IMPACTS OF CLIMATE FACTORS INFLUENCING RICE PRODUCTION IN BANGLADESH

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IMPACTS OF CLIMATE FACTORS INFLUENCING RICE PRODUCTION IN BANGLADESH

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*This is to certify that thesis entitled "**IMPACTS OF CLIMATE FACTORS INFLUENCING RICE PRODUCTION IN BANGLADESH"** submitted to the Faculty of Agribusiness Management, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in AGRICULTURAL STATISTICS**, embodies the result of a piece of bona fide research work carried out by **MAHMUDA AKTER**, Registration No. 13-05631 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

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DEDICATED TO

MY BELOVED

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ABSTRACT

The world is under pressure to provide food for its more than 7 billion of citizen right now and by 2050 it is expected that the world will be the home to around 9 billion people. Bangladesh is a densely populated country and home to more than 160 million people which is struggling to manage the sufficient production of rice and wheat. Besides over population burden, climate change has been threatening to food security in Bangladesh as well as in the world. This study was aimed to determine the specific effects of variable on rice production. Climate data has been procured from the Bangladesh Meteorological Department (year 2011-2018) and rice production data were collected from DAE (Department of Agricultural Extension) and BBS (Bangladesh Bureau of Statistics). These data were analyzed using Ordinary Least Squares (OLS), Generalized Least Squares (GLS) and Feasible Generalized Least Squares (FGLS) methods.

The results showed that increased climate variability, climate extremes in particular exacerbate risk. Rice yields are sensitive to rainfall extremes, with both deficient and surplus rainfall increasing variability. Additionally, climate inputs, non-climate input, normally, high yielding variety seeds are found to be increasing average in agricultural yield. The results of this study, has shown important policy implication. The higher variability in agricultural production has tendency to greater variability in the earnings of the rural poor who have been experiencing severe financial and credit constraints. Suitable policies are needed to be installed to mitigate climate impacts on agriculture sector to the highest extent.

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LIST OF ABBREVIATIONS

BADC	**:** Bangladesh Agricultural Development Corporation
BBS	**:** Bangladesh Bureau of Statistics
BMD	**:** Bangladesh Meteorological Department
BSCAA	**:**Bureau of South and Central Asian Affairs
COP	**:** Conference of the parties
DAE	**:**Department of Agricultural Extension
FAO	**:** Food and Agriculture Organization
FY	**:** Fiscal Year
GDP	**:**Gross Domestic Product
GM	**:** Genetically Modified
GFP	**:** Good farming practices
GoB	**:** Government of Bangladesh
IRRI	**:** International Rice Research Institute
IUCN	**:** International Union for Conservation of Nature
IPCC	**:** Intergovernmental Panel on Climate Change
IPMP	**:**Integrated Pest Management Policy
MoEF	**:** Ministry of Environment and Forest
MT	**:** Metric Ton
NARS	**:**National Agricultural Research Systems
NAPA	**:**National Adaptation Program of Action
OECD	**:**Organization for Economic Co-operation and Development
ODA	**:** Overseas development assistance
SRDI	**:**Soil Resources Development Institute
UNFCCC	**:** United Nations Climate Change Conference
UNEP	**:** United Nations Environment Programme

CHAPTER ONE
INTRODUCTION

1.1General Overview

Bangladesh is mostly agrarian country and agriculture is dedicated in ensuring the food security of the country. Bangladesh has attained self-sufficiency in food production in 2013 and therefore the goal to ensuring food to all have adapted in the 'Vision 2021' of the Government of Bangladesh (Planning Commission, 2010). The most important challenge in Bangladesh's agriculture is to keep continue increased food production to meet the increasing demand from the domestic market due to over population growth. Besides the food security, agriculture sector alone contributes about 12% of the GDP and employ 44% workforce of the country. Thus agriculture sector has received topmost priority sector by the government to keep continuous development. Agriculture sector is directly associated with the rural poverty as the sector benefits livelihood of the rural poor people who account for majority of the population of Bangladesh. Agriculture sector is the major player in contributing to income and employment generation in Bangladesh (Planning Commission, 2009).

Most of the farmers in Bangladesh are marginal farmers and mainly occupying subsistence farming. Crop production is the major platform in raising rural income and creating jobs for the poor people (MoEF, 2009).It has been recognized that Bangladesh is one of the most climate vulnerable countries in the world. Bangladesh is located between the Himalayas and the Bay of Bengal and this country is very prone to natural disasters (World Bank, 2009). Climate change has been enhancing the intensity and frequency of occurrences of storms, salinity, drought, irregular rainfall, high temperature, flash floods, etc. that resulted from global warming. Global warming is causing shortfall in food production in the tropical countries (UNEP, 2009).

1.2 Background Information

Regarding the impact of global warming and climate change issues, Bangladesh is identified worldwide as one of the most vulnerable countries because of its unique geographic location, low elevation from the sea, dominance of floodplains, high levels of poverty, high population density, and over dependence on nature and extraction natural resources and services.

Bangladesh has got a long history of several extreme climatic events claiming millions of lives and destroying past development gains. The variation in rainfall pattern has been combined with increased snow melt from the Himalayas and temperature extremes. These have been resulted in crop production failure and damage, preventing farmers and those dependent from meaningful earning opportunities.

The constant climate change pattern has been imposing impacts on our families, communities, state, environment and life including eroding our assets, investment and future. Climate change and global warming causing threats in settlements and leading to displacement of the number of people from their land due to riverbank erosion, permanent inundation and sea level rise which are increasing in a rapid fashion every year. It is alarming that resources and efforts of government and people are quickly drained addressing the impact of one event when another hazard strikes. Consequently, the impacts of global warming and climate change have been challenging our development efforts, human security and the future constantly. However, recent studies ranked Bangladesh in the 7th victim position due to climate change. But due to enhancing to capacity to face such disaster, Bangladesh managed to show highly potential capacity in managing disasters and ranked third in the world (Prothom Alo, 5th December, 2019).

Bangladesh has been experiencing the detrimental impacts of global warming and climate change since many decades. These impacts include hotter summer, irregular monsoon, untimely rainfall heavy rainfall for short period leading to water logging and landslides, very little rainfall in dry period, increased river flow and inundation during monsoon, increased frequency, intensity and recurrence of floods, crop damage due to flash floods and monsoon floods, drought causing crop production failure, enhanced period cold spell, salinity intrusion along the coast leading to scarcity of potable water and redundancy of prevailing crop practices, coastal erosion, riverbank erosion, mortality due to extreme heat and extreme cold, increasing mortality, morbidity, prevalence and outbreak of malaria, dengue, cholera and diarrhea.

The impacts of climate change are imposing significant stress to our human ability, physical and environmental resources, and economic activities. Intergovernmental Panel on Climate Change (IPCC) in its AR4 described with high-confidence climatic anomalies and their impacts on Bangladesh.

The risks appeared due to climate change in Bangladesh are asfollows:

Impacts on the Environment	**Impacts on Sectors and Socio-Economic Resources**
Increased frequency and severity of floods, droughts, storms and heat waves Rainfall pattern changes Changes in growing seasons and regions Changes in water quality and quantity Glacial melt Sea level rise	Water resources Agriculture and forestry Food security Human health Infrastructure (e.g. transport) Settlements: displacement of inhabitants and loss of livelihood Coastal management Industry and energy Disaster response & recovery plans

The victims of the impact changes are increasing day by day and seeking refuge due to their home loss, land, settlement to river erosion, coastal erosion,and permanent inundation. The number of families and villages who lose their homes permanently to rivers every year are perhaps one of the highest in Bangladesh in the world. Studies showed that many of the slum dwellers in the metropolitan areas are the victims of riverbank erosion.

Security concern has been raising due to climate changes. The security issues are associated with both 'freedom from want' aspects of human security (e.g.food security, livelihood security, health security, water security and environmental security) and freedom from fear' aspects (e.g. asset security, personal security, political security and tenure security).

It is evident that the climate change in Bangladesh has generated insecurities for life, food, water, property, settlement, livelihood assets, livelihoods and others. Reduction in securities directly or indirectly is the result of climate change. Degradation in the environment, land resources degradation ultimately reduces food securities, health securities. Environmental degradation, degradation of land resources ultimately reduces food securities, health securities etc and simultaneously increases conflicts over resources and livelihood persuasions.

The major insecure domains which have been spotted are discussed shortly as follows:

Food security: Crop losses due to flood, cyclone, storm surge and drought are increasing every year. Salinity and permanent inundation are also hindering crop production greatly.

Water scarcity: Prolonged dry season, reduced precipitation and drought are resulting scarcity of drinking water. Contamination of fresh water resources with saline water are found to be evident in the coastal aquifer.

Loss of property and life: An increasing number of people are suffering loss or damage to their properties and even lives. Increased storm surges, cyclone, floods, river bank erosion destroysand damage peoples' properties including house, land, cattle, poultry and other livelihood assets and living essentials. Recurrent disaster appearance and frequent disasters increases damage and loss by many folds.

Loss due to land degradation: Due to huge climate change, the river bank and costal erosion are increasing at an alarming rate. Studies found that a 45 cm sea-level rise will inundate almost 10.9% of our territory and will displace 5.5 million people of our coastal regions. Salinity intrusion into the country side reached up to 100km and degrades land resources. Land use for farming, shrimp and other uses in the declining context generates conflicts.

Loss of livelihoods: Livelihood opportunities are reducing day by day due to land loss and degradation, scarcity of water, floods, and other hazards reduces. Fishing opportunities have been reducing due to rough sea. Working days and opportunities are reduced prior, during and after disasters by limiting access to services due to health hazards, mal nutrition and other illness.

Insecurity of women: Women and disadvantaged groups are more sufferer during disasters asthey don't receive warning in time and women has to take care of their children, elderly and disabled.

Displacement: People are forced to move from their land to other places which raises conflicts for resources where they move. Generally, most of the migrants end up in the urban slums, particularly in Dhaka (capital),and there is some evidence that this constant influx of people is contributing to rising crime and insecurity in these areas.

1.3 Significance and Justification of the Study

Very few studies have been done in Bangladesh to investigate the pattern and trend of rainfall, temperature, relative humidity, solar radiation, heat budget and energy balance on various ecosystem, and meteorological application on rice production. However, from the previous studies conducted in Bangladesh, it was evident that very few of them have intensively examined the relationship between climate change and crop production (Ferdous and Baten, 2011). Accordingly, crop-oriented research (particularly on major staples) is pledged to formulate better policy suggestions for sustainable development. Given the high dependence of rice yield on climate variables (i.e., change), there is a vital need to assess the potential impacts of climate change (i.e., maximum temperature, minimum temperature, rainfall and humidity) on different types of rice yields (productivity). Because an understanding of the national impacts of recent climate trends on major food crops would help to anticipate impacts of future climate changes on the food security of the country.

1.4 Objectives of the study

The study was aimed to determine the following objectives:

1. To study the climate change pattern in Bangladesh.
2. To assess the situation of climate change in Bangladesh.
3. To find out the influences of climate factors on the production of Rice.
4. To estimate a model between climate change and Rice production in Bangladesh.

1.5. Key Research Questions

- What is the climate change pattern in Bangladesh?
- What is the pattern of temperature in Bangladesh?
- What is the pattern of rainfall in Bangladesh?
- What is the humidity pattern of Bangladesh?

CHAPTER TWO

REVIEW OF LITERATURE

2.1.Climate of Bangladesh

Bangladesh is located the tropics and has a tropical monsoon climate mainly characterized by huge seasonal variations in high temperatures, high humidity and rainfall. Regional climatic variations in this flat country are at minimum. Three seasons are generally categorized: 1) a hot, muggy summer from March to June; 2) a hot, humid and rainy monsoon season from June to November; and 3) a warm-hot, dry winter from December to February. Generally, maximum summer temperatures range between 38 and 41 °C (100.4 and 105.8 °F). April is the hottest month with high temperature in most parts of Bangladesh. January is the coolest month, when the average temperature in most part of the country is 16–20 °C (61–68 °F) during the day and around 10 °C (50 °F) at night.

In the winter, winds are mostly from the north and northwest, blowing gently at 1 to 3 kilometers/hour (0.6 to 1.9 mph) in northern and central areas and 3 to 6 kilometers/hour (1.9 to 3.7 mph) near the coast. From March to May, violent thunderstorms, can be experienced and producing winds of up to 60 kilometers per hour (37.3 mph). It has been observed that during the intense storms of the early summer and late monsoon season, southerly winds of more than 160 kilometers per hour (99.4 mph) cause waves to crest as high as 6 meters (19.7 ft) in the Bay of Bengal, which brings disastrous flooding to coastal areas.

Bangladesh experiences flood every year due to heavy rainfall. Annual rainfall in most parts of the country is at least 2,300 mm (90.6 in) in contrast to the relatively dry western regionof Rajshahi, where the annual rainfall is about 1,600 mm (63.0 in). This due to its location just south of the foothills of the Himalayas, where monsoon winds turn west and northwest and the Sylhet region in northeastern Bangladesh receives the greatest average precipitation. Report showed that from 1977 to 1986, annual rainfall in that region ranged between 3,280 and 4,780 mm (129.1 and 188.2 in) per year. Average daily humidity from

March to July ranges from 55 to 81% (lows) and from July highs of between 94 and 100%, based on readings taken at selected stations nationwide in 1986.

