded temperature 25.66 °C , western zone temperature recorded 25.63 °C, north-western zone temperature recorded 25.61 °C, south-eastern zone temperature recorded 25.28 °C and north-eastern zone temperature recorded 25.02 °C.

Again, it was observed from Figure 4.18 c) that the highest average minimum temperature for monsoon for the period of 1988 to 1997 was recorded in the south-western zone which was 25.87 °C followed by north-western zone temperature recorded 25.75 °C, south-central zone temperature recorded 25.71 °C, western zone temperature recorded 25.7 °C, northern part of the northern region temperature recorded 25.65 °c, south-eastern zone temperature recorded 25.45 °C and north-eastern zone temperature recorded 24.91 °C.

From Figure 4.18 d) it was noticed that highest average minimum temperature for monsoon for the period of 1988 to 2007 was recorded in the western zone which was 26.11 °C followed by south-western zone temperature recorded 26.11 °C, north-western zone temperature recorded 26.02 °C, south-central zone temperature recorded 25.93 °C, nothern part of the northern region recorded temperature 25.81 °C, south-eastern zone recorded temperature 25.62 °C and north-eastern zone 25.33 ° Celcious of temperature.

From Figure 4.18 e) it was observed that the highest average minimum temperature for monsoon for the time period of 2008 to 2017 was recorded in the south-western zone which was 26.32 °C followed by south-western zone recorded temperature 26.28 °C, north-western zone .



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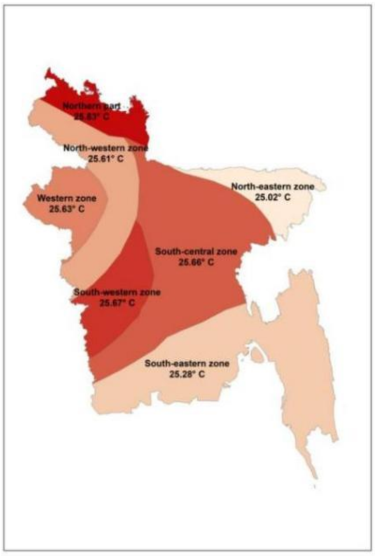

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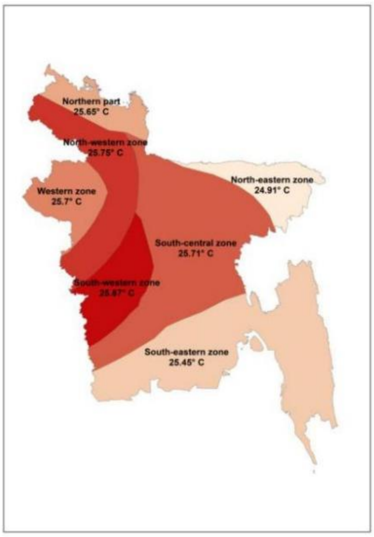

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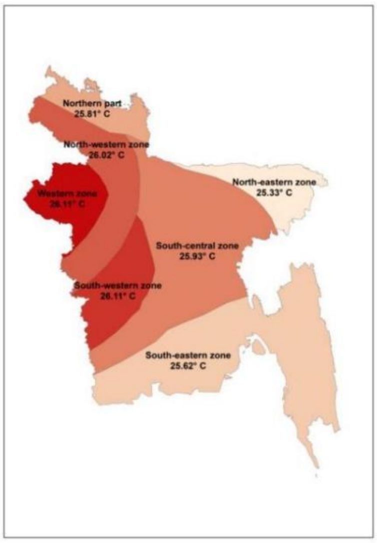

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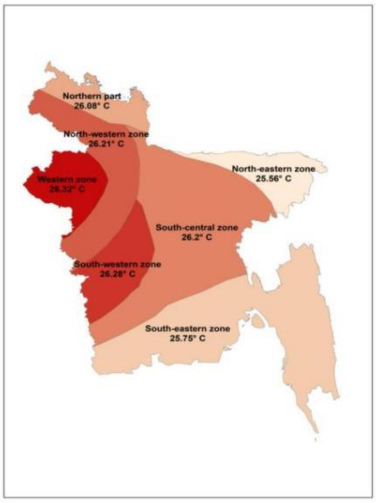


e)

Figure 4.18 a) Climatic zonal average minimum temperature of Bangladesh from 1968 to 1977 for monsoon . b) Climatic zonal average minimum temperature of Bangladesh from 1978 to 1987 for monsoon c) Climatic zonal average minimum temperature of Bangladesh from 1988 to 1997 for monsoon d) Climatic zonal average minimum temperature of Bangladesh from 1998 to 2007 for monsoon e) Climatic zonal average minimum temperature of Bangladesh from 2008 to 2017 for monsoon.

Source: Analyzed by Author, based on BMD data set, 2022.

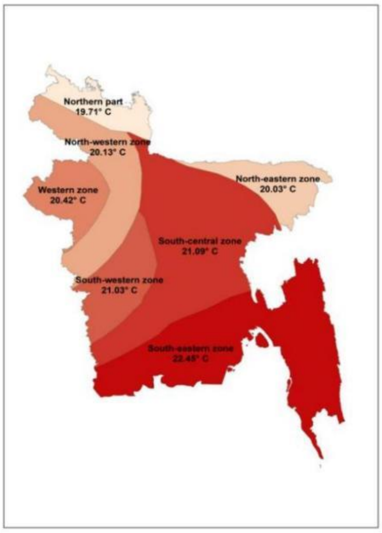
Temperature recorded 26.21 °C, south-central zone temperature recorded 26.2 °C, northern part of the northern region temperature recorded 26.08 °C, south-eastern zone 25.75 °C and north-eastern zone 25.56 °Celcious temperature.

4.1.4.5 Post-monsoon Temperature: In Bangladesh post-monsoon season comprises with the month of October and November. During this season temperature gradually decreases due to the cycle of season. From Figure 4.19 a) it was observed that the highest average minimum temperature for post-monsoon during the period of 1968 to 1977 was recorded in the south-eastern zone which was 22.45 °C followed by south-central zone recorded temperature 21.09 °C , south-western zone recorded temperature 21.03 °C, western zone recorded temperature 20.42 °C, north-western zone recorded temperature 20.13 °C, north-eastern zone recorded temperature 20.03 °C and northern part of the northern region recorded temperature 19.71 °Celcious of temperature.

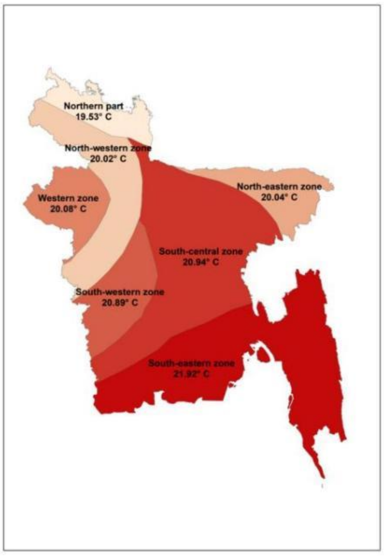
From Figure 4.19 b) it was observed that during the period of 1978 to 1987 the average minimum temperature for post-monsoon was recorded in the south-eastern zone which was 21.92 °C followed by south-central zone recorded temperature 20.94 °C, south-western zone recorded temperature 20.89 °C, western zone recorded temperature 20.08 °C, north-eastern zone recorded temperature 20.04 °C, north-western zone recorded temperature 20.02 °C and northern part of the northern region recorded temperature 19.53 degree celcious.

From Figure 4.19 c) it was noticed that the average minimum temperature for post-monsoon for the period of 1988 to 1997 was recorded in the south-eastern zone which was 21.82 °C followed by the south-central zone temperature recorded 20.93 °C, south-western zone temperature recorded 20.76 °C, north-eastern zone temperature recorded 20.26 °C, north-western zone temperature recorded 20.05 °C, western zone temperature recorded 19.85 °C and northern part of the northern region temperature recorded 19.64 degree Celcious.

From Figure 4.19 d) it was observed that the average minimum temperature for post-monsoon during the period of 1998 to 2007 was recorded in the south-eastern zone which was 21.79 °C followed by south-central zone recorded temperature 21.22 °C , south-western zone recorded temperature 20.82 °C, north-eastern zone recorded temperature 20.26 °C, north-western zone recorded temperature 20.3 °C, western zone temperature recorded 20.17 °C and northern part of the northern region recorded temperature 20.12 degree Celcious.



a)



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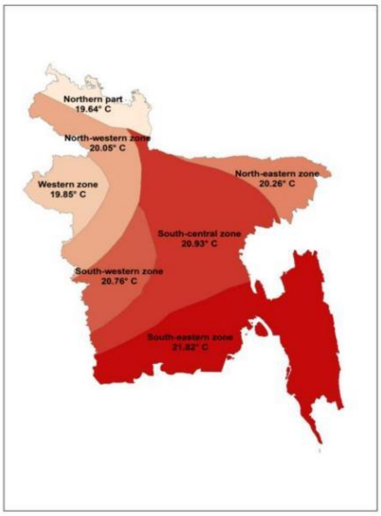

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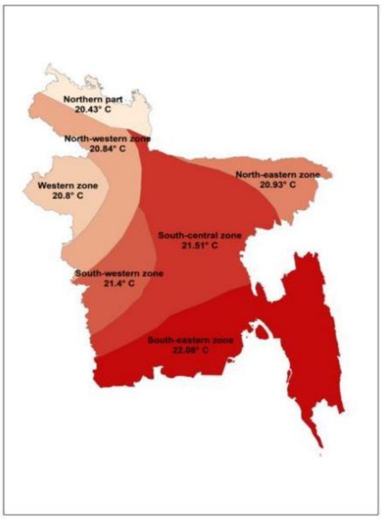

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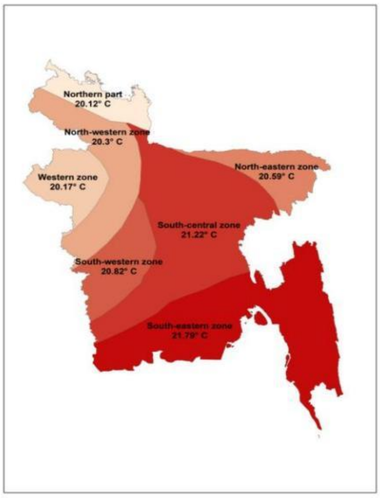


e)

Figure: 4.19 a) Climatic zonal average minimum temperature of Bangladesh from 1968 to 1977 for postmonsoon . b) Climatic zonal average minimum temperature of Bangladesh from 1978 to 1987 for postmonsoon c) Climatic zonal average minimum temperature of Bangladesh from 1988 to 1997 for postmonsoon d) Climatic zonal average minimum temperature of Bangladesh from 1998 to 2007 for postmonsoon e) Climatic zonal average minimum temperature of Bangladesh from 2008 to 2017 for postmonsoon.

Source: Analyzed by Author, based on BMD data set, 2022.

From Figure 4.19 e) it was observed that the highest average minimum temperature for the period of 1968 to 1977 was recorded in the south-eastern zone which was 21.79 °C followed by south-central zone 21.22 °C, south-western zone 20.82 °C, north-eastern zone 20.59 °C, north-western zone 20.3 °C, western zone 20.17 °C, and northern part of the northern zone 20.12 °C.

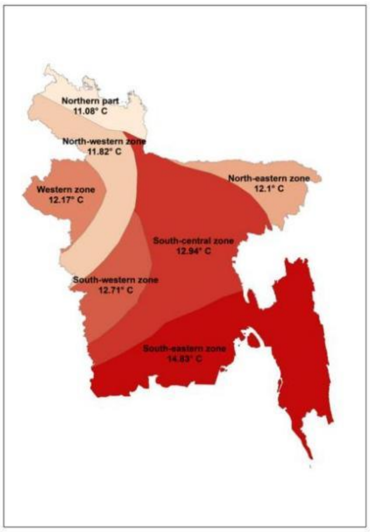
4.1.4.6 Dry or Winter Temperature: In Bangladesh, dry or winter season comprises with the districts of December, January and February which is almost cold in the cycle of seasons. During this season the average temperature is less than any other seasons of Bangladesh. From Figure 4.20 a) it was observed that the average minimum temperature for dry/winter for the time period of 1968 to 1977 was 14.83 °C followed by south-central zone temperature recorded 12.94 °C, south-western zone temperature recorded 12.71 °C, western zone temperature recorded 12.17 °C, north-eastern zone temperature recorded 12.1 °C, north-western zone temperature recorded 11.82 °C and northern part of the northern region temperature recorded 11.08 °C.

From Figure 4.20 b) it was observed that the average minimum temperature for dry/winter for the time period of 1978 to 1987 was recorded in the south-eastern zone which was 16.18 °C followed by south-western zone recorded temperature 13.54 °C, south-central zone recorded 13.4 °C, north-eastern zone temperature recorded 12.95 °C, north-western zone temperature recorded 12.33 °C, western zone temperature recorded 12.27 °C and northern part of the northern region temperature recorded 11.31 degree Celcious of temperature.

It was observed from Figure 4.20 C) that the average minimum temperature for dry/winter for the time period of 1988 to 1997 was recorded in the south-eastern zone which was 14.89 °C followed by south-central zone temperature recorded 13.49 °C, south-western zone temperature record 13.09 °C, north-eastern zone temperature recorded 13.08 °C, north-western zone temperature recorded 12.29 °C, northern part of the northern region temperature recorded 12.05 °C and western zone temperature recorded 11.91 degree Celcious temperature.

From Figure 4.20 d) it was observed that the average minimum temperature for dry/winter for the time period of 1998 to 2007 was recorded in the south-eastern zone which was 15.05 °C followed by south-central zone temperature recorded 14.13 °C, north-eastern zone temperature recorded 13.72 °C, south-western zone 13.09 °C, north-western zone 12.93 °C, northern part of the northern region 12.78 °C and western zone 12.7 degree Celcious.

Again, from Figure 4.20 e) it was observed that the average minimum temperature for dry/winter for decade of 2008 to 2017 was recorded in the south-eastern zone which was 14.87 °C, followed by south-central zone 14.17 °C, north-eastern zone 13.73 °C, south-western 13.41 °C, north-western zone 12.79 °C, northern part of the northern region 12.76 °C and western zone 12.5 °C.



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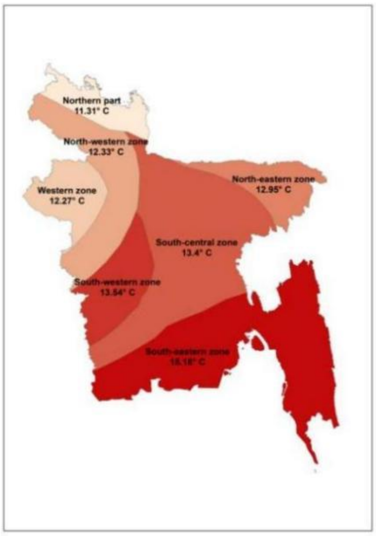

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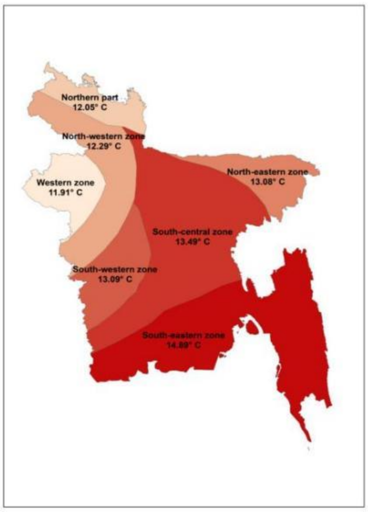

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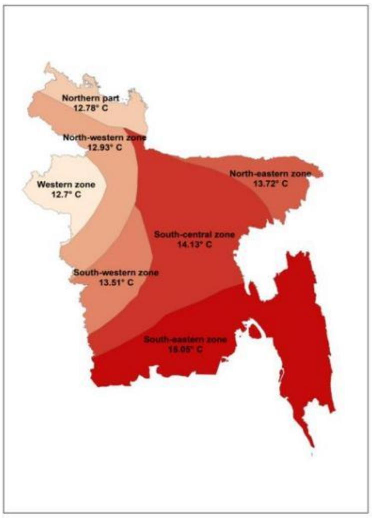

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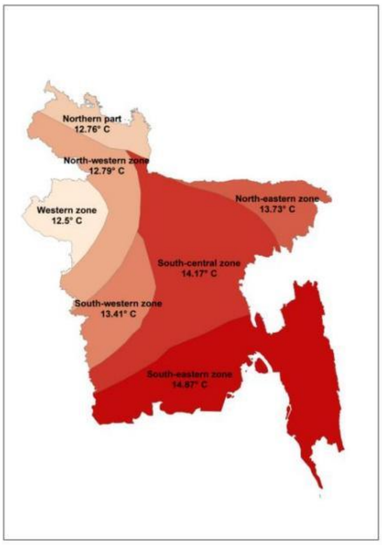


e)

Figure: 4.20 a) Climatic zonal average minimum temperature of Bangladesh from 1968 to 1977 for dry/winter. b) Climatic zonal average minimum temperature of Bangladesh from 1978 to 1987 for dry/winter c) Climatic zonal average minimum temperature of Bangladesh from 1988 to 1997 for dry/winter d) Climatic zonal average minimum temperature of Bangladesh from 1998 to 2007 for dry/winter e) Climatic zonal average minimum temperature of Bangladesh from 2008 to 2017 for dry/winter.

Source: Analyzed by Author, based on BMD data set, 2022.

4.1.5 Climatic zonal-wise average temperature (Tmin) trends

4.1.5.1 South-eastern Climatic zonal temperature trends/increase from 1968 to 2017

The South eastern Climatic zone is consisted with the districts of Chattragram, Cox's Bazar, Bandarban, Rangamati, Khagrachari, Feni, Noakhali, Bhola, Patuakhali, Borguna, part of Bagerhat, part of Khulna and part of Satkhira where located the Meteorological stations are- Chattragram (City), Chattragram (Ambagan), Cox's Bazar, Kutubdia, Rangamati, Sandwip, Teknaf, Hatiya, M. Court, Bhola, Patuakhali, Khepupara, Feni, Sitakunda. The average minimum temperature trends of this climatic zone have been calculated and found from the temperature record of those meteorological stations.

Table 4.6: Decadal Average Minimum Temperature range of South-east zone of Bangladesh from 1968 to 2017.

Decades	Temperature Range (Average) °C
1968-1977	21.14
1978-1987	21.69
1988-1997	21.83
1998-2007	21.90
2008-2017	22.01

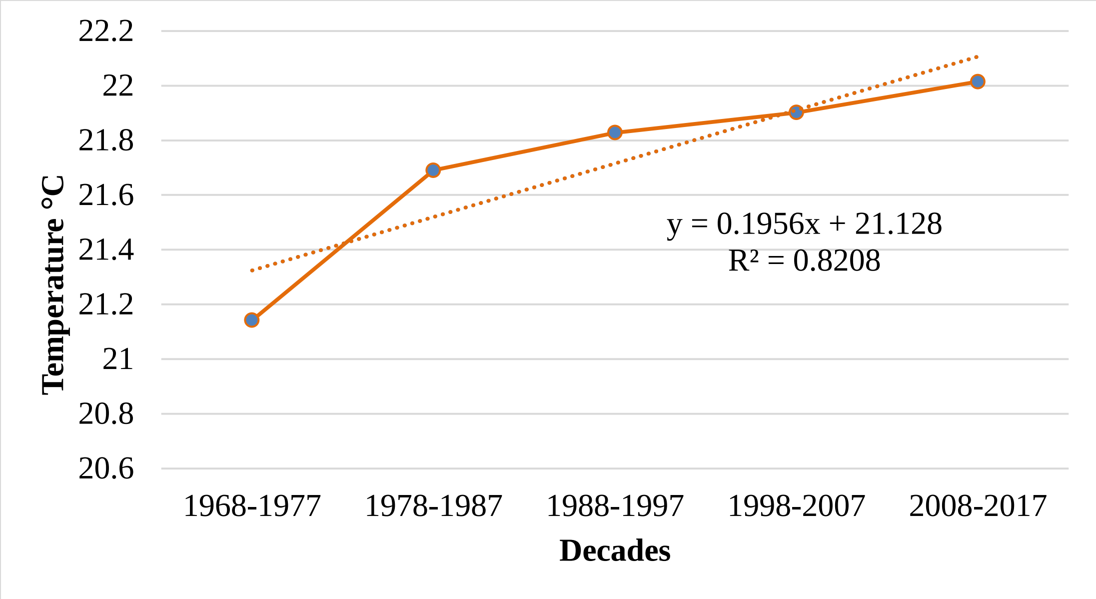


Figure 4.21: Trends of Average Minimum Temperature of South-east zone Bangladesh from 1968 to 2017

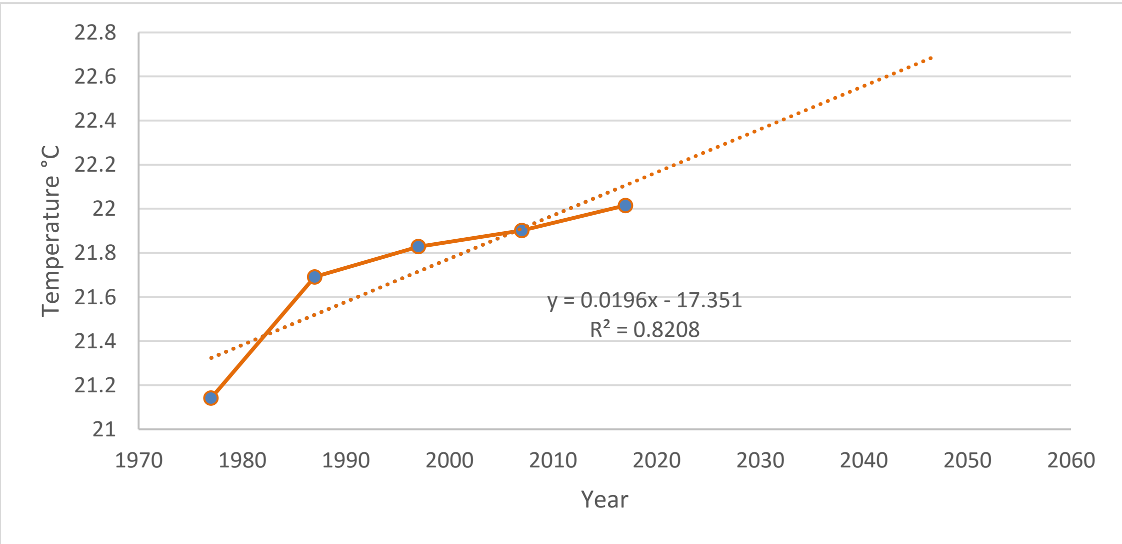


Figure 4.22: Projected Trends of Minimum Temperature of South-east zone Bangladesh

From Figure 4.21 it is noticed that the average minimum temperature of south-east climatic zone of Bangladesh has increased 0.978 °C during the time period of 1968 to 2017 at a rate of 0.1956 °C per decade. From Figure 4.22 it is found that at a rate of 0.0196 °C per year the average temperature of this region will increase 0.6468 °C in 2050 and 1.6268 °C in 2100.

4.2.5.2 North- eastern Climatic zonal temperature increase from 1968 to 2017

The north eastern climatic region is consisted with the districts of Sylhet, Moulvibazar and Sunamgonj where two meteorological stations Sylhet and Sreemongal are situated. Temperature data from these two stations were analyzed and found that there is a increasing trend of temperature and in the last 50 years from 1968- 2017 the temperature has increased 0.91 °C which is a little bit higher than the IPCC predicted 0.85 °C in the last decade.

Table 4.7: Decadal Average Temperature Range of North-Eastern zone

Decades	Temperature Range (Average) °C
1968-1977	19.29
1978-1987	19.84
1988-1997	19.89
1998-2007	20.28
2008-2017	20.35

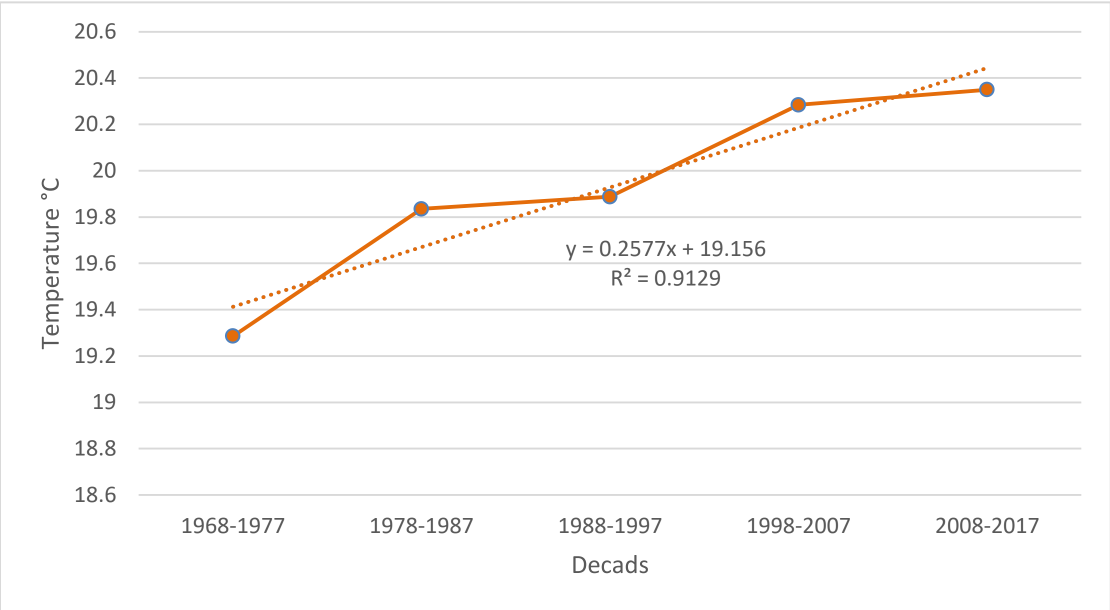


Figure 4.23: Trends of Average Temperature of North-Eastern zone of Bangladesh from 1968 to 2017.

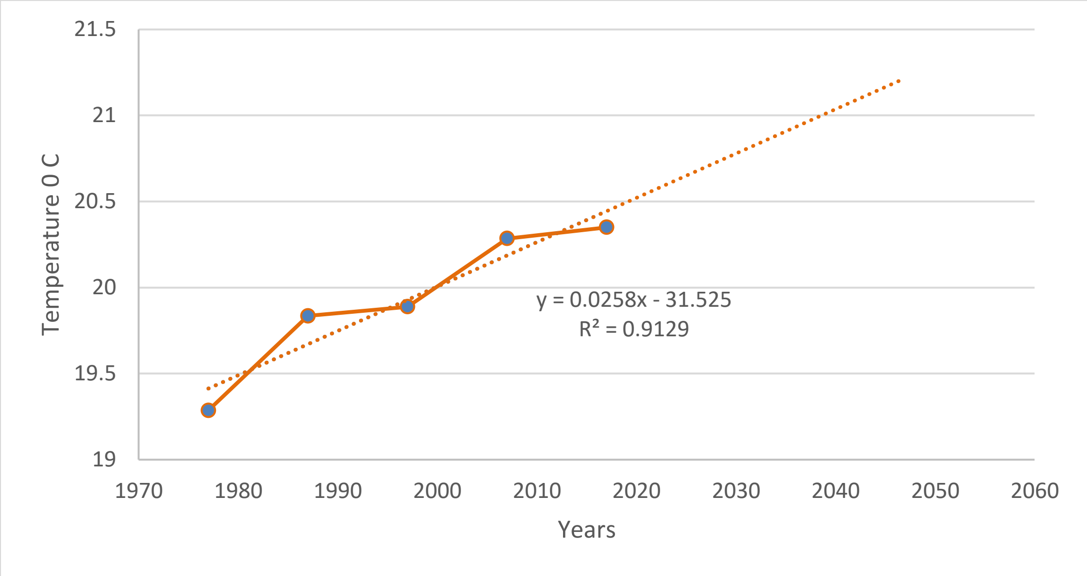


Figure 4.24: Projected Trends of Average Temperature of North-Eastern zone of Bangladesh

From Figure -4.23 It is noticed that in the fifty years period of 1968 to 2017 the average temperature of the North Eastern zone the temperature has increased 1.2885 0C at a rate of 0.2577 °C per decade. From Figure 4.24 it is found that the projected rate of average temperature of this climatic zone is 0.0258 °C. And at this rate the temperature will increase 0.8514 °C in 2050 and 2.1414 °C in 2100.

4.2.5.3 Northern Part of the Northern Region Temperature:

This climatic zone is consisted with the northern districts of Panchagar, Nilphamari, Lalmonirhat, kurigram, Part of Rangpur where two meteorological stations Rangppur and Syedpur are located. From the temperature record of these two stations the trends/ change has been detected.

Table 4.8: Trends of Average Temperature of Northern part of the northern zone of Bangladesh from 1968 to 2017.

Decades	Temperature Range (Average) °C
1968-1977	20.05
1978-1987	19.91
1988-1997	19.96
1998-2007	20.38
2008-2017	20.45

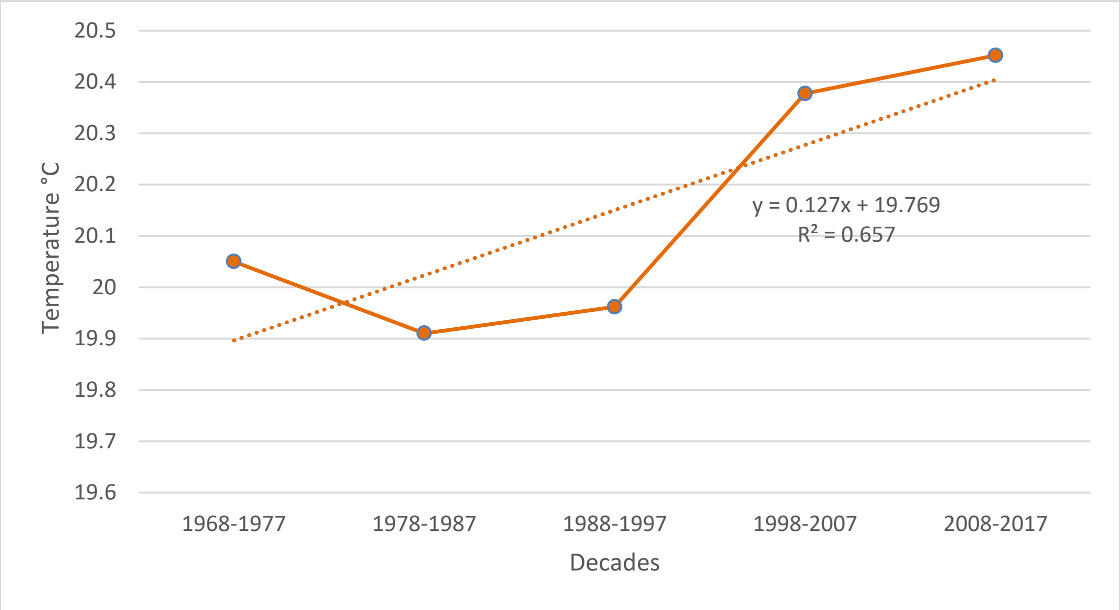


Figure 4.25: Trends of Average Temperature of Northern part of the northern zone of Bangladesh from 1968 to 2017

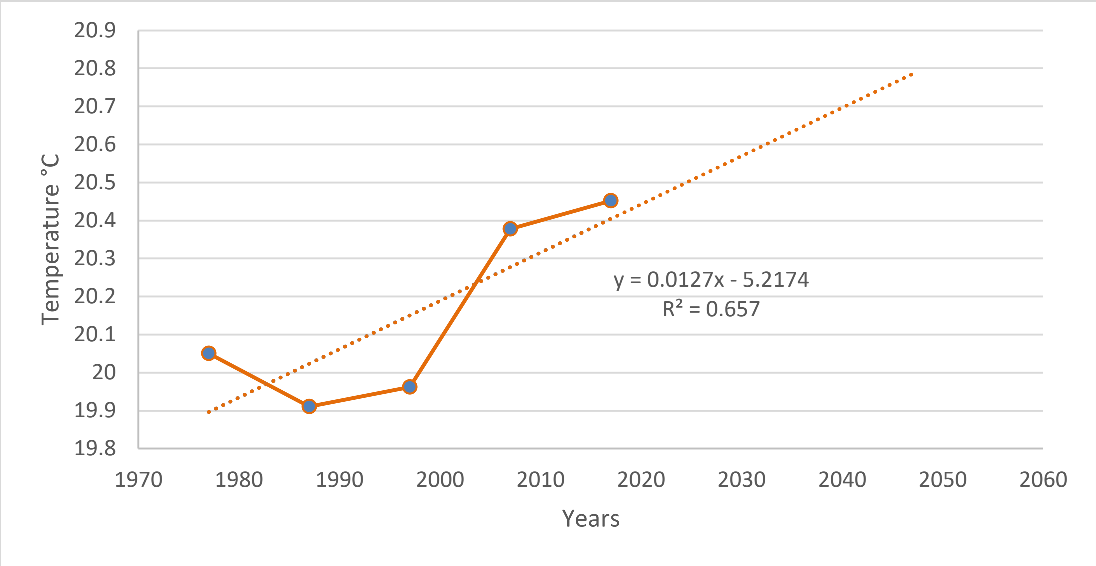


Figure 4.26: Projected Trends of Average Temperature of Northern part of the northern zone of Bangladesh

From Figure -4.25 it is noticed that the average temperature of the northern part of the northern region of Bangladesh has increased 0.635 °C at the rate of 0.127 °C per decade in the period of 1968 to 2017 in 50 years. From Figure 4.26 it is noticed the projected trend of average temperature of the northern part of the northern region has increased at the rate of 0.0127 °C per year. The temperature will increase 0.4191 °C and in 2100 it will increase 1.0541 °C.

4.2.5.4 North- Western Region Temperature:

North -Western region constitute with the districts of Dinajpur, part of Thakurgaon, Gaibandha, Bogra, Sirajgonj, Pabna, Kustia, Meherpur, Chuadanga. In this climatic region three meteorological stations Bogra, Dinajpur, Chuadanga are located and temperature trends of this region has been detected from these three stations.

Table 4.9: Trends of Average Temperature of North-Western zone of Bangladesh from 1968 to 2017.

Decades	Temperature Range (Average) °C
1968-1977	20.07
1978-1987	20.13
1988-1997	20.39
1998-2007	20.89
2008-2017	20.79

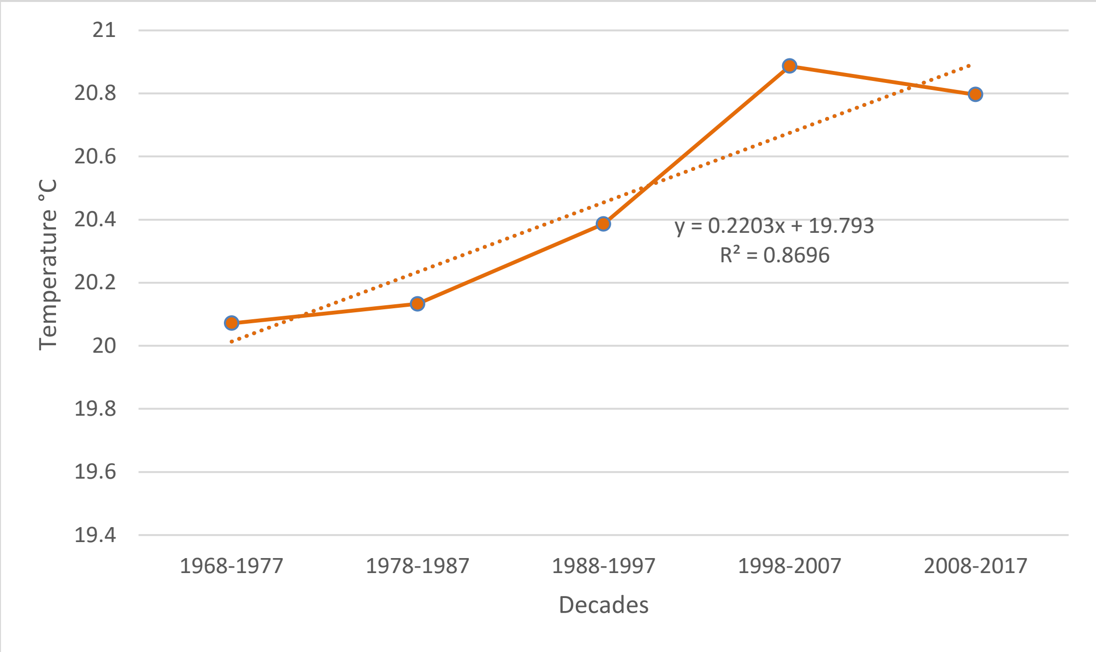


Figure 4.27: Trends of Average Temperature of North-Western zone of Bangladesh from 1968 to 2017.

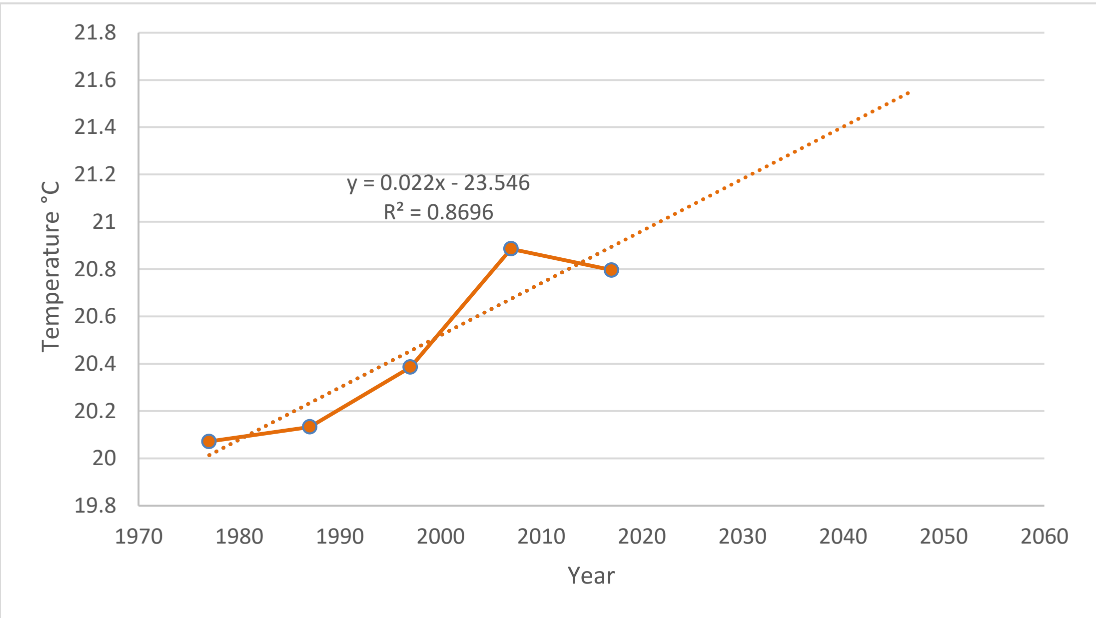


Figure 4.28: Projected Trends of Average Temperature of North-Western zone of Banglades

From Figure 4.27 it is observed that the average temperature of the north-western climatic zone of Bangladesh has increased 1.1015 °C in the 50 years period from 1968 to 2017 at the rate of 0.2203 °C per decade. We know the western zone is comparatively hot zone of the country. The increasing trend of this region is higher than other regions. From Figure 4.28 it is also observed the projected trend of the temperature of this region. The temperature of this will increase 0.726 °C in 2050 and 1.826 °C in 2100 at a rate of 0.022 °C per year.

