AGRICULTURAL VULNERABILITY AND ADAPTATION TO CLIMATE CHANGE: A CASE OF RICE FARMERS IN THE SOUTHERN PART OF BANGLADESH

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CERTIFICATE

This is to certify that thesis entitled, **"AGRICULTURAL VULNERABILITY AND ADAPTATION TO CLIMATE CHANGE: A CASE OF RICE FARMERS IN THE SOUTHERN PART OF BANGLADESH"** submitted to Department of Agricultural Economics under the Faculty of Agribusiness Management, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURAL ECONOMICS,** embodies the result of a piece of bona fide research work carried out by **FAIJUL ISLAM** bearing Registration No. **10-04020** under my supervision and guidance. No part of the thesis has been submitted for any other degree.

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

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ABSTRACT

This study is motivated by the susceptibility of rice farming to climate change and partly by the limited studies on this topic in Bangladesh. The study has investigated the socioeconomic condition, adaptation strategies, barriers to adaptation as well as influencing determinants of adaptation strategies of costal rice farmers using survey data of 120 households through simple random sampling from two costal Upazillas namely Betagi under the district of Barguna and Golacipa under the district of Patuakhali of Bangladesh. Different statistical analysis including Multinomial Logistic (MNL) model are employed to fulfill the objectives of the study. The results reveal that salinity, cyclones & storms, and flood are the major vulnerabilities of the households. The farmers have perceived a gradual increase in temperature but abnormality in rainfall which has serious impact on rice production. Most of the farmers have experienced food scarcity during the months of Agrahayon, Poush, Ashwin and Kartik due to lack of employment opportunities in the area. Farmers have taken a range of adaptation strategies to reduce the adverse impact of climate change. The major adaptation strategies are direct-seeded rice, supplementary irrigation, cultivation of HYV, adjusting planting calendars and techniques, livestock, duck and poultry rearing, and cultivation of non-rice crops. However, lack of weather forecast information, lack of knowledge concerning appropriate adaptation and poor information on early warning systems are among the important barriers to adaptation.

The results of MNL model indicate that farming experience, access to agricultural credit, access to electricity, access to information and extension services have significant influence on the choice of adaptation strategies. Government policy should target improving farmers' access to credit, electricity and extension services, and provide HYV varieties suitable for the local condition to enhance the adaptation capacity of the vulnerable rice farmers.

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LIST OF ABBREVIATIONS AND ACRONYMS

AIC	Agricultural Information Centre
BADC	Bangladesh Agricultural Development Corporation and
BSRRSO	Bangladesh Space Research and Remote Sensing Organization
BARC	Bangladesh Agricultural Research Council
BBS	Bangladesh Bureau of Statistics
BCCSAP	Bangladesh Climate Change Strategy and Action Plan
BINA	Bangladesh Institute of Nuclear Agriculture
BRRI	Bangladesh Rice Research Institute
DAE	Department of Agricultural Extension
et al.	and others (at elli)
FAO	Food & Agriculture Organisation
FGD	Focus Group Discussion
GCM	Global Climate Model
GDP	Gross Domestic Product
GoB	Government of Bangladesh
HYVs	High yielding varieties
IIA	Independence of irrelevant alternatives
IPCC	Intergovernmental Panel on Climate Change
IWRM	Integrated Water Resource Management
JSC	Junior School Certificate
KII	Key Informant Interview

MNL	Multinomial logit
NAPA	National Adaptation Program of Action
NCSA	National Capacity Self-Assessment
NGOs	Non Government Organizations
No.	Number
PSC	Primary School Certificate
SAAOs	Assistant Agricultural Officers
SPSS	Statistical Package for Social Sciences
sq. km	Square Kilometer
SSC	Secondary School Certificate
T. Aman	Transplanted Aman
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
VIF	Variance Inflation Factor
WB	World Bank

CHAPTER ONE
INTRODUCTION

1.1. Background

Bangladesh is only 147,570 km^2 in South Asia with a population density of about 1,115.62 persons/km2 (World Population Review, 2019). The country is considered as one of the most vulnerable countries to climate change (World Bank, 2013; IPCC, 2007). Extreme climatic hazards such as floods, sea level increase, cyclonic storm surges, riverbank erosion, saline intrusion, and drought present significant risks to the life, livelihoods, and food safety of 64 percent of the farm-dependent rural population (Alam, 2016; GoB, 2011; IPCC, 2007). Bangladesh ranks 160 out of 181 climate vulnerability nations as well as the 33rd most susceptible nation to climate change (GAIN, 2017).The topography and geographical location of Bangladesh makes it especially vulnerable to extreme weather occurrences such as hurricanes, floods and storm surges (MFAN, 2018). Its vulnerability is triggered not only by its biophysical variables (being a flat, small, delta nation subjected to floods and cyclones) (Ayers et al., 2014) but also by its socioeconomic variables (such as elevated agricultural reliance, population density, and poverty) (Thomas et al., 2013).

Bangladesh is an agricultural country. However, agriculture is highly susceptible to climate change. It is anticipated that climate change have a negative effect on agricultural yields in the 21st century through greater temperatures, more variable rainfall and extreme climate events such as floods, cyclones, droughts and rising sea levels (WB 2010; IPCC 2007; Isik & Devadoss 2006; Molua, 2002). Rice is one of the most important crop to feed the increasing population of the world (Shimono et al., 2010). More than half of the world's population lives on rice (Maclean and Dawe, 2002). Rice is a staple crop in Bangladesh (Alauddin and Quiggin, 2008). Thus, any decrease in rice production due to climate change would seriously impair the country's food safety issue. Consequently, quantifying the impacts of climate change on rice farming and evaluating rice farmers’ ability to adapt to climate change are subjects of pressing research.

1.2. Climate change and rice cultivation in Bangladesh

Bangladesh is an agrarian nation. Agriculture sector plays an important role in the overall economic development of Bangladesh. Rice is that the staple food for concerning166 million individuals of the country. The agricultural sector (crops, animal farming, forests, and fishing) contributes 14.23 percent to the country’s GDP, provides employment about 40.62 percent of the labour force (Bangladesh Economic Review, 2018). The population is increasing about 2 million every year, and if the population increments in light of present conditions, the all-out population will be 38 million by 2050 (Shelly et al., 2016). Climate change and its impact on rice farming is not the latest occurrence in the context of Bangladesh. Average temperature increases with constant dry spells before and during the rainy season, greater seasonal rainfall variability and heavy successive downpour at the end of the monsoon are frequently observed (Kabir et al., 2017). The potential for tropical cyclones and floods continues to increase in coastal salinity-prone regions, with 10 percent of the region is 1 meter above sea level and greater exposure to tidal excursions (Ali, 1999).

However, during the period 2009-2012, the nation could considerably boost rice output by cultivating high yielding varieties and maintaining the growths. Rice cultivation for most Bangladeshis is the cornerstone of Bangladesh's economy and a significant diet. Rice is cultivated in Aus season (mid-March–August), Aman season (end of June–beginning of January) and Boro season (mid-November–mid-June) in Bangladesh (BBS, 2014). Apparently, boro season productivity is continually growing based on an extensive irrigation system, but water scarcity threatens it. In addition, extensive monsoon irrigation places pressure on the accessibility of soil and surface water (Alauddin and Quiggin, 2008). Optimum temperatures for maximum photosynthesis range from 25 °C to 30 °C for rice under the climatic conditions of Bangladesh (Basak, 2010).

Rain-fed T.aman rice is also susceptible to enhanced variability in rainfall and heavy runoff from time to time. The arable land is constantly decreasing during the Aus season owing to low productivity and constant and extremely dry periods in summer (Islam et al., 2017; Sarker et al., 2014; Ruane et al., 2013).

Temperatures in Bangladesh have increased over the previous three centuries (GOB & UNDP, 2009), especially during the monsoon season, and they have increased by 0.7ºC per decade across Bangladesh (Ahsan et al., 2011). By 2030 the average temperature would rise by 1°C and by 1.4°C by 2050 (IPCC, 2007; FAO, 2006). Rainfall is extremely variable and the distribution has been increasingly uneven (Ahsan et al., 2011). The number of days without rain is increasing, although the total annual rainfall remains almost the same. Rainfall produces extreme events like floods and droughts which have noticeably adverse impacts on rice yields and production of Aman rice was declined by 20% to 30% in the northwestern region in 2006 when a drought occurred (UNDP, 2007; GOB & UNDP, 2009). Since independence in 1971, the country has experienced 12 severe droughts, which affected nearly 50% of the land area (Shahid & Behrawan, 2008; Ahmed, 2006). The Barind Tract (a northwestern upland region with hard red clay soil) is expected to be at higher risk of droughts by 2050, due to a potential temperature rise of 2°C and a 10% drop in precipitation (FAO, 2007; FAO, 2006). Rice growing calendar is shown in Figure 1.2a The production of rice has been increased over the years in Bangladesh (Figure 1.2.b).

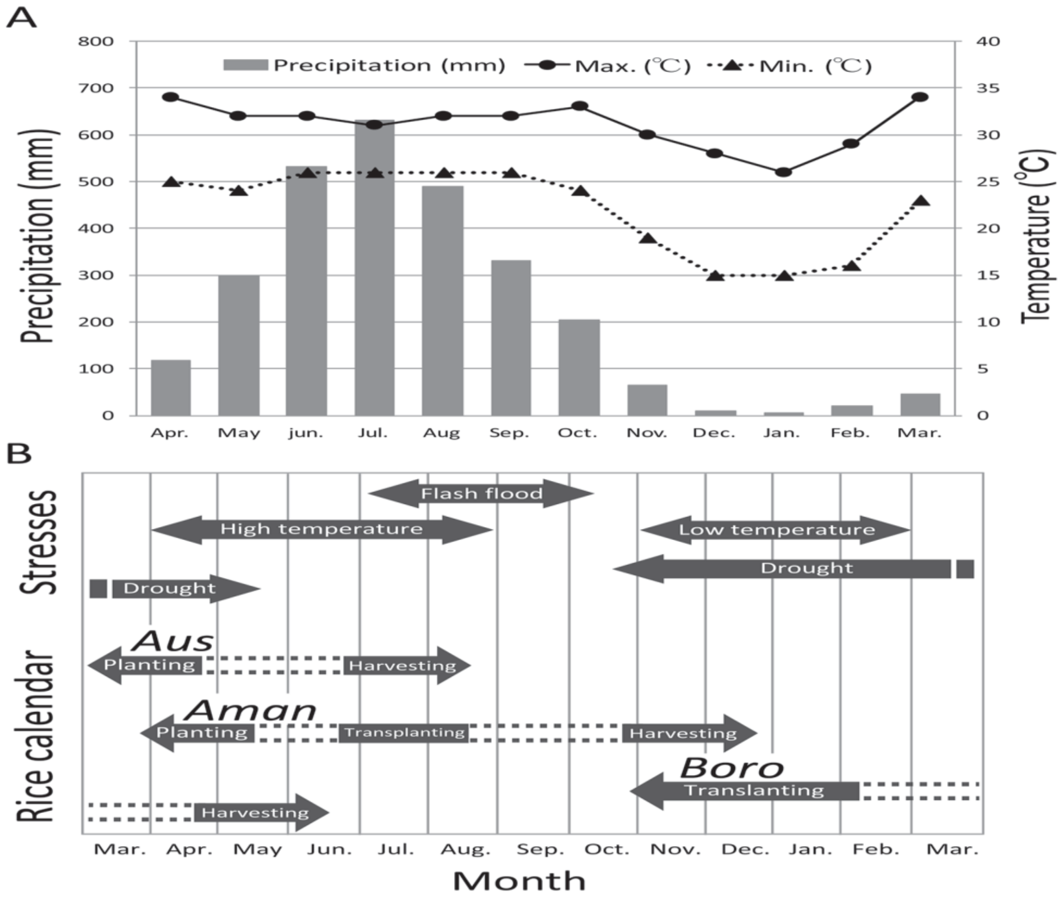


Fig 1.2.a : Agro climatic conditions and rice calendar of Bangladesh.

A. The line graph (continuous line) shows monthly maximum temperature (°C) and the broken line shows monthly minimum temperature (°C); the bar graph showing the mean monthly precipitation (mm) throughout the year.

B. The above block arrows indicate the different kinds of stresses induced by the agro climatic parameters throughout the year and the lower block arrows with dashes represents the rice crop calendar of Bangladesh.

Source: Adapted from Shelley et al. (2016).

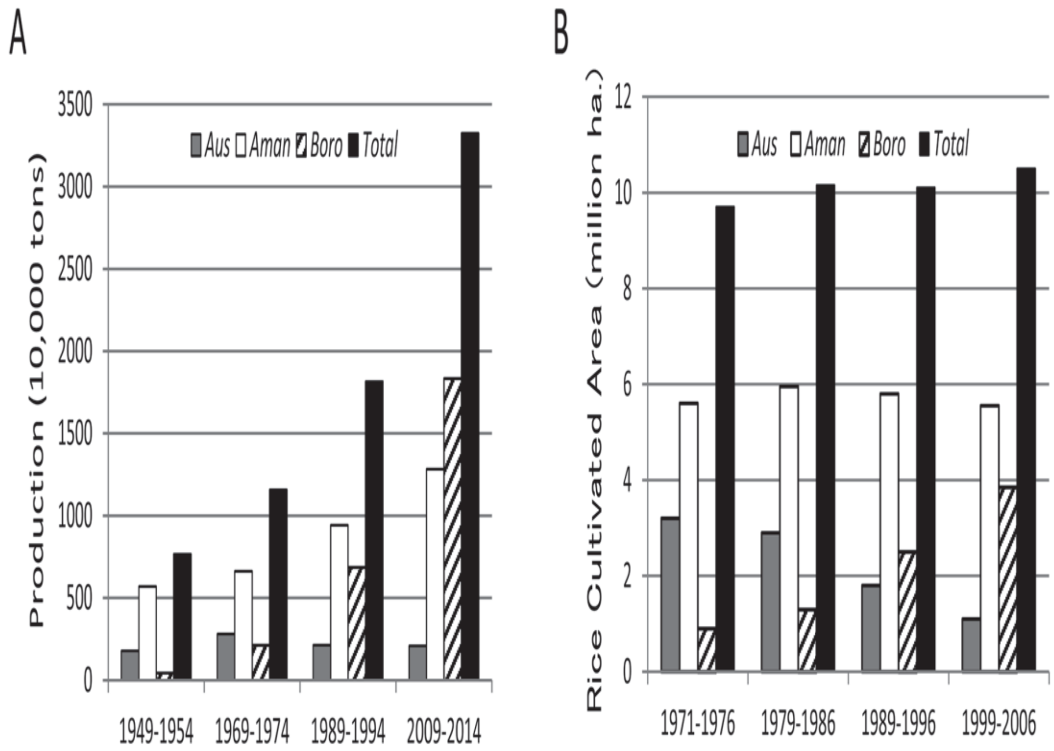


Fig 1.2.b. Trends of rice production and rice cultivated area over time in Bangladesh.

A. Production of rice in different growing seasons i.e., aus, aman, and boro and total production of rice for the period 1949 to 2014.

B. Trend of rice cultivated area in different growing seasons and total cultivated area for the period 1971 to 2006.

Source: Adapted from Shelley et al. (2016).

1.3. Adaptation strategies and vulnerability of farmers

Adaptation to climate change and variability refers to the adjustments in human-environment systems in response to actual and/or anticipated climatic conditions to avoid or to alleviate related risks or to realize potential opportunities (IPCC, 2007; IPCC, 2014; IPCC, 2007).

The government of Bangladesh is committed to reducing the vulnerability of climate change. The National Adaptation Program of Action (NAPA) was launched in 2005. It has identified 15 priority activities with a special focus on agriculture and water resources.

The National Capacity Self-Assessment (NCSA) for implementing the provisions of multilateral agreements, including the UNFCCC and UNCCD, was launched in 2007. It has put a high priority on capacity building for climate change adaptation. The government prepared the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) in 2008 and revised it in 2009. The Sixth Five Year Plan approved in 2011 emphasized mainstreaming and strengthening climate change adaptation across various sectors including improved crop production practices, enhancing public awareness, climate research, and data collection.