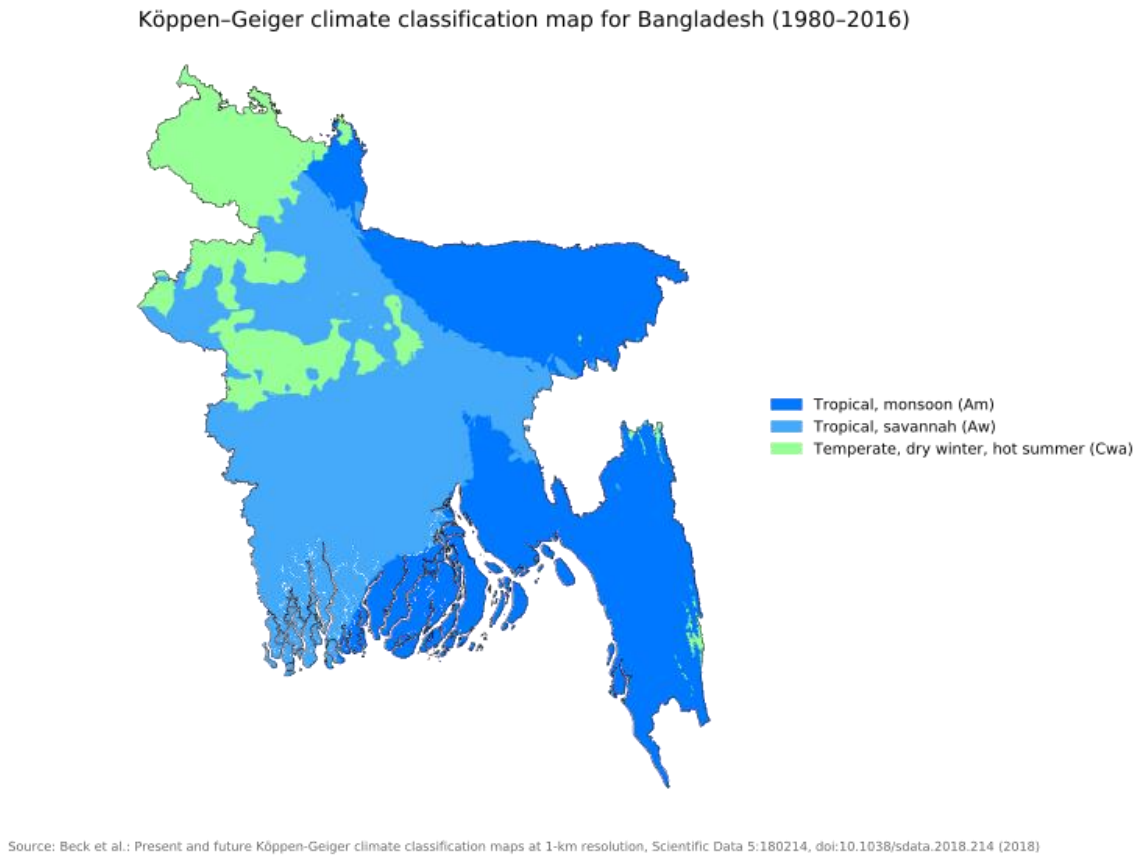


Plate.1: Koppen-Geiger Climate Classification Map for Bangladesh (1980-2016)

During the monsoon season, Bangladesh experiences about 80% rain falls of the year. Generally, the monsoons originated from the contrasts between low and high air pressure areas which is the outcome of differential heating of land and water. During the April and May (hot months) hot air raises over the Indian subcontinent, creating low-pressure areas into which rush cooler, moisture-bearing winds from the Indian Ocean. This is known as the southwest monsoon, commencing in June and usually lasting through September. Categorizing against the Indian landmass, the monsoon flows in two branches, one of which strikes western India. The other travels through the Bay of Bengal and eastern India and Bangladesh, crossing the plain to the north and northeast before being turned to the west and northwest by the foothills of the Himalayas.

Bangladesh is prone to the natural calamities, such as tropical cyclones, floods, tornadoes, and tidal bores. Almost every year, destructive waves or floods caused by flood tides rushing up estuaries-ravage the country, particularly the coastal belt. Between 1947 and 1988, 13 severe cyclones hit Bangladesh, leading to mass destruction and havoc life and property. As for example, in the May 1985, a severe cyclonic storm packing 154 kilometer/hour (95.7 mph) winds and waves 4 meters (13.1 ft) high swept into southeastern and southern Bangladesh. The destruction events including killing of more than 11,000 persons, damaging more than 94,000 houses, killing some 135,000 head of livestock, and damaging nearly 400 kilometers (248.5 mi) of critically needed embankments.

2.2. Food Crops in Bangladesh

Food culture in Bangladesh is manly relied on grain food like rice, wheat etc. In Bangladesh, rice, wheat, mango and jute are considered as the primary crops, and rice and wheat are mostly staple crops or food crops in the many countries of the world (BSCAA, 2008).The expansion of irrigation networks allowed some wheat producers to switch to cultivation of maize which is mainly used in poultry feed manufacturing (BSCAA, 2008). Fortunately Bangladesh is blessed with fertile soil and ample of water supply and therefore,rice can be grown and harvested thrice in a year in many areas of Bangladesh (BSCAA, 2008).

Agriculture production practice in Bangladesh is heavily labor-intensive. Interestingly, agriculture in Bangladesh has achieved steady increases in food grain production despite the often unfavorable weather conditions due to wide ranges of application of modern technologies (BSCAA, 2008). These practices included but not limited to better flood control and irrigation, more efficient use of fertilizers, and the establishment of better distribution and rural credit networks (BSCAA, 2008).

Rice is production in 2005-2006 (July-June) was 28.8 million metric tons leading it to top crop in contrast to wheat which was produced 9 million metric ton in the same year (BSCAA, 2008). Over population burden continues to place a severe loadon productive capacity, causing food insufficiency, particularly of wheat which is being mitigated by foreign assistance and commercial imports (BSCAA, 2008). Underemployment is a concerning issue in Agriculture sector and is creating challenge in its ability to absorbing the additional manpower daily (BSCAA, 2008).

Following India, China, Indonesia,-Bangladesh is the fourth largest riceproducing country in the world(IRRI, 2008). Rice production in Bangladesh is heavily relied on diversified classes of insecticide uses including granular carbofuran, synthetic pyrethroids, and malathion exceeded 13,000 tons of formulated product in 2003 (Riches, 2007).Despite the insecticides are useful in enhancing rice production but pose serious threat to environment and even enhancing production cost to the poor rice farmers. The Bangladesh Rice Research Institute has been conducting research to enhance rice production through minimal use of insecticides and disseminating the knowledge to the farmers through different NGOs and international organizationsabout the possible ways to reduce insecticide use in riceproduction practices (IRRI, 2008).

In the late 1980s, little volume of wheat was consumed in Bangladesh as it not the traditional crop in Bangladesh. In the1960s and early 1970s, wheat was the only commodity for which local consumption increased because external food aid was most often provided in the form of wheat resulted in higher wheat production in the first half of the 1980s. Then domestic wheat production rose to more than 1 million tons per year which is still only 7 to 9 percent of total food grain production. In the 1985, record production of nearly 1.5 million tons was achieved, but in the following year production was declined to just over 1 million tons and about half the wheat is produced on irrigated land. The proportion of land engaged in wheat production remained essentially unchanged between 1980 and 1986, at around 6 percent of total planted area.

Wheat is the leading imported food grains, exceeding 1 million tons annually and raised to higher than 1.8 million tons in FY 1984, FY 1985, and FY 1987. The bulk volume of the imported wheat is financed under aid programs of the European Union, the United States and the World Food Program.

Food grains are produced mainly for subsistence and only a small percentage of total production makes its way into commercial channels. While the other food crops in Bangladesh, however, are grown mainly to meet the demand of the domestic market.

These include the combined record production of potatoes and sweet potatoes which accounted for 1.9 million tons in FY 1984; oilseeds, with an annual average production of 250,000 tons; and fruits such as bananas, jackfruit, mangoes, and pineapples. It is estimated that 7 million tons of sugar cane produced annually, most of it processed into a coarse, unrefined sugar known as gur, and sold in the domestic market.

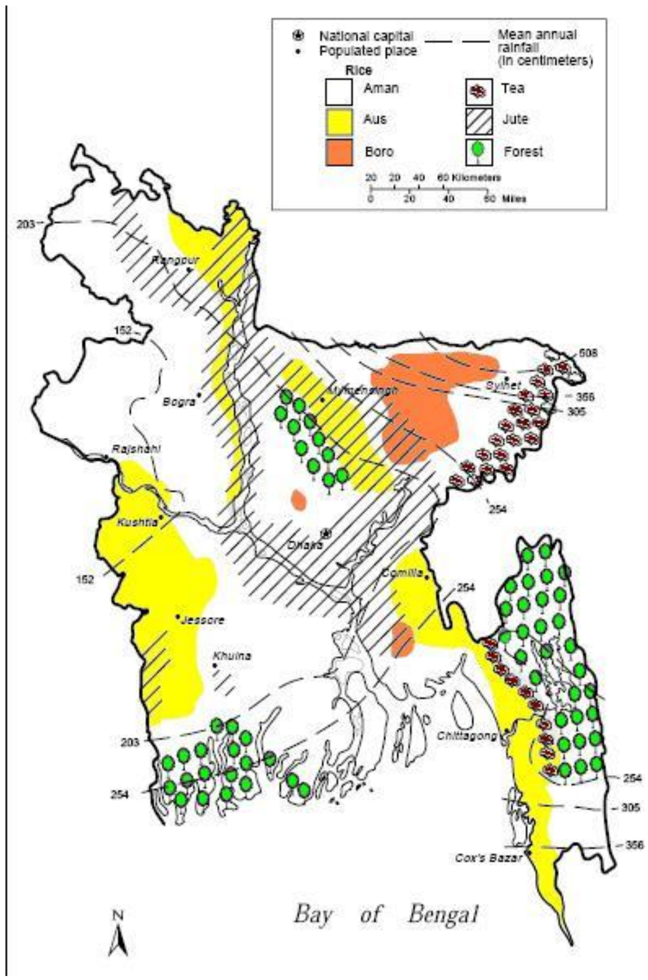


Plate.2: Map Showing the Growing Areas of Major Agricultural Products

Source: *Aman Aziz. Self-made based on public domain map from Library of Congress, US Government source.*

2.3. Impacts of Climate Change on Agriculture

Climate change has been appearing to the human civilization in the world. Human life is absolutely relied on from Agriculture. Agriculture is totally depends on climatic factors including temperature, rainfall, humidity, light intensity, radiation and sunshine duration. Therefore Agriculture is the most vulnerable sector and the reflection of the impact of the climate changes will appear as food deficit in near future. Climate change will lead to incidences of floods, droughts, high temperature, flash floods and floods, etc., are predicted to be more frequent and intense. And the salinity intuition might be appeared as more acute problem in future due to sea level rise.

2.4. Impact of Temperature on Crop Production

The vegetative and reproductive growth of every crop is mediated by a temperature range factor. The crop production faces constraints when temperature falls below the range or exceeded the upper limit. Results of a studyshowed that 1°C increase in maximum temperature at vegetative, reproductive and ripening stages causes decline in *Aman* rice production by 2.94, 53.06 and 17.28 tons respectively (Islam et. al., 2008). The prospect of growing wheat and potato would be severely impairedwith the change in temperature (by 2^0C and 4^0C). This will lead to production loss may exceed 60% of the achievable yields (Karim, 1993).It is needed to mention that higher temperature has negative effect on soil organic matter also.

2.5. Impact of Rainfall on Crop Production of Bangladesh

Crop production is heavily relied on another major climatic factor like rainfall. Water is critically needed for all crops to pass their critical stages to ensure their growth and development. Additionally, over rainfall causes unexpected flood and responsible for water logging condition leading to crop loss. Studies showed that 1mm increase in rainfall at vegetative, reproductive and ripening stages decreased *Aman* rice production by 0.036, 0.230 and 0.292 ton respectively (Rashid and Iftekhar, 2004). On the other hand, scarcity of water limits crop production while irrigation coverage is only 56% as provided by the Bangladesh Agriculture Development Corporation (BADC).

Plate.3*: IUCN / Shehzad Chowdhury*

2.6. Impact of Sea Level Rise on Crop Production

Sea level rise is the fatal outcome of climate change which affects agriculture in three ways, i.e., by salinity intrusion, by flooding and by increasing cyclone frequency and its depth of damage. Combined effects of these three factors are driving cause of decrease in agriculture production in the coastal zone. Sea level rise significantly causes salinity intrusionwhich will cause drastic reduction of agricultural production due to unavailability of fresh water and soil degradation.

2.7. Impact of Flood on Crop Production

Flood is always curse in agricultural production practices which has most deleterious effect on crop production of Bangladesh. Bangladesh has experienced 45% reduced agricultural production due the 1988 flood (Karim et. al., 1996). Higher discharge and low drainage capacity, resulted in increased backwater effects leading to increase the frequency of such devastating floods under climate change scenarios. Prolonged floods generally lead to delay in*Aman* plantation, resulting in significant loss of potential *Aman* production which has been observed during the floods of 1998. Over the recent years,Loss of *Boro* rice crop from flash floods has become a regular phenomenon in the *haor* areas in Bangladesh. From the above facts and based on all the direct and induced adverse effects of climate change on agricultural practices, it can be concluded that crop agriculture would be even more vulnerable in Bangladesh in the tropics (World Bank, 2000).

2.8. Impact of Cyclone on Crop Production

Cyclone causes havoc to agricultural sector since many years leading to huge loss in crop production.An investigative report generated by FAO/GIEWS Global Watch (2007) at the time of the passage of cyclone SIDR, the main 2007 "*aman*" rice crop, accounting for about 70% of the annual production in the most affected area, was almost close to harvest. Department of Agricultural Extension of Bangladesh has estimated that the loss in rice equivalent is at some 1.23 million tonnes, with 535,707 tonnes in the four severely affected districts, 555,997 tonnes in seriously affected 9 districts and 203,600 tonnes in moderately affected 17 districts in Bangladesh.

2.9. Impact of Drought on Crop Production due to Climate Change

In pre-monsoon and post-monsoon periods, agriculture sector is mostly affected by droughts. Over the last 50 years,Bangladesh has experienced about 20 drought conditions. In the year of 1981 and 1982 droughts affected the production of the monsoon crops only. In the 1990s,the drought condition in north-western Bangladesh had led to a shortfall of rice production of 3.5million tons. If other losses, such as, to other crops (all *rabi* crops, Sugarcane, Tobacco, Wheat etc.) as well as to perennial agricultural resources, such as, bamboo, betel nut, fruits like Litchi, Mango, Jackfruit,Banana etc are considered, the loss will be substantially much higher (Drought, updated on 2010).

2.10. **Resultant Impact and Economic Losses**

Climate changeintensify the natural calamities leading to damaging field crops in every year. In 1990's, drought inthe north western Bangladesh caused decline in rice production by 3.5 million tones. Unexpected flash flood in the *haor* areas had accounted for a loss of about 150,000 metric tonnes of rice at the beginning of 2010. World Bank and OECD have estimated that climate change may rise 40% of the overseas development assistance (ODA) to Bangladesh. Increased growth in agricultural sector is critically important in the increasing trend of GDP of a nation.

