CLIMATE CHANGE AND WATER STRESS IN NORTHWEST BANGLADESH: A STUDY ON FARMERS' PERCEPTION AND ADAPTATION MECHANISMS

A Thesis
By

TAHMINA AKHTER

Examination Roll No.:16AEP JD-29M
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MASTER OF SCIENCE (MS)
IN
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DEPARTMENT OF AGRICULTURAL ECONOMICS
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Approved as to style and content by

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(Professor Dr. Hasneen Jahan)	**(Dr. A. H. M. Saiful Islam)**
Supervisor	**Co-Supervisor**

(Professor Dr. Ismat Ara Begum)
Chairman
Examination Committee
&
Head

DEPARTMENT OF AGRICULTURAL ECONOMICS
BANGLADESH AGRICULTURAL UNIVERSITY
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DEDICATED TO MY PARENTS AND HUSBAND

ABSTRACT

The agriculture of Bangladesh is always vulnerable to unfavourable weather events such as, increasing temperature, water stress and rainfall variability. The patterns of variability and effects are varied across regions and gender. In these circumstances, the study examines the farmers' perception and adaptation mechanisms to climate change and water stress in Northwest Bangladesh. The empirical results from secondary sources showed that there is greater seasonal variability of climatic parameters and it is vividly evident that the climatic parameters (i.e. maximum temperature, minimum temperature, and rainfall) changes over the period of time. Out of 360 male and 360 female responses (i.e., husband and spouse) majority of the male and female revealed the perception of increasing temperature. Furthermore, both sexes mentioned that, the patterns of rainfall exhibits huge changes. Approximately, 70% male and 65% female argued that the drought occurs every year. Such an annual occurrence indicates that drought is the main barriers for agriculture in the Northwest Bangladesh. Furthermore, the study identified four major adaptation strategies with no adaptation at all as the base category. The short duration and drought tolerant rice varieties are the main adaptation practices which occupy 29 percent of the respondents. The determinants of adaptation decisions reveal that age of the female, extension frequency, drought severity and credit facilities are the influential factors for farm households' decision to adapt to climate change and water stress. On the other hand, age of the male household head and household size are the negative factors for farmers' adaptation decision. Finally, the present study identifies the constraints for ensuring proper adaptation measures which will help to accelerate agricultural production in the Northwest Bangladesh. Policy recommendations include easier access to relevant climate related information, wider access to female education, and ensuring institutional supports for the farmers'. In addition, at the time of designing and implementing climate change adaptation strategies it will be rational to consider the gender specific differences. Finally, region specific government policy on adaptation has to be ensured as it is termed as the second adaptation barriers in the study areas.

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The Author

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ABBREVIATIONS

^{0}C	Degree Celsius
BBS	Bangladesh Bureau of Statistics
BMD	Bangladesh Meteorological Department
DD	Deputy Director
e.g.,	Exempli gratia 'for the sake of example'.
et al.,	et alia (L.) 'and others'
FAO	Food and Agriculture Organization
GOB	Government of Bangladesh
i.e.,	id est. (L.). 'that is' (to say)
IPCC	Intergovernmental Panel on Climate Change
mm	Millimeter
OLS	Ordinary Least Squares
PCI	Problem Confrontation Index
SAAO	Sub Assistant Agriculture Officer
UNDP	United National Development Programme
WB	World Bank

CHAPTER 1
INTRODUCTION

1.1 Introduction

Bangladesh is one of the most sensitive hotspots for climate change and climate-related extreme events throughout the world (World Bank, 2013). Increasing temperature, water stress and rainfall variability along with severe and frequent floods and cyclones adversely affect agricultural production and place Bangladesh's food security at risk (GoB, 2011). *Boro* (irrigated) rice would endure the most of any adverse effect of climate change, and limit its ability to recover from *Aus* and *Aman* (rain-fed) rice crop losses due to extreme climate events (Yu *et al.,* 2010). Frequent regional droughts in northwestern Bangladesh cause greater yield losses relative to flooding and submergence (World Bank, 2013). On average, droughts affect about 47% of the total area of Bangladesh and 53% of the population (WARPO, 2005). Around 19 drought events took place in the last 50 years. Among them the droughts of 1973, 1978, 1979, 1981, 1982, 1992, 1994, 1995, 2000 and 2006 are worth mentioning. It is a regular phenomenon in many parts of the country, but the Northwest region is mostly a drought-prone and groundwater depleted area because of high variability of rainfall (Shahid and Behrawan, 2008). Together with much lower rainfall compared to the rest of the country (Paul, 1998), hence this area is relatively dry. In addition, the average annual rainfall in this part is 1329 mm whereas in the Northeast part it is 4338 mm (West *et al.,* 2007).

Moreover, over falling groundwater levels (Kirby *et al.,* 2014) which lead to a lack of access to water for drinking (Haq, 2014) and irrigation are greatest concern for the Northwest region of Bangladesh. However, it is not clear whether the declining groundwater levels in that region result from an observed decline in rainfall, or from excessive use, or from some combination of these and possibly other factors. In the northwest Bangladesh, water stress driven environmental shock such as drought has been identified as the major constraint for farmers and act as a blockage for agriculture. The degree to which an agricultural system is affected by climate change related events depends on its adaptive capacity. Indeed, adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damage, to take the advantage of opportunities, or to adjust with the consequences (IPCC, 2001). Given the significance of changes in water for agriculture, farmers have developed adaptation and coping strategies as a general survival strategy.

While perception and adaptations to climate change and water stress is important for long term policy responses and to address the current challenges of farmers to continue their farming practices. It is often observed that farmers respond to the climatic parameters such as, rainfall or temperature slowly as they do not face immediate challenge to their farm practices. In contrast, farmers consider water stress as their immediate agricultural risk and response rapidly to this risk through specific adaption strategies, i.e. water harvesting techniques, changes in crop planting dates, changes in agriculture practices, and changes in crops grown (Gandure *et al.,* 2012). Therefore, it is necessary to study the farmers' perception and adaptation strategies to climate change and water stress which will facilitate effective government policies in Northwest Bangladesh. The adaptation mechanisms for climate change and water stress will be identified precisely to understand farmers' behaviour and attitudes towards these distinct but closely related environmental consequences.

Furthermore, the gender gap provides reasonable grounds for the expectation that women (i.e. spouses) and men (i.e., husbands) will generally be affected differently by the effects of climate change and water stress and will therefore respond to and benefit differently from climate protection and adaptation measures (Masika, 2002; Mitchell *et al.,* 2007; World Bank, 2011; Ashby *et al.,* 2012). A significant body of literature on gender and climate change shows that women and men perceive and experience climate change differently, and usually women are more vulnerable due to their dependence on natural resources and structural inequity in their access and control of such resources (Ravera *et al.,* 2016). Some studies in the Asian context found that social class, household head, gender, age and stage of life may determine women's ability to respond to water scarcity (Huynh and Resurreccio'n, 2014). Similar interactions have been identified in Africa, where the joint effects of gender, access to education, land and credit are analysed as local determinants of the capacity to adapt to decreasing precipitation (Below *et al.,* 2012; Fosu-Mensah *et al.,* 2012). It is therefore, necessary to investigate how the role of gender and its interaction with cultural, social and economic factors work in determining the adaptive responses to climate change and water stress.

Based on the case of farmers in the northwest Bangladesh, this research will intend to link the macro-level evidence of a rise in temperature, rainfall and water stress through capturing the extent of farmers' awareness and perceptions of climate change, water stress and the types of adjustments they make in their farming practices in response to these changes as well as point out the barriers of adaptation for sustainable agricultural development. All these aspects will be examined from a gender sensitive view point to present an inclusive scenario of the farmers' attitude and behavior towards the environmental constraints they are facing in their farming.

1.2 Justification of the Study

Many agricultural adaptation options have been suggested in the literature. They encompass a wide range of scales (local, regional, global), actors (farmers, firms, government), etc. Most of these represent possible or potential adaptation measures rather than ones actually adopted. In Bangladesh several studies investigated farmers' adaptation measures but they are unable to answer which types of farmers adapt more and the variation of adaptation according to districts. Likewise, the existing studies also ignore the gender sensitivity as both the male and female are affected differently by changing climate and water stress and adjusted in a different ways. Therefore, the proposed research, as part of a more recent strand of adaptation research, would seek to capture the extent of farmers' awareness and perceptions of climate change water stress, identify the types of adjustments they make in their farming practices in response to these changes, as well as point out the barriers of adaptation for sustainable agricultural development in the northwest Bangladesh.

Furthermore, this study is very much relevant to the government's Sustainable Development Goals (SDGs). The district level knowledge will facilitate the local government to take appropriate actions for the specific district. The regional level knowledge will help government to formulate regional planning to mitigate the climate change groundwater problems. The research will significantly help the government of Bangladesh to take necessary steps to overcome the challenges of climate change and water stress for sustainable agriculture and to improve the status of farmers in the northwest region of Bangladesh. At the same fashion, the study will provide a direction of the appropriate adaptation mechanisms that farmers can follow, which will ensure the sustainable management of water resources. Policy makers, the Department of Agricultural Extension, the Department of Environment, local government authorities, NGOs, donor agencies and ultimately the farmers will be benefited from the knowledge gathered through the study. This research will also add new knowledge to the related research arena and the researchers will be benefited from these knowledge. Overall, the acquired knowledge can be utilized for the development of the farmers including women farmers who are deprived in many ways due to climate change and its related water scarcity problems in Bangladesh.

1.3 Research Questions

Some research questions are developed based on the objectives of the study. The questions will be answered through this research. The questions will be helpful in narrowing down and clarifying the research objectives. The first research question is related to objective one, second and third sum up objective two and finally the fourth research question deals with objective three.

Research Question No. 1: Do the farmers′ perception of climate change support the macro level evidence of a rise in temperature, water stress and a greater variability in rainfall?

Research Question No. 2: What is the magnitude of adaptation to climate change and water stress?

Research Question No. 3: What are the factors influencing the farmers′ decisions to adapt to climate change and water stress? and

Research Question No. 4: What are the barriers of adaptation to climate change and water stress?

1.4 Objectives of the Study

The overall goal of the proposed study is to capture farmers′ awareness and perception of climate change and water stress, the types and extend of adjustments they will make in their farming practices in response to these changes as well as the factors underpinning farmers′ decisions to adopt specific adaptation.

The specific objectives are:

(i) To examine the farmers′ perception of climate change and water stress;

(ii) To investigate the determinants of farmers′ choice of adaptation to climate change and water stress; and

(iii) To identify the perceived constraints of adaptation to climate change and water stress.

1.5 Outline of the Thesis

The thesis is organized as follows: Chapter 1 includes introduction, justification of the study, research questions, and objectives of the study. Review of literature at global level and national level are presented in Chapter 2. Chapter 3 gives a clear idea about selection of the study areas, selection of samples and sample size, sources and the coverage of data and analytical techniques for the study. Research question one will be answered in chapter 4, research question two and three will be answered in chapter 5. Chapter 6 deals with research question four and finally summary, conclusions and policy recommendations are given in chapter 7.

In a nut shell these can be viewed as:

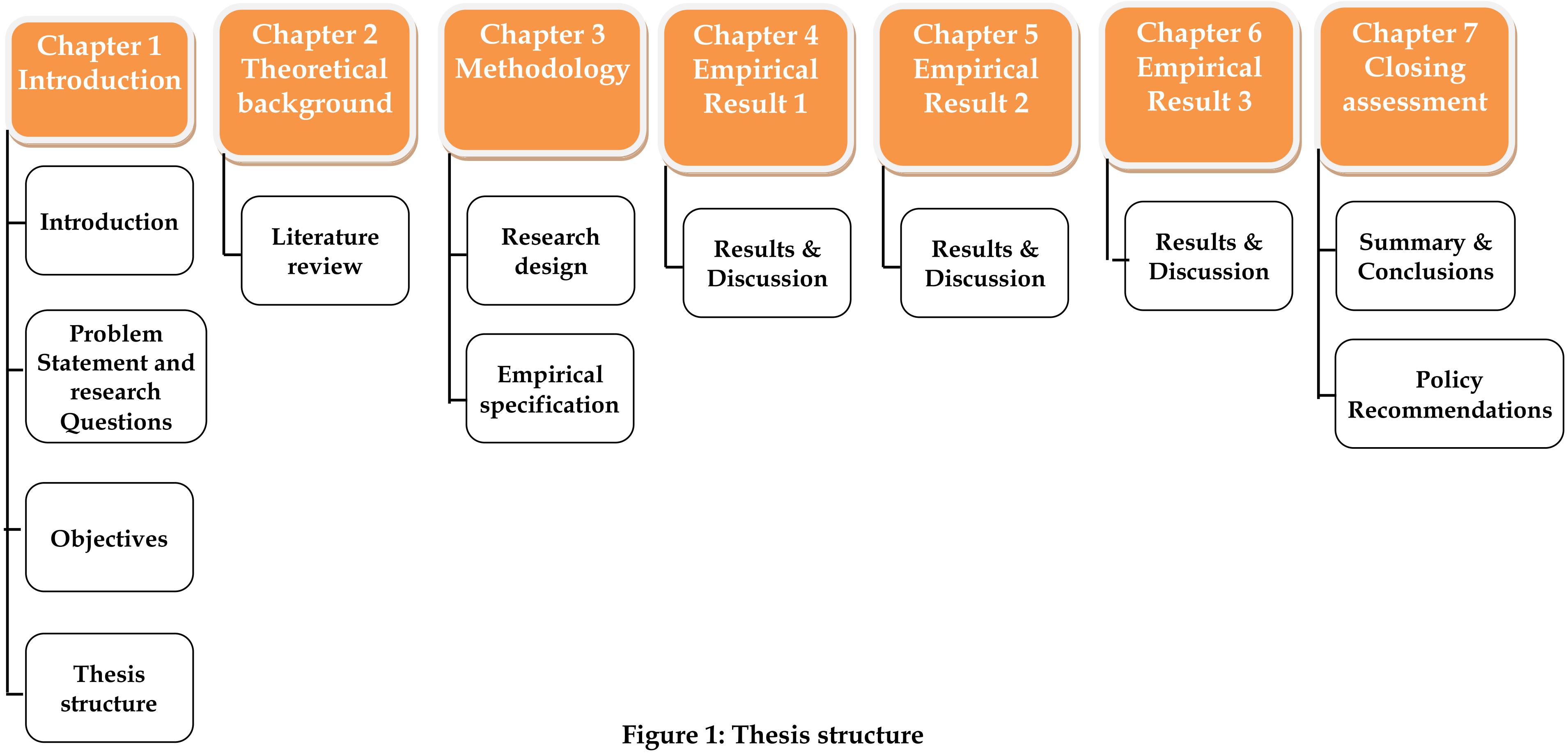


Figure 1: Thesis structure

CHAPTER 2
REVIEW OF LITERATURE

2.1 Introduction

A literature review is a text of a scholarly paper, which includes the current knowledge including substantive findings, as well as theoretical and methodological contributions to a particular topic. The purpose is to convey to the reader what knowledge and idea has been established on a topic and what is their strength and weakness (Taylor and Procter, 2005). This section of study is dealing with brief review of literature regarding farmers' perception of climatic change and water stress and adaptation mechanisms at national and global level.

2.2 Farmers' Perception to Climate Change and Water Stress

2.2.1 Farmers' perception at global level

Understanding farmer's perception of climate changes and modes of adjustments made in farming practices will offer some insights into necessary interventions to ensure a successful adaptation practice. Numerous literatures examined the differences between farmers' perception of their exposure to climate variability and change. Gandure *et al.* (2013) showed that all groups regardless of age and gender agreed that Gladstone is experiencing long-term changes in climate. The study also revealed the rainfall variability in terms of annual and seasonal variations with rainfall likely to be irregular from one year or season to the next. A number of studies in South Africa (Reid and Vogel, 2006; Quinn *et al.,* 2011) have found that the rural communities live with numerous livelihood risks including climate risks. Similarly in Gladstone, the livelihood vulnerability encompasses economic, environmental, social, political and policy dimensions. Tambo and Abdoulaye (2013) showed that a large share of the farmers' interviewed (92 %) perceived long-term changes in temperature and 39% believed that God is responsible for the changing climate. Kelkar *et al.* (2008) pointed out that, almost all the households felt that rainfall has declined in quantity and they could no longer rely on the timely onset of the monsoon. The study by Howe and

Leiserowitz (2013) in U.S showed that, beliefs of global warming had significant effects on subjective experiences with normal temperatures, particularly among those people who believed that global warming is not happening.

Various studies mainly focus on the farmer's perception regarding water stress (i.e. drought) and take initiative to mitigate this hazardous climatic event. For instance, Udmale *et al.* (2014) investigated the farmers' perception of drought impacts, local adaptation and administrative mitigation measures in India and found that about 92.8% farmers' perceived drought as a natural phenomenon, while 7.2% perceived it as a mismanagement of water resources. It was found that about 85.6% of farmers have experienced drought in the past years. Moreover, only 33.2% farmers believed that they were able to deal with drought, while majority indicating they were unable to mitigate drought impacts. Nguyen *et al.* (2016) mentioned that in Italy farmers perceived that temperature had increased over time and rainfall there had decreased in the last few decades. Likewise, the majority of the farmers agreed that groundwater had decreased over time. Desalegn *et al.* (2006) showed that on average drought prevails in Ethiopia once every two years and causes damage to both crops and livestock. Consequently, under such drought conditions, the farmers have adopted various coping strategies such as, the sale of labour and sale of livestock and their products.