Adaptation in rice farming includes disaster-tolerant and short-lived rice varieties, intensive irrigation, water-saving non-rice crop cultivation, integrated crop-farming, and homestead gardening (Alam et al.,2016; Arimi, 2014; Yu et al., 2010; FAO, 2006). Adaptation and cultivation of HYVs would decrease yield losses, combat pest assaults and illnesses, and at the same time boost yields.

Scholars mentioned that adaptation is one of the key policy options that determine the severity of the impact of climate change on agriculture (Lobell et al., 2008; Adger et al., 2003). Understanding the determinants of adaptive capacity is crucial to explaining the local autonomous adaptation process. All adaptation approaches require greater natural, social and economic resources and the adoption result for individual households depends on how access to the resources is distributed (McDowell and Hess, 2012).

Short-term adaptation could in the long run decrease farmers’ ability owing to increased input costs and volatility in crop prices (Kandlikar and Risbey, 2000).Adaptive measures that are capital-intensive and market-oriented increase social inequality and injustice (Hunsberger et al., 2015). Multiple vulnerabilities are asserted to limit adaptive capacity and decision-making (Agrawal, 2010).

Farmers are vulnerable to climate change and their adaptation policies mostly depend on their pre-existing access to financial, institutional, social, financial, institutional and political resources (Agrawal, 2010; Ribot, 2010; Adger et al., 2003). Thus one family may lose adaptive capacity when one’s falls into livelihood stress in changing climate. Limited access to information on climate change and adaptation policies, restricted access to resources, irrigation facilities, and inadequate land ownership are the major adaptation obstacles in the nation (Alam et al., 2018b; Delaporte and Maurel, 2016; Alauddin and Sarker, 2014; Arimi, 2014; Sarker et al., 2013; Deressa et al., 2009). Living shocks faced by tiny, marginal and landless farmers make them engage in off-farm operations, wage labour, bonded labour, and even migration (Alam et al., 2018b; Kabir et al., 2017).

Adaptation is emerging as a key policy response for reducing the adverse effects of climate change, and to protect the livelihood and food security of poor farmers (Alam et al., 2018a; IPCC, 2014; World Bank, 2013; Green and Raygorodetsky, 2010; Adger et al., 2009; Lobell et al., 2008). However, poor households' local adaptation strategies are often overlooked and not included when developing adaptation strategies (Nelson, 2011; Christoplos et al., 2009; Folke, 2006). Actions like government intervention are crucial in ensuring the sustainability of farm-level adaptations of the poor farmers (Stringer et al., 2009; Smit and Pilifosova, 2001). Farmers' adaptation strategies can be influenced by a range of factors, which are crucial for identifying appropriate options for enhancing adaptation.

Therefore, this study particularly focuses on to assess the livelihood condition of the costal rice farmers and their adaptation choices. There is limited research on adaptation in Bangladesh particularly for rice farmers' adaptation. The information is crucial to formulating and implementing an effective and sustainable adaptation policy in Bangladesh.

1.4. Objectives of the study

This main objective is to assess the livelihood condition and adaptation strategies of rice farmers in the coastal areas of Bangladesh. The specific objectives are:

i. To assess the livelihood status of the respondents;
ii. To assess the farmers perceptions of climate change and variability;
iii. To determine the barriers to adaptation; and
iv. To determine the factors affecting adaptation strategies of the farmers.

1.5. Research questions

The following research questionnaire set to address the objectives:

(i) What is the livelihood condition of the rice growers?;
(ii) What is the perception of climate change and variability of the households?;
(iii) What is the impact of climate change on their food security?;
(iv) What are the barriers to adaptation?; and
(v) What are determinants affecting adaptation strategies of the farmers?

1.6. Conceptual framework

Greenhouse gases emissions from human activities are responsible for climate change (Li et al., 2011; IPCC, 2007). Climate change leads to increased temperatures, changing rainfall patterns and amounts, and a higher frequency and intensity of extreme climate events such as floods, cyclone, droughts, and heat wave (Roudier et al., 2011; Tirado et al., 2010; IPCC, 2007). Temperature increases and erratic rainfall patterns affect crop agriculture most directly and adversely (Alam et al., 2018b; Lansigan et al., 2000; Rosenzweig & Tubiello, 2008; Almaraz et al., 2008). Changing climate over time affects rice crop production adversely (Behnassi, 2011).

The channels of the impacts of climate change are depicted in Figure 3. Changes in climate generally involve changes in two major climate variables: temperature and rainfall. The increase in temperature shortens the phenological phases of crops (such as planting, flowering and harvesting) (Roudier et al., 2011; Teixeira et al., 2011; Liu et al., 2010) and affects plant growth and development. The fluctuations and occurrence of extreme climate events reduce rice yields significantly, particularly at critical crop growth stages (Teixeira et al., 2013; Lansigan et al., 2000).

Rainfall extremes, through droughts and floods are very detrimental to rice productivity. Higher and/or heavy rainfall results in higher yield losses through flooding (Roudier et al., 2011; Reid et al., 2007; Rosenzweig et al., 2002). In contrast, insufficient rainfall leads to greater drought frequency and intensity, while increased evaporation leads to complete crop failure (Liu et al., 2010; Reid et al., 2007). To develop the concept of climate change, clarification of some term is given in Appendix A.

Conceptual framework of the study

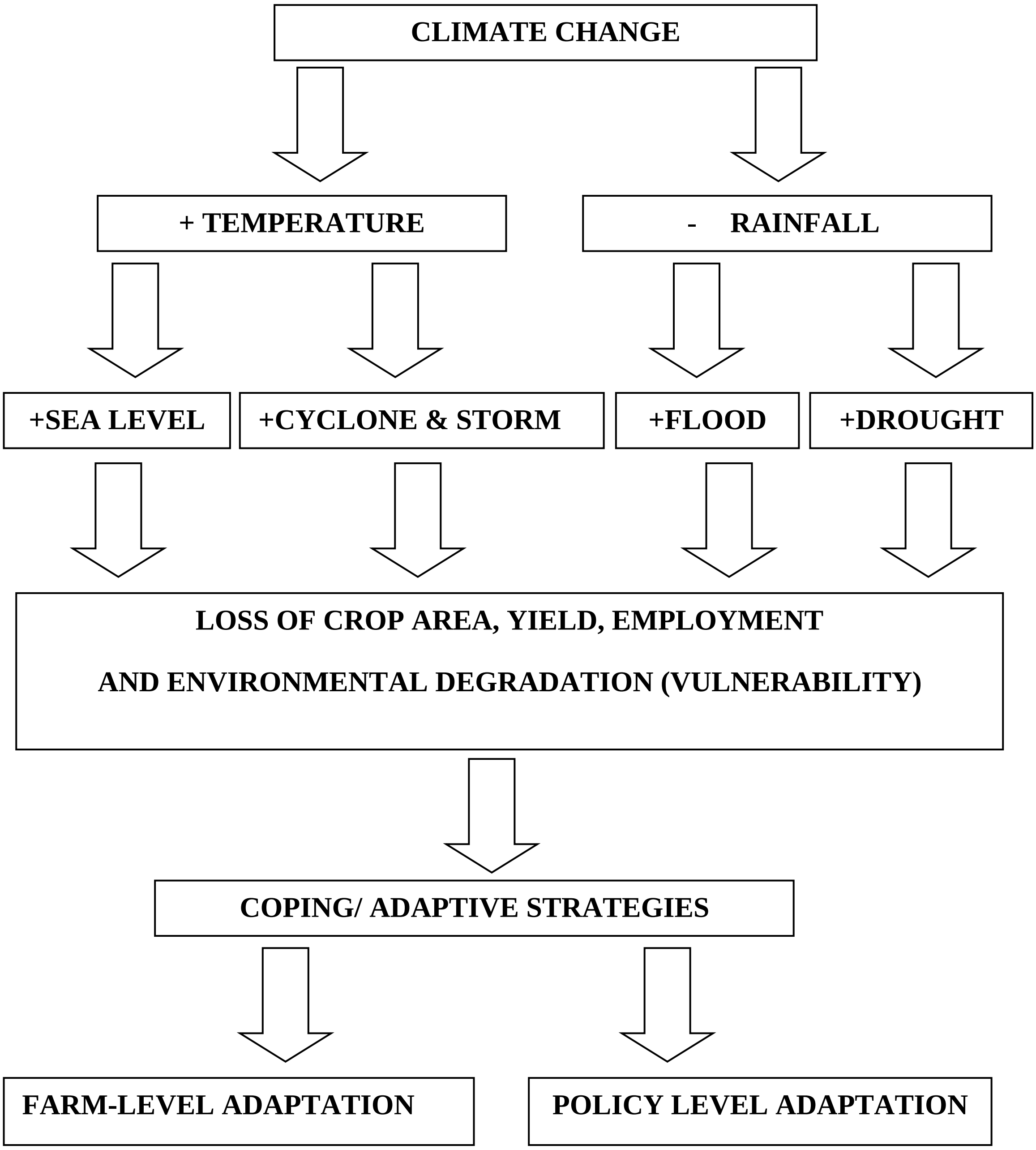


Figure 1.6.: Conceptual framework of the study.

Overall, temperature and rainfall changes reduce the cropped area, production level and yield. This reduction or fluctuation in rice yield warrant farmers' adaptability to minimize these adverse effects. However, adaptation strategies at the farm level vary from area to area and from farm to farm. Farmers' adaptive capacity is determined by their socio-demographic characteristics, farm characteristics and accessibility to institutional factors. These adaptation strategies can be farm level (autonomous) and/ or planned (government policy). This study assesses the adaptation strategies and barriers to adaptation of costal rice farmers in Bangladesh.

1.7. Contribution of the research

The contributions of this study are manifold. These are discussed below:

The mainstay of Bangladesh's economy is rice farming - the primary food source but highly susceptible to climate change issues. There is hardly any comprehensive study on agricultural vulnerability and adaptation to climate change on rice farmers in Bangladesh using standard econometric tools. The study will contribute in the body of literature through analyzing the livelihood condition, adaptation strategies and barriers to adaptation of the vulnerable costal rice farmers in Bangladesh. This study will provide important policy inputs to promote adaptation at the farm level and thus contribute to ensure food security of the country.

1.8. Organization of the thesis

In addition to this introductory chapter, the remainder of this paper is organized in five chapters.

Chapter 2 reviews the literature on climate change, farmer perception about climate change, adaptation strategies and their determinants and farmer vulnerability studies. This chapter also identifies gaps in the existing literature.

Chapter 3 outlines the detail of methodology employed in the research including a description of the study area, data source, analytical approach, model specification.

Chapter 4 describes the results and discussion of livelihood status, demographic information, farmer perception about climate change, food status throughout the year, barriers of adaptation and adapt to adaptation and the specified empirical models assessing the determinants of choices of adaptation strategy.

Chapter 5 concludes the study with policy implication and future research directions.

CHAPTER TWO
REVIEW OF LITERATURE

2.1. Introduction

This chapter outlines a detailed review of literature on climate change and its impact on agriculture particularly rice cultivation, adaptation strategies and vulnerability of farmers both in Bangladesh and global context. The gaps in the existing literature are discussed in Section 2.3.

2.2. Adaptation strategies and vulnerability of farmers to climate change

Minar et al. (2018) said that particularly at-risk coastal environments include mangroves, marsh deltas, low-lying coastal plains, sandy beaches, coastal wetlands, estuaries, and coral reefs. There are two choices for minimizing the mitigation and adaptation effects. Mitigation and adaptation options for Bangladesh need to be considered, although the nation has very restricted mitigation scope. That's why mitigation includes executing worldwide initiatives, and more local adaptation.

Amin (2018) recognized the potential for climate-resilient alternative livelihood practices to decrease climate change effects. Five focus group discussion (FGD) and 120 surveys were performed and interpreted for this research. Results indicated that housework and fishing were the most significant income-generating industries in Sreepur, Char phenua, Char mahisha, Elisha koralia under the Barisal district of Mehendiganj upazilla. This research indicates the prospect of climate-resilient alternative livelihood practices by evaluating the perceived fiscal importance of the loss of livelihood owing to absence of climate resilience and natural loss.

Alam et al. (2017a) created a holistic strategy to evaluate the vulnerability of 380 resource-poor rural riparian homes from char and river-bank populations in

Bangladesh, and tailored two main vulnerability assessment methods to the Livelihood Vulnerability Index (LVI) and the Climate Vulnerability Index (CVI) to integrate local and indigenous knowledge in the choice of sub-sub-specific expertise. The values of LVI and CVI were discovered to differ between char and river bank societies, with families living in char lands showing the most vulnerability to climate change. This research discovered that riparian homes were susceptible owing to their relative inaccessibility and low living status, which is linked to climate effects on river morphology, resulting in erosion and property loss.

Alam et al. (2017b) conducted research on perceptions of climate change and local adaptation policies of hazard-prone rural households in Bangladesh. Households acknowledged the impact of climate change on their livelihood assets, leading in an enhanced sense of vulnerability and resilience building. The research identified that significant approaches for adaptation include adopting new varieties of crops, altering planting times, homestead gardening, planting trees, and migration.

Alam (2017) studied vulnerability of riparian households in Bangladesh. The study used IPCC framework to assess the livelihood and climate vulnerability. The main drivers of vulnerability were found to be livelihood strategies and access to food, water and health facilities. Livelihood of the riparian households follow a vicious cycle of poverty. The study suggested for targeted policies and developmental approaches to enhance the adaptive capacity of char land and river-bank households across Bangladesh.

Kabir et al. (2017) noted a case study from a drought-prone village in western Bangladesh that investigated climate change trends and analyzed the dynamics, profitability and hazards of farmers ' adaptation. Adaptation interventions for farmers included modifications in crop systems, crop calendars, crop varieties, agricultural practices, crop diversification, and enhanced animal husbandry. Limited access to stress-tolerant varieties, extension facilities and accessible agricultural loans coupled with elevated manufacturing expenses, crop yield variability and output prices are the primary obstacles to adaptation. They proposed that for efficient adaptation to climate change, greater agricultural research and support facilities, accessible credit, community-focused farming education and training are crucial.

Haldar et al. (2017) performed a survey in 2014 in Khulna, three villages of Koyra upazilla that were significantly impacted by cyclone Aila on 25 May 2009. The research investigated the potential factors, local practices and coping strategies encountered by rice farming groups after cyclone Aila during their livelihood restoration cycle and discovered that at least 12 risks always disturb coastal farmers to grow rice, five of which have medium to elevated effects as a consequence of which rice farmers faced at least 16 distinct adaptation methods. Most importantly, it showed the statistical significance of production results in implementing various adaptation methods that affect rice output at a meaning rate of 5 percent. As a result, different adaptation options need to be strategically furnished as community-based practices for rice production along with the use of different inputs.

Sarker et al. (2017) used the Just–Pope production function structure to assess the impacts of climate change on the yields of rain fed Aman rice crops in Bangladesh, exposing that changes in peak temperatures have had beneficial and negative effects on yields in linear and quadratic functional types. The elasticity values in the balance function, however, verify that the peak temperature for Aman rice increases the risk while the minimum temperature is likely to reduce the variation in output. For Aman rice, rainfall has become increasingly risky.

Nahar (2016) created an aggregate farm household model to evaluate the effect on production, consumption, prices, welfare, and government's capacity to attain self-sufficiency in rice production of potential property loss and yields from climate change. The model is assessed on the Bangladesh rice market using information from the 2010 Household Income and Expenditure Survey in three alternative situations, and the findings showed that climate change contributes to productivity declines and national rice price increases.

Alam et al. (2016) evaluated the determinants of household adaptation decisions and the obstacles to adaptation of Bangladesh's 380 hazard-prone vulnerable households and concentrated on the impact of institutional access and social capital on adaptation decisions as a means of supporting and sustaining local adaptation. The results showed that family units were implementing adaptation policies, such as crop diversification, tree planting (adopted by big and medium-sized farmers) and household gardening and migration (adopted by tiny and landless farmers), just as hurdles to adaptation were observed heterogeneously among farming communities where access to credit and lack of information were observed of appropriate adaptation strategies.

Alam (2015) conducted a water scarcity research and droughts in many areas of the globe pose severe threats to farming communities ' livelihoods and the economy. This research explored the adaptation of rice farmers to water scarcity in a semi-arid climate in Bangladesh and identified variables that determine the adaptation response of farmers to address water scarcity. He showed that farmers with more farming experience, better education, and more safe tenure rights, better access to electricity and institutional equipment, and climatic impact consciousness are more likely to embrace alternative adaptation approaches.