It has been reported that salinity affected areas in coastal Bangladesh have increased from 0.83 million hectares in 1990 to 3.05 hectares in 2001(Karim and Iqbal, 2000). Another study estimated that in eastern Bangladesh alone14,000 tons of grain production will be reduced due to sea level rise in 2030 and 252,000 tons will be reduced by 2075 (present agricultural production in Bangladesh is 30 million tons). From 1m sea level rise will cause GDP reduction in the range of 28% to 57% (OECD, 2003).

2.11. Existing Adaptation Mechanisms and Constraints

Several ground-breaking initiative should be taken for the adaptations to climate change for agricultural sectors. These include the development of resilient variety, irrigation techniques, cropping pattern,sustainable land management, research,early warning, subsidies, supply of inputs etc. Bangladesh been trying to develop and coping mechanism against natural hazards like droughts, floods, tidal-surges etc. through support of the Government.

2.12. Scope of Study

Scientists of research institutions under National Agricultural Research Systems (NARS) have been working to innovate technologies that will be resilient to climate change to achieve optimum crop production. Research and developments of stress tolerant rice and wheat varieties can ensure food security by an increase in yield of up to 20%. These stress tolerant varieties include salt, submergence, drought, high temperature rice and wheat varieties.

In recent times, Bangladesh Rice Research Institute (BRRI) hasreleased salt-tolerant rice varieties. For example, BR-11, BR-23, BRRI rice -28, BRRI rice-41, BRRI rice-47, BRRI rice-53 and BRRI rice-54 using state-of-the-art gene-marker technology. Bangladesh Agricultural Development Corporation (BADC) multiplied seeds of BRRI rice-47 variety and disseminated by the Department of Agriculture Extension (DAE) to the farmers for cultivation in the salinity prone southern districts. Short duration varieties like BR-33 was innovated by BRRI and BINA-7 by theBangladesh Institute of Nuclear Agriculture (BINA) is successfully cultivated to avert so called *monga*situation in the northern Bangladesh. It was found that BRRI rice-32 and BRRI rice-52 can stand submergence during flash flood.

Furthermore, BADC is testing adaptability of an African rice variety known as NERICA-1 which is drought tolerant. Bangladesh Agriculture Research Institute (BARI) has been working with heat tolerant wheat and tomato varieties.

2.13. Irrigation

In the context of climate change Irrigation will be crucial tool to adapt the adverse situation. DAE has introduced 'Alternate Wetting and Drying(AWD)' irrigation technique and found to be promising in increasing water use efficiency for crop production. In 2009, in the comparatively dry Rajshahi and Rangpur division (Barind region), Barind Multipurpose Development Authority (BMDA) ensures irrigation for rice where 100 hour free electricity bill for irrigation of last year's *aman* season were provided to the farmers from the Ministry of Agriculture (MoA).

Government has provided a 20% rebate in the electricity bills for irrigation throughout the country to encourage irrigate cropping. Both the BADC and BMDA are in pursuit of increasing irrigation coverage by launching newer projects and programmes in every year. To achieve optimum food production, it has been suggested that the target of 150,000 ha of land to be brought under irrigation by 2012 (Planning Commission, 2009).

2.14. National and International Sources of Finance and Investments

The Green Climate Fund was established as a financial mechanism of the Copenhagen Accord predicts annual financing for developing countries rising to around $100 billion per year by 2020. The main aim of this fund was to support the developing countries to mitigate and adapt to climate change. As a matter of fact, in November 2010, Bangladesh appeared as one of the first three countries to tap into a pilot climate change fund to help developing and highly vulnerable nations adapt to climate change. Mainly, some part of this grant will be used to shore up the country's coastal embankment to withstand cyclones and storm surges, and also pay for water supply projects and promote farming of more resilient crops. However, these types of funds are needed to be administered properly with sound disbursement modalities, an appropriate governance structure and careful resource management.

Plate.4*: IUCN / Tanguar Haor Project (I)*

Plate.5*: IUCN / Tanguar Haor Project (II)*

2.15. Conclusion and Recommendations

The impacts of climate change on Bangladesh are not a future issue rather a prevalent event. Bangladesh is affected by flood and flash floods, droughts, salinity, temperature variations, erratic rainfall etc. and has resulted in crop losses. The target of rice production was increased and being subsequently achieved in the recent yearsdespite the country has shown resilience to climate change.Provision of price subsidy for fertilizer and other agricultural inputs has made them affordable to the farmers. Fostering research on stress tolerant technologies (fertilizer, seed, irrigation, agronomic practices) and their expansion were shown to be positive adaptive action against climate change. In order to know the real time impacts of climate change on crop production,comprehensive and coordinated studies are needed to conduct and it is also needed to conduct assessment of the needs for making correct policy decision to avert the crisis. Financial subsidies for crop production and to compensate crop losses were channeled to the farmers in a comparatively transparent fashion through their bank accounts. Farmersget instant expert opinion on problems of their crop fields through use of e-Agriculture (internet and village based platform). These 'farmers-friendly' actions encouraged farmers to work hard to achieve highest production in recent years. The MoA is constantly committed to harness efforts to ensure food security by ensuring all necessary steps. Allocation for subsidy of fertilizers and other assistances for desirable crop production, majority share come from the ministry's financial budget. Funding is constantly provided for research and development of stress resilient technologies by the fifteen affiliated departments of the MoA. Still there are huge challenges in producing more food crops for increasing population from decreasing arable lands prevails for food security of the country.

Elevated pressure for food production to meet the demand from the domestic market may undermine or overlook the deleterious effects of using genetically modified (GM) materials and hybrid seeds that might pose threat to human health. It is necessary to install the concepts of food safety regardingthe use of GM technologies to protect the health of the consumers. Bangladesh has attained the target of crop production. However, domestic crop production still supplemented with the import of rice, wheat and other crops to meet the food demand from the domestic market. Imports are augmented due to the loss of crop from uncertain climatic affects. The elevated rate of price of foodstuffs and agricultural inputs like fertilizers, seeds, agrochemicals along with their unavailability in the international markets make the economy of Bangladesh more vulnerable.Bangladesh is one of the leading countries in formulating and adopting NAPA and BCCSAP in compliance to the Bali Action Plan. Bangladesh has been participating in the COP of the UNFCCC and has been raising concerns of the country to the international forum. Climate Change Trust Fund is established locally and the fund comes from the local treasury. In order to combat the detrimental effects,major policy documents of the government included climate change and thorough considerations are needed to be formulated for policies supporting agriculture and other natural resources. However, multi-sectoral cooperation and coordination is required to attain the success. Good farming practices (GFP) are needed to be installed to ensure the quality & quantity offood produced and also in maintaining sustainability of the environment and natural resources.

CHAPTER THREE
METHODOLOGY OF THE STUDY

3.1. Selection of Models

In the past, studies have focused on estimating climate change impacts on mean agricultural outcomes only (*Guiteras 2009, Greenstone 2007, Fishman 2012, Gupta et al. 2014*). There are a handful of studies estimating climate change impacts on yield variability, with only one such study for India (*Kotani 2010*) where in increased climate variability is found to augment rice yield variability. Results from studies for other countries also show similar results (*Cabas et al. 2010, McCarl et al. 2008*). Implicit in such an approach is the idea of climate change leading to a mean shift in agricultural outcomes, with no changes of the underlying relationship between agricultural outcomes and climate. This is problematic for several reasons; for instance, in much of the scientific literature on climate change, focus is on changes in variability (especially in the hydrologic cycle, which determines both long and short run availability of water supply, a critical ingredient in agriculture) as a result of an altered climate; while such changes are incorporated in a "mean effect" framework, they are not restricted to it (*Krishnamurthy 2012*).

To estimate the effect of climate change on mean and variance of rice yields, this study estimates the stochastic production function formulated by *Just and Pope (1978,1979)*, which allows the effect of inputs on mean yield to differ from that on yield variance.
The basic specification is:

$$\mathbf{y = f(X,\beta) + \mu = f(X,\beta) + h(X,\alpha)\varepsilon}$$

where y is measure of output, X is the input vector, f(.) is the production function relating X to output with β being the vector of estimable parameters, h(X,α) is the risk (variance) function, such that h^2 is the yield variance; μ random shock distributed with mean zero and unitary variance, α is the vector of estimable parameters associated with the risk function (where $\alpha > 0$ implies that yield variance increases as X increases, and vice versa).

Most empirical studies have used the method of Feasible Generalized Least Squares (FGLS). Alternatively, Maximum Likelihood Estimation (MLE) can be used. However, FGLS estimation is employed in most empirical studies, although MLE is more efficient and unbiased than FGLS for small samples (*Saha et al. 1997*). Given the large sample size here, FGLS was used, as described in *Judge et al. (1988)*, to estimate a form of fixed effects panel model. The exact procedure is mentioned below (*Just and Pope 1978, Cabas et al. 2010*).

First stage entails regressing y on f(X, β) which gives the least squares residuals, $\hat{\mu}$ which ($\hat{\mu}=y-f(X,\hat{\beta})$), is a consistent estimator of μ. The second stage uses least square residuals from the first stage to estimate marginal effects of explanatory variables on the variance of production (α). In the second stage, μ^2 is regressed on its asymptotic expectation h(X, α) with h(.) assumed to be an exponential function. The third and final stage uses predicted error terms from the second stage as weights for generating FGLS estimates for the mean yield equation. The resulting estimator of β in this final step is consistent and asymptotically efficient under a broad range of conditions and the whole procedure corrects for the heteroscedastic disturbance term (*Just and Pope 1978*).

3.2. Basic Design of FGLS Estimator

The GLS estimator requires that σ_t be known for each observation in the sample. To make the GLS estimator feasible, we can use the sample data to obtain an estimate of σ_t for each observation in the sample. We can then apply the GLS estimator using the estimates of σ_t. When we do this, we have a different estimator. This estimator is called the Feasible Generalized Least Squares Estimator, or FGLS estimator.

Suppose that we have the following general linear regression model.

$Y_t = \beta_1 + \beta_2 X_{t2} + \beta_3 X_{t3} + \mu_t$ for $t = 1, 2, \ldots, n$

$\mathrm{Var}(\mu_t) = \sigma_t^2 =$ Some Function for $t = 1, 2, \ldots, n$

The rest of the assumptions are the same as the classical linear regression model. Suppose that we assume that the error variance is a linear function of X_{t2} and X_{t3}. Thus, we are assuming that the heteroscedasticity has the following structure.

$$Var(\mu_t) = \sigma_t^2 = \alpha_1 + \alpha_2 X_{t2} + \alpha_3 X_{t3} \qquad \text{for } t = 1, 2, \ldots, n$$

To obtain FGLS estimates of the parameters β_1, β_2, and β_3 proceed as follows.

Step 1: Regress Y_t against a constant, X_{t2}, and X_{t3} using the OLS estimator.

Step 2: Calculate the residuals from this regression, $\hat{\mu}_t$.

Step 3: Square these residuals, $\hat{\mu}_t^2$

Step 4: Regress the squared residuals, $\hat{\mu}_t^2$, on a constant, X_{t2}, and X_{t3}, using OLS.

Step 5: Use the estimates of α_1, α_2, and α_3 to calculate the predicted values $\hat{\sigma}_t^2$. This is an estimate of the error variance for each observation. Check the predicted values. For any predicted value that is non-positive replace it with the squared residual for that observation. This ensures that the estimate of the variance is a positive number (you can't have a negative variance).

Step 6: Find the square root of the estimate of the error variance, $\hat{\sigma}_t$ for each observation.

Step 7: Calculate the weight $w_t = 1/\hat{\sigma}_t$ for each observation.

Step 8: Multiply Y_t, , X_{t2}, and X_{t3} for each observation by its weight.

Step 9: Regress $w_t Y_t$ on w_t, $w_t X_{t2}$, and $w_t X_{t3}$ using OLS.

Properties of the FGLS Estimator

If the model of heteroscedasticity that you assume is a reasonable approximation of the true heteroscedasticity, then the FGLS estimator has the following properties.

1) It is non-linear.

2) It is biased in small samples.

3) It is asymptotically more efficient than the OLS estimator.

4) Monte Carlo studies suggest it tends to yield more precise estimates than the OLS estimator. However, if the model of heteroscedasticity that you assume is not a reasonable approximation of the true heteroscedasticity, then the FGLS estimator will yield worse estimates than the OLS estimator.

Assumptions for Panel data:

1. The data generating process is linear; it assumes observations as individuals or groups.

   $y_{it} = x'_{it}\beta + z'_{i}\gamma + \varepsilon_{I}$ - The data generating process is linear

   i= 1, 2, 3,…,N - we think of i as individuals or groups

   t= 1, 2, 3,….,T_i - usually, N >> T
2. $E[\varepsilon_i|X,z]=0$, X and z: exogenous.
3. $Var[\varepsilon_i|X,z]= \sigma^2 I$, Heteroscedasticity can be allowed.
4. Rank(X) = full rank.

3.3. Estimation

As the dataset is a Panel dataset, the following tests were conducted prior to estimation.

Panel unit root test

If the average T is ten or higher, the data series may be subject to serious unit root. However, if the data are constructed data from few other variables, the unit root problem may be eliminated. Pre-test the data for unit root is very useful to know if the data series is either stationary or not. Therefore a panel unit root test had conducted by STATA to see the expected result. To estimate the result of panel unit root, all the tests had been run. The hypotheses are-

H_0: Panels contain unit roots

H_1: Panels are stationary

We reject the null hypothesis when $p<0.001$.

a)Levin Lin Chu test:

This test can be performed only when the panels are non-stationary and to test the stationarity of the series, panel unit root test) were run based on the null hypothesis of unit root. Results reported in Appendix.I show that all variables were found to be accepting the null of common unit process at level but rejected the null hypothesis at first difference and thus we concluded that all variables were found to be stationary at first difference.