4.2.4.5 Temperature of Western Region

Western region is consisted with the districts of Nawabgonj, Joypurhat, Naogaon, Rajshahi and Natore. In this climatic zone two weather stations are located. They are Rajshahi and Ishurdi. The temperature trend of this region has been calculated based on these two stations.

Table 4.10: Decadal range of average temperature of western zone of Bangladesh from 1968 to 2017

Decades	Temperature Range (Average) °C
1968-1977	20.42
1978-1987	20.32
1988-1997	20.15
1998-2007	20.83
2008-2017	20.76

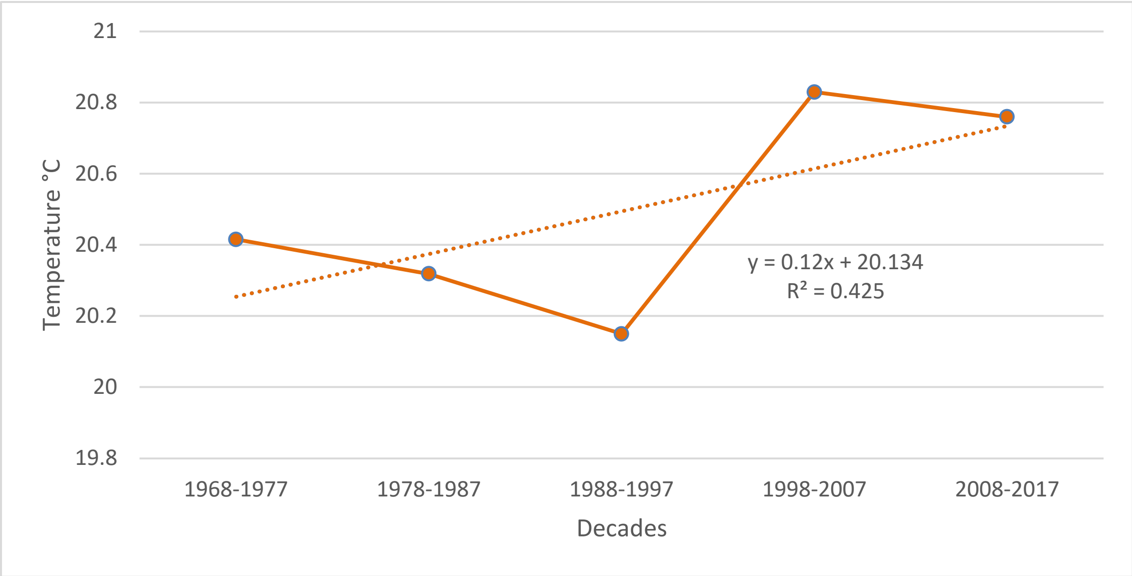


Figure 4.29: Trends of average temperature of western zone of Bangladesh from 1968 to 2017

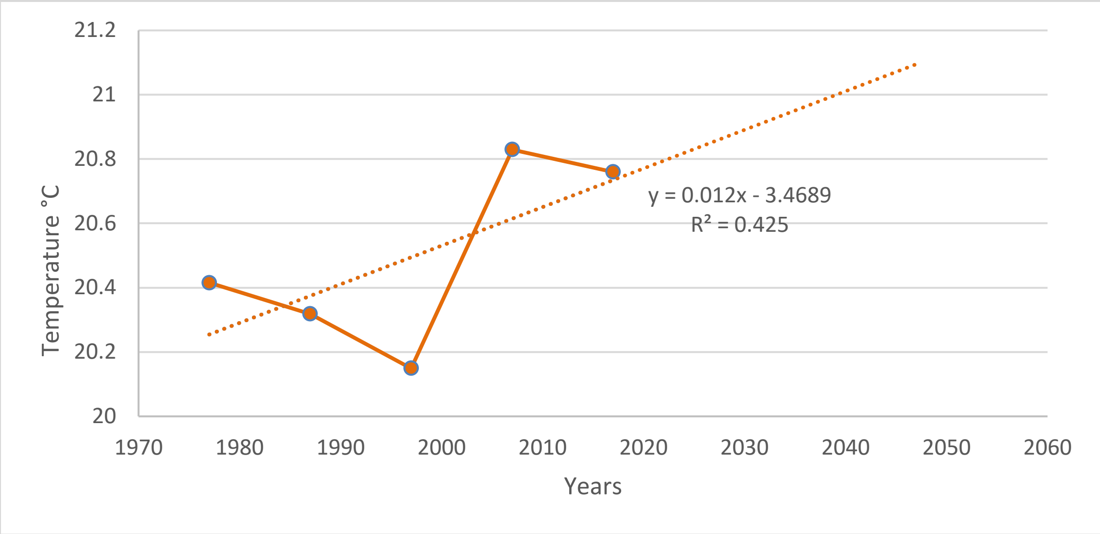


Figure 4.30: Projected Trends of average temperature of western zone of Bangladesh

From Figure 4.29 it is noticed that the average temperature of the western zone is increasing at the rate of 0.12 °C per decade and in the period of 1968-2017 the temperature has increased 0.6 °C . From Figure - 4.30 it is also noticed that the projected temperature is incresing at the rate of 0.012 °C per year and at this rate the avearge temperature will increase 0.396 °C in 2050 and 0.996 °C in 2100.

4.2.4.6 Temperature of South-western:

South western zone constitutes with the districts of Rajbari, Faridpur, Jhenidah, Magura, Jessore, Narail, Satkhira, Khulna. Figure - shows the temperature range of the five decades from 1968 to 2017. From this avrage temperature range the trends of temperature of this climatic zone has been detected.

Table 4.11: Decadal range of Average Temperature of South-western Zone.

Decades	Temperature Range (Average) °C
1968-1977	21.16
1978-1987	21.35
1988-1997	21.19
1998-2007	21.57
2008-2017	21.70

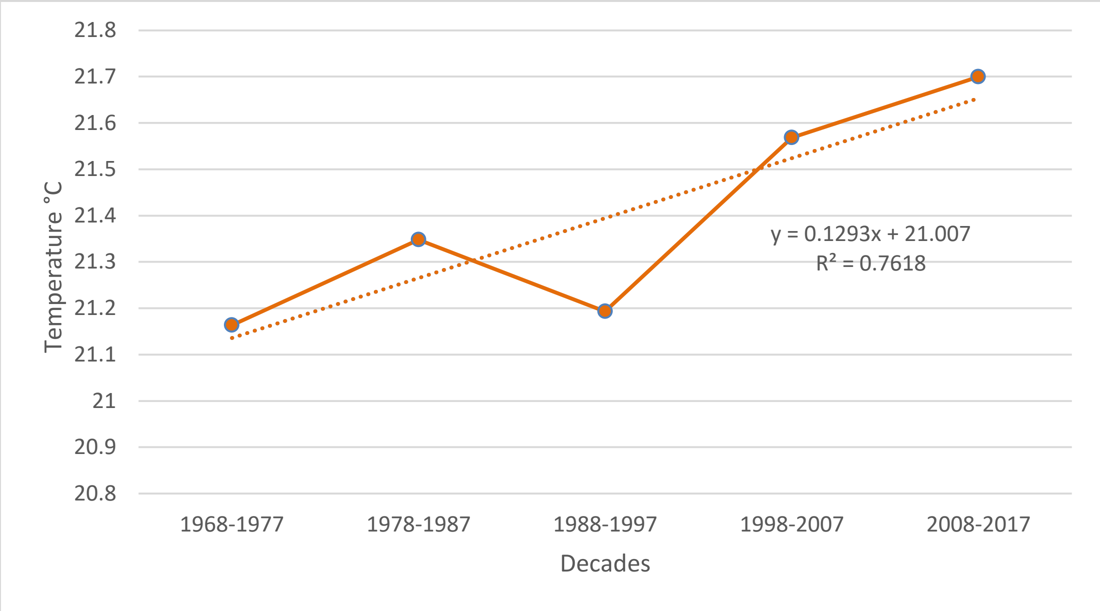


Figure 4.31: Trends of Average Temperature in South-Western Zone from 1968-2017

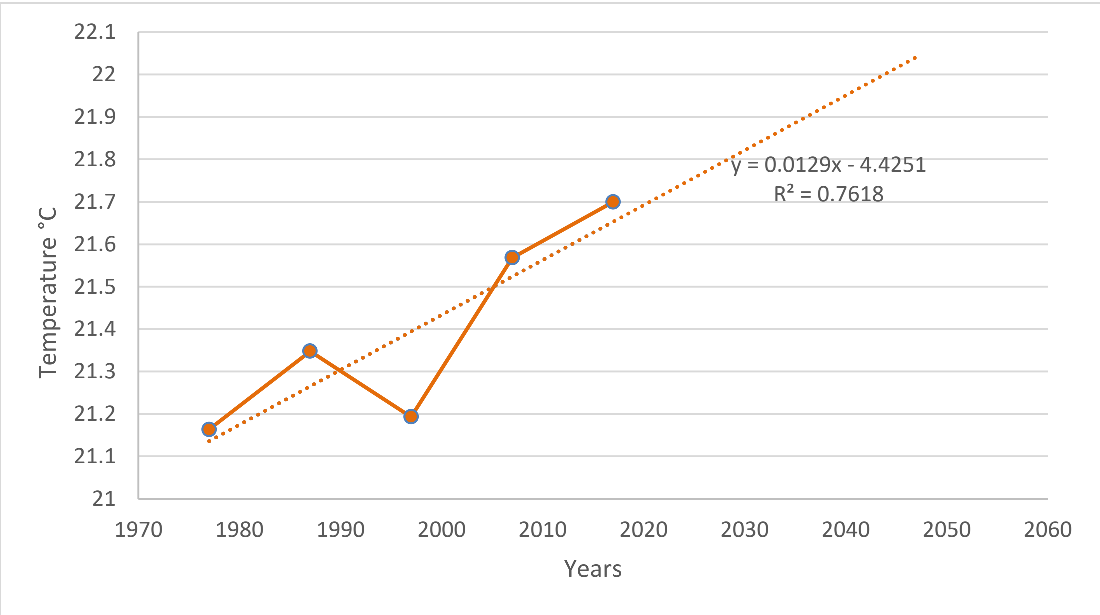


Figure 4.32: Projected Trends of Average Temperature in South-Western Zone

From Figure 4.31 it is noticed that the rate of average temperature of south-western zone is on the increase. The temperature of this region is increasing at a rate of 0.1293 °C per decade and at this the average temperature has increased 0.6465 °C in 50 years from 1968 to 2017. From

Figure 4.32 it is observed that projected rate of temperature increase is 0.0129 per year and at this rate the temperature will increase 0.4257 °C in 2050 and 1.0707 °C in 2100.

4.2.4.7 Temperature of South- Central:

South-central zone constitutes with the districts of Sherpur, Netrocona, Jamalpur, Mymonsingh, Tangail, Kishoregonj, Habigonj, Gazipur, Narshindi, Bhahmonbaria, Dkaka, Manikgonj, Narayangonj, Munshigonj, Madaripur, Chandpur, Cumilla, Shariatpur, Gopalgonj, Barishal, Pirojpur, and Bagerhat. Figure 4.33 shows the avearge temperature of this region. Thrends of average temperature of this region has been detected on the basis of the temperature range of this region.

Table 4.12: Decadal range of Average Temperature of South-Central Zone from 1968-2017

Decades	Temperature Range (Average) °C
1968-1977	20.76
1978-1987	20.90
1988-1997	21.30
1998-2007	21.62
2008-2017	21.75

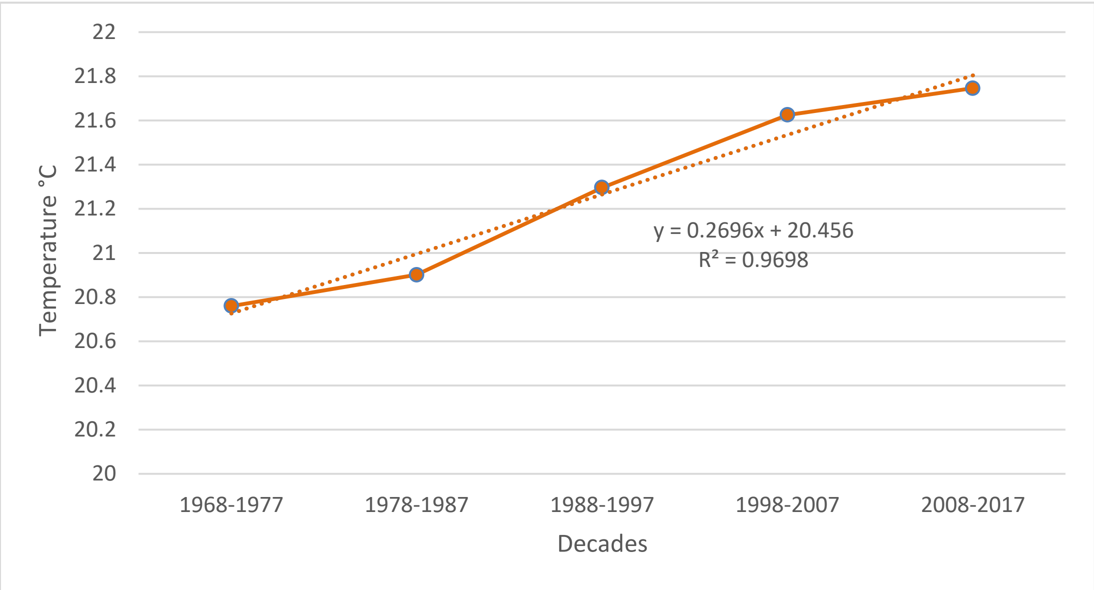


Figure 4.33: Trends of Average Temperature of South-Central Zone from 1968-2017

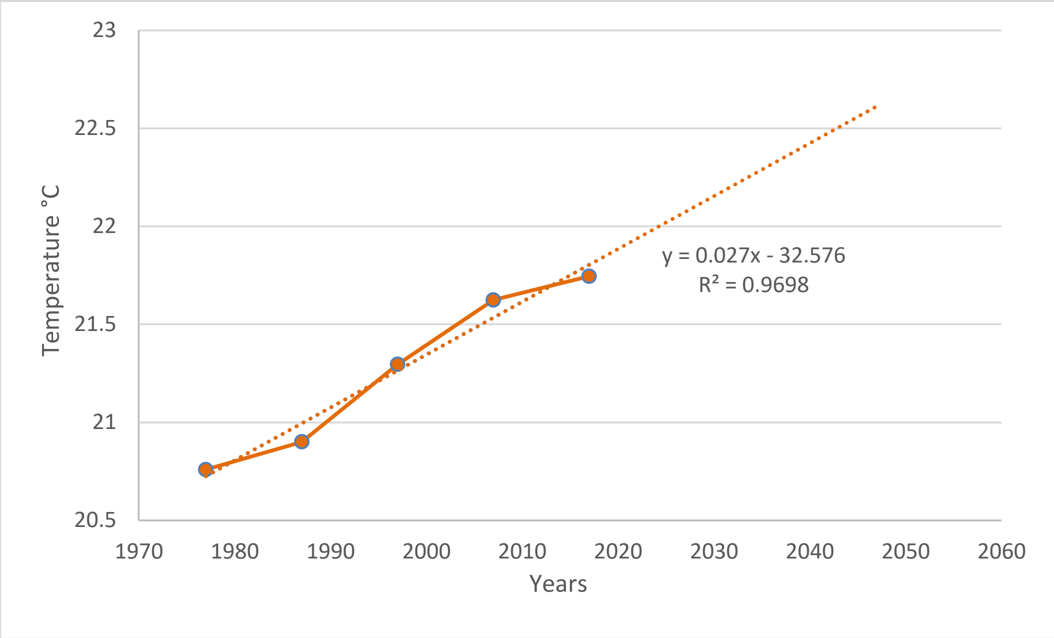


Figure 4.34 Projected Trends of Average Temperature of South-Central Zone

From Figure -4.33 it is observed that the trends of average temperature of south-central zone is on the increase. It is noticed that the average temperature of this region has increased 1.348 °C in the 50year period that is from 1968 to 2017 at a rate of 0.2696 °C per decade. From Figure 4.34 it also found that the temperature is increasing at a rate of 0.027 °C per year and at this rate the average temperature will increase 0.891 °C in 2050 and 2.241 °C in 2100.

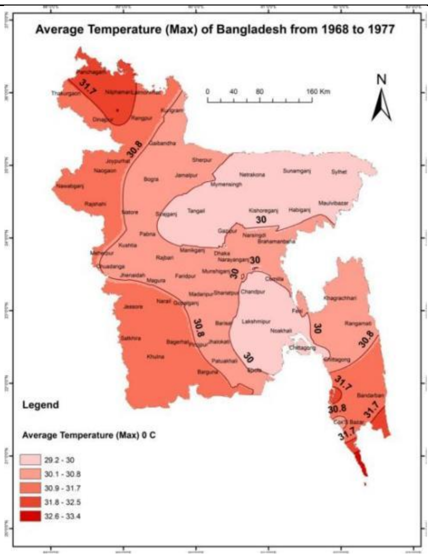
4.2 Maximum Temperature (Tmax) Trends and Variability of Bangladesh: 1968-2017

4.2.1 Introduction

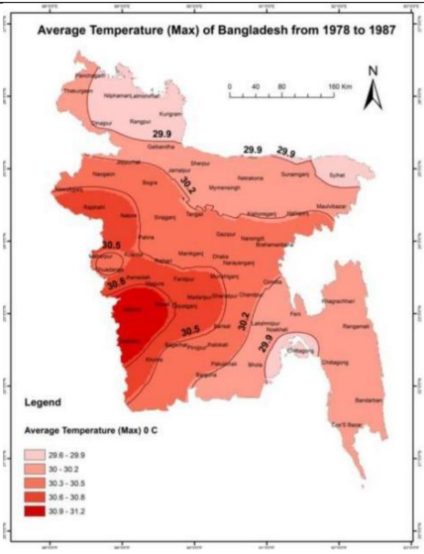
The trends and variability of maximum temperature of Bangladesh has been categorized average (Mean), average minimum and average maximum and standard deviation for the time period of 1968 to 2017 showing five decades.

4.2.2 Description of Decadal Trends and Variability of Maximum Temperature:

Various studies observed that the the trends and variability of maximum temperature are on the track of rise. From this study it was also found that the maximum temperature increase is a on the increasing because of worldwise temperature increase due to climate change.



a)



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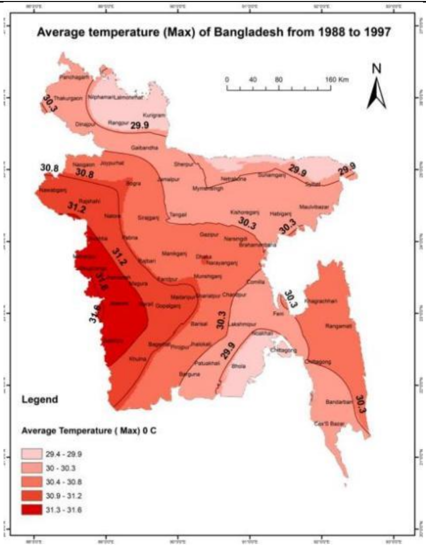

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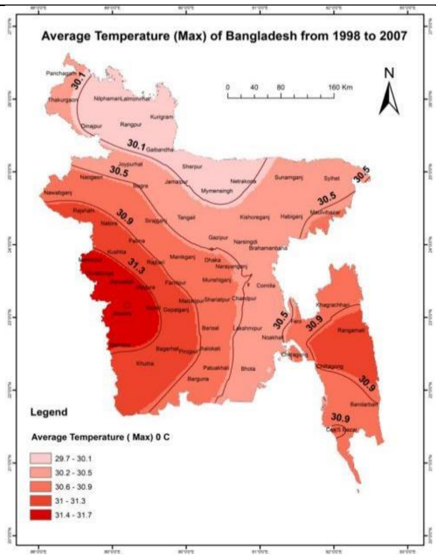

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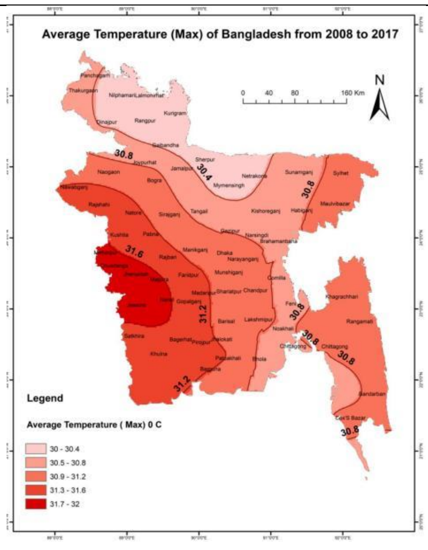


e)

Figure 4.35 a) Map of average temperature (T max) of Bangladesh from 1968 to 1977 b) Map of average temperature (T max) of Bangladesh from 1978 to 1987 c) Map of average temperature (T max) of Bangladesh from 1988 to 1997 d) Map of average temperature (T max)of Bangladesh from 1998 to 2007 e) Map of average temperature (T max) of Bangladesh from 2008 to 2017

Source: Analyzed by Author, based on BMD data set, 2022.

Figure 4.35 indicates the average temperature (Tmax) of Bangladesh from 1968 to 2017. From this map it was noticed that the average temperature (Tmax) of bangladesh ranges from 29.2-33.4 °C. From map 4.35 a) shows the average temperature (Tmax) of Bangladesh from 1968 to 1977. The highest average temperature range from 29.2-33.4 °C was observed in only part of the Cox's Bazar district which is under south-eastern zone. The lowest temperature range 29.2-30 °C was observed in part of south-central zone which include the districts of Mymensingh, Tangail, Netrokona, Kishoregonj, Hobigonj, Chandpur, part of north-eastern zone which inclue the districts of Sylhet, Moulvibazar, Sunamgonj, and part of south-eastern zone which include the districts of Luxmipur, Noakhali, part of Chittagonj.

4.35 b) indicates the average temperature (Max) of Bangladesh from 1978 to 1987. During this period the average temperature (Max) of Bangladesh ranges 29.6-31.2 °C was noticed. The highest temperature range 30.9-31.2 °C was observed in part of the south-western zone which include the districts of Jessore and part of Satkhira. The lowest temperature range 29.6-29.9 °C was observed in part of the northern part of the northern region which include the districts of Nilphamary, lalmonirhat, Kurigram, Rangpur, part of the north-western zone which include the districts of part of Dinajpur and Rangpur, part of the north-eastern zone which include the district of part of Sylhet under north-eastern zone,and part of the south-eastern zone which include the districts of part of Chittagonj and Noakhali.

Figure 4.35 c) indicates the average temperature (Max) of Bangladesh from 1988 to 1997. From this map it was noticed that the range of average temperature of Bangladesh was 29.4-31.6 °C during this decade. The highest temperature range 31.3-31.6 °C was observed in the part of the south-western zone which include the districts of Jessore, part of Satkhira, Jhenaidah, and part of the north - western zone which include the districts of Chuadanga, Meherpur. The lowest temperature range 29.4-29.9 °C was observed in part of the northern part of the northern region which include the districts of Nilphamari, Lalmonirhat, Rangpur, Kurigram, part of north-eastern zone which include the districts of part of Sylhet, and part of south-eastern zone which include the district of part of Bhola, Noakhali, Chittagonj.

Figure 4.35 d) indicates the average temperature (Max) of Bangladesh from 1998 to 2007. In this decade the temperature range 29.7-31.7 °C was existed. The highest temperature range 31.4-31.7 °C was observed in part of the south-western zone which include the districts of Jessore, Jhenaidha, part of Satkhira and part of the north-western zone which include the districts of Chuadanga and Meherpur. The lowest temperature range 29.7-30.1 °C was observed in most part of the northern part of the northern zone which include the districts of Nilphamary, Lalmonirhat, Rangpur Kurigram and part of Panchagar, part of north-western zone which include the districts of Dinajpur, rangpur, Gaibandha and part of the south-central zone which include the districts of Netrokona, Sherpur and part of Mymensingh.

Figure 4.35 e) indicates the average temperature (Max) of Bangladesh from 2008 to 2017. The average temperature range during this time was 30-32 °C. The highest temperature range 31.7-32 °C was noticed in part of the south-western zone which include the Jessore, Jhenaidha, part of Magura, Narail and part of the north-western zone which include the districts of Chuadanga and Meherpur. The lowest temperature range 30-30.4 °C was noticed in part of the northern part of the northern zone which include the districts of Nilphamary, Lalmonirhat, Rangpur Kurigram and part of Panchagar, part of north-western zone which include the districts of Dinajpur, rangpur, Gaibandha and part of the south-central zone which include the districts of Sherpur, part of Mymensingh and Netrokona.

Table 4.13 Decadal Average Temperature (Tmax) range of Bangladesh from 1968 to 2017

Decades	Temperature Range (Average) °C
1968-1977	30.56
1978-1987	30.23
1988-1997	30.40
1998-2007	30.70
2008-2017	30.97

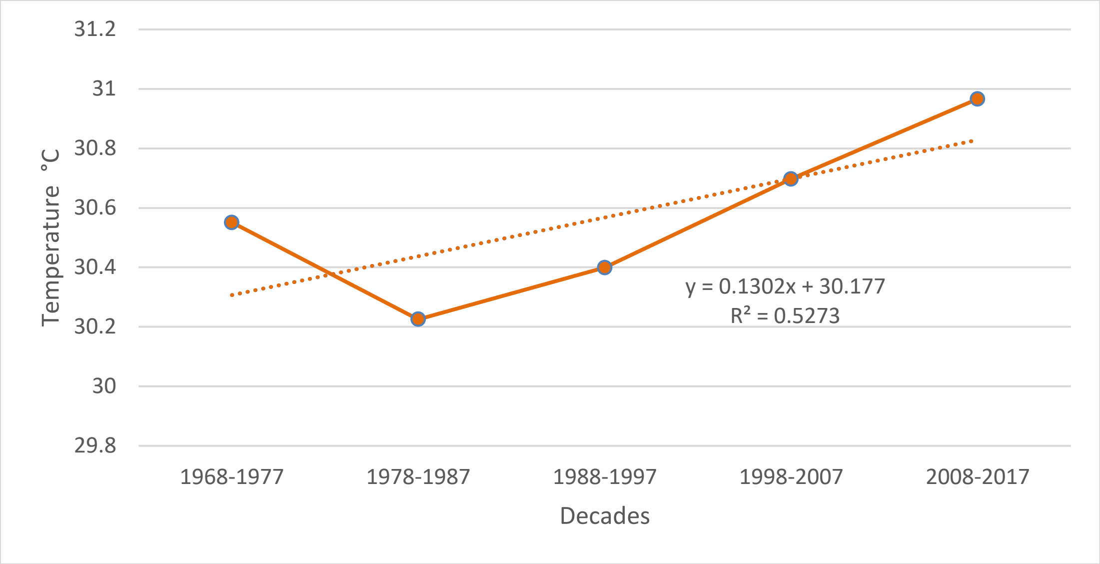


Figure 4.36: Trends of Average Temperature of Bangladesh from 1968 to 2017

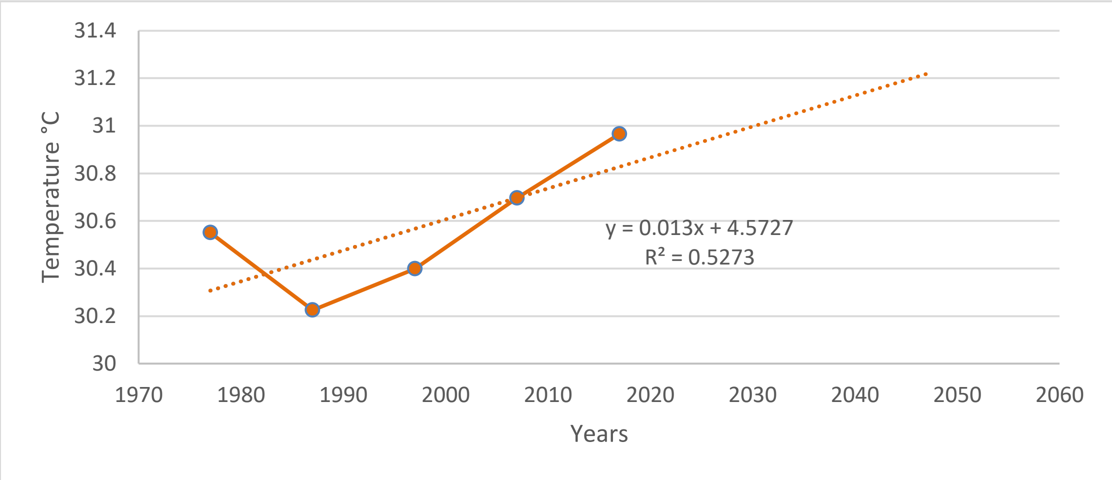


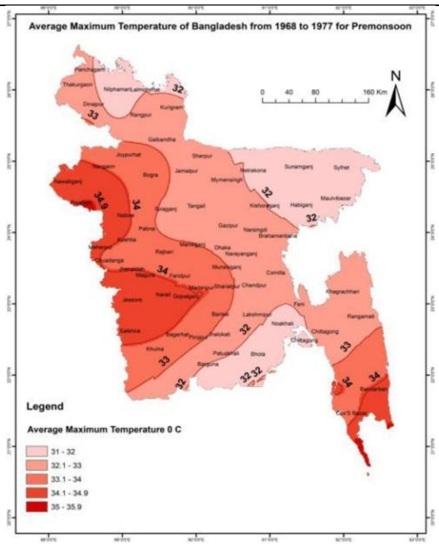
Figure 4.37: Projected Trends of Average Temperature of Bangladesh

From Figure 4.36 shows the trends of average temperature of Bangladesh for the period of 1968 to 2017. In this 50 years time period the temperature has increased 0.0651 °C at a rate of 0.1302 °C per decade. The projected trends of average minimum temperature is noticed in Figure 4.37. From this Figure it is noticed that the projected trends of temperature per year is 0.013 °C. And at this rate the average temperature will increase 0.429 °C in next 33 years in 2050 and 1.079 °C in 2100.

4.2.3 Description of Seasonal Trends and Variability of Maximum temperature:

The trends and variability of maximum temperature differ from season to season. It has been already mentioned that in Bangladesh four prominent seasons viz. premonsoon, monsoon, post-monsoon and dry are existed. Each season is characterized by different characteristics and the maximum temperature range differ from one another.

4.2.3.1 Maximum Temperature of Premonsoon: is the period which is consisted with the month of March, April and May and during this period the average maximum temperature remains on the increase and the weather is becoming hotter after ending period of the dry/winter season. Sometimes the *kalboishakhi* associated with the thderstrom are occurred during this season and causes devastation of properties and lives.



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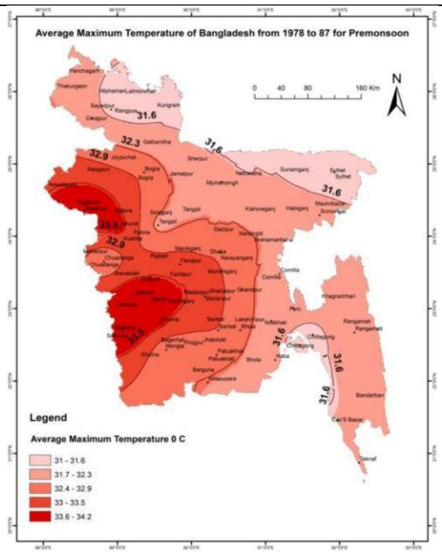

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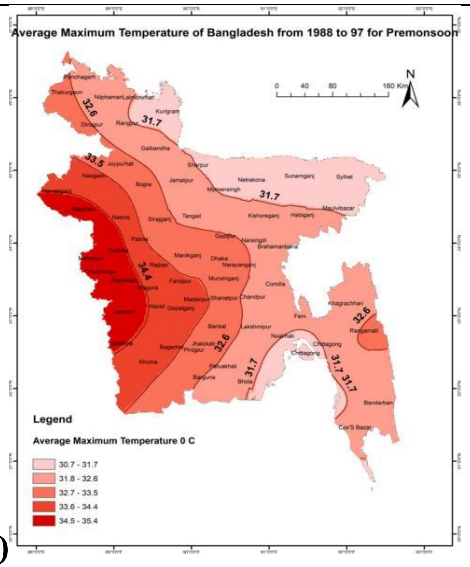

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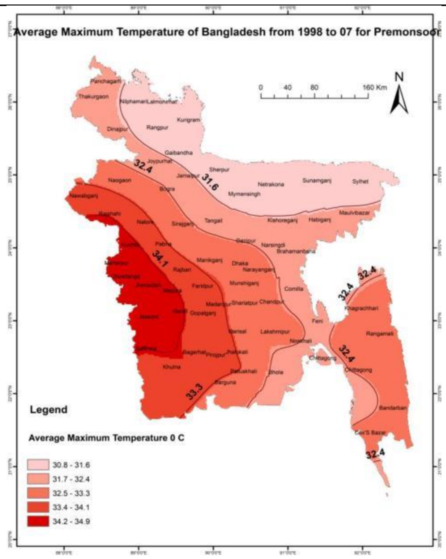

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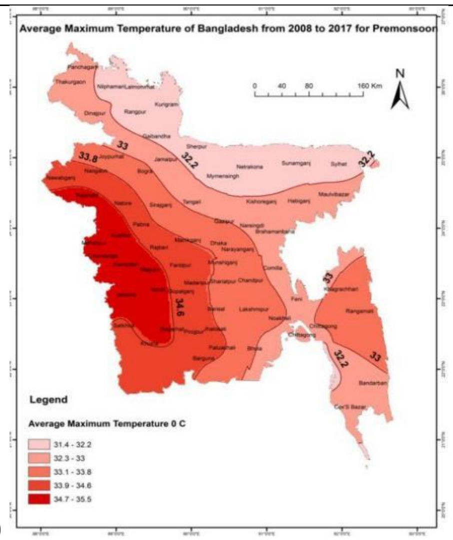


e)

Figure 4.38 a) Map of average maximum temperature of Bangladesh from 1968 to 1977 for Premonsoon b) Map of average maximum temperature of Bangladesh from 1978 to 1987 for Premonsoon c) Map of average maximum temperature of Bangladesh from 1988 to 1997 for Premonsoon d) Map of average maximum temperature of Bangladesh from 1998 to 2007 for Premonsoon e) Map of average maximum temperature of Bangladesh from 2008 to 2017 for Premonsoon

Source: Analyzed by Author, based on BMD data set, 2022.

Figure 4.38 indicates the Map of the Average Maximum Temperature of Bangladesh from 1968 to 2017 for Premonsoon. Map 4.38 a) indicates the average maximum temperature of Bangladesh from 1968 to1977 for Premonsoon. From this map it was observed that the temperature range 31-35.9 °C was existed during this decade. The highest temperature range 35-35.9 °C was observed in part of the Cox's Bazar Bandarban and Rajshahi district which is under the south-eastern zone. The lowest temperature range 31-32 °C was noticed in north-eastern zone which include the districts of Sylhet, Sunamgonj, Moulvibazar, part of the south-eastern zone which include the districts of Noakhali, Bhola, part of Patuakhali, Barguna, the part of south-central zone which include the districts of Netrokona, Hobigonj, part of Kishoregonj and the part of northern part of the northern region which include the district of Nilphamari, part of Panchagar, Lalmonirhat.

Figure 4.38 b) indicates the average maximum temperature of Bangladesh from 1978 to1987 for Premonsoon. The tamperature range 31-34.2 °C was existed during this decade. The highest temperature range 33.6-34.2 °C was observed in part of the south-western zone which include the districts of Jessore, Narail, part of Satkhira, Khulna and part of south-western zone which include the districts of Rajshahi, part of Natore and Nowabgonj districts. The lowest temperature range 31-31.6 °C was noticed in part of the north-eastern zone which include the districts of Sylhet, Sunamgonj and part of Moulvibazar, part of the northern part of the northern region, and part of the south-eastern zone which include the districts of part of Chittagong and Cox's Bazar.

Figure 4.38 c) indicates the average maximum temperature of Bangladesh from 1988 to1997 for Premonsoon. The temperature range 30.7-35.4 °C was observed during this decade. The highest temperature range 34.5-35.4 °C was observed in part of the south western zone which include Jessore, Jhenidah, part of Satkhira, part of the north western zone which include the districts of Meherpur, Chuadanga, Kustia and part of the western zone which include the districts of part of Rajshahi and Nawabgonj. Again, the lowest temperature range 30.7-31.7 °C was observed in north-eastern zone which include the districts of Sylhet, Sunamgonj, part of the Moulvibazar, part of the northern part of the northern zone which include the districts of Kurigram, part of Rangpur, Lalmonirhat, and part of the south-eastern zone which include the districts of part of Cox's Bazar, Chittagong, Noakhali, Bhola.

Figure 4.38 d) indicates the average maximum temperature of Bangladesh from 1998 to 2007 for Premonsoon. The temperature range 30.8-34.9 °C was noticed during this decade. The highest temperature range 34.2-34.9 °C was observed in part of south-western zone which include the districts of Jessore, Jhalokhati, part of Narail, Magura, Satkhira, Khulna, part of north-western zone which include the districts of Chuadanga, Meherpur, part of Kustia, and part of western zone which include the districts of part of Rajshahi. The lowest temperature range 30.8-31.6 °C was observed in part of the south-eastern zone which include the districts of Sylhet, Sunamgong, part of Moulvibazar, part of the south-central zone which include the districts of Netrokona, Sherpur, part of Mymensingh, Kishoregong, part of the northern part of the northern region which include the districts of Nilphamari, Lalmonirhat, Rangpur, Kurigram and part of the north-western zone which include the districts of Gaibandha, Rangpur.

Figure 4.38 e) indicates the average maximum temperature of Bangladesh from 2008 to 2017 for Premonsoon. The temperature range during this decade was observed as 31.4-35.5 °C. The highest temperature range 34.7-35.5 °C was observed in part of south-central zone which include the districts of part of Khulna, Bagerhat, part of south-western zone which include the districts of Jessore, Jhenidah, Magura, part of Narail, Satkhira, Khulna, part of north-western zone which include the districts of Meherpur, Chuadanga, Kustia and part of western zone which include the districts of part of Rajshahi. The lowest temperatuer range 31.4-32.2 °C was observed in part of the south-eastern zone which include the districts of Sylhet, Sunamgong, part of the south-central zone which include the districts of Netrokona, Sherpur, part of Mymensingh, Kishoregong, part of the northern part of the northern region which include the districts of Nilphamari, Lalmonirhat, Rangpur, Kurigram and part of the north-western zone which include the districts of Rangpur, part of Gaibandha.

Table 4.14: Decadal Average Maximum Temperature (Tmax) range of Bangladesh from 1968 to 2017 for Premonsoon.