Amin et al. (2015) tried to explore the impact of climate change (i.e. changes in peak temperature, minimum temperature, precipitation, moisture and sunshine) on the yield and crop region of four main food plants in Bangladesh (i.e. Aus rice, Aman rice, Boro rice and wheat). Heteroskedasticity and autocorrelation Consistent normal error (HAC) and feasible generalized least square (FGLS)) were used to determine climate-crop interrelations using information from time series at the domestic level for the period 1972–2010. Findings indicated that the impacts of all climate factors contributed significantly to the yield and crop region of main food plants with different variability between them. Maximum temperature statistically substantially impacted the output of all food plants with the exception of Aman rice and minimum temperature, but benefited from the yield and crop region of three other plants. Rainfall benefited considerably from the Aus rice crop region, but substantially impacted both Aman rice yield and crop area. Humidity has contributed statistically favorably to the output of Aus and Aman rice, but has had a statistically negative impact on the Aus rice crop region.

Huq et al. (2015) recognized and analyzed the effects of climate change, its cascading effects, and the effects of these effects on coastal Bangladesh's smallholder farming societies. Six communities of south-west coastal areas with physical and socio-economic vulnerability were researched. Using focus group conversations, a seasonal calendar, and historical transect analysis, primary information was gathered. The cumulative effects of the impacts of the first and second order triggered the impacts of the third order in the form of worsening property and circumstances of community livelihood.

Khan et al. (2015) examined the combined impacts of land-use modifications and natural disasters in Bangladesh's southwestern coastal region. Probit regression analysis was conducted to evaluate the connection with general revenue, agricultural output and outward migration between different disasters.

The assessment showed a general rise of 30 percent over the previous 13 years in shrimp cultivation ponds. Agricultural soil and vegetation, respectively, reduced by 48% and 3%. Because of both land-use activity and natural dangers, Barren and built-up regions improved by 73%. Household data analysis showed that cyclones and storm surges had significant impacts on revenue, agricultural manufacturing and migration.

Mottaleb et al. (2015) mixed information from the Bangladesh Household Income and Expenditure Survey (HIES) with Moderate Resolution Imaging Spectrora Diometer (MODIS), this research estimated household-level losses in rain-fed rice manufacturing. Using two limit assessment methods for Tobit, this research showed that rice production was considerably impacted by both drought and submergence. Findings disclosed that a one percent rise in the region impacted by drought at district level on average reduces the output of Aman seasonal rice by about 1382 kilograms per year and decreases the average rainfed household of 693 kilograms per year. They suggested that drought and submergence tolerant rice be disseminated and developed as well as short-lived rice varieties to minimize losses caused by drought and submergence during Aus and Aman rice seasons.

Moniruzzaman (2015) collected a sample of 11,389 farmers across Bangladesh from 2000, 2005, and 2010 and 30 years shifting average rainfall and temperature against each year, using a multinomial logit model. He discovered a climate-sensitive crop option. He discovered the effect on crop selection of various climate change situations and discovered a shift in crop selection in Bangladesh. In particular, the rise in temperature will disturb the decision of rainfed Aman rice plants and make farmers choose Boro, Aus and other plants based on irrigation. Unlike temperature, scenarios for rain-fed rice crop selection are not harmful.

Mamun et al. (2015) evaluated the pattern of three major climate factors (e.g. temperature, rainfall and relative humidity) for Rajshahi, Bangladesh using time series data for the period 1972-2010 and evaluated the connection between the factors and the yield of three major rice plants (e.g. Aus, Aman and Boro). Ordinary Least Squares (OLS) findings disclosed the important impacts of climate factors on rice yields, and these impacts differ between the three rice plants. The research also assessed local understanding and resource-based adaptation methods taken by farmers, such as changes in transplantation moment, changes in crop patterns, digging of ponds, choice of short-lived species, etc., to minimize the impact of climate differences on rice production, as well as suggesting the necessity and growth of temperature-tolerant of Aman and Boro.

Chowdhury et al. (2015) tried to investigate the prospective effect of climate change on the output of three distinct rice plants in Bangladesh (i.e., Aus, Aman and Boro). On the basis of country-level time series data for the period 1972-2014, a multiple regression analysis using the OLS technique is used to evaluate the climate-crop yield interrelations. They discovered that all climate factors had a substantial effect on the output of rice over the period under research, peak temperature is statistically important, and the yield of all three rice plants is badly affected, and rainfall is found to be important for all rice yields with beneficial impacts on Aus and Aman rice and adverse effects on Boro. They stressed the significance of adapting temperature-tolerant rice varieties and suggest that sustainable agriculture can play a crucial role in mitigating adverse effects of climate change.

Alauddin et al. (2014) considered using information from 1800 Bangladeshi farm-households in eight drought-prone and groundwater-depleted counties of three climate areas and logit models, this research breaks new ground in the investigation of farm-level climate change adaptation. Results showed that macro-level proof was backed by farmers ' perceptions of climate variability. Science-driven (e.g., drought-tolerant rice), environmental resource-depleting (e.g., groundwater) and crop-switching (e.g., non-rice plants) typified to reduce negative impacts of climate change adaptation policies. Some variables substantiated the choice of farmers to adapt substantially, such as severity of drought, extent of depletion of groundwater, level of education, farm size, access to climate data, and irrigation electricity, and agricultural subsidies. The main obstacles to adaptation were insufficient access to climate information and scientific research results, representing restricted irrigation facilities and resource base.

Uddin et al. (2014) examined farmers' adaptation to degrading environmental circumstances probable to be caused or exacerbated by global climate change. They examined four key parts: (1) the rate of self-reported implementation of adaptive processes (coping strategies) as a consequence of climate change; (2) the ranking of prospective coping strategies based on their perceived significance for agricultural undertakings; (3) the identification of socio-economic variables connected with the implementation of coping strategies; and (4) the ranking of prospective limitations for coping strategies. Results showed that most farmers identified themselves as having engaged in adaptive behaviour. Irrigation ranked first among farm adaptive measures among 14 adaptation approaches, while crop insurance ranked the least used. They clarified by using the logit model that out of eight variables surveyed, age, education, family size, farm size, family earnings, and cooperative participation were substantially linked to self-reported adaptation.

Rashid et al. (2014), in order to achieve viable adaptation alternatives in a climate vulnerable region, conducted a research to understand perception and adaptation policies at community level are essential. Findings revealed that the climate is unpredictable and with no favorable outlook or aspect connected with this shift, variability has risen over time. Due to water-logging, local individuals viewed changes in precipitation patterns, leading in delayed rice planting, reduced yield and damaged sesame and mungbean plants. The prolonged summer periods with rising average temperatures led in lower crop development length, higher pest infestations, and lower returns. Communities are adapting to this evolving situation by adopting elevated yields of salt-tolerant rice varieties, introducing fresh plants such as sesame and mungbean, and adopting tilapia, carp and prawn rice-fish plants instead of brackish water shrimp.

Ayers (2014) assessed the mainstreaming process in Bangladesh, one of the nations with important advancement in preparation for adaptation and mainstreaming. The article starts by arguing for mainstreaming, exploring connections and trade-offs between adaptation and growth, and reviewing the mainstreaming literature. Secondly, it examines how mainstreaming can be implemented in practice by reviewing an current four-step structure.

Amir et al. (2013) evaluated the effect of climate change and its effect on food security in Bangladesh's Kalapara Upazila district of Patuakhali and presented current climate change scenarios for Kalapara, evaluated the connection between climate change scenarios and agricultural manufacturing, and then prescribed climate change adaptive measures. The findings showed proof of climate change through climate data analysis, crop yields and perceptions of farmers. Evidence has been shown through the rise in temperature, rising natural disaster frequency, and uneven rainfall that directly affect Kalapara Upazila's food security situation. Climate change in Kalapara Upazila has led in a substantial decrease in agricultural production. The views of the people demonstrate that temperatures are increasing, there is no timely rainfall, and crop seasons are changing. They stated that absence of adequate understanding is the primary reason for adapting to these modifications.

Ahmed et al. (2013), due to favorable resources and ecological circumstances, studied freshwater prawns with fish in rice fields in the coastal region of southwest Bangladesh. This paper given an overview of an ecosystem-based strategy to integrated prawn-fish-rice farming in southwestern Bangladesh, providing a broad variety of social, financial and environmental advantages. They proposed that community-based adaptation strategies should be established to address the problems and could be moved from the coastal region to less susceptible inland regions, but caution that suitable adaptation strategies and an enabling institutional climate will be required.

Sarker et al. (2013) attempted to examine the selection of adaptation approaches for rice farmers to deal with and compensate the impacts of climate change and the determinants of those choices in Bangladesh's severe drought-prone district, Rajshahi. MNL model results show that gender, age, household head education, household property, annual farm income, farm size, tenure status, farmer-to-farmer expansion, access to credit, access to subsidies, and access to electricity all have an impact on farmers ' choice of climate change adaptation approaches.

Habiba et al. (2012) conducted, through a semi-structured questionnaire, a study with 718 farmers of irrigated and non-irrigated village farmers in 14 upazila in two serious drought-prone counties in northwestern Bangladesh. It evaluated farmers ' perception and consciousness, effects and measures of adaptation to drought. Not only did they identify drought as the most common catastrophe in the study region due to rainfall and variability in temperature, but soil water depletion, absence of canal and river drag, enhanced population, deforestation, etc. also accelerate drought in this region. . As a consequence of drought, agriculture as well as farmers' social life and health are threatened the most. To cope with drought, farmers have been adapting various practices mainly through agronomic management, crop intensification, water resource exploitation, etc.

Anik et al. (2012), in their research assessed climate-related perception and identified different adaptation approaches in North-East Bangladesh's low-lying regions. Six focus group debates and a survey of 120 homes were conducted to define the main climate occurrences that were temperature change, drought, heavy precipitation, cyclone and storm surges. In addition, there was a lack of fish accessibility, scarcity of water in drought seasons, and frequent flooding in rainy seasons as a result of these occurrences. Results also disclosed that a small percentage (10%) of participants had a good understanding of the current climate change. A total of 16 adaptive interventions were acknowledged in the study fields where crop diversification, floating garden, duck rearing, cage aquaculture, wave protection walls, canal re-digging, and embankment building were common. The current research disclosed that, faced with climate change adaptation, local experiences have merits that require unique consideration.

Sarker et al. (2012) noted the connection between the output of three major rice plants (e.g., Aus, Aman and Boro) and three major weather factors (e.g., peak temperature, minimum temperature and precipitation). They used time series information at an overall level for the 1972–2009 period to evaluate the connection between weather factors and rice yield using both the normal minimum squares and the techniques of average (quantile) regression. They discovered that for all rice yields the peak temperature is statistically important with beneficial impacts on Aus and Aman rice and adverse effects on Boro rice, minimal temperature has a statistically significant negative impact on Aman rice and a considerably beneficial impact on Boro rice and rainfall has a statistically significant impact on Aus and Aman rice.

Rahman et al. (2012) used the simulation system MRI-AGCM for the 2075–2099 period to simulate mean temperature and precipitation. Different changes in rainfall were estimated across different seasons: 0.64 percent in monsoon, 1.90 percent in post-monsoon and 13.46 percent in winter. Their projection over the same period for the mean temperature change was nearly 2.5 ° C.

Salauddin et al. (2012) analyzed the nature and magnitude of displacement in a village on the southwest coast of Bangladesh induced by severe climate occurrences. They indicated enhanced rural migration to urban migration in the face of climate change based on a study and focus group conversations. They also pointed out that, owing to climate-related extreme occurrences, marginal farmers would face enormous crop failures in the future.

Rahman (2011) submitted a study on climate change and its effect on agriculture, Bangladesh is one of the most susceptible nations to climate change due to its disadvantageous geographical place; flat and low topography; thick population; elevated levels of poverty; dependence on many livelihoods on climate-sensitive industries, especially crop and fisheries; and inefficiency in climate change. Many of the expected negative impacts of climate change, such as rising sea levels, higher temperatures, increased monsoon rainfall, higher cyclone intensity, etc., will exacerbate current stresses that already impede growth in Bangladesh. Every year, large sections of the nation are flooded and on the other side, drought has adversely affected the output of rice and thus the supply of food. Moreover, some 2.8 million hectares of coastal soil have already become salt.

Paul et al. (2011) tried to investigate native coping strategies and identify the underlying population, socio-economic and other appropriate factors that affect coping strategies in Bangladesh's three separate cyclone-prone coastal communities. He discovered that the implementation of a specific set of coping strategies depends not only on the magnitude, intensity and prospective effects of the cyclone, but also on era, gender, social class, dissemination of early warning data, local exposure, external aid, social protection and informal processes for sharing risks within the society.

Rimi et al. (2009), using the DSSAT crop simulation model, analyzed the trend of climate variables for the period 1950–2006 and assessed their likely impact on rice production in the Satkhira district. Trend evaluation of seasonal precipitation disclosed a statistically non-significant increase in the annual peak and minimum temperature trend and the annual complete precipitation and crop simulation model showed that Aus, Aman and Boro rice yields were adversely impacted by temperature increase, unexpected precipitation, flooding, drought and salinity. This research also proposed some adaptive strategies, such as creating crop cultivars tolerant of these risks, improving the use of crop varieties of short duration, changing planting dates, and using elevated beds and plants that consume less water.

Pouliotte et al. (2009), through a vulnerability research of a rural village in southwest Bangladesh, studied the connection between environmental change and growth. Villagers cope with a multitude of urgent pressures, and if anything, climate change is not taken into account individually. They noted environmental, political, and economic circumstances and adjustments in resource utilization schemes, especially shrimp farming, changing livelihood possibilities and increasing vulnerabilities of disadvantaged villagers to future environmental modifications, including climate change.

Nelson et al. (2009) considered that adaptation efforts in agriculture are focused on implementing policies that assist create rural livelihoods that are more resilient to climate change and catastrophe. Study disclosed an evaluation of the cost of productivity-enhancing investment in agricultural studies, rural highways, and irrigation facilities and effectiveness that can assist farmers adapt to climate change, and irrespective of the climate change situation, agriculture will be adversely impacted. They discovered that climate change improves infant malnutrition and dramatically decreases calorie intake, it is the adverse effects of climate change on children's health and well-being.

Wassmann et al. (2009) evaluated various rice production systems ' spatial and temporal vulnerabilities to climate change effects in Asia. The study initially described the hazards of rising thermal pressure and map areas where present temperatures already approach critical concentrations during the rice plant's sensitive phases. Possible heat stress adaptation options are obtained from areas where rice crops are already subjected to very elevated temperatures, including Iran and Australia. They found that assessments of geospatial vulnerability may become critical to the planning of targeted adaptation programs, but those policy frameworks are required to implement them.

Rashid et al. (2007) performed studies on climate change adaptation for Bangladesh agriculture's viable growth and discovered natural disasters such as elevated salinity in the land, frequent floods and droughts, tornado and storms– all directly or indirectly affecting agricultural activities and production. They noted that many of the agricultural activities, such as rapid harvesting and seeding, intercultural activities, irrigation and water management, disease and pest management, agricultural engineers must contribute to finding alternatives that match the nature of the issues in the agricultural sub-sectors.

Brouwer et al. (2007) conducted a case study in one of the world's poorest and most flood-prone nations, explored the complicated connection between environmental danger, poverty and vulnerability, concentrating on family and community vulnerability and adaptive coping systems. In a large-scale household study conducted in southeast Bangladesh, they inquired about their flood risk exposure, flood issues, flood harm, and coping processes for nearly 700 floodplain inhabitants residing without flood protection along the Meghna River. They showed that families with reduced revenue and less access to productive natural resources face increased exposure to flood risk and revenue and asset allocation disparities at the community level also tend to be greater at greater rates of risk exposure, suggesting that individual households are also jointly more susceptible. Regarding the identification of coping processes for dealing with flood incidents, they examined both the preparedness ex-ante family level for flood occurrences and the availability ex-post of community-level assistance and disaster relief.

