January 2016

# Impact Of Seasonality On Agricultural Productivity In Bangladesh

Mohammad Gulam Mostofa

# IMPACT OF SEASONALITY ON AGRICULTURAL PRODUCTIVITY IN BANGLADESH

by

Mohammad Gulam Mostofa

Bachelor of Science, Bangladesh Agricultural University, Mymensingh, 2003

Master of Science, Bangabondhu Sheikh Mujibur Rahman Agricultural University, 2009

A Thesis

Submitted to the Graduate Faculty

of the

University of North Dakota

in partial fulfillment of the requirements

for the degree of

Master of Science

Grand Forks, North Dakota
December
2016

This thesis, submitted by Mohammad Gulam Mostofa in partial fulfillment of the requirements for the Degree of Master of Science from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done and is hereby approved.

____________________________________

Daniel Biederman (chairperson)

____________________________________

David Flynn (committee member)

____________________________________

Prodosh Simlai (committee member)

This thesis is being submitted by the appointed advisory committee as having met all of the requirements of the School of Graduate Studies at the University of North Dakota and is hereby approved.

____________________________________

Dr. Grant McGimpsey
Dean of the School of Graduate Studies

____________________________________

Date

PERMISSION

| | |
|---|---|
| Title | Impact of Seasonality on Agricultural Productivity in Bangladesh |
| Department | Applied Economics |
| Degree | Master of Science in Applied Economics |

In presenting this thesis in partial fulfillment of the requirements for a graduate degree from the University of North Dakota, I agree that the library of this University shall make it freely available for inspection. I further agree that permission for extensive copying for scholarly purposes may be granted by the professor who supervised my thesis work or, in his absence, by the Chairperson of the department or the dean of the School of Graduate Studies. It is understood that any copying or publication or other use of this thesis or part thereof for financial gain shall not be allowed without my written permission. It is also understood that due recognition shall be given to me and to the University of North Dakota in any scholarly use which may be made of any material in my thesis.

Mohammad Gulam Mostofa

November 14, 2016

TABLE OF CONTENTS

LIST OF FIGURES

## LIST OF TABLES

Table Page

# ACKNOWLEDGMENTS

I am grateful to Almighty Allah for the good health and well-being that were necessary to complete this research. I would like to thank the Department of Economics of the University of North Dakota and the School of Graduate Studies for all the support I was given to excel my studies. I would like to thank Professor Dr. Biederman for his advisory and teachings. It has been a great pleasure to be his Teaching Assistant. I would like to express my profound and sincere gratitude to Dr. David Flynn for his patience, understanding, expertise, intellectual and outstanding suggestions throughout the course of my MS research. My sincere appreciation goes to Professor Dr. Cullen Goenner, MSAE Graduate Director, for his continued support, financial support, and for making resources readily available during my time in MSAE program. I wish to express my sincere appreciate to Dr. Prodosh Simlai for his guidance and teaching during my time in the master's program. I am also thankful to Michelle Garsky, Tami, and Kate for their encouraging and supporting me in many ways. I want to express my gratitude to my family members includes my parents, my wife Fatima, my son Mohiuddin, my daughter Musharat, my mother-in-law, and father-in-law for their financial support, love and faith throughout my studies. Without their support it would have been impossible to finish my thesis.

To my parents !

ABSTRACT

This paper studies the impact of seasonality on agricultural productivity in Bangladesh for the period of 1980-2013 for 7 regions. This study exploits regional fixed effect to estimate the impact of both observed and unobserved effects on agricultural productivity in order to control for regional differences. I used a panel dataset for the fixed and random effect regression model to control omitted variables bias and endogeneity. Findings from this study expressed that the effects of all the climate variables are not significant to rice, wheat, and pulse yield. Maximum temperature and minimum temperature wet for rice, minimum temperature dry and rainfall dry for wheat, and maximum temperature dry, rainfall wet, and humidity in both season for pulse are statistically significant and contribute to the crop production. Overall, climatic variables are of paramount importance for seasonality and agricultural productivity in Bangladesh.

# CHAPTER I

# INTRODUCTION

Agriculture is the key driver of the growth of Bangladesh economy. According to the provisional estimates of the Bangladesh Bureau of Statistics (BBS), the contribution of the agriculture sector to the Gross Domestic Product (GDP) stood at 12.65 percent in Fiscal Year (FY) 2013-14. The overall contribution of the broad agriculture sector was 16.33 percent of the GDP during the same period (Bangladesh Economic Review, 2014). In addition, the agriculture sector employs around 47.30 percent of the total labor force of the country (LFS, 2010, BBS). Seasonality is the period of time that passes between one production event and the next. Most of the major field crops produced in the Bangladesh seasonality occur over a 12-month period. Crop seasonality depends on climate variability factors like temperature, rainfall, humidity, cloud coverage, etc. Since crops follow a seasonal calendar and weather varies significantly between seasons, Bangladesh split the year into two seasons—dry (October to March) and wet (April to September). The climate of Bangladesh is characterized by high temperatures, heavy rainfall, high humidity, and fairly marked seasonal variations. The scientific models that forecast the impact of various scenarios of climate variability on the production of crops indicate that potential yields are projected to decrease with most projected increases in temperature in most tropical and subtropical regions (IPCC 2001). Agriculture production is always susceptible to unfavorable weather conditions and events. Despite technological progress such as improved high yielding crop varieties and irrigation facilities, weather and climate are still important determinants for agricultural productivity. According to the UNDP report (2008), the Bangladesh has been facing higher temperatures, particularly during the monsoon season over the last three decades. Furthermore, an annual mean temperature rise of 1 °C is forecasted by 2030, 1.4 °C by 2050 and 2.4 °C by 2100 (IPCC, 2007). The prediction for the dry season mean temperature showed a similar rising pattern of 1.1 °C by 2030, 1.6 °C by 2050 and 2.7 °C by 2100, while the projected value for the wet season mean temperature is 0.8 °C by 2030, 1.1 °C by 2050 and 1.9 °C by 2100 (Agrawala et.al., 2003; Ahmed, 2006). Based on the projections, it can be said that Bangladesh is likely to face more hot days and heat waves, longer dry spells and is at higher risk of drought. In general, the projected temperature increase will have adverse effects on the yields of major food crops, especially rice, wheat, and pulse thereby exacerbating vulnerability food supply.

## Research Question

How does the impact of climate variability on seasonality affect rice, wheat, and pulse productivity in Bangladesh?

## Rice

First and foremost, rice is the staple food of Bangladesh for 160 million people. The daily per capita calorie intake from rice has been falling, from 74.8 percent of total calories in 1995 to 69.6 percent in 2009 but rice contribution to per capita protein intake fell, from 65.3 percent to 56.2 percent, in the same period. Rice and wheat alone contribute 71 percent and 53 percent of the total per capita calorie and protein intake respectively. Especially in

Asia, where rice is the staple food of many rural and urban poor people, any negative effects on rice yields will directly move into major food shortage. For instance, the sea level rising causes flooding and salinity intrusion which may affect mega delta limiting future production (www.ricepedia.org). Global climate change has potentially grave consequences for rice production and consequently, global food security. The International Food Policy Research Institute (IFPRI) study forecasts a 15 percent decrease in irrigated rice yields in developing countries and a 12 percent increase in rice price as a result of climate change by 2050. The population growth rate is 1.20 percent per year. Due to this rate, the total population will become 233.2 million by 2050 (https://www.census.gov/population/international/files/ppt/Bangladesh93.pdf). However, Bangladesh faces a tremendous challenge for providing food security to the increasing population. Therefore, it is imperative to increase rice production in order to meet the growing demand for food emanating from population growth. The various climatic phenomena like cyclones, drought, changing rainfall patterns, temperature, and humidity cause significant damage to rice production almost every year. For instance, devastating cyclone Sidor in 2007 and cyclone Aila in 2009 caused severe damage to rice production (BBS, 2010). Aus rice is generally grown in March and April and then harvested in July and August. Aman rice is normally planted in June and August and then harvested in November and December. Boro rice is transplanted in December and January, and then harvested in April and May. According to the International Rice Research Institute (IRRI), a rise in night time temperature by 1 degree Celsius may reduce rice yields by about 10 percent.


Figure 1. Rice production trend over the years

This figure demonstrates the overall rice production in Bangladesh from 2003 to 2014

## Wheat

Wheat was one of the first of the grains to be domesticated by human being. Bread wheat is known to have been grown in the Nile Valley by 5000 BC and it is believed that the Mediterranean region was the centre of domestication. The civilization of West Asia and of the European peoples have been largely based on wheat, while rice has been more important in the East Asia. Since agriculture began, wheat has been the chief source of bread for Europe and the Middle East. It was introduced into Mexico by the Spaniards in the early part of 16th century and into Virginia, USA by English colonists early in the 17th century. Although it is one of the oldest of the cereal crops, it was introduced in Bengal between 1930 and 1931. Its importance as a food crop was recognized around 1942-43. The plants bear this edible grain in dense spikes. The culm of the mature wheat plant is a hollow, jointed cylinder that comprises three to six nodes and internodes. Wheat is grown under a wide range of climatic and soil conditions. It, however, grows well in clayey loam soils. In Bangladesh, it is a crop of rabi season which requires dry weather and bright sunlight. Well distributed rainfall between 40 and 110 cm is congenial for its growth (www.banglapedia.org). Almost 50% of the total world production of grain crop is occupied by wheat. In Bangladesh although it is less important than rice, it is now recognized as the second alternative cereal crop in the country. It is highly nutritious and a high energy food source. It is mostly used as ata or maida (wheat flour) for the preparation of bread and cakes. Flour from hard-kernelled wheat varieties are used in the manufacture of macaroni, spaghetti, noodles, and other paste products. White and soft wheat varieties have starchy kernels; their flour is preferred for biscuits, piecrust, and a wide range of breakfast foods. Wheat is also used in the manufacture of whiskey and beer, and the grain, the bran, and the vegetative plant parts make valuable livestock and poultry feed. The straw is used as fuel in the rural areas. Wheat is an especially critical food stuff for about 1.2 billion people who are classified as wheat-dependent, and 2.5 billion who are classified as wheat-consuming and live on less than $2 day per day. There are also about 30 million poor wheat producers and their families for whom wheat is the staple crop (FAOSTAT 2012). Demand for wheat in the developing world is projected to increase 60 percent by 2050 (Rosegrant and Agcaoili 2010).

