An Assessment of the Livelihood Vulnerability of the Riverbank Erosion Hazard and its Impact on Food Security for Rural Households in Bangladesh

A Dissertation Submitted for the Award of
Doctor of Philosophy

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February 2016

Dedicated to my father

the late Kayem Uddin Ahmed

ABSTRACT

As the effects of climate change and hazards are starting to be felt worldwide, there are certain frontline countries that are most at risk and Bangladesh is genuinely at risk in terms of its economic viability and food security unless its citizens develop adaptation strategies to compensate for these effects. This study analyses how the impacts of climate change and hazards (specifically riverbank erosion) are already jeopardising the livelihood and food security of rural riparian (riverbank and *char*) households in Bangladesh, compromising their access to arable land, and thereby holding back their potential for both sustenance and economic development.

The researcher has conducted extensive research in two severe riverbank erosion-prone districts in Bangladesh to assess the severity of these problems and to seek the strategies the affected people deploy to offset the effects. This study takes a holistic approach to two key vulnerability assessment methods – the Livelihood Vulnerability Index (LVI) and the Climate Vulnerability Index (CVI). Importantly, this study also develops an indicator-based Resilience Capacity Index (RCI) in order to understand the factors influencing the resilience capacity of these households.

This study reveals that the LVI and CVI values are different between *char* (sandbar) and riverbank communities: households inhabiting *char* lands display the most vulnerability to climate change and hazards. Also, riparian households are found to be vulnerable due to their relative inaccessibility and low livelihood status which, coupled with the impact of the climate on river morphology, are causing erosion and a loss of land with a consequent decrease in economic potential, thereby perpetuating a cycle of poverty. Creating employment opportunities, increasing the level of education and ensuring access to food, water and health services are potential strategies that are likely to enhance the resilience capacity of such vulnerable households in Bangladesh.

In regards to food security, more than 50% of the households are in the ‘food insecure’ category, with a per capita calorie consumption of 12% less than the standard minimum daily requirement. The estimated low Food Security Index (FSI) value indicates that these households can usually manage food twice per day for their family members. The results of logit modelling indicate that household size, educational attainment, adoption of livestock and access to non-farm earnings are

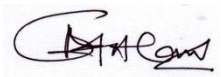
important determinants of household food security. This study also finds new evidence that suggests access to improved health care also needs policy support in parallel with improved access to food to achieve and to sustain long-term food security in Bangladesh. Properly targeted income transfers and credit programs along with infrastructure and human development programs in the erosion-affected areas across the country may have very high payoffs by improving food security, and thus, reducing poverty in the long-term.

To build resilience, households are autonomously adopting adaptation strategies such as diversifying crops, tree plantation (generally by large and medium farmers), and homestead gardening and migration (generally by small and landless farmers). However, some important barriers to adaptation are felt heterogeneously among the farming groups: among these are access to credit and a lack of information on appropriate adaptation strategies. The results of multi-nominal logit modelling indicate that the choice of an adaptation strategy is influenced significantly by a household head's education, household income, farm category, access to institutions and social capital. To support adaptation locally and to enhance households' resilience to cope better with riverbank hazards and other climate change issues, government intervention through planned adaptation such as access to institutions, credit facilities and a package of technologies through agro-ecologically based research are required.

This study has contributed to our knowledge base through tailoring various theories and approaches in the context of riparian households in Bangladesh. The innovative coping and adaptation strategies could provide new insights for households in other hazard-prone regions in the world. The analytical framework used for assessing vulnerability, resilience, household food security and adaptation strategies should be replicated in other countries having similar characteristics to Bangladesh that are experiencing adverse impacts from climate change.

CERTIFICATION OF DISSERTATION

I hereby affirm that the ideas, results, analyses and conclusions presented in this dissertation are entirely my own effort, except where otherwise acknowledged. It is also certified that the intellectual content of this research is original and has not been previously submitted for any other academic award.



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OUTCOMES OF THE THESIS

Nine journal papers, one book chapter and four conference papers have been drawn from this thesis as follows:

Journal Papers

1. Alam, GMM, Alam, K, Shahbaz, M & Clarke, ML (2016) **'**Drivers of vulnerability to climatic change in riparian *char* and river-bank households in Bangladesh: Implications for policy, livelihoods and social development', *Ecological Indicators*, (Under review).
2. Alam, GMM, Alam, K, Shahbaz, M & Filho, WL (2015) 'Hazard-prone rural communities in Bangladesh: How resilient are they to the impact of climate change and variability?', *Journal of Rural Studies*, (Under review).
3. Alam, GMM, Alam, K & Shahbaz, M (2015) 'Influence of household head physical health status on food security: Evidence from vulnerable rural households in Bangladesh', *World Development,* (Under review).
4. Alam, GMM, Alam, K & Shahbaz, M (2015) 'Influence of institutional access and social capital on adaptation choices: Empirical evidence from vulnerable rural households in Bangladesh', *Ecological Economics,* (Under review).
5. Alam, GMM, Alam, K, Shahbaz, M & Hossain, M (2015) 'Riverbank erosion hazards, food insecurity and rural household responses: An empirical evidence from Bangladesh', *Food Security,* (Under review).
6. Alam, GMM, Alam, K & Shahbaz, M (2015) 'Climate change perceptions and local adaptation strategies of hazard-prone rural households in Bangladesh', *Natural Hazards,* (Under review).
7. Alam, GMM, Alam, K & Shahbaz, M (2015) 'Livelihood cycle and vulnerability of rural households to climate change and hazards in Bangladesh,' *Environmental Management*, (Under review).
8. Alam, GMM, Alam, K & Shahbaz, M, M, Khatun, M & Mamun, SAK (2015) 'Does household income matter for mobile phone adoption? A case study from rural Bangladesh', *Information Technology & People*, (Under review).