All variables were tested for non stationarity and found to be stationary. The table of result is shown in Appendix.I.

b)Harris Tzavalis test:

All variables were tested for non stationarity and found to be stationary. The table of result is shown in Appendix.I.

c)Breitung test:

This result has 37% p-value and therefore contains unit roots. The table of result is shown in Appendix.I.

d)Im Pesaran Shin test:

All variables were tested for non stationarity and some panels are found to be stationary. The table of result is shown in Appendix.I.

e)Augmented Dicky Fuller and Phillips Perron test:

Since the present research paper focuses a model to analyze the effects of climate variation on different rice crops, we need to confirm zero degree of integration for each variable under study. Otherwise, the variables cannot be used for correlation, causality, and OLS estimations if they characterize different degrees of integration. Thus, first we need to make sure that the data series are free of unit roots, i.e. the series are stationary to make all results valid and all estimates consistent (Enders, 1995). In this regard, we have chosen two widely used methods: Augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1979) and Phillips-Perron (PP) test (Phillips and Perron, 1988) to check the presence of unit roots in the data series and the outputs were presented in table 3. Once stationarity in all variables is confirmed, we can run our comprehensive regression model.

All variables were tested for non stationarity and found to be stationary. The table of result is shown in Appendix.I.

All variables were tested for non stationarity and majority of them are found to be stationary.

Table.1: *Results of Unit Root Test (Augmented Dickey-Fuller & Phillips-Perron Tests)*

Variables	Integration of order for Mean yield of Rice
logMeanyeild	I(1)
logTemperature	I(0)
logRainfall	I(0)
logHumidity	I(0)
logHYV	I(0)

Note: MacKinnon (1996) one-sided p-values (at 1%, 5% & 10% level is -3.605, -2.936& -2.606 respectively) is used.

Source: Authors own estimation based on BMD, BBS and DAE.

Testing for Cross Sectional Dependence

Pesaran, Friedman and Frees tests were performed and cross sectional dependence was found in all data sets.

Testing for fixed versus random effects

Hausman test was performed and random effect model was found to be appropriate (Appendix.IV).

In light of the above results, panel corrected standard error (PCSE) estimates were obtained, which correct for cross sectional dependence, heteroscedasticity and autocorrelation. The parameters are estimated using a Prais Winsten (or OLS) regression. Equations have been estimated with district and year fixed effects.

Regression was run for rice, explaining mean yield. Mean yield depends on climate and non-climate inputs. Our results, however, show mean yields are best explained by levels of rainfall and temperature. We surmise therefore it is variability in climate that makes agriculture more risky.

3.4. Model Specification

Regression equation estimated for rice is :

$$\ln Mean\ Yield_{it} = \beta_1 + \beta_2 \ln Temperature_{it} + \beta_3 \ln Rainfall_{it} + \beta_4 \ln Huimidity_{it} + \beta_5 \ln HYV_{it} + v_{it}$$

where i refers to the district and t refers to the year; α_i denotes district level fixed effects; δ_t denotes year fixed effects; $Temperature_{it}$ is the average temperature; $Rainfall_{it}$ is the annual rainfall; HYV_{it} is the gross cropped area of rice per hectare in metric tons under HYV seeds; $Humidity_{it}$ is annual humidity; $\nu_{it}$is stochastic error terms where $\nu_{it} \sim N(0,1)$.

In our specifications we do not include inputs such as irrigation and fertilizer in the regression. Irrigation is likely to reduce production risk (Foudi and Erdlenbruch 2011) though some argue otherwise (Guttormsen and Roll 2013). Fertilizer use typically increases production risk even as it increases expected output (Just and Pope 1979, Rosegrant and Roumasset 1985, Roumasset et al.1987, Ramaswami 1992, Di Falco, Chavas, and Smale 2007). However, since the two are correlated with each other and also with HYV use their interactive effect is unclear and we leave this for further research.

3.4. Sources of Data

The data set which has been used in this study is a Panel data set. A panel data set has multiple entities, each of which has repeated measurements at different time periods. Panel data may have individual (group) effect, time effect, or both, which are analyzed by fixed effect and/or random effect models. Crops under study, namely rice, accounts for about 75 percent of agricultural land use (and 28 percent of GDP). Paddy production increased during the decade (1987), except for fiscal year 09, but annual growth was generally modest, keeping pace with the population.

About 75% of the total crop area and more than 80% of the total irrigated land is planted. Thus, rice plays an important role in the livelihood of the people of Bangladesh. The rice fields of Bangladesh expanded somewhat during the period of 2001-10. However, the area under irrigation has increased from about 5% to 73% from 1995 to 2008. At the same time, the proportion of modern varieties has increased from 12% to about 5%. Two flash-flood-resistant varieties for the submergence zones, BRRI Dhan 3 (Swarna-Sub 1) and BRRI dhan52 (BR11-Sub-1) were released. An early-maturing variety, BINA Dhan7 was also released for safe cultivation. BRRI dhan51 was developed when IRRI scientists invented an immersion resistance gene for a popular high-yielding Indian rice variety in 2004.

1. **Agricultural Data**

Data on agricultural variables spans the time period 2011-2018, and has been obtained from the latest BBS Agricultural Yearbook-2017,BBS Agricultural Yearbook-2015, BBS Agricultural Yearbook-2013 and BBS Agricultural Yearbook-2011 database. This is a district level database. Also, agricultural data like the production of Aus per hectare in metric tons, the production of Aman per hectare in metric tons, the production of Boro per hectare in metric tons, the production of HYV Aus per hectare in metric tons,the production of HYV Aman per hectare in metric tons, the production of HYV Boro per hectare in metric tons are taken from Department of Agricultural Extension (DAE) and Bangladesh Bureau of Statistics (BBS).

Districts in this database are according to 1984 base, data on districts formed after 1966 is given 'back' to the parent districts i.e. apportioned, based on percentage area of parent district transferred to the new district. Hence, the final database comprises of data for the parent districts only.

The variables of interest in this database include output of rice (measured in metric tons), total gross cropped area in each district (measured in hectares, and accounting for rice cultivation) under HYV seeds for rice (measured in hectares, again accounting for multiple cropping).

In our study the dependent variable is mean yield of Rice (metric tons of output per hectare). Another independent variable from this database is the gross cropped area of high yielding variety seeds (tons) under all available varieties of rice (Aus, Aman, Boro) under HYV seeds.

2. Climate Data

Climate data has been procured from Bangladesh Meteorological Department (BMD). The department contains 30 years of monthly climate data for 64 districts of Bangladesh for variables like rainfall, temperatures, cloud cover, humidity, and ground frost frequency, among others. The database used to compile this meteorological dataset is the publicly available Bangladesh Bureau of Statistics (BBS). It consists of monthly data on variables such as rainfall and temperature from 2011 to 2018.

The three independent variables used for this study from this dataset are rainfall, temperature and humidity. Rainfall is defined as the 12 month summation of monthly rainfall values. Temperature is the 12 month average of monthly average temperatures. Humidity is defined as the 12 month average of monthly average humidity.

The number of districts selected for each of the crops is 64 for rice which account for 100 percent of all Bangladesh crop production in recent years.

As previously mentioned, districts included in the BBS database are those that existed as of 1978. However, climate dataset has been created taking into account district boundaries as of 2002, which are very different from those of 1978. Districts that comprise the panel sample have been selected on the basis of districts that existed in the BBS database, and climate variables for these districts have been approximated from the district to which the largest area of the parent district was allocated (provided that it is more than 50 percent of total area of the parent district).

3.4. Data Input

As secondary data has been used for this study and the study is a dry research procedure, the data are collected from different sources, mainly the Statistical Yearbooks published by Bangladesh Bureau of Statistics. The data was inputed on an Microsoft Excel sheet according correctly with no compromise with mistakes. The data was mainly drawn as per the desired variables of the study which were selected by the author and her Supervisor.

3.5. Software and Statistical Packages

Analytical software STATA version 12.0 has been used for data analysis in this study along with Microsoft Excel 2007.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

In this section, the results would be presented for the model using the OLS and FGLS. I would begin with the descriptive statistics. This would be achieved with the help of tabulations.

4.1. Graphical Illustrations of Temperature, Rainfall and Humidity Patterns and Rice Productivity (Aus, Aman, Boro) for all divisions of Bangladesh (2011-2018)

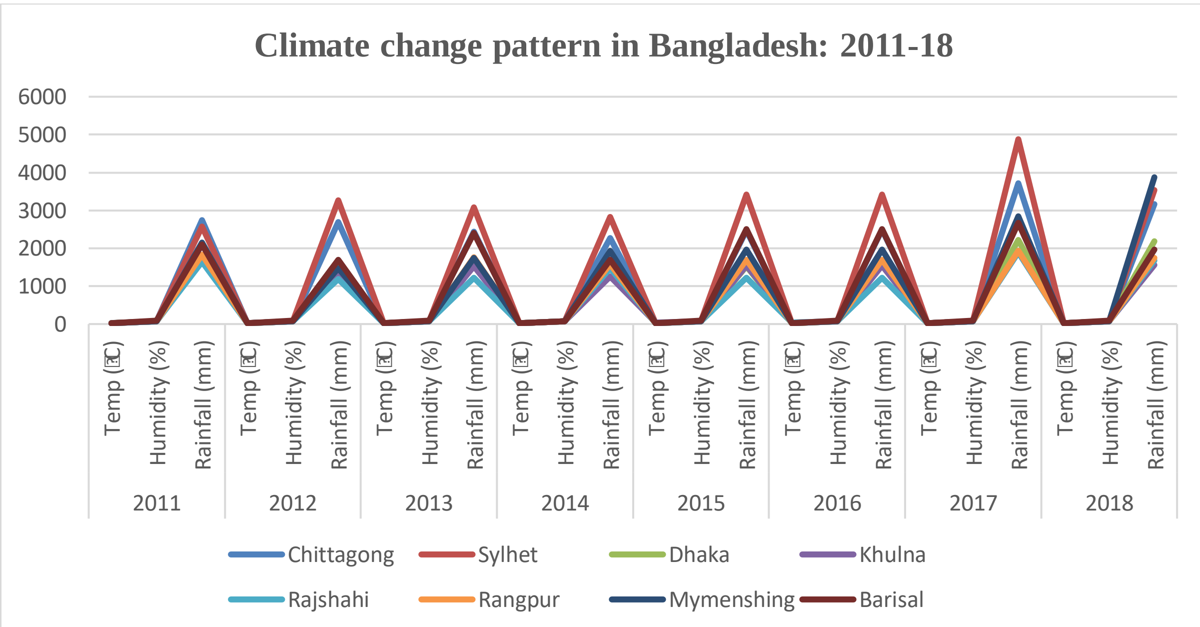


Fig 1: Climate change pattern in Bangladesh over the period of 2011-2018 (Division-wise)