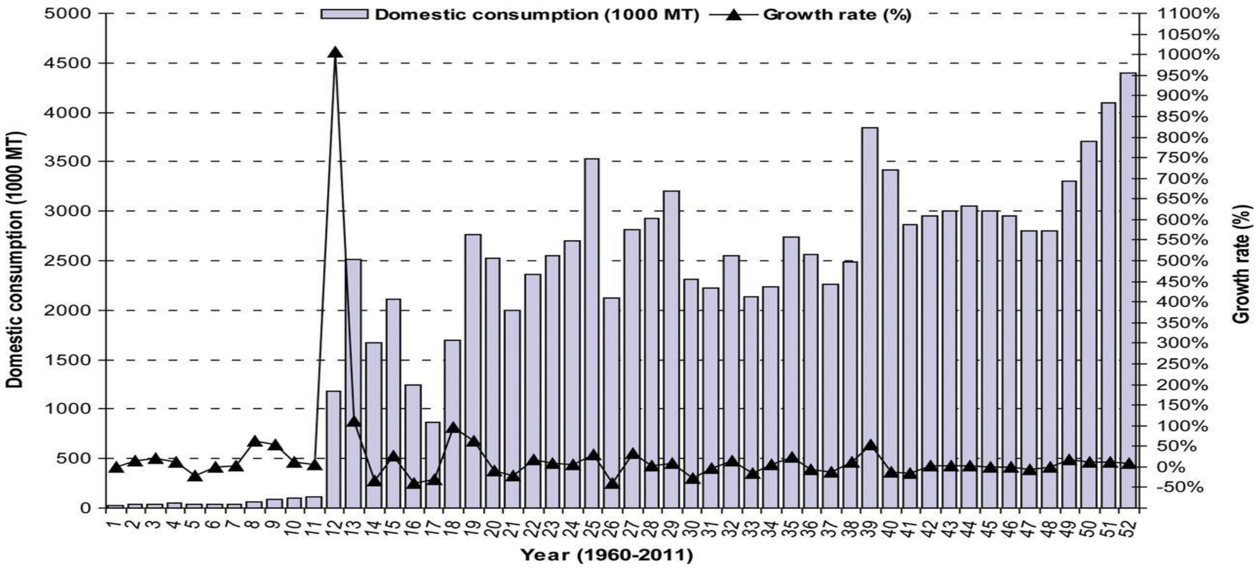

Figure 2. Domestic consumption (1000 MT) and growth rate (%) of wheat from 1960 to 2011 in Bangladesh.

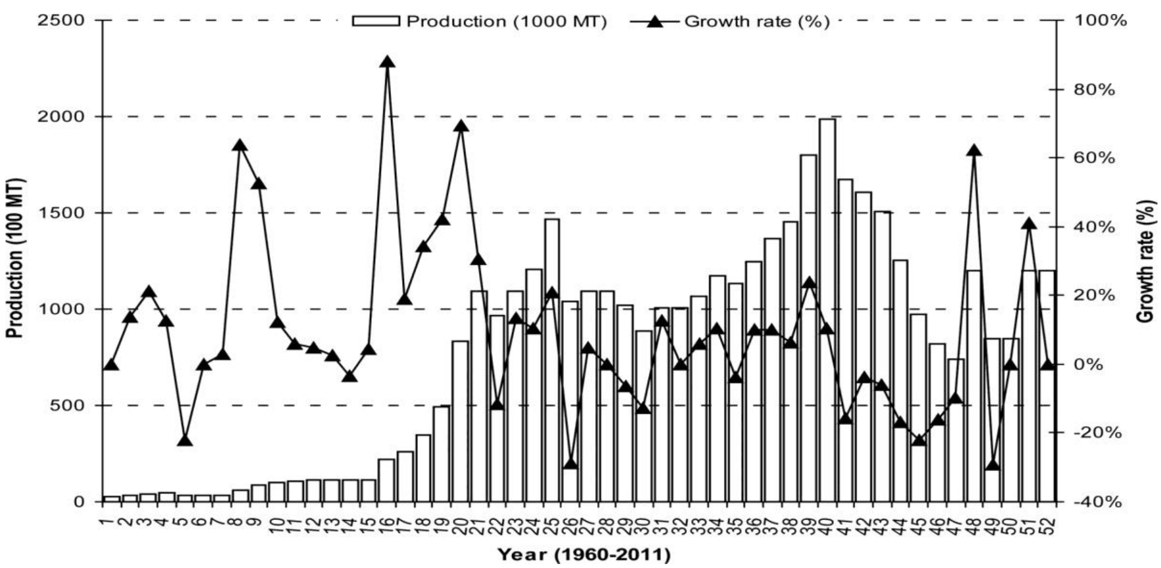

Figure 3. Yearly production (1000 MT) and growth rate (%) of wheat from 1960 to 2011 in Bangladesh

It is apparent that from the 52 years' worth of data, in the last 5 years, increased domestic consumption of wheat (Fig. 1) can be linked to increases in population and changes in eating habits. Production (Fig. 2) did not increase sufficiently to match the growth because of climate variability.

**Pulse**

Many varieties of pulses are grown in different parts of Bangladesh. Pulses have traditionally been called the poor man's meat since these are the cheapest source of protein in the daily diet of most people in Bangladesh. For this reason, about 7.3 lakh hectare of land (9% of the net cropped area) of the country is devoted to pulse cultivation (BBS, 2008). Among the pulses grown extensively in the country, kheshari occupies the largest area and highest production, followed by lentil, chickpea and blackgram (BBS, 2000). Although many hectares are dedicated to its production, the per capita consumption of pulse in Bangladesh is only 12 gm/day which is much lower than the recommended daily consumption of 80 gm/day (BBS, 2010). This is because there is still not enough pulse production.

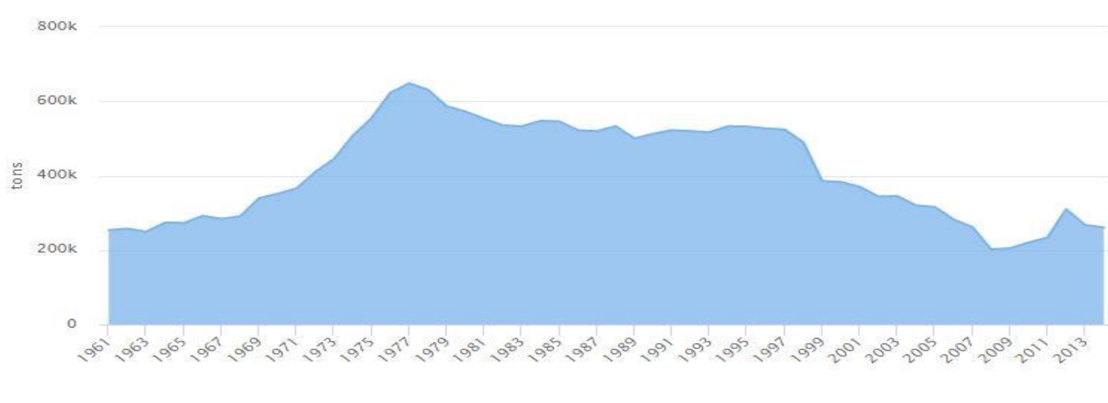


Figure 4. Pulse production over the years from 1961 to 2013 (source: FAOSTAT)

In this paper, much attention has been given to the effects of seasonality on agricultural output due to climate variability because of the relevance of agriculture to the Bangladesh economy and the sensitivity of crop yields to climate conditions. This study compiles and uses a unique panel data set of 7 regions of Bangladesh for the period of 1980—2013. Recently, panel data studies have emerged that attempt to correct the limitations of both cross-sectional and time-series studies, by accounting for fixed regional effects and estimating the effects of climatic variability changes non-linearly over a diversity of regions and climates. I use region fixed effects to estimate the impact of changes in temperature, rainfall, humidity, and cloud coverage on agricultural productivity.

I also use agricultural output per hectare of rice, wheat, and pulse, as measures of agricultural productivity. Few studies have been done in Bangladesh to investigate the pattern and trend of rainfall, temperature, humidity, and cloud coverage on rice, wheat, and pulse yields. Very few previous studies have intensely examined the relationship between climate variability and crop production. The purpose of the study is to analyze the relationship between climatic variables and yields of rice, wheat, and pulse in Bangladesh.

# CHAPTER II

## LITERATURE REVIEW

There are not numerous studies in Bangladesh that discuss the relationship between climatic variables and yield of rice, wheat, and pulse. Only a few economists have done some research regarding this vital issue. Using both Ordinary Least Squares and median quantile regression, Sarker et al (2012) did time series analysis for assessing three rice crops like Aus, Aman, and Boro. They did not consider regional effect and unobserved heterogeneity in their analysis. They only consider maximum and minimum temperature and rainfall as independent variables and found significant relationship between climate variable and agricultural productivity. My paper is closely related to two recent papers, Lobell et al (2007) and Lobell et al (2011). Lobell et al (2007) analyzed the relationship between crop yield and three climatic variables (minimum temperature, maximum temperature, and precipitation) for 12 major California crops. The authors found that the relationship between yield and climate can provide a foundation for forecasting crop production within a year and for projecting the impact of future seasonality. Lobell et al (2011) examines a 20-year country level panel to estimate global impacts of temperature and precipitation trends on crop yields, and found that changes have declined yields for some crops. Several studies have been conducted in recent years in Bangladesh that indicate that climate variables are factors of rice, wheat, and pulse production. Rimi et al. (2009) have conducted a study on the trend and prediction of future climate change scenarios with the Global Climate Model

(GCM) to examine the impacts of climate change on rice production. The study concluded that temperature variations had spectacular implications on crop yield. The production of Aus rice (a summer crop) has decreased significantly with increasing maximum temperature, whereas the production of Boro rice (a winter crop) has increased significantly with the increase of minimum temperature. Another study conducted by Awal and Siddique (2011) estimated the trend of rice production by employing the ARIMA model but they did not consider climate influence. Hossain and Silva (2012) have conducted an initiative to find out the impact of climate change on rice and wheat yield in Bangladesh. Their study concluded that warming is expected to severely reduce the yield of various crops, including rice and wheat, directly affecting the food security of 160 million people in Bangladesh. Sarker et al. (2012) carried out a study to examine the relationship between three climate variables (maximum temperature, minimum temperature and rainfall) and three different rice crops (Aus, Aman and Boro). They considered 1971–1972 fiscal years' yield as the yield of 1972. However, to ensure consistency between climate parameters and yield, the authors accounted 1972's climate for 1972's yield. In the case of calculating climate data for Boro rice, the study should merge two calendar years' data into one (for example, from December of 1971 to May of 1972 for 1972's yield), as they considered the growing months for Boro rice to be December-May. That is why their study might not represent the real relation between seasonality and crop yield. In addition, the authors did not considered humidity as a climate variable although this variable has significant influence on crop production.