2.2.2 Farmers' perception in Bangladesh

Even though detailed studies related to farmers' perception in Bangladesh are exiguous, some studies partially deal with this burning issue. Alauddin and Sarker (2014) conducted a study in ground water depleted areas of Bangladesh and mentioned that majority (95.9%) of the farmers belief are in favour of the increased severity and frequency of droughts. Most farm households (92.0% and 93.3%) respectively perceived a decline in the availability of both groundwater and surface water during the summer season. In addition, farmers believed that temperatures have increased with a decrease in rainfall over the past two decades. These perceptions align with the existing evidence (see e.g., GoB and UNDP, 2009;

Nishat and Mukherjee, 2013). Habiba and Shaw (2014) identified that approximately 90%of the farmers in Rajshahi and Chapai Nawabganj figured out that drought occurred frequently as a consequence of climate change and it is the most prevalent disaster in this area, mainly comes in pre-*kharif* season. Davis and Ali (2014) investigated the local perceptions of climate change impacts and adaptation in rural Bangladesh. The findings showed that most of the respondents had a clear understanding of what was directly affecting their lives and livelihoods in terms of climate trends and the wider environment over the long term. Men and women widely expressed concerns about drought, lack of rainfall, and lowered groundwater levels. Furthermore, men tended to talk much more about problems with arable agriculture whereas women were much more concerned with problems with accessing drinking and washing water, family health problems, food security, livestock health, and lack of social power. The findings of Habiba *et al.* (2012) revealed that farmer's perceived a changed climate in recent years. They not only identified that drought is the most prevalent disaster because of rainfall and temperature variation, but also groundwater depletion, lack of canal and river dragging, increased population, deforestation, etc. accelerate drought in Northwestern Bangladesh.

Table 2.1: Summary of some relevant studies on farmers' perception

Authors & Years	Methodology used	Time period	Country	Conclusions
Kabir *et al.* (2017)	Descriptive statistics, Costs and returns, Stochastic dominance analysis	Secondary data (1948-2013) and Primary data on 2014	Chuadanga and Rajshahi (Durgapur) district in Bangladesh	Farmers perceived climate changes included increases in temperature and decreases in rainfall which were as consistent with the trends of Chuadanga climate records.
Nguyen *et al.* (2016)	Crop model simulation, Decision Support System for Agro technology Transfer (DSSAT), and Discrete Stochastic Programming (DSP)	2012-2013	Oristano, Italy	Most of the farmers perceived that climate change is occurring and there has been an increased temperature trend, but also increased precipitation. Farmers' perceptions and experiences were based on their beliefs, knowledge, and experiences of climate change

Authors & Years	Methodology used	Time period	Country	Conclusions
Alauddin and Sarker (2014)	Surveying 1800 farm households, Logit model- Binary model and MNL model	2011-2012	8 districts of Bangladesh	Farmer's perception of climatic variability supported macro-level evidence. About 98.0% and 97.9% of the farmers perceived an increase in temperatures, while 95.2%and 94.9% respectively perceived a decrease in annual and summer rainfall.
Udmale *et al.* (2014)	Surveying 223 farm households, descriptive and inferential statistics, non-parametric test, Kruskal-Wallis H-test, and Mann-Whitney U-test have been used.	May 2013	Maharashtra State, India	The most immediate economic impacts of drought are decreased in yield of cereals, horticultural crops, livestock production and loss of employment. Social impacts incorporates population migration, impacts on health and schooling of children, hopelessness and sense of loss, conflicts in society for water, and malnutrition due to changed food preferences were also reported. Finally, the environmental impacts are increases in average atmospheric temperature, pasture-forest degradation, deteriorated water quality, damage to fish habitat-wild.

Authors & Years	Methodology used	Time period	Country	Conclusions
Gandure *et al.* (2013)	13 FGDS, a set of descriptive statistics were used.	2009	Central South Africa	Farmers' perception of climate risk is influenced by the socio-economic and political factors. The combined effects of rainfall and temperature on livelihoods are perceived to be much greater. And farmers expressed greater concern about the impact of weeds, insects and worms which is the ultimate consequences of climate change.
Tambo and Abdoulaye (2013)	FGDs, Descriptive statistics, Content analysis and Mann-Whitney U test	2010	Savannas of Borno state of Nigeria	Most of the farmers have noticed changes in climate and drought is a major problem faced by farmers. The Sudan savanna suffered from severe droughts in the 1970 and 1980s which resulted in severe famine and loss of human and animal life.

Source: See in the column one.

2.3 Farmers' Adaptations to Climate Change and Water Stress

2.3.1 Farmers' adaptations at global level

Adaptation of agriculture to climate is known as a very important policy to reduce the vulnerability and the negative impacts; as a result, there is increasing attention on the pressing need for adaptation throughout the world agriculture. According to IPCC, adaptation refers to 'adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities' (IPCC, 2007). Most farmers perceive climate change and take adaptation measures against it. For example, Below *et al.* (2010) placed about 104 different adaptation strategies followed by farmers which are broadly categorised into: farm management and technology; farm financial management; diversification of farm and off-farm activities; government interventions in infrastructure, health and risk reduction; and knowledge management, networks and governance.

While major adaptation measures like new crops or crop varieties and livelihood diversification are adopted by farmers throughout the continent, others are peculiar to certain regions, and the choice of the adaptation options is influenced by different contextual factors (Bryan *et al.,* 2009; Deressa *et al.,* 2009; Gbetibouo *et al.,* 2010; Hisali *et al*., 2011; Below *et al.,* 2012; Fosu-Mensah *et al.,* 2012). Most of the research on farmers' adaptation to climate change in Africa has concentrated on the Sahel region of West Africa, partly due to the severe droughts and famines in this region in the 1970 and 1980s (West *et al.,* 2008) and on the rainforest ecological zones. Desalegn *et al.* (2006) showed that average drought prevails in the Upper Awash River Basin, Ethiopia, once every two years and causes damage to both crops and livestock. Consequently, under such drought conditions, the farming communities have adopted various coping strategies, such as the sale of labour and sale of livestock and their products. The survey results also revealed that farmers in the rain fed agriculture areas practice mainly contour bunding to mitigate drought impacts.

2.3.2 Farmers' adaptations in Bangladesh

Drought-prone areas of Bangladesh have adopted a holistic approach to livelihood adaptation practices on rural communities without a specific focus on rice farming, and have relied on qualitative analysis examined by most studies (Ahmed and Chowdhury, 2006; FAO, 2006; Habiba *et al.*, 2013). FAO (2006) pursued some major adaptation strategies accomplished by farmers, including the enhancement of mango plantations, excavation of ponds and deep tube-well facilitated irrigation, the plantation of short-duration and drought tolerant crop varieties, and homestead gardening. Habiba *et al.* (2013) examined qualitative data from field visits in 12 upazillas of two drought-prone districts (Rajshahi and Chapai Nawabganj) and their results recommended the composition of livelihood adaptations in long-term planning, successive growth in research and development activity on new crops, improved access to credit, the improvement of information networks, and the advancement of an enabling institutional environment.

Sarker *et al.* (2013) used data involving 550 rice farm households from two upazillas in the Rajshahi district (Tanore and Godagari) to analyze farm-level adaptation using a multinomial logit model. The study recognized factors that determined choice of adaptation strategies. Although, Ahmed and Chowdhury (2006), FAO (2006) and Habiba *et al.* (2013) identified useful indicators, these studies suffer from two limitations. First, they each traced general livelihood issues rather than a specific examination of rice farming, which is a major omission as rice is the mainstay of Bangladesh's food sector. Second, with the contribution of rice to the rural economy and its sensitivity to climate change notwithstanding, neither study provided apt quantitative analysis of farm-level adaptation to climate change, farmer's likely adaptation strategies to minimize the effect of climate change to rice farming, or of the implications of these adaptations.

Table 2.2: Summary of some relevant studies on farmers' adaptation

Authors & Years	Methodology used	Time period	Country	Conclusions
Ali and Erenstein (2017)	Interviewing 950 farmers, Probit model, The Censored Least Absolute Deviation (CLAD), Propensity Score Matching (PSM)	2014	Four main provinces (i.e. Punjab, Khyber Pakhtunkhwa, Sindh and Balochistan) of Pakistan	Younger farmers and farmers with higher levels of education are more likely to use the adaptation practices. Farmers adopting more adaptation practices had higher food security levels than those who did not, and experienced lower levels of poverty.
Davis and Ali (2014)	Conducting 30 FGDs and KIIs and NVivo – qualitative data analysis program developed by QSR International	2012	12 districts (e.g. Barguna, Chittagong, Dinajpur, Habiganj, Jessore, Khulna, Laxmipur, Mymensingh, Naogaon, Narsingdi, Netrokona and Rangpur) of Bangladesh	Respondents had a clear understanding about climate change and adaptation allowed farmers' to cope with declining groundwater levels for agriculture and domestic use as well as adaptation and coping varied according to location, livelihood, and the assets and endowments people have at their disposal.

Authors & Years	Methodology used	Time period	Country	Conclusions
Alauddin and Sarker (2014)	Surveying 1800 farm households, Logit model- Binary model and MNL model	2011-2012	8 districts (Chapai Nawabganj, Nagaon, Rajshahi, Natore, Pabna, Chuadanga, Bogra and Gazipur) of Bangladesh	Farmers' perceptions of climatic variability supported macro-level evidence. Science-driven (e.g., drought tolerant rice), environmental resource-depleting (e.g., groundwater), and crop-switching (e.g., non-rice crops) typified preferred farm-level adaptation strategies to alleviate adverse effects of climate change.
Tambo and Abdoulaye (2013)	Surveying 200 smallholder farm households, FGDs, Descriptive statistics, Content analysis and Mann-Whitney U test	2010	Savannas of Borno state of Nigeria	Most of the farmers have noticed changes in climate and have consequently adjusted their farming practices to adapt. There are no large differences in the adaptation practices across the region, but farmers in Sudan savanna agro-ecological zone are more likely to adapt to changes in temperature than those in northern Guinea savanna.

Authors & Years	Methodology used	Time period	Country	Conclusions
Gbetibouo (2010)	Surveying 794 households, Moran's I test, Kruskal-Wallis test, unrelated biprobit model, Heckman probit model and MNL model	2004-2005	Limpopo River Basin of South Africa	Majority of the respondents had a clear understanding about climate change but only half of them have adjusted their farming practices to account for the impacts of climate change.
Deressa *et al.* (2009)	Interviewed 1000 households, Discrete choice model- MNL model	2004-2005	Nile Basin of Ethiopia	The level of education, gender, age, and wealth of the head of household; access to extension and credit; information on climate, social capital, agro ecological settings, and temperature all influence farmers' choices. The main barriers include lack of information on adaptation methods and financial constraints.

Authors & Years	Methodology used	Time period	Country	Conclusions
Hasan and Nhemachena (2008)	Surveying 8000 farm households, Multinomial choice analysis- MNL model	2002	11 African countries.	Specialized crop cultivation (mono-cropping) is the agricultural practice most vulnerable to climate change, Warming, especially in summer, poses the highest risk. It encourages irrigation, multiple cropping and integration of livestock. Better access to markets, extension and credit services, technology and farm assets (labor, land and capital) are critical for helping African farmers adapt to climate change.

Source: See in the column one

2.4 Conclusions

The above mentioned reviews indicate that farmer's perception and adaptation mechanisms are burning issues in order to cope with the changing climatic situation especially in ground water depleted areas. Although, throughout the world a pile of researches have been carried out, in Bangladesh few studies focused on these issues. For that reason, the present study attempts to capture climate change and water stress problems in ground water depleted areas in Bangladesh for safeguarding agricultural productivity and identifying the proper adaptive measures.

CHAPTER 3
MATERIALS AND METHODS

3.1 Introduction

This chapter illustrates the research methods and methodology used in the study and offer explanations for the choice of it. The research methods or techniques refer to the methods that the researchers actually use in performing research operations. Moreover, research methodology is a way to systematically solve the research problem. This chapter gives a clear idea about selection of the study areas, selection of samples and sample size, sources and the coverage of data used for the study and also deals with the analytical techniques for the study. The present research is based on both the primary and secondary data. Secondary data have been collected from various secondary sources and primary data have been collected from the respondents directly through personal interviews.

3.2 Study Area and Data

To document the farmers' perception and adaptation mechanisms under the existing scenarios of climate change and water stress, three major drought-prone and groundwater-depleted areas of Bangladesh were selected. The study area Rajshahi, Bogra and Dinajpur are considered as High, Medium and low water scarcity area. The data set for the present study covers both primary and secondary data. Monthly data on maximum temperature, minimum temperature and rainfall were collected from the Bangladesh Meteorological Department (BMD) for 3 weather stations which cover the water stressed areas of Bangladesh for the period of 1982–2015. These monthly data were then converted as the average annual and average agricultural crop growing seasons, for instance, *Kharif* crops and *Rabi* crops (BBS, 2015). Hence, the climate variables are characterised by average maximum temperature, minimum temperature, and rainfall for the agricultural crop growing seasons. Furthermore, a pilot survey was conducted for the production year 2016-2017 for an on-field trial of the survey instrument. The final version of the questionnaire followed minor amendments based on the pilot survey. To validate the information of the survey, focus group discussions (FGD) were carried out in the study areas. The study used multistage random sampling techniques, initially, three upazillas were selected from three districts; after that one union was selected from each of the district as sampling point and 6 villages were chosen from the selected union (i.e. the study covers 3 districts, 3 upazillas, 3 unions and 18 villages). Some twenty farm households in each village were selected as sample. The dataset ended up with 360 male respondents and 360 female respondents' valid observations from three upazillas of three districts located in three drought-prone and groundwater-depleted areas of Bangladesh. The male and female (i.e., husband and spouse) respondents were taken from the same family. They were surveyed separately for the validity of the data.

3.3 Empirical Methodology

3.3.1 Empirical specification for climate change and water stress perception

Farmers' perception of climate change and water stress were analysed through derivation of a useful set of descriptive statistics. Before investigating that, the study primarily focuses on the trends of climate change in the concerned three ground water depleted areas. To build the quantitative justification for climate change, present study conducted trend analysis for three major climate variables with time (t) as an explanatory variable over the entire period. This can be accomplished by using either ordinary least squares (OLS) or quantile regression (QR) depending on the distribution of the dependent variable. The OLS approach is applied when the dependent variable (i.e., climate variable) is normally distributed, whereas QR is employed when the variable is not normally distributed. We checked the distribution of each climate variables against time by drawing histograms with normal density plot, Box plot, Quantiles plot, and Shapiro wilk test of normality before we selected the OLS or QR regression type. In addition, the original data set has been log transformed and again the distributional graphs and test were carried out before using QR regression. An inspection of these tests revealed that the annual average maximum and minimum temperature of Bogra district did not follow a normal distribution, but the climate variables of other regions appeared to have a normal distribution. Therefore, Ordinary Least Square regression (OLS) estimation was selected for the annual average maximum temperature, minimum temperature, and rainfall of Rajshahi and Dinajpur district, whereas quantile regression (QR) was selected for the annual average maximum and minimum temperature of Bogra district. Moreover, the OLS estimation was also selected for the annual average rainfall of Bogra district. These methods are best suited to estimate the central tendency of our data.

Nevertheless, the data set of our study encompasses more than 20 years of observations which require testing for stationarity (Chen *et al*., 2004). Therefore, this requirement necessitates further investigation of the data series to ensure that it is stationary before we estimate the regression. Accordingly, the study carried out an Augmented Dickey–Fuller (ADF) test (i.e., the presence of unit roots for each variable) (Dickey and Fuller, 1979). Therefore, on the basis of the distribution of the dependent variables the following regression models are employed:

The classical least squares (OLS) regression method demonstrates us how the conditional mean function of y changes with the vectors of covariates x. Essentially, in a single equation econometric model, the parameter coefficients are generally estimated as:

$$\sum \epsilon_i^2 = \min_{\beta \in R^p} \sum_{i=1}^{n} (y_i - x_i\beta)^2 \qquad (1)$$

where y_i is the endogenous variable, x_i is a vector of exogenous variables and β being a vector of p parameters to be estimated.