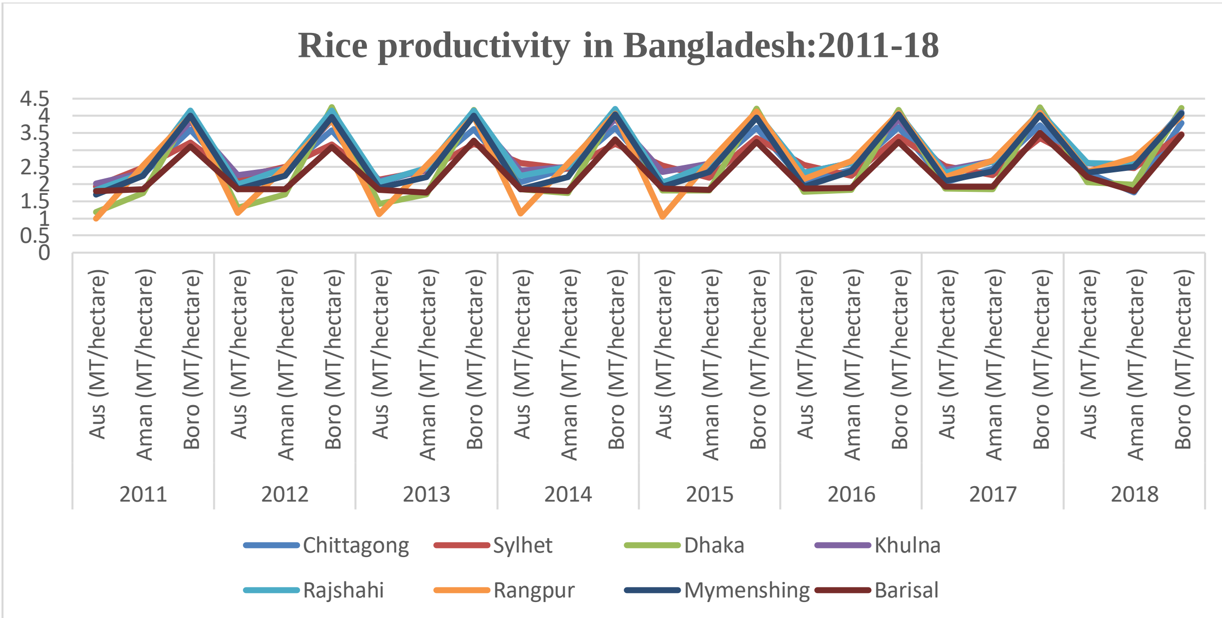


Fig 2: Rice productivity trends in Bangladesh over the period of 2011-2018

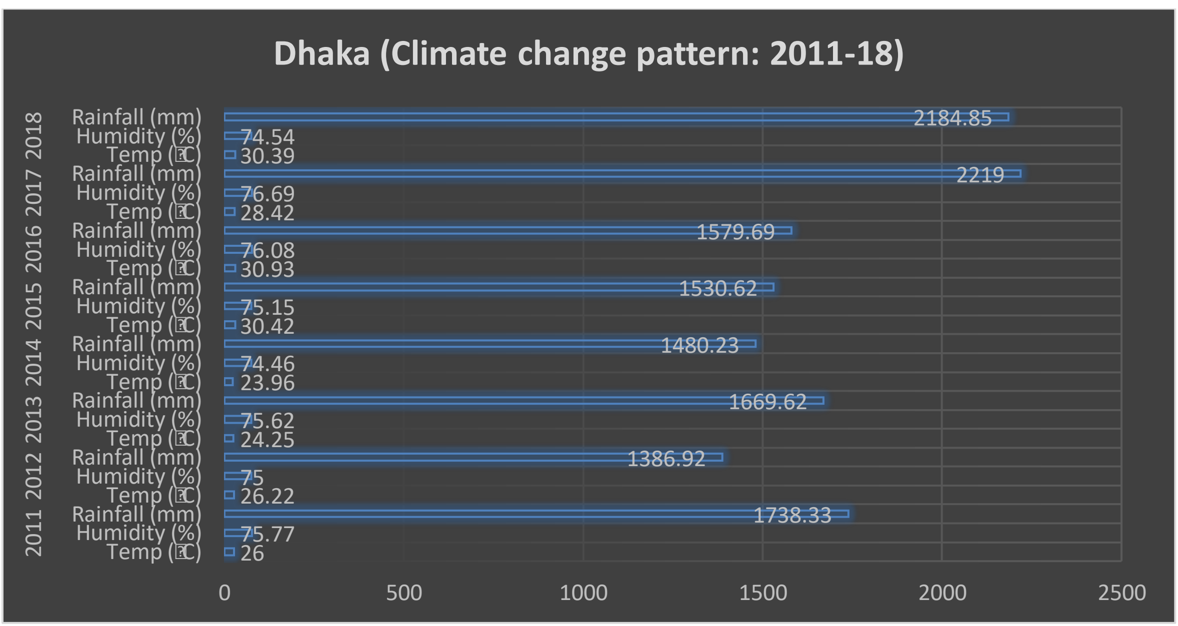


Fig 3: Climate change pattern in Dhaka division over the period of 2011-2018

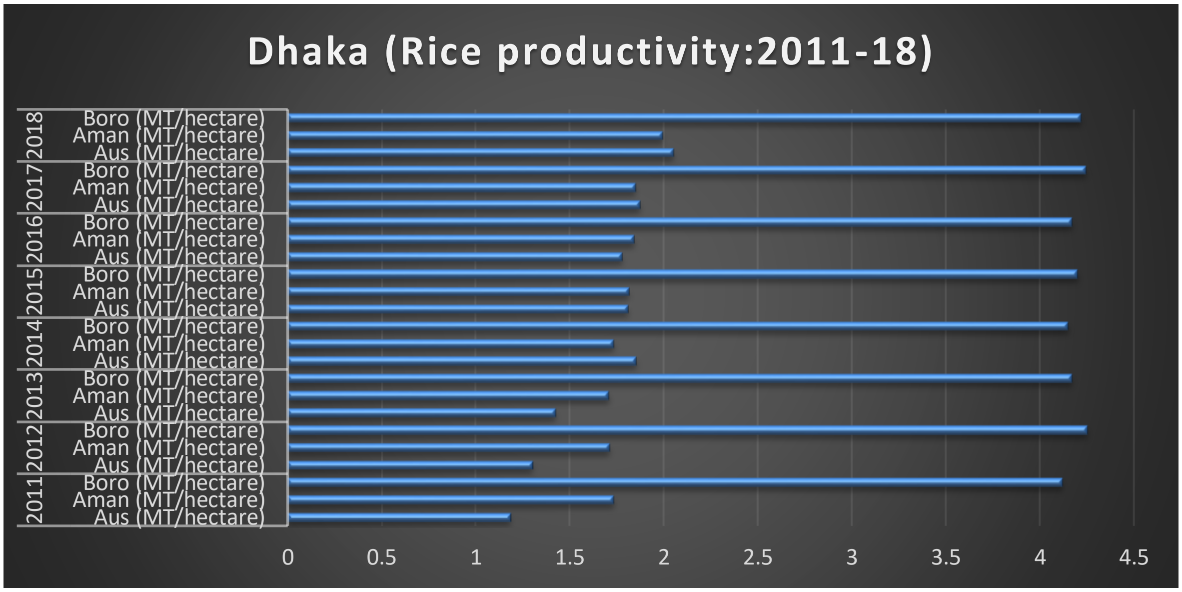


Fig 4: Rice productivity trends in Dhaka division over the period of 2011-2018

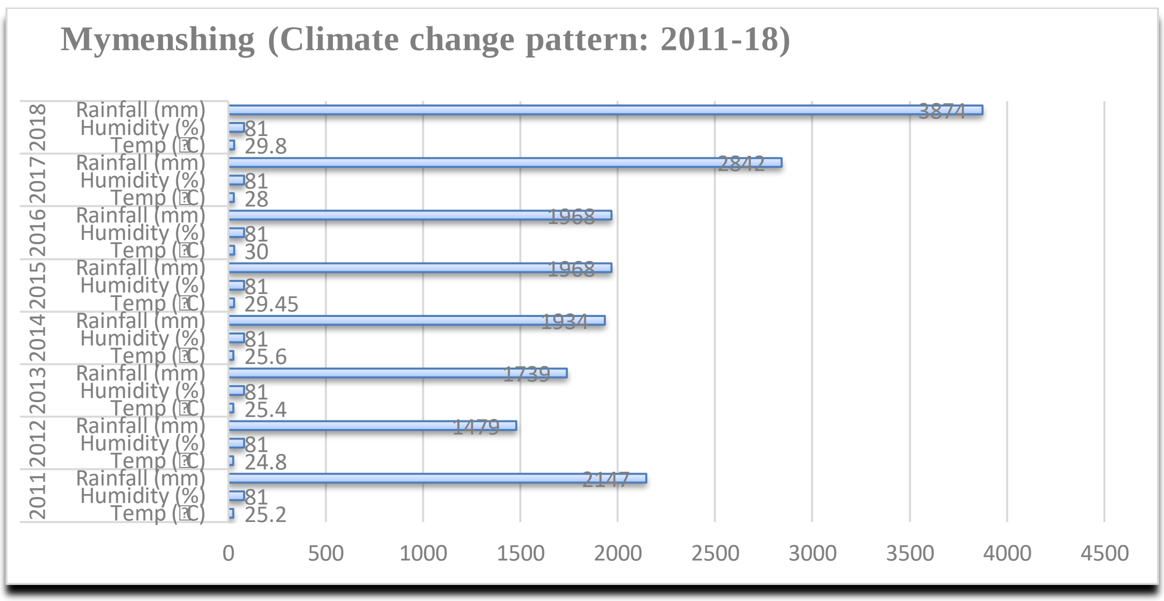


Fig 5: Climate change pattern in Mymensingh division over the period of 2011-2018

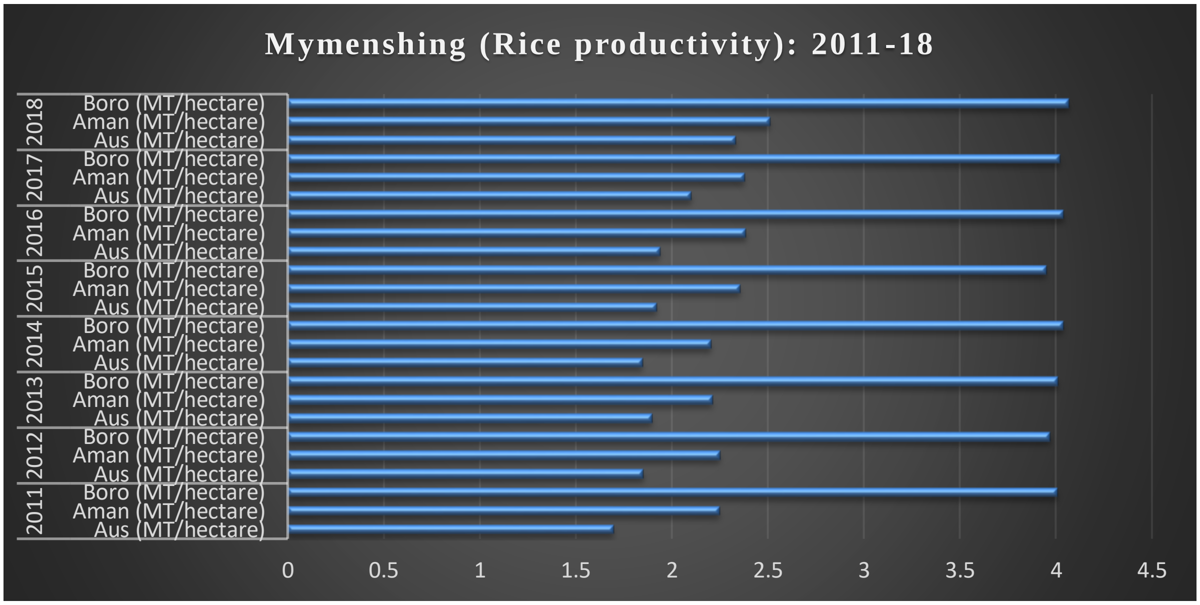


Fig 6: Rice productivity trends in Mymensingh division over the period of 2011-2018

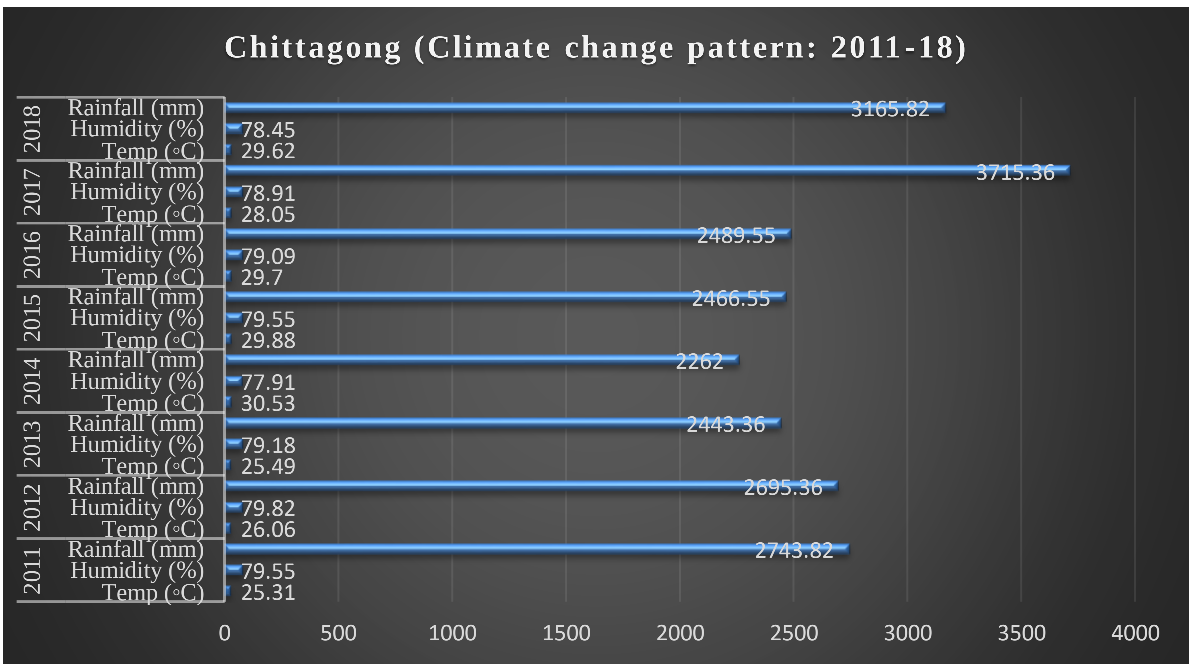


Fig 7: Climate change pattern in Chittagong division over the period of 2011-2018

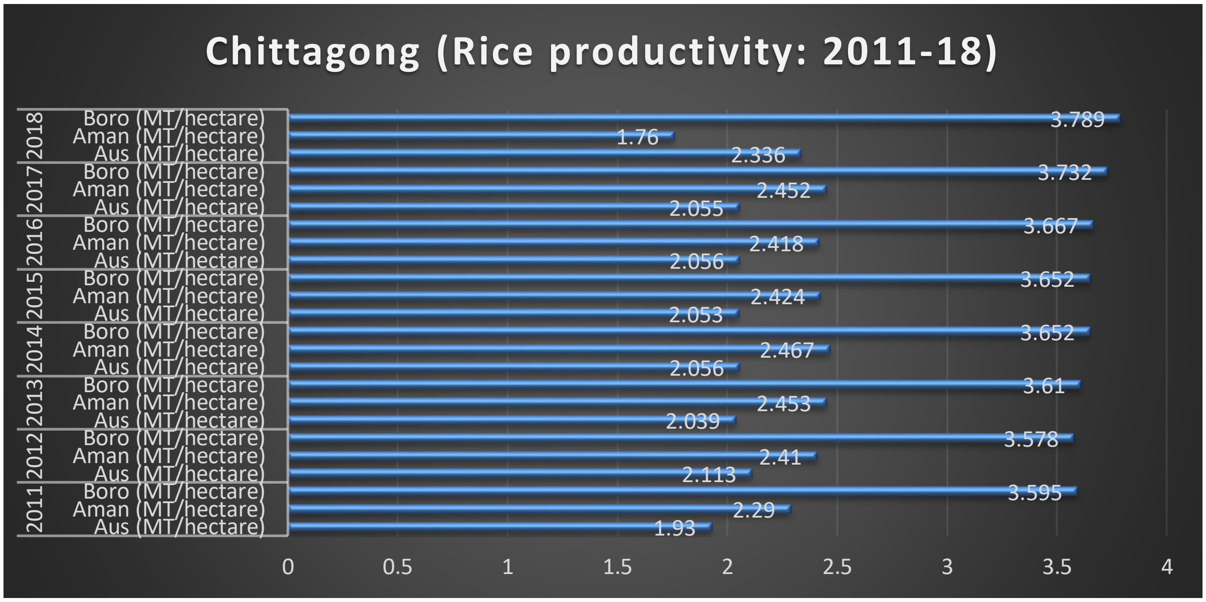


Fig 8: Rice productivity trends in Chittagong division over the period of 2011-2018