Decades	Temperature Range (Average) °C
1968-1977	32.91
1978-1987	32.32
1988-1997	32.66
1998-2007	32.72
2008-2017	33.29

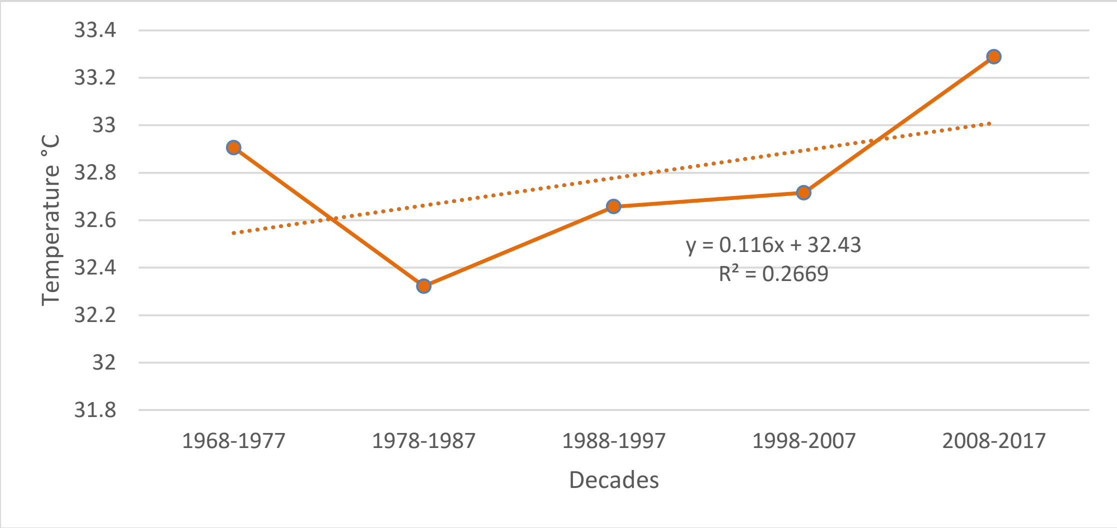


Figure 4.39:Trends of Average Maximum Temperature (Tmax) of Bangladesh from 1968 to 2017 for Premonsoon

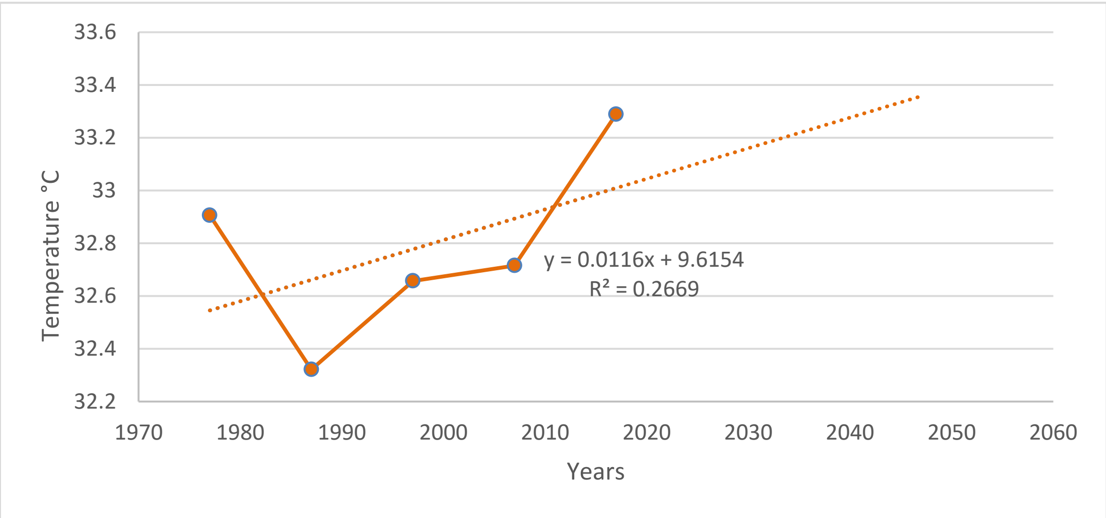
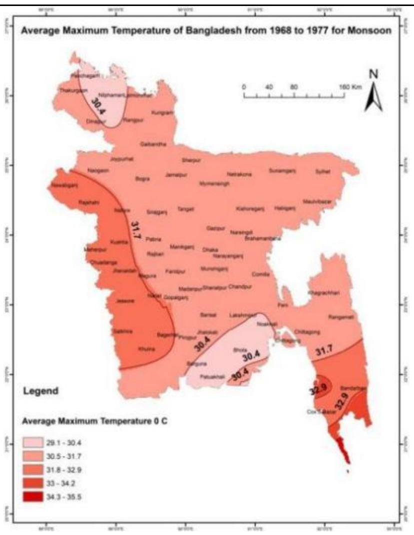


Figure 4.40: Projected Trends of Average Maximum Temperature (Tmax) of Bangladesh for Premonsoon

From Figure 4.39 it is observed that during the time period of 1968 to 2017 in 50 years time period the average maximum temperature of Bangladesh for Premonsoon has increased 0.58 °C at a rate of 0.116 °C per decade. From Figure 4.40 it is also observed that at a rate of 0.0116 °C per year the the average maximum temperature will increase 0.3828 °C in 33 years and later in 2050 the temperature will increase 0.9628 °C.

4.2.3.2 Maximum Temperature of Monsoon: is the period which is consisted with the month of June, July, August and September. During this season heavy rainfall occur due to heavy downpour. This time the temperature also remains higher magnitude.



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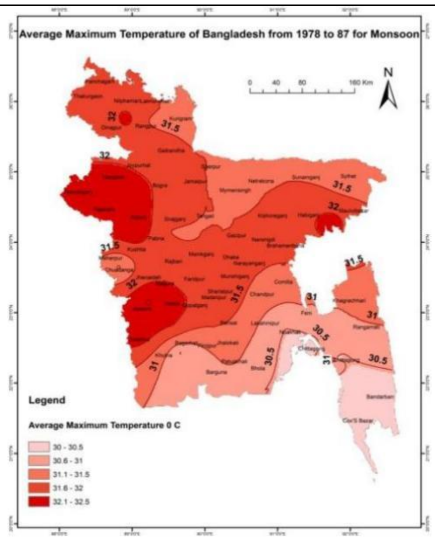

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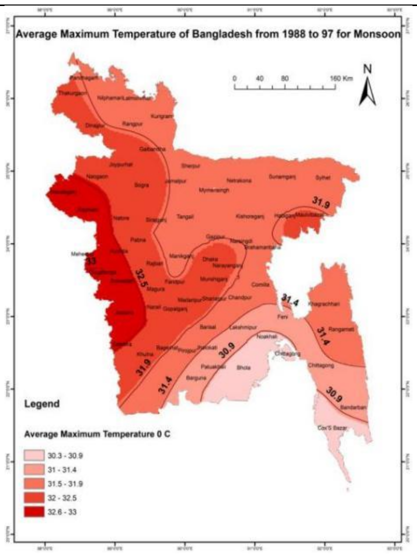

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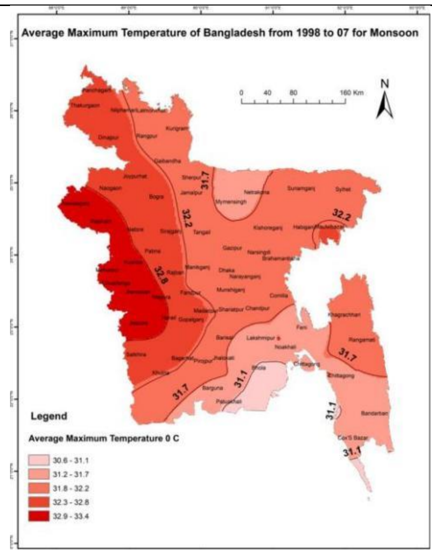

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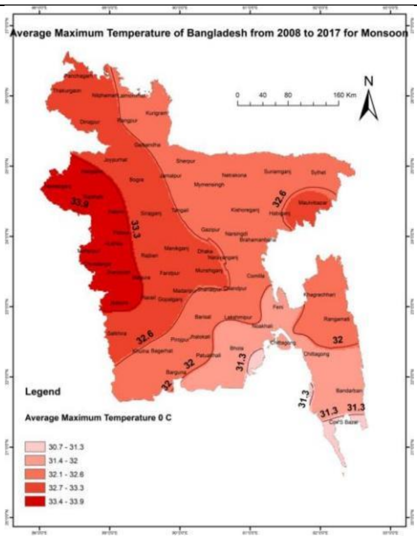


e)

Figure 4.41 a) Map of average maximum temperature of Bangladesh from 1968 to 1977 for Monsoon b) Map of average maximum temperature of Bangladesh from 1978 to 1987 for Monsoon c) Map of average maximum temperature of Bangladesh from 1988 to 1997 for Monsoon d) Map of average maximum temperature of Bangladesh from 1998 to 2007 for Monsoon e) Map of average maximum temperature of Bangladesh from 2008 to 2017 for Monsoon

Source: Analyzed by Author, based on BMD data set, 2022.

Figure 4.41 indicates the map of Average Maximum Temperature of Bangladesh from 1968 to 2017 for Monsoon. Map 4.41 a) indicates the average maximum temperature of

Bangladesh from 1968 to 1977 for monsoon. From this map it was observed that the temperature range during this decade was noticed from 29.1- 35.5 °C. The maximum temperature range 34.3-35.5 °C was observed in Teknaf under the south-eastern zone. The lowest temperature range 29.1-30.4 °C was observed in part of south-eastern zone which include the part of Bhola, Noakhali, Patuakhli and Borguna, part of the northern part of the northern region which include the districts of Niphamari, part of Panchagar and part of the north-western zone which include the districts of part of Dinajpur.

Figure 4.41 b) indicates the average maximum temperature of Bangladesh from 1978 to 1987 for monsoon. From this map it was observed that the tempeartuer range during this decade was existed from 30-32.5 °C. The highest temperature range 32.1-32.5 °C was observed in western zone, and part of south-western zone which include the districts of Jessore, Narail, part of Magura, Satkhira and Syedpur under northern part of the norther region. The lowest temperatuer range 30-30.5 °C was noticed in part of the south-eastren zone which include the districts of part of Cox's bazar, bandarban, Nowakali.

Figure 4.41 c) indicates the average maximum temperature of Bangladesh from 1988 to 1997 for monsoon. From this map it indicates that the average maximum temperatuer range during this decade was existed from 30.3 -33 °C. The highest temperature range 32.6-33 °C was observed in part of the south-western zone which include the districts of Jessore, part of Jhenaidah, Satkhira, part of the north-western zone which include the districts of Meherpur, Chudanga, part of Kustia, and part of the western zone which include the districts of Rajshahi, Nowabgong. Again, the lowest temperature range 30.3-30.9 °C was observed in part of the south-eastern zone which include the districts of Cox's Bazar, part of Bandarban, Noakhali, Bhola, Patuakhali.

Figure 4.41 d) indicates the average maximum temperature of Bangladesh from 1998 to 2007 for monsoon. From this map it was noticed that the avearge maximum temperature during this decade was existed from 30.6-33.4 °C . The avearge maximum tempearture range 32.9-33.4 °C was observed in part of the south-western zone which include the districts of Jessore, Jhenaidah, part of Magura, Narail, part of the north-western zone which include the districts of Meherpur, Chudanga, Kustia, and part of the western zone which include the districts of Rajshahi, Nowabgong. The lowest temperature range 30.6-31.1 °C was observed in Bhola, part of Meherpur under south-eastern zone.

Figure 4.41 e) indicates the average maximum temperature of Bangladesh from 2008 to 2017 for monsoon. From this map it was noticed that the average temperature range during this decade was recored from 30.7-33.9 °C. The highest tempeartuere range was 33.4-33.9 °C was observed in part of the south-western zone which include the districts of Jessore, Jhenaidah, part of Magura, part of the north-western zone which include the districts of Meherpur, Chudanga, Kustia, part of Pabna, Natoer and part of the western zone which include the districts of Rajshahi, Nowabgong, part of Naogaon. The lowest tempeartuer range 30.7-31.3 °C was observed in Teknaf and part of Bhola under south-eastern zone.

Table 4.15: Decadal Average Maximum Temperature (Tmax) range of Bangladesh from 1968 to 2017 for Monsoon

Decades	Temperature Range (Average) °C
1968-1977	31.28
1978-1987	31.25
1988-1997	31.63
1998-2007	31.95
2008-2017	32.36

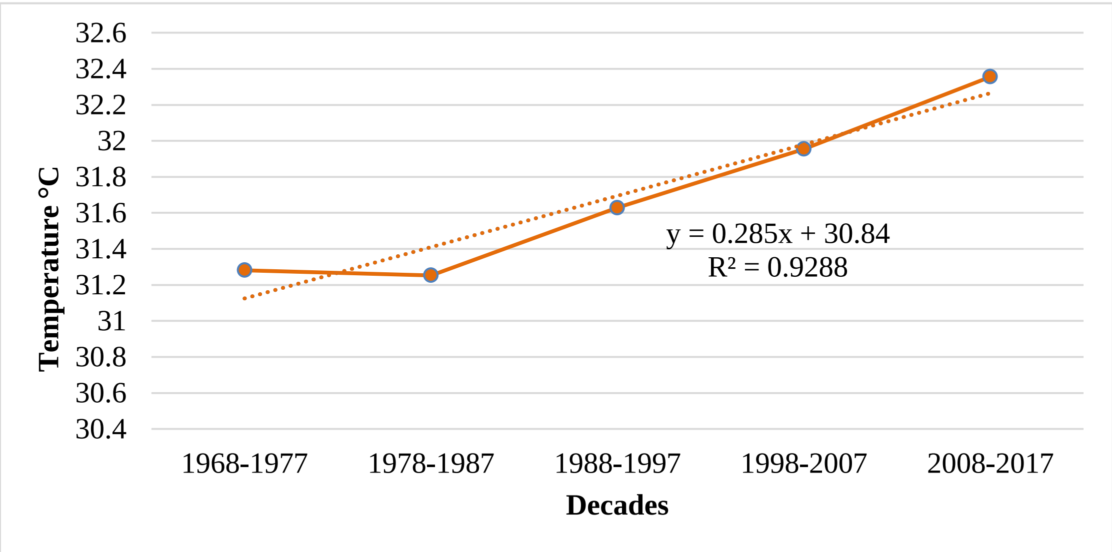


Figure 4.42: Trends of Average Maximum Temperature (Tmax) of Bangladesh from 1968 to 2017 for Monsoon.

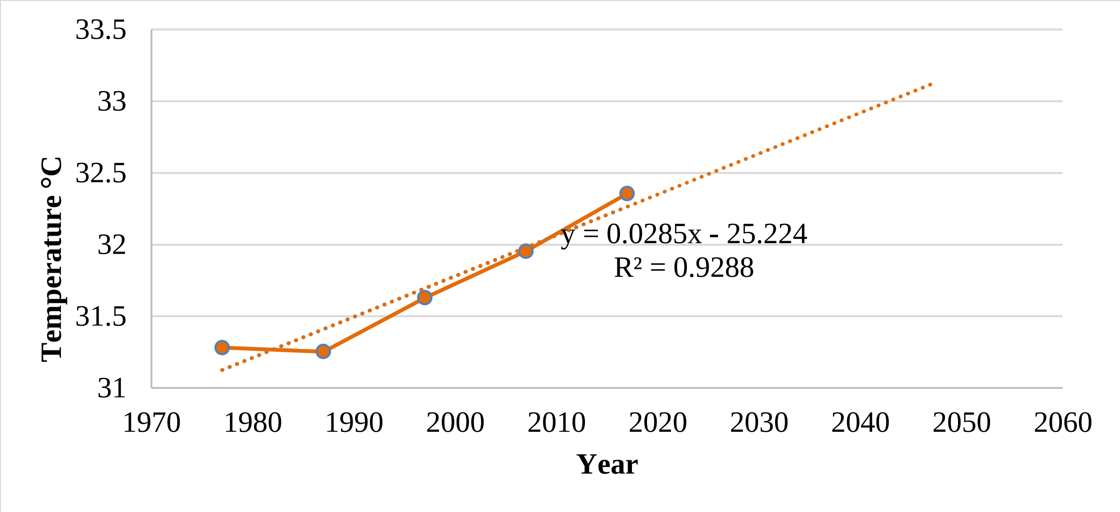
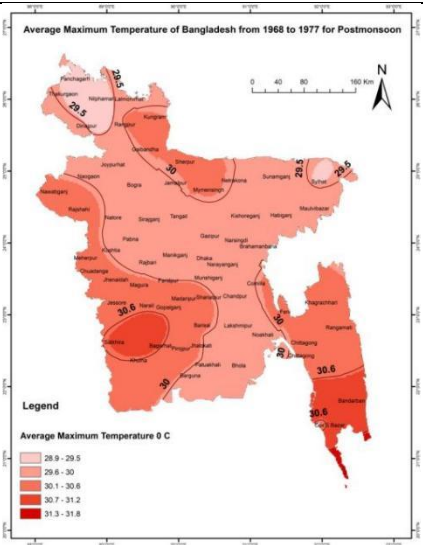


Figure 4.43: Projected Trends of Average Maximum Temperature (Tmax) of Bangladesh for Monsoon.

From Figure 4.42 it is observed that the average maximum temperature of Bangladesh for monsoon has increased 1.425 °C for the period of 1968 to 2017 at a rate of 0.285 °C per decade. Figure 4.43 shows the projected trends of average maximum temperature which indicates that in 2050, the temperature will increase 0.9405 °C and in 2100 it will increase 2.3655 °C at a rate of 0.0285 °C per year.

4.2.3.3 Post-monsoon: This season comprises with the months of October and November. During this time the average temperattuer is gragually decreasing due to the cycle of season. The average temperature range remains limited between 29- 31 °C. In this season sometimes cyclones occur due formation of depression in the deep sea.



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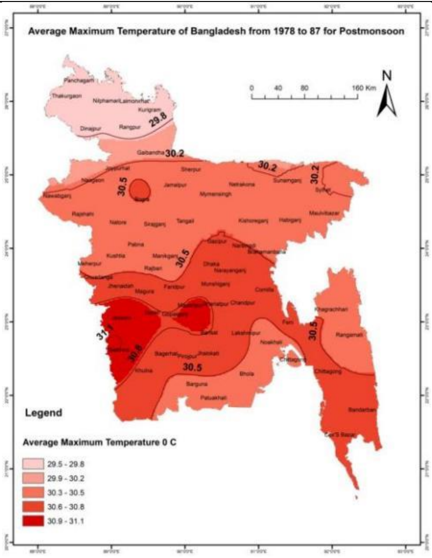

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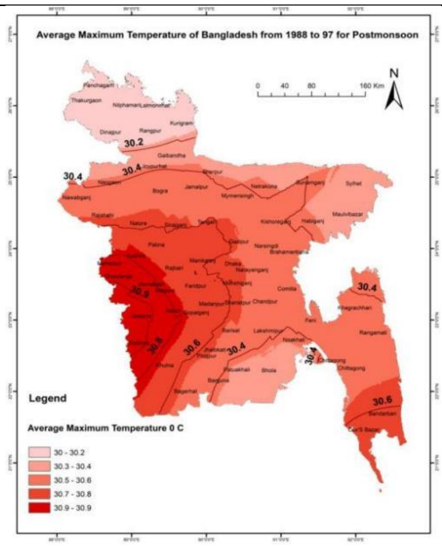

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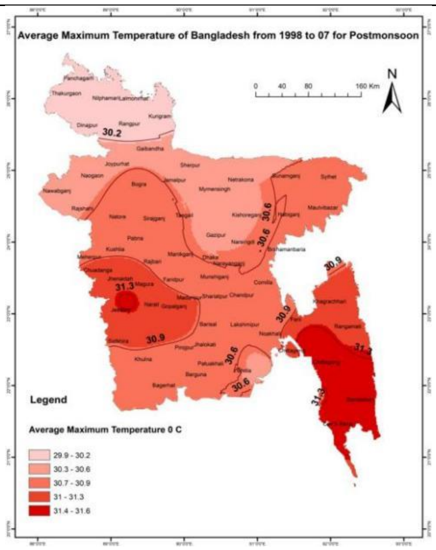

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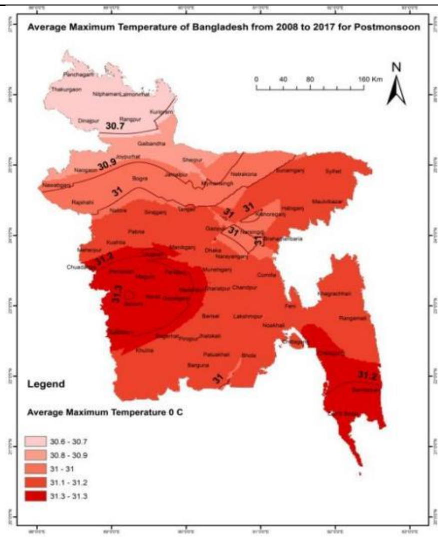


e)

Figure 4.44 a) Map of average maximum temperature of Bangladesh from 1968 to 1977 for post-monsoon b) Map of average maximum temperature of Bangladesh from 1978 to 1987 for post-monsoon c) Map of average maximum temperature of Bangladesh from 1988 to 1997 for post-monsoon d) Map of average maximum temperature of Bangladesh from 1998 to 2007 for post-monsoon e) Map of average maximum temperature of Bangladesh from 2008 to 2017 for post-monsoon.

Source: Analyzed by Author, based on BMD data set, 2022.

Figure 4.44 indicates Map of Average Maximum Temperature of Bangladesh from 1968 to 2017 for post-monsoon. Map 6.38 a) indicates the avearge maximum temperature of

Bangladesh from 1968 to 1977 for post-monsoon. From this map it was noticed that the temperature range 28.9-31.8 °C was existed during this decade. The highest temperature range 31.3-31.8 °C was observed in Teknaf and part of Banderban under south-east zone. The minimum temperature range 28.9-29.5 °C was observed in part of sylhet under north-east zone, part of the northern part of the northern region which include the districts of Panchagar, Nilphamari, and part of the north-western zone which include the districts of part of Thakurgaon, Dinajpur.

Figure 4.44 b) indicates the average maximum temperature of Bangladesh from 1978 to 1987 for post-monsoon. From this map it was noticed that the temperature range during this decade was from 29.5-31.1 °C. The highest temperature range 30.9-31.1 °C was observed in part of south-western zone which include the districts of Jessore, part of Satkhira, Khulna. The lowest temperature range 29.5-29.8 °C was noticed in northern part of the northern region which include the districts of Panchagram, Nilphamari, Lalmonirhat, Kurigram, Rangpur and part of the north-western zone which include the districts of Thakurgaon, part of Dinajpur, Rangpur.

Figure 4.44 c) indicates the average maximum temperature of Bangladesh from 1988 to 1997 for post-monsoon. The temperature range during this decade was existed from 30-30.9 °C. The highest temperature range 30.9-30.9 °C was observed in part of the south-western zone which include the districts of Jessore, Jhenaida, part of Narail, Magura, Satkhira, part of the north-western-zone which include the districts of Meherpur, Chuadanga and part of Satkhira, Khulna. The lowest temperature range 30-30.2 °C was observed in northern part of the northern region which include the districts of Panchagram, Nilphamari, Lalmonirhat, Kurigram, Rangpur and part of the north-western zone which include the districts of Thakurgaon, part of Dinajpur, Rangpur.

Figure 4.44 d) indicates the average maximum temperature of Bangladesh from 1998 to 2007 for post-monsoon. From this map it was observed that the temperature range during this decade was existed from 29.9-31.6 °C. The highest temperature range 31.4-31.6 °C was observed in part of the south-eastern zone which include the districts of Chittagong, Bandarban, and Cox's bazar.and part of Jessore. The lowest temperatuer range 29.9-30.2 °C was noticed in northern part of the northern region which include the districts of Panchagram, Nilphamari, Lalmonirhat, Kurigram, Rangpur and part of the north-western zone which include the districts of Thakurgaon, part of Dinajpur, Rangpur.

Figure 4.44 e) indicates the average maximum temperature of Bangladesh from 2008 to 2017 for post-monsoon. From this map it was noticed that the temperature range 30.6-31.3 °C was existed during this decade. The highest temperature range 31.3-31.3 °C was observed in part of the south-eastern zone which include the districts of Cox's Bazar, part of Bandarban, part of Chittagong, part of the south-western zone which include the districts of Jessore, Jhenaidah, part of Khulna, Satkhira, and part of the south-central zone which include the districts of Madaripur, part of Khulna, Satkhira, and part of the north-western zone which inccclude the districts of Chuadanga. The lowest temperature range 30.6-30.7 °C was observed in northern part of the northern region which include the districts of of Panchagram, Nilphamari, Lalmonirhat, Kurigram, Rangpur and part of the north-western zone which include the districts of Thakurgaon, Panchagar, Lalmonirhat, Kurrrigram, Rangpur. and part of the north-western zone which include the districts of Panchagar, Dinajpur.

Table 4.16: Decadal Average Maximum Temperature range of Bangladesh from 1968 to 2017 for Postmonsoon

Decades	Temperature Range (Average) °C
1968-1977	30.10
1978-1987	30.48
1988-1997	30.50
1998-2007	30.83
2008-2017	31.07

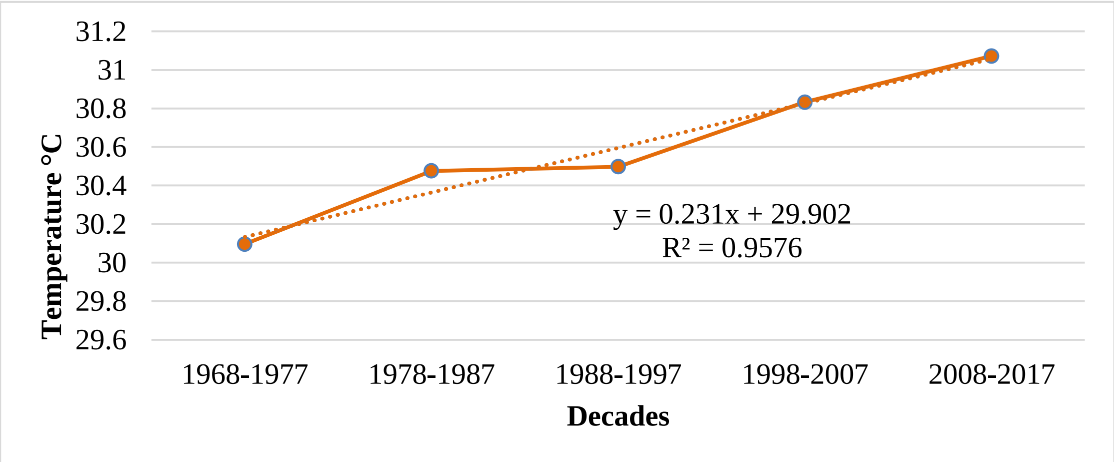


Figure 4.45: Trends of Average Maximum Temperature (Tmax) of Bangladesh from 1968 to 2017 for Postmonsoon.

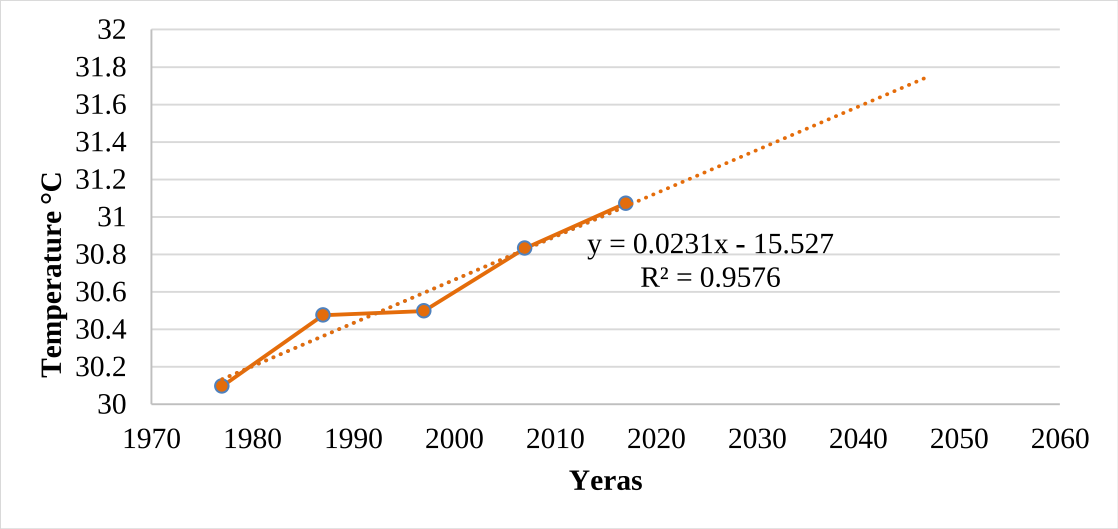
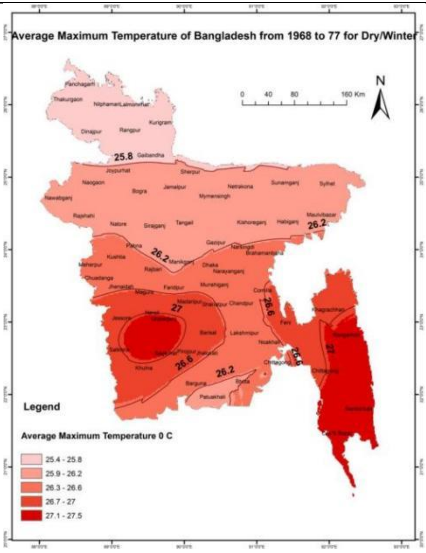


Figure 4.46: Projected Trends of Average Maximum Temperature(Tmax) of Bangladesh for Postmonsoon.

From Figure 4.45 it is noticed that the average maximum temperature of Bangladesh from 1968 to 2017 in 50 years period has increased 1.155 °C at a rate of 0.231 °C and Figure -4.46 it is also noticed that in 2050 the temperature will increase 0.7 °C and in 2100 the temperature will increase 1.9173 °C at a rate of 0.0231 °C.

4.2.3.4 Dry or Winter: The months December, January and February constitute Dry/ Winter season. In this season the temperature is gradually decreasing more and sometimes it remains in the lowest position of 8-9 °C during the month of January.



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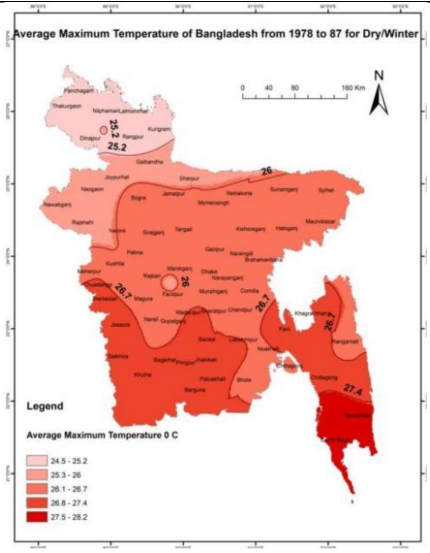

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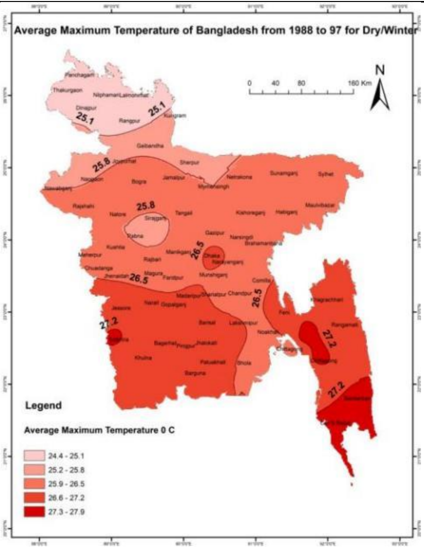

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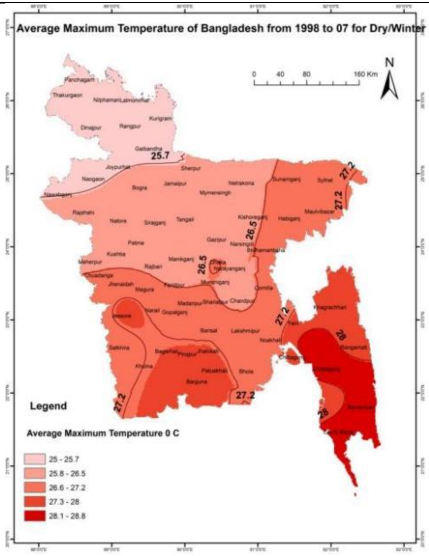

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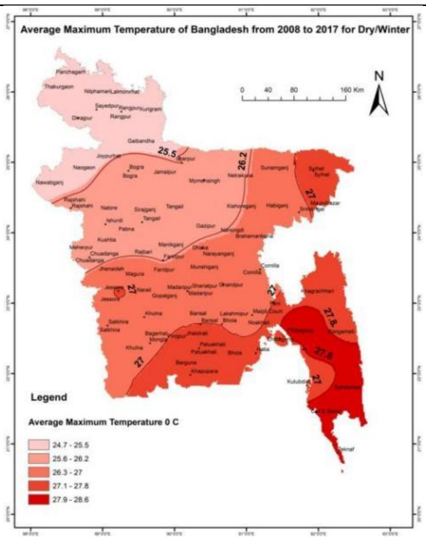


e)

Figure 4.47 a) Map of average maximum temperature of Bangladesh from 1968 to 1977 for Dry/ Winter b) Map of average maximum temperature of Bangladesh from 1978 to 1987 for Dry/ Winter c) Map of average maximum temperature of Bangladesh from 1988 to 1997 for Dry/Winter d) Map of average maximum temperature of Bangladesh from 1998 to 2007 for Dry/Winter e) Map of average maximum temperature of Bangladesh from 2008 to 2017 for Dry/Winter

Source: Analyzed by Author, based on BMD data set, 2022

Figure 4.47 indicates the average maximum temperature of Bangladesh from 1968 to 2017 for dry/ winter season. Map 4.47 a) indicates the average maximum temperature of

Bangladesh from 1968 to 1977 for dry/winter. From this map it was observed that the average maximum temperature range during this decade was existed from 25.4-27.5 °C. The highest temperature range 27.1-27.5 °C was observed in Bandarban, Rangamati, Cox's Bazar and part of Chittagong which wesre under south-eastern zone and part of Khulna under south-sentral zone. The lowest temperatuer range 25.4-25.8 °C was observed in northern part of the northern region which include the districts of Panchagar, Nilphamari, Lalmonirhat, Kurigram and part of Rangpur and part of north-western zone which include the districts of Thakurgaon, Dinajpur, part of Rangpur, Gaibandha.

Figure 4.47 b) indicates the average maximum temperature of Bangladesh from 1978 to 1987 for dry/winter. The this map it was observed that the average maximum temperature range during this decade was existed from 24.5-28.2 °C . The highest temperature range 27.5-28.2 °C was observed in Cox's Bazar, part of Bandarban, Chittagong under south-eastern zone. The lowest temperature range 24.5-25.2 °C was observed in northern part of the northern region which include the districts of Panchagar, Nilphamari, Lalmonirhat, Kurigram and part of Rangpur and part of north-western zone which include the districts of Thakurgaon, Dinajpur, part of Rangpur, gaibandha.

Figure 4.47 c) indicates the avearge maximum temperature of Bangladesh from 1988 to 1997 for dry/winter. The maximum temperature range 24.4- 27.9 °C was observed during this decade. The highest maximum temperature range 27.3-27.9 °C was observed in part of Cox's bazar, Bandarban, Chittagong under south-eastern zone. Again, the lowest maximum temperatuer range 24.4-25.1 °C was observed in northern part of the northern region which include the districts of Panchagar, Nilphamari, Lalmonirhat, Kurigram and part of Rangpur and part of north-western zone which include the districts of Thakurgaon, part of Dinajpur, Rangpur.

Figure 4.47 d) indicates the average maximum temperature of Bangladesh from 1998 to 2007 for dry/winter. The average maximum temperature range 25-28.8 °C was observed during this decade. The highest temperature range 28.1-28.8 °C was observed in part of Cox's bazar, Bandarban and part of Chittagong. Again, the lowest temperature range 25-25.7 °C was observed in northern part of the northern region which include the districts of Panchagar, Nilphamari, Lalmonirhat, Kurigram and part of Rangpur and part of north-western zone which include the districts of Thakurgaon, Dinajpur, Rangpur, Gaibandha and part of the north-western zone which include the districts of Naogaon, part of Nowabgang.

Figure 4.47 e) indicates the average maximum temperature of bangladesh from 2008 to 2017 for dry/winter. The average maximum temperature range 24.7-28.6 °C was observed in whole the time during this decade. The maximum temperature temperature range 27.9-28.7 °C was observed in Bandarban, part of Cox's Bazar, Chattagram. And the lowest temperature range 24.7-25.5 °C was observed in northern part of the northern region which include the districts of Panchagar, Nilphamari, Lalmonirhat, Kurigram and part of Rangpur and part of north-western zone which include the districts of Thakurgaon, Dinajpur, Rangpur, Gaibandha and part of the north-western zone which include the districts of Nowabgang, part of Naogaon.

Table 4.17: Decadal Average Maximum Temperature (Tmax) range of Bangladesh from 1968 to 2017 for Dry/Winter.

Decades	Temperature Range (Average) °C
1968-1977	26.49
1978-1987	26.57
1988-1997	26.44
1998-2007	26.91
2008-2017	26.72

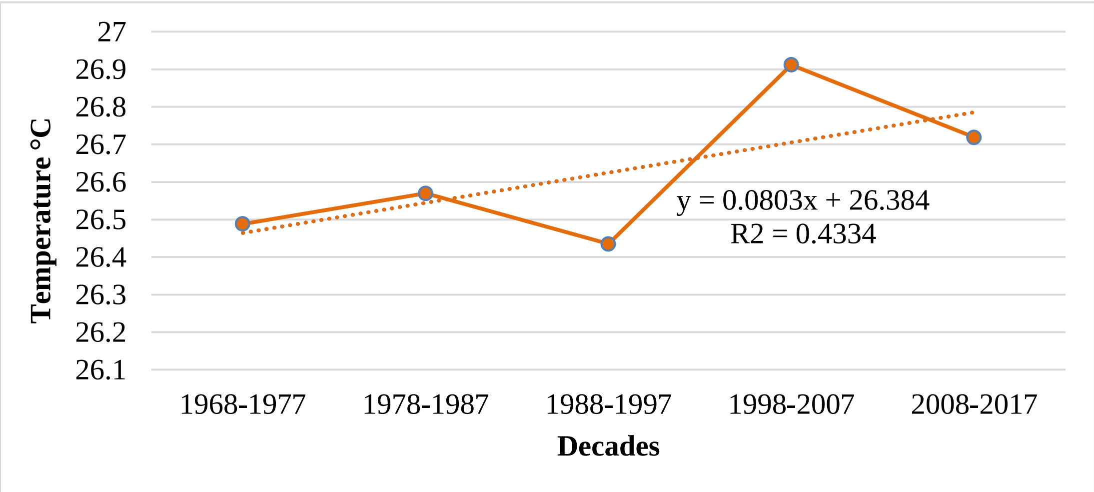


Figure 4.48: Trends of Average Maximum temperature of Bangladesh from 1968 to 2017 for Dry/Winter Season

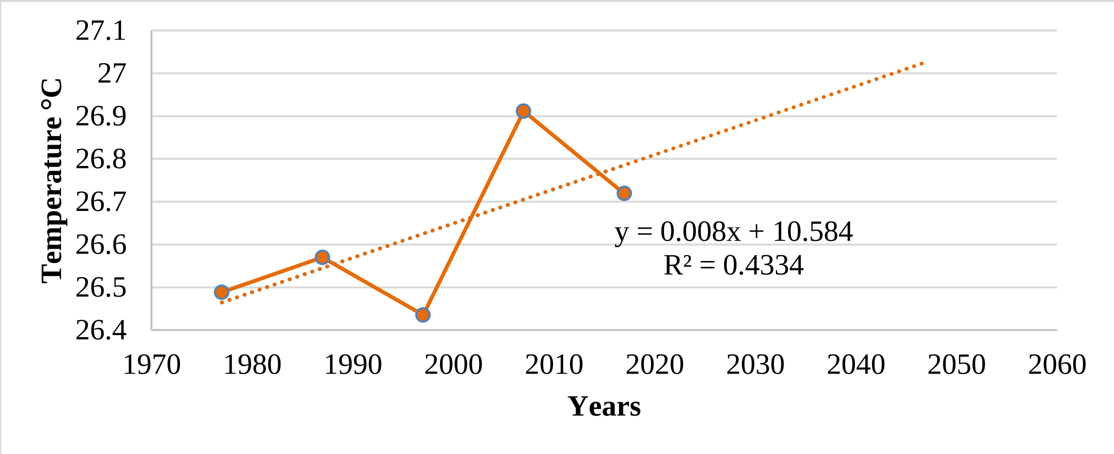


Figure 4.49: Projected Trends of Average Maximum temperature of Bangladesh for Dry/Winter Season

From Figure -4.48 it is noticed that the average maximum temperature of Bangladesh for the period of 1968 to 2017 for dry/winter in 50 years period has increased 0.4015 °C at rate of .0803 °C per decade. From the projected Figure 4.49 it noticed that in 2050 the temperature will increase 0.264 and in 2100 it will increase 0.664 °C at a rate of 0.008 °C per year.