In my study, I consider region specific panel data on weather variables, crop area, and crop yield and estimate effects separately across the crops. This type of study has not been previously conducted I designed my study to overcome previous shortcoming. Moreover, I do not consider time- invariant region- specific characteristics like technology trends, soil quality, plant growth, etc. to avoid the endogeneity problem.

The International Food Policy Research Institute in the USA projects that world demand for wheat will rise from 552 million tons in 1993 to 775 million tons by 2020 (Rosegrant et al. 1997). At the same time, climate change-induced temperature increases are likely to reduce wheat production in developing countries (where around 66 percent of all wheat is produced) by 20–30 percent (Esterling et al. 2007; Lobell et al. 2008; Rosegrant and Agcaoili 2010). The Intergovernmental Panel on Climate Change (IPCC, 2007) noted that global climate change will have a major impact on crop production. CIMMYT and ICARDA (2011) estimated that 20–30 percent wheat yield losses will occur by 2050 in developing countries as a result of a predicted temperature increase of 2–3 °C. Wheat production is also sensitive to temperature: it requires a low 19.5°C temperature at certain stages to obtain a desirable yield and temperature fluctuations wheat-growing areas is worsening the ability to produce this crop ((Hossain et al., 2009; 9 197 Hossain and Teixeira da Silva, 2012; Hossain et al., 2011; 2012a, b; Hakim et al., 2012; 198 Hossain and Teixeira da Silva, 2013).

Finally, this study differs from previous studies of climate variability impacts on crop yields in Bangladesh in that I estimate historical impacts on crop yields but not future predictions because I estimate climate trends and yield within a dataset of realized observations for the same region and years.

# CHAPTER III

# DATA AND METHODOLOGY

***Data***

I used two categories of data, one is agricultural data and another is climatic or weather related data for my analysis. There are various sources for this data. First and foremost, I rely on the incredibly rich and valuable data provided by the Yearbook of Agricultural Statistics, Bangladesh Agricultural Research Council (BARC), and Food and Agricultural Organization (http://faostat.org). This website is very popular and valuable for agricultural research across the world. My study is considering three major agricultural crops (rice, wheat, and pulse) defined by the Agriculture Wing, Bangladesh Bureau of Statistics (BBS). The sources of agriculture data are: Yearbook of Agricultural Statistics, BBS. The Yearbook reports agricultural data at the regional level. There are 23 agricultural regions defined by the BBS and each region is composed of one or more current administrative districts and 7 divisions cover 23 agricultural regions in Bangladesh. The Yearbook of Agricultural Statistics produces estimates of acreage, production and yield per acre for more than 100 crops grown in the country. I collected rice, wheat, and pulse acreage, production, and yield per acre data from various versions of the Yearbook of Agricultural Statistics for the time period of 1980-2013. I converted acre to hectare in my analysis.

I also collected monthly rainfall, maximum and minimum temperature, rainfall, humidity, and cloud coverage data for the period of 1980-2013 from Bangladesh Agricultural Research Council (BARC). There are 32 weather stations in Bangladesh and they cover 7 divisions. Weather data varies across weather stations. Since crop follow the seasonal calendar and weather varies significantly between seasons, I split a calendar year into two seasons – dry (Oct- March) and wet (April-Sept). These two seasons also called Rabi (dry) and Kharif (wet) seasons, respectively. All weather variables are, thus, for two seasons. In the case of temperature, data on monthly maximum and monthly minimum are available. So, I created a seasonal average of maximum and minimum temperatures. Not only the average but also the fluctuation of temperature in each season might impact agricultural productivity. Average monthly rainfall data is available; I created seasonal averages of rainfall for dry and wet seasons. Similarly, I created averages seasonal data on cloud coverage and humidity conditions.

Table 1. Descriptive Statistics

| Variables name | Mean | Std Dev | Min | Max |
|---|---|---|---|---|
| Rice yield | 1.5755 | 0.2892 | 1.02 | 2.76 |
| Wheat yield | 2.099 | 0.57308 | 0.98 | 3.17 |
| Pulse yield | 0.34176 | 0.23 | 0.026 | 1.101 |
| Maximum temp dry | 29.13 | 0.76755 | 27.06 | 31.8 |
| Maximum temp wet | 32.41 | 0.95013 | 30.31 | 35.18 |
| Minimum temp dry | 15.1 | 1.394 | 10.2 | 19.3 |
| Minimum temp wet | 18.03 | 0.7471 | 15.23 | 19.45 |
| Rainfall dry | 71.6 | 46.18 | 42.76 | 248 |
| Rainfall wet | 348 | 141.96 | 103.16 | 844.6 |
| Humidity dry | 79.7 | 3.82 | 69.33 | 88.33 |
| Humidity wet | 82.82 | 2.68 | 75.66 | 88.83 |
| Cloud coverage dry | 2.14 | 0.4523 | 1.033 | 3.63 |
| Cloud coverage wet | 5.43 | 0.5151 | 4 | 6.73 |
| Observations | | | 238 | |
| Year | | | 34 | |

The descriptive statistics exhibits in table 1, portray the basic characteristics of all the explanatory variables and dependent variable. The mean yield of wheat is the highest, and the mean yield of pulse is the lowest among the three major crops. But standard deviation of wheat yield is larger than standard deviation of rice yield. It is noted that average maximum temperature (Celsius) in the wet season has increased while dry seasons experienced more temperature fluctuations. On the other hand, minimum temperature in the wet season is higher than minimum temperature in the dry season. Rainfall for both seasons has generally increased, but with more regional variation in the wet season. The percentage of humidity is almost the same in both seasons. Clouds conditions for the country is more in the wet season.

Table 2. Correlation between rice yield and explanatory variables

| | Riceyi~d | Ricearea | MaxtemD | MaxtemW | MinitemD | Minitemw | Rainfa~D | Rainfa~W | Humidi~D | Humidi~W | Cloude~D |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Riceyield | 1.0000 | | | | | | | | | | |
| Ricearea | -0.1492 | 1.0000 | | | | | | | | | |
| MaxtemD | -0.0105 | 0.2333 | 1.0000 | | | | | | | | |
| MaxtemW | 0.1069 | -0.1409 | 0.1235 | 1.0000 | | | | | | | |
| MinitemD | 0.0396 | 0.0766 | 0.5082 | -0.3114 | 1.0000 | | | | | | |
| Minitemw | -0.0503 | 0.0955 | 0.2467 | 0.3215 | 0.2604 | 1.0000 | | | | | |
| RainfallD | -0.0293 | 0.0922 | -0.0160 | -0.1893 | 0.1945 | 0.0981 | 1.0000 | | | | |
| RainfallW | 0.3316 | 0.1237 | 0.0852 | -0.7042 | 0.3406 | -0.3116 | 0.2084 | 1.0000 | | | |
| HumidityD | -0.2986 | 0.3418 | -0.1093 | 0.0541 | -0.2518 | 0.0095 | 0.1599 | -0.1327 | 1.0000 | | |
| HumidityW | -0.2422 | 0.4693 | 0.1595 | -0.3964 | 0.0601 | -0.0914 | 0.1608 | 0.2785 | 0.6465 | 1.0000 | |
| CloudeCove~D | 0.1751 | 0.1637 | 0.1805 | -0.2020 | 0.3422 | -0.0100 | 0.4290 | 0.3096 | 0.0117 | 0.0750 | 1.0000 |

From the above table, it is assumed that the maximum temperature and rainfall during the wet season and cloud coverage during the dry season are positively correlated with rice yield. On the contrary, rice area, rainfall, temperature, and humidity during the dry season are negatively correlated with rice yield.

Table 3. Correlation between pulse yield and explanatory variabl

```
. corr Pulseyield Pulseareaha MaxtemD MaxtemW MinitemD Minitemw rainfalld rainfallw HumidityD HumidityW
(obs=238)
```

| | Pulsey~d | Pulsea~a | MaxtemD | MaxtemW | MinitemD | Minitemw | rainfa~d | rainfa~w | Humidi~D | Humidi~W |
|---|---|---|---|---|---|---|---|---|---|---|
| Pulseyield | 1.0000 | | | | | | | | | |
| Pulseareaha | 0.0462 | 1.0000 | | | | | | | | |
| MaxtemD | -0.0258 | 0.3120 | 1.0000 | | | | | | | |
| MaxtemW | 0.5852 | -0.2053 | 0.1235 | 1.0000 | | | | | | |
| MinitemD | -0.2220 | 0.4731 | 0.5082 | -0.3114 | 1.0000 | | | | | |
| Minitemw | 0.1211 | 0.1777 | 0.2467 | 0.3215 | 0.2604 | 1.0000 | | | | |
| rainfalld | -0.0248 | 0.2566 | -0.0533 | -0.2703 | 0.1399 | -0.1167 | 1.0000 | | | |
| rainfallw | -0.1458 | -0.0404 | -0.1267 | -0.0675 | -0.0514 | -0.0789 | -0.0284 | 1.0000 | | |
| HumidityD | -0.3054 | -0.1793 | -0.1093 | 0.0541 | -0.2518 | 0.0095 | -0.0558 | 0.0734 | 1.0000 | |
| HumidityW | -0.5543 | -0.1108 | 0.1595 | -0.3964 | 0.0601 | -0.0914 | 0.0172 | 0.0598 | 0.6465 | 1.0000 |

From the table, it is observed that pulse area, maximum temperature wet, and minimum temperature wet have positive relationships with pulse yield. The remaining variables are negatively correlated with pulse yield.