The OLS regression may not be suitable when the distribution of the response is skewed because it may upshot in misleading regression coefficients (Reeves and Lowe, 2009). The OLS regression is also very sensitive to outliers and does not provide an accurate result if the assumptions of linearity, homoscedasticity, normality, and independence of the residuals are not satisfied (Rao and Toutenburg, 1999). The quantile regression seeks to extend the estimation of conditional quantile functions—models in which quantiles of the conditional distribution of the response variables are expressed as functions of observed covariates (Koenker and Bassett, 1978). Specifically, quantile regression estimates the conditional quantiles: E (Q(τ X = x) = $\acute{x}\beta_{\tau}$.

where Q(τ) are percentiles or quantiles and Q(τ) can easily be obtained by sorting the values of y from smallest to largest and counting off values from left to right. Compared to the single value summary of E(y), the mean of y, the set of quantiles gives much more information about the distribution of y. Note the different parameter vector of βτ for each quantile τ. Thus, quantile regression minimises the sum of absolute residuals, whereas ordinary least squares minimises the sum of squares. The quantile regression provides parameter coefficients for any quantile in the range from 0 to 1 conditional on the covariates or exogenous variables. This can be represented as

$$\sum \in_i^2(\tau) = \min_{\beta \in R^p} \sum_{i=1}^{n} \tau(y_i - x_i\beta)^2 \text{ for any quantile } \tau\epsilon(0,1) \quad (2)$$

Our quantile model specification follows equation (2) and can be specified as

$$Q_\tau[y \,|\, X] = \alpha_\tau + X\beta \qquad (3)$$

where y is the climatic variable, $Q_\tau[y \,|\, X]$ is the τ^{th} quantile of y conditional on the covariance matrix X that include time.

3.3.2 Binary logit model for adaptation decision

The study follows the methodology of Alauddin and Sarker (2014) for analysing the adaptation decisions and strategies. Farmers' adaptation decision is a binary variable, y, take the value (= 1 if the household adapt to climate change and water stress; 0 otherwise). We could define y = $\begin{cases} 1 \\ 0 \end{cases}$ where 1 indicates the positive outcome with probability P_r and 0 indicates the negative outcome with probability $(1 - P_r)$. The odds of observing the positive outcome is:

$$\Omega = \frac{P_r\,(y=1)}{P_r\,(y=0)} = \frac{P_r\,(y=1)}{1-P_r\,(y=1)} \quad (4)$$

The log of the odds is the logit, which is a function of exogenous variables. Eq. (5)specifies the logit model:

$$\ln\left[\frac{P_r\,(y=1/x)}{1-P_r\,(y=1/x)}\right] = \ln\,\Omega(x) = \beta_0 + \beta_1 Mage + \beta_2 Medu + \beta_3 Fage + \beta_4 F\,edu + \beta_5 Hsize + \beta_6 FS + \beta_7 Extfre + \beta_8 DS + \beta_9 Sav + \beta_{10} Cred \quad (5)$$

where Mage = Male age, Medu = Male years of schooling, Fage = Female age, Fedu = Female years of schooling, Hsize = Household size, FS = Farm size, Extfre = Extension frequency, DS = Drought severity, Sav = Saving, and Cred = Credit.

3.3.3 Problem confrontation index for adaptation barriers

The present study used mathematical techniques to identify the perceived constraints of adaptation of agricultural practices in climate change and water stressed situation. Barriers of adaptation of agricultural practices were analyzed with the aid of Problem Confrontation Index (PCI) (Dhar, *et al.*, 2018; Uddin *et al.*, 2017). An overall score of the barriers faced by the farmers in three study areas was computed for each farmer by adding their scores of the problems in all 15 selected problems. For pointing out the extent of difficulty each farmers' were asked to answer the four responses such as frequently, occasionally, rarely, and not at all, and the assigned weights to these responses were numbered as 3, 2, 1 and 0, respectively. Hence, the possible range of the problem confrontation score for each problem could be ranged from 0 to 3 and the overall problem confrontation score for 15 perceived barriers could be 0 to 45 where, 0 indicated there was no problem and 45 indicated that the problem was very frequent.

The PCI for perceived barriers was computed by using the following formula:

$$PCI = (P_{frequently} \times 3) + (P_{occasionally} \times 2) + (P_{rarely} \times 1) + (P_{not\ at\ all} \times 0) \quad (6)$$

where, $P_{frequently}$= Number of responses indicating the problem occurred frequently; $P_{occasionally}$ = Number of responses indicating the problem occurred occasionally; P_{rarely} = Number of responses indicating the problem occurred rarely; and $P_{not\ at\ all}$ = Number of responses indicating no problem at all.

The problems were ranked according to their PCI score which denoting the severity of the perceived barriers in the study areas.

3.4 Conclusions

The chapter shows the survey methods of collecting data and the job of selecting samples were carefully done. Multistage random sampling techniques were used to achieve the objectives of the study. To investigate the farmers' perception to climate change and water stress the study uses a set of descriptive statistics and to build the quantitative justification of the rate of change, the present research also uses econometric tools. To present the adaptation decision regarding the changing climatic scenarios the study uses logit model. The logit model helps to examine the determinants of the farmers' adaptation decision. Moreover, the perceived barriers of adaptation are investigated with the help of mathematical techniques.

CHAPTER 4

EMPIRICAL RESULTS: FARMERS' PERCEPTION

4.1 Introduction

This chapter provides an understanding for the gender sensitive farmers' perception of climate change and water stress in Northwest Bangladesh using farm level survey data. Before investigating farmers' perceived belief, the study primarily focuses on the trends of climate change in the concerned three ground water depleted areas using secondary data sources. In addition, to build the quantitative justification for climate change, the present study estimates trend models for three major climate variables with time (t) as an explanatory variable over the entire period. Nevertheless, the data set of our study encompasses 34 years (i.e., 1982-2015) of observations which require testing for stationarity, considering this study carried out an Augmented Dickey–Fuller (ADF) test. Finally, this chapter deals with the perceptions of climate change and water stress based on the answers of husband and spouse.

4.2 Climate Trends

To capture the actual variability, the study used seasonal trend analysis such as, *Kharif* and *Rabi* and there is greater seasonal variability of climatic parameters. Overall, Figure 4.1 illustrates that, the temperature (i.e., annual and *kharif* season) of Rajshahi district increased dramatically whereas the rainfall and *Rabi* season temperature decreased sharply. This result aligns with Kabir *et al*. (2017) and Al-Amin *et al*. (2017). Even though, the annual average maximum temperature climbed steadily over the last 34 years with high fluctuation but there exists seasonal variability. In Rajshahi district during *kharif* season (March-September), the average maximum temperature increased sharply with minimal fluctuation whereas in the *Rabi* season (October-February), the average maximum temperature declined slightly following elevated fluctuation. Furthermore, the annual and *kharif* season average minimum temperature increased dramatically but the *Rabi* season average minimum temperature remained constant with little fluctuation over the period of time. However, the annual and seasonal average rainfall decreased slowly with high fluctuation.

Figure 4.2 shows that the annual and *kharif* season average maximum temperature of Dinajpur district raised rapidly whereas in *Rabi* season the average maximum temperature decreased slowly. Moreover, the annual and seasonal average minimum temperature increased rapidly but the annual and seasonal average rainfall decreased slightly. The annual and seasonal average trends of temperature and rainfall of Bogra district are presented in Figure 4.3. Although, the annual and *kharif* season average maximum temperature are leveled off, the *Rabi* season average maximum temperature dropped steadily. However, the annual and seasonal average minimum temperature increased gradually but the rainfall decreased slowly.

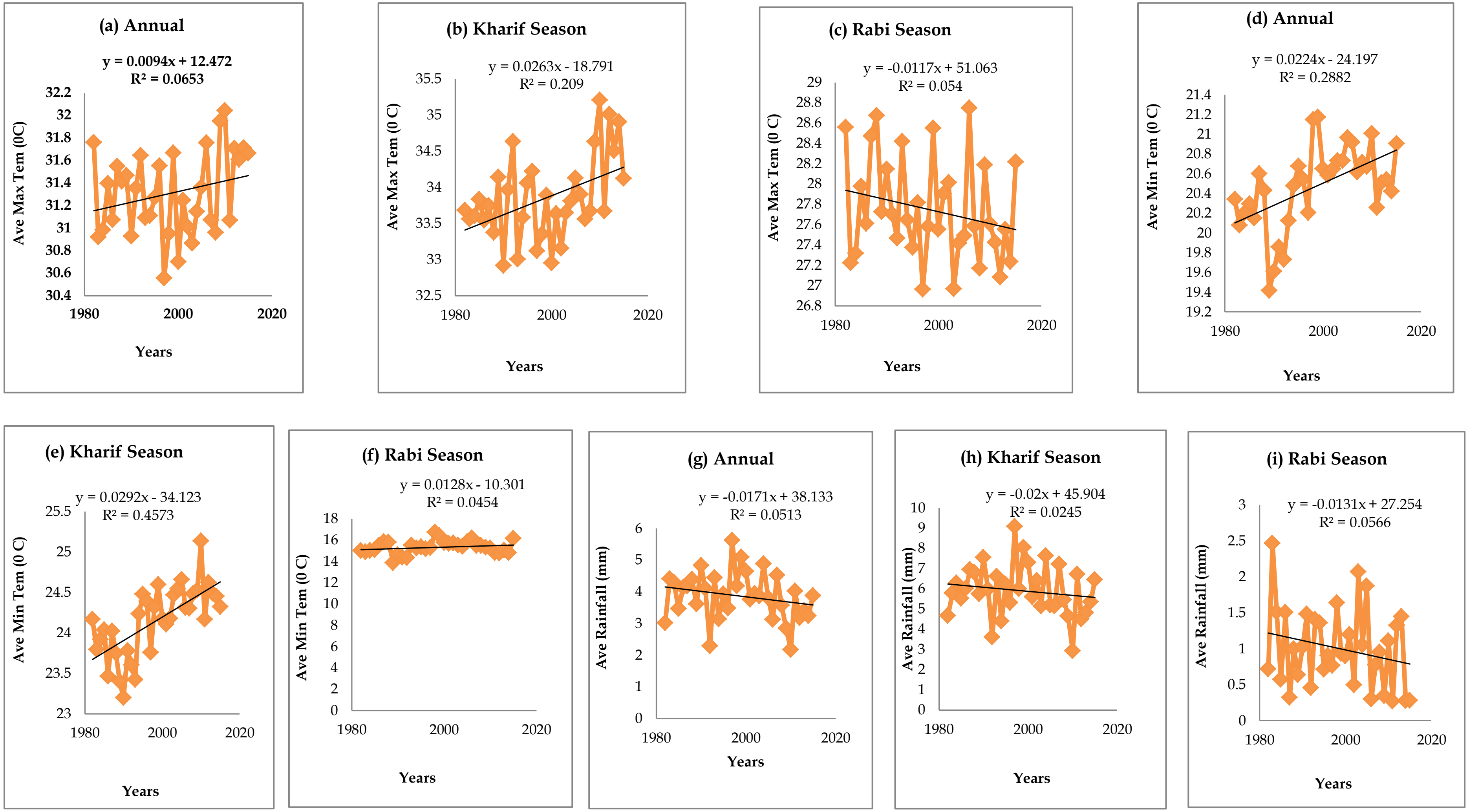


Figure 4.1: Trends of annual and seasonal average maximum temperature, minimum temperature, and rainfall of Rajshahi district.

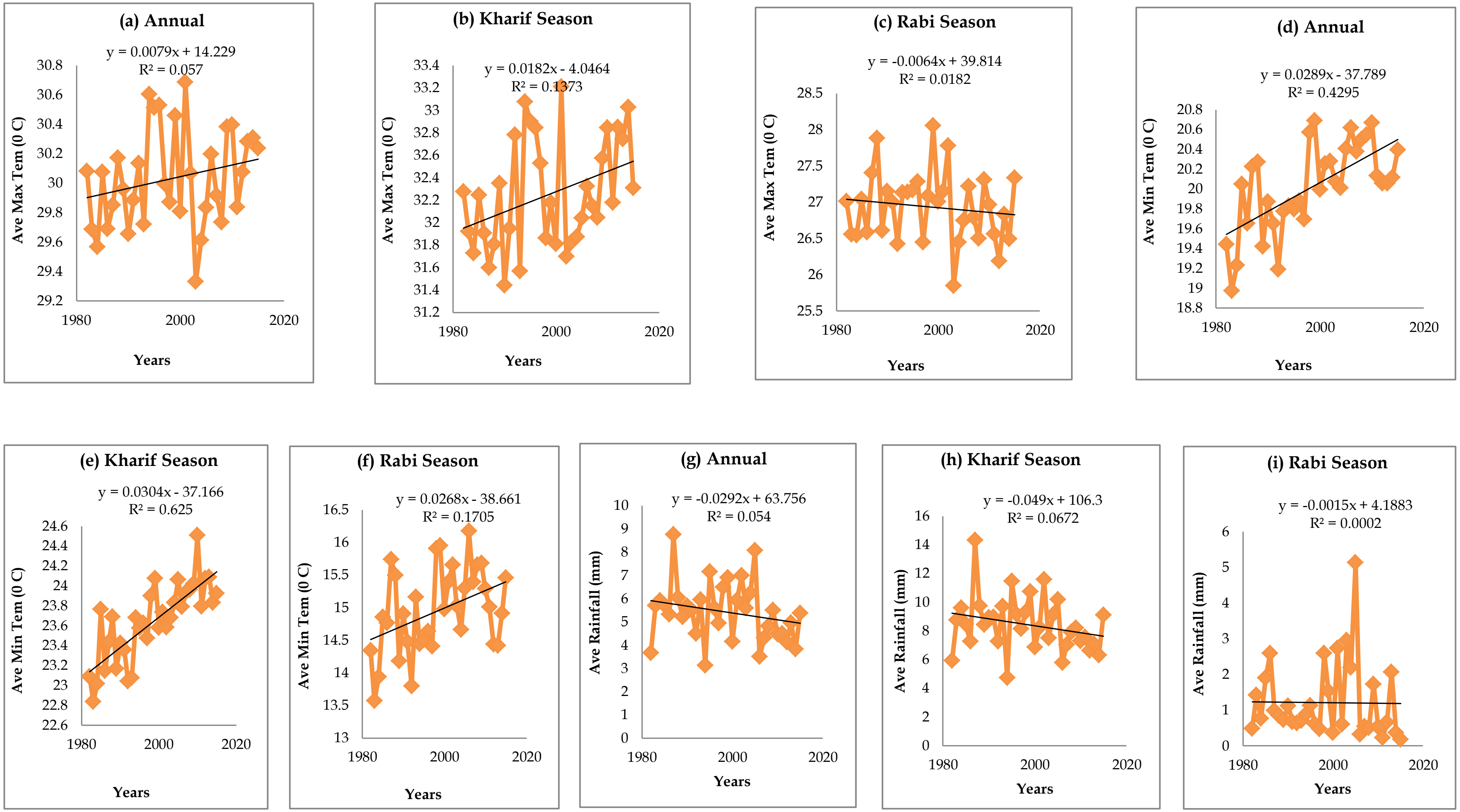


Figure 4.2: Trends of annual and seasonal average maximum temperature, minimum temperature, and rainfall of Dinajpur district.

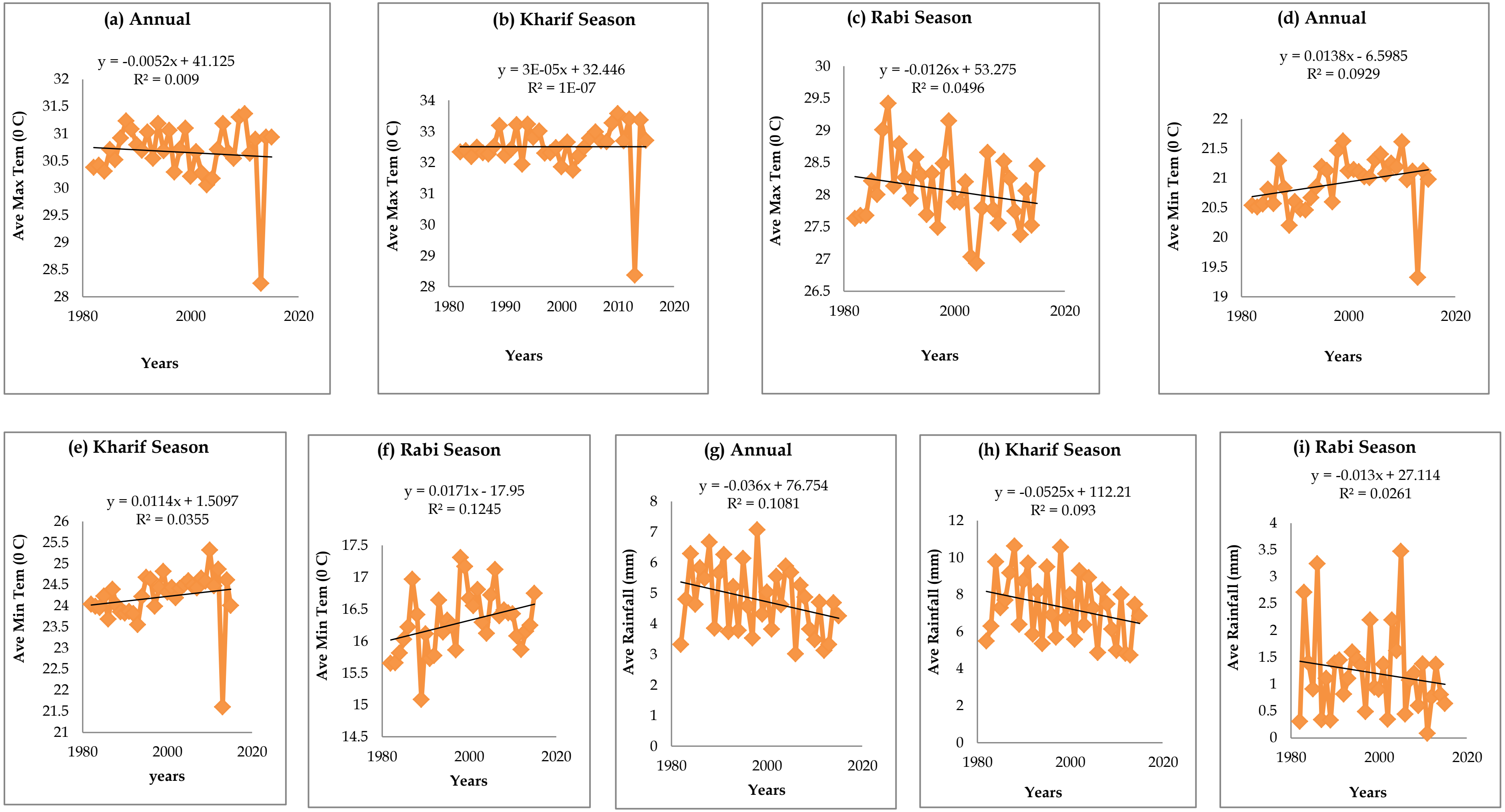


Figure 4.3: Trends of annual and seasonal average maximum temperature, minimum temperature, and rainfall of Bogra district.