4.2.4 Description of Climatic Zonal Trends and variability of Maximum Temperature:

4.2.4.1 Introduction:

Bangladesh has been divided into seven climatic zones according to Haron er rashid.
The climatic zones are as follows: -

1. South-eastern zone
2. North-eastern zone
3. Northern part of the northern zone
4. North-western zone
5. Western zone
6. South western zone
7. South central zone

The temperature trends of the above mentioned climatic zone are described bellow in the perspective of average minimum and average maximum basis.

4.2.4.1 Districts under climatic zone as prescribed by Haroun or Rashid (1991)

Table 4.18 Districts under climatic zones.

Name of the Climatic Zones	Name of the Districts
South-eastern zone	Barguna, Patuakhali, Bhola, Lakshmipur, Noakhali, Feni, Khagrachari, Rangamati, Chattagram, Bandarban, Cox's Bazar
North-eastern zone	Sylhet, Sunamganj, Moulvibazar
Northern part of the northern region	Panchagar, Thakurgaon, Nilphamari, Lalmonirhat, Rangpur, Kurigram
North-western zone	Dinajpur, Gaibandha, Bogra, Sirajganj, Pabna, Kustia, Meherpur, Chuadanga
Western zone	Nawabganj, Rajshahi, Naogaon, Joypurhat, Natore
South-western zone	Rajbari, Jhenaidah, Magura, Faridpur, Jessore, Narail, Satkhira, Khulna
South-Central zone	Dhaka, Manikgonj, Munshiganj, Narayanganj, Mymensingh, Sherpur, Jamalpur, Netrokona, Tangail, Kishoregonj, Gazipur, Hobiganj, Narshindhi, Brahmanbaria, Cumilla, Chandpur, Madaripur, Shariatpur, Gopalganj, Barishal, Pirojpur and bagerhat.
Source: Adapted from Rashid (1991)	

4.2.4.1 Average Maximum Temperature: From Figure 4.50 a) it was observed that the average maximum temperature for the time period of 1968 to 1977 was recorded in the northern part of the northern region with recorded temperature 31.47 °C followed by western zone recorded temperature 31.04 °C, north-western zone recorded temperature 30.84 °C, south-western zone recorded temperature 30.69 °C, south-eastern zone temperature recorded

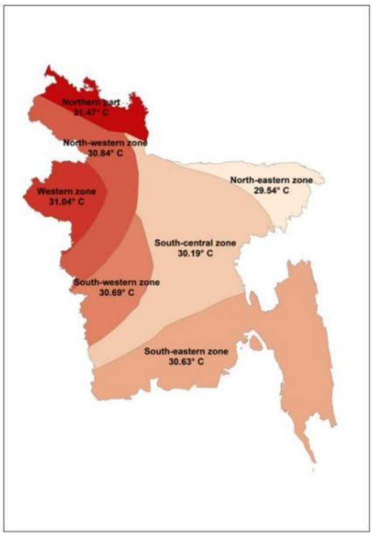
30.63 °C, south-central zone temperature recorded 30.19 °C and north-eastern zone temperature recorded 29.54 degree Celcious.

From Figure 4.50 b) it was observed that the average maximum temperature for the period of 1978 to 1987 the south-western zone received 30.74 °C followed by western zone received temperature 30.49 °C, south-central zone received temperature 30.31 °C, north-western zone received temperature 30.2 °C, south-easten zone temperature received 30.11 °C, north-eastern zone received temperature 29.95 °C and northern part of the northern region received temperature 29.75 degree Celcious.

From Figure 4.5°C) it was observed that the average maximum temperature for the period of 1988 to 1997 was recorded in the south-western zone which was 31.07 °C followed by western zone recorded temperature 30.89 °C, north-western zone recorded temperature 30.51 °C, south-central zone recorded temperature 30.41 °C, south-eastern zone recorded temperature 30.27 °C, north-eastern zone recorded temperature 30.94 °C and northern part of the northern region recorded temperature 29.81 °C.

From Figure 4.50 d) it was observed that the average maximum temperature for the period of 1998 to 2007 was recorded in the south-western zone which was 31.23 °C followed by south-western zone temperature recorded 30.76 °C, western zone temperature recorded 30.76 °C, north-western zone temperature recorded 30.51 °C, south-central zone temperature recorded 30.49 °C , north-eastern zone temperature recorded 30.34 °C and northern part of the northern region temperature recorded 29.93 °C.

It was observed from Figure -4.50 e) that the average maximum temperature for the period of 2008 to 2017 was recorded in the south-western zone which was 31.52 °C followed by western zone temperature recorded 31.18 °C, south-eastern zone temperature recorded 30.98 °C, north-western zone temperature recorded 30.84, south-central zone temperature recorded 30.83 °C, north-eastern zone temperature recorded 30.75 °C and northern part of the northern region temperature recorded 30.19 degree celcious.



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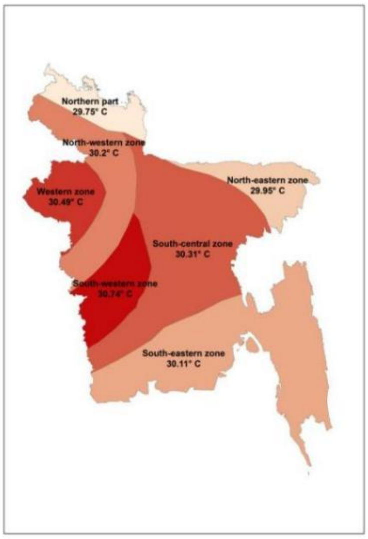

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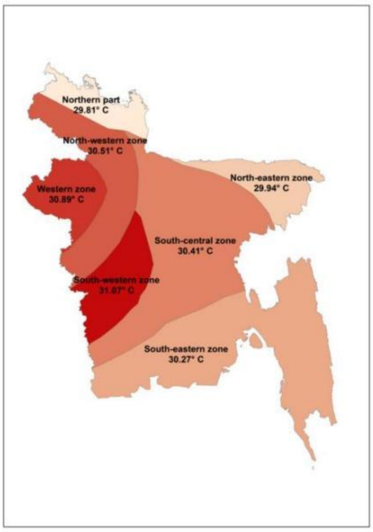

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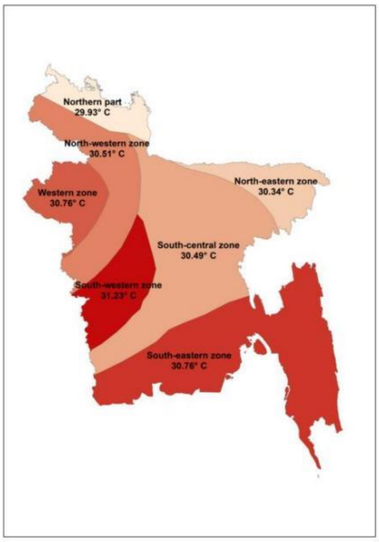

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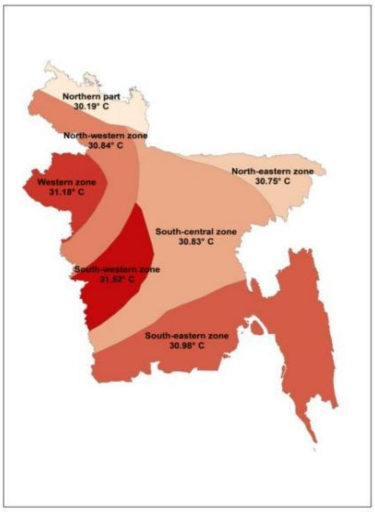


e)

Figure 4.50 a) Climatic zonal maximum temperature (T max) of Bangladesh from 1968 to 1977 b) Climatic zonal maximum temperature (T max) of Bangladesh from 1978 to 1987 c) Climatic zonal maximum temperature (T max) of Bangladesh from 1988 to 1997 d) Climatic zonal maximum temperature (T max) of Bangladesh from 1998 to 2007 e) Climatic zonal maximum temperature (T max) of Bangladesh from 2008 to 2017.

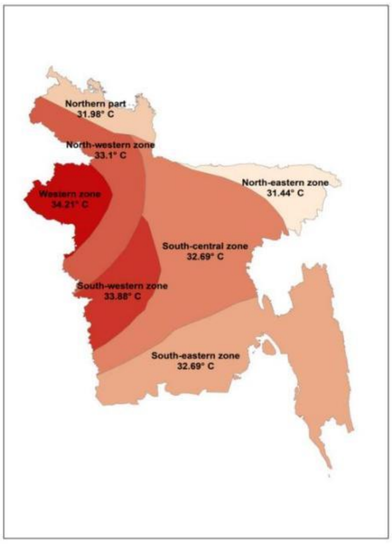
Source: Analyzed by Author, based on BMD data set, 2022.

4.2.4.2 Premonsoon: In premonsoon period the maximum temperature increases gradually in the cycle of season. From Figure 4.51 a) it was observed that the average maximum temperature for premonsoon for the period of 1968 to 1977 was recorded in the western zone which was 34.21 °C followed by south-western zone temperature recorded 33.88 °C, north-western zone temperature recorded 33.1 °C, south-central zone temperature recorded 32.69 °C, south-eastern zone temperature recorded 32.69 °C, northern part of the northern region temperature recorded 31.98 °C and north-eastern zone temperature recorded 31.44 °C.

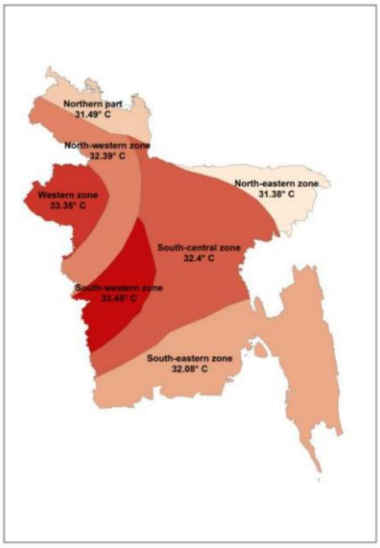
From Figure 4.51 b) it was observed that during the period of 1978 to 1987 the average maximum temperature for premonsoon was recorded in the south-eastern zone with temperature recorded 33.45 °C followed by western zone temperature recorded 33.35 °C, south-central zone temperature recorded 32.4 °C, north-western zone temperature recorded 32.39 °C, south western zone 32.08 °C ,northern part of the northern region temperature recorded 31.49 °C and north-eastern region temperature recorded 31.38 °C.

Figure 4.51 c) indicate the map of maximum average temperature for premonsoon for the period of 1998-2007. From this Figure it was observed that during this season the temperature was recorded in the south-eastern zone which was 34.14 °C. followed by western zone temperature recorded 34.09 °C, north-western zone temperature recorded 33.18 °C, south-central zone temperature recorded 32.56 °C, south-eastern zone temperature recorded 32.34 °C, northern part of the northern region 31.9 °C and north-eastern zone temperature recorded 31.19 °C.

Figure 4.51 d) showed the average maximum temperature for premonsoon for the period of 1998 to 2007. From this Figure it was observed that the highest temperature was recorded in the south-western zone which was 34 °C followed by western-zone recorded temperature 33.38°C, south-eastern zone recorded temperature 32.76 °C, north-western zone temperature recorded 32.57 °C, south-central zone 32.36 °C, north-eastern zone 31.35 °C and northern part of the northern region 31.29 °C.



a)



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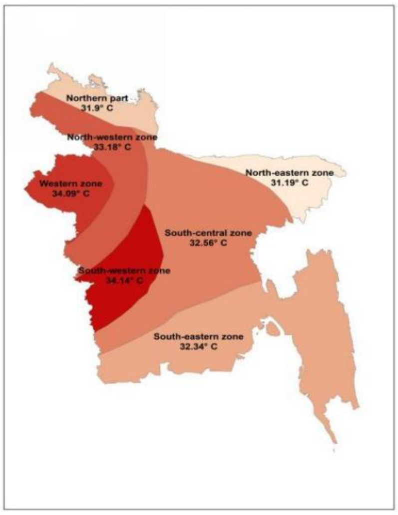

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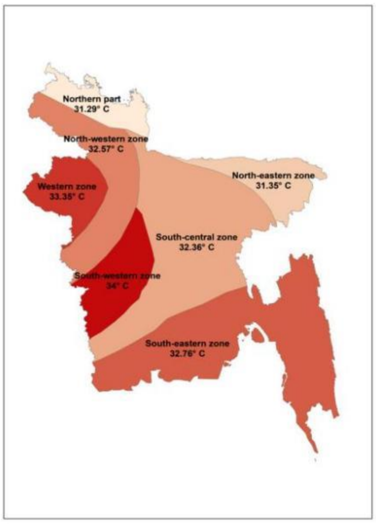

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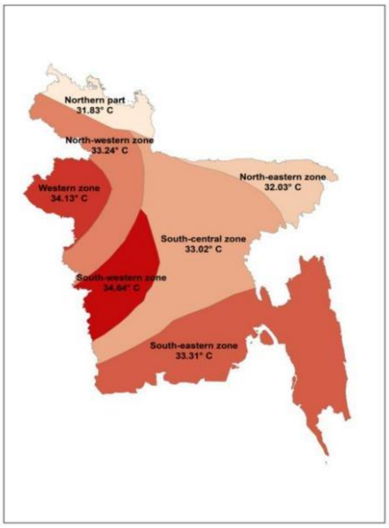


e)

Figure :4.51 a) Climatic zonal maximum temperature of Bangladesh from 1968 to 1977 for premonsoon b) Climatic zonal maximum temperature of Bangladesh from 1978 to 1987 for premonsoon c) Climatic zonal maximum temperature of Bangladesh from 1988 to 1997 for premonsoon d) Climatic zonal maximum temperature of Bangladesh from 1998 to 2007 for premonsoon e) Climatic zonal maximum temperature of Bangladesh from 2008 to 2017 for premonsoon.

Source: Analyzed by Author, based on BMD data set, 2022.

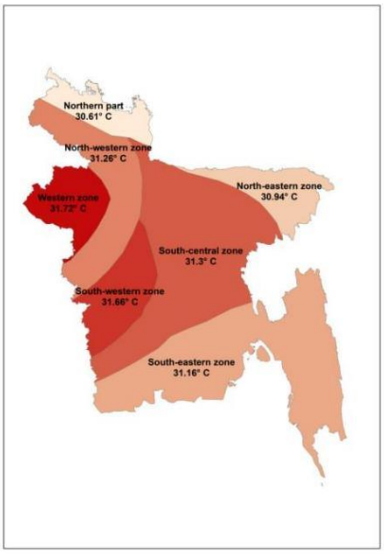
Again from Figure 4.51 e) it was noticed that the average maximum temperature for premonsoon for the period of 2008 to 2017 was recorded in the south-western zone which was 34.64 °C followed by western zone 34.13 °C, south-eastern zone 33.31 °C, north-western zone 33.24 °C, south-central zone 33.02 °C, north-eastern zone 33.03 °C and northern part of the northern region 31.83 °C.

4.2.4.3 Monsoon: The average maximum temperature during the monsoon is usually hot although at this season the maximum rainfall occurs. From Figure -4.52 a) it was observed that the average maximum temperature for monsoon for the period of 1968 to 1977 was recorded in the western zone which was 31.72 °C followed by south-western zone temperature recorded 31.66 °C, south-central zone 31.3 °C, north-western zone 31.26 °C, south-eastern zone 31.16 °C, north-eastern zone 30.94 °C and northern part of the northern region temperature recorded 30.61 degree celcious.

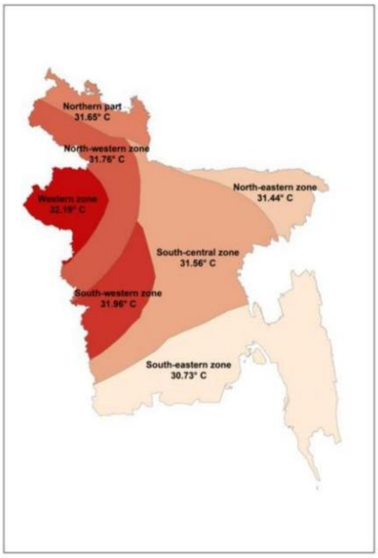
From Figure 4.52 b) it was observed that the average maximum temperature for monsoon for the period of 1978 to 1987 was recorded in the western zone recorded temperature was 32.19 °C followed by south-western zone temperature recorded 31.96 °C, north-western zone 31.76 °C,northern part of the northern region 31.66 °C, south-central zone 31.56 °C,north-eastern zone temperature recorded 31.44 °C and south-eastern zone temperature recorded 30.73 degree Celcious recorded.

From Figure 4.52 c) it was again observed that the average maximum temperature for monsoon during the period of 1988 to 1997 was recorded in the western zone the temperature recorded was 32.51 °C followed by south-western zone temperature recorded was 32.34 °C , north-western zone 32.2 0c, south-central zone temperature recorded 31.85 0c, northern part of the northern region 31.78 °C, north-eastern zone 31.67 °C and south-eastern zone 31.23 0 recorded temperature .

From Figure 4.52 d) it was also observed that during the period of 1998 to 2007 the average maximum temperature for monsoon was recorded in the western zone with temperature recorded 32.81 °C followed by south-western zone 32.73 °C, north-western zone 32.52 °C, northern part of the northern region 32.1 °C, south-central zone 31.99 °C, north-eastern zone 31.98 °C and south-eastern zone 31.56 °C temperature recorded.



a)



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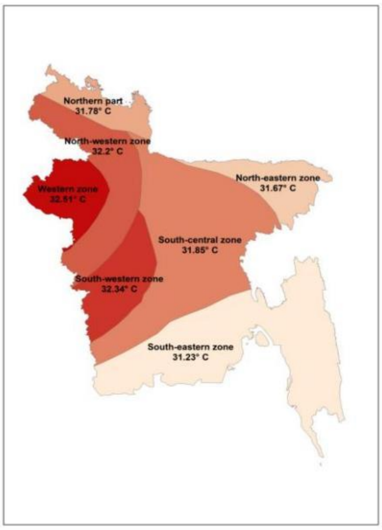

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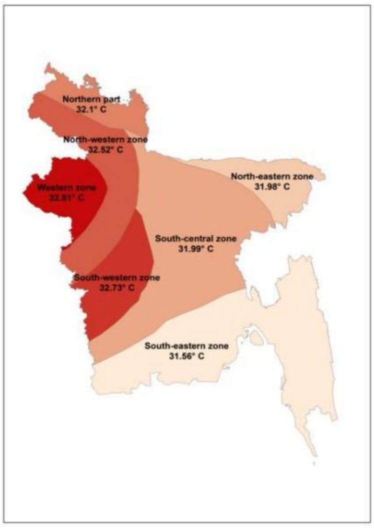

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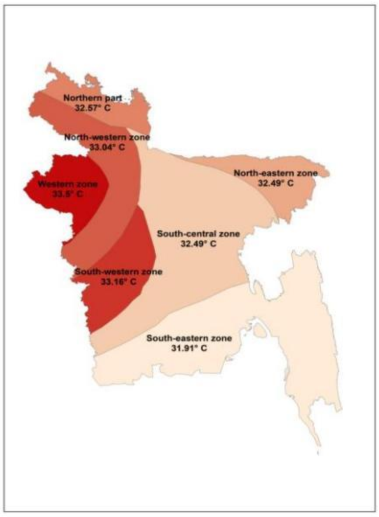


e)

Figure : 4.52 a) Climatic zonal maximum temperature of Bangladesh from 1968 to 1977 for monsoon b) Climatic zonal maximum temperature of Bangladesh from 1978 to 1987 for monsoon c) Climatic zonal maximum temperature of Bangladesh from 1988 to 1997 for monsoon d) Climatic zonal maximum temperature of Bangladesh from 1998 to 2007 for monsoon e) Climatic zonal maximum temperature of Bangladesh from 2008 to 2017 for monsoon.

Source: Analyzed by Author, based on BMD data set, 2022.

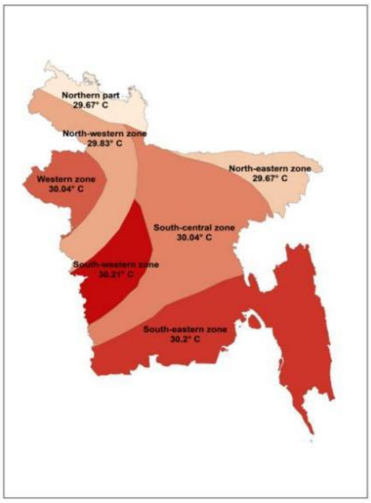
Again, from Figure 4.52 e) it was also observed that during the decade of 2008-2017 the average maximum temperature for monsoon was recorded in the western zone with temperature 33.5 °C followed by south-western zone 33.16 °C, north-western zone 33.04 °C, northern part of the northern region 32.67 °C, north-eastern zone 32.49 °C, south-central zone 32.49 °C and south-eastern zone 31.91 degree Celcious.

4.2.4.4 Post-monsoon: This season consists of the month of October and November remains somewhat less warm than other season except dry or winter. From Figure 4.53 a) it was observed that during the period of 1968 to 1977 the average maximum temperature for post-monsoon was recorded in the south-western zone with recorded temperature 30.21 °C followed by south-eastern zone 30.2 °C, western zone 30.04 °C, south-central zone 30.04 °C, north-western zone 29.83 °C, north-eastern zone 29. 67 °C and northern part of the northern region temperature recorded 29.67 degree Celcious.

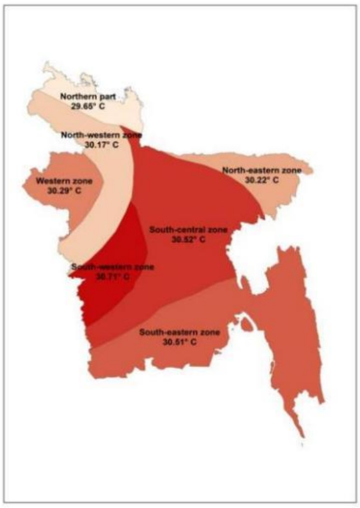
From Figure 4.53 b) it was also observed that during the decade of 1978 to 1987 the average maximum temperature for post-monsoon was recorded in the south-western zone which was 30.71 °C followed by south-central zone 30.52 °C, south-eastern zone 30.51 °C, western zone 30.29 °C , north-eastern zone 30.22 °C, north-western zone 30.17 °C, and northern part of the northern region temperature recorded 29.65 degree Celcious.

From Figure 4.53 c) it was observed that during the period of 1988 to 1997 the average maximum temperature for post-monsoon was recorded in the south-western zone which was 30.79 °C followed by south-central zone 30.52 °C, western zone 30.49 °C, south-eastern zone 30.48 °C, north-western zone 30.43 °C, north-eastern zone 30.32 °C, northern part of the northern region 30.04 °C temperature recorded.

From Figure 4.53 d) it was also observed that the average maximum temperature for post-monsoon for the period of 1998 to 2007 was recorded in the south-western zone which was 31 °C followed by south-eastern zone 30.98 °C, north-eastern zone 30.65 °C, south-central zone 30.64 °C, western zone 30.54 °C, north-western zone 30.51 °C and northern part of the Northern region temperature recorded 30 °C.



a)



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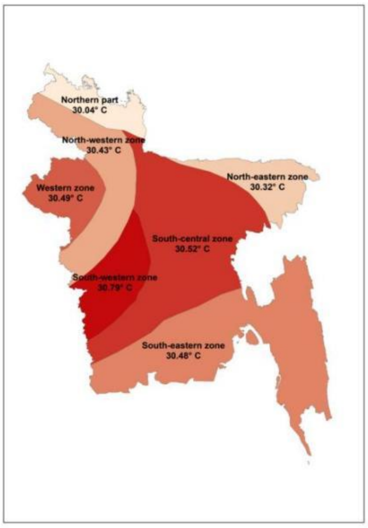

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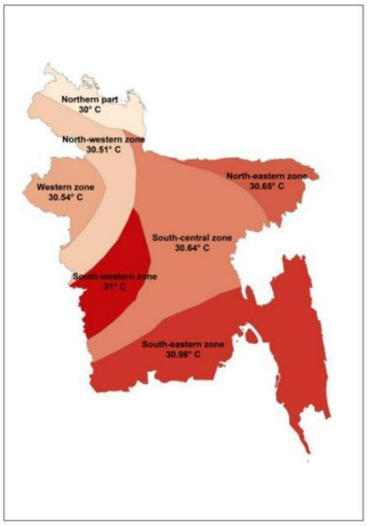

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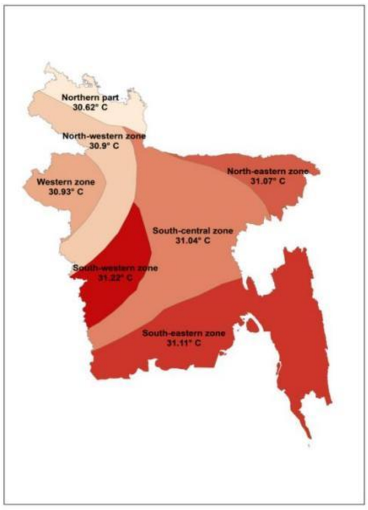


e)

Figure :4.53 a) Climatic zonal maximum temperature of Bangladesh from 1968 to 1977 for postmonsoon b) Climatic zonal maximum temperature of Bangladesh from 1978 to 1987 for postmonsoon c) Climatic zonal maximum temperature of Bangladesh from 1988 to 1997 for postmonsoon d) Climatic zonal maximum temperature of Bangladesh from 1998 to 2007 for postmonsoon e) Climatic zonal maximum temperature of Bangladesh from 2008 to 2017 for postmonsoon.

Source: Analyzed by Author, based on BMD data set, 2022.

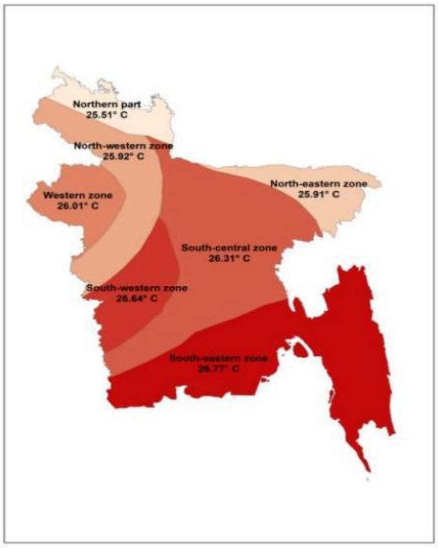
Again, from Figure 4.53 e) it was noticed that during the decade of 2008 to 2017 the average maximum temperature for post-monsoon was recorded in the south-western zone temperature recorded 31.22 °C followed by south-eastern 31.11 °C, north-eastern zone 31.07 °C, south-central 31.04 °C, western zone 30.93 °C, north-western zone 30.9 °C and northern part of the northern region temperature recorded 30.62 degree Celcious.

4.2.4.5 Dry/Winter: The months December, January and February constitute the dry/ winter season when the average maximum temperature fall down. During this period temperature variation are noticed in different climatic zones. From Figure 4.54 a) it was observed that the average maximum temperature for dry/winter during the period of 1968 to 1977 was recorded in the south-eastern zone which was 26.77 °C followed by south-western zone temperature recorded 26.64 °C, south-central zone 26.31 °C ,western zone 26.01 °C, north-western zone 25.92 °C, north-eastern zone 25.91 °C and northern part of the northern region 25.51 °C.

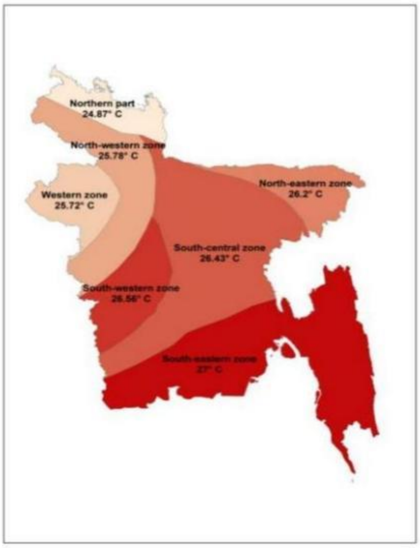
From Figure 4.54 b) it was also observed that during the period of 1978 to 1987 the average maximum temperature recorded in the south-western zone which was 27 °C followed by south-western zone temperature recorded 26.56 °C , south-central zone 26.43 °C, north-eastern zone 26.2 °C, north-western 25.78 °C,western zone 25.72 °C and northern part of the northern region temperature recorded 24.87 degree Celcious.

From Figure 4.54 c) it was noticed that the average maximum temperature for dry/winter for the period of 1988 to 1997 the highest temperature recipient climatic zone was the south-eastern zone which received 26.86 °C followed by south-western 26.47 °C, south-central 26.25 °C, north-eastern zone 26.14 °C, western zone 25.85 °C,north-western zone 25.61 °C and northern part of the northern region 24.75 degree Celcious.

Figure -4.54 d) indicate the average maxmimum temperature for dry/winter for the period of 1998 to 2007. From this Figure it was observed that the south-eastern zone received highest amount of temperature which was 27.56 °C followed by south-eastern zone temperature recorded 26.85 °C, south-western zone 26.77 °C, south-central 26.45 °C, western zone 25.77 °C, North-western zone 25.73 °C, and northern part of the northern region temperature received 25.14-degree Celcious.



a)



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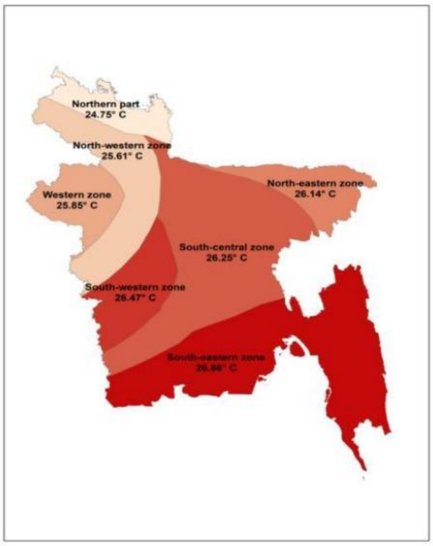
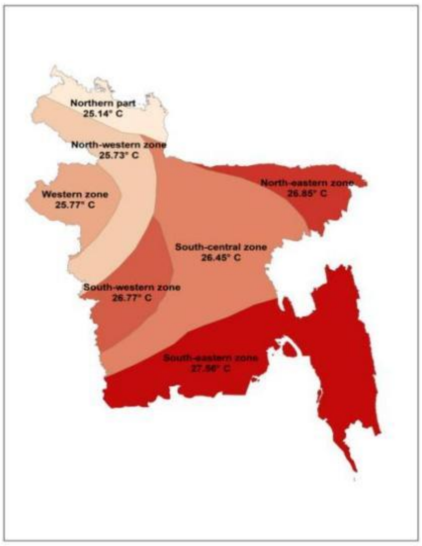


C)



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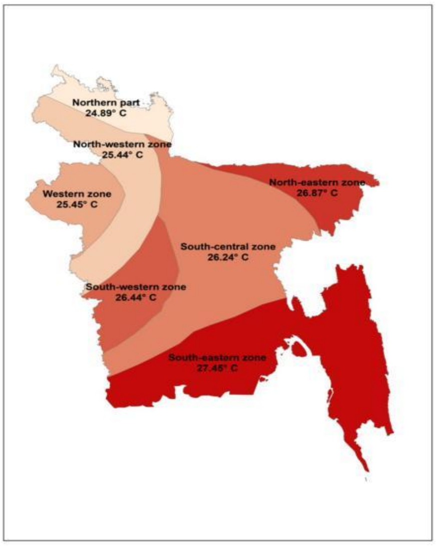


e)

Figure :4.54 a) Climatic zonal maximum temperature of Bangladesh from 1968 to 1977 for dry/winter b) Climatic zonal maximum temperature of Bangladesh from 1978 to 1987 for dry/winter c) Climatic zonal maximum temperature of Bangladesh from 1988 to 1997 for dry/winter d) Climatic zonal maximum temperature of Bangladesh from 1998 to 2007 for dry/winter e) Climatic zonal maximum temperature of Bangladesh from 2008 to 2017 for dry/winter.

Source: Analyzed by Author, based on BMD data set, 2022.

Again Figure 4.54 e) indicate the average maximum temperature for dry/winter for the decade of 2008 to 2017. From this Figure it was observed that the highest temperature was recorded in the south-eastern zone which was 27.45 °C followed by north-eastern zone 26.87 °C, south-western zone 26.44 °C, south-central zone 26.24 °C, western zone 25.45 °C, north-western zone 25.44 °C and northern part of the northern region temperature recorded 24.89 degree Celcious.

4.2.5 Climatic Zonal Average Temperature (Tmax) Trends:

4.2.5.1 South-Eastern:

From table -4.19 it is found the average temperature (Tmax) of the south-eastern zone from which the trends of temperature has been detected.

Table 4.19: Decadal Average Temperature (Tmax) Range of South-Eastern Zone

Decades	Temperature Range °C
1968-1977	30.73
1978-1987	30.11
1988-1997	30.16
1998-2007	30.63
2008-2017	30.80

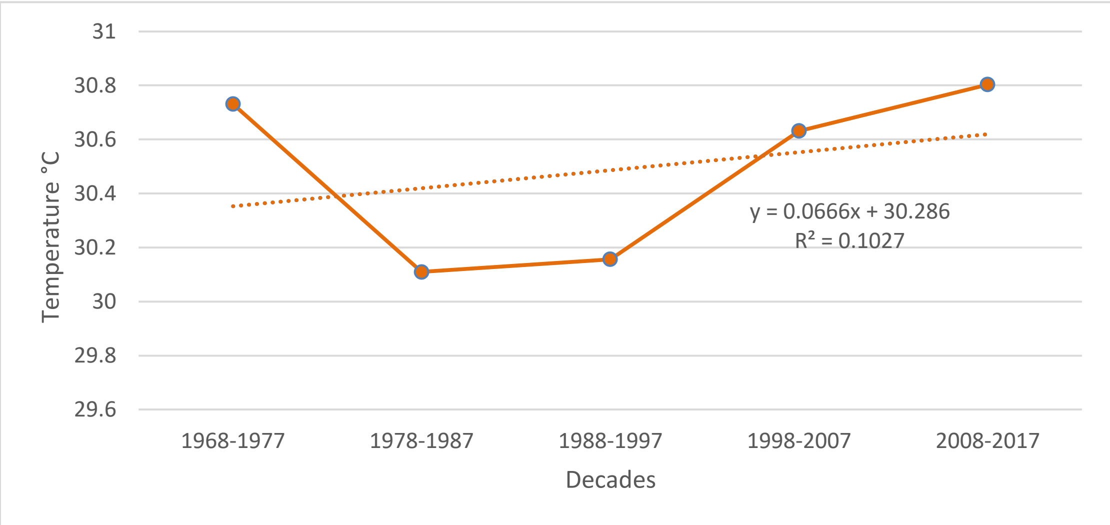


Figure 4.55: Trends of Average Maximum temperature of South-Eastern Zone from 1968-2017

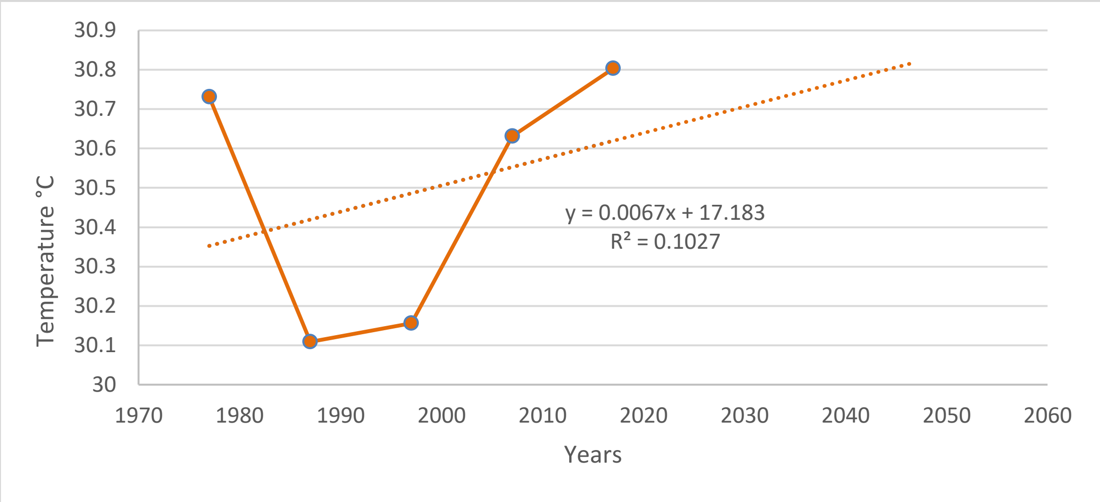


Figure 4.56: Projected Trends of Average Maximum temperature of South-Eastern Zone

From Figure 4.55 it is noticed that the average temperature (Tmax) of the South-Eastern zone is on the increase. It is also observed that the average temperature of this climatic region has increased 0.333 °C in the 50 years from 1968 to 2017 time period at a rate of 0.0666 °C. From Figure 4.56 it is also observed that the projected rate of increasing the average temperature is 0.0067 °C and at this rate the average temperature will increase 0.2211 °C in 2050 and 0.5561 °C in 2100.

4.2.5.2 North-Eastern:

Table 4.20 shows the average temperature (Tmax) of the North-Eastern zone of Bangladesh.

The average temperature range of this zone has been detected from the table bellow.

Table 4.20: Decadal Average Temperature (Tmax) Range of North-Eastern Zone.