Table 4. Correlation between wheat yield and explanatory variables

```
. corr Wheatyield Wheatarea MaxtemD MinitemD RainfallD HumidityD CloudeCoverageD
(obs=238)
```

| | Wheaty~d | Wheata~a | MaxtemD | MinitemD | Rainfa~D | Humidi~D | Cloude~D |
|---|---|---|---|---|---|---|---|
| Wheatyield | 1.0000 | | | | | | |
| Wheatarea | 0.8405 | 1.0000 | | | | | |
| MaxtemD | -0.2736 | -0.3427 | 1.0000 | | | | |
| MinitemD | -0.3398 | -0.4839 | 0.5082 | 1.0000 | | | |
| RainfallD | -0.1720 | -0.2570 | -0.0160 | 0.1945 | 1.0000 | | |
| HumidityD | 0.1659 | -0.0377 | -0.1093 | -0.2518 | 0.1599 | 1.0000 | |
| CloudeCove~D | -0.2962 | -0.3322 | 0.1805 | 0.3422 | 0.4290 | 0.0117 | 1.0000 |

It is really interesting that wheat area has a highly positive correlation with wheat yield. It is very close to 1. The humidity dry season also has a positive correlation with wheat yield. The other explanatory variables have negative correlation with wheat yield.

## METHODOLOGY

### *Variables*

There are two type of variables used in this study. First and foremost, the dependent variable of this study is the yield of three major crops: rice, wheat, and pulse. Five weather variables are considered as independent variables. The five weather variables are average maximum temperature, average minimum temperature, rainfall, humidity, and cloud coverage for both dry and wet seasons. The endogeneity may arise due to omitted variable bias and simultaneity bias. In order to control for this endogeneity and heterogeneity, regions dummies are considered as independent variables. I use six dummy variables for six of the seven regions because one region, the Barisal used as a reference variable.

### *Model specification*

Stationarity and unit root are vital issues for panel data and time series data before executing the regression. As the data set of this present study contained over 34 years of observations for 7 regions verifying the stationarity is important before selecting the regression models. For determining the stationarity of panel data, the Levin-Lin-Chu unit root test is a very popular test. Therefore, the Levin-Lin-Chu test is performed to verify the presence of unit root.

Table 5 . The Levin-Lin-Chu unit root test

| Variables name | Adjusted t* | P value |
|---|---|---|
| Rice yield | -2.32 | 0.0501 |
| Rice Area | -2.96 | 0.049 |
| Wheat yield | -3.23 | 0.025 |
| Wheat area | -3.1 | 0.039 |
| Pulse yield | -4.21 | 0.019 |
| Maximum temp dry | -2.88 | 0.002 |
| Maximum temp wet | -3.87 | 0.0001 |
| Minimum temp dry | -2.94 | 0.0016 |
| Minimum temp wet | -2.64 | 0.004 |
| Rainfall dry | -6.11 | 0.001 |
| Rainfall wet | -4.99 | 0.0001 |
| Humidity dry | -5.316 | 0.0001 |
| Humidity wet | -3.68 | 0.0002 |
| Cloud coverage dry | -6.63 | 0.003 |
| Cloud coverage wet | -3.36 | 0.002 |

From the table 5, it is indicated that all variables data are stationary because the p value is significant and the null hypothesis is rejected. So, there is no unit root problem in the dataset.

Table 6. Heteroscedasticity test

White's test for Ho: homoskedasticity
against Ha: unrestricted heteroskedasticity
chi2(77) = 5.98
Prob > chi2 = 0.1200

Cameron & Trivedi's decomposition of IM-test

| Source | chi2 | df | p |
|---|---|---|---|
| Heteroskedasticity | 5.98 | 77 | 0.12 |
| Skewness | 3.49 | 11 | 0.2 |
| Kurtosis | 1.68 | 1 | 0.23 |
| Total | 11.15 | 89 | 0.55 |

White's general test for heteroscedasticity is actually a special case of the Breusch-Pagan test. The default Breusch-Pagan test is a test for linear forms of heteroscedasticity. In this default form, the test does not work well for non-linear forms of heteroscedasticity. The null hypothesis is that the error variances are all equal versus the alternative which is that the error variances are a multiplicative function of one or more variables. A large chi-square indicates that heteroscedasticity is present. However, in this analysis, the chi-square value is small, indicating heteroscedasticity is not a problem. Probability value is greater than chi-square value so that the null hypothesis is not rejected. It means that there is little or no heteroscedasticity.

Table 7. Multicollinearity test

| Variable | VIF | 1/VIF |
|---|---|---|
| HumidityW | 3.57 | 0.280372 |
| MaxtemW | 3.26 | 0.307136 |
| CloudeCove~W | 3.04 | 0.329333 |
| RainfallW | 2.95 | 0.339305 |
| HumidityD | 2.89 | 0.346317 |
| MinitemD | 2.23 | 0.448235 |
| MaxtemD | 2.09 | 0.479258 |
| CloudeCove~D | 1.83 | 0.547486 |
| Ricearea | 1.64 | 0.610831 |
| Minitemw | 1.48 | 0.673411 |
| RainfallD | 1.36 | 0.736608 |
| Mean VIF | 2.39 | |

A common rule of thumb is that if VIF > 5, then multicollinearity is high. From the above table, it appears that all VIF variables are less than 5. Only humidity wet season VIF is very close to 4. Therefore, multicollinearity is not a great problem for regression analysis and results.

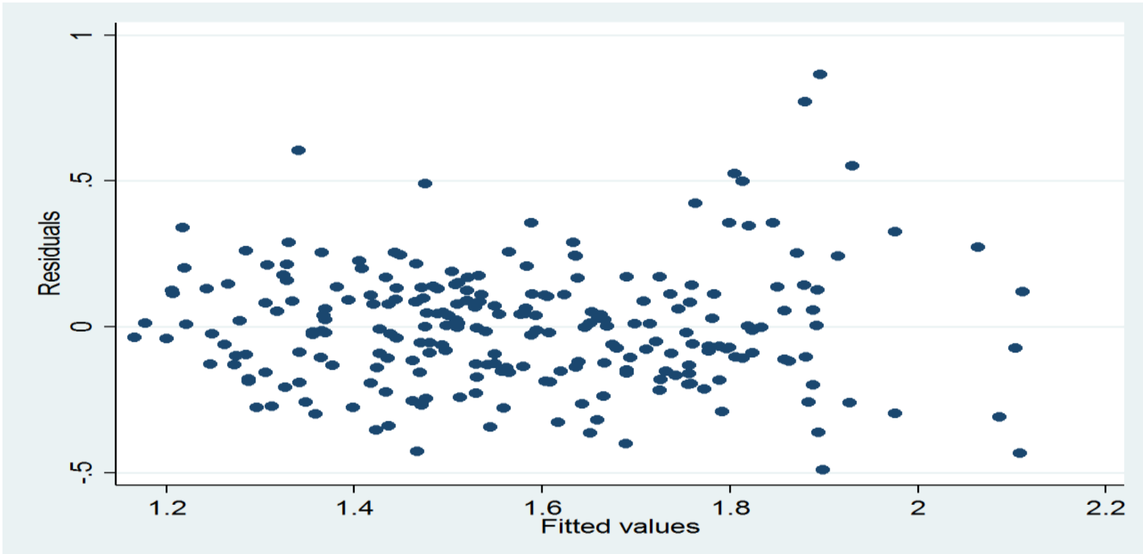


Figure 5 : Residual versus fitted value

Table 8. Summary of residuals

```
. sum res
```

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| res | 238 | 2.13e-11 | .20392 | -.489704 | .8651142 |

The residuals appear on the y axis and the fitted values appear on the x axis. The variation around the estimated regression line is constantly suggesting that the assumption of equal error variances is reasonable.

### *Regression model*

The pooled OLS regression model for this study:

$Yield_{i,t} = \beta_0 + \beta_i.Climate\ variables + \varepsilon_{i,t}$

Here I pooled all 238 observations together and ran the regression model but neglecting the cross section and time series nature of data.

$$Y_{i,t} = \beta_0 + \beta_1 Maxtemp_{i,t} + \beta_2 Mintemp_{i,t} + \beta_3 Rainfall_{i,t} + \beta_4 Humidity_{i,t} + \beta_5 Cloudcoverage_{i,t} + \beta_6 Region\ dummy + \varepsilon_{i,t}$$

where, Y= yield (kg/ha) for rice, wheat, pulse

i= region/agricultural zone, t= time (year)

Maxtemp= Average yearly maximum temperature (°C) both dry and wet season

Mintemp= Average yearly minimum temperature (°C) both dry and wet season

Rainfall= Average yearly rainfall (mm) both dry and wet season

Humidity= Average yearly humidity (%) both dry and wet season

Cloud coverage= Average cloud coverage (octas) both dry and wet season

Here, yield is the dependent variable, Climate variables and region dummy are the independent variables.

The fixed effects allow for heterogeneity or individuality among seven regions by allowing then to have their own intercept value. The fixed effect assumption is that the unobserved individual specific effect is correlated with explanatory variables. That is why the intercept may differ across regions but the intercept does not vary over time.

The random effect assumption is that the individual specific effects are uncorrelated with explanatory variables. Here our seven regions have a common mean value for the intercept. After having the regression, I did the Hausman test to check which model is the best.

The unobserved characteristics of the regions or divisions might influence agricultural productivity. Time invariant region specific characteristics such as soil quality can impact agricultural productivity. Regions also vary with respect to altitude and physiography (e.g., flood plains, basins, beels, tracts, hills and terrace). These and other characteristics specific to regions may have an impact on the agricultural productivity of that area. At the same time, I controlled for shocks or effects that are specific to certain years such as major improvements in technology that became available in a certain year. Therefore, I also controlled unobserved effects using regional dummies. Since it is highly likely that the errors are correlated over time, that is, the assumption of i.i.d. errors do not hold, I need a more realistic error structure. I assumed that errors are correlated within regions but not across multiple regions.