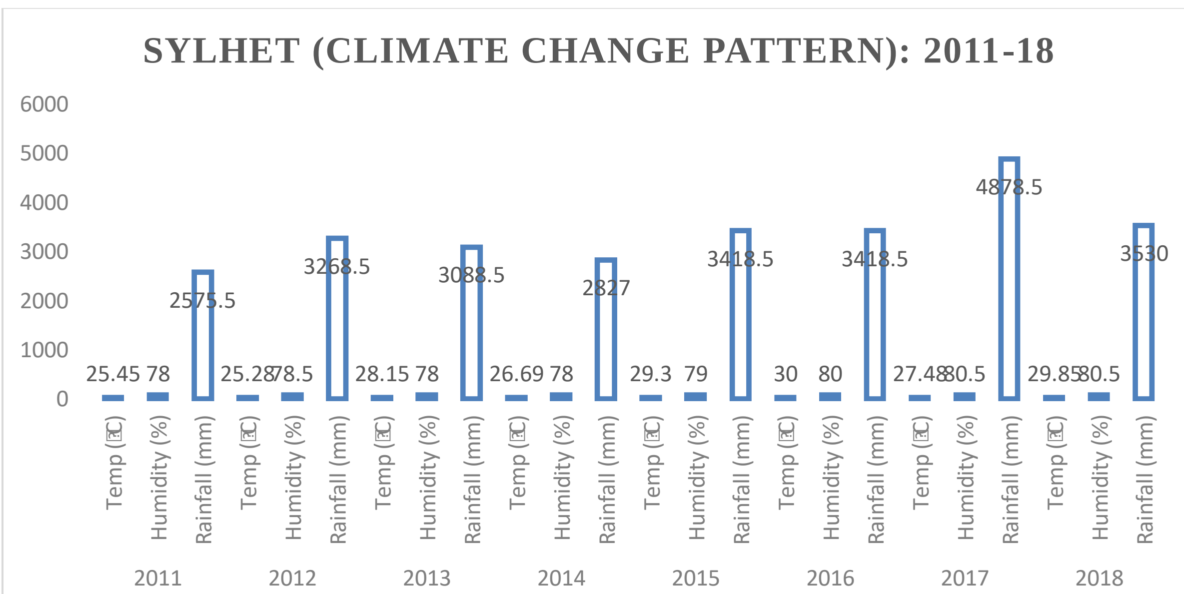


Fig 9: Climate change pattern in Sylhet division over the period of 2011-2018

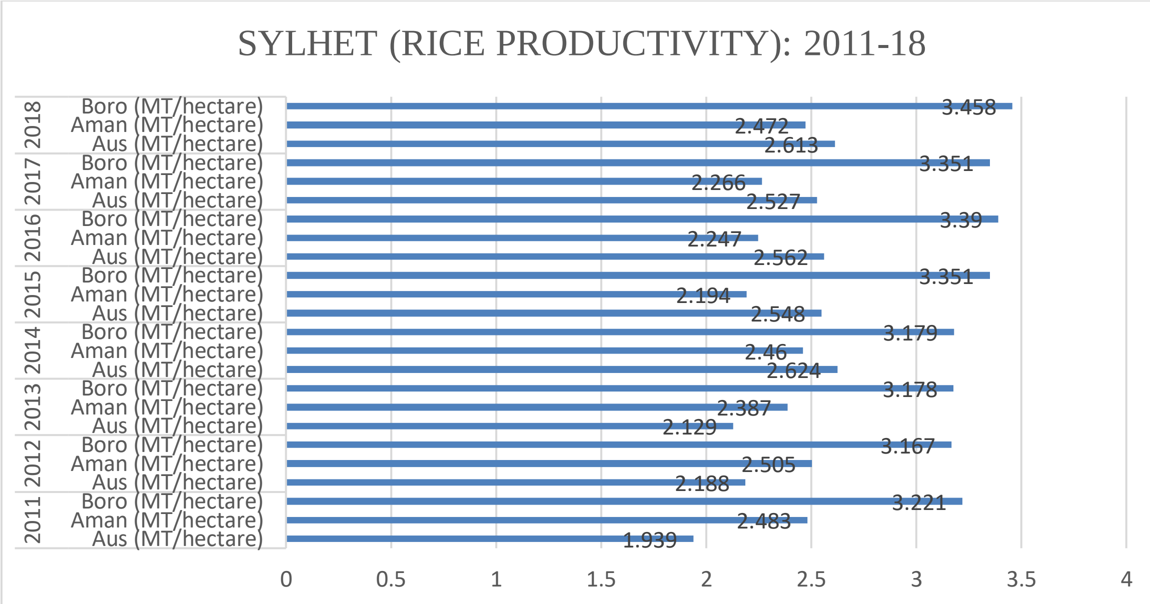


Fig 10: Rice productivity trends in Sylhet division over the period of 2011-2018

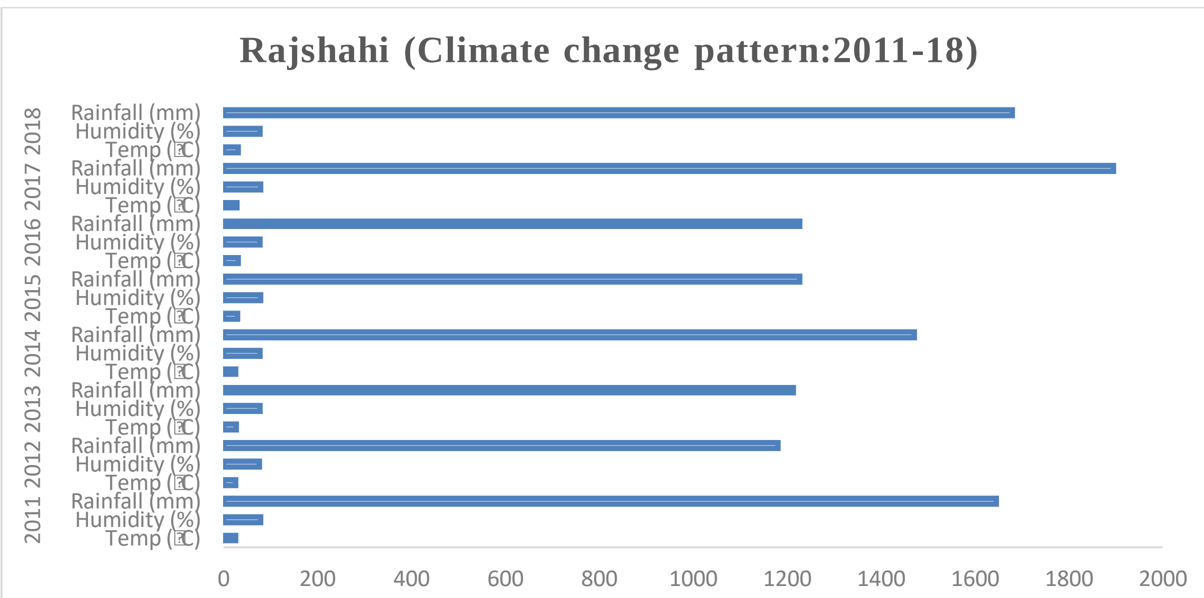


Fig 11: Climate change pattern in Rajshahi division over the period of 2011-2018

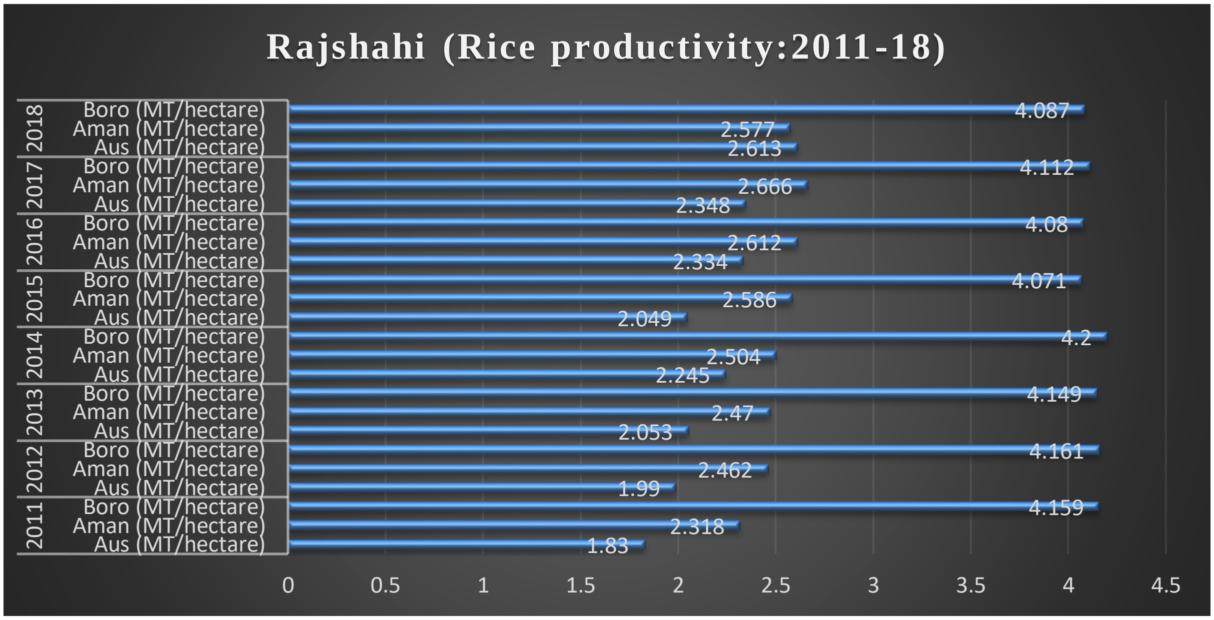


Fig 12: Rice productivity trends in Rajshahi division over the period of 2011-2018

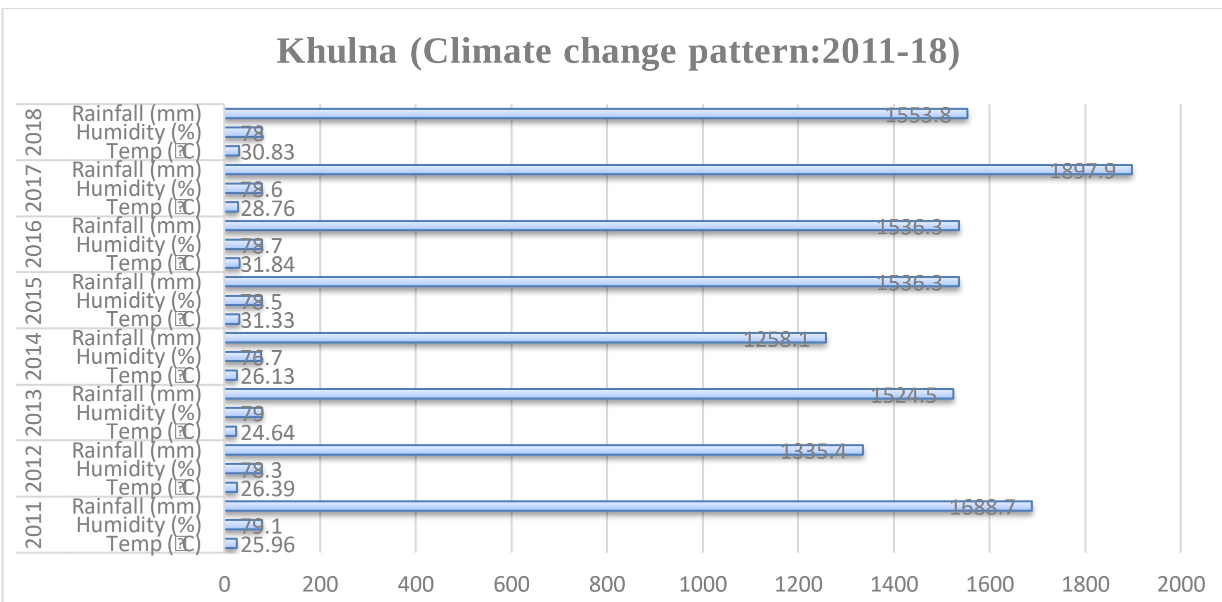


Fig 13: Climate change pattern in Khulna division over the period of 2011-2018

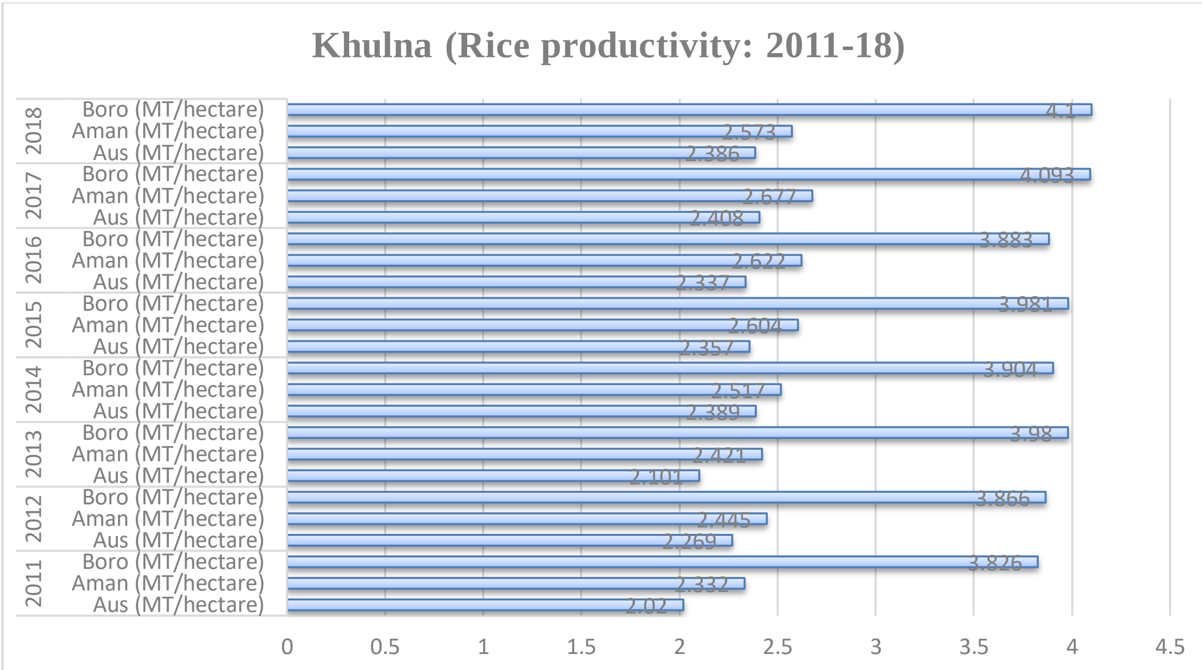
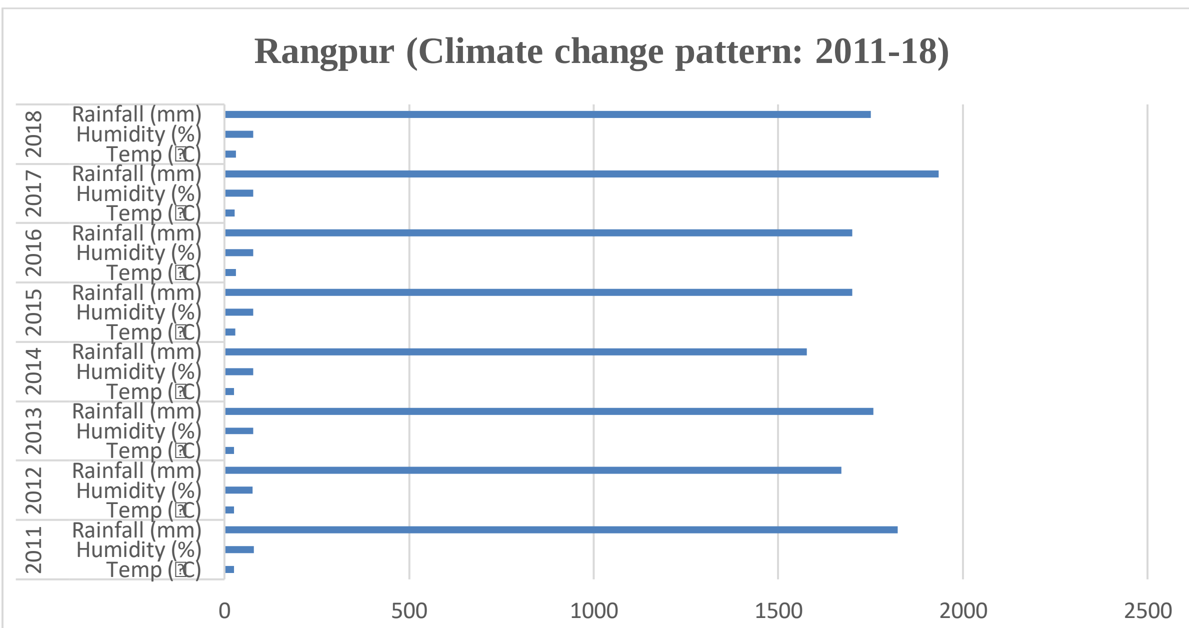