The Augmented Dickey Fuller (ADF) test is carried out to determine the stationarity of the selected climatic variables. From Table 4.1 it is vividly evident that the annual and seasonal average maximum temperature, minimum temperature, and rainfall of the study areas are non-stationary except the *Rabi* season rainfall of Dinajpur district. The results indicate that the climatic parameters (i.e. maximum temperature, minimum temperature, and rainfall) changes over the period of time. However, the *Rabi* season rainfall of Dinajpur district is integrated of order zero, thus this data series are stationary in their level form. Therefore, the variables with I(1) must be first differenced before estimation of any model (Gujrati, 2004; McCarl *et al*., 2008).

The quantitative justification of climate change over the period of time is presented in Table 4.2. The study found that in the high water scarce area (i.e. Rajshahi), the t-value for annual average minimum temperature associated with their p-value illustrates that the average annual minimum temperature is highly significant. The result indicates that of an additional year the annual average minimum temperature has increased by 0.02^0C. In addition, the R-square value indicates that 29% of the variation in annual average minimum temperature is explained by the time. Furthermore, in the low scarce area (i.e. Dinajpur), the annual average minimum temperature is significant at 1% level. The result indicates that of an additional year the annual average minimum temperature has increased by 0.03^0C.

The coefficient estimates for the 25^{th}, 50^{th}, and 75^{th} percentile and the linear regression coefficient estimates for climatic variables are presented in Table 4.3. The quantile regression results of annual average minimum temperature of the medium water scarce area (i.e. Bogra) indicate that, time has a larger impact on the higher to lower quantiles valued as 0.023 (50^{th}) and 0.025 (75^{th}) of annual average minimum temperature distribution significantly. However, of an additional year the annual average rainfall in this area has decreased by 0.04 mm.

Table 4.1: Augmented Dickey-Fuller (ADF) test for determining the stationarity of the data series.

Variables	**Rajshahi**			**Dinajpur**			**Bogra**		
	Annual	Kharif Season	Rabi Season	Annual	Kharif Season	Rabi Season	Annual	Kharif Season	Rabi Season
Maxt	0.535 (0.826)	0.588 (0.838)	0.112 (0.711)	0.497 (0.817)	0.530 (0.825)	0.183 (0.733)	0.163 (0.727)	-0.192 (0.609)	0.227 (0.746)
Mint	0.223 (0.745)	0.408 (0.795)	0.219 (0.744)	0.921 (0.901)	1.282 (0.946)	0.495 (0.817)	0.219 (0.743)	0.047 (0.691)	0.434 (0.802)
Rainfall	-0.505 (0.489)	-0.296 (0.571)	-1.603 (0.102)	-0.437 (0.517)	-0.414 (0.526)	-1.637 (0.095)	-0.567 (0.463)	-0.458 (0.509)	-1.184 (0.211)

Note: The value in the parenthesis indicates p-value. The Augmented Dickey-Fuller (ADF) tested the null hypothesis of that the relevant series contains a Unit root I(1) against the alternative that it does not.

Table 4.2: The results of the linear trend model of changes in climate variables for the 1982-2015 periods

Area	**Climate variables**	**Intercept**	**Coefficient**	**t- value**	**p-value**	**R-squared**
Rajshahi (High Scarce Area)	Maxt	12.472	0.009	1.50	0.145	0.0653
	Mint	-24.197	0.022***	3.60	0.001	0.2882
	Rainfall	38.133	- 0.017	-1.32	0.198	0.0513
Dinajpur (Low Scarce Area)	Maxt	14.229	0.008	1.39	0.174	0.057
	Mint	-37.789	0.029***	4.91	0.000	0.4295
	Rainfall	63.756	- 0.029	-1.35	0.186	0.054

Note: *** represents the 1% level of significance

Table 4.3: The results of the quantile regression model of changes in climate variables for the 1982-2015 periods

Bogra (Medium Scarce Area)					
Climate variables	**Test statistics**	**OLS**	**Selected quantiles**		
			25th Percentile	**50th Percentile**	**75th Percentile**
Maxt	Intercept	41.125	20.855	6.249	38.774
	Coefficient	- 0.005	0.005	0.012	- 0.004
	t- value	-0.54	0.18	1.05	- 0.40
	p-value	0.593	0.856	0.300	0.690
	R^2/Pseudo R^2	0.009	0.014	0.003	0.000
Mint	Intercept	- 6.598	-12.862	-25.280	-28.482
	Coefficient	.0138*	0.017	0.023***	0.025**
	t- value	1.81	0.89	3.62	2.56
	p-value	0.080	0.381	0.001	0.015
	R^2/Pseudo R^2	0.093	0.185	0.194	0.086
Rainfall	Intercept	76.754			
	Coefficient	- 0.036*			
	t- value	-1.97			
	p-value	0.058			
	R^2/Pseudo R^2	0.108			

Note: *** represents the 1% level of significance; ** represents the 5% level of significance; * represents the 10% level of significance.

4.3 Significant Climatic Events

Table 4.4 summarises the past significant climatic events from secondary sources to have clear scenarios of the Northwest Bangladesh. The insights of the study areas can be found from the following information which might be helpful for the future. The study intentionally used climatic events from 1973 to focus Bangladesh while information before 1971 was excluded because Bangladesh has its own identity from the edge of 1971. As the data sources of climatic events are not well organized for that reason, lack of events is available on secondary sources which are the main draw backs of this part. Table 4.4 shows that out of ten climatic events from 1973 to 1998 Northwest Bangladesh faced drought in seven times as the foremost problem for agriculture. The intensity of drought was higher in the year 1973, 1978-1979, and 1981 which brought immense loss in agricultural sector mainly crop agriculture. Along with drought the region also faced flood, causing loss of cultivated areas. The Northwest area faced famine in the early stage of Bangladesh (i.e., 1974) due to severe drought occurred in 1973.

Table 4.4: Past significant climatic events of Northwest Bangladesh

Year	Location	Events	Damage
1973	Northern Bangladesh	Severe drought	One of the severest in the present century, responsible for the 1974 famine in northern Bangladesh.
1975	Bangladesh	Drought	Affected 47% of entire country; suffered about 53% of the total population.
1978-79	Bangladesh	Severe drought	Widespread damage to crops; reduced rice production by about 2 million tons; directly affected about 42% of the cultivated land and 44% of the population.
1981	Bangladesh	Severe drought	Adversely affected crop production.
1982	Bangladesh	Drought	Caused a total loss of rice production amounting to about 53000 tons.
1987	Northern Bangladesh	Catastrophic flood	Affected 57,300 sq. km which is about 40% of the total area; estimated to be a once in 30-70 year; excessive rainfall both inside and outside of the country;
1989	Naogaon, Nawabganj, Nilpahamari and Thakurgaon of North-west Bangladesh	Drought	Dried up most of the rivers in NW Bangladesh, dust syndrome occurred for a prolonged period due to drying up the topsoil.
1993	Twenty-eight districts of Bangladesh	Severe floods	Thousands of hectares of crops went under water.
1994-1995	North-west Bangladesh	Drought	Persistent drought; caused immense damage to crops like rice and jute.
1998	Two-thirds of the total area of Bangladesh	Severe floods	Worst flood in recorded history; a combination of heavy rainfall within and outside country, synchronization of peak flows of major rivers and a very strong backwater effect coalesced into a mix; flooded over two-thirds of the total area of Bangladesh, lasted for more than two months, damaged a lot.

Source: Banglapedia, Asiatic Society of Bangladesh.

4.4 Farmers' Perception of Climate Change and Water Stress

4.4.1 Perception regarding temperature and rainfall

The study asked farmers' perception about temperature and rainfall over the last 20 years. Their responses were then analysed for the betterment of agriculture and policy responses. Out of 360 male and 360 female responses (i.e. Husband and Spouse) majority of the male and female were agreed upon the perception of increasing temperature. Table 4.5 reveals that 92% male and 79% female mentioned that over the last 20 years the temperature is increasing whereas only 2% and 4% were claimed no change. However, 6% male and 11% female thought that the temperature is decreasing; this may be because of the individual's perceived belief about the change and may be because of the variation in the responses of different district. As we know that the climatic variables fluctuate regarding regions or seasons.

Figure 4.4 shows the perception of farmers' about rainfall in response to question of changes of rainfall over the last 20 years. Both husband and spouse were asked about the long term changes in rainfall. About 49% male and 27% female pointed out that the rainfall was decreasing over the last 20 years. Furthermore, both sexes think that, the patterns of rainfall exhibits huge changes, incorporating changes in the timing of rains, unexpected rainfall, rainfall with strong storms or winds, and finally rainfall with more thunderstorms and lighting.

Table 4.5: Perception of temperature over the last 20 years

Gender	Increased	Decreased	No change	Don't know	Total
Male	91.67	6.11	2.22	0.00	100.00
Female	79.44	10.83	4.44	5.28	100.00

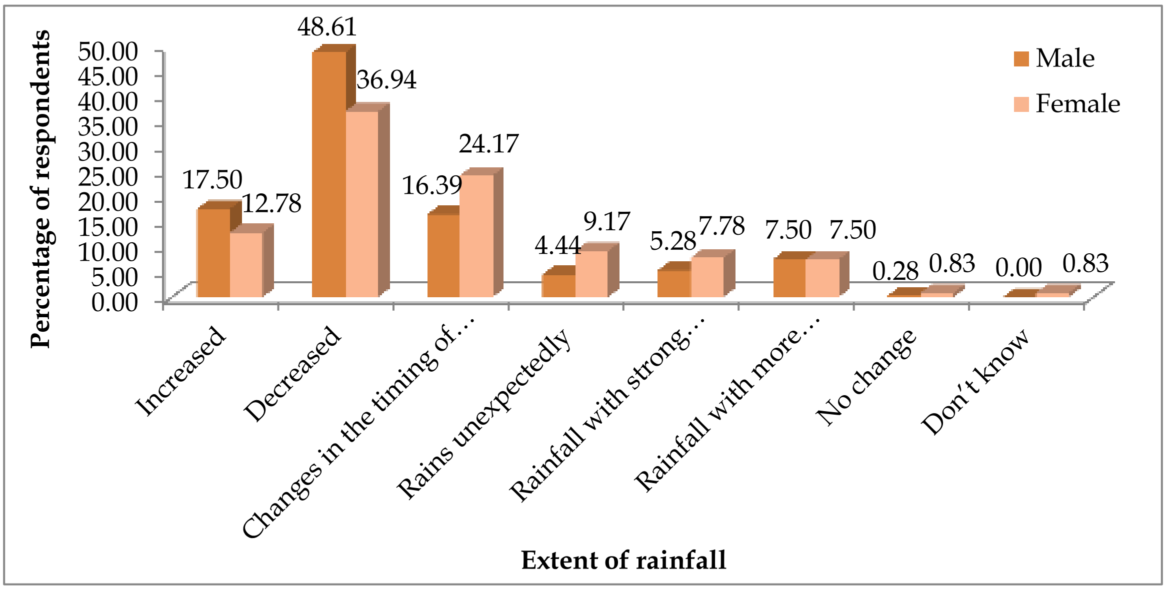


Fig 4.4: Perception of rainfall over the last 20 years

4.4.2 Perception regarding water stress

Even though Bangladesh faces worse climatic events, water stress (i.e. drought) is the main problem for Northwest Bangladesh. This water stress acts as a bottleneck for agricultural productivity especially in this ground water depleted areas. Farmers' in these water stressed areas were asked to mention about their belief of drought. Majority of the farmers (i.e., both husband and spouse) believed that nature itself is responsible for drought. About 15% male and 11% female thought that drought is the consequence of both natural and manmade problems.

Table 4.6: Farmers' beliefs about water stress

Gender	Natural disaster	Man-made disaster	Both	Total
Male	77.78	6.94	15.28	100.00
Female	79.72	8.89	11.39	100.00

The frequency of drought is presented in Figure 4.5. Approximately, 70% male and 65% female argued that the drought occurs every year. Such an annual occurrence indicates that drought is the main barriers for agriculture in the Northwest Bangladesh. Only a small portion showed reluctant attitude about drought, among the two groups of respondents, the proportion of female was higher in this regards (i.e., male tends to 1% and female tends to 4%).

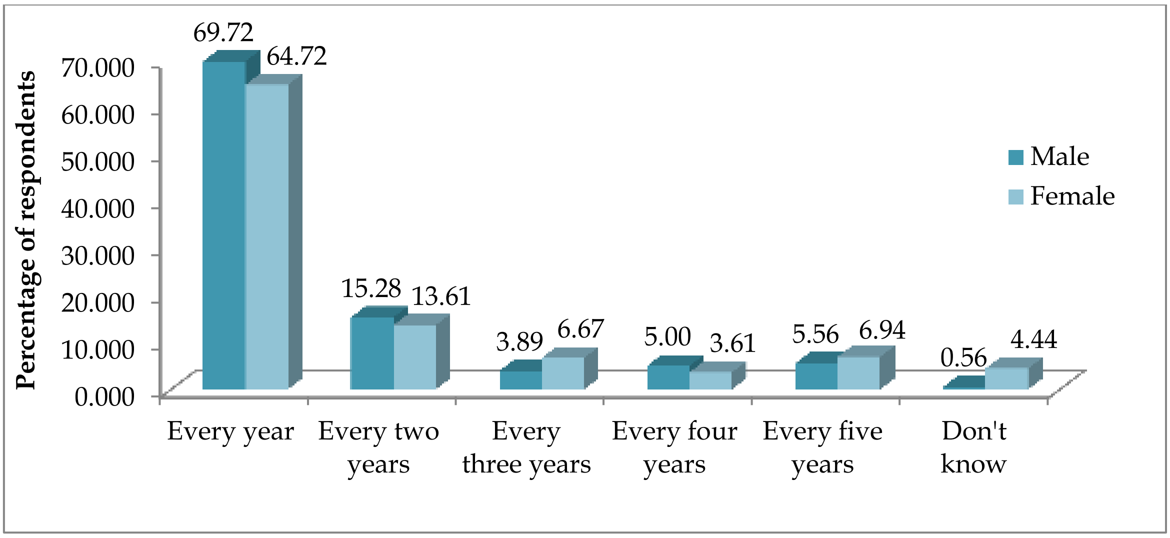


Figure 4.5: Frequency of drought occurrence

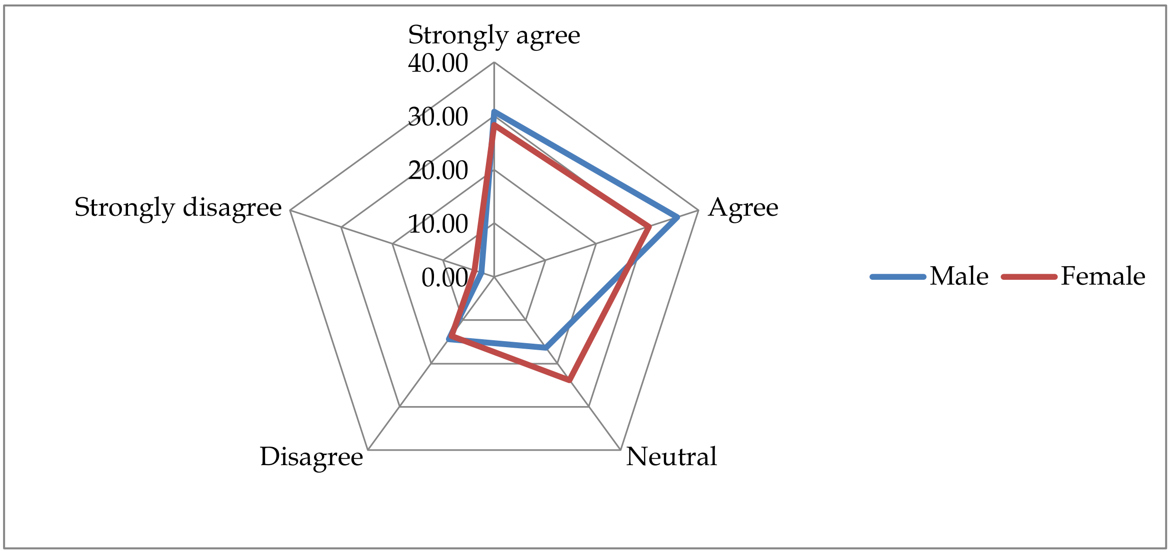
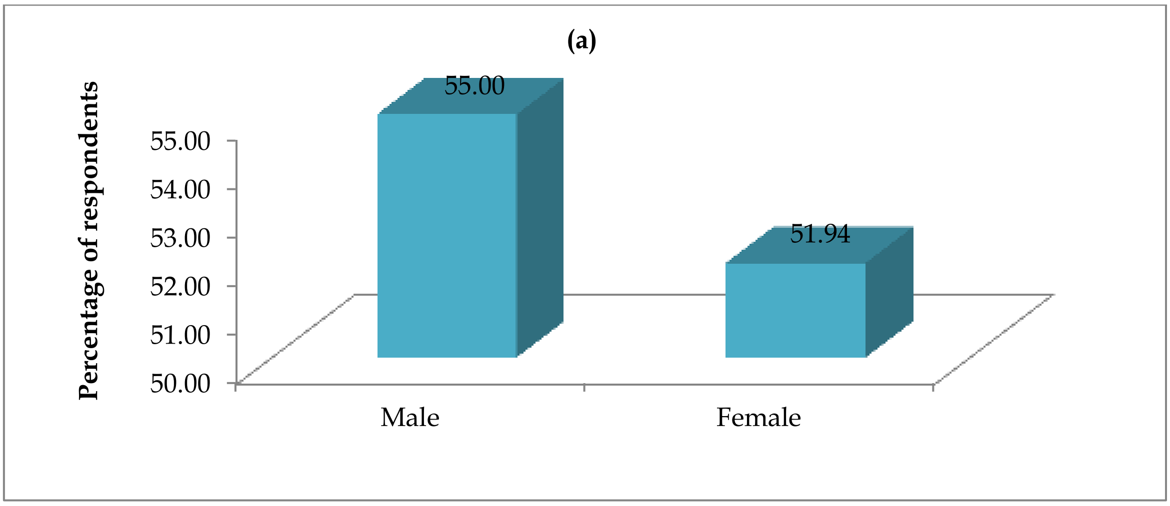