## CHAPTER IV

## RESULTS AND DISCUSSIONS

### The Regression Results for Rice

Table 9. Compare rice pool OLS regression results with fixed and random effect models

| | (1) | (2) | (3) |
|---|---|---|---|
| Variables name | Rice yield | Rice yield | Rice yield |
| Rice area (ha) | -0.00002*** | 0.00002*** | 0.00002* |
| | (0.0000) | (0.0000) | (0.0000) |
| Maximum temperature dry (C) | -0.0849*** | -0.0233 | -0.0234 |
| | (0.0254) | (0.0197) | (0.0204) |
| Maximum tem wet (C) | 0.2364*** | 0.0765*** | 0.1023*** |
| | (0.0257) | (0.0277) | (0.0279) |
| Minimum tem dry (C) | 0.0061 | 0.0065 | 0.0040 |
| | (0.0144) | (0.0107) | (0.0110) |
| Minimum tem wet (C) | 0.0267 | 0.0480*** | 0.0599*** |
| | (0.0221) | (0.0166) | (0.0169) |
| Rainfall dry ( mm) | -0.0006* | -0.0003 | -0.0003 |
| | (0.0003) | (0.0002) | (0.0002) |
| rainfall wet( mm) | 0.0013*** | -0.0001 | -0.0000 |
| | (0.0002) | (0.0002) | (0.0002) |
| Humidity dry (percent) | -0.0160*** | 0.0064 | 0.0040 |
| | (0.0060) | (0.0051) | (0.0053) |
| Humidity wet (percent) | 0.0016 | 0.0031 | 0.0047 |
| | (0.0095) | (0.0082) | (0.0085) |
| Cloud coverage dry (octas) | 0.0096 | 0.0014 | 0.0084 |
| | (0.0403) | (0.0305) | (0.0315) |
| Cloud coverage wet (octas) | 0.2372*** | 0.0471 | 0.0542 |
| | (0.0459) | (0.0361) | (0.0373) |
| Dummy (1) chittagong | | | 0.3829*** |
| | | | (0.0809) |
| Dummy (2) Dhaka | | | 0.5620*** |
| | | | (0.0793) |
| Dummy (3)Rajshahi | | | 0.4224*** |
| | | | (0.0801) |
| Dummy (4) Khulna | | | 0.4636*** |

| | | | |
|---|---|---|---|
| | | | (0.0728) |
| Dummy (5) Sylhet | | | 1.0039*** |
| | | | (0.0767) |
| Dummy (6) Rangpur | | | 0.4944*** |
| | | | (0.0721) |
| Constant | -4.7283*** | -2.2037** | -3.6806*** |
| | (1.0892) | (1.0805) | (1.0906) |
| N | 238 | 238 | 238 |
| adj. R-sq | 0.484 | 0.209 | |

Notes. Standard errors in parentheses *p<0.1, **p<0.05, ***p<0.01

Rice regression results are showing in table 6. The first specification model 1 (Pooled OLS regression) includes all climate variables without control of omitted variable bias. The results further indicated that rice area, maximum temperature dry and wet season are statistically significant at 1% level. But rice area and maximum temperature dry season are found to be negative for rice yield. Rainfall dry and humidity dry are also negatively significant for rice yield. However, Rainfall wet is found to be positive significant for rice yield. It can be concluded that from the OLS regression, maximum temperature wet and rainfall wet are standardized coefficient for rice yield because they are positively significant and influence the rice yield. The first specification model 1(Pooled OLS) results are inconsistent and biased because of omitted variable bias and endogeneity issue. This study considered only weather variables but there are many explanatory variables influencing the rice yield such as, soil quality, technology, inputs (fertilizer, labor, pesticides etc.), government incentives like subsidies or tax reduction for farmers etc. Natural disasters like floods, cyclones, hurricanes, and salinity jeopardize the agricultural productivity. So, all those factors actuate me to apply fixed effect and random effect model in lieu of pooled OLS.

The second specification model 2(Fixed effect regression results) includes all climate variables and region dummies because the region is fixed. I created six dummy variables for six regions and one region is categorical or reference variable. From the table, it is seen that rice area, maximum temperature wet and minimum temperature wet are positively significant with rice yield. This means that wet season temperature is very important for rice production. There are various reasons for the insignificance of dry temperature for rice yield. First and foremost, higher temperature shock leads to a reduction in photosynthetic rates by affecting photosystem and the Rubisco function and thereby inhibiting crops yields. Nevertheless, low temperature may cause chilling injury in plants. Possibly, these are the reasons for the insignificant results for dry temperature.

Rainfall in both seasons is insignificant but we know it is a very important variable for rice production especially for boro rice production. I found some reason for its insignificance; one is intense rainfall during the monsoon season can also lead to soil erosion or the wash out of surface soil and the depletion of plant nutrients in soil due to runoff. Another reason is that destructive floods may devastate crop production and farmers can suffer production losses as a result of the insufficient and erratic rainfall during the seasons. According to agronomists, very high or very low humidity is not effective for rice production. Crops tend to absorb soil nutrients for optimum yield when there is sufficient humid air. Relative humidity directly controls the plant water relationship and indirectly influences plant growth, photosynthesis rates, pollination, and ultimately crops yield.

Excessive cloud coverage is also detrimental to crop yield. All dummy variables are insignificant and collinearity in model 2 results because time-invariant characteristics of the individuals are perfectly collinear with rice yield.

The next specification model 3 (random effect) includes all climate variables and six region dummy variables. Rice area, maximum temperature wet, minimum temperature wet, and all dummy variables are positively significant with rice yield. The rationale behind the random effects is that the variation across the regions is assumed to be random and uncorrelated with explanatory variables. One advantage is that I can include time invariant variables. The pooled OLS adjusted $R^2$ value indicated that 48 % variability in yield is explained by climatic factors but in the fixed effect model adjusted $R^2$ value shows that 20 % variability in rice yield is explained by the climatic factors, which does justify the influence on rice yield.

To decide between fixed or random effect for rice I estimated the Hausman test where the null hypothesis is that the preferred model is random effect, the alternative the fixed effect.

***Hausman Test***

```
 chi2(11) = (b-B)'[(V_b-V_B)^(-1)](b-B)
          =       16.28
Prob>chi2 =      0.1309
(V_b-V_B is not positive definite)
```

From the Hausman test, random effect is better than fixed effect because Prob>chi2 = 0. 1309.This means that the null hypothesis is not rejected so that random effect model is accepted.

Table 10. Compare AIC and BIC between the pooled OLS and the fixed effect model for rice:

| Model | Obs | AIC | BIC |
|---|---|---|---|
| Fixed | 238 | -247.8 | -202.7 |
| Pooled OLS | 238 | -58.44 | -16.77 |

It is clear that the fixed effect model is better than the pooled the OLS regression model because the fixed effect model AIC and BIC are smaller than pooled OLS AIC and BIC. Therefore, the fixed effect model is accepted in this regard.

Overall, the random effect model results are more accurate and unbiased for rice yield.

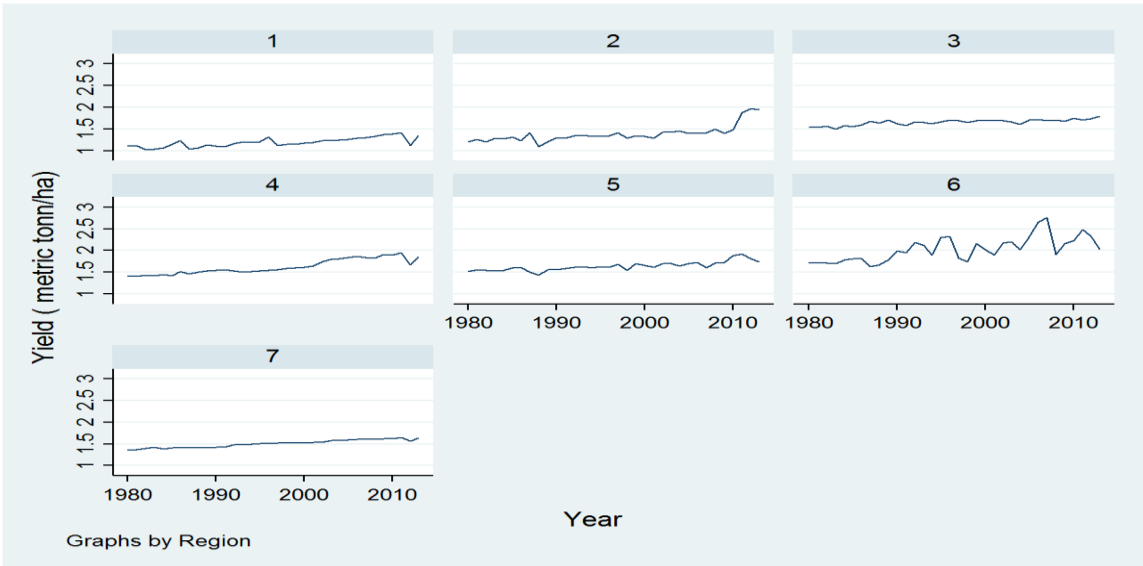


Figure 6. Rice yield in the different regions (from 1980 to 2013)

Regions code : 1= Barisal, 2= Chittagong, 3= Dhaka, 4= Rajshahi, 5= Khulna, 6= Sylhet, 7= Rangpur.

The above figure indicates that Sylhet is the best region for rice production. Barisal and Dhaka produce more rice. The lowest region is Rangpur.

### *The Regression Results for Wheat*

Wheat is a rabi crop which means that it is a dry season crop. I considered only dry season temperature, rainfall, humidity, and cloud coverage because this crop is planting period to harvest period is in dry season. It is obvious that from the table 10, wheat area, minimum temperature dry, humidity dry, and cloud coverage are statistically significant with wheat yield in the first specification model 1 (Pooled OLS regression) but cloud coverage is negatively significant. The other variables did not show any significant results. The pooled OLS estimates are totally inconsistent because of omitted variable bias. The second model specification (fixed effect model) demonstrated that wheat area (1 % level), minimum temperature dry (5% level), and rainfall (10% level) are statistically significant. In this case, the region is fixed and the region dummies are correlated with explanatory variables. That is why all dummies are insignificant in that case.