Ahmed (2006) examined the attitudes of local people about previous and present climate change and its impact on rural livelihoods in Northwest Nawabganj and Naogaon, two drought-prone districts. More accurately, they stated that in the summer the average temperature had risen while the winter duration had decreased but with an improved amount of cold spells. It has been noted that the frequency of drought and the incidence of pests and illnesses linked to climate has risen in the study fields. Small and marginal farmers, salary workers, tiny traders / businessmen and fishermen are the main financial livelihoods recognized. Their primary adaptive methods include pond excavation and rainwater retention in canals, mango cultivation, and bird rearing for livestock and poultry.

FAO (2006) analyzed the adaptive capacity of rural livelihood organizations in 12 villages of four sub-districts in the northwestern districts of Chapai-Nawobgonj and Naogaon. They estimated that in summer the average temperature had risen and reduced in winter. Rainfall, on the other hand, had become more variable and drought frequency had risen. Aman is the crop most impacted by drought: sometimes manufacturing losses are as high as 70%. To mitigate climate vulnerabilities, the main adaptive approaches of families were the installation of DTW irrigation, pond excavation, mango farming, short-lived cultivation and drought-tolerant plant varieties and homestead gardening.

Smit et al. (2003) discovered that nations with restricted financial resources, low technology levels, poor information and skills, poor infrastructure, volatile or weak institutions, and unfair empowerment and resource access have restricted adaptability and are extremely susceptible. They noted that present adaptation understanding and adaptive ability is inadequate for credible adaptation forecast; it is also inadequate for strict assessment of scheduled government adaptation alternatives, measures, and policies. Existing evaluations of adaptation alternatives have severe constraints.

Ali (1999) examined the vulnerability of climate change in his studies, citing Bangladesh as one of the world's most susceptible nations to climate change and discussing the potential effects of climate change in Bangladesh through tropical cyclones, storm surges, coastal erosion, and backwater effects. Possible land loss owing to beach erosion owing to sea level rise on Bangladesh's eastern shore is investigated.

2.3. Gaps in the existing literature

Less adaptive capability theoretically implies a high risk of vulnerability. However, in quantitative research, adaptive capacity is poorly discussed in evaluating vulnerability and often does not recognize differential effects in altering social systems (Smit and Pilifosova, 2003). There are few studies on farmers’ perception of climate change, adaptation strategies and barriers to adaptation in Bangladesh (For example,Sarker et al., 2019; Alam, 2017; Alam et al., 2017a; Islam et al., 2017; Sarker and Islam, 2016; Alam et al., 2016; Mottaleb et al., 2015; Alauddin and Sarker, 2014; Sarker et al., 2013).

However, most of the studies on adaptation were accomplished at north-western drought-prone areas of Bangladesh (Alam,2015; Alauddin et al.,2014; Sarker et al.,2013; Rashid et al.,2007; Anik et al.,2012; Habiba et al.,2012). Very limited studies were conducted at the southern part of Bangladesh (Amin,2018; Kabir et al., 2017; Ahmed et al.,2013; Amir et al.,2013). More particularly, to the best of researcher's knowledge, there is no study on costal rice farmers' adaptation strategies and barriers to adaptation which is crucial to develop adaptation policy in the country.

CHAPTER THREE

METHODOLOGY

3.1. Introduction

This chapter outlines the details of methodology in order to answer the research objectives. This includes description of the study area, data collection and their sources, the empirical models and their specifications employed in analyzing the data.

3.2. Topography of Bangladesh

The location of the country in South Asia is between 20º34' and 26º 38' north latitude and 88º01' and 92º41' east longitude (BBS, 2017). Bangladesh is a subtropical monsoon country. The average winter temperature is 17-20.6ºC, average summer temperature remains at 26.9-31.1ºC and average rainfall varies across regions (Shahid, 2010; Shahid and Behrawan, 2008).

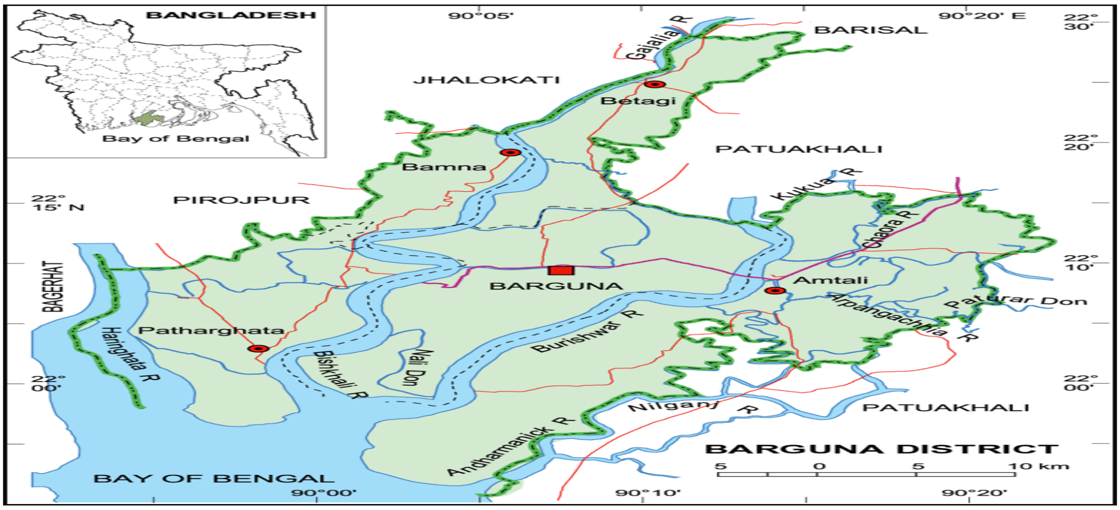
Agriculture is the predominant source of livelihood in rural areas and contributing 11.70% in GDP and employing 42.7% of labour force (BBS, 2017). Bangladesh is the fourth largest rice producing country in the world. In 2015-2016 financial year, 51.804 million metric tons of rice was produced (BBS, 2017). Average size of farm holdings was 3.1 acres in 1960 (Rashid, 1978) and it reduced to 1.23 acres/person in 2014 (WB, 2015). Land holdings are largely fragmented and there is a predominance of small and marginal farmers. There has been also significant land use change by bringing crop diversification from double to triple crops (Islam, 2015). In the year 2014-2015, aman rice was cultivated in 48.44% and boro was42.40% of land (BBS, 2014). T. aman is a rainfed crop and in other two seasons, irrigation is the source of water. Approximately, 60% of the cultivated area is under irrigation coverage (FAO, 2013) and rice accounts for 75.01% area of total cultivated area (BBS, 2014).

However, Bangladesh confronted loss in Boro rice production in changing climate (GAIN, 2015) and Aman season rice faces the most production losses due to natural hazards like floods, heavy downpour and water rush (BBS, 2014).

3.3. Description of the study area

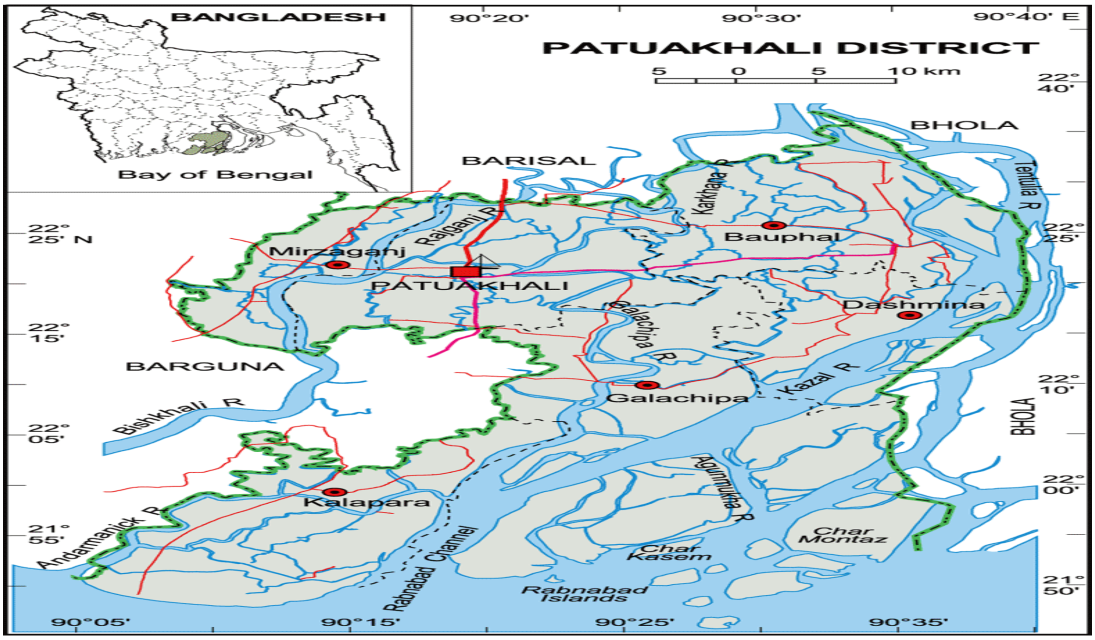
The study area for this research includes southern areas of Bangladesh where salinity and sea level rise are the emerging problem. After review of literature and newspapers reports the study areas were selected purposively. The study areas were Betagi Upazila of Barguna District and Galacipa Upazila of Patuakhali District.

Betagi is under the Division of Barisal, Bangladesh. It is located at 22.4167°N 90.1681°E . It has 22,156 households and a total area of 167.75 km². Betagi had a population of 110,926 where 49.95% male and 50.05%female. Average literacy rate were 87% (7+ years), compared to the national average of 72.4% (BBS 2017). There are some rivers such as Paira River, Bishkhali River, Khakdon River, Baleshwar River and Haringhata River. Agriculture is the main profession of the people. Fishing is also a prominent profession of this district. Paddy, jute, and different types of vegetables are the main product of agriculture sector. The vulnerability index of Betagi is included at Appendix B.



Source: http://maps-of-bangladesh.blogspot.com/2010/05/political-map-of-barguna-district

Galacipa is an Upazila of Patuakhali District in the Division of Barisal, Bangladesh. Galacipa is surrounded by rivers. The two major rivers are Laukathi and Lohalia, which are directly connected with the Bay of Bengal. It is located at 22.1639°N 90.4306°E and has 49,982 households with a total area of 1267.89 km². The Bay of Bengal is very close to the upazila. Due to the river, Galachipa is a famous for rice and other cropsproduction. Others famous river of Galachipa are Agunmukha and Bura Gaurang. Galachipa has a population of 286,307. Males constitute 51.36% of the population, and females 48.64%. The average literacy rate is 29.4% (7+ years) (BBS, 2017). Agriculture and fishing are the main profession of the most of the people. Paddy, jute, and different types of vegetables are the main product of agriculture sector. The vulnerability index of Golacipa is included at Appendix B.



Source:http://maps-of-bangladesh.blogspot.com/2010/05/political-map-of-patuakhali-district

The reasons for selecting the areas includes:

- the areas are the most vulnerable to climate change and vulnerability.
- livelihood of the people mainly depends on agriculture.
- so far there is no such study conducted in the areas.

3.4. Study population and sampling strategy

The population of this study is all farm households residing in the selected villages (Table. 3.4). Thus there are many farm households. The standard statistical formula for selecting a sample size results in a huge number which is impractical for an individual researcher because of time and funding constraints (Blaikie 2010; Gilbert 2008). Since all the farmers in the area face similar socio-economic, environmental and climate conditions in their farming activities, they make up a mostly homogeneous group which validates the use of a small sample size which can be representative of the whole population (Alam, 2016; Blaikie 2010; Gilbert 2008). Therefore, sample size is determined purposively depending on the context rather than a statistical formula. This study aimed to survey a sample of 120 rice farming households. In addition, 5% of the population has been regarded as a suffi- ciently large sample size for survey research (Bartlett et al., 2001). Respondents were selected randomly within the villages.

Table 3.4: Sample size of the population

Name of District	Name of Upazila	Name of villages	Respondent No.
Patuakhali	Galacipa	Boro Chor Kajol, Dokkhin Chor Biswas, Borosiba and Sotosiba	60

Barguna	Betagi	Mayarhat, Brtmor, Uttorvora and Dokkhinvora.	60

A completed list of all rice farming households in the respective villages was collected from the Sub-Assistant Agricultural Officers (SAAOs) in the study areas. The numbered list provided names and addresses of farmers with their farm sizes. Afterwards, a computer-generated random number table was applied to the list to select 120 farm households. In this way the randomness in the sampling procedure was ensured.

3.5. Questionnaire survey

3.5.1. The design of the questionnaire

The main objective of the questionnaire was to determine agricultural vulnerability and adaptations due to climate change and the farmers' perception of the impact of climate change on rice production and to evaluate how farmers were responding to climate change. Accordingly, a draft questionnaire was developed. The questions were directly related to the research questions of this study.

The questionnaire had eight sections: households' socio-demographic characteristics, farm characteristics, land and soil characteristics, institutional accessibility, farmers' perception of climate change, impact of climate change on rice production, farmers' adaptations strategies in the face of climate change, and costs and returns in the production year. The details of these sections are discussed below:

The first section of the questionnaire (Section A) gathered farm households' socio demographic information. It included household head's gender, age, education, main occupation, secondary occupation, household size, annual farm income, non-farm income and household assets.

The second section (Section B) was on farm characteristics: farm size, including own land, rented-in land, rented-out land, leased-in land, leased-out land and homestead land. It also included households' tenure status, livestock ownership and the farming experience of the household head.

The third section (Section C) focused on overall livelihood status of the households. It consists of access to sanitary toilet, tube well, electricity, contraceptive method, sending children to school, member of cooperative society, etc.

The fourth section (Section D) contained dietary diversity of nutrious of family food consumption and production. It justifies the food security status of the household.

The fifth section (Section E) was to elicit farmers' perceptions about climate change over the past 10–20 years. Farmers provided their opinions on changes to the major climate variables of interest to this study as well as drought, availability of groundwater, availability of surface water, heat wave and cold wave. For each climate attribute, there were four mutually exclusive options: increased, decreased, remained the same, and don't know.

The sixth section (Section F) queried vulnerabilities of climate change that include salinity , temperatures, sea level rise, precipitation, cyclones and storm surge, flood , rainfall, land, erosion, drought. For each climate attribute, there were five mutually exclusive options: very high, high, medium, low, very low.

The seventh section (Section G) focused on farmers' adaptation to the changing climate. Farmers were asked whether they had undertaken any adaptation strategies in order to limit adverse climate change impacts on rice production. Farmers were provided with a set of options from which they could choose. This section also included questions regarding adapt to the adaptation (other adjustment mechanisms to the adaptation strategies) as well as barriers to adaptation.

3.5.2. Validity and reliability of the questionnaire

Validity and reliability are two very important issues in surveying. They are concerned with the psychological characteristics of measurement and its precision as measurements are hardly perfect, particularly in the case of questionnaire responses, which can be hard to measure accurately and hence often result in measurement errors (Williams, 2003).

Validity of the questions in this questionnaire were theoretically defined and based on the literature on the impact of climate change and adaptation at the farm level. The variables or questions were drawn from the literature on the topic and reviewed by the academician. Therefore, the questions are content valid.

Reliability of the questionnaire can be achieved by internal consistency (Williams, 2003). The internal consistency of the questionnaire was achieved by asking respondents questions in more than one way during face-to-face interview and testing consistency in responses.

3.5.3. Pre-piloting of the questionnaire

It is important to test a questionnaire in order to identify any ambiguities in the questions and to identify the range of probable responses for each question. The test is not a formal process rather more of an information gathering technique (Williams, 2003). Accordingly, the questionnaire was trialled with academics and discipline experts at Bangabandhu Sheikh Mujibur Rahman Agricultural University and Sher-e-Bangla Agricultural University. The questionnaire was also tested with the Upazilla Agriculture Extension Officer of Betagi and Galacipa Upazillas as well as SAAOs in the study areas. The questionnaire was amended after each session. This procedure made the questionnaire unequivocal, suitable and acceptable to the final respondents.

3.5.4. Piloting the questionnaire

Based on the pre-piloting test and informal interviews with Agricultural Extension Officers and SAAOs in the study area, the draft questionnaire was modified to accommodate new questions and to remove irrelevant ones. It is essential to test the questionnaire with a similar population to the proposed survey group in order to check how respondents respond to the questions. It also provides suggestions for alternatives (Greasley, 2008; Muijs, 2004; Williams, 2003). After the preliminary testing, the amended questionnaire underwent a formal pilot programme with ten individual farmers.