Decades	Temperature Range (Average) °C
1968-1977	29.58
1978-1987	30.06
1988-1997	30.05
1998-2007	30.49
2008-2017	30.93

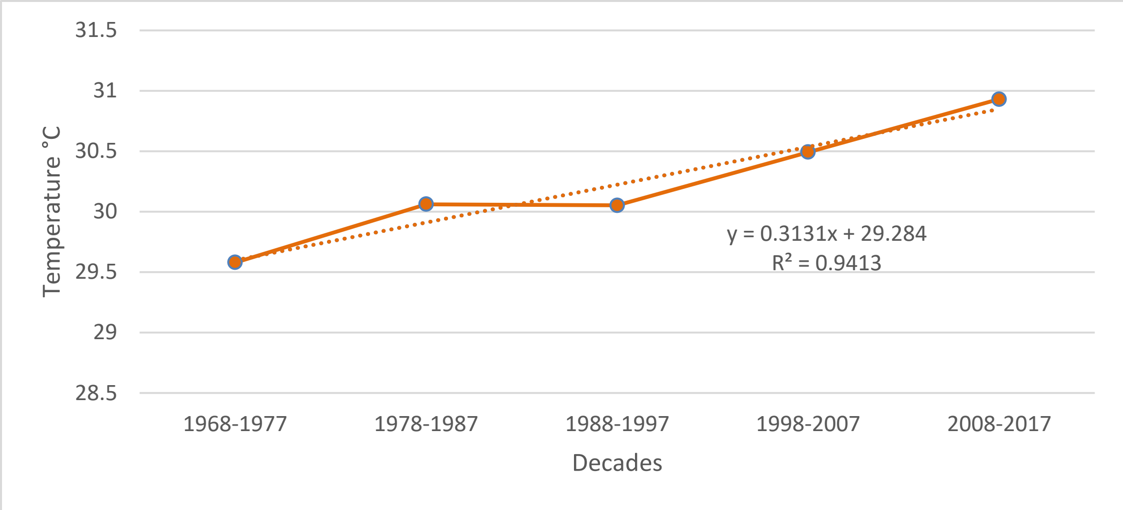


Figure 4.57: Trends of Average Maximum temperature of North-Eastern Zone from 1968-2017

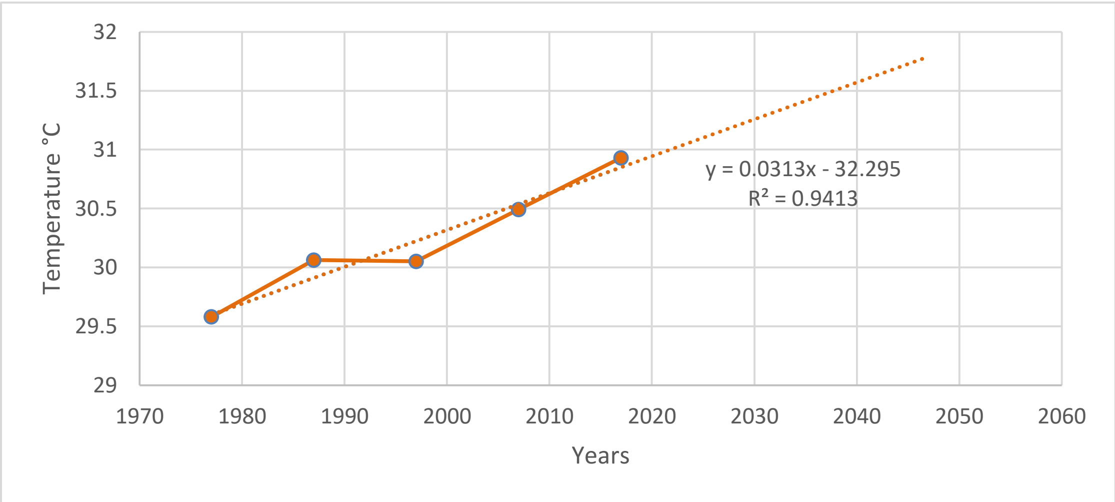


Figure 4.58: Projected Trends of Average Maximum temperature of North-Eastern Zone

From Figure 4.57 it is noticed that the trends of average temperature (Tmax) of the North-Eastern zone is on the increase and the increasing rate is 0.3131 °C per decade. At this rate the temperature has increased 1.5655 °C in the 50year period from 1968 to 2017. From Figure 4.58 it is also found that the projected rate of average temperature of this zone is 0.0313 °C per year. At this rate the average temperature (Tmax) of this zone will increase 1.0329 °C in 2050 and 2.5979 °C in 2100.

4.2.5.3 Northern Part of the Northern Region:

Table 4.21 shows the average temperature (Tmax) of the Northern Part of the Northern region. From this table the trends of the average temperature have been detected.

Table 4.21: Decadal Average Temperature (Tmax) Range of Northern Part of the Northern Region.

Decades	Temperature Range °C
1968-1977	32.12
1978-1987	29.64
1988-1997	29.65
1998-2007	29.80
2008-2017	30.14

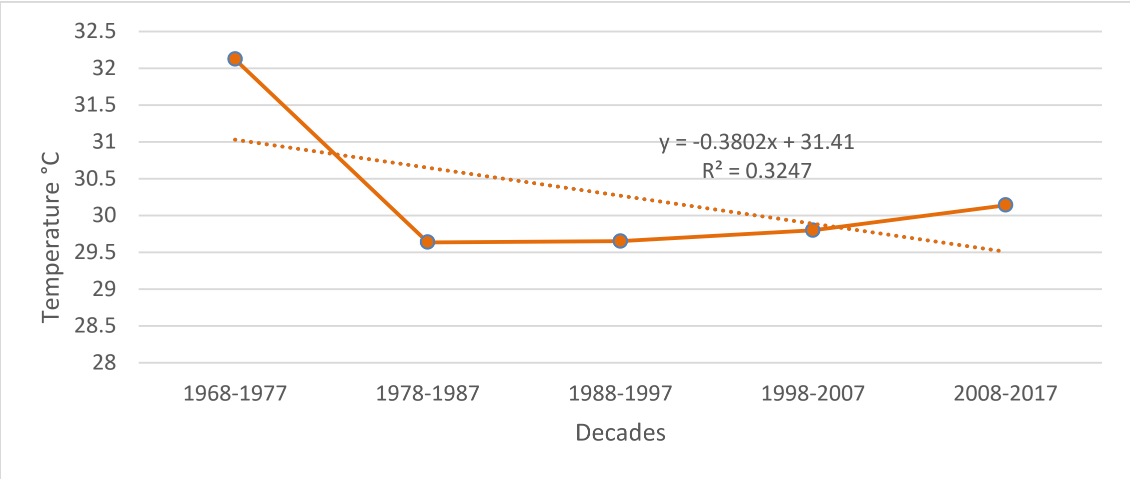


Figure 4.59: Trends of Average Maximum Temperature of Northern Part of the Northern Region from 1968-2017

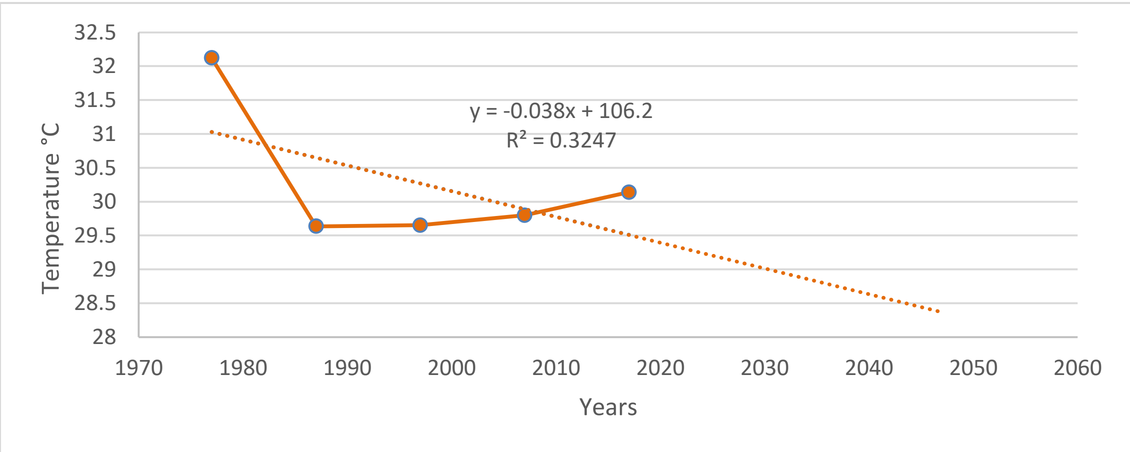


Figure 4.60: Projected Trends of Average Temperature of Northern Part of the Northern Region

From Figure 4.59 it in noticed that the average temperature (Tmax) of the northern part of the northern region is on the declining trend. The average temperature of this region is decreasing at a rate of 0.3802 °C and in the time period of 1968 to 2017 the temperature has decreased 1.901 °C. From Figure 4.60 it is also observed that the projected decreasing trends of temperature is 0.038 °C per year. And at this rate the temperature will decrease 1.254 °C in 2050 and 3.154 °C in 2100.

4.2.5.4 North-Western:

Table -4.22 shows the decadal rage of average temperature (Tmax) of the North-Western zone. From this table the trends of temperature of this region have been detected.

Table 4.22: Decadal Average Temperature (Tmax) Range of North-Western Zone from 1968-2017

Decades	Temperature Range °C
1968-1977	30.52
1978-1987	30.06
1988-1997	30.87
1998-2007	30.71
2008-2017	30.98

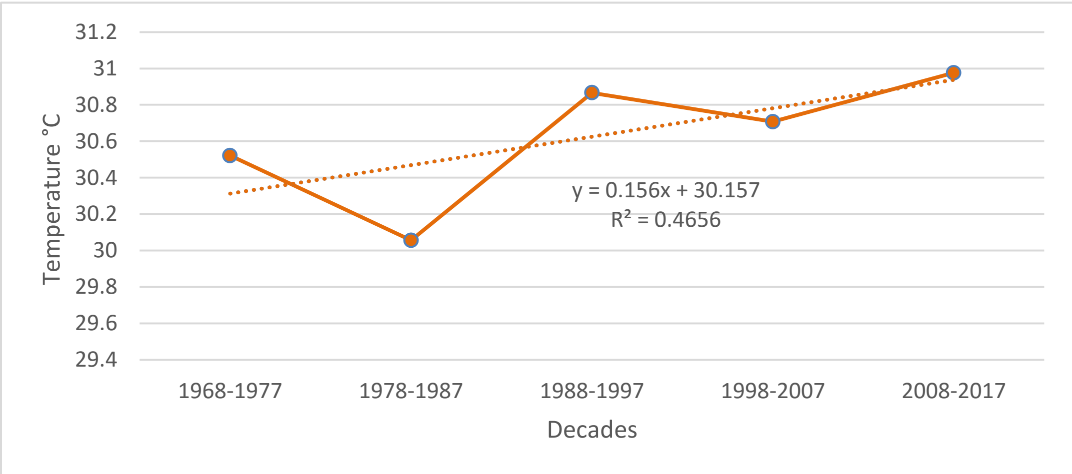


Figure 4.61: Trends of Average Temperature of North-Western Zone from 1968-2017

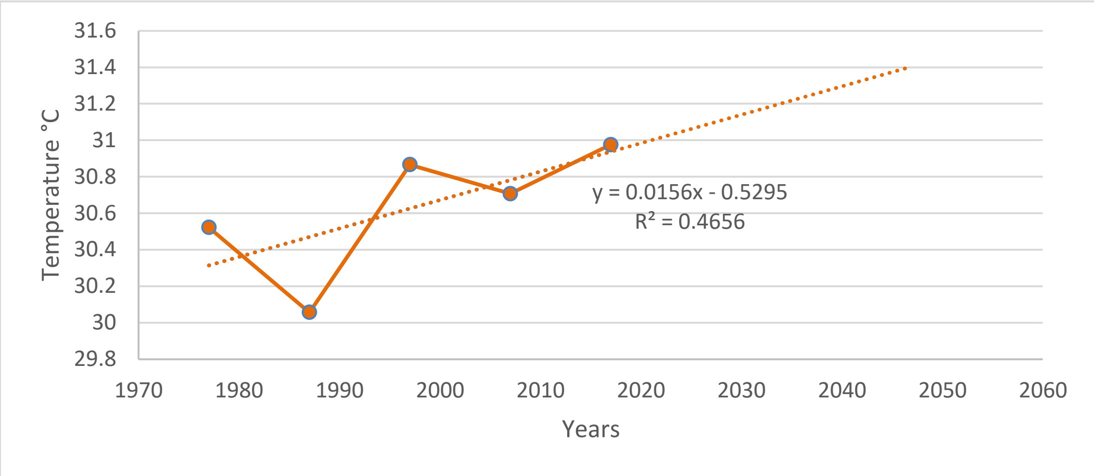


Figure 4.62: Projected Trends of Average Temperature of North-Western Zone

From Figure 4.61 it is observed that the trends of average temperature (Tmax) of the north-western zone of Bangladesh is on the increase. The temperature is increasing at a rate of 0.156 °C per decade and in the 50 years period from 1968 to 2017 the temperature has increased 0.78 °C. From Figure 4.62 it also observed that the projected increasing of temperature is 0.0156 °C per year and at this rate the average temperature of this region will increase 0.5148 °C in 2050 and 1.2948 °C in 2100.

4.2.5.5 Western:

Table shows the average temperature (Tmax) range of the western zone from which the trends of the temperature has been detected.

Table 4.23: Decadal Average Temperature (Tmax) Range of Western Zone from 1968-2017

Decades	Temperature Range °C
1968-1977	31.17
1978-1987	30.95
1988-1997	31.12
1998-2007	31.11
2008-2017	31.52

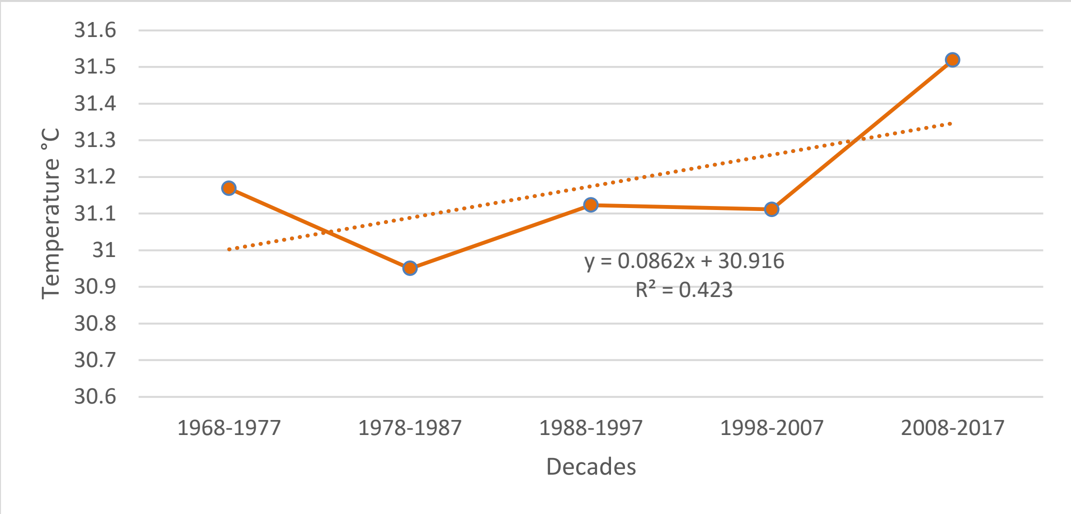


Figure 4.63: Trends of Average Maximum temperature of Western Zone from 1968-2017

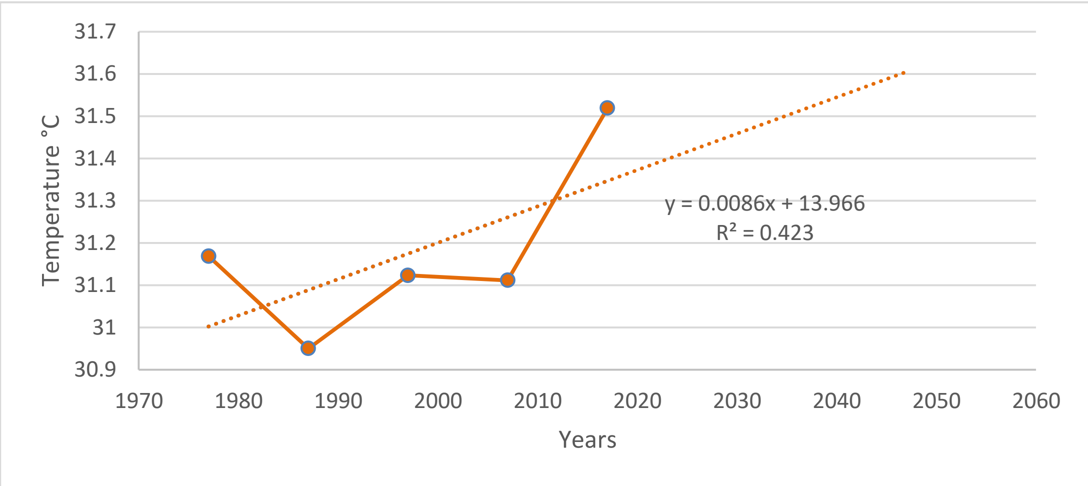


Figure 4.64: Projected Trends of Average temperature of Western Zone

From Figure 4.63 it is observed that the trends of average temperature (Tmax) of the the western zone of Bangladesh is on the increase. The temperature is increasing at the rate of 0.0862 °C per decade and the average temperature has increased 0.431 °C in the 50 years period of 1968 to 2017. From Figure 4.64 it is also observed that the projected rate of increasing the average temperature is 0.0086 °C per year and at this rate the temperature will increase 0.2838 °C in 2050 and 0.7138 °C in 2100.

4.2.5.6 South-Western:

According to the data (Table 4.24), the temperature range (averaged over the decade) (Tmax) has increased over time the south-western zone. From 1968-1977, the average temperature range was 30.99°C, while in the most recent decade from 2008-2017, the average temperature range was 31.59°C. This increase in temperature is likely due to a combination of factors, including human activities such as burning fossil fuels and deforestation, which release greenhouse gases into the atmosphere and contribute to global warming.

Table 4.24 Decadal Average Temperature (Tmax) Range of South-Western Zone

Decades	Temperature Range (Average) °C
1968-1977	30.99
1978-1987	31.05
1988-1997	31.19
1998-2007	31.33
2008-2017	31.59

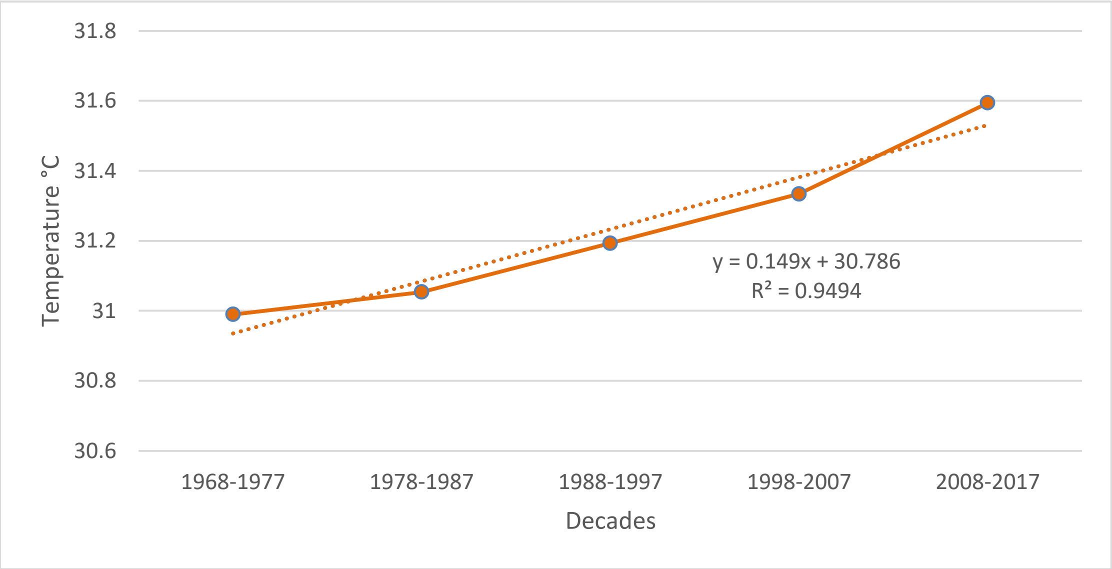


Figure 4.65 Trends of Average Maximum Temperature of South-Western Zone from 1968-2017

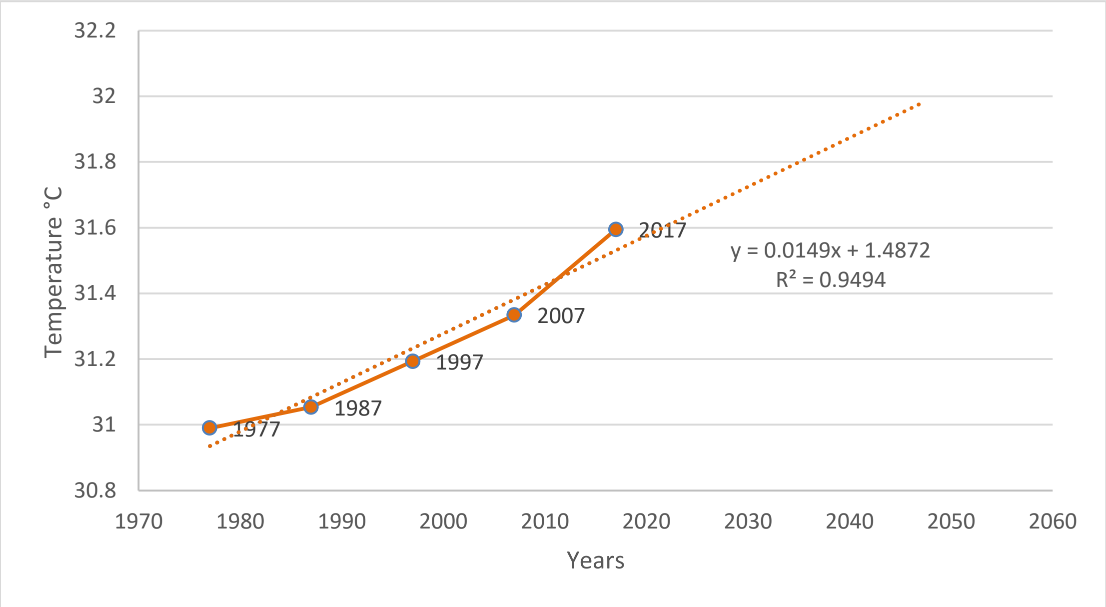


Figure 4.66 Projected Trends of Average Temperature of South-Western Zone

From Figure 4.65 it is found that the average temperature (Tmax) of the south western region is on the increase. The average temperature is increasing at the rate of 0.149 °C per decade and in the 50 years time period from 1968 to 2017the temperature will increase 0.745 °C. From fig -4.66 it is observed that the projected trends of temperature is 0.0149 °C per year. At this rate the average temperature will increase 0.4917 °C in 2050 and 1.2367 °C in 2100.

4.2.5.7 South-Central:

The average temperature range (Tmax) has increased over time, as can be seen from the data (Table 4.25) . In the first decade from 1968-1977, the average temperature range was 30.17°C, while in the most recent decade from 2008-2017, the average temperature range was 30.94°C. This increase in temperature over time is consistent with the trend of global warming that has been observed in recent decades.

It's worth noting that there are variations in the temperature range from year to year, and these fluctuations can be influenced by a variety of factors, such as El Niño/La Niña events, volcanic eruptions, solar radiation, and human activities. However, the overall trend of increasing temperatures over time is a clear indication of the impact of human activities on the environment and the urgent need for action to mitigate the effects of climate change.

Table 4.25: Decadal Average Temperature (Tmax) Range of South-Central Zone

Decades	Temperature Range (Average) °C
1968-1977	30.17
1978-1987	30.28
1988-1997	30.46
1998-2007	30.61
2008-2017	30.94

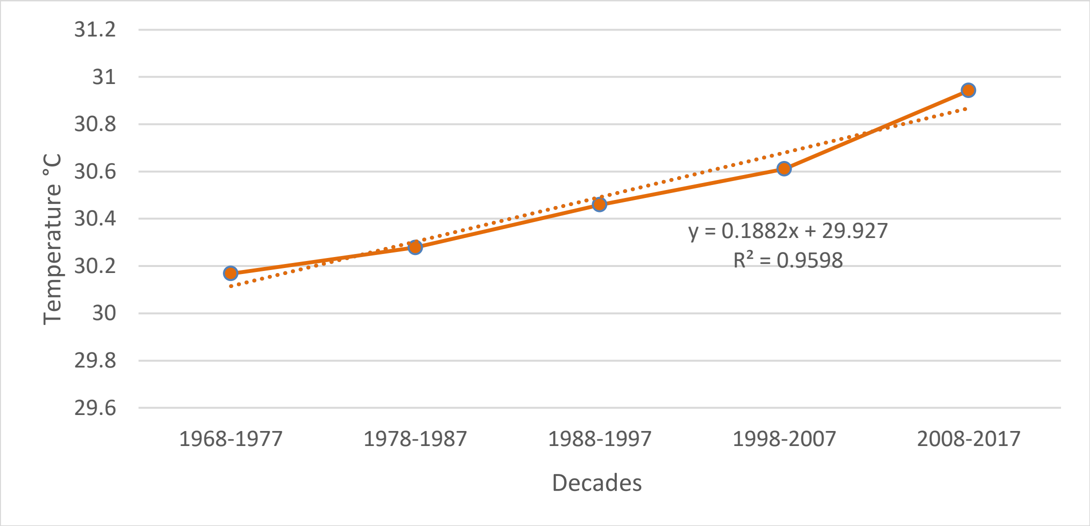


Figure 4.67: Trends of Average Maximum Temperature of South-Central Zone from 1968-2017

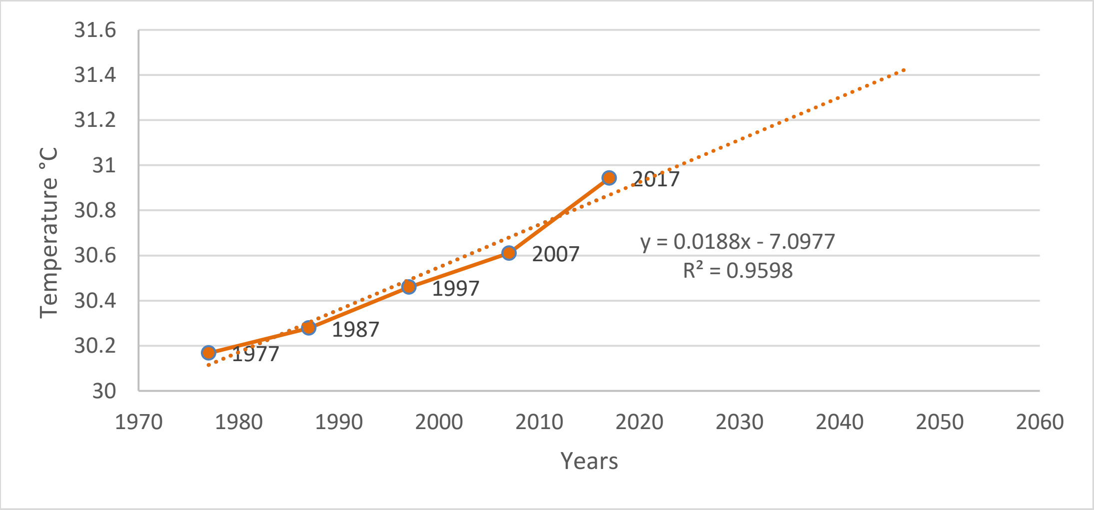


Figure 4.68: Projected Trends of Average Temperature of South-Central Zone.

From Figure 4.67 it is observed that the average temperature (Tmax) of south-central zone is on the increase. The increasing rate of the temperature is 0.1882 °C per decade and in the 50 year period from 1968 to 2017 the temperature has increased 0.941 °C . From Figure 4.68 it is also noticed that the projected trends rate of the temperature is 0.0188 per year and at this rate the average temperature will increase 0.6204 °C in 2050 and 1.5604 °C in 2100.

CHAPTER 05

RAINFALL TRENDS AND VARIAABILITY IN BANGLADESH

RAINFALL TRENDS AND VARIAABILITY IN BANGLADESH

5.1 Introduction:

Bangladesh is a country located in the tropical monsoon climatic region where maximum rainfall occurs during the monsoon season. Rainfall is an important factor for the farmers community of our country for irrigation purpous. But over rainfall or less or no rainfall causes obstacles for the production of crops especially during the period of over rainfall when flood occurs and destroy a vast amount of crops. It is believed that due to climate change the intensity of rainfall is also increasing all over the world along with Bangladesh. But, recent studies reveals that the time of occurring the rainfall does not remain only for the rainy season. It is also occurring about all the year round. This is happening due to impact of climate change.

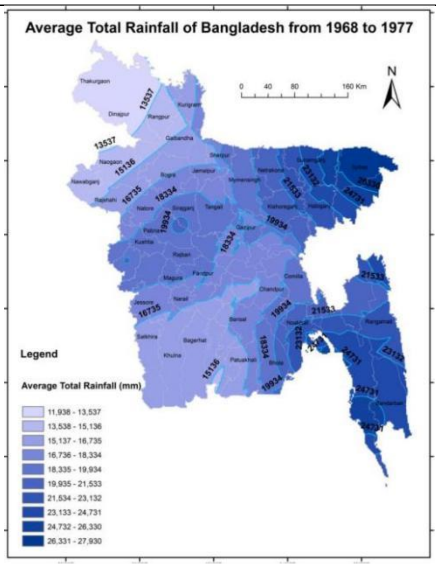
The Inter-Governmental Panel on Climate Change (IPCC, 2007) has predicted that in Bangladesh rainfall will increase steadily till the end of the century. Besides, various studies indicated that rainfall pattern in Bangladesh will also change due to the impact of climate change. Islam (2009) in a study projected that by 2018; annual rainfall in Bangladesh will increase at least 5.3 %. So, in the perspective of climate change it is therefore to understand the trends of rainfall in the country.

From the following presentation of map it will be easy to understand the trend and variability of rainfall pattern of Bangladesh.

5.2 Description of Decadal Trends and Variability of Rainfall

For the in-depth understanding of the rainfall trend and variability of the last fifty years (1977-2017) decdal rainfall trends has been shown in detail in the below map presentation. The trend analysis has been discussed macro level and tried to show the rainfall occurrence fluctuation over the climatic regions of the country.

a)



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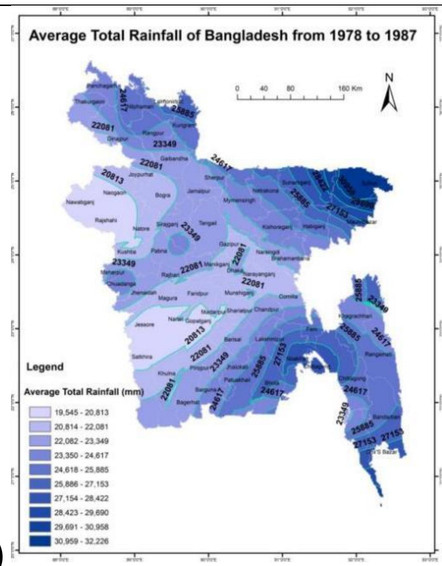

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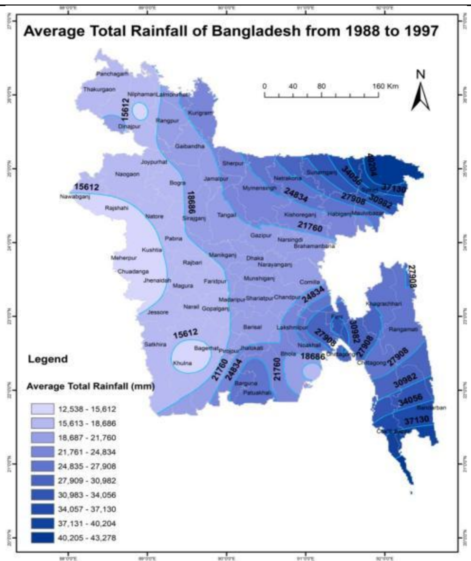
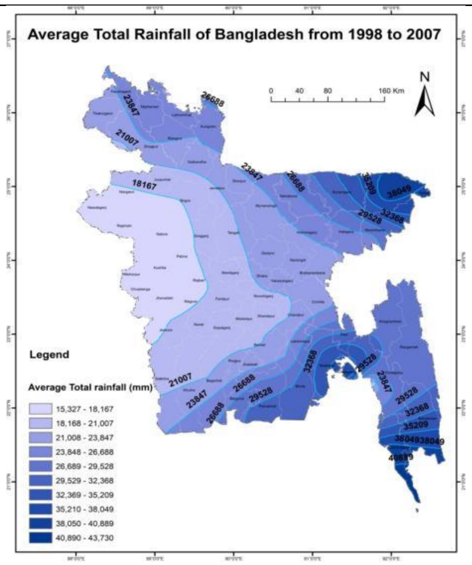


d)



e)

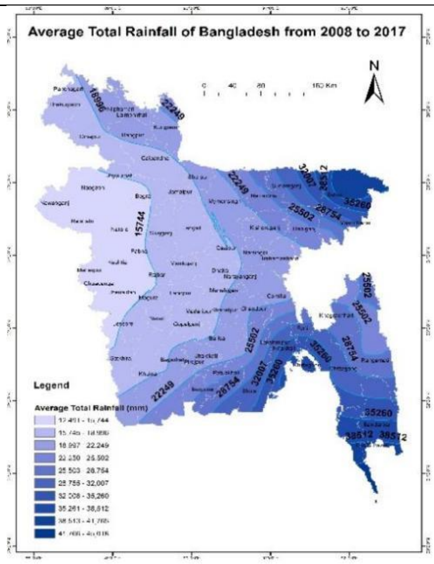


Figure 5.1 a) Map of average total rainfall of Bangladesh from 1968 to 1977 b) Map of average total rainfall of Bangladesh from 1978 to 1987 c) Map of average total rainfall of Bangladesh from 1988 to 1997 d) Map of average total rainfall of Bangladesh from 1998 to 2007 e) Map of average total rainfall of Bangladesh from 2008 to 2017

Source: Analyzed by Author, based on BMD data set, 2022

From Figure 5.1 indicates the average total rainfall of Bangladesh from 1968 to 2017. From map 5.1 a) indicates the average total rainfall of Bangladesh from 1968 to 1977. During this decade the the average rainfall range 11938-27930 mm rainfall was observed. The highest rainfall range 26331-27930 mm rainfall was observed in the district of Sylhet under north-east region. The highest rainfall in occurred in every yaer or decade due the geographical location of this region. This region is situated at the foot -edge the Hymalayan Mountain. This why the average rainfall is more than any other climatic region. The lowest average rainfall range 11,938-13,537 mm was observed in part of the norther part of the northern region and part of the north-western zone which include the districts of Thakurgaon and part of Dinajpur.

From Figure 5.1 b) indicates the average total rainfall of Bangladesh from 1978 to 1987. From this map it was observed that the average total rainfall range 19545-32226 mm during decade was observed . The highest rainfall range 30959-32226 mm rainfall was recorded in Sylhet under north-eastern zone . From this it was also noticed that this zone is the highest recored zone of this decade. The lowest rainfall range 19545-20813 mm rainfall was recorded in western zone which include the districts of rajshahi, Nawabgang, part of Naogaon. This region is recognized as less rainfall zone because of geographical location.

From Figure 5.1 c) indicates the average total rainfall of Bangladesh from 1988 to 1997. From this map it was observe that the average total rainfall during this decade was recorded from 12,538-43,278 mm rainfall . The highest rainfall range 40,205-43238 was recorded in Sylhet under noerth-eastttern zone . And this zone is also ranks top in average rainfall record during this decade. Again The lowest average rainfall range 12538-15612 mm rainfall was recorded in part of westen zone , part of noerth -wetern zone and part of south-western zone . The districts are part of rajshahi, Meherpur, Chuadanga, Kustia,part of part of Jhenaidah respectvily. Part of Khulna was recorded as the lowest rainfall record during this decade.

From Figure 5.1 d) indicates the average total rainfall of Bangladesh from 1998 to 2007. From this map it was also noticed that the average total rainfall range during this decade was recorded from 15327-43730 mm . The highest rainfall range 40890- 43730 was recorded in teknaf of Cox's bazar under south-east region . The second highest rainfall range 38050-40889 was recorded in Sylhet under norther-eastern zone. The lowest average total rainfall range 15327-18167 mm rainfall was recorded in western zone which include the districts of Rajshahi, Nawabgang, part of Naogaon, part of south western zone which include the districts

Meherpur, Chuadanga, Kustia, Pabna and part of north-western zone which include the districts of Jhenaidah, part of Jessore, Rajbari, Magura.

From Figure 5.1 e) indicates the average total rainfall of Bangladesh from 2008 to 2017. From this map it was observed that the average total rainfall range 12491-45018 was recorded during this decade. The highest rainfall range 41766-45018 mm was recorded in Teknaf of Cox's bazar under south east region. The second highest rainfall range was recorded in sylhet under north-eastern zone. The lowest rainfall range 12491- 15744 mm was recorded in western zone which include the districts of Rajshahi, Nowabgong, Noagan, part of south-western and north-western zone which include the districts of Jhenaidah, Jessore.