Fig 14: Rice productivity trends in Khulna division over the period of 2011-2018



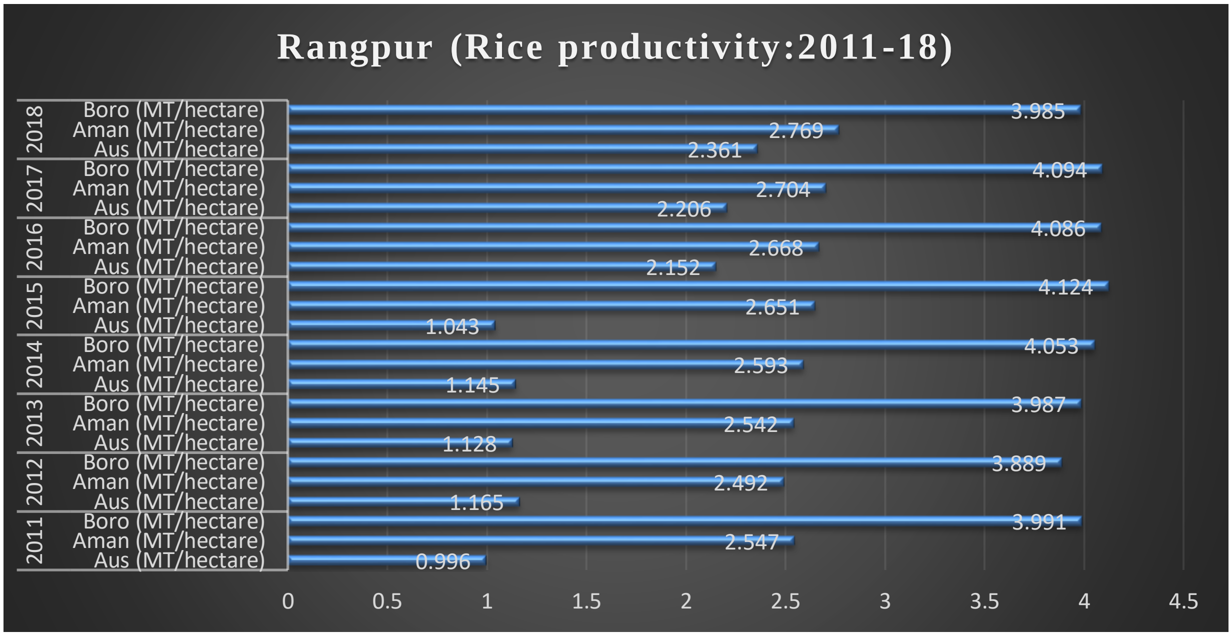


Fig 16: Rice productivity trends in Rangpur division over the period of 2011-2018

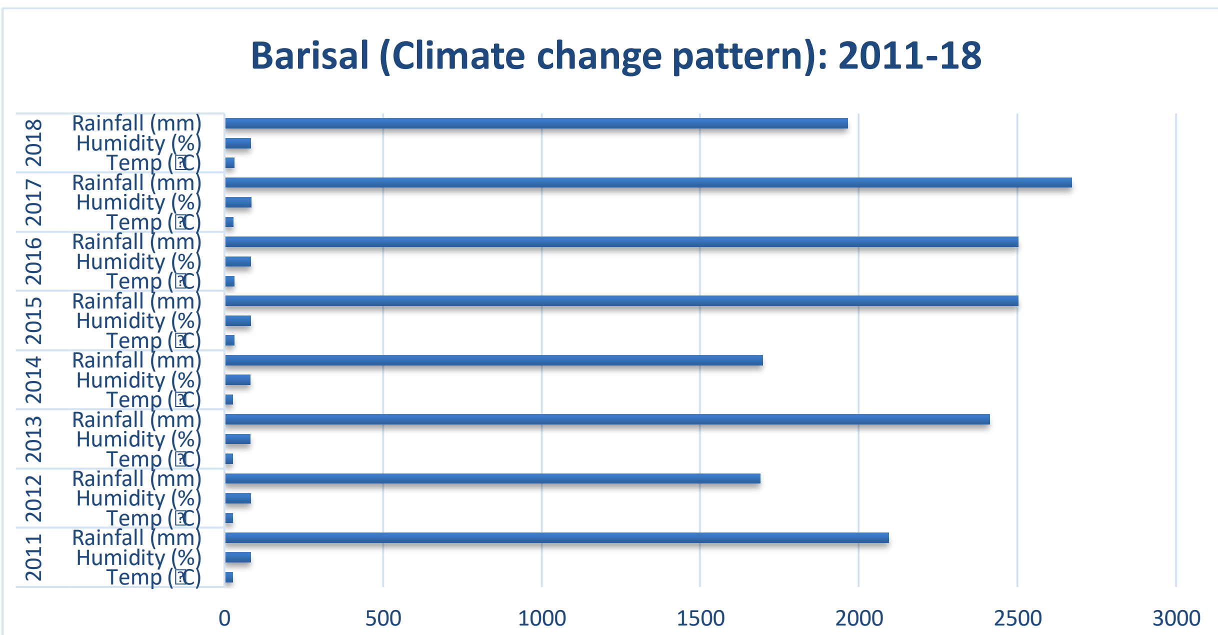


Fig 17: Climate change pattern in Barisal division over the period of 2011-2018

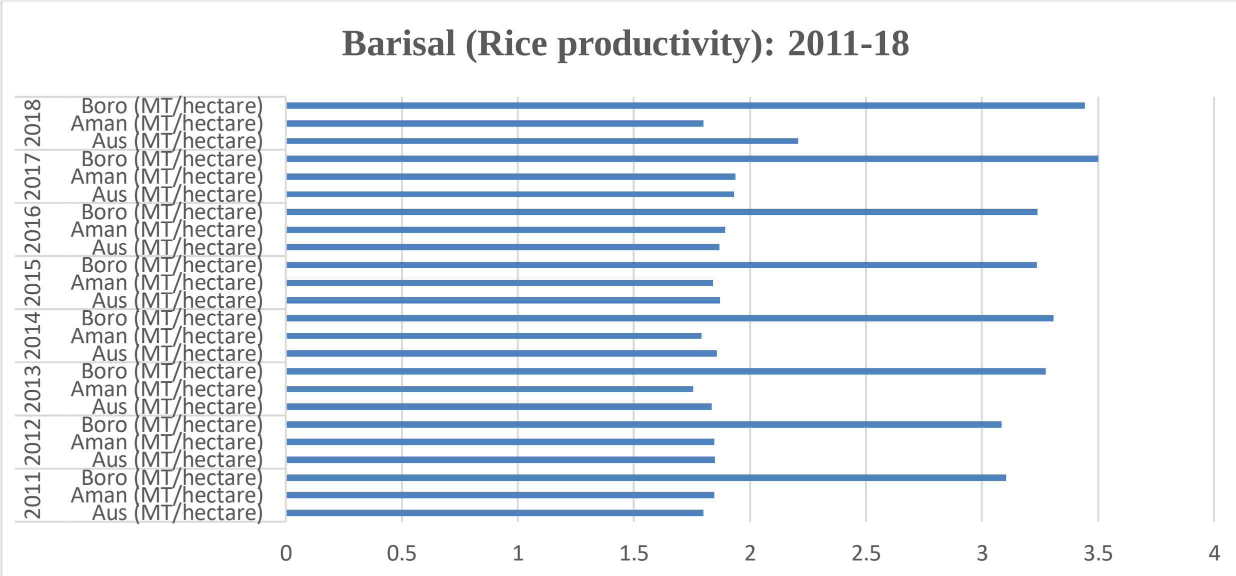


Fig 18: Rice productivity trends in Barisal division over the period of 2011-2018

4.2.a) Descriptive Statistics for Panel Data

Table.2: *Descriptive Statistics for Panel Data with Skewness and Kurtosis*

Variable	Mean	SD	Min	Max	Skewness	Kurtosis
lnMeanyeild	11.796	0.955	8.945	22.355	0.0000	0.0000
lnTemperature	3.265	0.050	3.028	3.429	0.0002	0.0000
lnRainfall	7.551	0.345	6.968	8.690	0.0000	0.8739
lnHumidity	4.361	0.041	4.234	4.443	0.0000	0.0000
lnHYVarea	11.576	0.782	9.471	13.114	0.0000	0.6028

In this table, kurtosis values are positive which means that they have a peak distribution. The positive values of skewness tells that the tail on the right side of the distribution is longer or fatter. Also, because both the min and max values for all the years in both specifications has positive values one is expected to use a log form because it is mathematically acceptable. Finally, the standard deviation from the mean is higher for mean yield for all the years from 2011-2018.

4.2.b) Assumption test using VIF

Table 3.*Using VIF to test for multicollinearity for mean yield of Rice*

Variable	logMeanyield	
	VIF	1/VIF
lnHumidity	1.12	0.891681
lnRainfall	1.1	0.912619
lnHYV	1.03	0.974707
lnTemperature	1.01	0.985826
Mean VIF	1.06	

The VIF quantifies how much variance is inflated. A VIF value between 1 to 2 means that there is no correlation among the kth predictor and the remaining predictor variables and hence variance of coefficient b_k in regression model is not inflated at all. As a rule of thumb VIF exceeds 4 needs further investigation and VIFs exceeding 10 is sign of serious multicollinearity. Hence looking at the VIF values for logMeanyield shows that it varies in the tune of 1.01 to 1.12 which means that there is no correlation among the predictor. Hence, no multicollinearity exists using specification logMeanyield as dependent variable.

4.2.c) Hausman Fixed and Random Effect Verification

The Hausman tests the Null Hypothesis that H_0: β= Random effect is appropriate against the Alternative H_1: β=Fixed effect is appropriate. For the model, the chi square has value of 6.01 with probability P=0.1985 (Appendix.IV), here we do not reject the null hypothesis and draw the conclusion that the mean yield is a random effect model.

$Chi^2(4)$ = (b-B)'[(V_b-V_B)^(-1)](b-B)

= 6.01

Prob>chi^2 = 0.1985

4.3. Results for the Model using Mean Yield of Rice for OLS, GLS, FGLS

Table.4:*Results for Mean Yield Model*

MY	OLS Coef.	Std. Err.	t	P>t	GLS Coef.	Std. Err.	z	P>z	FGLS Coef.	Std. Err.	z	P>z
Temp	0.866	0.625	1.385	0 .083	0.830	0.629	1.320	0.093	0.856	0.622	1.376	0.084
Rain	-0.139	0.048	-2.929	0.002	-0.141	0.047	-3.012	0.001	-0.132	0.043	-3.086	0.001
Hmdt	1.352	0.490	2.759	0.003	1.340	0.446	3.007	0 .001	1.362	0.428	3.179	0.001
HYV	0.831	0.041	20.505	0.000	0.831	0.041	20.059	0.000	0.831	0.040	20.608	0.000
_cons	-5.485	4.088	-1.342	0.180	-5.309	4.160	-1.276	0.202	-5.485	4.068	-1.348	0.178
R^2	0.426				0.543				0.394			
F(4,497)	112.36											

The table above shows the results of regression parameters and their respective standard errors and p values for Mean Yield specification using three estimators. The aim is to check reliability by verifying whether the estimates vary with respect to the different estimators. The yellow, green and blue paints show the slight differences in the standard error depicting which estimator has the lowest standard error.

This implies that difference between OLS and GLS is in the variance of the estimates. And the real reason, to choose, GLS over OLS is indeed to gain asymptotic efficiency (smaller variance for $n \rightarrow \infty$. It is important to know that the OLS estimates can be unbiased, even if the underlying (true) data generating process actually follows the GLS model. If GLS is unbiased then so is OLS (and vice versa).

Ordinary least square regression analysis is conducted for Mean Yield. Standardized beta coefficients of annual total rainfall, annual average percentage of humidity and area cropped under HYV seeds are found to be significant with t value of -2.929, 2.759 and 20.505 respectively. The associated probabilities for the variables also stood at

P<0.01.On average, for one unit increase in annual total rainfall, Mean Yield will decrease by 0.139 units' ceteris paribus. On average, for one unit increase in annual average percentage of humidity, Mean Yield increases by 1.352 units' ceteris paribus. And on average, for one unit increase in HYV area, Mean Yield increases by 0.831 units' ceteris paribus. We reject the null hypothesis and conclude, there is sufficient evidence that beta coefficients of annual total rainfall, annual average percentage of humidity and area cropped under HYV seeds are significantly different from zero. Average temperature variable in the model is insignificant as P values are more than 0.05. The OLS model fits the data well at 0.10 significance level (F=112.360and P<0.01). R^2 -Adjusted of 0.4706 says that this model accounts for 47.06% of the total variance in the mean yield of Rice.