Figure 4.6: Status of water scarcity

Figure 4.6 reveals that about 31% male and 28% female strongly agree that water availability is not enough during drought period where as 36% male and 30% female agree this. However, only a small percentage (i.e. 3% male and 4% female) strongly disagree about the scarcity of water during drought period.

As our study is in ground water depleted areas, the water is often regarded as one of the major scarce resources for agricultural production. Consequently, the scarcity of water and the marginal utility of water are so high which may create conflicts among the farmers. Our present study showed that 55% male and 52%

female recognized water as the scarce resource which causes conflicts in the locality. Moreover, they also mentioned that, although the conflict was so high but they are mainly solved by their neighbour followed by UP members and UP chairman.



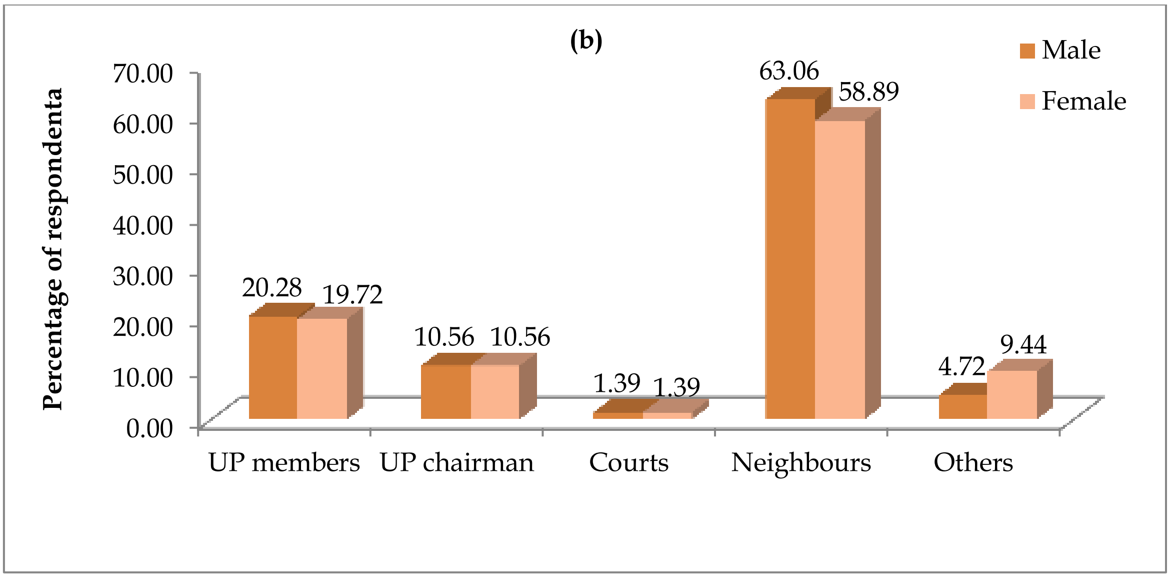


Figure 4.7: (a) Water conflict; (b) Mitigating water conflicts

Farmers' preparedness against drought is presented in Figure 4.8 which indicate that approximately 39% male and 28% female mentioned that they are highly prepared against drought, implying that in the study areas they actually taking some sort of adaptive measures as a safeguard against water stress. Moreover 34 % male and 43% female were in moderate position in this regards.

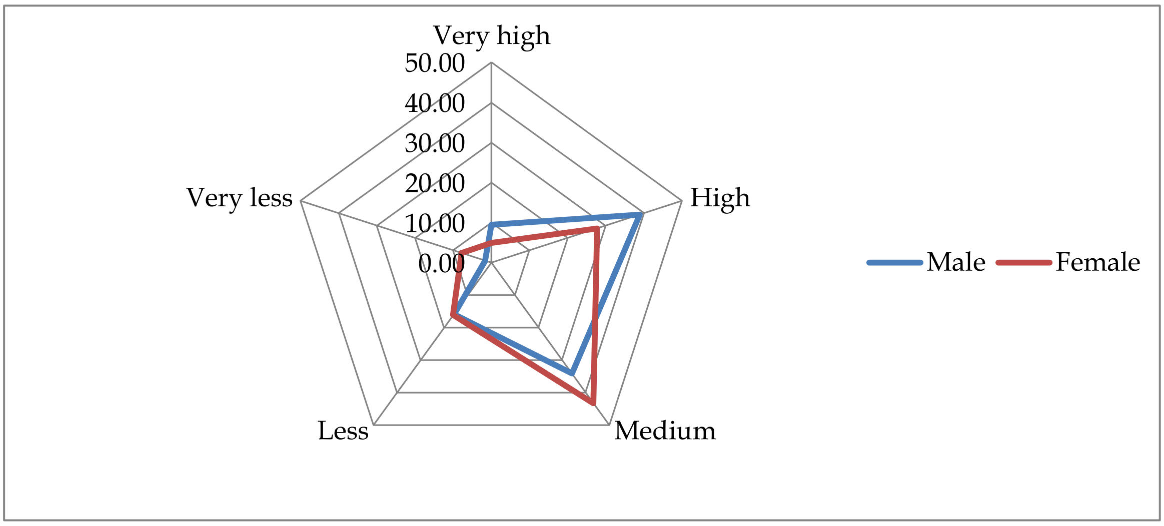


Figure 4.8: Farmers vigilance against water stress

Various factors are responsible for climate change and water stress among which the study mainly focus on five factors based on the farmers' belief about the causes. About 49% male and 47% female argued that deforestation is the main reason for climate change and water stress. The respondents recognized pollution as the second cause followed by natural phenomenon and bush burning.

Table 4.7: Farmers perceived belief about the causes of climate change and water stress

Particulars	**Male**					**Female**				
	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree
Pollution	48.06	46.67	3.06	2.22	0.00	44.44	43.06	11.11	0.83	0.56
Deforestation	49.44	43.06	5.00	1.94	0.56	46.67	42.22	8.06	2.22	0.83
Bush Burning	5.83	35.28	39.72	14.17	5.00	4.44	34.17	41.39	16.94	3.06
Desert encroachment	0.28	6.39	52.78	26.67	13.89	0.28	6.67	53.06	26.94	13.06
Natural phenomenon	25.00	31.39	19.44	18.89	5.28	27.22	30.00	24.17	15.00	3.61

4.5 Conclusions

Based on the findings of this research, it can be concluded that over the years the Northwest Bangladesh faces problems with climate change and water stress. Both secondary and primary data have consistent results although the perceptions about these changes vary from gender perspective. Majority of the husbands and wives in the study areas are concerned about the change although their vigilance against the changes varied.

CHAPTER 5

EMPIRICAL RESULTS: FARMERS' ADAPTATION

5.1 Introduction

This chapter mainly deals with farmers' adaptation strategies in the ground water depleted areas of Northwest Bangladesh and identifies the determinants of adaptation decision. As the respondents are from the same family the adaptation strategies do not vary regarding the gender. For that reason the gender differences in case of adaptation are not the main concern in this chapter rather the chapter mainly focuses on the household's actual adaptation practices and the factors that influence the adaptation decision of the households.

5.2 Farmers' Actual Adaptation Strategies

Various literatures showed that the adaptation strategies taken by farmers varied significantly according to the region and land topography. In our study areas, that is, ground water depleted areas of Northwest Bangladesh, the study found four adaptation strategies and take no adaptation at all as the base category. Table 5.1 shows the adaptation strategies in the study areas. Short duration and drought tolerant rice varieties are the main adaptation practices occupies 29 percent of the respondents, whereas supplementary irrigation for *Aman* and *Boro* rice is the second preferred adaptation strategy. The findings are interesting as the study areas are ground water depleted area for that reason the main adaptation strategies are related to the water scarcity. Due to excessive climate change and water stress the rice farmers are switching from rice to non-rice *Rabi* crops and horticultural crops which takes the third position in adaptation practices. About 40 respondents mentioned that they are more focused on water preservation and improved their channels for irrigation. However, 12 percent of the farmers' are reluctant to the climate change and water stress related adaptation strategies and they are not taking any preventive measures to combat with changing climatic scenarios. Figure 5.1 reveals the clear view of the percentage of the respondents preferred adaptation strategies.

Table 5.1: Current adaptation strategies to combat climate change and water stress in the study areas

Adaptation Practices	Frequency	Percent	Cum.
No adaptation at all	43	11.94	11.94
Short duration and drought tolerant rice varieties	103	28.61	40.56
Supplementary irrigation for *Aman* and *Boro* rice	98	27.22	67.78
Cultivation of non-rice *Rabi* crop and horticultural crops	76	21.11	88.89
Water harvesting techniques and improved irrigation channels	40	11.11	100.00
Total	**360**	**100.00**	

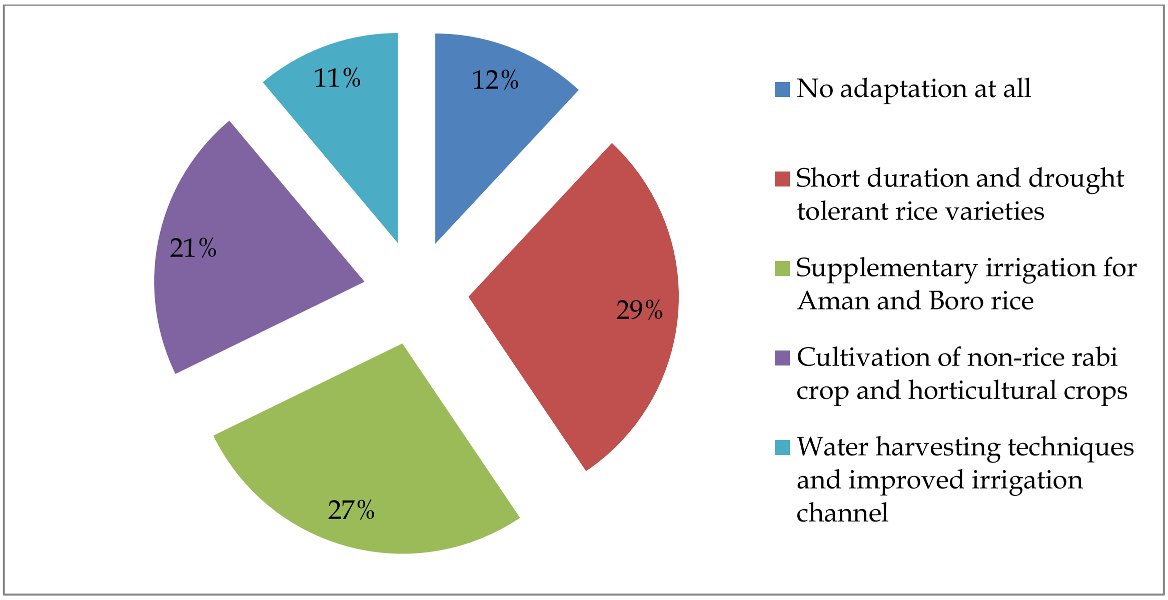


Figure 5.1: Current adaptation strategies in climate change and water stress areas of Bangladesh

5.3 Determinants of Farmers' Adaptation Decision

Our study assumed that, farmers' decisions to undertake adaptation strategies is a function of male and female characteristics, family characteristics, farm characteristics, institutional factors, and climate variable. The results of these findings are presented in Table 5.2. The results represent the estimated parameters and marginal effects. The marginal effects suggest that age of the female, extension frequency, drought severity, and credit facilities are the influential factors for farm households' decisions to adapt to climate change and water stress. Results reveal that, the drought severity is the most positive influential factor (0.1734) in the farmers' decision to adapt to climate change followed by credit facilities (0.0420). Conversely, age of the male household head and household size are the negative factors for farmers' adaptation decision. This may be due to the fact that, aged household heads are more conservative in new adaptation. Actually they are the laggard group in the adaptation area. This result is consistent with the findings of Clay *et al*. (1998).

Table 5.2: Determinants of farmers' adaptation decision

Variables	**Decision to adapt to climate change and water stress (1 = Yes; 0 = No)**			
	Estimated parameters	**Std. Err.**	**Marginal effects**	**Std. Err.**
Male age (years)	-0.0757*	0.0401	-0.0047*	0.0024
Male years of schooling	-0.0280	0.0537	-0.0017	0.0033
Female age (years)	0.0970**	0.0475	0.0060**	0.0029
Female years of schooling	0.0222	0.0574	0.0015	0.0035
Household size (number)	-0.2815**	0.1328	-0.0174**	0.0082
Farm size (acre)	0.0745	0.0921	0.0046	0.0057
Extension frequency	0.0440*	0.0245	0.0027*	0.0015
Drought severity (dummy)	2.8106***	0.000	0.1734***	0.0305
Saving (dummy)	-0.2248	0.4307	-0.0139	0.0266
Credit (dummy)	0.6811*	0.3890	0.0420*	0.0241
Constant	0.4999	1.2337		
LR chi-square	70.30***			
Log likelihood	-96.543522			
Pseudo R2	0.2669			
Number of observation	360			

Note: ***, **, * indicate the significance level at 1%, 5% and 10% respectively.

5.4 Conclusions

Based on the findings of this research, it can be concluded that short duration and drought tolerant rice varieties, supplementary irrigation for *Aman* and *Boro* rice, cultivation of non-rice *Rabi* crop and horticultural crops, and water harvesting techniques and improved irrigation channels are the main adaptation strategies in the study areas. Moreover, the frequent extension visit positively influence the adaptation decision of the farm households because their visit motivates the farmers' for adaptation and provides them valuable climate related information which accelerate the adaptation practices. In the same fashion, the access to credit facilities represents the farmers' ability to adapt as the credit facility indicates the availability of liquid money. The liquid money helps the farmers' to take prompt decision in case of adaptation to mitigate unpleasant climatic events.

CHAPTER 6

EMPIRICAL RESULTS: THE PERCEIVED CONSTRAINTS OF ADAPTATION

6.1 Introduction

This chapter deals with farmers' perceived barriers to using different adaptation measures in the ground water depleted areas of Bangladesh. The aim of this chapter is to identify the constraints for ensuring proper adaptation measures which will help to accelerate agricultural production in the Northwest Bangladesh.

6.2 Overall Problem Confrontation Index (PCI) of Adaptation Barriers

In this section, adaptation barriers of Bogra, Dinajpur and Rajshahi are discussed according to the respective PCI score. Hence, higher PCI score means the higher adapted barrier in the study area. Figure 6.1 shows that the lack of water achieved score 832 among the all barriers while the score of absence of government policy on adaptation, lack of credit, risk of adaptation and lack of information are 811, 747, 702 and 666 respectively. In addition, the PCI score of rest of the barriers such as shortage of labor, shortage of land, poor soil quality, shortage of farm inputs, lack of farm animals, practiced land tenure system, traditional belief, poor extension services, lack of weather forecasting and non-availability of facilities are 630, 598, 657, 553, 271, 512, 313, 599, 585 and 572 respectively. So, it is clear that the higher PCI score indicates the higher severe condition among the adaptation barriers in the study area.