3.5.5. Conducting the survey

The survey was conducted from January to February 2019. The researcher himself collected the survey data. Moreover, one focus group discussions (FGDs) in each village and key informant interview (KII) were also conducted in the study areas.

Through focus group discussions we investigated about the agricultural vulnerability, adaptation, perception about climate change and barriers to mitigate the effects of climate change. Secondary data were collected from different published sources such as Bangladesh Bureau of Statistics, World Bank, Food and Agriculture Organization etc.

3.5.6. Data coding, entry and cleaning

After collecting the completed questionnaire, it was coded for data entry. Data from the completed questionnaires were entered into the Microsoft excel by the researcher. Statistical Package for Social Sciences (SPSS; version 15) and STATA 14 were used to analyze the data. The SPSS is a useful software package for questionnaire surveys because of its flexibility, ease to use and its convertibility into other packages' files (Williams 2003).

Once the data entry was completed, the data were then cleaned by producing frequency figures for each question and examining the outliers. Consequently, a large number of completed questionnaires were rechecked to avoid inconsistencies. At this stage, the data file was ready for final analysis.

3.6. Data analyzing methods

Both descriptive and statistical analysis such as Multinomial logit model (MNL) were used for analyzing the data.

3.6.1. Descriptive Analysis

Tabular technique of analysis was generally used to find out the socio-demographic profile of the respondent, to determine livelihood status, demographic information, farmer perception about climate change, food security status throughout the year, and barriers to adaptation. It was used to get the simple measures like average, percentage etc.

3.6.2. Coping Strategy Index

To cope up with the adverse effects of climate change the farmers take some coping strategies, they are selling of livestock, duck and poultry, spending previous savings, credit from rural usury, Institutional microcredit, sale and mortgage of some plots of land, sale of other assets, family members' migration to other areas, mainly urban. The coping strategies to climate change was calculated based on the following index formula

$$CSI = CS_L \times 1 + CS_M \times 2 + CS_H \times 3 + CS_{VH} \times 4$$

where, CSI = Coping Strategy Index

CS_L = Frequency of farmers rating coping strategy as Low

CS_M = Frequency of farmers rating adaptation strategy as Medium

CS_H = Frequency of farmers rating adaptation strategy as having High

CS_{VH} = Frequency of farmers rating adaptation strategy as having High

3.6.3. Model Specification

In order to assess the factors influencing choice of adaptation strategies Logit or Probit models can be used to explain categorical variables (Wooldridge, 2009). Farmers can adopt more than one adaptation strategies. MNL model estimates simultaneously all binary logit among categories or choices performing all possible comparisons (Alauddin and Sarker, 2014). In this study MNL model was employed since the choice of adaptation was more than one. It was assumed that all the categories were mutually exclusive.

The model for each category of the outcome variable is specified as,

$$\ln Y_{i((n|b)} = \ln \frac{\text{Prob}\ (Y=n|x)}{\text{Prob}\ (Y=b|x)}$$

Here, b is the reference category and n is the number of categories. The model needs a base category to interpret the log-odds ratio. So, we can get n-1 (log-odds ratios). The probability (Y_i) of choosing one strategy j among a total of n alternatives conditional upon explanatory variables x_i takes the following form,

$$\text{Prob}\ (Y_i | x_i) = \frac{e^{\beta jxi}}{\Sigma^{n}_{k=1}\ e^{\beta jxi}}$$

This MNL model as formulized in Greene (2003) estimates the utility from choosing one particular strategy (as shown in the numerator) relative to the sum of utilities from different choices (expressed in the denominator) (Alam et al., 2016). MNL model requires that the odds ratio does not have impact on other probabilities; which is the assumption of independence of irrelevant alternatives (IIA) in order to get an unbiased and consistent estimator. The choice of adaptation strategies is assumed to be influenced by socio-economic factors, institutional accessibility and livelihood status.

For each strategy the complete model is specified as follows;

$$\text{In } (Y_{i(j/b)} | Xi) = \beta_{0,Yi} + \beta_{1,Yi} X_{1i} + \beta_{2,Yi} X_{2i} + \beta_{3,Yi} X_{3i} + \beta_{4,Yi} X_{4i} + \beta_{5,Yi} X_{5i} + \beta_{6,Yi} X_{6i} + \beta_{7,Yi} X_{7i} + \beta_{8,Yi} X_{8i} + \beta_{9,Yi} X_{9i} + \beta_{10,Yi} X_{10i} + \beta_{11,Yi} X_{11i} + \beta_{12,Yi} X_{12i} + \varepsilon_i$$

Where,

Y_i = Probability of choosing strategy

X_{1i} = Age

X_{2i} = Education

X_{3i} = Gender

X_{4i} = Experience

X_{5i} = Access of electricity

X_{6i} = Access to extension service

X_{7i} = Farmer to farmer contract

X_{8i} = Access to credit

X_{9i} = Access to information

X_{10i}= Income

X_{11i}= Family size

X_{12i}= Farm size

β_0……… β_{11} = Coefficient of the respective variable

ε_i = Error Term

In order to determine the probability of each adaptation strategy is computed from the MNL model. There are six main adaptation strategies such as cultivation of HYVs, supplementary irrigation, direct-seeded rice, cultivation of non-rice crops, adjusting planting calendars and techniques and livestock, duck and poultry rearing. Adjusting planting calendars and techniques has been chosen as the base category so that factors influencing different strategies in comparison with adjusting planting calendars and techniques can be assessed. The study also tested the collinearity using the correlation matrix with all the explanatory variables and multicollinearity through VIF (range of VIF is 1.05-2.60) and did not find any problem.

3.6.4. Research design: An overview

The below diagram (Figure 3.6.3.) links the research objectives, theories and approaches, data requirements, and major methods of analysis in this study.

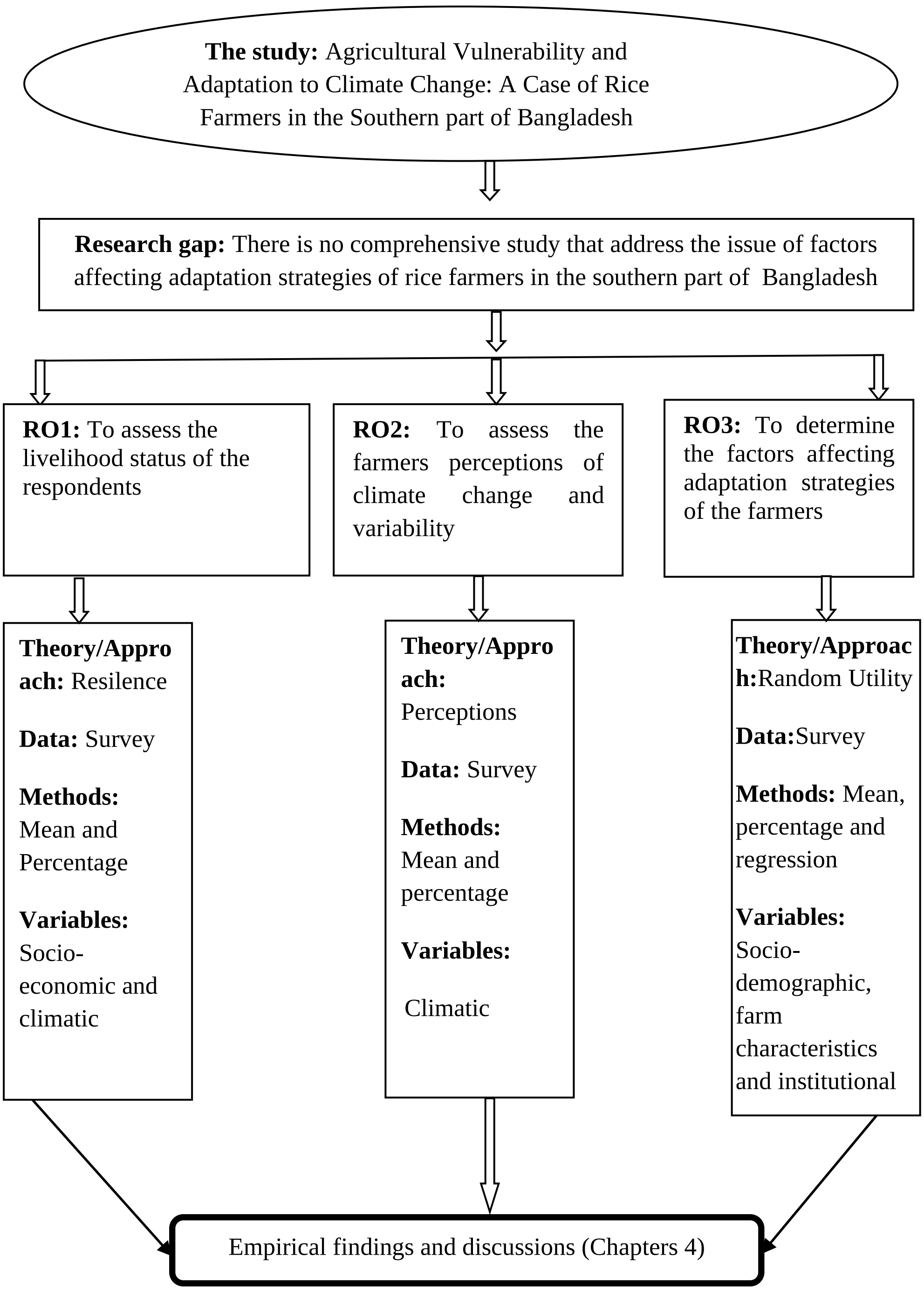


Figure 3.6.3. : Research design

Source: Prepared by author, 2019

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1. Introduction

This chapter provides results on socio-demographic character, livelihood status, food status throughout the year farmers' perception on climate change, adaptation choices, barriers to adaptation and MNL model for assessing the factors determining adaptation choices in different phases.

4.2. Socio-economic characteristics of sample households

4.2.1. Age Distribution

In the study, all categories of farmers of the study area were classified into different age groups as presented in table 4.2.1. It is evident from the table that most of the farmers were middle aged in the study area. Out of the total sample farmers 21.00 percent belonged to the age group of 20-30 years, 62 percent belonged to the age group of 31-50 years and 17 percent fell into the age group of above 45. This finding imply that majority of the sample farmers were in the most active age group of 31-50 years indicating that they provided more physical efforts for farming.

Table 4.2.1. Age Distribution

Age category	Percent (%)
20-30 years	21
31-50 years	62
Above 51 years	17

Source: Field Survey, 2019.

4.2.2. Educational status

Education increases the efficiency of man. Education of farmers helps to adopt due to climate change. Bangladesh it has, an adult literacy rate of 72.30% (BER, 2017). Table 4.2.2 shows 11 percent farmers were illiterate, 48.70

percent farmers had primary education, 32.80 percent farmers had completed J.S.C level education, 7.50 percent farmers had completed their secondary level education. Literacy status is good at the study area compared to the national level literacy status.

Table 4.2.2. Educational status

Level of education	**Percent (%)**
Illiterate	11.00
Primary school certificate	48.70
Junior school certificate	32.80
Secondary School Certificate	7.50

Source: Field Survey, 2019.

4.2.3. Source of Income

Agriculture provides employment about 41 percent of the labour forcea ccording to Quarterly Labour Force Survey 2015-16 (BER, 2017). In the study area, the selected farmers were engaged with various types of occupation along with rice cultivation. The occupation was classified into agriculture and non-agriculture. It was observed from the figure that, crops farming is the main source of income about 78.25% income comes from crops farming. Around 84 percent of the rural people of the country depend on agriculture for their livelihood directly or indirectly (Mirza et al., 2015). Some of them had opportunity to be engaged in other activities. The following table 4.2.3. showed that 4.19%, 6.26%, and 2.17% income comes from fisheries, livestock, duck and poultry and business respectively.

Table 4.2.3. Source of income

Types of occupation		Percent (%)
Agriculture	Crops	78.25
	Fisheries	4.19
	Livestock, Duck and	6.26

	Poultry	
Non-Agriculture	Business	2.17
	Other occupation (selling labour, rickshaw pulling, boat, handicrafts etc.)	7.45
	Safety net (VGD/VGF, food for work etc.)	1.18
	Charity (fitra, jakat)	0.5

Source: Field Survey, 2019.

4.2.4. Gender and marital status

The proportion of women in the agricultural labour force increased from less than 20 per cent to 33.6 per cent of the total (Asaduzzaman 2010, citing Bangladesh Bureau of Statistics, various years). Table 4.2.4 depicts that 83.17 percent of farmers were male and 16.83 percent were female. Women are less involved in agriculture compared to national data it means women empowerment is limited here. In the study area, 89.33 percent of the farmers were married and 10.67 percent were unmarried.

Table 4.2.4. Gender and marital status

Particulars	Percent (%)
Male	83.17
Female	16.83
Married	89.33
Unmarried	10.67

Source: Field Survey, 2019.

4.2.5. Farm size and ownership

The study farmers are categorized as: landless farmers (less than 49 decimal), small farmer (50-249 decimal), medium farmer (250-749 decimal) and large farmer (above 750 decimal) (GOB, 2009). The table 4.2 shows that in the sample, 19.46 percent were landless farmer, 67.19 percent were small farmer, 11.48 percent were medium farmer and only 1.87 percent were large farmer.

Table 4.2.5: Farm size and ownership

Types of farmers	Percentage (%)
Land less (less than 49 decimal)	19.46
Small Farmer (50-249 decimal)	67.19
Medium Farmer (250-749 decimal)	11.48
Large Farmer (above 750 decimal)	1.87

Source: Field Survey, 2019.

4.2.6. Income status

Almost 21.80 percent of the population live in poverty, and 11.30 percent of the population live in extreme poverty (BER, 2018). The $1.90/person/day Purchasing Power Parity (PPP) line is the current definition of extreme poverty (World Bank, 2011). It is evident from the table 4.2.6 that 12.15% farmers are below the extreme poverty line, which indicates that their yearly income below Tk. 56000. Most of the farmer's yearly income belonged to the category of Tk. 57000-160,000. The per capita income of a Bangladeshi is Tk.160060 (BER,2019). Therefore, in the study area about 62% farm households are below per capita income, this result showed the inequality of income among the population.

Table 4.2.6.: Income status

Level of income	Percent (%)
Less then 56000	12.15
57000-160,000 Tk.	50.21
161,000-250,000 Tk.	28.61
Above 261,000 Tk.	7.03

Source: Field Survey, 2019.

4.3. Livelihood status and institutional accessibility

Institutional accessibility indicates farmers' access to extension services, subsidies, electricity, cooperation from NGOs etc. These factors play a vital role in crop production. The Table 4.3 exhibits that only 48.17% of households have access to extension services. Subsidies, particularly for small and landless farmers, are crucial for ongoing agricultural production. However, only 35% of households receive government subsidies in the form of agricultural inputs and money. Most of the farm households of Betagi Upazilla have access to electricity but in Golacipa Upazilla have no access to electricity for the geographical constraint. According to the Bangladesh Power Development Board (2018) 90% of the population had access to electricity. About 91.17% and 97.02% farm households have the access to sanitary toilet and tube well water means safe water facility in the study area. In Bangladesh, access to sanitation remains moderate at 55.9 per cent (United Nation Children's Fund, 2013).

Table 4.3: Livelihood status and institutional accessibility of the farmers.

Particulars	**Yes %**	**No %**
Sanitary toilet	91.17	8.83
Tube well water	97.02	2.98
Electricity	50	50
Send children to school	99.17	0.83
Saving accounts	47.50	52.50
Member of cooperative society	32.50	67.50
Utilize IT for and family planning activities	24.17	75.83
Received any training in your profession	25.00	75.00
Get cooperation from other village people	36.67	63.33
Allow women in decision making process	95.00	5.00
Contract with NGO Workers	54.15	45.83
Any access to agricultural extension services	48.17	51.83
Access to credit from government agencies or NGOs	37.75	62.25
Open the 10-taka account	27.50	72.50
HYVs cultivation	62.46	37.54
Agricultural subsidy from government	35.00	65.00

Source: Field Survey, 2019.

4.3.1. Access to weather information

Accurate weather forecasting and its accessibility to farmers play a very important role, particularly in determining planting and harvesting times of crops. However, table 4.3.1 shows the major source of getting information was television. From television 42.10 percent farmers had access to weather information. 26.25 percent of the farmers had access to information through mobile phone.