Table 5.1: Decadal Average Total Rainfall Range

Decades	Rainfall (Range) in mm
1968-1977	19418.39081
1978-1987	24177.50982
1988-1997	23112.29381
1998-2007	25044.31429
2008-2017	24113.45714

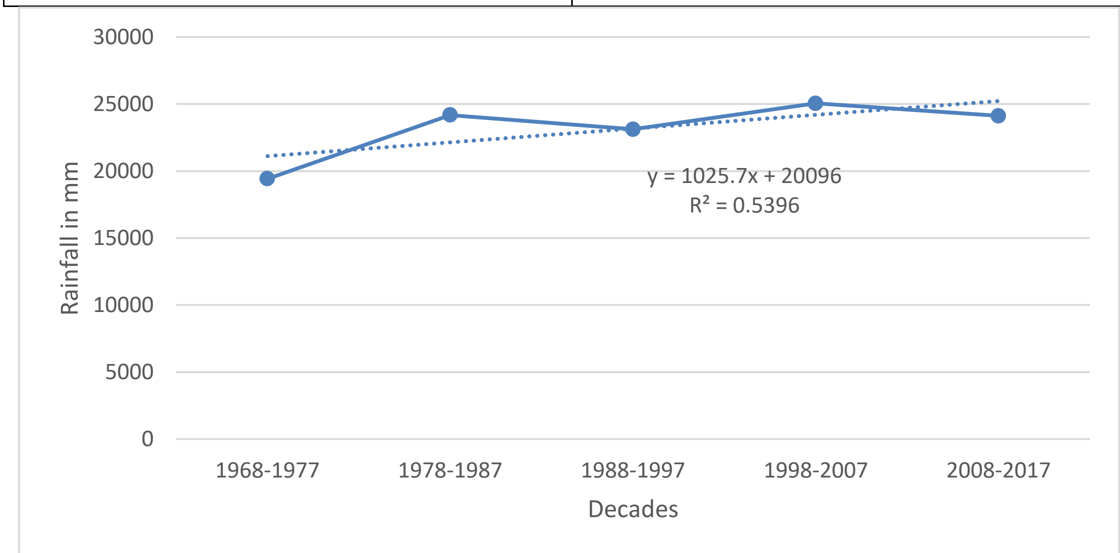


Figure 5.2: Trends of Average Total Rainfall of Bangladesh

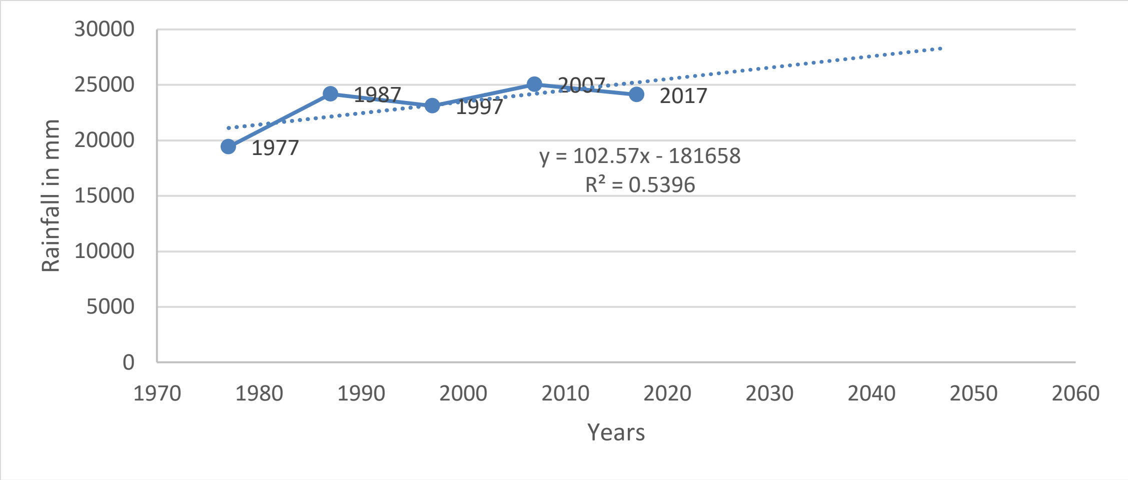
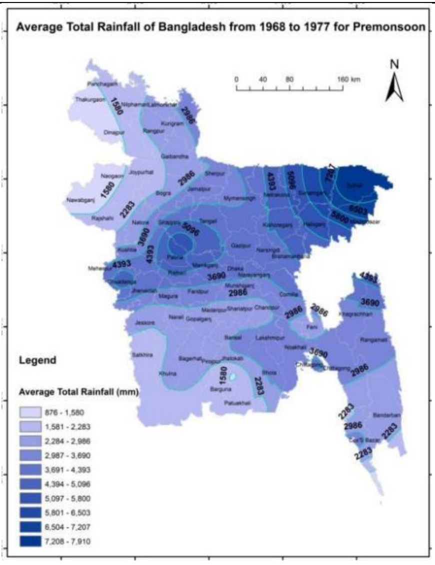


Figure 5.3 Projected Trends of Average Total Rainfall of Bangladesh

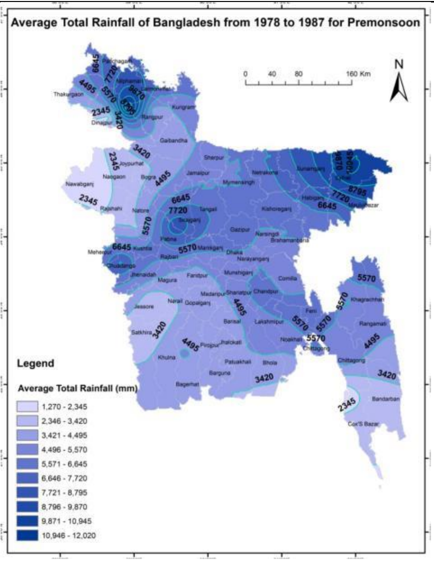
From Figure 5.2 it is observed that the average total rainfall of Bangladesh is on the increase. It is increasing at a rate of 1025 mm per decade and in the 50 years period from 1968 to 2017 the total rainfall has increased 5125 mm. From Figure 5.3 it is also observed that the projected rainfall is increasing at a rate of 102 mm per year and average total rainfall will increase 3366 mm in 2050 and 8466 mm in 2100.

5.3 Description of Seasonal Trends and Variability of Rainfall

5.3.1 Premonsoon: During this season usually, few rainfalls are occurred in comparision to themonsoon season. But sometimes due to *kalboishakhi* during this season rainfall occurs more.



a)



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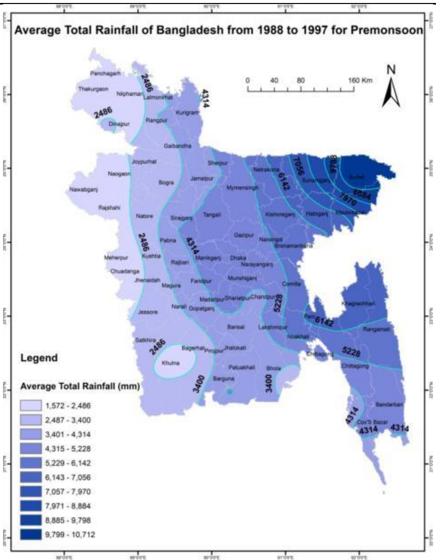

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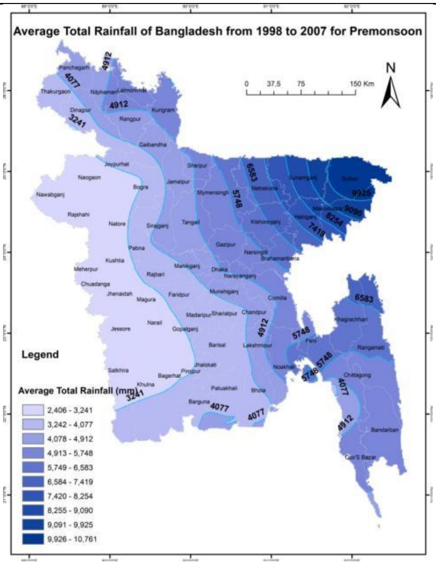

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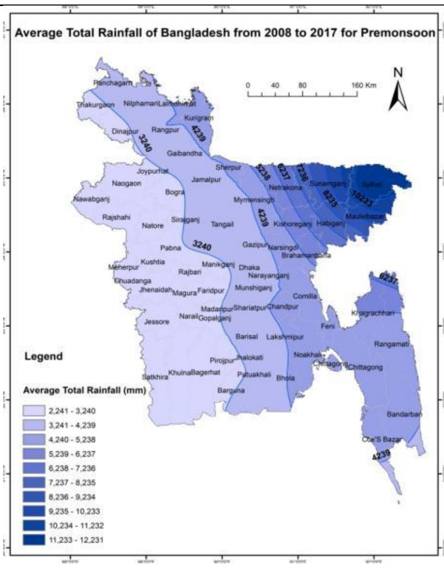


e)

Figure 5.4 a) Map of average total rainfall of Bangladesh from 1968 to 1977 for Premonsoon b) Map of average total rainfall of Bangladesh from 1978 to 1987 for Premonsoon c) Map of average total rainfall of Bangladesh from 1988 to 1997 for Premonsoon d) Map of average total rainfall of Bangladesh from 1998 to 2007 for Premonsoon e) Map of average total rainfall of Bangladesh from 2008 to 2017 for Premonsoon.

Source: Analyzed by Author, based on

BMD data set, 2022.

From Figure 5.4 a) indicates the average total rainfall of Bangladesh from 1968 to 1977 for Premonsoon. The avearge total rainfall during this decade ranges from 876-7910 mm. The highest total average rainfall recorded during this decade was 7208-7910 mm . The districts of Sylhet poses this record under north-east region. The lowest rainfall range 876-1580 mm was recorded in part of Nowabgong and Naogaon districts under western zone, part of Thakurgaon and Dinajpur districts of north-western zone,part of Satkhira, Khulna, Bagerhat, Borguna, Patuakhali districts of south-eastern zone .

From Figure 5.4 b) indicates the average total rainfall of Bangladesh from 1978 to 1987 for Premonsoon. From this map it was observed that the range of avearge total rainfal during this decade was recorded from 1270-12020 mm . The highest rainafall range 10946-12020 mm was recorded in Sylhet under north- eastern zone and sydpur of northern part of the northern zone. The lowest rainfall range 1270-2345 mm was recorded in part of Nowabgong, Noagoan, Rajshahi districts of western zone. Part of Jessore and Stkhira of south-western zone and part of cox's bazar.

From Figure 5.4 c) indicates the average total rainfall of Bangladesh from 1988 to 1997 for Premonsoon. From this map it was observed that the average total rainfall range 1572- 10712 mm was recorded during this decade. The highest rainfall range 9799-10712 mm was recorded in Sylhet under north-eastern zone. The lowest rainfall range 1572-2486 was recorded in Panchagar, part of Nilphamari, of northern part of the northern region, Thakurgaon, part of Dinajpur of north-western zone, Nowabgong, part of Rajshahi ,Nowgaon ,Meherpur, Chuadanga, part of Kustia of of Western zone and part of Khulna .

From Figure 5.4 d) indicates the average total rainfall of Bangladesh from 1998 to 2007 for Premonsoon. From this map it was observed that the average total rainfall range 2406-10761 mm observed during this decade. The highest rainfall range 9926-10761 was recorded in Sylhet under north-eastern zone. This zone also also poses the highest rainfall record. The lowest rainfall range 2406-3241 mm was recorded in western zone which include the districts of rajshahi, Nowabgong, naogaon, part of Natore, part of north-western zone which include the districts of Meherpur, Chuadanga, Kustia, part of south-western zone which include the districts of Jessore, Jhenaidha, Magura, Narail, part of Satkhiar,and part of south-central zone which include the districts of part of khulna, Bagerhat, Satkhira.

From Figure 5.4 e) indicates the average total rainfall of Bangladesh from 1988 to 1997 for Premonsoon. From this map it was observed that the avrage Total rainfall range during this decade was 2241-12231 mm. The highest average total rainfall range 11233-12231 mm was recorded in Sylhet of north-eastern zone. And this zone also posses the highest temperature record than any other climatic regions of Bangladesh. The lowest rainfall range 2241-3240 mm was recorded in part of the northern part of the northern region which include the districts of part of Thakurgaon, Dinajpur, western zone which include the districts of Rajshahi,Nowabgong,Naogaon, part of Natore, part of north-western zone which include the districts of Meherpur, CHuadanga, Kustia, part of Pabna, part of south-western zone which include the districts of Jessore, Jhenidah, Magura, Narail,Rajbari,part of faridpur, satkhira, part of south -central zone which include the districts of part of Satkhira, Khulna, Bagergat and part of south-eastern zone which include the of part of Satkhira, Khulna, Bagergat ,Batguna, Pirojpur.

Table 5.2 Decadal Average Total Rainfall Range of Premonsoon

Decades	Rainfall (Range) in mm
1968-1977	3113.78
1978-1987	4900.76
1988-1997	4205.49
1998-2007	4506.37
2008-2017	4075.05

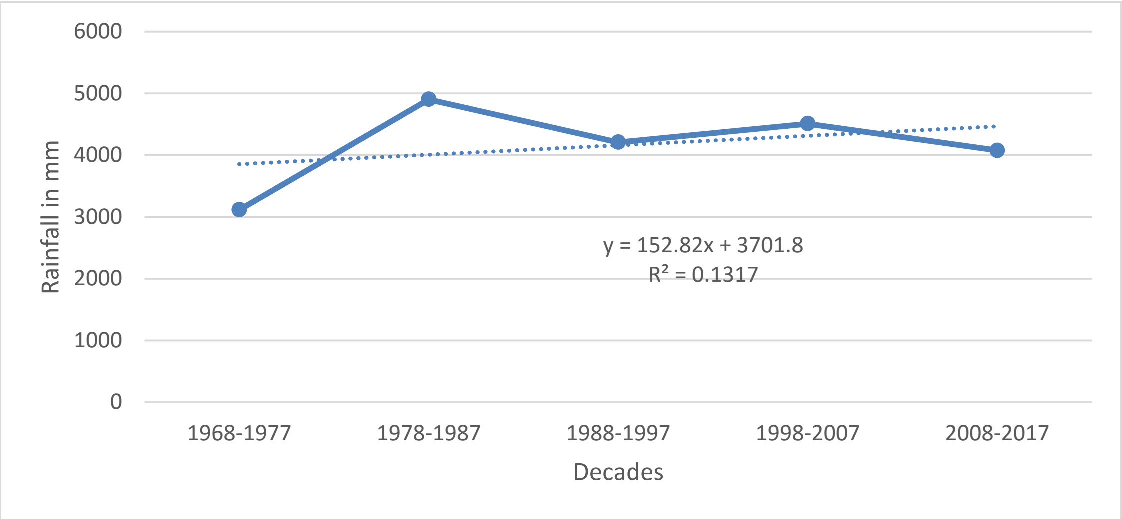


Figure 5.5 Trends of Average Total rainfall of Bangladesh for Premonsoon.

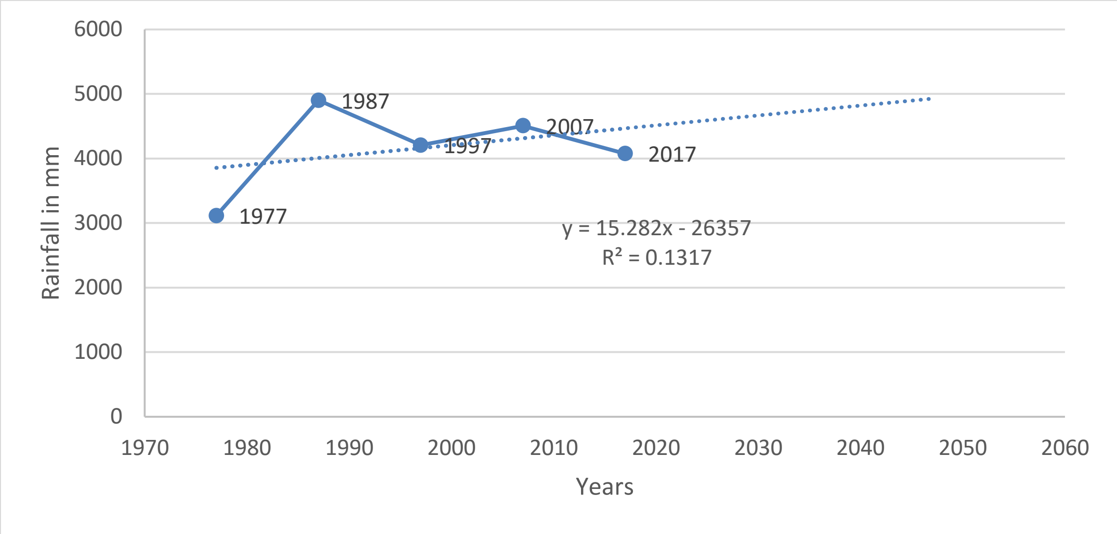
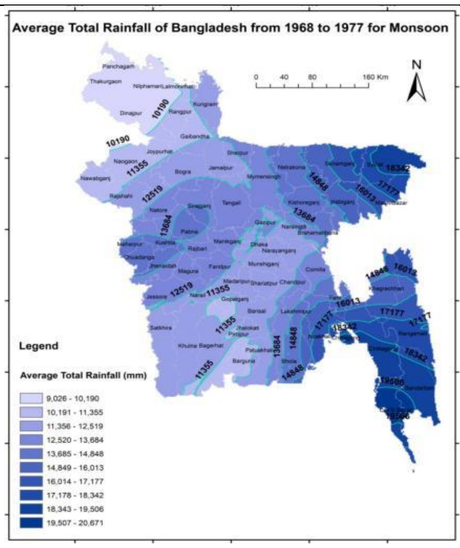


Figure 5.6 Projected Trends of Average Total rainfall of Bangladesh for Premonsoon.

From Figure 5.5 it is observed that the average total rainfall of Bangladesh is on the increase and it is increasing 153 mm per decade in the premonsoon period. The average total rainfall in this decade has increased 765 mm in 50 years period from 1968 to 2017. From Figure -5.6 it is also observed that the projected trends of average total rainfall is increasing at a rate of 15 mm per year and it has increased 495 mm in 1950 and 1245 mm in 2100.

5.3.2 Monsoon: This season is consisted with the month of Junne, July, August and September. During this season usually heavy downpour is occurred. In this season floods ore occurred because during this time most of the rivers remains brim to the broom due to



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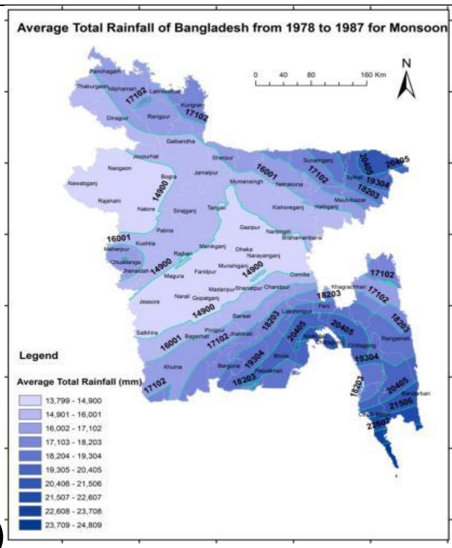

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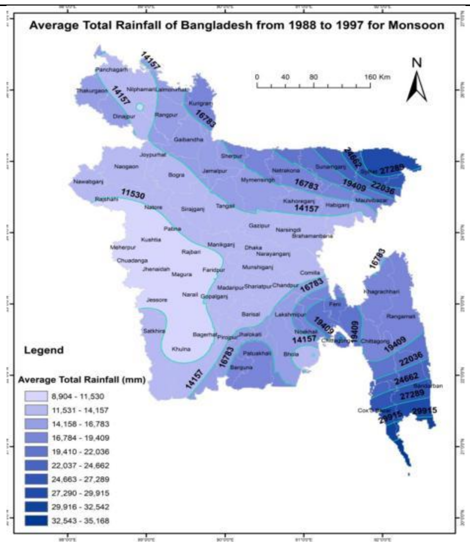

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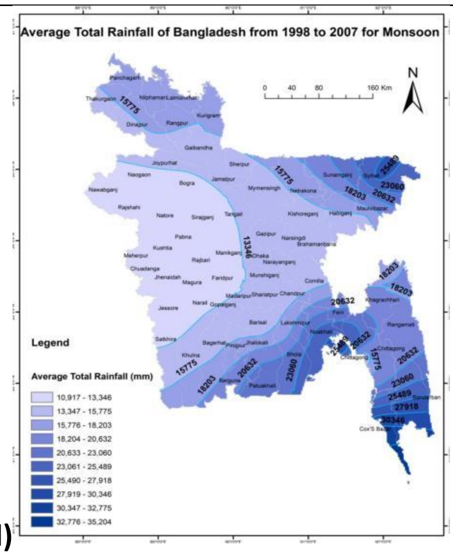

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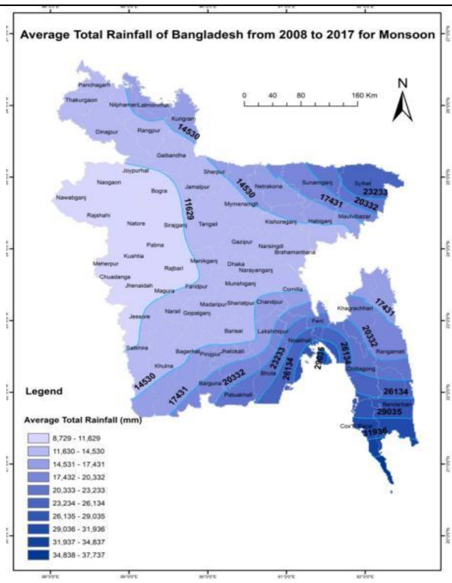


e)

Figure 5.7 a) average total rainfall of Bangladesh from 1968 to 1977 for Monsoon. b) average total rainfall of Bangladesh from 1968 to 1977 for Monsoon. c) average total rainfall of Bangladesh from 1968 to 1977 for Monsoon. d)average total rainfall of Bangladesh from 1968 to 1977 for Monsoon. e) average total rainfall of Bangladesh from 1968 to 1977 for Monsoon.

Source: Analyzed by Author, based on

BMD data set, 2022.

heavy downpour and overflows the riverside causing floods. Sometimes the flood causes heavy loses of property and lives.

From Figure 5.7 a) indicates the average total rainfall of Bangladesh from 1968 to 1977 for Monsoon. From this map it was noticed that the average total rainfall range during this decade was recorded from 9026-20671 mm . The highest rainfall range 19507-20671 was recorded in Teknaf of south-eastern zone . Cox's bazar, Bandarban, Rangamati, Khagrachari of this zone also posses the second highest rainfall which is the range of 18343-19506 mm. Besides Sylhet region also posses the second highest rainfall occurrence. The lowest avearge total rainfall range 9026-10190 was recorded in part of the northern part of the northern region which include the districts of Panchagar, Nilphamary, part of Lalmonirhat, Rangpur and part of the north-western zone which include the districts of Thakurgaon, part of Dinajpur.

From Figure 5.7 b) indicates the average total rainfall of Bangladesh from 1978 to 1987 for Monsoon. From this map it was noticed that the average total rainfall range during this decade was recorded from 13799-24809 mm . The highest average total rainfall range 23709-24809 was recorded in Tknaf of south-eastern zone and part of Sylhet of north-eastern zone. The lowest average total rainfall range 13799-14900 was recorded in western zone which include the districts of Rajshahi, Nawabgong, Naogaon, part of Natore and pat of south-central zone which include the districts of Dhaka, Naryangong, Munshigonj, Manikgonj, Faridpur, Gopalgonj, Gazipur, Madaripur, Part of Cumilla. The districts of Jessore, Magura, Narail, part of Satkhira of south-western zone also experienced the lowest rainfall range during this decade.

From Figure 5.7 c) indicates the average total rainfall of Bangladesh from 1988 to 1997 for Monsoon. From this map it was noticed that the average total rainfall range during this decade was recorded from 8904-35168 mm. The highest ranifall range 32543-35168 mm was observed in Sylhet under north-east region and Teknaf under south-east region. The lowest rainfall range 8904-11530 mm was recorded in Thakurgaon, Nilphamari under northern part of the northern region, part of Rajshahi of western zone, Meherpur, Chuadanga, Kustia, part of Pabna of north-western zone, Jessore, Magura, Rajbari, Faridpur, Narail, part of Satkhira of north-western zone and Part of Khulna, Bagerhat of south-central zone.

From map Figure d) indicates the average total rainfall of Bangladesh from 1998 to 2007 for Monsoon. From this map it was noticed that the average total rainfall range during this decade was recorded from 10917-35204 mm. The highest average total rainfall range 32776-35204 mm was recorded in Teknaf under Cox's Bazar district of south - east zone. The lowest rainfall range 10917-13346 mm was recorded in western zone which include the districts of Rajshahi, Nowabgong, part of Noagaon, North-western zone which include the districts of Chuadanga, Kustia, part of Pabna, Narore, Bagrura, part of Kustia, Meherpur, Chuadanga. And south western -zone which include the districts of Jessore, Mgura, Jhenidah, Rajbari, part of Faridpur, part of Satkhira .

From Figure 5.7 e) indicates the average total rainfall of Bangladesh from 2008 to 2017 for Monsoon. From this map it was noticed that the avearge total rainfall range during this decade was recorded from 8729-37737 mm. The avearge rainfall range 34838-37737 mm was recorded in Teknaf of Cox's Bazar under south-east zone. The lowest rainfall range 8729-11629 mm was recorded in western zone which include the districts of Rajshahi, Nowabgong, Noagaon, North-western zone which include the districts of Chuadanga, Kustia, part of Pabna, Narore, Bagrura, Kustia, Meherpur, Chuadanga, Pabna, part of Sirajgong, part of Bogra. And south western -zone which include the districts of Jessore, part of Magura, Jhenidah, rajbari, part of Faridpur, part of Satkhira.

Table 5.3 Decadal Average Total Rainfall Range of Monsoon

Decades	Rainfall (Range) in mm
1968-1977	14211.01
1978-1987	17303.41
1988-1997	16194.49
1998-2007	17615.43
2008-2017	17650.14

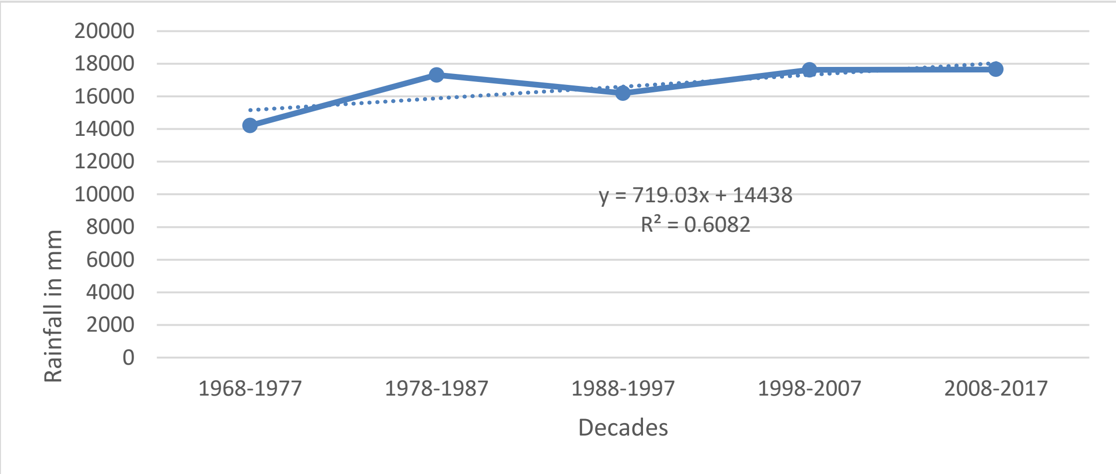


Figure 5.8 Trends of Average Total Rainfall of Bangladesh for Monsoon

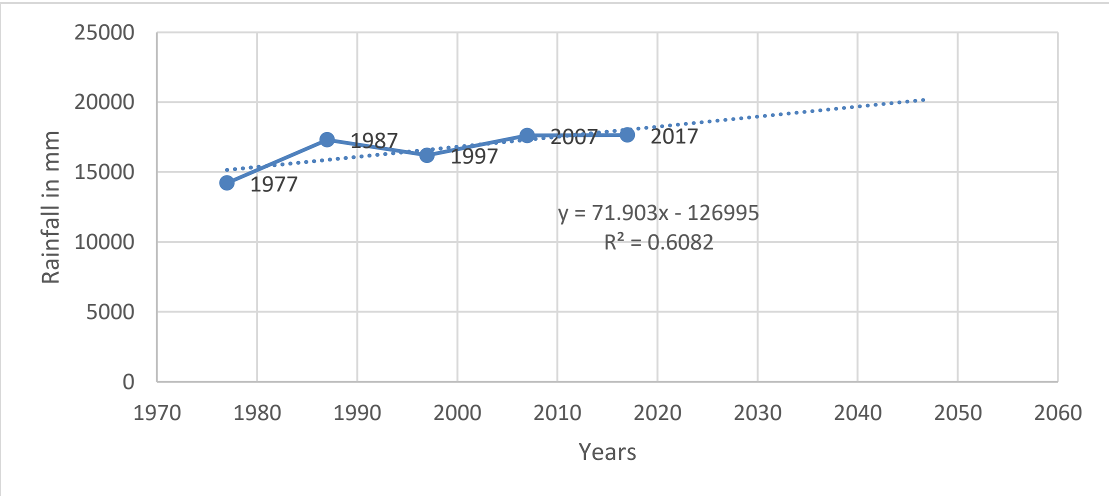
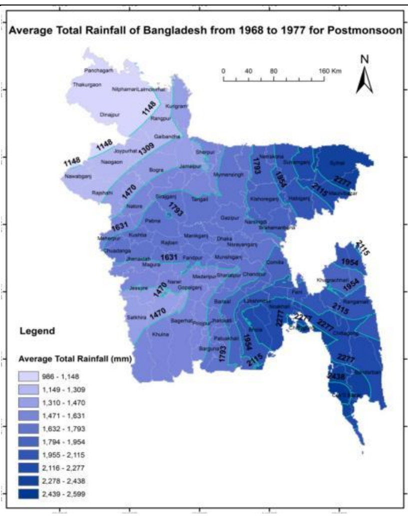


Figure 5.9 Projected Trends of Average Total Rainfall of Bangladesh for Monsoon

From Figure -5.8 it is observed that the trends of average total rainfall of the Bangladesh for monsoon is on the increase. The rate of increasing the average total rainfall is 719 mm per decade. And the rainfall has increased 3595mm for the period of 50 years from 1968 to 2017. From Figure 5.9 it is also observed that the projected rate of increasing rainfall is 72 mm per year. And at this rate the rainfall will increase 2376 mm in2050 and 5976 mm in 2100.

5.3.3 Postmonsoon

In Bnagladesh, during post-monsoon season sometimes heavy downpour continues and in this period average decadal rainfall range nearly from 1000-2600 mm and during this period the highest rainfall also occur in Sylhet region.



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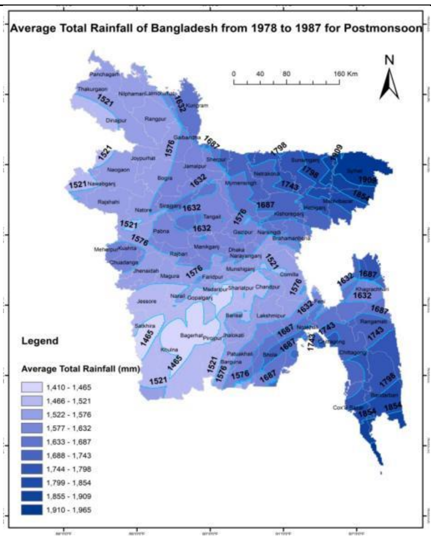

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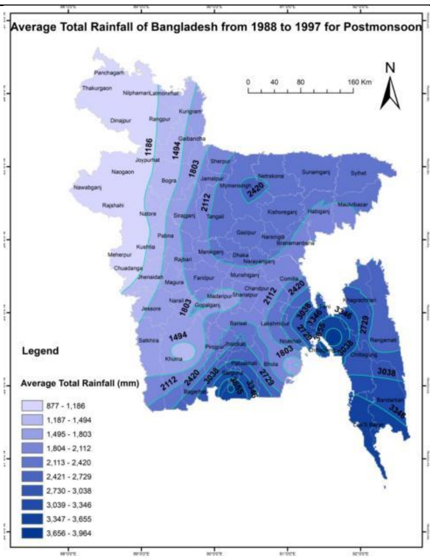

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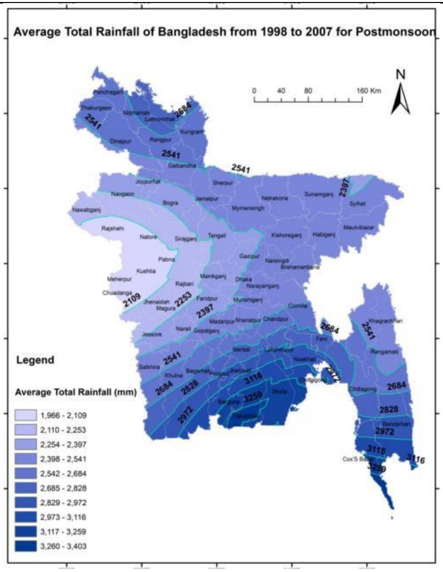

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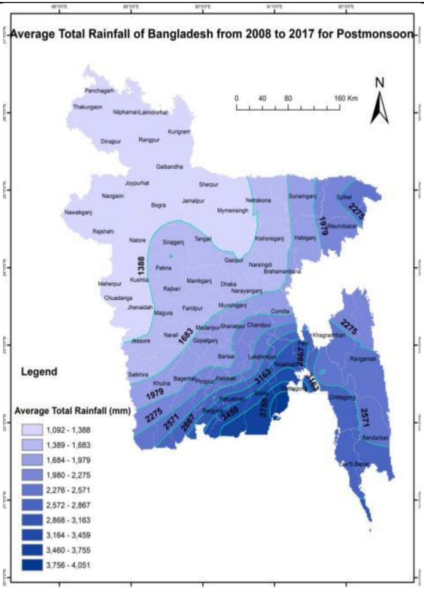


e)

Figure 5.10 a) Average total rainfall of Bangladesh from 1968 to 1977 for Post-monsoon. b) Average total rainfall of Bangladesh from 1978 to 1987 for Post-monsoon c) Average total rainfall of Bangladesh from 1988 to 1997 for Post-monsoon. d) Average total rainfall of Bangladesh from 1998 to 2007 for Post-monsoon. e) Average total rainfall of Bangladesh from 2008 to 2017 for Post-monsoon.

Source: Analyzed by Author, based on BMD data set, 2022.

From Figure 5.10 a) indicates the average total rainfall of Bangladesh from 1968 to 1977 for post-monsoon. The average total rainfall range 986-2599 mm was recorded during this decade. The highest rainfall range 2439-2599 mm was recorded in Sylhet,of south-east zone and Teknaf of Cox'z Bazar under south-east zone. The lowest rainfall range 986-1148 mm was recorded in part of the northern part of the northern region which include the districts of Panchagar, Nilphamary, part of lamonirhat, part of Rangpurand part of the north-west region which include the districts of Thakurgaon, Dinajpur, part of Rangpur.

From Figure 5.10 b) indicates the average total rainfall of Bangladesh from 1978 to 1987 for post-monsoon. The average total rainfall range 1410-1965 mm recorded during this decade. The highest average total rainfall range 1910-1965 mm was recorded in Sylhet and Teknaf under north-east and south-east region respectively. In this decade the highest rainfall also occurred in Sylhet and Cox's Bazar divisions. The lowest rainfall range 1410-1465 mm was recorded in part of Rajshahi, Bagerhat,Satkhira districts.

From Figure 5.1 C) indicates the average total rainfall of Bangladesh from 1988 to 1997 for post-monsoon. The average total rainfall range 877-3964 mm was recorded during this decade. The highest average total rainfall range 3656-3964 mm was recorded in Chittagong , Cox's Bazar, and Barguna under south-east zone. In this decade it was observed that Chittagong division experienced the highest rainfall record than other divisions. The lowest avrage total rainfall range . Dhaka and Sulhet division also experienced heavy downpour during this decade. The lowest average total rainfall range 877-1186 mm was recorded in part of the northern part of the northern region which include the districts of Panchagar, Nilphamari part of north-western zone which include the districts of Thakurgaon, Dinajpur,and western zone which include the districts of Meherpur, Chuadanga, part of Kustia.

From Figure 5.10 d) indicates the average total rainfall of Bangladesh from 1998 to 2007 for post-monsoon. The average total rainfall range 1966-3403 mm was recorded during this decade. The highest average total rainfall range 3260-3403 mm was recorded in south - eastern zone which include the districts of coastal area and Cox's Bazar. The average total lowest rainfall range 1966-2109 mm was recorded part of western zone which include the districts of part of Rajshahi and part of north-western zone which include the district of Chuadanga, Ishurdi.

From Figure 5.10 e) indicates the average total rainfall of Bangladesh from 2008 to 2017 for post-monsoon. The average total rainfall range 1092-4051 mm was recorded in this decade . The highest average total rainfall range 3556-4051 mm was recorded in southern part of the south-east zone and the lowest average total rainfall range was recorded in northern part of the northern region, western zone, north-western zone and part of south-central zone.

Table 5.4 Decadal Average Total Rainfall Range of Postmonsoon

Decades	Rainfall (Range) in mm
1968-1977	1805.11
1978-1987	1630.10
1988-1997	2188.40
1998-2007	2624.23
2008-2017	2087.54

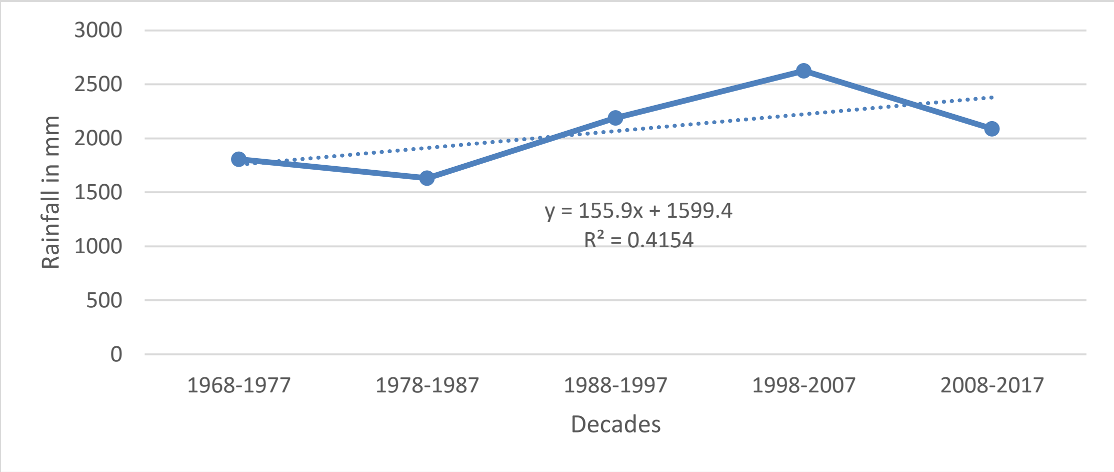


Figure 5.11 Trends of Average Total Rainfall of Bangladesh for Postmonsoon

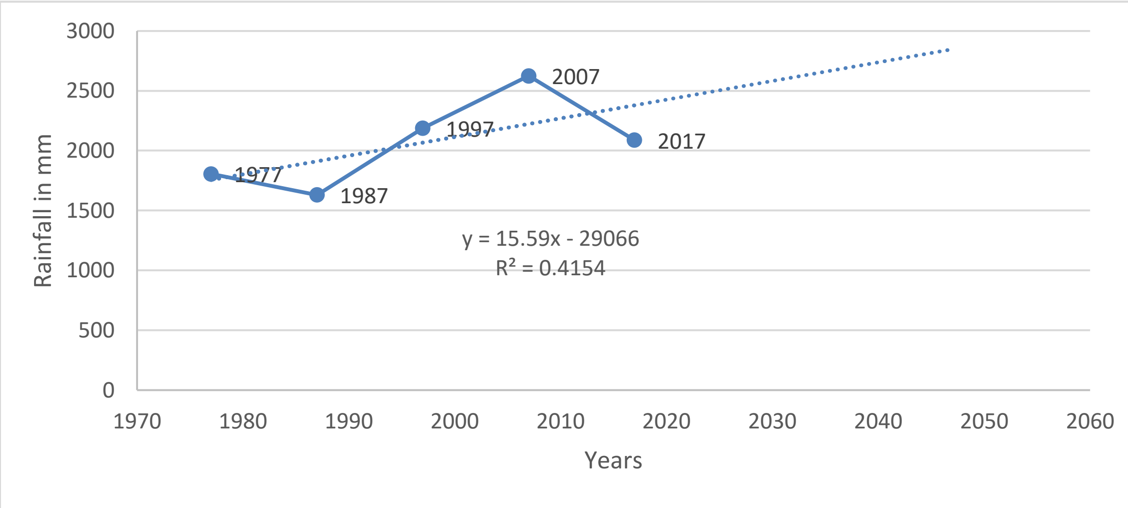
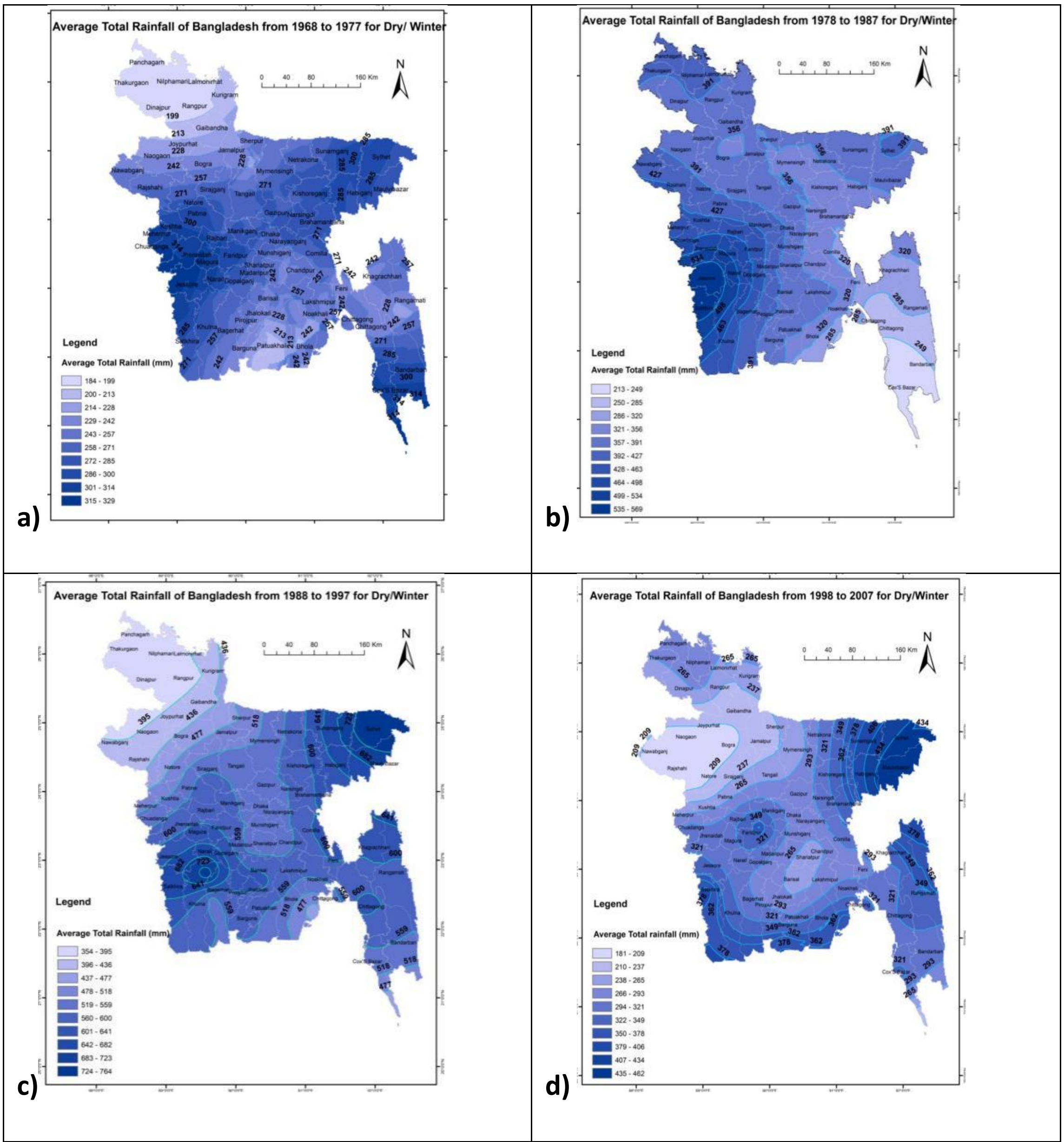


Figure 5.12 Projected Trends of Average Total Rainfall of Bangladesh for Postmonsoon

From Figure 5.11 it is noticed that the trends of average total rainfall of Bangladesh for the postmonsoon period is on the increase. The rainfall has increased 780 mm in 50 years period from 1968 to 2017 at the rate of 156 mm per decade. From Figure 5.12 it is also observed that the projected trends of the average total rainfall is 16 per mm year. And at this rate the rainfall will increase 528 mm in 2050 and 1328 in 2100.