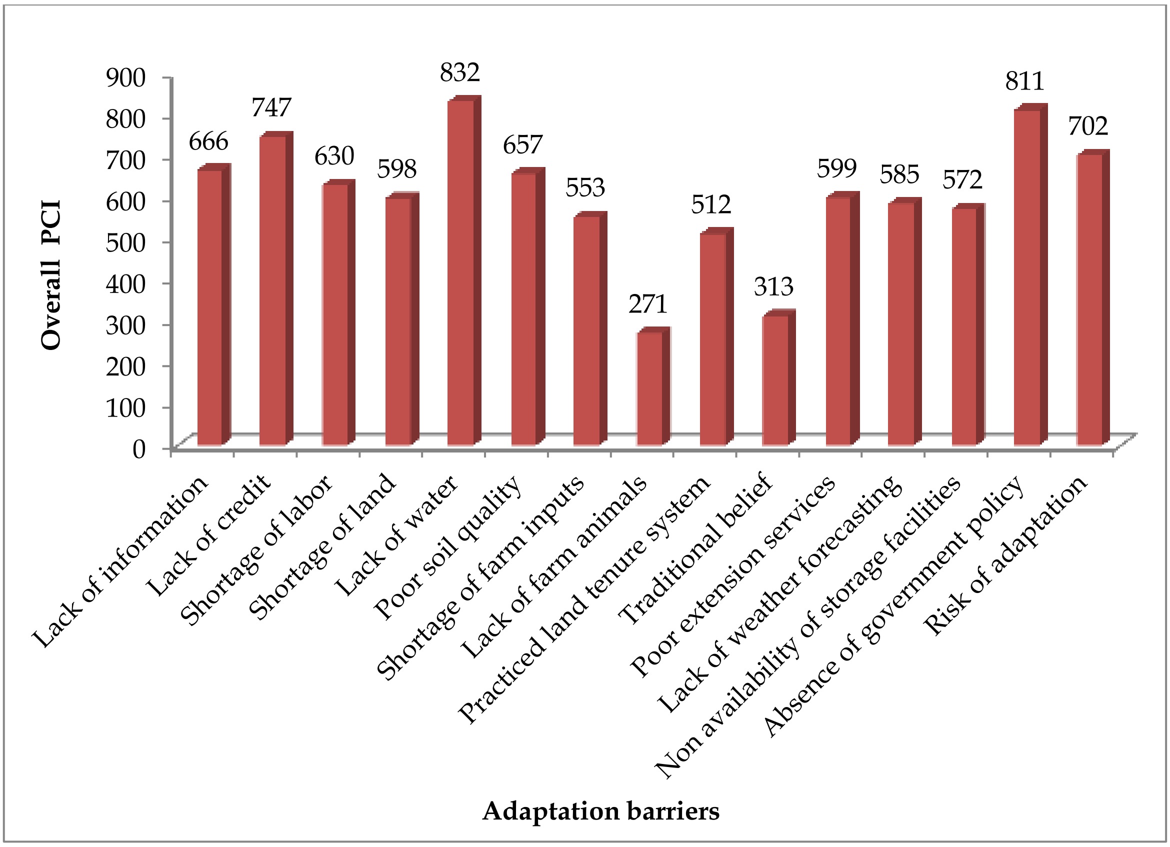


Figure 6.1: Overall adaptation barriers

6.3 Adaptation Barriers According to Farmers' Perception

Adaptation barriers of the farmers are measured according to their individual perception. The farmers were asked about their problems perception for gaining the PCI score during field survey in the study areas. Then the problems are ranked according to the order of PCI score. Hence, 15 adaptation barriers are discussed with the PCI score and rank order respectively.

6.3.1 Lack of information/knowledge

Lack of appropriate knowledge on farming practice is a great issue for the farmers. Study reveals that, the PCI score of the problem 'Lack of Information' in Bogra, Dinajpur and Rajshahi are 228, 236 and 202 while the rank order is 3rd, 6th and 10th. Results also show that the higher rank of that barrier in Bogra district than the others, respectively. It indicated that the lack of information spread-up in this district.

6.3.2 Lack of credit/money

Inadequate credit facility is another major problem faced by the farmers in the research areas. The credit lending process of different formal credit lending institutions is not transparent to them and as a result, they have to depend on different informal sources of credit like moneylenders, relatives, friends, etc for cultivating crops. The PCI score of this problem in three districts named Bogra, Dinajpur and Rajshahiare 245, 242 and 260 with holding the rank of 2nd, 5th and 3rd respectively. The result means that all the areas faced the problem 'Lack of Credit', but the barrier is comparatively higher in Bogra district.

6.3.3 Shortage of labor

Labor is the main input item to produce any kind of things especially in agricultural sector for farming. More and efficient labor plays a vital role to produce more products accordingly. On the other hand, the lacking of labor has a great impact on production. In Bangladesh, this problem is varied area to area. Current study finds the variation of it in Bogra, Dinajpur and Rajshahi district by the scoring and order rank. The PCI score of those areas were 210, 244 and 176. Also their rank orders are 6th, 4th and 12th. That means the shortage of labor is higher in Dinajpur district for the rank of 4th.

6.3.4 Shortage of land

Non-availability of land during farming period is another important factor to the farmers. The farmers did not have the land what they had needed lease and mortgage for production purposes. Therefore, this problem considered as adaptation barrier in the study areas. Study reveals that the PCI score and rank order are 188,182, 228 and 9th, 11th, 5th in the area of Bogra, Dinajpur and Rajshahi districts respectively. The most land shortage area is Rajshahi among the three study areas.

6.3.5 Lack of water

Lack of water is another adaptation barrier in the study areas. Lack of water severity has measured by the PCI score and rank order in the areas of Bogra, Dinajpur and Rajshahi districts. Study reveals that the PCI score are 221, 306 and 305 in Bogra, Dinajpur and Rajshahi districts, respectively. Moreover, the rank orders are found 5th in Bogra and 1st in both of the region Dinajpur & Rajshahi. It indicates that the lack of water is a first and most severe adaptation barrier during irrigation period in the study area.

6.3.6 Poor soil quality

Poor soil quality is a problem which is also called another adaptation barrier. Good quality of soil meant the good production of crops. This study measured the PCI score and rank order for the soil quality adaptation barrier. Hence, the PCI scores are 221, 228 and 208 in Bogra, Dinajpur and Rajshahi districts. The rank orders are 5th in Bogra and 7th in both Dinajpur & Rajshahi. In addition, it meant that poor soil quality is higher in Bogra than Dinajpur and Rajshahi.

6.3.7 Shortage of farm inputs

Lack of good quality inputs is one of the major problems faced by the farmers in the research areas. Precisely, availability of good quality seeds and fertilizers is infrequent to the farmers. According to the perceptions of the farmers, the PCI score of this problem stands 171, 210 and 172 in case of Bogra, Dinajpur and Rajshahi farmers, respectively. This resulted in a rank of this problem as 11th, 9th and 13th accordingly. That means the most adaptation barrier of farm inputs is in the area of Dinajpur district.

6.3.8 Lack of farm animals/oxen

Another adaptation barrier is the lack of farm animal in the study areas. The PCI score and the rank of lack of farm animal in Bogra is 97 and 13. On the other hand, PCI score of that is 100 and 74 but the rank is 15th for both of the areas of Dinajpur and Rajshahi. It is clear that, the lack of farm animal barrier is higher in Bogra district than the others.

6.3.9 Practiced land tenure system

The PCI score and rank order for the barrier of 'practiced land tenure system' are 157, 149, 206 and 12th, 13th, 8th in Bogra, Dinajpur and Rajshahi districts respectively. Result indicates that the higher rank is 8th in Rajshahi district for the barrier of land tenure system than the others districts.

6.3.10 Traditional belief

Traditional belief of the farmers is considered as an adaptation barrier in this study. This barrier is calculated as PCI score which is 96, 124, and 93 in Bogra, Dinajpur and Rajshahi districts, respectively. But the rank order 14th is similar for all areas which meant the rate of traditional belief in the areas are also same.

6.3.11 Poor extension services

A noticeable number of farmers in the research areas stated that they experienced lack of extension contact. The frequency of visit by the extension agents in the research areas is very limited. The problem was ranked as 10th, 8th and 11th as per the PCI score of 178, 220 and 201 in Bogra, Dinajpur and Rajshahi, respectively.

6.3.12 Lack of weather forecasting

Lack of weather forecasting is one of the major problems faced by the farmers in the research areas. According to the perceptions of the farmers, the PCI score of this problem stands 194, 187 and 204 in case of Bogra, Dinajpur and Rajshahi farmers. The rank order of that problem in Bogra and Dinajpur districts are 7th while the rank order is 9th in Rajshahi.

6.3.13 Non availability of storage facilities

Availability of storage facilities is weak and as a result, storing of products for future sale is reasonably uncertain. This problem is ranked as 8th, 12th and 6th with PCI score of 191, 171 and 210 according to the farmers' perception in Bogra, Dinajpur and Rajshahi districts, respectively.

6.3.14 Absence of government policy on adaptation

Absence of government policy on adaptation is a problem which is also called an adaptation barrier. This study measured the PCI score and rank order for the adaptation barrier. Hence, the PCI scores are 262, 275 and 274 in Bogra, Dinajpur and Rajshahi districts. The rank orders are 1st in Bogra and 2nd in both Dinajpur and Rajshahi. In addition, it meant that absence of government policy on adaptation is so much higher in Bogra, Dinajpur and Rajshahi districts respectively.

6.3.15 Risk of adaptation

Current study found that the variation of adaptation risk in Bogra, Dinajpur and Rajshahi district by the PCI scoring. The PCI score of those areas are 225, 244 and 233. Also the 4th order of rank was found in Bogra and Rajshahi while in Dinajpur, the rank order was 3rd. It meant that the risk of adaptation barrier is much higher in those study areas.

Table 6.1: Barriers of adaptation

Barriers	Adaptation Barriers in Bogra						Adaptation Barriers in Dinajpur						Adaptation Barriers in Rajshahi					
	F (3)	O (2)	R (1)	N (0)	PCI	Rank Order	F (3)	O (2)	R (1)	N (0)	PCI	Rank Order	F (3)	O (2)	R (1)	N (0)	PCI	Rank Order
Lack of information/ knowledge	41	40	25	14	228	3	47	35	25	13	236	6	34	35	30	21	202	10
Lack of credit/money	39	57	14	10	245	2	47	42	17	14	242	5	46	50	22	2	260	3
Shortage of labor	21	63	21	15	210	6	38	55	20	7	244	4	10	57	32	21	176	12
Shortage of land	18	50	34	18	188	9	32	29	28	31	182	11	32	50	32	6	228	5
Lack of water	32	52	21	15	221	5	83	26	5	6	306	1	79	30	8	3	305	1
Poor soil quality	28	49	39	4	221	5	30	55	28	7	228	7	18	56	42	4	208	7
Shortage of farm inputs	11	46	46	17	171	11	26	48	36	10	210	9	17	28	65	10	172	13
Lack of farm animals/oxen	4	25	35	56	97	13	6	24	34	56	100	15	1	22	27	70	74	15
Practiced land tenure system	14	35	45	26	157	12	22	21	41	36	149	13	32	39	32	17	206	8
Traditional belief	8	22	28	62	96	14	14	32	18	56	124	14	4	27	27	62	93	14
Poor extension services	23	33	43	21	178	10	40	38	24	18	220	8	25	41	44	10	201	11
Lack of weather forecasting	12	60	38	10	194	7	14	56	33	17	187	10	7	74	35	4	204	9
Non availability of storage facilities	25	42	32	21	191	8	16	41	41	22	171	12	36	34	34	16	210	6
Absence of government policy on adaptation	52	45	16	7	262	1	65	33	14	8	275	2	59	39	19	3	274	2
Risk of adaptation	41	35	32	12	225	4	47	38	27	8	244	3	31	55	30	4	233	4

Note: F = Frequently, O = Occasionally, R = Rarely, N = Not at all and PCI = Problem confrontation index.

6.4 Conclusions

The present study shows that, there is variation of adaptation barriers in the study areas which may be due to the unobserved heterogeneity. Absence of government policy on adaptation, lack of credit/money, lack of water, risk of adaptation, shortage of labor, poor soil quality, and lack of weather forecasting are the main adaptation barriers irrespective of the three ground water depleted areas.

CHAPTER 7

SUMMARY, CONCLUSIONS AND POLICY RECOMMENDATIONS

7.1 Summary and Conclusions

The agriculture of Bangladesh is always vulnerable to unfavorable weather events like, increasing temperature, water stress and rainfall variability. The patterns of variability and effects are varied regarding regions. Frequent regional droughts in northwestern Bangladesh cause greater yield losses and it is a regular phenomenon in this regions. In the northwest Bangladesh, water stress driven environmental shock such as drought has been identified as the major constraint for farmers and act as a blockage for agriculture. The degree to which an agricultural system is affected by climate change related events depends on its adaptive capacity. Given the significance of changes in water for agriculture, farmers have developed adaptation and coping strategies as a general survival strategy. Furthermore, farmers' adaptation strategies depend on so many factors such as, socioeconomic, family characteristics, farm characteristics, and institutional factors. For that reason, it is utmost necessary to investigate the farmers' perception and adaptation strategies together with the barriers of adaptation, which will give cleat insights of the changing climatic situations. However, the is gender sensitivity in climate change and water stress perception and adaptation because women and men perceive and experience climate change differently, and usually women are more vulnerable due to their dependence on natural resources and structural inequity in their access and control of such resources. Given this backdrop, the endeavour of the present study is to examine the gender sensitive farmers' perception and adaptation strategies in ground water depleted areas of Northwest Bangladesh. To achieve the objectives, the study used multistage stratified random sampling techniques. Initially, three upazillas were selected from three districts; after that one union was selected from each of the district as sampling point and 6 villages were chosen from the selected unions. Some twenty farm households in each village were selected as sample.

The dataset ended up with 720 (i.e., 360 male respondents and 360 female respondents) valid observations from the three drought-prone and groundwater-depleted areas of Bangladesh. In addition, the study also analysed the secondary temperature and rainfall data to support the macro level evidence of a rise in temperature and water stress and a greater variability in rainfalls.

The empirical results showed that there is greater seasonal variability of climatic parameters. The temperature (i.e., annual and *kharif* season) of Rajshahi district increased dramatically whereas the rainfall and *Rabi* season temperature decreased sharply. Likewise, the annual and *kharif* season average maximum temperature of Dinajpur district rose rapidly whereas in *Rabi* season the average maximum temperature decreased slowly. The annual and seasonal average trends of temperature and rainfall of Bogra district shows that, the annual and *kharif* season average maximum temperature are leveled off, the *Rabi* season average maximum temperature dropped steadily. However, the annual and seasonal average minimum temperature increased gradually but the rainfall decreased slowly. Finally, it is vividly evident that, the climatic parameters (i.e. maximum temperature, minimum temperature, and rainfall) changes over the period of time.

The study asked farmers' perception about temperature, rainfall and water stress over the last 20 years. Out of 360 male and 360 female responses (i.e. husband and spouse) majority of the male and female revealed the perception of increasing temperature. About 92% male and 79% female mentioned that over the last 20 years the temperature is increasing whereas only 2% and 4% were claimed no change. Moreover, about 49% male and 27% female pointed out that the rainfall was decreasing over the last 20 years. Furthermore, both sexes think that, the patterns of rainfall exhibits huge changes, incorporating changes in the timing of rains, unexpected rainfall, rainfall with strong storms or winds, and finally rainfall with more thunderstorms and lighting. Majority of the farmers (i.e., both husband and spouse) believed that nature itself is responsible for drought. About

15% male and 11% female thought that drought is the consequence of both natural and manmade problems. Approximately, 70% male and 65% female argued that the drought occurs every year. Such an annual occurrence indicates that drought is the main barriers for agriculture in the Northwest Bangladesh. Various factors are responsible for climate change and water stress among which the study mainly focus on five factors based on the farmers' belief. About 49% male and 47% female argued that deforestation is the main reason for climate change and water stress. The respondents recognized pollution as the second cause followed by natural phenomenon and bush burning.

The second interest of this research is to point out the adaptation strategies. Based on the findings of this research, it can be concluded that short duration and drought tolerant rice varieties, supplementary irrigation for *Aman* and *Boro* rice, cultivation of non-rice *Rabi* crop and horticultural crops, and water harvesting techniques and improved irrigation channels are the main adaptation strategies in the study areas. The short duration and drought tolerant rice varieties are the main adaptation practices which occupies 29 percent of the respondents. The determinants of adaptation decisions reveal that age of the female, extension frequency, drought severity, and credit facilities are the influential factors for farm households' decisions to adapt to climate change and water stress. On the other hand, age of the male household head and household size are the negative factors for farmers' adaptation decision. Finally, the present study identifies the constraints for ensuring proper adaptation measures which will help to accelerate agricultural production in the Northwest Bangladesh. The adaptation barriers of the study areas are discussed according to the respective PCI score. The higher PCI score means the higher adaptation barrier in the study area. Lack of water achieved score 832 among the all barriers while the score of absence of government policy on adaptation, lack of credit, risk of adaptation and lack of information are 811, 747, 702 and 666 respectively.