Generalized least square model were also computed, panels are homoscedastic with no autocorrelation. Total of 512 observations were analyzed using four explanatory variables. It is seen from the model that the variable rainfall, humidity andHYV Area are significant. Furthermore, when compared Generalized least square model with Ordinary least square there seems to be not much difference observed among standardized beta estimates as both the estimators reveals similar results when Mean Yield is used as a dependent variable. The GLS model fits the data well at 0.05 significance level, (chi= 430.00, P<0.001) and interpretation of estimates for GLS estimator is like the OLS estimator. Estimates obtained from Generalized Least square estimator are the same with those of Ordinary least square. Further, investigation was computed using the estimated or feasible generalized least square. Estimates proves more efficient when compared to OLS and GLS model but with the disadvantage that the standard error estimates are conditional on the estimated disturbance covariance and this is validated by Beck and Katz (1995). Mean Yield as a dependent variable with HYV Area is the significant variable in the model, standard errors of the FGLS model when compared with OLS and GLS models are more reliable and consistent.

Based on the mean yield specification for OLS, GLS and FGLS shows that the constant term is negative with values of 5.485. This means that those stochastic factors not included in the model have a negative influence on performance. On average one unit increase in the coefficients of these variables will cause yield to decrease by 5.485units all things being equal.

Overall Analysis of Results

For clarity purpose, this section shows what has been done. In investigating the determinants of climate change impacts on rice production in Bangladesh, I have used mean yield as the dependent variable. Consistency was also investigated using several alternative estimators like OLS, GLS and FGLS. This agrees with Nemeth (2004 p.301) who clarifies that when repeated measurement produces the same results then the work is reliable and this is true because I have repeated the mean yield model with three different estimators. Validity check was further investigated by examining how strong the model is in case of any accidental circumstances of the research and this was done by correcting for Standard errors.

CHAPTER FIVE

SUMMARY AND CONCLUSIONS, RECOMMENDATIONS, LIMITATIONS AND AREAS OF FURTHER RESEARCH

5.1. Summary and Conclusions

Using 8 years district level panel dataset for rice in Bangladesh, we find that increased climate variability, climate extremes in particular, exacerbate risk. Rice yields are sensitive to rainfall extremes, with both deficient and surplus rainfall increasing variability. In addition to climate inputs, non-climate input, namely, high yielding variety seeds are found to be increasing average agricultural yield. As the econometric results could be subject to omitted variable bias, we leave it for further research to employ a richer set of mean and variability shifters than employed in this paper.

Based on the mean yield specification for OLS, GLS and FGLS shows that the constant term is negative with values of 5.485. This means that those stochastic factors not included in the model have a negative influence on performance. On average one unit increase in the coefficients of these variables will cause yield to decrease by 5.485units all things being equal.

The analysis presented in this study has important policy implications. Higher variability in agricultural production will lead to greater variability in incomes of the rural poor, who already face severe financial and credit constraints. Hence, it is imperative to undertake suitable policies to mitigate climate change impacts on this sector to the extent possible.

5.2. Recommendation, Limitations and Areas of Further Research

5.2.1. Recommendations

The results of our study may guide the government policy makers and rural development practitioners in designing the appropriate adaption strategies in the country. Adaptation policies should target different climatic zones based on the constraintsand potentials of each zone in view of recommending uniform interventions. To increase the resilience of crop farming sector of Bangladesh, immediate actions are required taking the current and anticipated climate change impacts into consideration. Based on the findings, our study suggests some essential climate adaptation policy recommendations which the government and policy makers may consider to address the challenges that farmers are likely to face as a result of climate change. Such recommendations include strengthening research capacity for the development of new cultivars and farming techniques with the changes in climate, enhancement of various enterprise diversification activities, making provision of crop insurance program and strengthening agricultural extension systems for disseminating up-to-date agricultural adaptation technologies to the farmers. Diversifying and generating off-farm employment opportunities in rural Bangladesh may also be crucial measures for the sustenance of rural masses. The present study was focused only on climate change impacts on net crop incomes. Future studies may consider analyzing the climate change impacts on other agricultural sectors, e.g. fisheries and livestock to assess the economic benefits or losses. We also suggest more research efforts in future for in-depth analyses of the economic impacts of climate change on farm income at the rural household level using a more holistic approach.

Besides from subsidies and rehabilitation for the first time the Government, has given various incentives to farmers for crop production. In recent times, financial assistance of around BDT 750 crore for diesel fuel for the irrigation *boro* rice was distributed among the farmers through their bank accounts. The farmers those who are affected by the flash flood will be given free seeds and fertilizers that will cost BDT 48 crore for the *boro* season in 2011. In order to compensate the loss of *boro* rice by flash floods in *haor* areas, fertilizers worth BDT 26 crore were distributed free among 346,100 farmers to enhanced *Aus* production and this program is running since 2011.

Thirty two farmers have been awarded Bangabandhu National Agriculture Award, 1415 is awarded to 32 farmers and entrepreneurs to encourage more food production. Government has increased allocation for fertilizer subsidy, irrigation and other inputs and research activities which are some notable financial contributions provided by the Government. Such initiative of supporting for enhanced production is a crucial adaptive measure for sustained production.

Farmers need to gain profit by selling their products that will encourage them to grow more crops subsequently. Interventions for smallholder farmers like storage facility to reduce post-harvest losses are needed. In that case increasing Agro-processing facilities as well as promoting community mobilizations are important. To ensure fair market price of crop products, the MoA is arranging to establish ‘Agri-business Cell’ in the ministry.

Meanwhile, The Directorate of Agricultural Marketing (DAM) has started 15 retailers and 60 growers markets throughout the Bangladesh to ensure fair price and to eliminate middleman ship in agricultural marketing.

Land is the only established foundation for crop production. Soil resources of the country are experiencing pressure for increased food production to meet the increasing domestic demand due to over population growth. In order to enhance the soil capacity to support the crop growth, increasing cropping intensity and mineralization of soil organic matter are essential. Soil Resources Development Institution (SRDI) of the MoA has been working to improve soil health and preserve it for future generation (SRDI, 2010). The institute has prepared Upazilla Land and Soil Resources Utilization Guide for 459 upazillas throughout the country as a guideline for the farmers for fertilizer application. Thisguide book will help farmers to apply fertilizers according to the need based on fertility status of the soil. Furthermore, MoA is working with the Ministry of Land to enact proposed Agricultural Land Conservation and Land Use Act, 2011 to safeguard agricultural lands from encroachments for developments. Fertile soil is the prerequisite for better productivity and organic manures can increase soil fertility and productivity. The MoA has been encouraging farmers to use organic fertilizers like compost, farmyard manure to preserve soil health.Moreover, the farmers are recommended to use green manure and biofertilizer instead of chemical fertilizers to preserve soil health. Agronomic practices including intercropping with leguminous crops, alternate cropping, reduced tillage, soil mulching etc. are applied by the farmers to maintain soil fertility. These initiatives will reduce the use of chemical fertilizers and ultimately will mitigate emissions from them.

Adaptation and mitigation are achieved through financial and technological means. Following the investment made by the Bangladesh government in disaster preparedness and adopting other strategies for climate change, the main challenge appeared in this moment is financing and implementing the strategies(World Bank, 2010).

National Adaptation Program of Action (NAPA) has already addressed immediate and urgent needs to deal with climate change event. Climate change has propelled an initiative to develop a multi-donor trust fund contributed by the Bangladesh Government and the development partners. A commitment was made in the Copenhagen Accord at COP-15 to establish 'Copenhagen Green Climate Fund' to aid projects design in order to mitigate greenhouse gases.

The BCCSAP urged to manage funds from international communities on grant basis. This fund will help to access to the technologies required for efficient mitigation programme. Bangladesh government has already established 'Climate Change Trust Fund' amounting to 100 million USD. Already, this funding has been using in the implementation of plans spelled out in the BCCSAP (MoEF, 2009).NARS institutions has included agenda of climate change which are implementing various research projects funded by the development partners along with GoB.

It was confirmed by the Climate Change Strategy and Action Plan (2009) that additional amount of fund allocation will be required for sustained adaptive measures. Meanwhile, the Bangladesh Government has invested over 10 billion USD and adopts policies to combat climate change impacts (World Bank, 2010).It was estimated about 500 million USD will be needed to implement action plans of BCCSAP for first two years (MoEF, 2009). A credible assessment should be conducted to incorporate other sectors in a logical way. In general, the costing for managing climatic disturbances in agriculture sector is calculated in terms of the amount of crop loss. However, more integrated approach considering issues like loss of damages lands, agricultural land, risk health, reduce employment, harms livestock etc. to ascertain the total loss in figures. This is highly important in negotiations for funding in both home andabroad.

The Policy makers are not clearly aware of the impact of climate change. The National Adaptation Program of Actions (NAPA) has developed guidelines for adaptation measures to combat climate change impacts. Recently, the revised version of National Agriculture Policy of 2011, has added climate change as one of its three priority areas. Some issues associated with the impact from temperature rise and variation in precipitation on agriculture called for further attention. The Agriculture Extension Policy of 1996 has given emphasis on sustainable agricultural development and explicit consideration on extension of climate resilient variety or cropping pattern is needed to incorporate. Seemingly, the Integrated Pest Management Policy (IPMP) of 2002 should provide guidelines on climate change and disaster risk reduction issues. There is an implicit mentioning that the policy should devised in way that those will be self-reliance of farmers through promotion of locally developed and crop management practices which will eventually address adaptation to climate change. National Seed Policy should put priority on seed production likely to be affected by climate change through advanced technologies.

5.2.2. Limitations of this study

For any research based on climate change, a data set of weather indicators of several years is needed. In this study, the author could use only 8 years of dataset starting from 2011 to 2018. The results could be more detailed and findings of differences about climate indicators could be more significant over time if a larger scale of data could be collected. No data was purchased for this study as it is a non-funded research work solely done by the author. This limitation can be eliminated if a good fund is invested.

Another limitation of the study is data unavailability. Many important variables like average amount of fertilizer used per hectare in districts in a year, percentage of irrigated land in districts in a year are not recorded in Bangladesh. Therefore these important but unavailable variables could not get included while these variables have thriving influences on Rice productivity in Bangladesh.

5.2.3. Area of Further Research

In our specifications we do not include inputs such as irrigation and fertilizer in the regression. Irrigation is likely to reduce production risk (Foudi and Erdlenbruch 2011) though some argue otherwise (Guttormsen and Roll 2013). Fertilizer use typically increases production risk even as it increases expected output (Just and Pope 1979, Rosegrant and Roumasset 1985, Roumasset et al.1987, Ramaswami 1992, Di Falco, Chavas, and Smale 2007). However, since the two are correlated with each other and also with HYV use their interactive effect is unclear and we leave this for further research.

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APPENDIX

Appendix. I

Levin-Lin-Chu unit-root test

	Statistic	p-value
Unadjusted t	-2.20E+02	
Adjusted t*	-2.40E+02	0.000

Harris-Tzavalis unit-root test

	Statistic	z	p-value
rho	-0.115	-18.75	0

Breitung unit-root test

	Statistic	p-value
lambda	-1.4272	0.0768

Im-Pesaran-Shin unit-root

	Statistic	p-value
W-t-bar	-24.0771	0

Table.1: *Results of Unit Root Test (Augmented Dickey-Fuller & Phillips-Perron Tests)*

Variables	Integration of order for Mean yield of Rice
logMeanyeild	I(1)
logTemperature	I(0)
logRainfall	I(0)
logHumidity	I(0)
logHYV	I(0)

Appendix. II

Table.2: *Descriptive Statistics for Panel Data with Skewness and Kurtosis*

Variable	Mean	SD	Min	Max	Skewness	Kurtosis
lnMeanyeild	11.796	0.955	8.945	22.355	0.0000	0.0000
lnTemperature	3.265	0.050	3.028	3.429	0.0002	0.0000
lnRainfall	7.551	0.345	6.968	8.690	0.0000	0.8739
lnHumidity	4.361	0.041	4.234	4.443	0.0000	0.0000
lnHYVarea	11.576	0.782	9.471	13.114	0.0000	0.6028

Appendix. III

Table 3.*Using VIF to test for multicollinearity for mean yield of Rice*

Variable	logMeanyield	
	VIF	1/VIF
lnHumidity	1.12	0.891681
lnRainfall	1.1	0.912619
lnHYV	1.03	0.974707
lnTemperature	1.01	0.985826
Mean VIF	1.06	

Appendix. IV

HAUSMAN RESULT				
	coefficients			
	(b)	(B)	(b-B)	sqrt(diag(V_b-V_B))
	fe	re	differences	S.E.
lnTemperature	-0.06986	0.829804	-0.8996601	0.4338332
lnRainfall	-0.16188	-0.14108	-0.0208072	0.131385
lnHumidity	-0.1411	1.339541	-1.480645	2.271562
lnHYVarea	0.887346	0.831387	0.055959	0.1165415

chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)

= 6.01

Prob>chi2 = 0.1985

Appendix. V

Table.4: *Results for Mean Yield Model*

MY	OLS				GLS				FGLS			
	Coef.	**Std. Err.**	**t**	**P>t**	**Coef.**	**Std. Err.**	**z**	**P>z**	**Coef.**	**Std. Err.**	**z**	**P>z**
Temp	0.866	0.625	1.385	0 .083	0.830	0.629	1.320	0.093	0.856	0.622	1.376	0.084
Rain	-0.139	0.048	-2.929	0.002	-0.141	0.047	-3.012	0.001	-0.132	0.043	-3.086	0.001
Hmdt	1.352	0.490	2.759	0.003	1.340	0.446	3.007	0 .001	1.362	0.428	3.179	0.001
HYV	0.831	0.041	20.505	0.000	0.831	0.041	20.059	0.000	0.831	0.040	20.608	0.000
_cons	-5.485	4.088	-1.342	0.180	-5.309	4.160	-1.276	0.202	-5.485	4.068	-1.348	0.178
Adj R^2	0.4706											
F(4,497)	112.36											