Table 4.3.1. : Access to weather information

Information tools	Percent
Radio	9.05
TV	42.10
Mobile phone	26.25
Neighbors	14.38
NGO workers	4.17
Extension Workers	4.05

Source: Field Survey, 2019.

4.3.2. Access to medical services

The table 4.3.2 exhibits, in the study area 20 percent farmers had the access of medical service from MBBS doctor, 42.50 percent farmers had the access of medical service from village doctor, 35.83 percent farmers had the access of medical service from homeopathic doctor. A very few farmers received for medical service from quack. Table 4.3.2. : Access to medical services

Types of treatment	Percent
MBBS doctor	20.00
Village doctor	42.50
Homeopathic doctor	35.83
Quack	1.67

Source: Field Survey, 2019.

4.4. Food security status

According to World Food Summit of 1996, food security is defined as“ when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life’’. Food, in the hierarchy of needs, is the most basic need for sustenance of life and is the perennial problem issue for a healthy and active life of mankind. Food security is not just an economic problem but also a social issue. Here we discuss on only the availability and accessibility of food security indicator.

Food security is a basic factor for the development of human capital and starter for the overall development of the society (Nath, 2015). However, the Figure 4.5 indicates that many of the households in the study areas experienced food insecurity situation. If the food insecurity situation is continued for the long run the households might not fit for the agricultural work. They will be the burden for the society if the situation is not improved

Adequacy of food refers to the ability of food to obtain food over time. Inadequacy of food means not availability of food over time. Most of the farmers experience food scarcity during the months of Agrahayon and Poush and Ashwin and Kartik due to lack of work facility. They considered ‘adequate’ for rest of the months because farmers harvest their crops during these months and their working facility is sound.

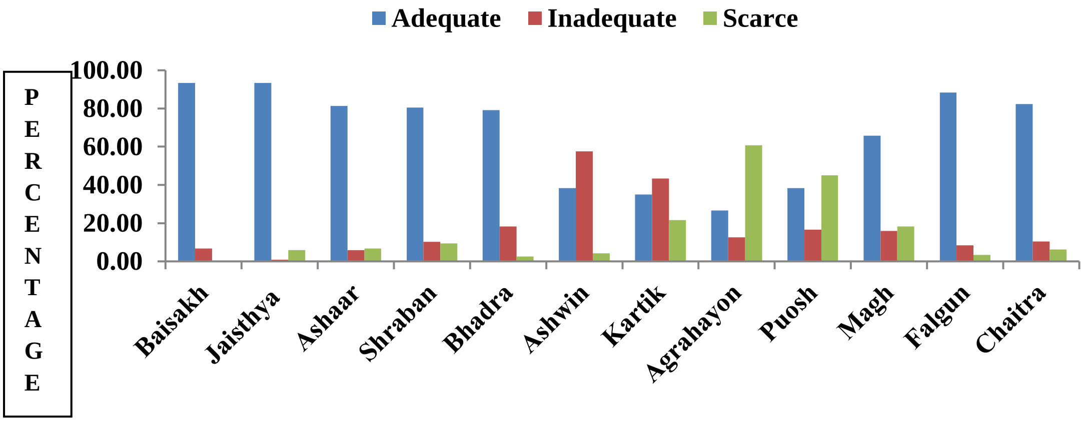


Figure4.5:Food security status throughout the year, Source: Field Survey, 2019.

4.6. Farmers' perception of climate change and variability

4.6.1. Farmers' perception of temperature

This study explores farmer perception about temperature changeover the past 20 years. The figure 4.6.1. shows that most of the farmers observed increase in temperature annually in summer. Farmers reported that in summer, temperature is intolerable for some time which was not so severe before 10 years back. Perception about temperature increase has also been reported in earlier studies (Alam et al., 2017a; Ishaya and Abaje, 2008; Mertz et al., 2009; Shrestha et al., 2017).

In winter farmers perceived both increase and decrease in temperature. Most of them reported an increase in temperature in winter, they are not feeling cool like past days but suddenly they feel very cool during the winter season. Also, September to October is the driest period and there is a possibility of drought (Ayeb-Karlsson et al., 2016). The annual average temperature in Bangladesh has an increasing trend over the last few decades (Goosen et al., 2018). Rising temperature is very alarming overall the country specially to southern part of Bangladesh. By 2050 temperature will increase by 1.5ºC, it will increase the see level which submerged the southern part including my study area, a lot of people will be homeless and agriculture will be severely damaged.

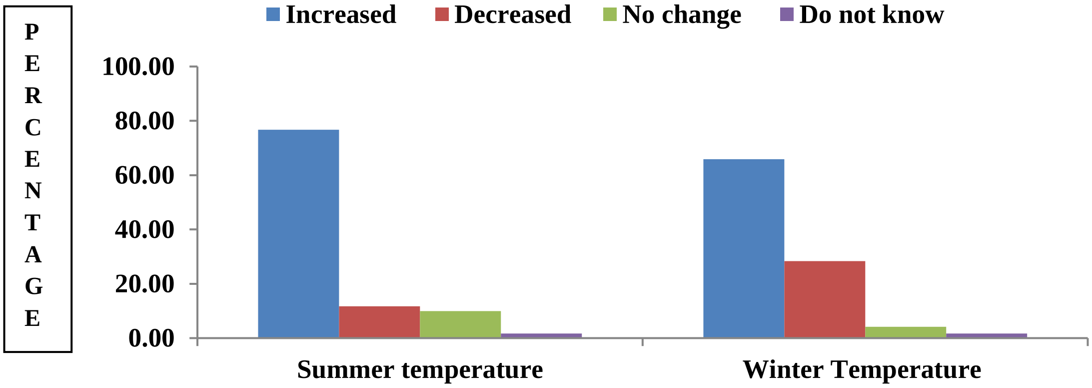


Figure 4.6.1.: Farmers' perception about temperature change

Source: Field Survey, 2019.

4.6.2. Farmers' perception of rainfall

The Figure 4.6.2. depicts farmers‘ perception of rainfall change over the past 20 years. Most of the farmers reported that the amount of rainfall increased annually but rainfall is not useful because it comes abnormally and creates flood situation which damages crops and it is common for both winter and summer.

Quadir (2006) studied rainfall patter from 1951 to 2007 of 9 coastal BMD stations and found that only 5 stations showed an increasing trend, while 4 stations showed a negative trend for monsoon period rainfall. For winter and pre-monsoon period, there is an increasing trend of rainfall for all stations. It is observed that there is an increasing effect during the monsoon months (June to September). All these may suggest an erratic behavior of rainfall. A significant increase in annual and pre-monsoon rainfall in Bangladesh is observed (Sahid, 2011).

The uneven rainfall is increasing in Bangladesh. During rainy season specially during heavy rainfall also very dangerous at my study area because it causes more salinity. Far heavy rainfall the saline comes from the deep part of soil for the wash away of the surface soil. Farmers said that during rainy season they more sufferer. The erratic behavior of rainfall also create flood which damaged the agricultural crops.

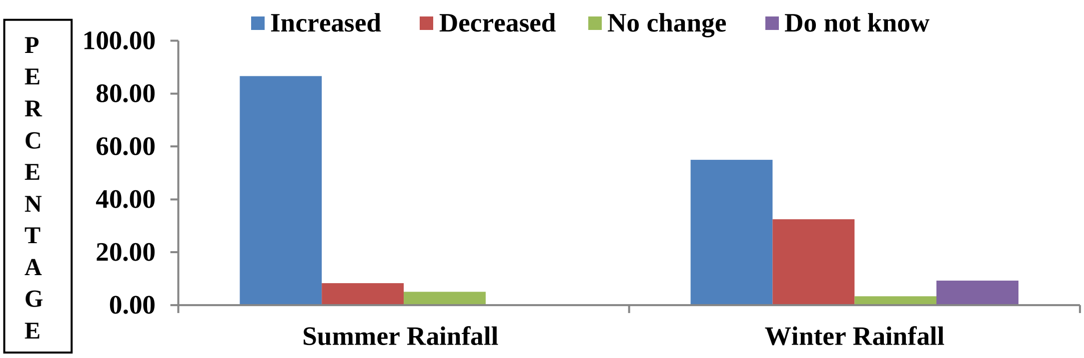


Figure 4.6.2.: Farmers‘ perception about rainfall change

Source: Field Survey, 2019.

4.6.3. Farmers' perception about frequency of extreme events

The Figure 4.6.3. shows that flood is the most frequent extreme event of climate change and is increasing year by year. The frequency of drought and storm is also greater than ever. Some respondents reported that the frequency of extreme events is decreasing, though the negligible percentage has no idea of the frequency of extreme events.

In the last 50 years, Bangladesh suffered around 19 drought events. Among them, the droughts of 1973, 1978, 1979, 1981, 1982, 1992, 1994, 1995, 2000 and 2006 are worth mentioning (Habiba et al. 2012). Bangladesh is the most vulnerable country in the world to tropical cyclones. A severe tropical cyclone hits Bangladesh on an average every 3 years (Rahman, 2011).

Bangladesh ranks sixth among the most vulnerable country to floods in the world. Extreme flood frequency has increased in recent years. In the last 25 years, Bangladesh has experienced six severe floods (Rahman, 2011). Farmers' perception and previous study are very parallel both indicate that extreme events are more frequent and the trend is increasing.

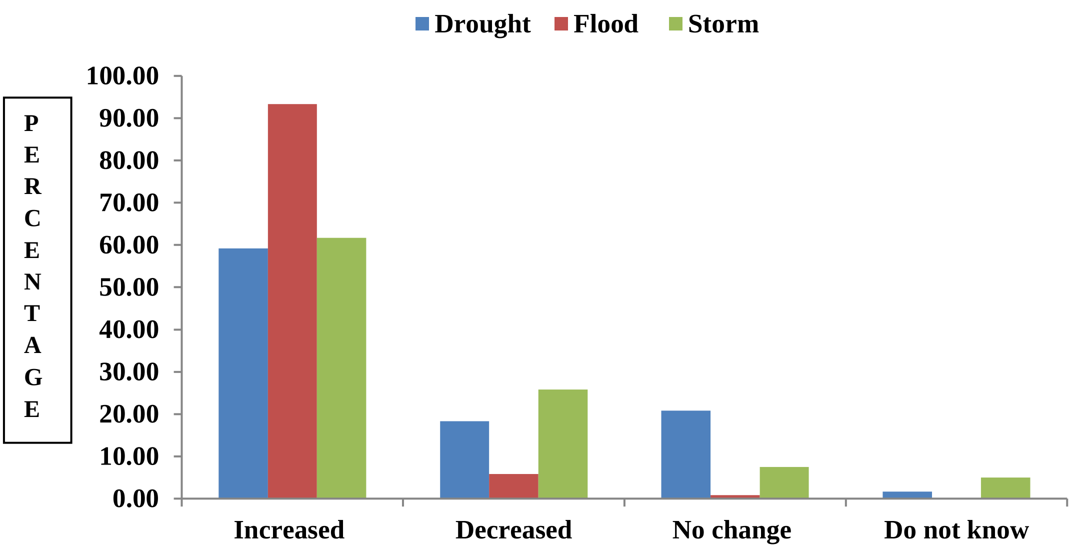


Figure 4.6.3: Farmers' perception about frequency of extreme events

Source: Field Survey, 2019.

4.6.4. Farmers‘ perception about intensity of extreme events

Most of the respondents are aware of the intensity of extreme events though tiny respondents have no idea about intensity of extreme events. Respondents mentioned that among the intensity of the extreme events, the storm ranked first, followed by flood and drought (Figure 4.6.4).

Sidar in November 2007 had damaged 2.3 million households which is equivalent to about US$1.7 billion (GOB, 2009). Aila hit the southern coast of Bangladesh in May 2009 that affected nearly 5 million people and causing infrastructure damage of over US$60 million (Rahman, 2011). Rice production losses due to drought in 1982 were about 50% more than losses due to floods the same year. Flood losses in 1997 were about 1 million tons and valued at around USS500 million (FAO, 1006).

About 18% of the Rabi crops and 9% of the Kharif crops are highly vulnerable to annual drought problems (Karim et al., 1999). In 1998 and 2007 the country experienced severe floods which inundated over 70% of the country and destroyed over 85,000 houses, affected almost 1 million households and destroyed 1.2 million acres of crops. The damages from these floods were more than US$1 billion (Rahman, 2011). Therefore, the intensity of extreme events is very disastrous that supported by farmer’ perception and previous study.

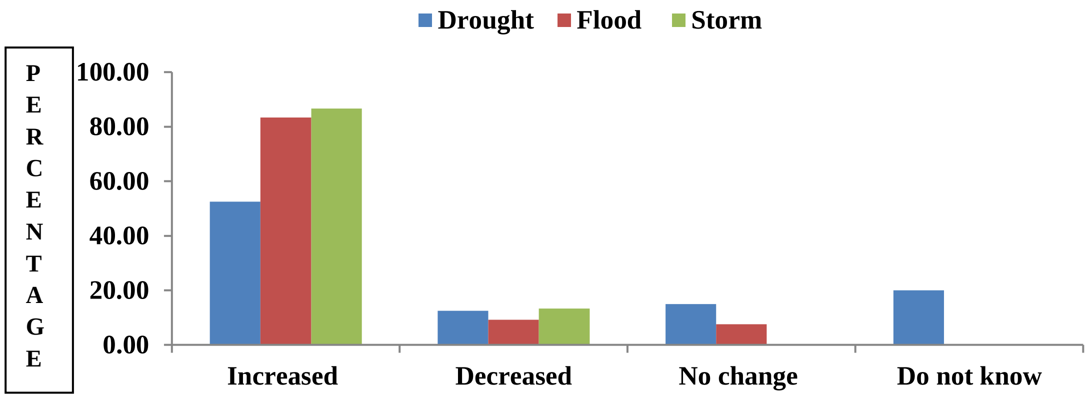


Figure 4.6.4: Farmers‘ perception about intensity of extreme event

Source: Field Survey, 2019.

4.7. Farmers' perception about vulnerabilities

Vulnerabilities to climate change to farmers in the study are found like salinity, temperature, sea level rise, precipitation, cyclones & storms, flood, rainfall, land erosion, and drought. The respondents think that flood, land erosion, cyclone, storm and rain fall, have very high-level vulnerability. Sea level rise, saline intrusion drought and temperature are at high level vulnerability (Figure 4.7).

Vulnerability is the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC, 2007). Gossen et al. (2018) clarified that temperature, rainfall, land erosion, drought, salinity, cyclone, and storm have been increasing trends over the decades. Riverbank erosion along the main rivers is a recurrent phenomenon (Alam, 2016; Alam et al., 2018a; Islam 2016).

The sea level at the Bay of Bengal rises slightly higher than global average sea levels (Delta plan, 2015). Sea-level rise is a major threat to our existence and for coastal agriculture. Coastal zones are the most vulnerable areas to salinity intrusion and it follows an increasing pattern (Rahman, 2011). Both farmers' perception and previous studies summarize that vulnerability is very startling for agriculture. In the study area land erosion is a crucial vulnerability, a lot of land is being eroded every year especially rainy season. As a result, farmers are expiating cultivable land, in case of small farmer or landless farmers land erosion become the curse. Cyclones and storm surge are very terrific for agriculture, they totally deteriorated the agricultural crops and others.