Table 11. Compare wheat pool OLS regression results with fixed and random effect models

| | Pooled OLS | Fixed | Random |
|---|---|---|---|
| Variables name | Wheatyield | Wheatyield | Wheatyield |
| Wheat area (ha) | 0.00001*** | 0.00001*** | 0.00001*** |
| | 0 | 0 | 0 |
| Maximum temperature Dry (C) | -0.0096 | 0.0206 | 0.0212 |
| | -0.0278 | -0.0285 | -0.0284 |
| Minimum temperature Dry (C) | 0.0787*** | 0.0441** | 0.0434** |
| | -0.0174 | -0.0179 | -0.0177 |
| Rainfall (mm) | 0.0001 | 0.0001* | 0.0001** |
| | -0.0001 | -0.0001 | -0.0001 |
| Humidity Dry (percent) | 0.0376*** | 0.0099 | 0.0096 |
| | -0.005 | -0.0069 | -0.0068 |
| Cloud Coverage Dry(octas) | -0.0820* | -0.038 | -0.0376 |
| | -0.0437 | -0.045 | -0.045 |
| Dummy chittagong | | | -0.1658** |
| | | | -0.0835 |
| Dummy Dhaka | | | -0.5826*** |
| | | | -0.1038 |
| Dummy Rajshahi | | | -0.9155*** |
| | | | -0.1379 |
| Dummy Khulna | | | -0.2593*** |
| | | | -0.0693 |
| Dummy Sylhet | | | -0.3465*** |
| | | | -0.0786 |
| Dummy Rangpur | | | -0.3142*** |
| | | | -0.1033 |
| Constant | -2.1836** | -0.5778 | -0.2399 |
| | -0.8873 | -0.9415 | -0.9641 |
| N | 238 | 238 | 238 |
| adj. R-sq | 0.766 | 0.572 | |

Notes.Standard errors in parentheses *p<0.1, **p<0.05, ***p<0.01

The third model specification (random effect) used regional dummies to control for heterogeneity and unobserved effects. Wheat area (1% level), minimum temperature dry (5 % level), rainfall (5 % level), and all dummies except Chittagong have 1 % level of significance with wheat yield. It is interesting that rainfall variable is positively significant with wheat yield. It is justified because wheat is a rain fed crop. All regions are better than the Barisal region (categorical or reference variable) because dummy variables are statistically significant with wheat yield. The pooled OLS adjusted $R^2$ value expressed that 76 % variability in wheat yield is explained by the climatic factors. Nevertheless, the fixed effect adjusted $R^2$ value expressed 57 % variability in wheat yield which is explained by the climatic factors. This strongly justifies the climatic influence on wheat crop.

To decide between fixed or random effect for wheat I estimated the Hausman test where the null hypothesis is that the preferred model is random effect, the alternative the fixed effect.

***Hausman Test***

```
    chi2(6) = (b-B)'[(V_b-V_B)^(-1)](b-B)
            =        0.16
Prob>chi2 =      0.9999
```

From the Hausman test, random effect is better than fixed effect because Prob>chi2 = 0.999. This means that the null hypothesis is not rejected so that the random effect model is accepted.

Table 12. Compare AIC and BIC between Pooled OLS and fixed effect model for wheat

| Model | Obs | AIC | BIC |
|---|---|---|---|
| Fixed | 238 | 2.605 | 30.38 |
| Pooled OLS | 238 | 71.48 | 95.79 |

It is observed that the fixed effect model is better than pooled the OLS regression model because the fixed effect model AIC and BIC are smaller than pooled OLS AIC and BIC. Therefore, the fixed effect model is accepted in this regard. Overall, the random effect model results are more accurate and unbiased for wheat yield.

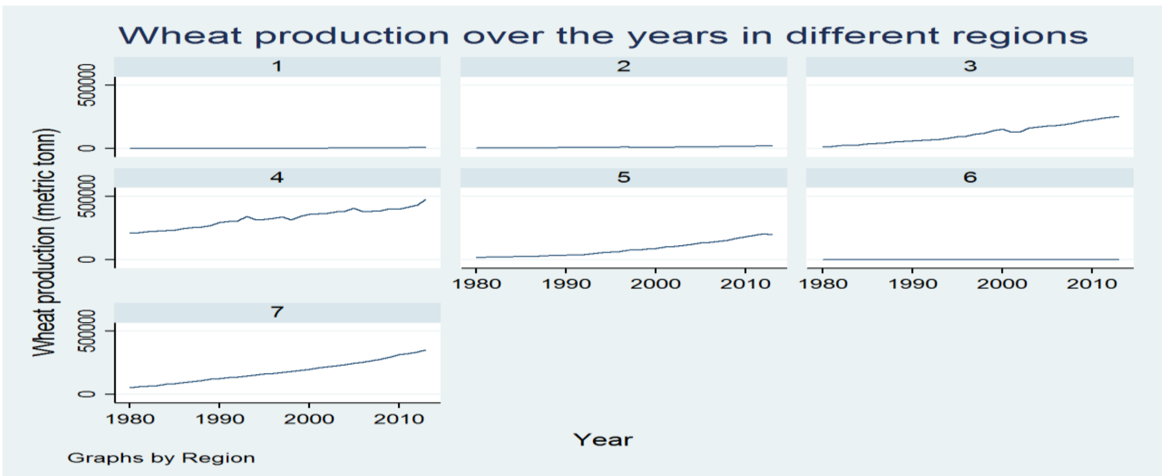


Figure 7**.** Wheat production in the different regions (from 1980 to 2013)

Regions code: 1= Barisal, 2= Chittagong, 3= Dhaka, 4= Rajshahi, 5= Khulna, 6= Sylhet, 7= Rangpur.

The Rajshahi and Dhaka divisions are the largest areas of wheat production in Bangladesh. Barisal is the lowest region for wheat production.

### *The Regression Results for Pulse*

From table 13, it is clear that pulse area, maximum temperature wet, maximum temperature dry, minimum temperature dry season, rainfall wet, and humidity dry are significant in OLS regression, which implies that these variables have significant and robust effects on overall production of pulse in Bangladesh. It is interesting that the impact of the average maximum temperature in wet season is positive and highly significant for the three models.

Table 13. Compare pulse pool OLS regression results with fixed and random effect models

| | (1)<br>Pulse yield | (2)<br>Pulse yield | (3)<br>Pulse yield |
|---|---|---|---|
| Pulse area (ha) | 0.0000*** | -0.00001 | -0.00001 |
| | (0.0000) | (0.0000) | (0.0000) |
| Maximum temp Dry (C) | -0.0353* | 0.0064 | 0.0048 |
| | (0.0201) | (0.0104) | (0.0107) |
| Maximum temp wet (C) | 0.1577*** | 0.0404*** | 0.0502*** |
| | (0.0201) | (0.0142) | (0.0143) |
| Minimum temp Dry (C) | -0.0242** | -0.0058 | -0.0075 |
| | (0.0112) | (0.0058) | (0.0060) |
| Minimum temp wet (C) | -0.0139 | 0.0102 | 0.0116 |
| | (0.0164) | (0.0085) | (0.0088) |
| Rainfall Dry (mm) | 0.0001 | -0.0000 | -0.0000 |
| | (0.0000) | (0.0000) | (0.0000) |
| Rainfall wet (mm) | -0.0001* | 0.0001** | 0.0001** |
| | (0.0000) | (0.0000) | (0.0000) |
| Humidity Dry (percent) | -0.0168*** | 0.0072*** | 0.0058** |
| | (0.0046) | (0.0026) | (0.0027) |
| Humidity wet (percent) | -0.0078 | 0.0100** | 0.0118*** |
| | (0.0075) | (0.0045) | (0.0046) |
| D2 | | | 0.4211*** |
| | | | (0.0494) |
| D3 | | | 0.5767*** |
| | | | (0.0329) |
| D4 | | | 0.7406*** |
| | | | (0.0304) |
| D5 | | | 0.2552*** |
| | | | (0.0233) |
| D6 | | | 0.3585*** |
| | | | (0.0270) |
| D7 | | | 0.2440*** |
| | | | (0.0286) |
| constant | -1.3395* | -2.6700*** | -3.3548*** |
| | (0.7870) | (0.5779) | (0.5944) |
| N | 238 | 238 | 238 |
| adj. R-sq | 0.518 | 0.124 | |

Notes. Standard errors in parentheses *p<0.1, **p<0.05, ***p<0.01

But OLS estimates are biased and inconsistent. Rainfall wet, humidity dry, and humidity wet also have a positive and significant impact on the fixed effect and random effect models. All region dummies are highly significant with pulse yield. All three models that individual specific effects are uncorrelated with explanatory variables. It is concluded that temperature maximum wet, rainfall wet, humidity dry and wet are the greatest interest variables for pulse because they have positive impact on pulse productivity in Bangladesh.

To decide between fixed or random effect for pulse I estimated the Hausman test where the null hypothesis is that the preferred model is random effect, the alternative the fixed effect.

*Hausman Test*

```
  chi2(9) = (b-B)'[(V_b-V_B)^(-1)](b-B)
          =        12.77
Prob>chi2 =       0.1733
(V_b-V_B is not positive definite)
```

From the Hausman test, the random effect is better than the fixed effect because Prob>chi2 = 0.1733. This means that the null hypothesis is not rejected so that random effect model is accepted.

Table 14. Compare AIC and BIC between pooled OLS and fixed effect model for pulse:

| Model | Obs | AIC | BIC |
|---|---|---|---|
| Fixed | 238 | -536.20 | -498.00 |
| Pooled OLS | 238 | -186.10 | -144.43 |

It is obvious that the fixed effect model is better than the pooled OLS regression model because the fixed effect model AIC and BIC are smaller than the pooled OLS AIC and BIC. Therefore, the fixed effect model is accepted in this regard.