7.2 Policy Recommendations

The findings of this study have several policy recommendations for creating an enabling environment for adaptation to climate change and water stress in Northwest Bangladesh. These include easier access to relevant information, wider access to female education and ensuring institutional support (i.e., credit facilities) for the farmers'. In addition, with these policies, priority has to be given on gender issues. At the time of designing and implementing climate change adaptation strategies, it will be rational to consider the gender specific differences. Finally, region specific government policy on adaptation has to be ensured as it is termed as the second adaptation barriers in the study areas.

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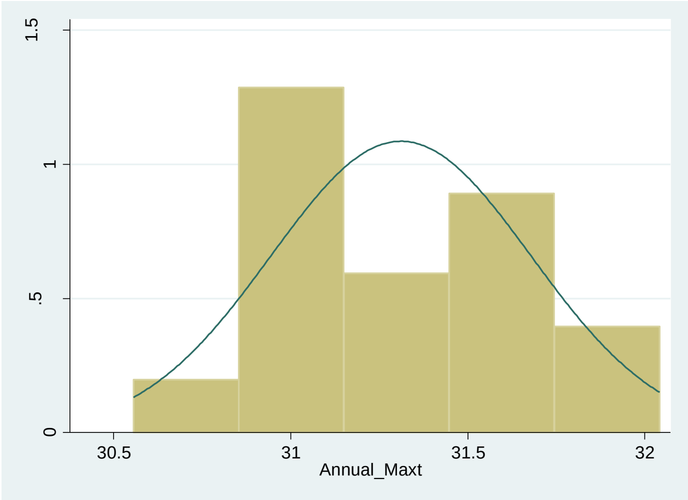
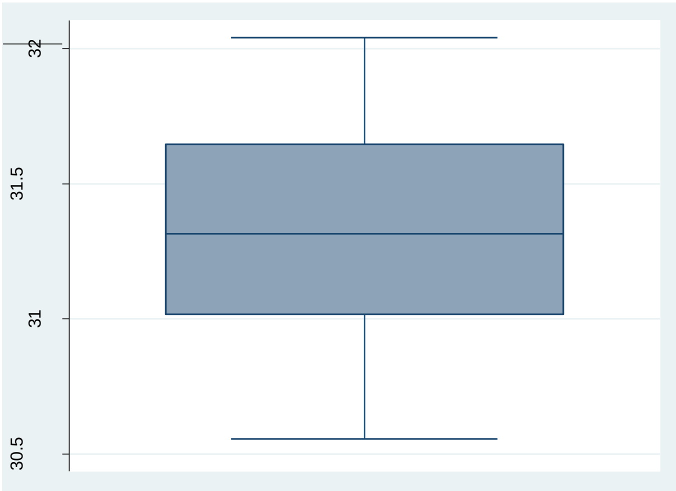
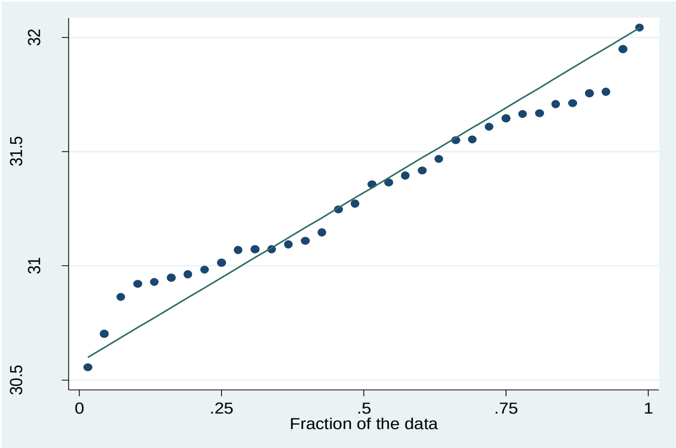
APPENDIX