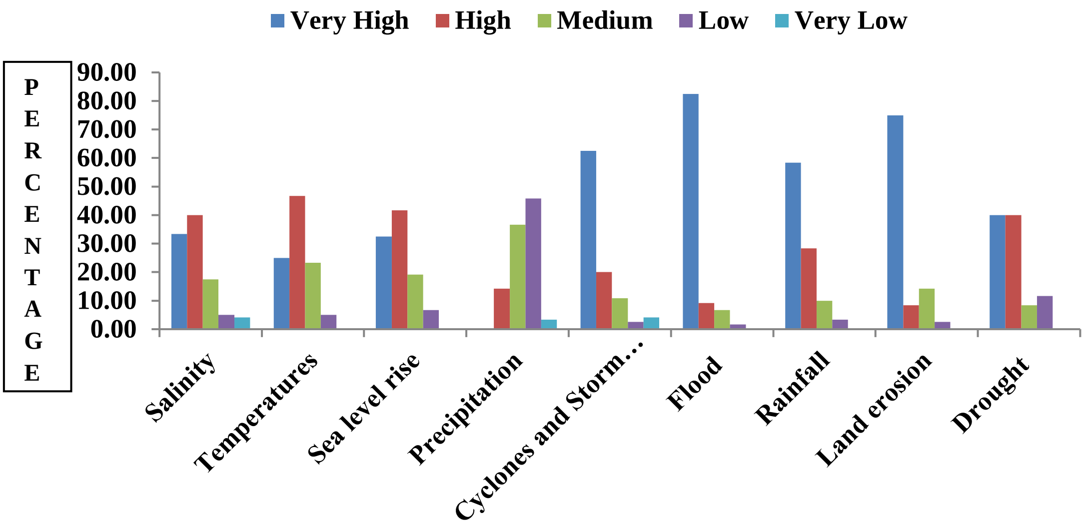


Figure 4.7: Farmers‘ perception about vulnerabilities

Source: Field Survey, 2019.

4.8. Adaptation strategies of farmers

The Figure 4.8 represents the adaptation strategies adopted by the farmers. The adaptation strategies are own irrigation equipment, direct-seeded rice, greater emphasis on Aman with supplementary irrigation, cultivation of different rice varieties, adjusting planting calendars, adjusting planting techniques, diversifying crops and varieties, vegetables cultivation, homestead gardening, managing water use, diversifying income sources, reinforcing human and asset safety, livestock rearing, poultry & duck rearing, family members’ migration to other areas, mainly urban areas, off-farm work(van, auto rickshaw driving etc) and petty business/small business.

The study focuses on short-term on-farm planned adaptations. Most adopted strategies for all farmers are, cultivation of saline, flood and drought tolerant rice and cultivation of water saving non-rice and horticulture crops. Adaptations to saline tolerant, flood tolerant and drought-tolerant rice varieties have been largely promoted by DAE (Department of Agricultural Extension) and also subsidized by the government (Shelley et al., 2016). Most of the farmers adopt horticultural crops than other crops in their field and homestead area. These crops include pulse, watermelon, potato, pulses, chickpea, sweet gourd, and onion (Alauddin and Sarker, 2014; BBS, 2014). The variety cultivated during the Boro season is relatively new in Bangladesh.

Supplementary irrigation during Aman and Aus seasons are often required due to inadequate and delayed rainfall. Small and landless farmers used supplementary irrigation more than large and medium farmers. Changing planting dates and others such as changing harvesting date, use of water saving technology and so on (Alauddin and Sarker, 2014) are more preferred by large and medium farmers compared to small and landless farmers.

Any adaptation regulated and facilitated by institutions such as local or national government, national and international non-governmental organizations is defined as planned adaptation. Livestock, poultry and duck rearing and homestead gardening are the common adaptation strategies, though the negligible percentage of farmers are not adopting. Direct seeded rice, supplementary irrigation in Aman season and changing planting dates are least adapted strategies in the study area. Direct seeded rice is a broadcast variety, widely cultivated in Asian countries where both water scarcity and labor shortage are high (Kumar and Ladha, 2011).

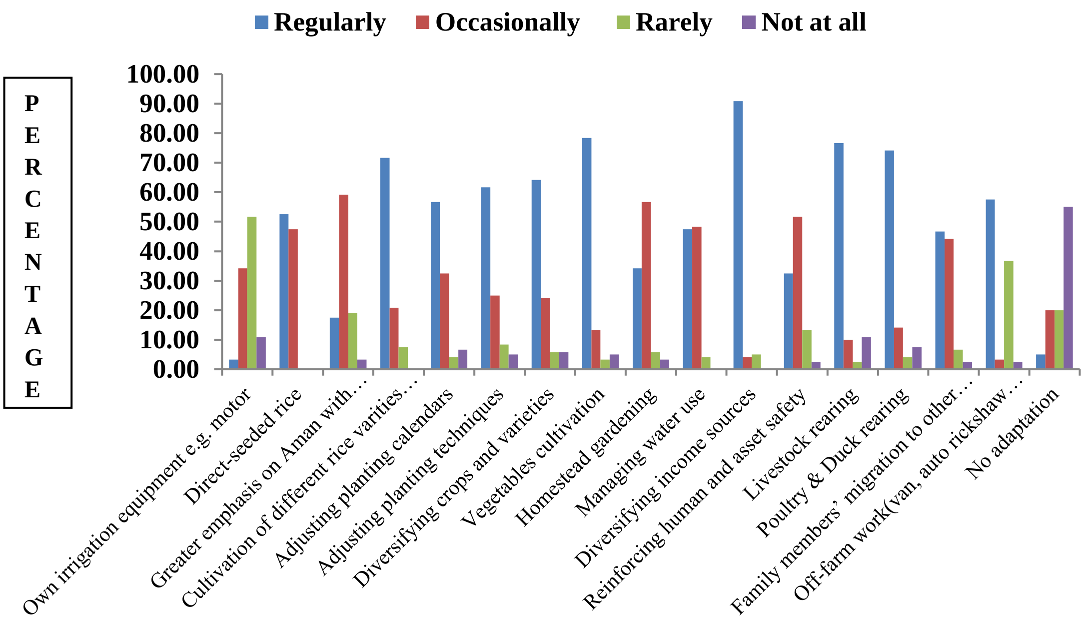


Figure 4.8: Adaptation strategies of farmers, Source: Field Survey, 2019.

4.9. Coping Strategies

Adaptive strategies might resolve one problem but they sometimes create other problems which necessitate a coping strategy (Paul 1998; Mertz 2009). Coping strategy is necessary to survive so farmers minimize the situation through performing an option. In the study area farmers mainly try to cope by selling of livestock, duck and poultry, spending previous savings, credit from rural usury, Institutional microcredit, sale and mortgage of some plots of land, sale of other assets, family members' migration to other areas, mainly urban. The table 4.9 showed about the coping strategies index with ranking. Most of farmers take as coping strategy sale of livestock, duck and poultry, at instant they try to minimize the adverse effect of calamities. Spending previous savings is the second most coping strategy. To cope up with the adverse situation farmers secure the credit from the rural usury these are common scenario.

Coping Strategies	**Coping Stategies Index**	**Rank**
Sale of livestock, duck and poultry	395	1
Spending previous savings	374	2
Credit from rural usury	368	3
Institutional microcredit	356	4
Sale and mortgage of some plots of land	341	5
Sale of other assets	297	6
Family members' migration to other areas, mainly urban	291	7

Table 4.9: Coping Strategies Index

Source: Field Survey, 2019.

4.10. Barriers to adaptation

In the study area farmers appear some barriers to adaptation such as lack of weather and potential climate change and weather forecast information, lack of money, lack of knowledge concerning appropriate adaptation, shortage of labour, lack of water for irrigation, lack of market for selling products, lack of education, poor agricultural extension service delivery, poor information on early warning systems and inadequate knowledge of how to cope or build resilience (Figure 4.10).

About 90% farmers mentioned lack of information about climate change is a barrier to adaptation (Figure 4.10). This scenario is crucial because information and knowledge are important to build perception which further influences adaptation (Apata et al., 2009). This survey depicts that 79.17% of farmers mentioned lack of knowledge concerning appropriate adaptation as a barriers to adaptation.

Lack of financial resources in terms of credit, money or saving (74.17%) are also crucial barriers faced by farmers. Similar constraints are mentioned in earlier studies (e.g. Shrestha et al., 2017; Sarker et al., 2013; Deressa et al., 2009) which are also in line with vulnerability scholarship. Poor agricultural extension service is also a crucial barrier to adaptation. Institutional accessibility of farmers such as financial institutions for credit, extension services, and information about climate conditions has a significant effect on the choice of adaptation (Alam et al., 2016).

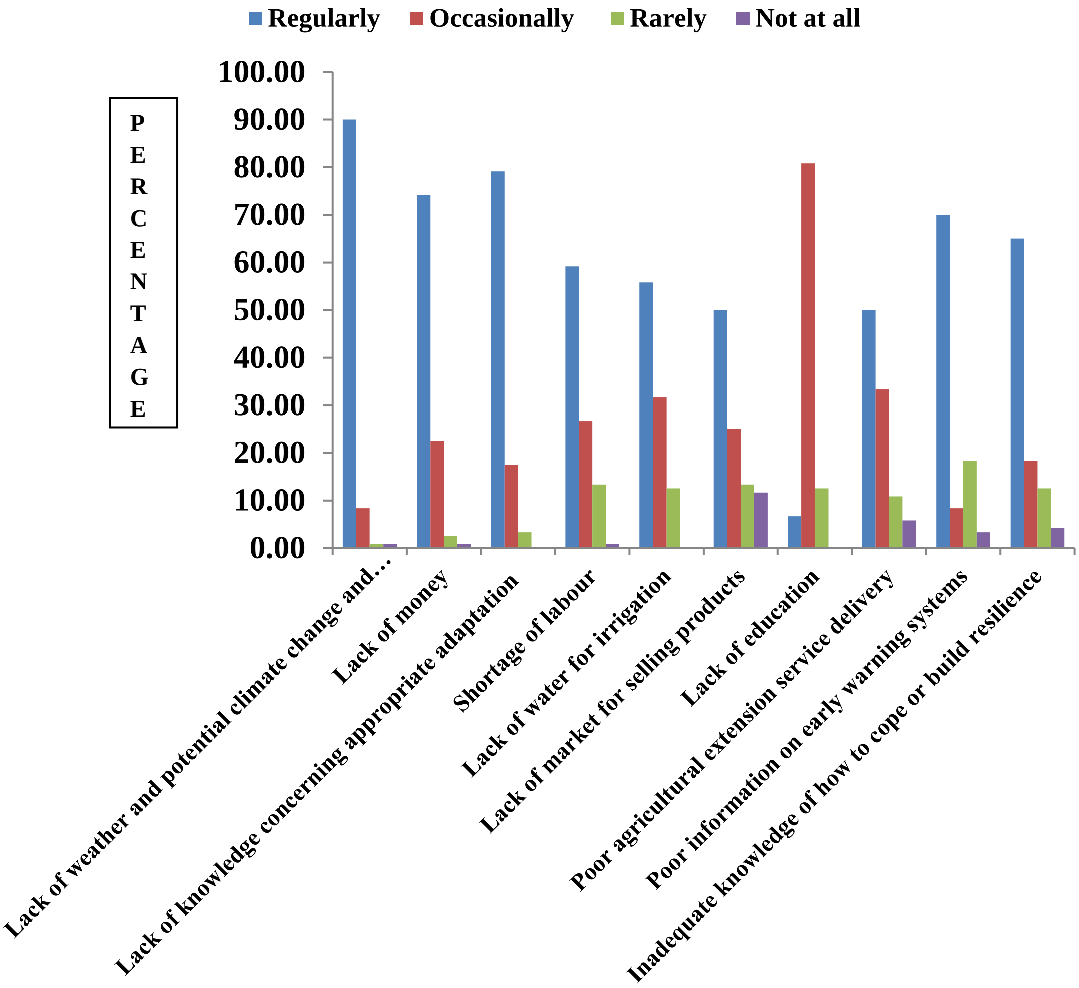


Figure 4.10: Major barriers to adaptation

Source: Field Survey, 2019.

4.11. Econometric Model Results

Table 4.11 presents the results of the MNL model of estimated parameters and marginal effects. Overall, the model offers a good fit with factors predicting the adoption of adaptation strategies by the study households. The chi-square statistics (LR–88.16) indicate the strong explanatory power of the model. Goodness of fit of the model given by the McFadden pseudo R^2 of 0.22 also indicates reasonable explanatory power of the model (Table 4.11). Moreover, most of the explanatory variables in the model were found to be statistically significant with an expected sign (see discussion below).

4.11.1. Age of household head

The age of the household head acts as a proxy for experience and so influences the adoption of adaptation strategies. The study found the household head's age was a significant positive (0.165) factor on adopting cultivation of non-rice crops. It implies that a one unit (year) increase in a respondent's age will increase the probability of adopting cultivation of non-rice rops by 0.165 relative to the base category while the effect on the remaining options is negligible. Negative relationship implies that a one unit (year) increase in a respondent's age will decrease the probability of adopting the particular adaptation strategy. The same interpretation holds true for the other variables. It may be due to the fact that experienced people have good knowledge about weather and climate variability and thus adapt to this risk-aversion strategy. This finding is consistent with previous adaptation studies (Hisali et al., 2011; Deressa et al., 2009).

4.11.2. Level of education

The study found a significant positive relationship on the adoption of HYV crops and supplementary irrigation and cultivation of non-rice crops. This finding supports the empirical evidence that farmers with higher educational levels were likely to adapt better to climate change in the African context (Gebrehiwot and van der Veen, 2013; Deressa et al., 2011) and in Bangladesh (Alam, 2015; Alauddin and Sarker, 2014).

4.11.3. Gender of household head

This study found a significant positive relationship between adopting the strategies of cultivation of HYV crops, supplementary irrigation and livestock, duck and poultry rearing for male-headed households. This result is in accordance with the field experience.

4.11.4. Experience

The model results found the farming experience was significant positive factor on adopting cultivation of HYV, supplementary irrigation, direct seeded rice and livestock, poultry and duck rearing. This implies that the probability of adaptation to climate change is greater for those who have more experience. This finding is consistent with previous adaptation studies (Hisali et al., 2011; Deressa et al., 2009).

4.11.5. Access to electricity

We found evidence that suggests a household's access to electricity facilities greatly influences the likelihood of adopting adaptation strategy. High access to electricity increases the probability of adopting adaptation strategies such as cultivation of HYV, supplementary irrigation, direct seeded rice and livestock, poultry and duck rearing which were found significant positive.

4.11.6. Access to extension service

The model results found the access to extension service was significant positive factor on adopting cultivation of HYV, direct seeded rice and livestock and cultivation of non rice crops. This implies that the probability of adaptation to climate change is greater for those who have more access to extension service.

4.11.7. Farmer to framer extension service

This study found a significant positive relationship between adopting the strategies of supplementary irrigation and direct seeded rice for farmer to farmer contract. It raveled that the probability of adaptive strategy adoption in higher for those farmers who have connections with different farmers compared to farmers not participating in such coordinated actions.

Table: 4.11. Estimated results from MNL model.

Explanatory Variables	Adaptation Strategies (Dependent Variables)				
	Cultivation of HYV	**Supplementary irrigation**	**Direct seeded rice**	**Cultivation of non rice crops**	**Livestock, Duck and poultry rearing**
	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
Constant	-6.593 (5.56)	-0.736 (5.062)	1.211 (5.104)	-15.141** (7.164)	-2.646 (5.945)
Age	-0.008 (0 .06)	-0.066 (0.059)	-0.021 (0.060)	0.165* (0.103)	-0.075 (0.077)
Education	1.282* (0.74	1.013* (0.667)	0.819 (0.693)	1.620** (0.825)	0.992 (0.798)
Gender	-2.393** (1.13)	-2.068** (0.982)	-2.381** (1.023)	-2.088* (1.177)	-3.215** (1.406)
Experience	0.138* (0.09)	0.184** (0.084)	0.169** (0.084)	0.1011 (0.093)	0.228** (0.093)
Access to Electricity	2.744* (1.48)	1.921* (1.442)	2.868** (1.415)	3.071* (1.572)	3.317** (1.527)
Access to Extension service	1.710* (0.99)	-0.644 (0.889)	1.777** (0.891)	1.456* (1.088)	-1.021 (1.049)
Farmer to farmer contract	0.54 (1.25)	1.254 ** (1.121)	0.714** (1.128)	0.887 (1.315)	1.197 (1.245)
Access to credit	0.375* (1.02)	0.990** (0.920)	-1.036 (0.922)	-0.769 (1.098)	1.177** (1.065)
Access to information	0.330** (0.90)	0.166* (0.917)	0.152** (0.914)	0.086** (1.089)	0.755* (1.122)
Income	-.00002** (8.80)	-4.07 (7.40)	-.00001* (8.821)	-.00001* (8.80)	-.00001 (9.67)
Family size	0.912** (0.36)	0.495* (0.334)	0.350 (0.330)	0.649* (0.391)	0.564* (0.394)
Farm size	0.0111* (0.006)	0.007 (0.006)	0.004 (0.006)	0.008 (0.007)	-0.004 (0.007)

Log likelihood = -162.26939

Pseudo R^2 = 0.2136

LR (Chi-square) = 88.16

N = 120. Adjusting planting time and techniques is used as base category.
Standard errors are indicated in parentheses.