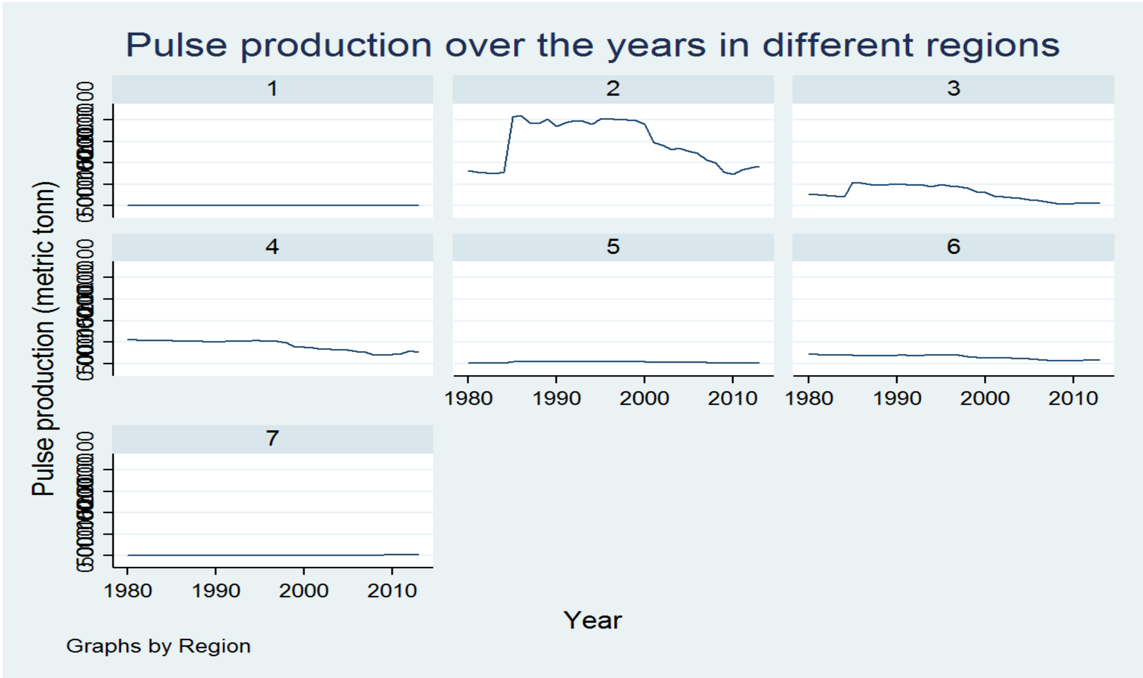


Figure 8. Pulse production in the different regions from 1980 to 2013

Regions code: 1= Barisal, 2= Chittagong, 3= Dhaka, 4= Rajshahi, 5= Khulna, 6= Sylhet, 7= Rangpur.

From the above figure, it is apparent that the Chittagong region produced the highest pulse crop production in Bangladesh. The Rangpur and Barisal regions are the lowest parts of pulse production.

# CHAPTER V

## FURTHER RESEARCH

In my study, I did not include major crop price behavior due to data shortage. Further study may include a forecast of the yearly commodity prices using a real price. Real prices adjust to the changes in new technology, changes in consumer tastes and preferences, changes in government policies, world events, and so on. It may help farmers and producers to make a decision on continuing to grow the crop and also help them in increasing productivity of the crop. Another suggestion for future research, forecasting rice, wheat, and pulse prices, understanding the relationship between the exchange rate and commodity prices and to analyze the effect of time, seasonality, exchange rate on the crop prices.

# CHAPTER VI

## SUMMARY OF THE STUDY

The main goal of the study was to examine the seasonality effect on major crop productivity due to climatic variable change. Actually, there was no robust estimate of the seasonality effect due to climate change. Although there were some studies estimating the effect, they never consider regional variations. In this study, I have created a dataset for seven divisions for the period of 1980-2013. I controlled heterogeneity among the regions through the fixed effect and random effect models. Using regional fixed effects, I estimated the impact of the changes in climatic variables on the productivity of rice, wheat, and pulse. I found that when regional variations are considered, it significantly changes the sign of the estimates. The impact differs significantly with the choice of climate variables. For example, the most influential climate variables for rice production were observed to be maximum temperature and minimum temperature wet in this study. This finding ensured that temperature maximum and minimum in both season augmented beyond their optimum requirement may be jeopardized to the rice yield. For wheat production, minimum temperature dry and rainfall are found as influential variables to increase the wheat production. Rainfall is very important for wheat production because it is a rain fed crop. The other explanatory variables are statistically insignificant. This does not mean that they are not important for wheat crop. The fact is that their optimal use was not confirmed for wheat production. Optimum use of variables is very important to get significant results.

For pulse production, I found maximum temperature dry, rainfall wet, and humidity in both seasons are statistically significant. These are the interest variables for pulse production. Overall findings from this study proved whether climate variables during the last 34 years have affected major crops yield in Bangladesh. This impact was both positive and negative. The negative effect is that higher temperature in dry and wet season, declining soil moisture or humidity, increasing drought in dry season, more variability in monsoon rain, and more salinity in soil are likely scenarios for Bangladesh in the last couple of decades. The Intergovernmental Panel on Climate Change (IPCC) climate model projects that South Asia will experience an increase of 0.5 degree Celsius along with a 4 % rainfall increase from 2010 to 2039 during kharif or wet season months. By 2100, some scenarios predict a 2-degree temperature increase and 7 % rainfall increase. Depending on regional variations, technology advances, and farmer adjustments, these changes could have significant positive or negative impacts on Bangladesh agricultural productivity. My study gives the message for scientists and policy makers about the robust estimates of the seasonality effect on agricultural productivity due to climate variability under different conditions.