5.3.4 Dry/Winter

Dry or winter season is usually rainless and during this season the rainfall range from 100-400 mm per decade . The highest rainfall occur in the Sylhet district during this season.



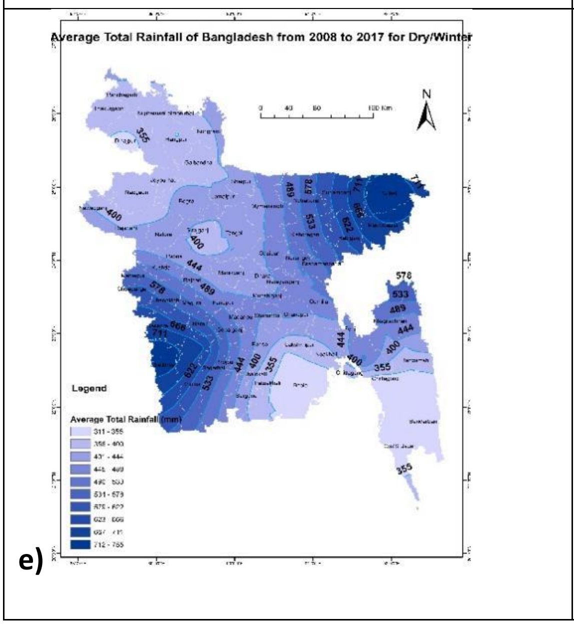


Figure 5.13 a) Average total rainfall of Bangladesh from 1968 to 1977 for dry/Winter b) Average total rainfall of Bangladesh from 1978 to 1987 for dry/Winter. c) Average total rainfall of Bangladesh from 1988 to 1997 for dry/Winter d) Average total rainfall of Bangladesh from 1998 to 2007 for dry/Winter. e) Average total rainfall of Bangladesh from 2008 to 2017 for dry/Winter.

Source: Analyzed by Author, based on

BMD data set, 2022.

From Figure 5.13 a) indicates at the average total rainfall the average total rainfall of Bangladesh from 1968 to 1977 for dry/Winter. From this map it was observed the range 184-329 mm was recorded during this decade. The highest average total rainfall range 315-329 was recorded in north-eastern, part of south-eastern, part of north-western and part of south-western zone. The lowest total average rainfall range 184-199 mm was recorded in northern part of the northern region, part of north-western zone.

From Figure 5.13 b) indicates the average total rainfall of Bangladesh from 1978 to 1987 for dry/Winter. From this map the total average rainfall range 213-569 mm was observed during this decade. The highest average total rainfall range 535-569 mm was recorded in northern part of the northern region, part of the north-western zone, part of the western zone, part of the south-western zone and part of the south-central zone. The lowest average total rainfall range 213-249 mm was recorded in Cox's Bazar area of south-eastern zone.

From Figure 5.13 c) indicates the average total rainfall of Bangladesh from 1988 to 1997 for dry/Winter. The average total rainfall range 354-764 mm was recorded during this decade. The highest average total rainfall range 724-764 mm was recorded in Sylhet of north-eastern zone, part of south-western zone, part of south-central zone. The lowest total average rainfall range 354-495 mm was recorded in northern part of the northern region, north-western zone and part of western zone.

From map 5.13 d) indicates the average total rainfall of Bangladesh from 1998 to 2007 for dry/Winter. From this map it was observed that the average total rainfall during this decade was recorded from 181-486 mm. The highest average total rainfall record 435-462mm was observed in Sylhet under north-east region. Besides , the lowest temperature record 181-209 mm was observed in the districts of Rajshahi, Nowabgonj, Noagaon under western zone.

From Figure 5.13 e) indicates the average total rainfall of Bangladesh from 2008 to 2017 for dry/Winter. The average total rainfall during this decade was recorded from 311-755 mm . The highest average total rainfall range 712-755 mm was recorded in Sylhet of north-east region and also part of Satkhira of south-west region. The lowest total average range 311-355 mm was recorded in Naogaon, part of Rajshahi, part of Nowabgang of western region and also in part of Dinajpur.

Table 5.5 Decadal Average Total Rainfall Range of Dry/Winter

Decades	Rainfall (Average) in mm
1968-1977	259.61
1978-1987	365.09
1988-1997	554.25
1998-2007	298.43
2008-2017	447

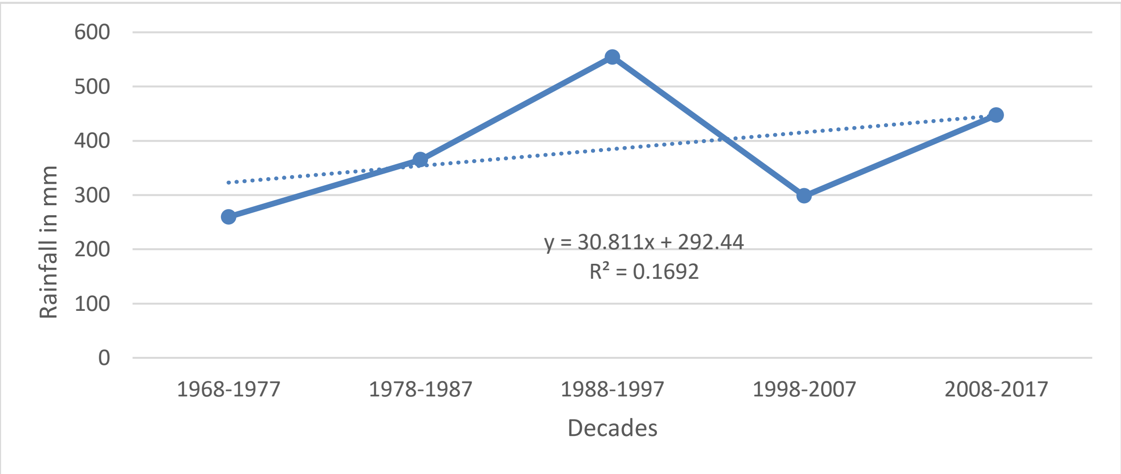


Figure 5.14 Trends of Average Total Rainfall of Bangladesh for Dry/Winter

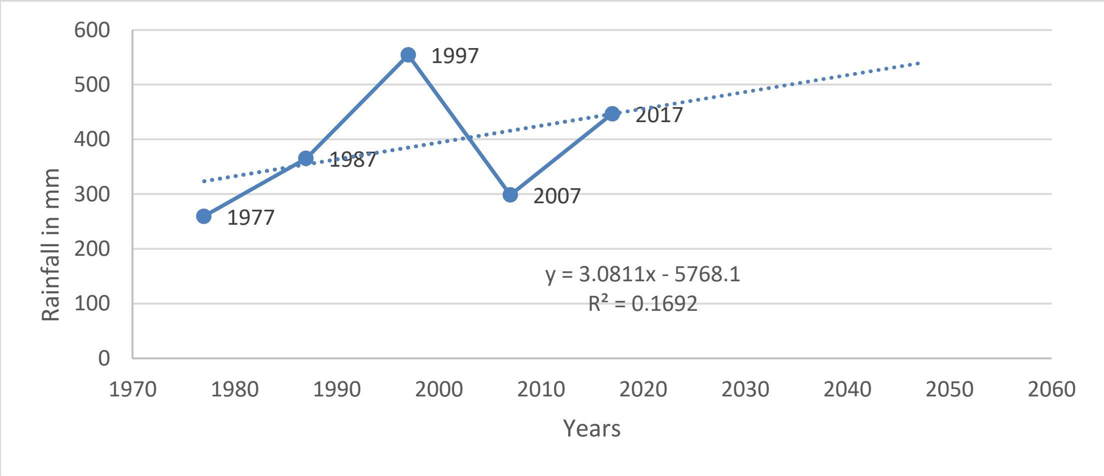


Figure 5.15 Projected Trends of Average Total Rainfall of Bangladesh for Dry/Winter

From Figure 5.14 it is observed that the average total rainfall of Bangladesh for dry is on the increase. The increasing trend is 30 mm per decade and in the 50 years period the rainfall has increased 150 mm . From Figure – 5.15 it is also noticed that the projected trend is 3 mm per year. And in 2050 the rainfall will increase 99 mm and 249 mm in 2100.

5.4 Description of Climatic Zonal Trends and Variability of Rainfall

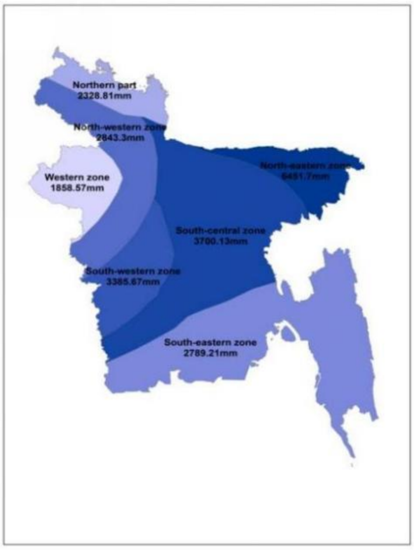
5.4.1 Introduction: Rashid (1991) has divided Bangladesh into seven climatic zones which include south-eastern, north-eastern, northern part of the northern region, north-western, western, south-western and south-central zones. Again, in Bangladesh there are four prominent seasons, namely Pre-monsoon (March to May), Monsoon (June to September), Post-monsoon (October to November) and Dry or Winter (December to February). Pre-monsoon is the period which consists of the months of March, April, May and June. From this study it has been found that there is fluctuation or change of decdal average total rainfall between the climatic regions irrespective of different seasons as mentioned above.

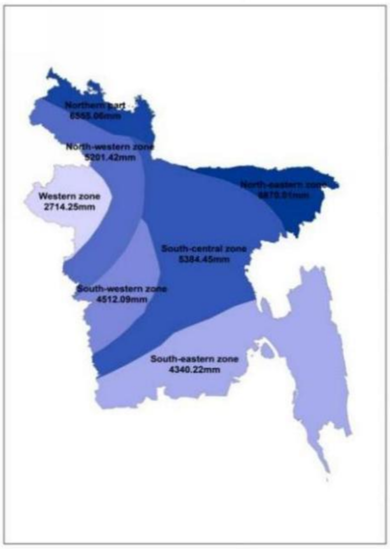
5.4.1 Premonsoon: In premonsoon season which is consisted of the month of March, April and May. In this season there remains decade- wise climatic zonal variations of rainfall. From Figure 5.16 a) it was found that the average total rainfall varied from climatic zone to zone. From this Figure it was also observed that in the decade of 1968 to 1977 north-eastern region which is consisted of the districts of Sunamgonj, Sylhet and Moulvibazar was the highest recipient of rainfall with 6454 mm. From this Figure it was also observed that western zone which comprises with the districts of Rajsgahi, Nawabgonj, Natore, and part of Joypurhat

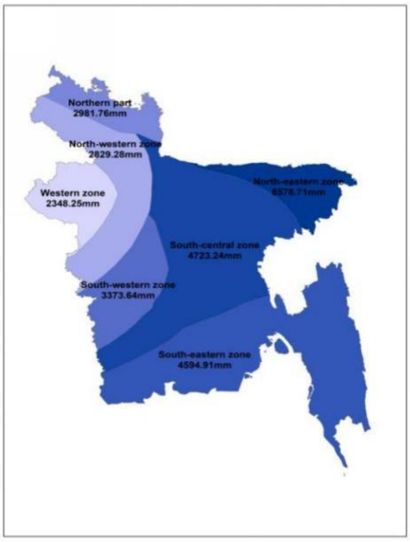
was the lowest recipient of rainfall during this decade with 1858 mm average total rainfall record. On the other hand from this map it was also found that the second highest recipient of rainfall was the south-central zone with 3700 mm record. The other average total rainfall recipient climatic zones are south-western zone 3386 mm, north-western zone 2843 mm, south-eastern zone 2789 mm and northern part of the northern region 2329 mm .

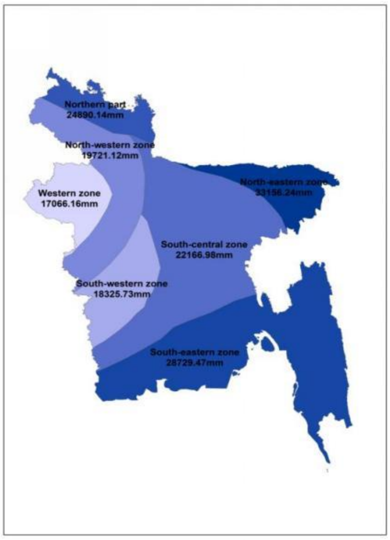
From Figure 5.16 b) it was found that during the decade of 1978 to 1987 the north-eastern zone was also the highest recipient of average total rainfall of 8870 mm followed by northern part of the norther region 6555 mm, south-central zone 5383 mm, north-western zone 5201 mm, south-western 4512 mm, south-eastern zone 4340 mm and western zone 2714mm.

From Figure 5.16 c) it was also observed that during the decade of 1988 to 1997 north-western zone was the highest recipient of average total rainfall which is 8578 mm record followed by

a) 

b) 

c) 

d) 

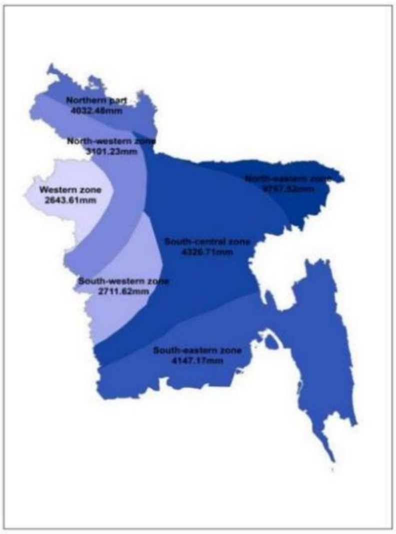
e) 

Figure:5.16 a) Climatic zonal trends of average total rainfall from 1968 to 1977 for premonsoon. b) Climatic zonal trends of average total rainfall from 1978 to 1987 for premonsoon c) Climatic zonal trends of average total rainfall from 1988 to 1997 for premonsoon d) Climatic zonal trends of average total rainfall from 1998 to 2007 for premonsoon e) Climatic zonal trends of average total rainfall from 2008 to 2017 for premonsoon.

Source: Analyzed by Author, based on BMD data set, 2022.

South-central zone with 4723 mm rainfall, south-eastern zone with 4595 mm, south-western zone 3374 mm, northern part of the northern region 2982 mm, north-western zone 2829 mm and western zone 2348 mm.

From Figure 5.16 d) it was observed that the north-eastern zone received the highest rainfall of average 33156 mm during the decade of 1988 to 2007 followed by south-eastern zone received 28729 mm , northern part of the northern region received 24890 mm, south-central zone 22167 mm, north-western zone 19721 mm, south-western zone 18326 mm and western zone 17066 mm.

From Figure 5.16 e) it was observed that the north-eastern zone was the highest recipient of average total rainfall of 9758 mm during the decade of 2008 to 2017 followed by south-central zone receiving 4327 mm, south-eastern zone receiving 4147 mm, northern part of the northern region receiving 4032 mm, north-western zone 3101 mm, south-western zone 2711mm and western zone 2644 mm.

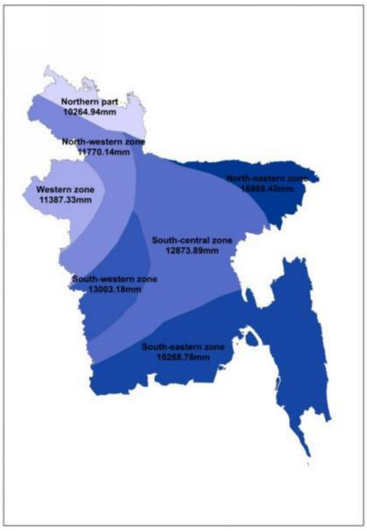
5.4.2 Monsoon: This season is consisted with the month of June, July, August and September. Usually in this season, Bangladesh received the highest amount of rainfall due to heavy downpour. From Figure 5.17 a) it was observed that the north-eastern zone received the highest amount of average rainfall amounting to 16989 mm during the decade of 1968 t0 1977 followed by south-eastern zone received amounting 15269 mm, south-western zone received amounting 13003 mm, north-western zone received amounting 11770 and western zone received amounting 11387 mm of rainfall.

From Figure 5.17 b) it was noticed that during the decade of 1978 to 1987 the north-eastern zone was the highest recipient of average total rainfall amounting 18690 mm followed by the south-eastern zone received amounting 18621 mm, northern part of the northern region received amounting 16946 mm, north-western zone received amounting 15586 mm, south-central zone received amounting 15275 mm, south-western zone received 14798 mm and western zone received 14352 mm of rainfall.

From Figure 5.17 c) it was observed that the highest recipient of average total rainfall of this season was the north-eastern zone receiving 23370 mm during the decade of 1988 to 1997 followed by south-eastern zone receiving 18350 mm, northern part of the northern region which received 15100 mm, south-central zone received 13837 mm, north-western zone received 13062 mm, western zone received 12355 mm and south-western zone received 11354 mm of rainfall.

From Figure 5.17 d) it was observed that during the decade of 1998 to 2007 the highest receipent of average total rainfall was the north-eastern zone with receiving 21164 mm of rainfall followed by south-eastern zone received 20703 mm , northern part of the northern region received 16781 mm, south-central received 14448 mm, north-western zone received 13572 mm, south-western zone received 12533 mm and western zone received 12220 mm of rainfall.

From Figure 5.17 e) it was observed that the highest recipient of average total rainfall during the decade of 2008 to 2017 was the south-eastern zone which received the rainfall amounting to 21007 mm followed by north-eastern zone received 21100 mm, northern part of the northern region received 14599 mm, south-central zone received 13725 mm, north-western zone received 11641 mm, south-western zone received 11558 mm and western zone received 9921 mm of rainfall.



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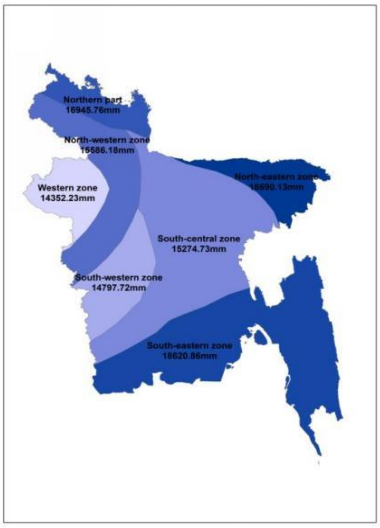

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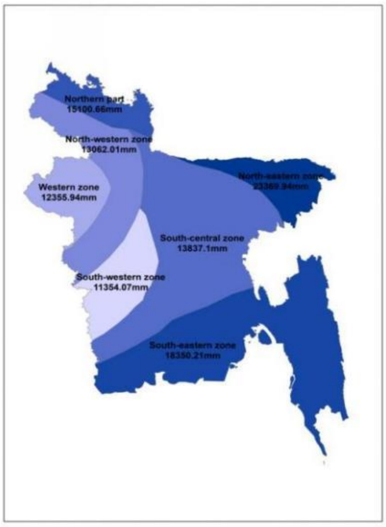

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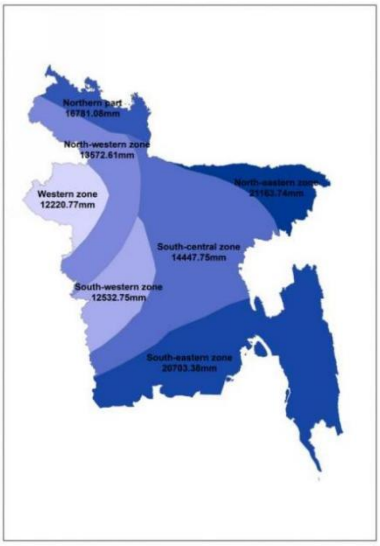
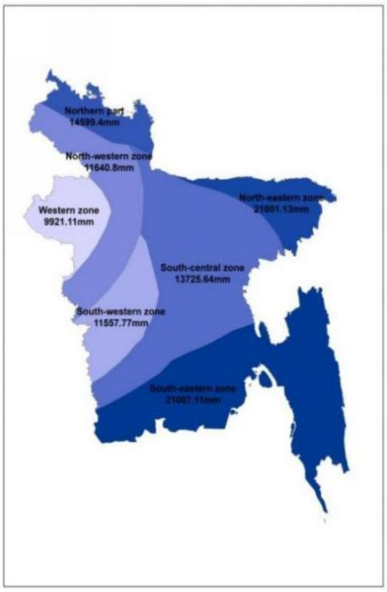


d

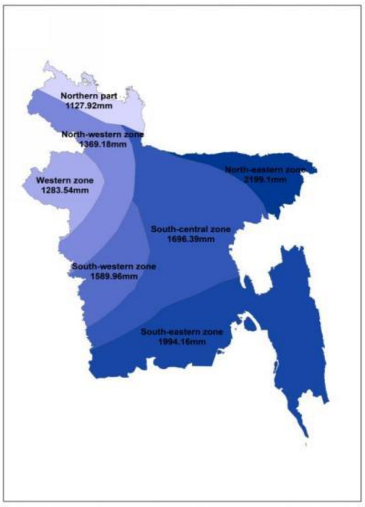


e

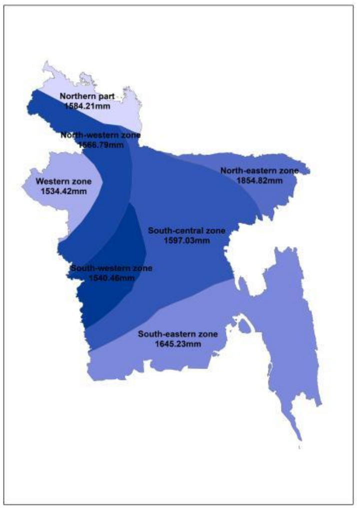
Figure:5.17 a) Climatic zonal trends of average total rainfall from 1968 to 1977 for monsoon. b) Climatic zonal trends of average total rainfall from 1978 to 1987 for monsoon c) Climatic zonal trends of average total rainfall from 1988 to 1997 for monsoon d) Climatic zonal trends of average total rainfall from 1998 to 2007 for monsoon e) Climatic zonal trends of average total rainfall from 2008 to 2017 for monsoon.

Source: Analyzed by Author, based on

BMD data set, 2022.



a)



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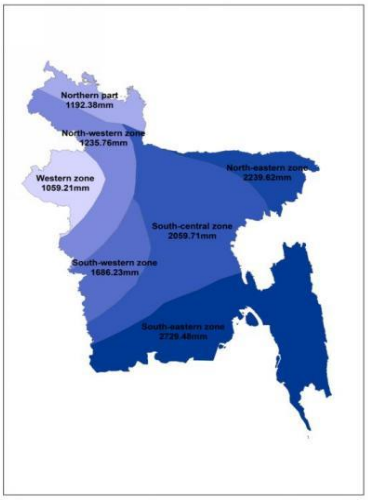

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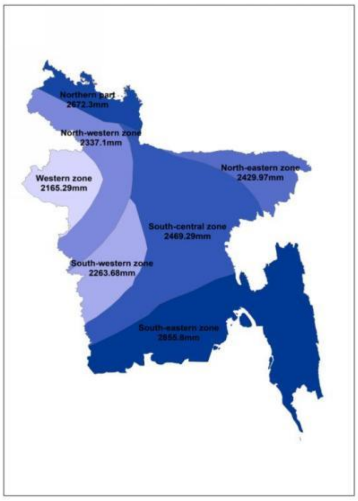

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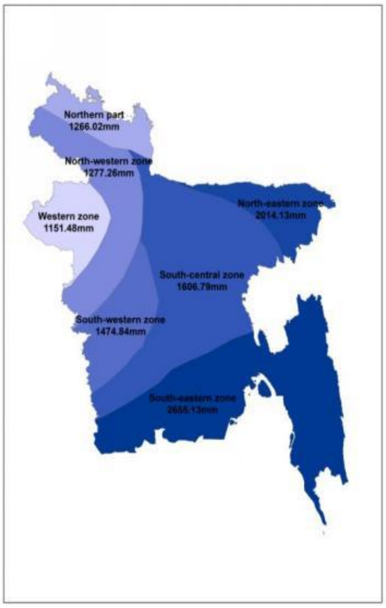
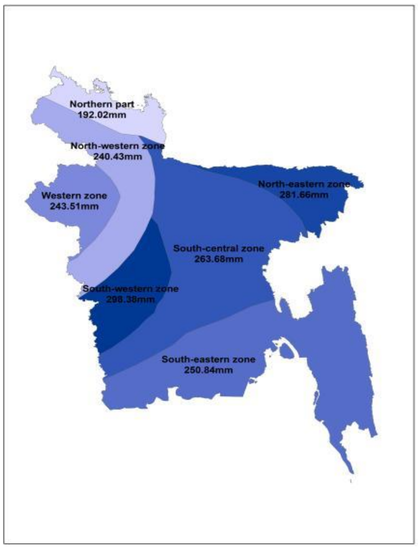


e)

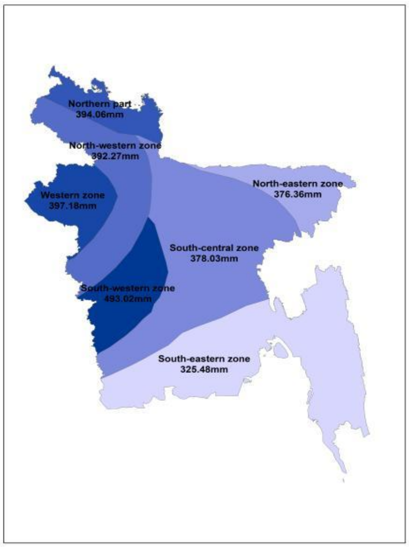
Figure:5.18 a) Climatic zonal trends of average total rainfall from 1968 to 1977 for postmonsoon. b) Climatic zonal trends of average total rainfall from 1978 to 1987 for postmonsoon c) Climatic zonal trends of average total rainfall from 1988 to 1997 for postmonsoon d) Climatic zonal trends of average total rainfall from 1998 to 2007 for postmonsoon e) Climatic zonal trends of average total rainfall from 2008 to 2017 for postmonsoon.

Source: Analyzed by Author, based on

BMD data set, 2022.



a)



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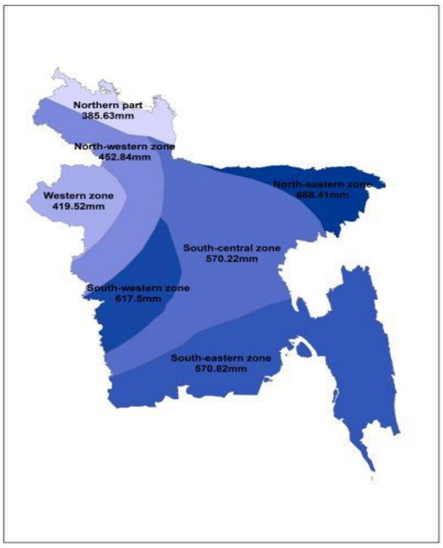

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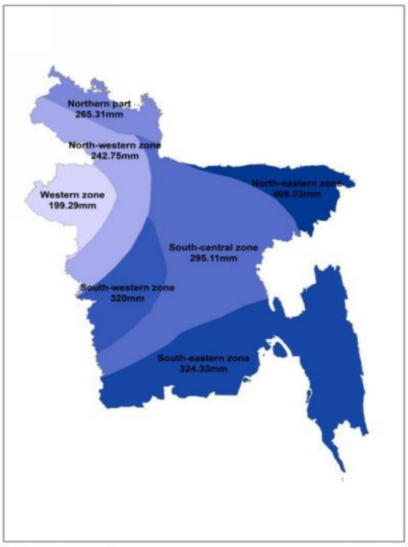

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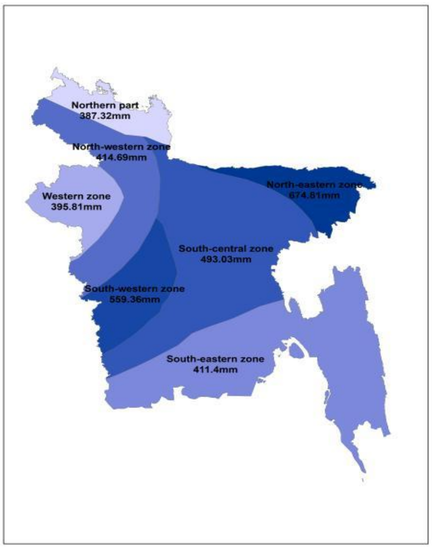

e)

Figure:5.19 a) Climatic zonal trends of average total rainfall from 1968 to 1977 for dry/winter. b) Climatic zonal trends of average total rainfall from 1978 to 1987 for dry/winter c) Climatic zonal trends of average total rainfall from 1988 to 1997 for dry/winter d) Climatic zonal trends of average total rainfall from 1998 to 2007 for dry/winter e) Climatic zonal trends of average total rainfall from 2008 to 2017 for dry/winter.

Source: Analyzed by Author, based on BMD data set, 2022.

5.4.3 Postmonsoon: This season is consisted with the month of October and November. With the advent of this season the average total rainfall decreases. From Figure 5.18 a) it was observed that the north-eastern zone ranked highest in receiving the average total rainfall amounting 2199 mm during the decade of 1968 to 1977 followed by south-eastern zone received 1994 mm , south-central zone receiving 1696 mm, south-western zone received 1590 mm, western zone received 1283 mm, north-western zone received 1369 mm, western zone received 1283 mm and northern part of the northern zone received 1128 mm.

From Figure 5.18 b) it was noticed that the highest recipient of total average rainfall during the decade of 1978 to 1987 was the north-eastern zone with receiving rainfall amounting 1855 followed by south-eastern zone received rainfall amounting to 1645 mm, northern part of the northern region received 1584 mm, north-western zone received 1567 mm, south-western zone received 1540 mm and western zone received 1534 mm of rainfall.

Figure 5.18 c) showed that the highest amount of rainfall recipient climatic zone was the south-eastern zone which was 2729 mm during the decade of 1988 to 1997 followed by north-eastern zone received 2240 mm of rainfall, south-central zone received 2060 mm, south-western zone received 1686 mm, north-western zone received 1236 mm, northern part of the northern region received 1192 mm and western zone received 1059 mm of rainfall.

From Figure 5.18 d) it was observed that during the decade of 1998 to 2007, the average total rainfall recipient climatic zone was south-eastern zone which received 2855 mm rainfall followed by northern part of the northern region received 2672mm, south-central zone received 2469 mm, north-eastern zone received 2430 mm , north-western zone received 2337 mm, south-western zone received 2264 mm and western zone received 2165 mm of rainfall.

From Figure 5.18 e) it was observed that the average total rainfall during the decade of 2008 to 2017 was recorded as highest in the in the south-eastern zone which was 2655 mm followed by 2014 mm recorded in the north-eastern zone, 1607 mm recorded in the south-central zone, 1475 mm recorded in the south-western zone, 1277 mm recorded in the north-western zone, 1266 mm in the northern part of the northern zone and 1151 mm in the western zone.

5.4.4 Dry or Winter: This season is consisted of the months of December, January and February. In Bangladesh, in this season very few rainfall occurs because of her geographical location and season cycle. From Figure 5.19 a) the average total rainfall during the decade of 1968 to 1977 was recorded in the south-western zone which was 298 mm followed by 282 mm recorded in the north-eastern zone , 264 mm recorded in the south-central zone, 251 mm recorded in the south-eastern zone, 244mm recorded in the western zone, 240 mm recorded in the north-western zone and 192 mm recorded in the northern part of the northern region.

From Figure 5.19 b) it was observed that during the decade of 1978 to 1987 period the highest average total rainfall was recorded in the south-western zone which was 493 mm of rainfall followed by western zone recorded 397 mm, northern part of the northern region recorded 394 mm, north-western zone recorded 392 mm, south-central zone recorded 378 mm, north-eastern zone recorded 376 mm and south-eastern zone recorded 325 mm of rainfall.

From Figure 5.19 c) it was noticed that during the decade of 1988 to 1997 period the average highest rainfall was recorded in the north-eastern zone which was 688 mm followed by south-western zone recorded 617 mm of rainfall, south-eastern zone recorded 571 mm, south-central zone recorded 570 mm, north-western zone recorded 453 mm, western zone recorded 420 mm and northern part of the northern region recorded 386 mm of rainfall.

From Figure 5.19 d) it was observed that the highest average rainfall recorded in the decade of 1998 to 2007 was 408 mm in north-eastern zone followed by 324 mm recorded in the south-eastern zone, 320 mm recorded in south-western zone, 295 mm recorded in the south-central zone, 265 mm recorded in the northern part of the northern region, 243 mm recorded in the north-western zone and 199 mm recorded in the western zone.

From Figure 5.19 e) it was observed that in the decade of 2008 to 2017 period the highest average rainfall was recorded in the north-eastern zone which was 675 mm of rainfall followed by 559 mm recorded in the south-western zone, 493 mm recorded in the south-central zone, 415 mm recorded in the north-western zone, 411 mm recorded in the south-eastern zone, 396 mm recorded in the western zone and 387 mm in the northern part of the northern region.

5.5 Climatic zonal-wise average rainfall trends:

5.5.1 South-Eastern zone:

Table 5.6 Decadal Average Total Rainfall Range of South-Eastern Zone

Decades	Rainfall (Average) in mm
1968-1977	21455.12
1978-1987	24773.05
1988-1997	28123.88
1998-2007	29662.93
2008-2017	31209.21

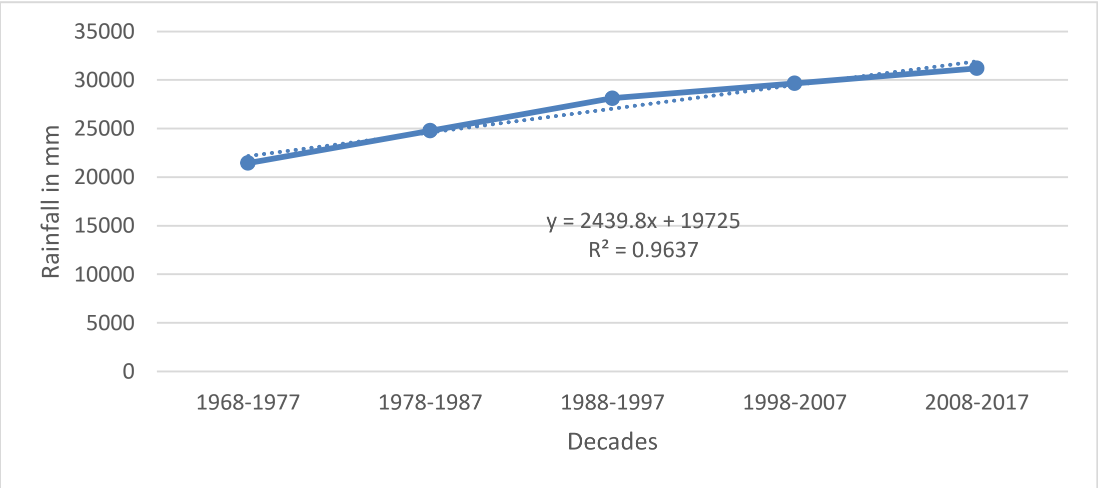

Figure 5.20 Trends of Average Total Rainfall of South-Eastern Zone

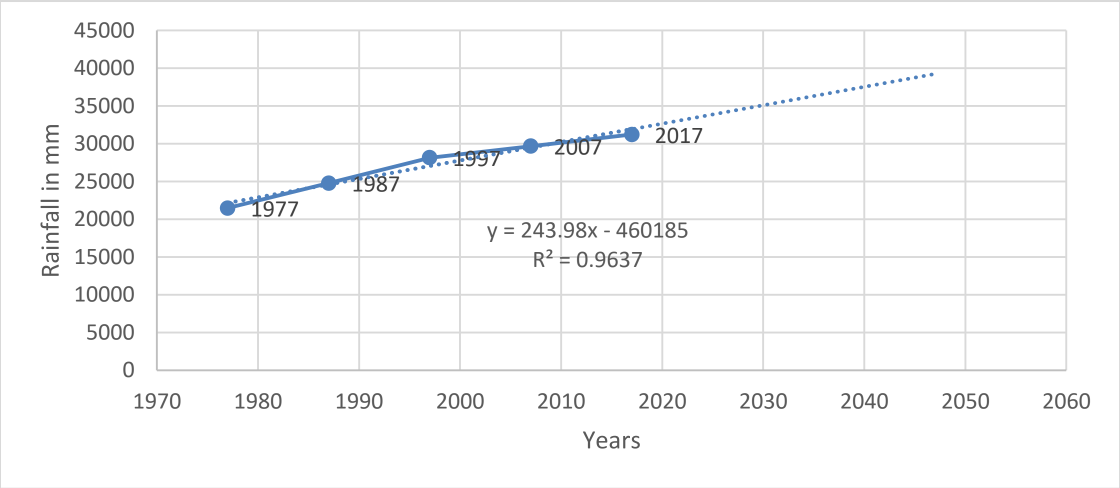

Figure 5.21 Projected Trends of Average Total Rainfall of South-Eastern Zone.