*p< 0.10

**p< 0.05

***p< 0.001

4.11.8. Access to credit

Access to credit has been reported to have a significant positive impact on adaptation decisions (Bryan et al., 2009; Deressa et al., 2009). This study found a significant positive relationship between adopting the strategies of cultivation of HYV, supplementary irrigation and livestock, duck and poultry rearing for access to credit.

4.11.9. Access to information

Information on climate change can create awareness among farmers and increase the probability of adopting adaptation strategies (Alam, 2016; Deressa et al., 2009). The model results found a significant positive relationship between adopting the strategies of cultivation of HYV, supplementary irrigation, direct seeded rice, cultivation of non-rice crops and livestock, duck and poultry rearing for access to information.

4.11.10. Income

The result of the model shows that negative and significant relationship between family income and adoption of adaptive strategies of cultivation of HYV, direct seeded rice and cultivation of non-rice crops. This implies that farmers with high income are less likely to adopt adaptive strategies. Perhaps farmers were facing loss every year, they did not get proper price of crops for this, got discouraged in adopting in agriculture for increasing income.

4.11.11. Family size

Family size is positive and significantly related to farmers' adaptation strategies of cultivation of HYV, supplementary irrigation, cultivation of non-rice crops and livestock, duck and poultry rearing. This positive sign indicates that with increasing size of the family, the probability of farmers' adoption of an adaptive strategy increases. Large family size makes available more labor which can actively engage in work, better facilitating the adoption of adaptive measures against climate change effects (Deressa et al.,2009, 2008)

4.11.12. Farm size

The model results found the farm size was significant positive factor on adopting of cultivation of HYV, supplementary irrigation. This implies that the probability of adaptation to climate change is greater for those who have more land.

CHAPTER FIVE

CONCLUSION, POLICY IMPLICATIONS AND LIMITATION

5.1. Introduction

This chapter summaries the main finding of the study and provide some recommendations and future research direction. The organization of this chapter is as follows: Section 5.2 summarizes the main findings to answer the three research objectives. Section 5.3 provides some policy recommendations based on the findings. and Section 5.5 presents further research directions.

5.2. Summary of the findings

Bangladesh is the most climate vulnerable country in the world. This study has investigated the livelihood condition and adaptation strategies of rice farmers in the coastal areas of Bangladesh. The study also assessed the determinants of the choice of adaptation strategies. Data were collected from 120 rice growers using structured survey questionnaire in 2019. Different statistical analysis including MNL model was conducted to fulfill the objectives of the study.

Major vulnerabilities to climate change are salinity, temperature, sea level rise, precipitation, cyclones & storms, flood, rainfall, land erosion, and drought. Most of the farmers experienced scarcity of food during Kartik, Agrahayon, Poush but the rest of the month they passed with adequate food. An agricultural subsidy is very rare and only 35 percent of farmers got it. Agricultural extension service is very poor only 29 percent of farmers have access to information. Only 18.33% of households have access to regular weather information, with television as the major source, but most of them share the weather information to their neighbors. Farmers' perceptions about climate change reveal that temperature has increased and rainfall has decreased over the last 20 years but abnormalities in rainfall are reported. However, most farmers perceived that in winter temperature has decreased over time. Others extreme events like a storm, flood, and drought have been increasing and among floods is earlier than season noticed in previous years. Others extreme events like a storm, flood, and drought have been increasing and among floods is earlier than season noticed in previous years.

The survey results reveal that nearly 97% of farm households adopted adaptive measures to limit the adverse impact of climate change on rice production. The adaptation strategies include own irrigation equipment e.g. motor, direct-seeded rice, greater emphasis on Aman with supplementary irrigation, cultivation of different rice varieties, adjusting planting calendars, adjusting planting techniques, diversifying crops and varieties, vegetables cultivation, homestead gardening, managing water use, diversifying income sources, reinforcing human and asset safety, livestock rearing, poultry & duck rearing, migration mainly urban areas, off-farm work(van, auto rickshaw driving etc) and petty business/small business.

However, most practiced adaptation strategies are cultivation of HYVs, supplementary irrigation, direct seeded rice, cultivation of non-rice crops diversifying crops varieties, adjusting planting calendars, vegetable cultivation, homestead gardening, livestock, poultry and duck rearing which can be considered as agriculture related adaptations. Farmers also took other adjustment mechanisms including obtaining loans from rural money lenders and relatives, loans from NGOs, sale of livestock and spending previous savings.

Farmers identified the main barriers to adaptation are a lack of climate change and weather forecast information, lack of money, lack of knowledge concerning appropriate adaptation, shortage of labor, lack of water for irrigation, lack of market for selling products, lack of education, poor agricultural extension service delivery, poor information on early warning systems and inadequate knowledge of how to cope or build resilience.

5.3. Policy implications and recommendations

The following specific recommendations are made from my empirical study for maintaining or improving rice production in Bangladesh in the face of climate change:

- BRRI and BINA already have developed various saline-tolerant varieties, flood-tolerant varieties, drought-tolerant varieties, short duration varieties etc., the results revealed that a large part of the farmers are cultivating local varieties and also, they are damaged economically. It may be that they are not well concerned to adopt HYVs to cope up with the adverse effects of climate change. So, DAE, BADC and NGOs can be involved in introducing these varieties to the farmers so that they are encouraged to adopt the varieties quickly.
- Necessity of Agricultural Information Centers (AIC) is at high priority basis because farmers have been suffering lack of proper information and inefficient use of technology. We found that most of the farmers have lack of knowledge concerning appropriate adaptation, AIC can provide proper knowledge of adaptation strategies.
- Extension service should be more available, farmers do not get enough service from DAE. They can disseminate the modern technologies to the farmers to minimize the impacts of climate change. More access of modern technologies to farmers can bring wellbeing economically.
- Famers are feeling lack of irrigation especially supplementary irrigation at Aman season. Policymakers should place more emphasis on Aus and Aman rice (as they are mainly rain-fed crops) by allowing supplementary irrigation to increase overall rice production. BADC can play vital role to ensure the facility of irrigation.

- Household access to weather information could also enhance adaptation and reduce the adverse effects of climate change. However, the analysis shows that more than 80% of the farmers in the study area do not get any information regarding weather while the remaining farmers get mostly inaccurate and irregular weather forecasts. Weather forecasts should be made available regularly through cell phone systems, television and/or radio. The Bangladesh Space Research and Remote Sensing Organization (BSRRSO) can take a leading role in this activity.

- Government subsidy is also very essential for the small and landless farmers but very negligible percentage of farmers get facilitated from the subsidy of government. Here some mismanagements also occurred as a result they can not reach the subsidy what government announced for them. So, policy makers should rethink about the system of providing subsidy. We think that cash money is better as subsidy and dissemination system should not be traditional, SAASs can provide a list of real receptors of subsidy then the agriculture ministry can provide the subsidy as cash money to the farmers bank account; otherwise the real suffers can not catch the benefit of subsidy.

- Lack of finance is a common phenomenon of our farmers. Policymakers have to reconsider about the financial facility of farmers because farmers are maker of the nation; their sound existence is the sign of wellbeing. Krishi Bank can provide loan without any interest to small and landless farmers because they are more vulnerable to climate change or any natural calamities. But real scenario is different farmers go to rural usury for finance and they victims with the high interest rate; they get impoverished day by day and vicious cycle of poverty. To survive our farmers government should be attentive on financial facility of farmers and create an easiest way of providing loan to small and landless farmers.

- Agricultural marketing should be a vital issue of policy makers, because now-a-days it’s a very common scenario; farmers don’t get fair price of their products and become looser every year. In the study area we saw that they are facing problem of selling agricultural products. In true sense there is no active government institute to monitor the agricultural marketing system. Department of Agricultural Marketing is also liable to monitor and supervise this system but it is a matter of regret that its totally an inactive institute for lack of efficient officials. To ensure the fair price of agricultural products government should deeply rethink about the DAM; it must be redesigned with the official who are expert about agricultural marketing and agribusiness like graduate of agricultural economics and agricultural marketing.

5.4. Limitations and future research focus

This research focused only on the most saline intrusion, sea level rise, and flood-prone areas of Bangladesh due to time and budget constraints. However, the literature indicates different regions are impacted differently by changes in climate. Therefore, future research can be undertaken in the drought-prone and severe groundwater depleted areas, haor and riverbank erosion-prone areas of Bangladesh. This may provide an avenue for policymakers to devise region-specific adaptation policies that will have the potential to address the adverse effects of climate change more effectively.

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APPENDICES

Appendix A

CLIMATE CHANGE

Climate Change – Refers to any change in climate over time, whether due to natural variability or as a result of human activity. (IPCC TAR, 2001a)

Climate change – Refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or in land-use. (IPCC TAR, 2001 b)

Climate change – A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. See also climate variability. (UNFCCC)

Climate Change – The climate of a place or region is changed if over an extended period (typically decades or longer) there is a statistically significant change in measurements of either the mean state or variability of the climate for that place or region. (Changes in climate may be due to natural processes or to persistent anthropogenic changes in atmosphere or in land use. Note that the definition of climate change used in the United Nations Framework Convention on Climate Change is more restricted, as it includes only those changes which are attributable directly or indirectly to human activity.) (UN/ISDR, 2004)

VULNERABILITY

Vulnerability –The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity. (IPCC TAR, 2001)

Vulnerability – the degree to which the exposure unit is susceptible to harm due to exposure to a perturbation or stress, and the ability (or lack thereof) of the exposure unit to cope, recover, or fundamentally adapt (become a new system or become extinct) (Kasperson et al., 2000) It can also be considered as the underlying exposure to damaging shocks, perturbation or stress, rather than the probability or projected incidence of those shocks themselves. (UNDP, 2005)

Vulnerability – The extent to which a natural system or human society is unable to cope with the negative impacts of climate change, variability and extremes. It depends on changes in climate as well as the sensitivity and adaptive capacity of the system or society. (Australian Greenhouse Office. 2003) Vulnerability – Refers to the magnitude of harm that would result from a particular hazardous event. The concept recognises, for example, that different sub-types of a receptor may differ in their sensitivity to a particular level of hazard. Therefore climate vulnerability defines the extent to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. It depends not only on a system's sensitivity but also on its adaptive capacity. Hence arctic alpine flora or the elderly may be more vulnerable to climate change than other components of our flora or population. (UKCIP, 2003)

ADAPTATION

Adaptation - Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation (IPCC TAR, 2001 a)

Adaptation - Practical steps to protect countries and communities from the likely disruption and damage that will result from effects of climate change. For example, flood walls should be built and in numerous cases it is probably advisable to move human settlements out of flood plains and other low-lying areas...(UNFCCC, 1992)

Adaptation -Is a process by which strategies to moderate, cope with and take advantage of the consequences of climatic events are enhanced, developed, and implemented. (UNDP, 2005)

Adaptation - The process or outcome of a process that leads to a reduction in harm or risk of harm, or realisation of benefits associated with climate variability and climate change. (UK Climate Impact Programme (UKCIP, 2003)

AUTONOMOUS AND PLANNED ADAPTATION

When adaptation action is taken locally by individual farmer without institutional interference, it is called autonomous adaptation. On the contrary any adaptation regulated and facilitated by institutions such as local or national government, national and international non-governmental organisations is defined as planned adaptation. The study focuses on the adaptation strategies planned by national institutions and implemented at regional level. For example, rice variety cultivated in the study area are invented by BRRI and BARC, promoted and distributed by the Department of Agriculture Extension under local government.

MALADAPTATION

Maladaptation – Any changes in natural or human systems that inadvertently increase vulnerability to climatic stimuli; an adaptation that does not succeed in reducing vulnerability but increases it instead. (IPCC TAR, 2001)

COPING CAPACITY

Coping Capacity – The means by which people or organizations use available resources and abilities to face adverse consequences that could lead to a disaster. (In general, this involves managing resources, both in normal times as well as during crises or adverse conditions. The strengthening of coping capacities usually builds resilience to withstand the effects of natural and human-induced hazards.) (UN/ISDR, 2004)

Coping capacity – Capacity refers to the manner in which people and organisations use existing resources to achieve various beneficial ends during unusual, abnormal, and adverse conditions of a disaster event or process. The strengthening of coping capacities usually builds resilience to withstand the effects of natural and other hazards (European Spatial Planning Observation Network)

EXTREME WEATHEREVENT

Extreme weather event – An event that is rare within its statistical reference distribution at a particular place. Definitions of "rare" vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile. By definition, the characteristics of what is called "extreme weather" may vary from place to place. An "extreme climate event" is an average of a number of weather events over a certain period of time, an average which is itself extreme (e.g., rainfall over a season). (IPCC, TAR, 2001 a)

Extreme event – An extreme weather event refers to meteorological conditions that are rare for a particular place and/or time, such as an intense storm or heat wave. An extreme climate event is an unusual average over time of a number of weather events, for example heavy rainfall over a season. (Australian Greenhouse Office. 2003)

MAINSTREAMING

A definition of ‘mainstreaming’ does not yet exist, although the term is widely used. It seems that ‘mainstreaming’ is used interchangeably with ‘integration’. Mainstreaming refers to the integration of adaptation objectives, strategies, policies, measures or operations such that they become part of the national and regional development policies, processes and budgets at all levels and stages (UNDP, 2005). The term is also used to describe the process of integrating adaptation to climate change into development assistance (e.g., Agrawala (2005), Klein (2002)).

RESILIENCE

Resilience – Amount of change a system can undergo without changing state. (IPCC, TAR, 2001)

Resilience – Resilience is a tendency to maintain integrity when subject to disturbance. (UNDP, 2005)

Resilience – The ability of a system to recover from the effect of an extreme load that may have caused harm. (UKCIP, 2003)

Resilience – The capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organizing itself to increase its capacity for learning from past disasters for better future protection and to improve risk reduction measures. (UN/ISDR, 2004)

VULNERABILITY ASSESSMENT

Vulnerability assessment identifies who and what is exposed and sensitive to change. A vulnerability assessment starts by considering the factors that make people or the environment susceptible to harm, i.e. access to natural and financial resources; ability to self-protect; support networks and so on. (Tompkins, E. et al., 2005)

CLIMATE VARIABILITY

Climate Variability - Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability). See also climate change. (IPCC TAR, 2001)

STRATEGY

Strategy – Refers to a broad plan of action that is implemented through policies and measures. A climate change adaptation strategy for a country refers to a general plan of action for addressing the impacts ofclimate change, including climate variability and extremes. It may include a mix of policies and measures, selected to meet the overarching objective of reducing the country’s vulnerability. (UNDP, 2005)

Appendix B

Climate Vulnerability Index of Betagi ,Barguna (0 means no vulnerability, 1 means highly vulnerable)

Table B.1. Climate Vulnerability Index of Betagi, Barguna

Particulars	Vulnerable range
People affected due to natural disaste	0.35
Heat stress	0.3
Ground water quality depletion and degradation	0.31
Ground water quality depletion and degradation	0.43
Land availabilty for livestock	0.51
Water availability	0.51
Crop yield vulnerability	0.64
Decrease in livestock & poultry health vulnerability	0.42
Land availability for agriculture	0.27
Change in fish culture	0.29
Rail network vulnerability	0.21
Road network vulnerability	0.38

Source: Bangladesh Delta Plan, 2015

Climate Vulnerability Index of Galacipa ,Patuakhali (0 means no vulnerability, 1 means highly vulnerable)

Table B.2. Climate Vulnerability Index of Galacipa ,Patuakhali

Particulars	Vulnerable range
People Affected Due to Natural Disaste	0.58
Heat Stress	0.23
Ground Water Quality Depletion and Degradation	0.41
Ground Water Quality Depletion and Degradation	0.33
Land Availabilty for Livestock	0.36
Water Availability	0.46
Crop Yield Vulnerability	0.53
Decrease in Livestock & Poultry Health Vulnerability	0.58
Land Availability for Agriculture	0.4
Change in Fish Culture	0.49
Rail Network Vulnerability	0.35
Road Network Vulnerabilit	0.45

Source: Bangladesh Delta Plan, 2015