APPENDICES

Appendix A

Consent Form

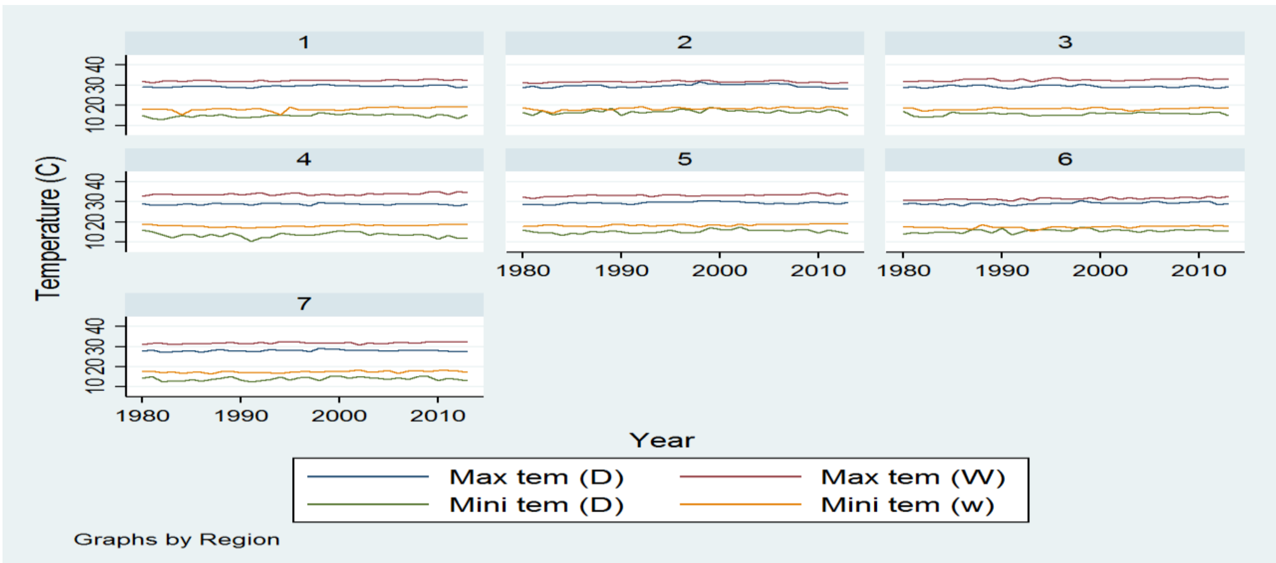


Figure 9. Temperature pattern in the different regions in Bangladesh

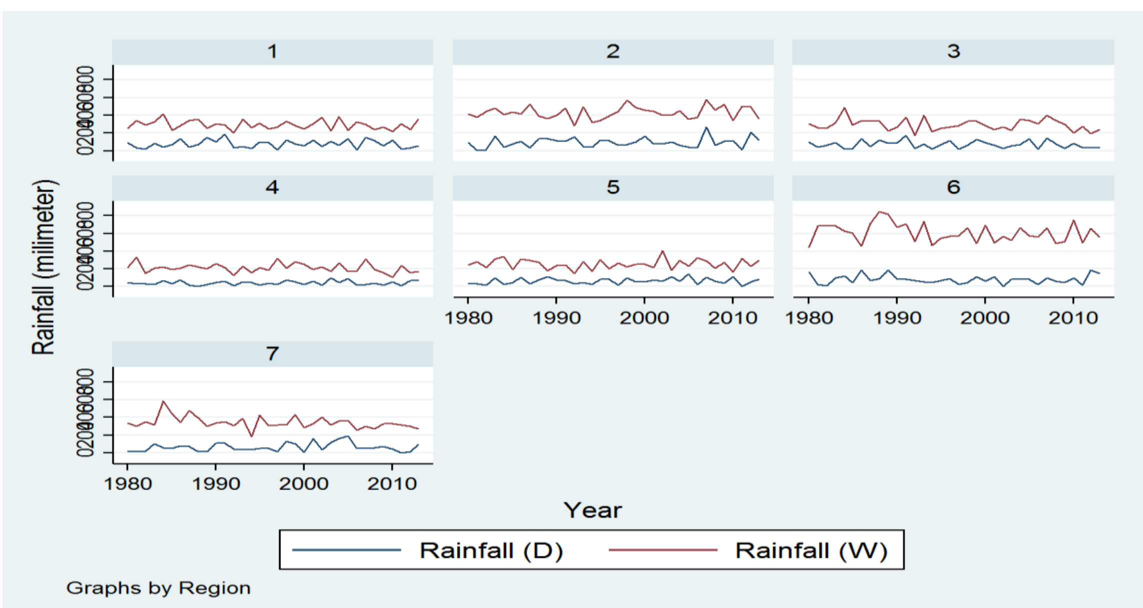


Figure 10. Rainfall pattern in the different regions in Bangladesh

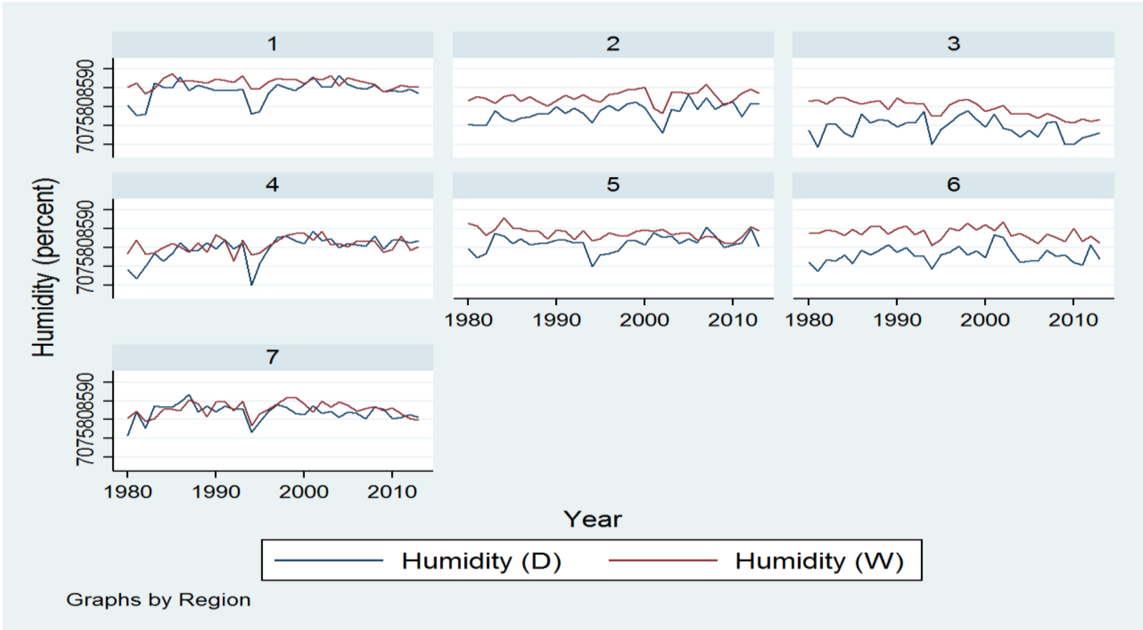


Figure 11. Humidity pattern in the different regions in Bangladesh

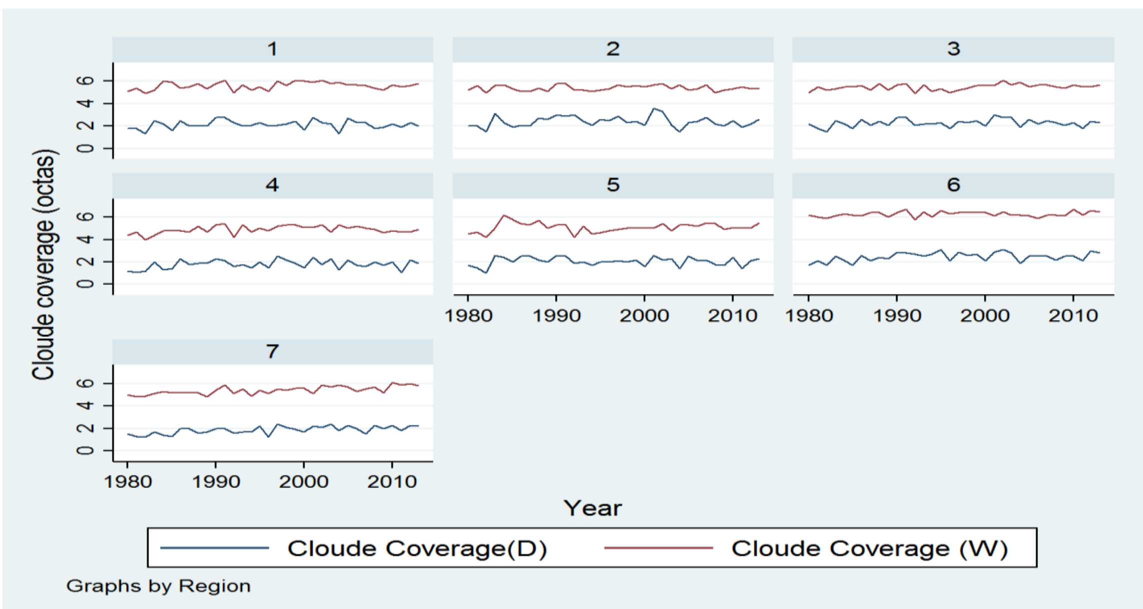


Figure 12. Cloud coverage pattern in the different regions in Bangladesh

# REFERENCES


Agrawala, S.T.O., Ahmed, A.U., Smith, J., Aalst, M.V. (2003). Development and Climate Change in Bangladesh: Focus on Coastal Flooding and the Sundarbans; *Organization for Economic Co-operation and Development (OECD*): Paris, France.

Ahmed, A.U. (2006). Bangladesh Climate Change Impacts and Vulnerability. Climate Change Cell, Department of Environment, CDMP, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh.

Awal, M.A., & Siddique, M.A.B. (2011). Rice Production in Bangladesh Employing by ARIMA Model. *Bangladesh Journal of Agricultural Research*, 36, 51–62.

Bangladesh Bureau of Statistics. (2000). Yearbook of Agricultural Statistics. Ministry of Planning, Dhaka, Bangladesh.

Bangladesh Bureau of Statistics. (2008). Yearbook of Agricultural Statistics. Ministry of Planning, Dhaka, Bangladesh.

Bangladesh Bureau of Statistics. (2007). Yearbook of Agricultural Statistics. Ministry of Planning, Dhaka, Bangladesh.

Bangladesh Bureau of Statistics. (2010). Yearbook of Agricultural Statistics. Ministry of Planning; Dhaka, Bangladesh.

Bangladesh Bureau of Statistics. (2011). Yearbook of Agricultural Statistics. Ministry of Planning; Dhaka, Bangladesh.

Bangladesh Economic Review. (2014). Government of the People's Republic of Bangladesh, Dhaka, Bangladesh.

CIMMYT and ICARDA. (2011). Wheat global alliance for improving food security and the livelihoods of the resources-poor in the developing world. Proposal submitted by CIMMYT and ICARDA to the CGIAR consortium board.

Esterling WE, Aggarwal PK, Batima P, Brander KM, Erda L,Howden SM, Kirilenko A, Soussana JF, Schmidhweer J, Tubiello FN. (2007). Climate change, impacts, adaptation and vulnerability. Contribution of working group-11 to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: *Cambridge University Press*, 273–313.

Hossain A, Sarker MAZ, Saifuzzaman M, Akhter MM, Mandal MSN. (2009). Effect of sowing dates on yield of wheat varieties. *Bangladesh Journal of Progressive Science and Technology*, 7, 5–8.

Hossain A, Sarker MAZ, Hakim MA, Lozovskaya MV, Zvolinsky VP. (2011). Effect of temperature on yield and some agronomic characters of spring wheat (Triticum aestivum L.) genotypes. *International Journal of Agricultural Research Innovation and Technology* 1, 44–54.

Hakim MA, Hossain A, Teixeira da Silva JA, Zvolinsky VP, Khan MM. (2012). Yield, protein and starch content of 20 wheat (Triticumaestivum L.) genotypes exposed to high temperature under late sowing conditions. *Journal of Scientific Research*, 4,477–489.

Hossain, M.K., T.A. Masron, A.A. Kamil, A. Mustafa and M.A. Baten. (2012). Influence of environmental constraints on rice productive technical efficiency in Bangladesh. Proceedings of the International Conference on Management, Economics and Finance, Hilton Hotel, Kuching, Sarawak, Malaysia.

Hossain A, Lozovskaya MV, Zvolinsky VP, Teixeira da Silva JA. (2012a). Effect of soil and climatic conditions on yield-related components performance of spring wheat (Triticum aestivum L.) varieties in the northern Bangladesh. Natural Sciences. *Journal of Fundamental and Applied Researches*, 2, 77–86.

Hossain A, Lozovskaya MV, Zvolinsky VP, Teixeira da Silva JA. (2012b). Effect of soil and climatic conditions on phenology of spring wheat varieties in the northern Bangladesh. Natural Sciences. *Journal of Fundamental and Applied Researches*, 2, 86–97.

Hossain A, Teixeira da Silva JA, Lozovskaya MV, Zvolinsky VP,Mukhortov VI. (2012e). High temperature combined with drought affect rainfed spring wheat and barley in south-eastern Russia: yield, relative performance and heat susceptibility index. *Journal of Plant Breeding and Crop Science*, 4, 184–196.

https://www.census.gov/population/international/files/ppt/Bangladesh93.pdf

http://faostat.fao.org

Intergovernmental Panel on Climate Change (IPCC). (2001). Climate Change. *Third Assessment Report.*

Intergovernmental Panel on Climate Change (IPCC). (2007). Climate change, impacts, adaptation and vulnerability. In Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. *Cambridge University Press*: Cambridge, UK.

Labour Force Survey. (2010). Statistical Year Book of Bangladesh.

Lobell, D.B., Cahill, K.N., Field, C.B. (2007). Historical Effects of Temperature and Precipitation on California Crop Yields. *Climate Change*, 81, 187–203.

Lobell, D.B., W. Schlenker, and J. Costa-Roberts. (2011). Climate trends and global crop production. *Science*, 333, 616-642.

Lobell DB, Burke MB, Tebaldi C, Mastrandrea MD, Falcon WP, Naylor RL. (2008). Supporting online materials for: Prioritizing climate change adaptation needs for food security in 2030. Science, 319, 607–610.

Rimi, R.H.; Rahman, S.H.; Karmakar, S.; Hussain, S.G. (2009). Trend Analysis of Climate Change and Investigation on its Probable Impacts on Rice Production at Sathkhira, Bangladesh, *Pakistan Journal of Meteorology*, 6, 37–50.

Sarker, M.A.R. (2012). Impacts of Climate Change on Rice Production and Farmers' Adaptation in Bangladesh. Ph.D. Thesis, University of Southern Queensland, Toowoomba, Australia.

United Nations Development Program (UNDP). (2008). Fighting Climate Change: Human Solidarity in a Divided World. Human Development Report. *Oxford University Press.*

WWW.ricepedia.org.