Appendix A: Distribution of Dependent Variables

A.1: Rajshahi Maximum temperature





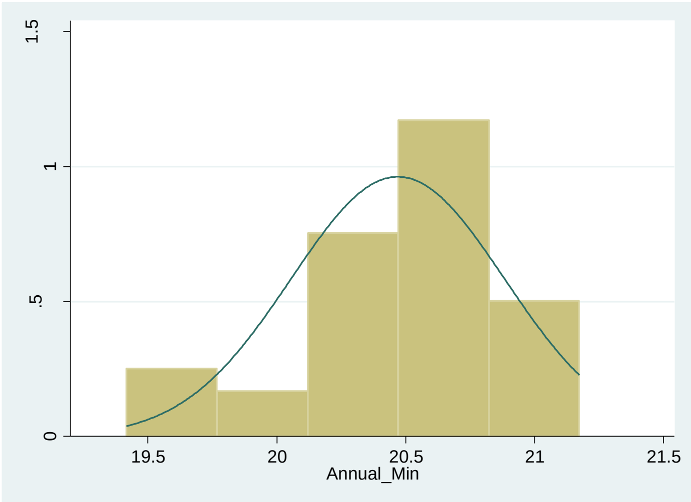


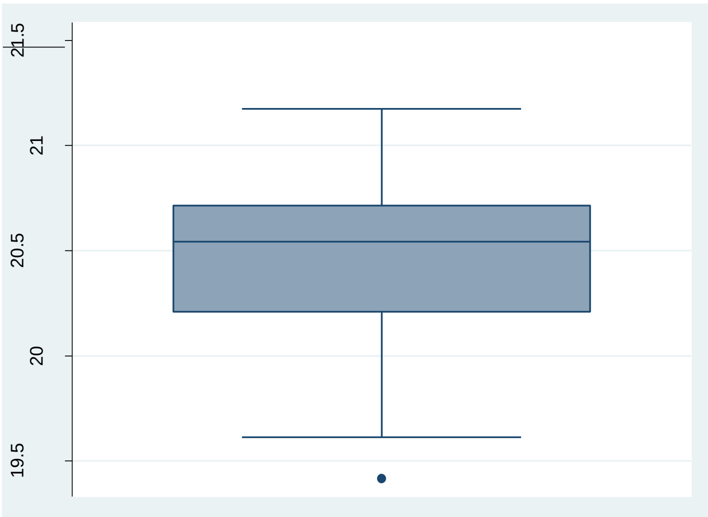
. swilk Annual_Maxt

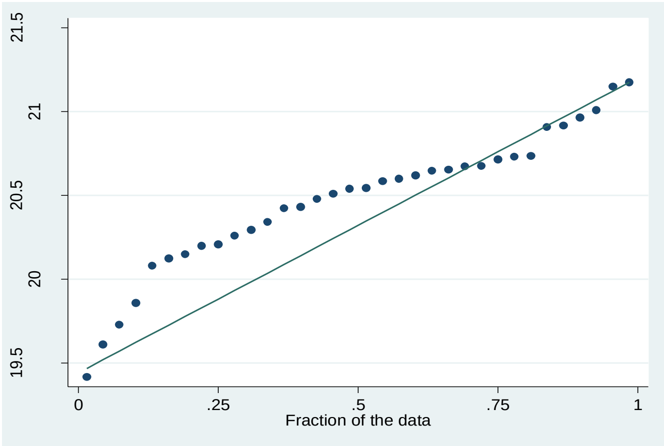
Shapiro-Wilk W test for normal data

Variable	Obs	W	V	z	Prob>z
Annual_Maxt	34	0.97236	0.965	-0.074	0.52943

A.2: Rajshahi Minimum temperature





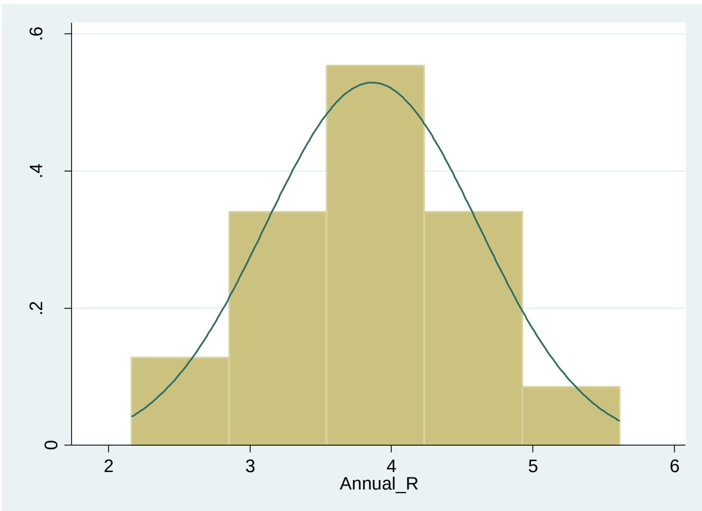


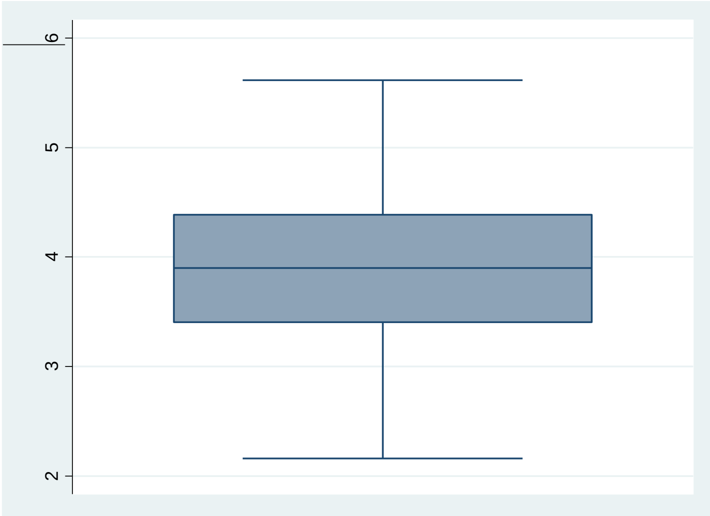
. swilk Annual_Min

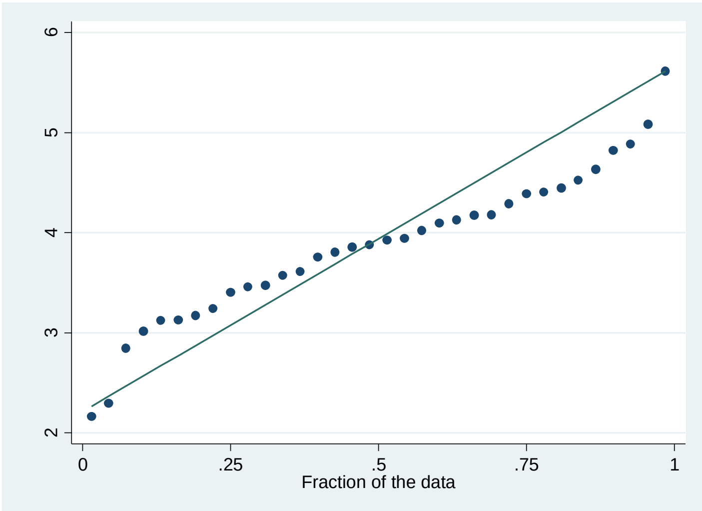
Shapiro-Wilk W test for normal data

Variable	Obs	W	V	z	Prob>z
Annual_Min	34	0.96304	1.290	0.531	0.29759

A. 3: Rajshahi_Rainfall





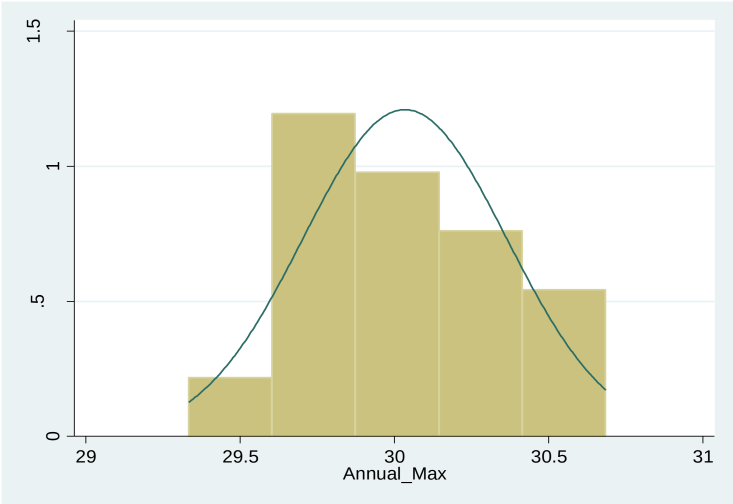


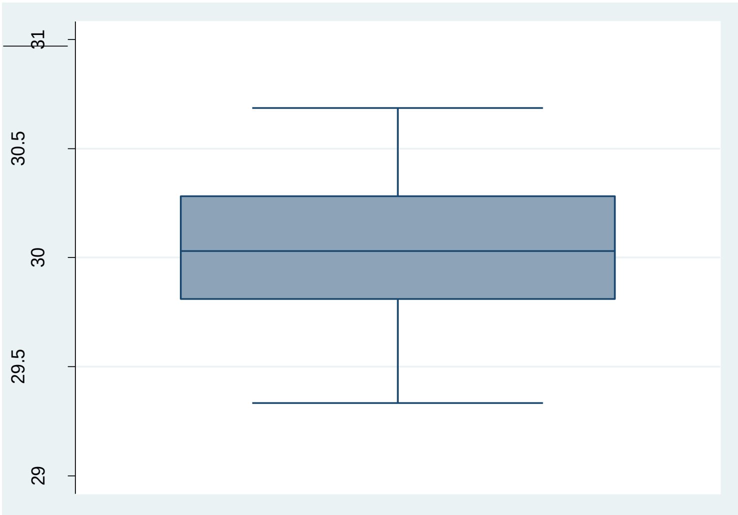
. swilk Annual_R

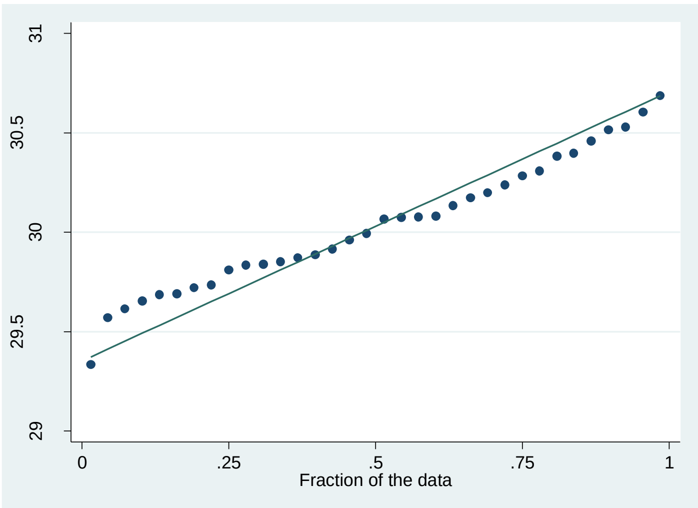
Shapiro-Wilk W test for normal data

Variable	Obs	W	V	z	Prob>z
Annual_R	34	0.99128	0.304	-2.478	0.99339

A.4: Dinajpur Maximum temperature





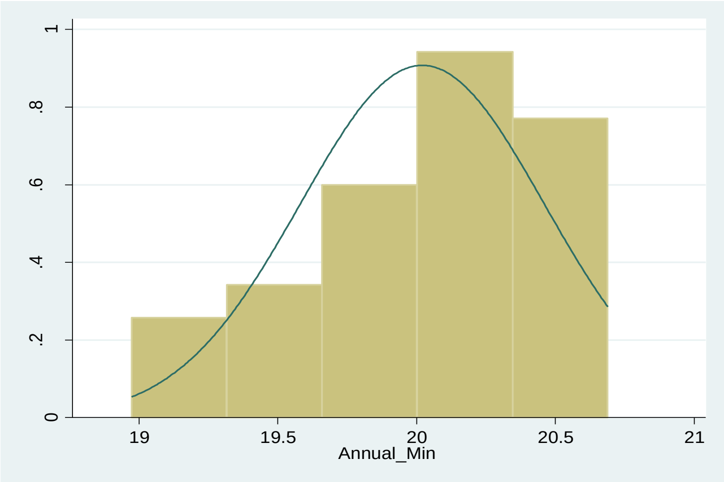


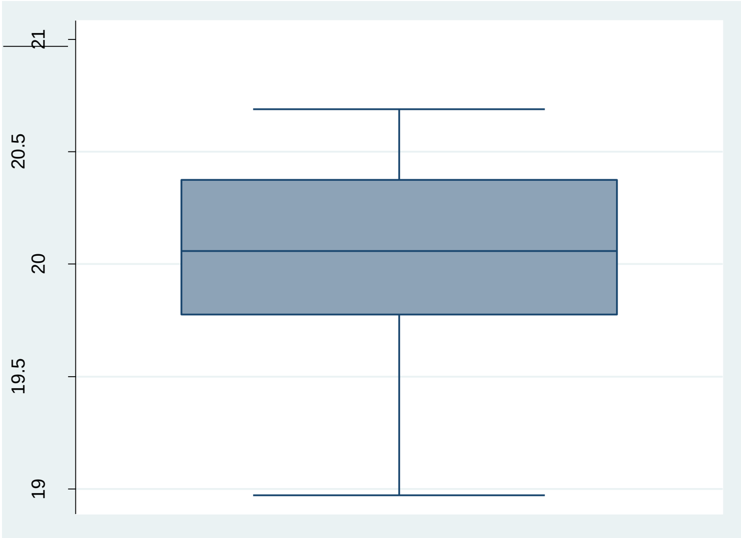
. swilk Annual_Max

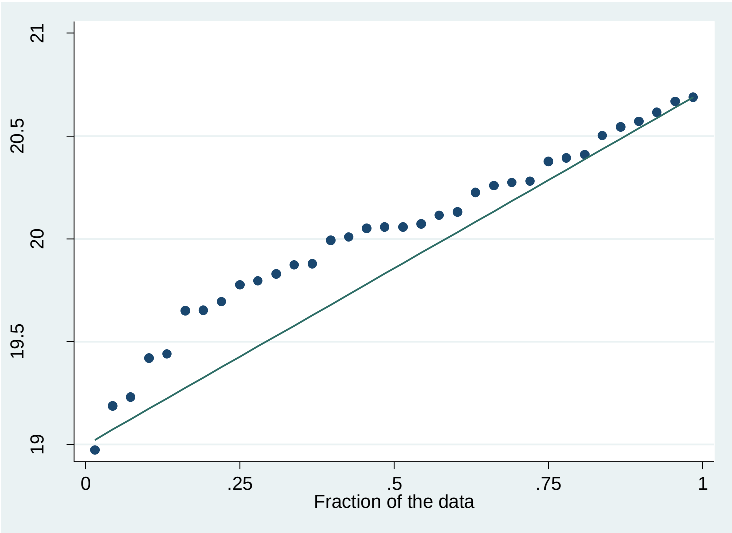
Shapiro-Wilk W test for normal data

Variable	Obs	W	V	z	Prob>z
Annual_Max	34	0.98190	0.632	-0.956	0.83049

A.5: Dinajpur Minimum temperature





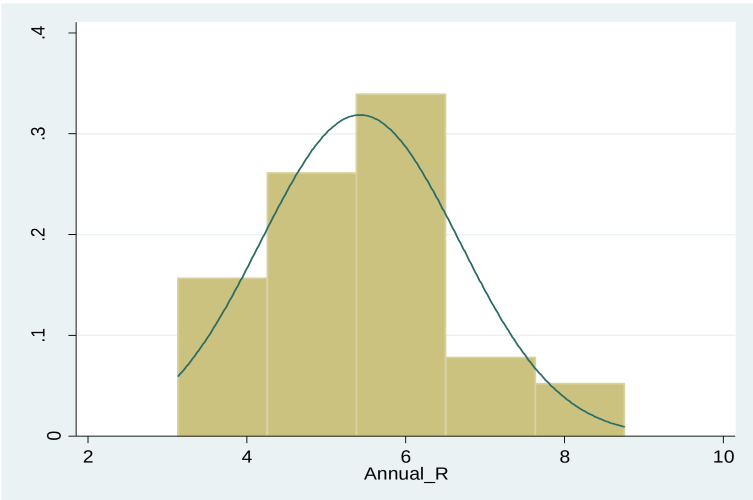


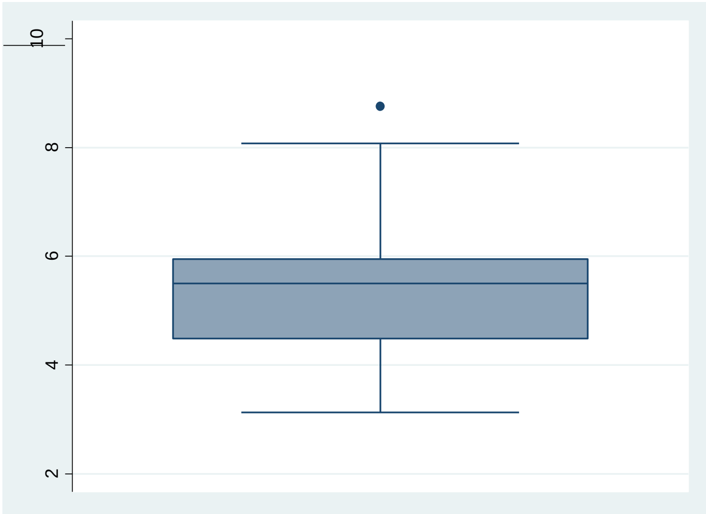
. swilk Annual_Min

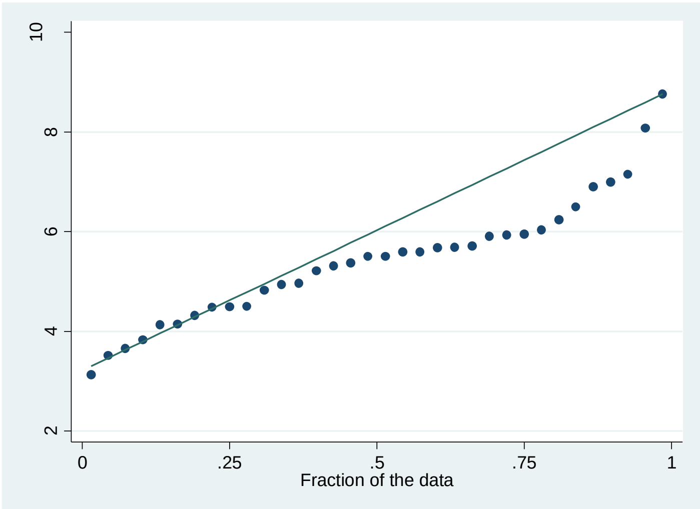
Shapiro-Wilk W test for normal data

Variable	Obs	W	V	z	Prob>z
Annual_Min	34	0.96503	1.221	0.416	0.33874

A.6: Dinajpur Rainfall





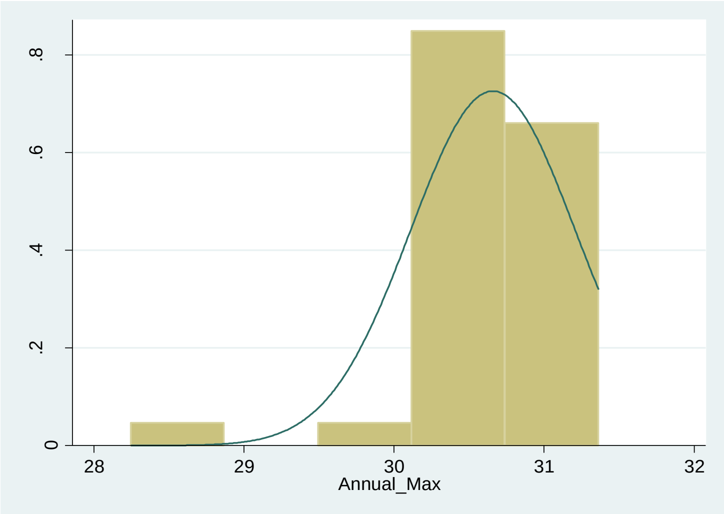


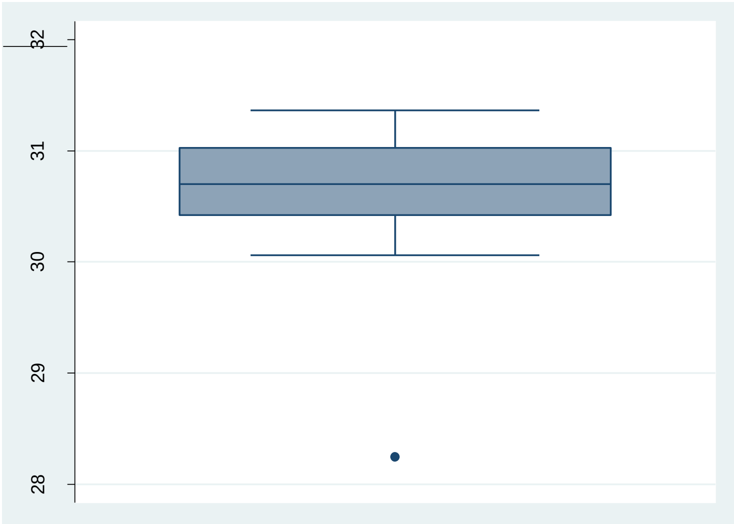
. swilk Annual_R

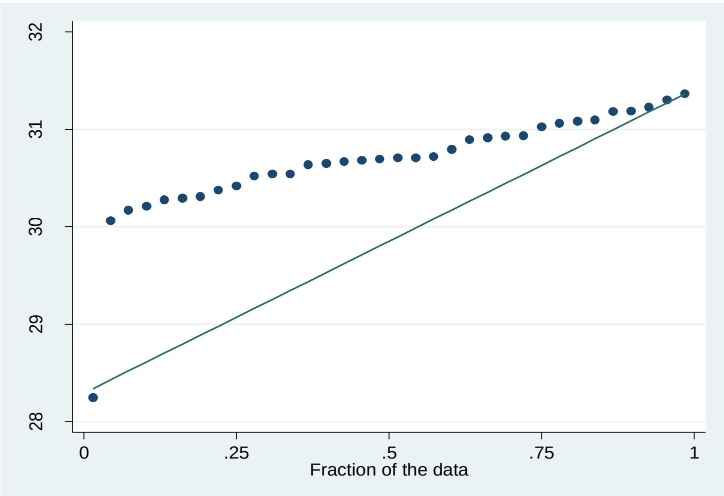
Shapiro-Wilk W test for normal data

Variable	Obs	W	V	z	Prob>z
Annual_R	34	0.97198	0.978	-0.046	0.51816

A.7: Bogra Maximum temperature





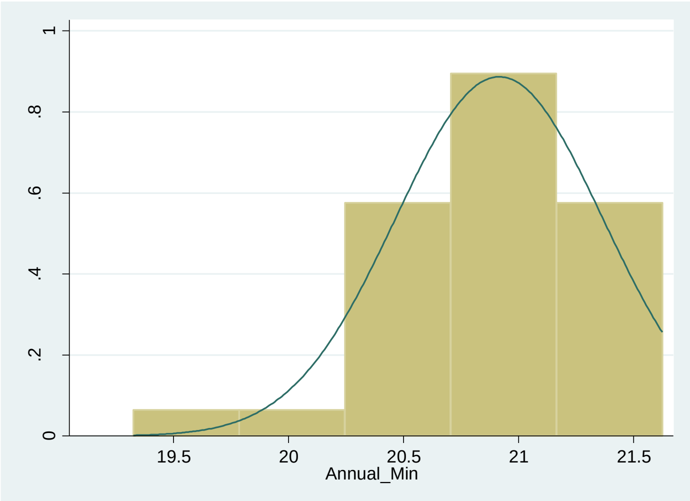


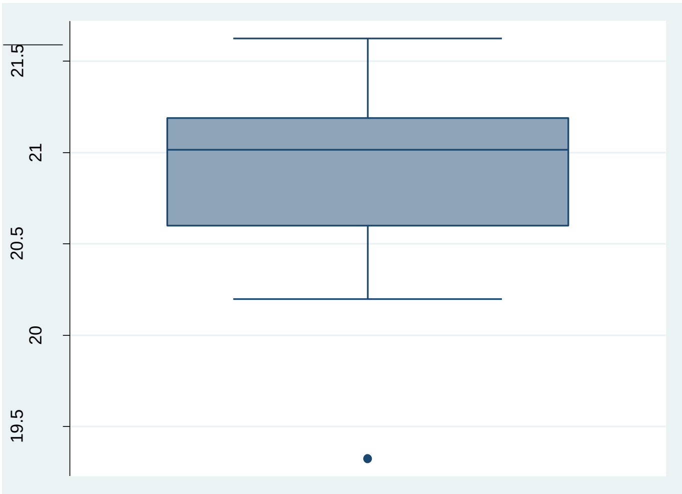
. swilk Annual_Max

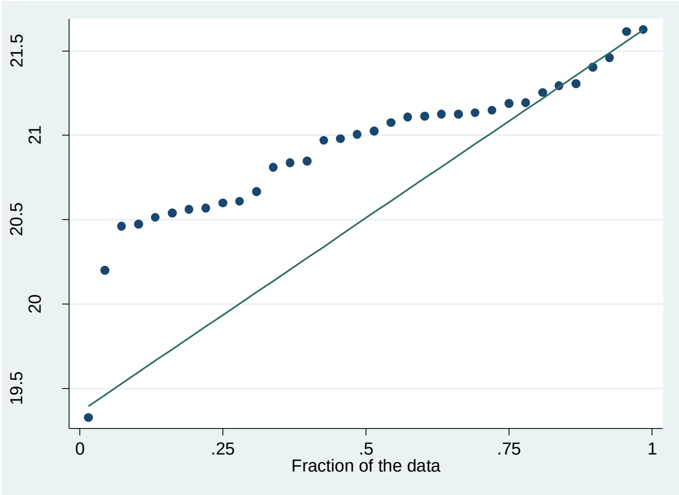
Shapiro-Wilk W test for normal data

Variable	Obs	W	V	z	Prob>z
Annual_Max	34	0.78190	7.616	4.230	0.00001

A.8: Bogra Minimum temperature





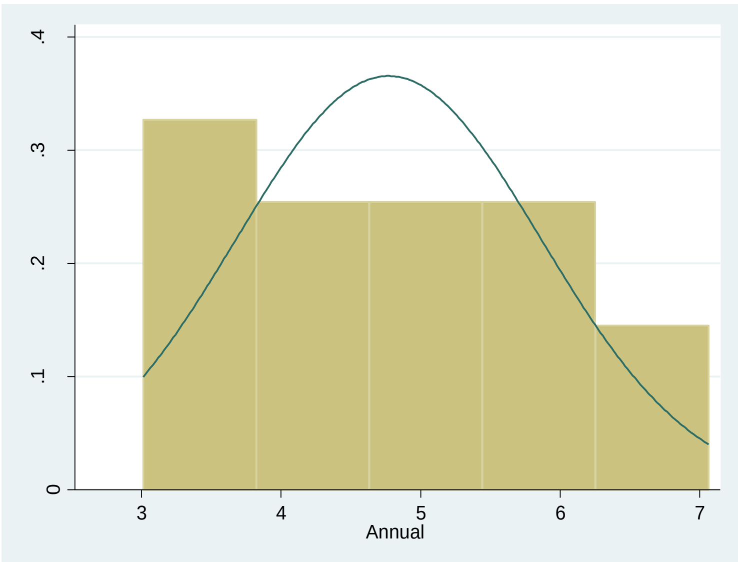


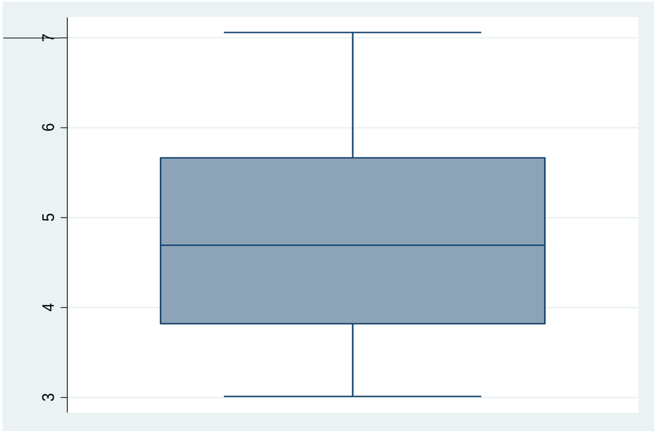
. swilk Annual_Min

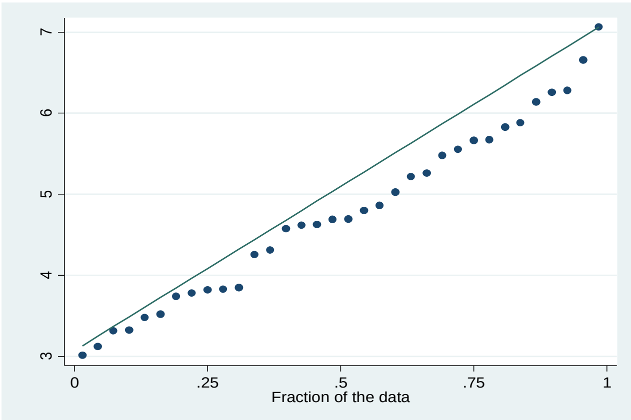
Shapiro-Wilk W test for normal data

Variable	Obs	W	V	z	Prob>z
Annual_Min	34	0.90966	3.155	2.394	0.00834

A.9: Bogra Rainfall







. swilk Annual

Shapiro-Wilk W test for normal data

Variable	Obs	W	V	z	Prob>z
Annual	34	0.96812	1.113	0.223	0.41175

Appendix B

B.1: Augmented Dickey-Fuller (ADF) test for determining the stationarity of the data series.

Variables	Rajshahi			Dinajpur			Bogra		
	Annual	Kharif Season	Rabi Season	Annual	Kharif Season	Rabi Season	Annual	Kharif Season	Rabi Season
Maxt	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
Mint	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
Rainfall	I(1)	I(1)	I(1)	I(1)	I(1)	I(0)	I(1)	I(1)	I(1)