In the south-eastern climatic zone of Bangladesh the average total rainfall of Bangladesh is on the increase. From Figure 5.20 The rainfall is increasing at a rate of 2439 mm per decade and in the 50 year period from 1968 to 2017 the rainfall has increased 12195 mm. From Figure 5.21 The projected trend of rainfall of this region is 244 per year and at this rate the rainfall will increase 8052 mm in 2050 and 20252 mm in 2100.

5.5.2 North-Eastern:

Table 5.7 Decadal Average Total Rainfall Range of North-Eastern Zone

Decades	Rainfall (Range)
1968-1977	28586
1978-1987	30009.5
1988-1997	33101.5
1998-2007	32477.5
2008-2017	32675.5

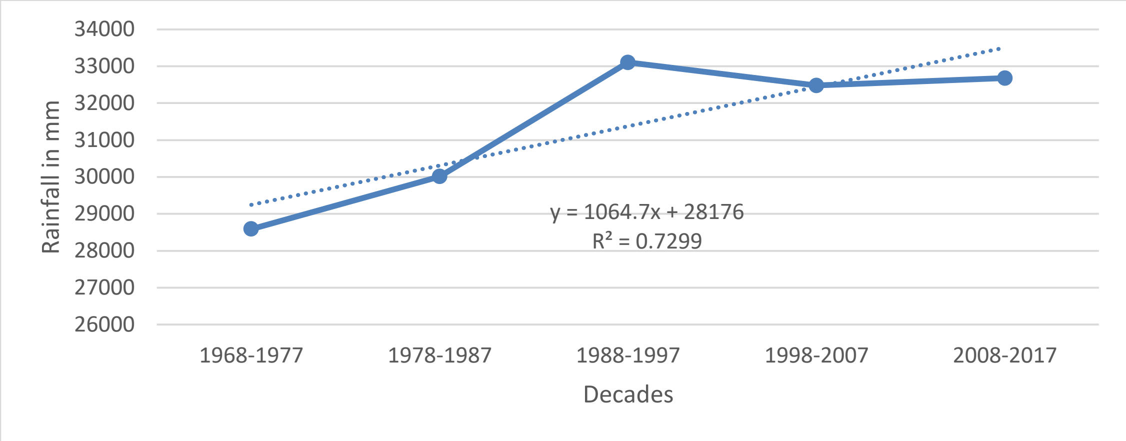

Figure 5.22 Trends of Average Total Rainfall of North-Eastern Zone.

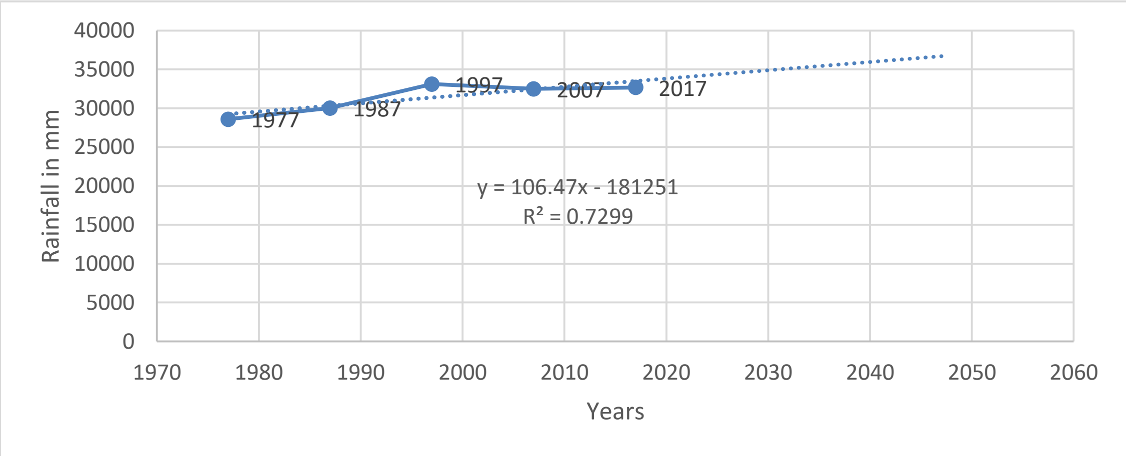

Figure 5.23 Projected Trends of Average Total Rainfall of North-Eastern Zone.

From Figure 5.22 it found that the average total rainfall of the north-eastern region of Bangladesh in on the increasing trend. The rainfall will increase at the rate of 1064 per decade and it has increased 5320 mm in the 50 years period from 1968 to 2017. From Figure 5.23 it is also found that the projected trend of the average total rainfall is 106 mm per year. And at this rate the rainfall will increase 5618 mm in 2050 and 8798 mm in 2100.

5.5.3 Northern Part of the Northern Region:

Table 5.8 Decadal Average Total Rainfall Range of Northern Part of the Northern Region.

Decades	Rainfall (Range)
1968-1977	13989.67
1978-1987	30135.73
1988-1997	17511
1998-2007	24982.5
2008-2017	19682

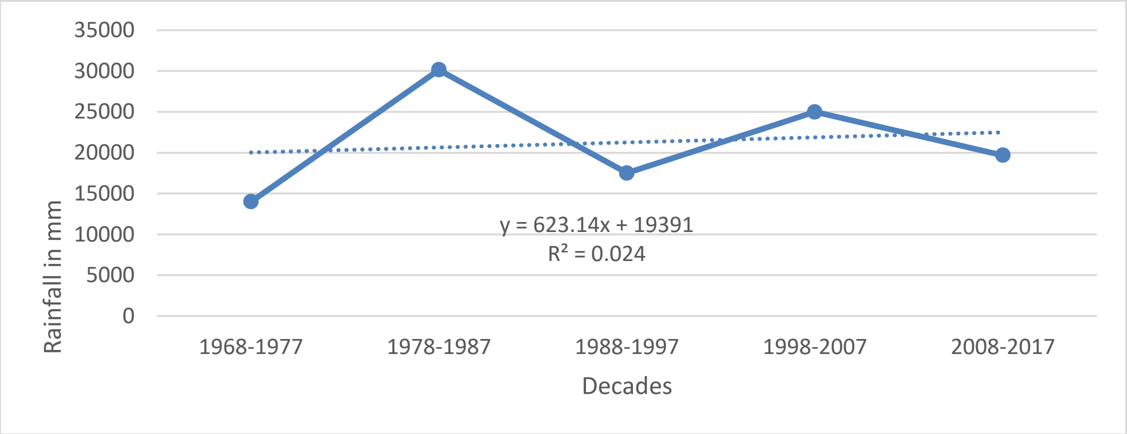

Figure 5.24 Trends of Average Total Rainfall of Northern part of the Northern Region

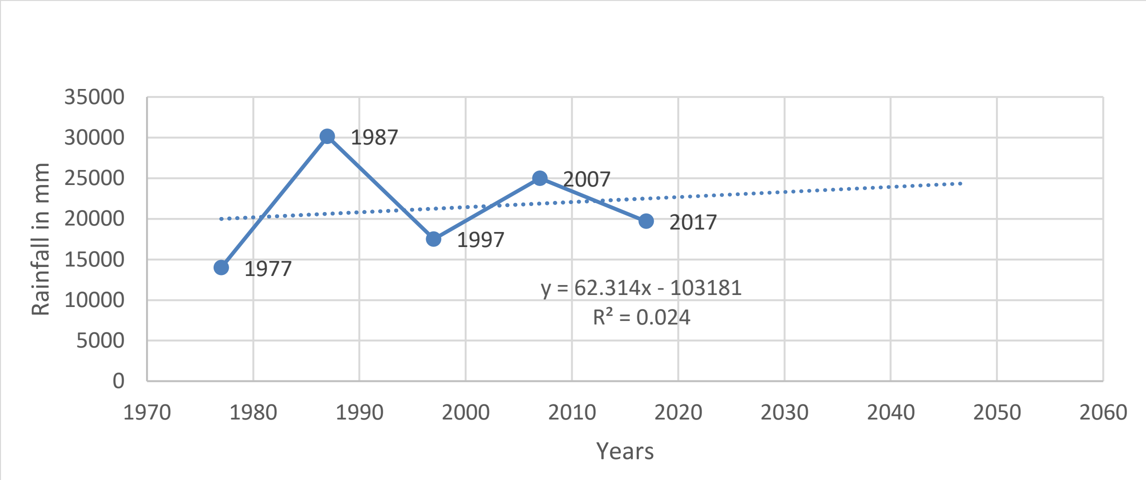

Figure 5.25 Projected Trends of Average Total Rainfall of Northern part of the Northern Region

From Figure 5.24 it is found that the average total rainfall of northern part of the northern region is on the increase and the rainfall has increased 3115 mm in the 50 years period from 1968 to 2017 at the rate of 623 mm per decade. The projected trend of average total rainfall is noticed from Figure 5.25 from this Figure it is also observed that the rainfall will increase 2046 mm in 2050 and 5146 in 2100 at the rate of 62 mm per year.

5.5.4 North-Western:

Table 5.9 Decadal Average Total Rainfall Range of Northern Part of the North-Western Region.

Decades	Rainfall (Range)
1968-1977	17363.01
1978-1987	22859.82
1988-1997	16826.67
1998-2007	18749.33
2008-2017	15209

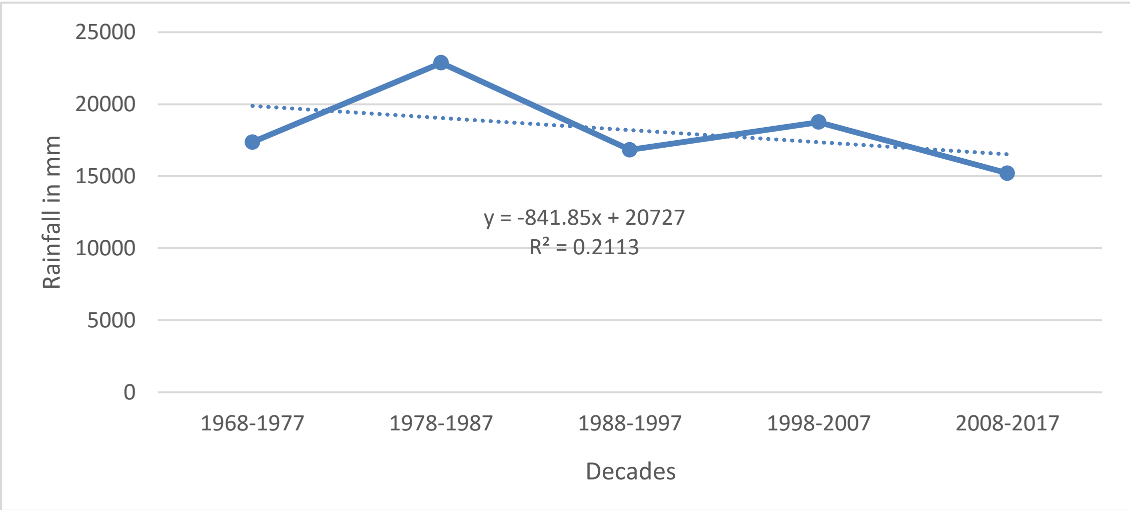

Figure 5.26 Trends of Average Total Rainfall of North-Western Zone

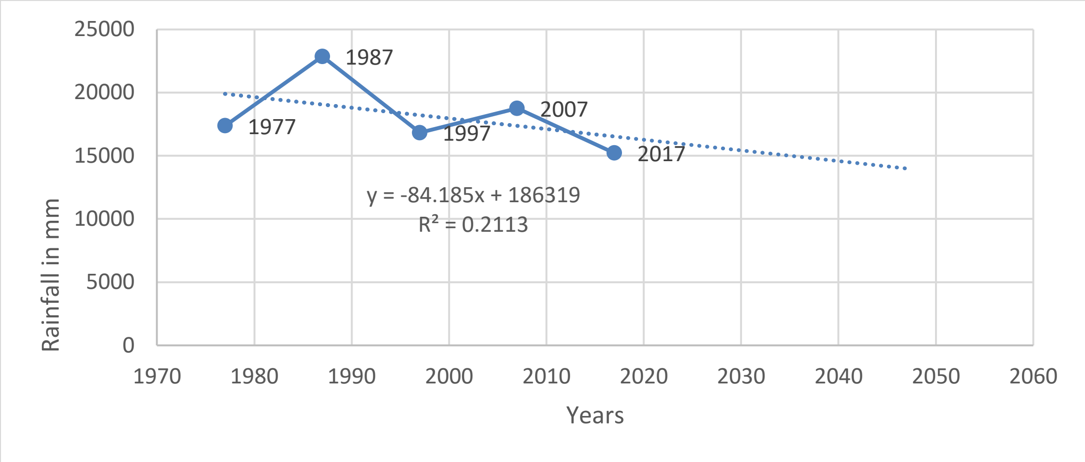

Figure 5.27 Projected Trends of Average Total Rainfall of North-Western Zone

From Figure -5.26 it is found that the average total rainfall of the north-western zone is on the decrease and the rainfall has decreased 4205 mm at a rate of 841 mm per decade. From Figure 5.27 it is also found that the projected trend of the rainfall is 84 mm per year and at this rate the rainfall will decrease 2772mm in 2050 and 6972 mm in 2100.

5.5.5 Western:

Table 5.10 Decadal Average Total Rainfall Range of Western Region.

Decades	Rainfall (Range)
1968-1977	13299.5
1978-1987	15481
1988-1997	14765
1998-2007	15517.5
2008-2017	13022

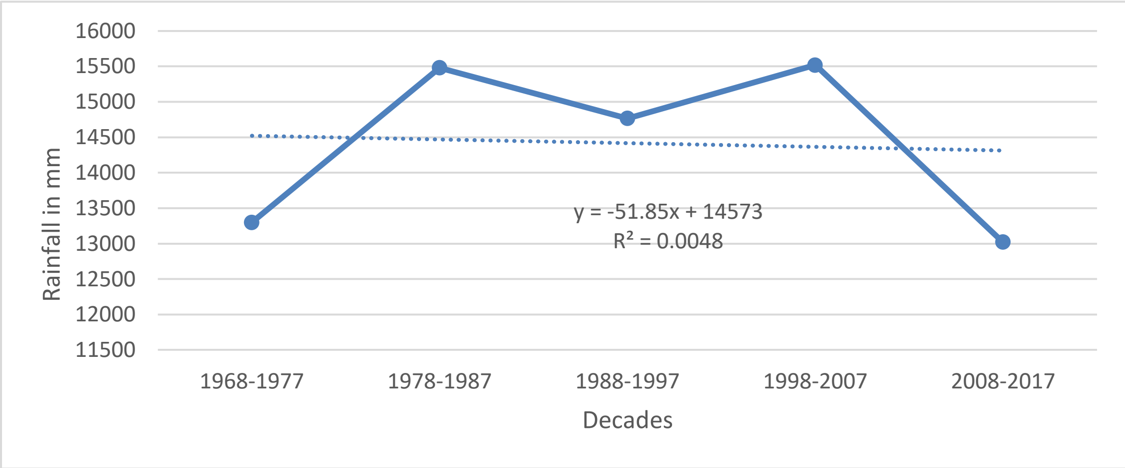

Figure 5.28 Trends of Average Total Rainfall in Western Zone

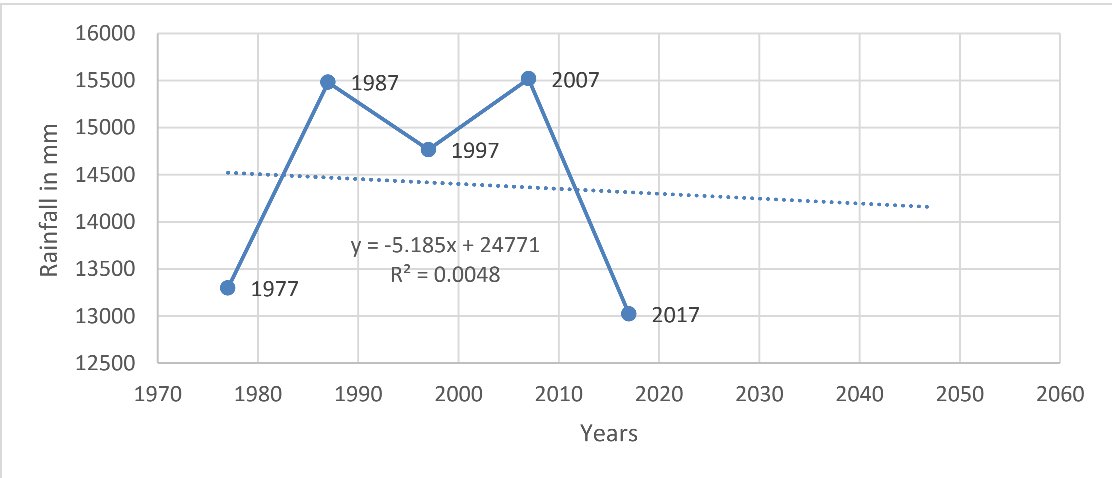

Figure 5.29 Projected Trends of Average Total Rainfall in Western Zone

The average total rainfall of the western zone of Bangladesh in on the decrease. From Figure 5.28 - it is noticed that the rainfall is decreasing at a rate of 51 mm per decade and at this rate the rainfall has decreased 255 mm in the 50 years period from 1968 to 2017. Again, from

Figure 5.29 - it also observed that the projected yearly decreasing rate is 5 mm per year. And at this rate the rainfall will increase 165 mm in 2050 and 415 mm in 2100.

5.6.6 South-Western:

Table 5.11 Decadal Average Total Rainfall Range of South-Western Region.

Decades	Rainfall (Range)
1968-1977	14880
1978-1987	17791
1988-1997	17056.75
1998-2007	18666
2008-2017	16653

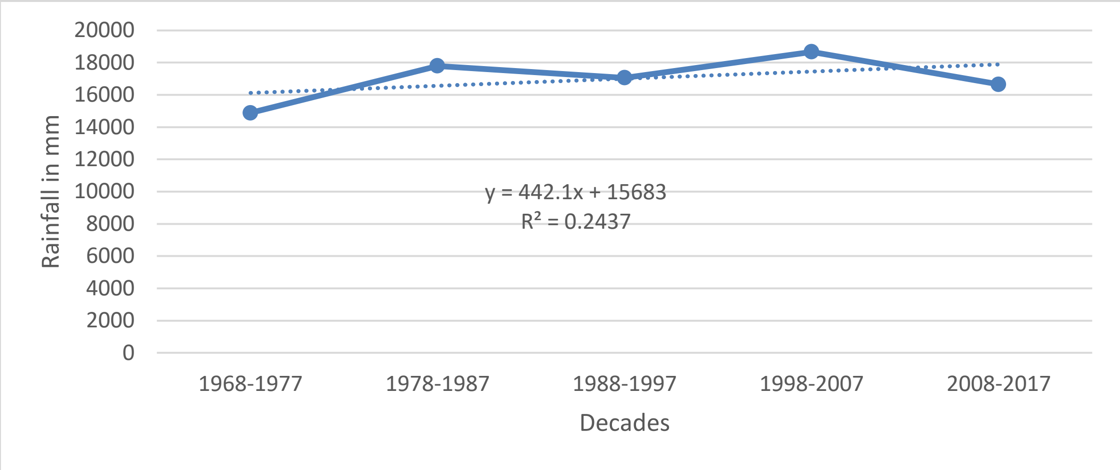

Figure 5.30 Trends of Average Total rainfall of South-Western Region

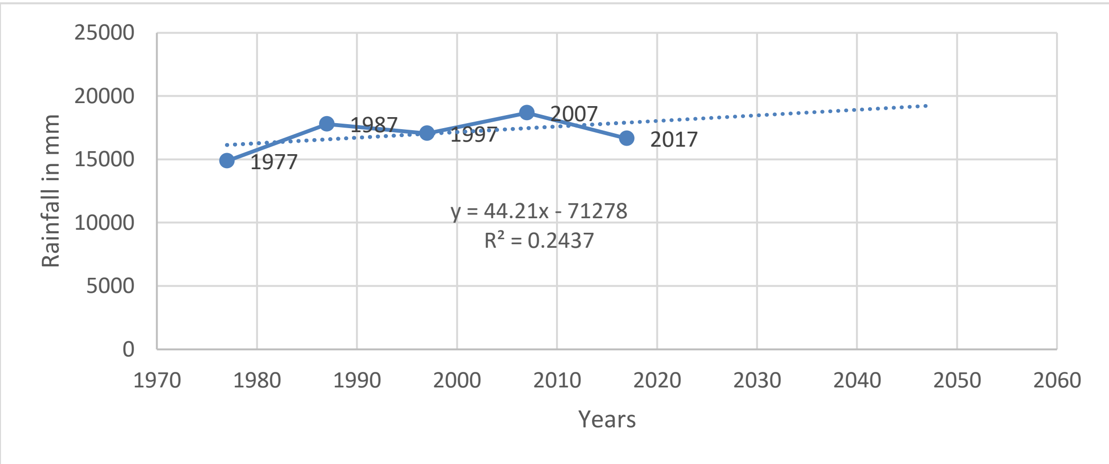

Figure 5.31 Projected Trends of Average Total rainfall of South-Western Region

From Figure 5.30 it is observed that the average total rainfall of south-western zone of Bangladesh is on the increase. The rainfall is increasing at rate of 442 mm per decade and at this rate the rainfall has decreased 2210 mm in the 50 years time period from 1968 to 2017.

From Figure 5.31 it is also noticed that the projected rate of rainfall increase is 44 mm per year and at this rate the rainfall will decrease 1452 mm in 2050 and 2739 mm in 2100.

5.5.7 South-Central:

Table 5.12 Decadal Average Total Rainfall Range of South-Central Region.

Decades	Rainfall (Average) in mm
1968-1977	19183.78
1978-1987	22694.53
1988-1997	19459.25
1998-2007	21120.25
2008-2017	19201.13

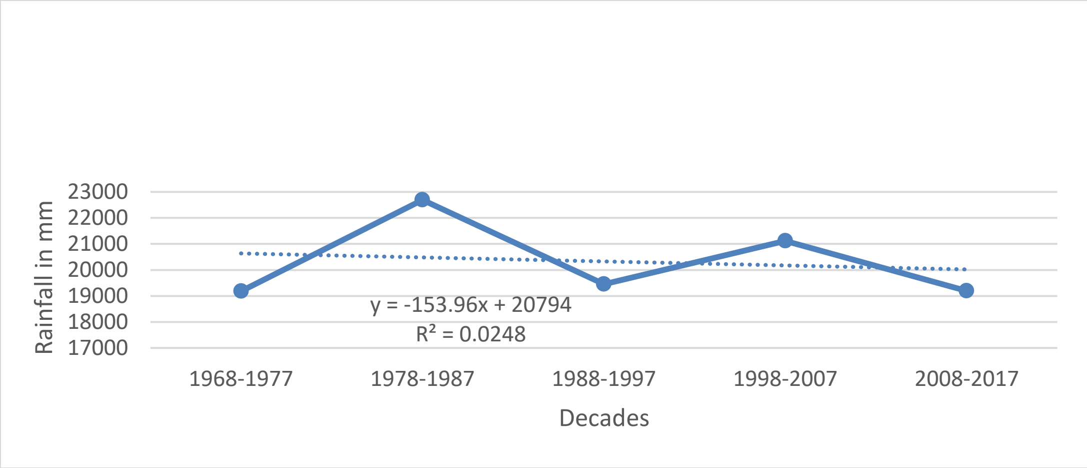

Figure 5.32 Trends of Average Total Rainfall of South-Central Zone

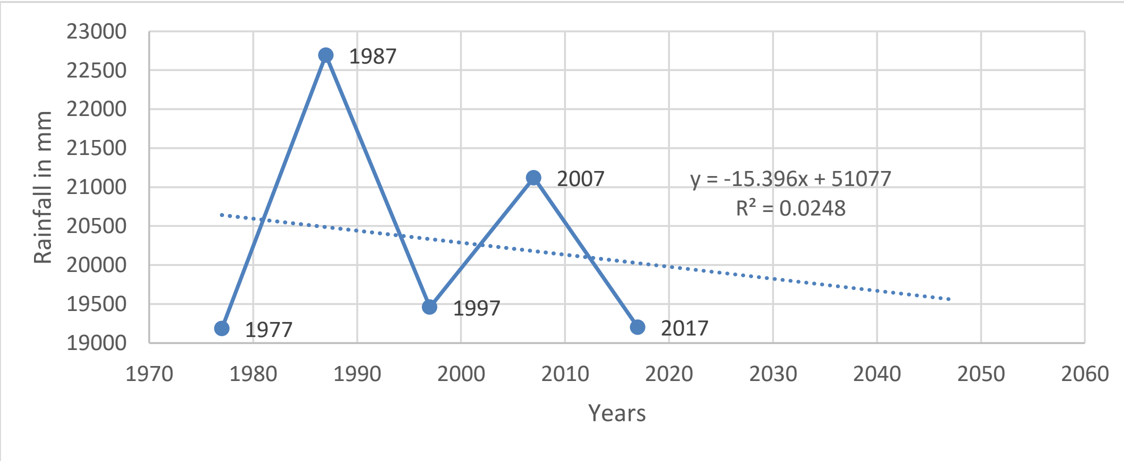

Figure 5.33 Projected Trends of Average Total Rainfall of South-Central Zone

From Figure 5.32 it is found that the average rainfall of the south-central zone is on the decreasing condition. The rainfall is decreasing at a rate of 153 mm per decade. And at this decade the rainfall has decreased 765 mm in 50 years period from 1968 to 2017. From Figure

5.33 it is also observed that the projected rate of decreasing is 15mm per year and at this rate the rainfall will decrease 459 mm in 2050 and 1245 mm in 2100.

CHAPTER: SIX

SUMMARY AND CONCLUSION

Summary and Conclusion

6.1 Introduction:

This study has been completed with in depth analysis of temperature and rainfall data for the last fifty years (1968-2017) period by using appropriate method and techniques with detail map presentation by using arc-gis. I believe the results and findings of the study will help the researchers, academics, policy makers, government and non-government organizations for further research related to the temperature and rainfall variability of Bangladesh.

6.2 Summary of the findings:

The summary of the decadal trends and changes in minimum temperature (Tmin) of Bangladesh from 1968 to 2017 is given below:

The average minimum temperature trend in Bangladesh has been increasing steadily from 0.19°C per decade in the period of 1968-1977 to 0.95°C per decade in 2008-2017. The projected trend indicates that the average minimum temperature is expected to increase from 0.63°C per decade in the period of 2018-2050 to 1.58°C per decade in 2051-2100.

The average minimum temperature trend for the pre-monsoon and monsoon seasons has been consistently increasing, from 0.21°C per decade in 1968-1977 to 1.05°C per decade in 2008-2017. The projected trend indicates that the average minimum temperature for these seasons is expected to increase from 0.69°C per decade in the period of 2018-2050 to 1.7°C per decade in 2051-2100.

The average minimum temperature trend for the post-monsoon and dry/winter seasons has also increased, but at a slower pace, from 0.02°C per decade in 1968-1977 to 0.1°C per decade in 2008-2017. The projected trend indicates that the average minimum temperature for these seasons is expected to increase from 0.07°C per decade in the period of 2018-2050 to 0.17°C per decade in 2051-2100.

In summary, the data reveals a clear upward trend in temperature for all seasons in Bangladesh . However, the pre-monsoon and monsoon seasons show the most significant increase in temperature.

The summary of the decadal trends and change in maximum temperature (T_{max}) of Bangladesh during 1968 to 2017 is given below:

The data is presented for four seasons - pre-monsoon, monsoon, post-monsoon, and dry/winter - and for average and maximum temperatures.

The data shows that the average temperature trend increased from 0.13°C per decade in 1968-1977 to 0.65°C per decade in 2008-2017, with a projected increase to 1.08°C per decade in

2051-2100. The maximum temperature trends show a similar pattern of increase over time, with the highest increase in temperature projected for the monsoon season.

In terms of seasons, the table shows that the highest temperature increase was observed and projected for the monsoon season, with an average maximum temperature trend of 1.43°C per decade observed from 2008-2017 and a projected trend of 2.37°C per decade for 2051-2100. The lowest temperature increase was observed and projected for the dry/winter season, with an average maximum temperature trend of 0.40°C per decade observed from 2008-2017 and a projected trend of 0.66°C per decade for 2051-2100.

The Summary of the decadal trends and changes in minimum temperature(T_{min}) of Bangladesh for climatic zones during 1968- 2017 is given below:

Data shows the trends in temperature in various regions of a country from 1968 to 2017, and projected changes up to 2100. The temperature trends are given in degrees Celsius per decade. The regions included in the data are South-Eastern, North-Eastern, Northern Part of the Northern Region, North-western, Western, South-Western, and South-Central.

For each region, the data shows the temperature trends observed during different decades from 1968 to 2017, as well as the projected temperature changes up to 2100. The observed trends show that temperature has been increasing in all regions during the past few decades. The projected changes indicate that the temperature will continue to rise in all regions throughout the 21st century.

The highest temperature trends are observed in the North-Eastern and South-Central regions, with projected changes of up to 2.24°C per decade by 2100. The Western region shows the lowest temperature trends among all regions, with projected changes of only 0.10°C per decade by 2100.

The summary of the decadal trends and changes in Maximum Temperature (T_{max}) of Bangladesh for climatic zones during 1968-2017 are given below:

The data shows that, the South-Eastern region experienced a gradual increase in temperature trends over the observed period, with an initial decadal change of 0.0666°C in 1968-1977, reaching a high of 0.33°C in 2008-2017, and then projected to reach 0.56°C in 2051-2100.

The North-Eastern zone showed a more rapid increase in temperature trends, with a decadal change of 0.3131°C in 1968-1977, increasing to 1.57°C in 2008-2017 and projected to reach 2.60°C in 2051-2100.

The Northern Part of the Northern Region, on the other hand, experienced a significant decrease in temperature trends, with a decadal change of -0.3802°C in 1968-1977, decreasing to -1.90°C in 2008-2017 and projected to decrease further to -3.15°C in 2051-2100.

The North-western region showed a moderate increase in temperature trends, with a decadal change of 0.156°C in 1968-1977, increasing to 0.78°C in 2008-2017 and projected to reach 1.29°C in 2051-2100.

The Western region experienced a gradual increase in temperature trends, with a decadal change of 0.0862°C in 1968-1977, increasing to 0.43°C in 2008-2017 and projected to reach 0.70°C in 2051-2100.

The South-Western region showed a moderate increase in temperature trends, with a decadal change of 0.149°C in 1968-1977, increasing to 0.75°C in 2008-2017 and projected to reach 1.23°C in 2051-2100.

The South-Central region experienced a steady increase in temperature trends, with a decadal change of 0.1882°C in 1968-1977, increasing to 0.94°C in 2008-2017 and projected to reach 1.56°C in 2051-2100.

In summary, the table shows that different zones in the region experienced varying decadal changes in temperature trends over the observed period and are projected to continue to do so in the future, with some regions experiencing significant increases or decreases in temperature.

The summary of the decadal trends and changes in average total rainfall of Bangladesh during 1968-2017 is given below:

The average annual rainfall is shown to be consistently at 1025 mm from 1968 to 1987. However, there is a significant increase in the decadal changes of rainfall from 1988 to 2017, with an increase from 1025 mm in 1987 to 5125 mm in 2017. The projected rainfall changes show a further increase, with 3366 mm in 2018 to 8466 mm in 2100.

The pre-monsoon rainfall shows a similar pattern of increase, with a consistent 153 mm from 1968 to 1987, followed by an increase from 306 mm in 1988 to 765 mm in 2017. The projected rainfall changes show an increase from 495 mm in 2018 to 1245 mm in 2100.

The monsoon rainfall category shows the largest amount of rainfall, with a consistent 719 mm from 1968 to 1987, followed by an increase from 1438 mm in 1988 to 3595 mm in 2017. The projected rainfall changes show an increase from 2376 mm in 2018 to 5976 mm in 2100.

The post-monsoon rainfall category also shows a pattern of increase, with a consistent 156 mm from 1968 to 1987, followed by an increase from 312 mm in 1988 to 780 mm in 2017. The projected rainfall changes show an increase from 528 mm in 2018 to 1328 mm in 2100.

The dry/winter rainfall category shows the smallest amount of rainfall, with a consistent 30 mm from 1968 to 1987, followed by an increase from 60 mm in 1988 to 150 mm in 2017. The projected rainfall changes show an increase from 99 mm in 2018 to 249 mm in 2100.

Overall, the data shows a consistent pattern of increase in the amount of rainfall across all categories, with the largest increase observed in the monsoon rainfall category. This increase is expected to continue in the future, with the projected rainfall changes showing a further increase in the amount of rainfall in all categories.

The summary of the decadal trends and changes in average total rainfall in Bangladesh for the different climatic regions during 1968-2017 are given below

The given data is about the trends of rainfall and decadal changes in rainfall from 1968 to 2017, as well as the projected rainfall changes from 2018 to 2100. The data is divided into different zones in India, including the South-Eastern zone, North-Eastern zone, Northern Part of the Northern Region, North-western zone, Western zone, South-Western zone, and South-Central zone.

The South-Eastern zone shows the largest amount of rainfall, with a consistent 2439 mm from 1968 to 1987, followed by an increase from 4878 mm in 1988 to 12195 mm in 2017. The projected rainfall changes show a further increase, with 8052 mm in 2018 to 20252 mm in 2100.

The North-Eastern zone also shows a pattern of increase in the amount of rainfall, with a consistent 1064 mm from 1968 to 1987, followed by an increase from 2128 mm in 1988 to 5320 mm in 2017. The projected rainfall changes show an increase from 3498 mm in 2018 to 8798 mm in 2100.

The Northern Part of the Northern Region shows a consistent amount of rainfall, with 623 mm from 1968 to 1987, followed by an increase from 1246 mm in 1988 to 3115 mm in 2017. The projected rainfall changes show a further increase, with 2046 mm in 2018 to 5146 mm in 2100.

The North-western zone shows a pattern of decrease in the amount of rainfall, with a consistent -841 mm from 1968 to 1987, followed by a decrease from -1682 mm in 1988 to -

4205 mm in 2017. The projected rainfall changes show a further decrease, with -2772 mm in 2018 to -6972 mm in 2100.

The Western zone shows a consistent decrease in the amount of rainfall, with -51 mm from 1968 to 1987, followed by a decrease from -102 mm in 1988 to -255 mm in 2017. The projected rainfall changes show a further decrease, with -165 mm in 2018 to -415 mm in 2100.

The South-Western zone shows a pattern of increase in the amount of rainfall, with a consistent 442 mm from 1968 to 1987, followed by an increase from 884 mm in 1988 to 2210 mm in 2017. The projected rainfall changes show an increase from 1452 mm in 2018 to 3652 mm in 2100.

The South-Central zone shows a pattern of decrease in the amount of rainfall, with a consistent -153 mm from 1968 to 1987, followed by a decrease from -306 mm in 1988 to -765 mm in 2017. The projected rainfall changes show a further decrease, with -495 mm in 2018 to -1245 mm in 2100.

Overall, the data shows a mixed pattern of increase and decrease in the amount of rainfall across different zones in India. The South-Eastern and North-Eastern zones show a consistent pattern of increase in the amount of rainfall, while the North-western and Western zones show a consistent pattern of decrease. The Northern Part of the Northern Region and South-Western zone show a pattern of increase, and the South-Central zone shows a pattern of decrease in the amount of rainfall. These patterns are expected to continue in the future, with the projected rainfall changes showing further increase or decrease in the amount of rainfall across different zones.

The summarise results shows that decadal trends and changes in minimum and maximum temperatures of Bangladesh from 1968 to 2017. The data shows a clear upward trend in temperature for all seasons in Bangladesh. The pre-monsoon and monsoon seasons show the most significant increase in temperature. The data also presents the temperature trends in various regions of Bangladesh, indicating that the temperature has been increasing in all regions during the past few decades. The projected changes indicate that the temperature will continue to rise in all regions throughout the 21st century. The highest temperature trends are observed in the North-Eastern and South-Central regions, with projected changes of up to 2.24°C per decade by 2100. Finally, the write-up suggests that urgent measures should be taken to mitigate the adverse effects of climate change, such as sea-level rise, more frequent natural disasters, and changes in agricultural productivity.

6.3 Conclusion:

The study discusses in depth the last fifty years (1968-2017) temperature and rainfall variability of Bangladesh from which we have a clear conception about the trends of climate change of Bangladesh . From this study we observed that both the average minimum and maximum temperature and also average rainfall remain on the increasing trends which has a far-reaching impact on the overall development of the country. Experts believe that the increasing trends of temperature and rainfall will cause the country a huge devastation especially the coastal region will be most affected. A large number of people living in the coastal region will be displaced and homeless and for their existence they will be migrating to the urban areas including Dhaka, the capital city and other big cities of the country for work and survival.

Since, Bangladesh will be the worst affected country of climate change although her contribution to the increase of temperature and rainfall is negligible, we should negotiate the climate deal agreement with the developed nations of the world who contribute a lot to the emission of green house gases and are mostly responsible for the present climate change for which Bangladesh has to face frequent natural disasters like floods, cyclones, tidad surges, storms and incur huge economic losses hampering on going development works of the country.

From this study it has been found that both average temperature and rainfall of the country will be increasing and in future we have face scorching heat and heavy downpour about all the year round and sea-level rise will be displacing a vast number of people living in the coastal region will be the worst affected so, we have to take long term plan to cope with this situation among which adaptation and mitigation strategy are needed to be implemented.

The present government have taken the climate change issue very seriously and are negotiating with the developed nations for climate risk of the country and compensation internationally as well as also formulated DELTA plan to combat climate change issues in Bangladesh .

Alongside the government many non-government organizations are also working with the climate change issues of Bangladesh especially giving importance the people of coastal region who will be the worst sufferers of climate change.

Both the government and non-government activities are making aware of the people about the consequences of the impact of climate change. I believe such activities will help them somewhat tension free.

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