Book Chapter

Alam, GMM, Alam, K, Shahbaz, M & Filho, WL (2016) 'Strategies and barriers to adaptation: Evidence from hazard-prone rural households in Bangladesh'. In: Filho, WL & Nalau, J (eds), *Limits to Adaptation: Insights and Experiences*, Springer.

Conference Papers

1. Alam, GMM, Alam, K & Shahbaz, M (2014) 'Determinants of food security: An empirical analysis from Bangladesh resource-poor rural households, Paper presented at the Symposium on Research Journeys and the Production of Knowledge, 24 October 2014, USQ, Springfield.
2. Alam, GMM, Alam, K, Shahbaz, M, Khatun, M & Mamun, SAK (2014) 'The causal relationship between rural household income and mobile phone adoption: A case study from Bangladesh, Paper presented at the Symposium on Broadband-enabled Communities and Regional Development, 10-11 November 2014, USQ, Toowoomba.
3. Alam, GMM, Alam, K & Shahbaz, M (2015) 'Is migration is an appropriate coping strategy for hazard-prone rural households in Bangladesh?', Paper presented at the Symposium on Language, Culture and Technology in a Connected World, 1 June 2015, USQ, Toowoomba.
4. Alam, GMM, Alam, K & Shahbaz, M (2015) 'Analysing Livelihood Status and Policy Options to Improving Food Access for Resource-Poor Rural Households in Bangladesh', Paper presented in the HRD Student Seminar at USQ, 19-20 November, USQ, Toowoomba.

ACKNOWLEDGEMENTS

My PhD dream has come true thanks to the contribution of many people, although it is hardly possible to acknowledge my debt and gratefulness to all of them. Let me take the opportunity to acknowledge special gratefulness to a special few. First and foremost, I give thanks to Almighty Allah for unparalleled grace and strength to bring this work to realisation.

I feel proud to express my deepest sense of gratitude and hearty appreciation to my supervisors Associate Professor Khorshed Alam and Associate Professor Shahbaz Mushtaq for their time, scholastic guidance, incisive criticism, proper instruction and continuous supervision throughout the period of this PhD journey. Without their total cooperation and sacrifice it would not have been possible to complete the thesis within two and half years only.

In addition, I would like to express my gratitude to Professor MA Sattar Mandal, Rezaul Karim Talukder, Md Ferdous Alam, SM Fakhrul Islam, M Kamruzzaman, WHM Zaim, Mizanul Haque Kazal, Akhtaruzzaman Khan, Dr Monayem Miah, Dr Rayhan Hayat Sawer, Dr Abdur Rashid Sarker and many others for their insightful comments and guidance throughout my PhD research which enrich my research from various perspectives. The contribution of Professor Michèle L Clarke, University of Nottingham, UK, Professor Walter Leal Filho, Manchester Metropolitan University, UK and Associate Professor Moazzem Hossain, Griffith University, Australia is highly acknowledged. Their comments and suggestions really help to set the right direction of this research.

I sincerely acknowledged the University of Southern Queensland, Australia, for awarding me USQ Post Postgraduate Research Scholarship for International PhD and later on top-up scholarship and award for thesis editing. I express my gratitude to Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh, for granting me study leave to undergo the PhD study.

I would like to express great appreciation to the most vulnerable riparian households in the study areas for their wholehearted participation in this study. The agriculture officers, NGO workers and community leaders in the study area also

deserve much appreciation for extending their kind cooperation to conduct the study. The enumerators really done a wonderful job and rightly deserve much credit.

It is also my pleasure to express my gratitude that I have gained much knowledge through working with Professor Roger Lawrey, Head, School of Commerce, Professor Geoff Cockfield and Professor Julie Cotter, Director, Australian Centre for Sustainable Business and Development, as a research assistant for a range of projects. I also acknowledged the Deputy Vice-Chancellor (Research and Innovation) Professor Mark Harvey, Professor Barbara de la Harpe, Dean, Faculty of Business, Education, Law and Arts, and Professor Peter Terry, Director Research for providing me various assistance during my PhD period at USQ. My thanks also goes to the academic staff of USQ especially Professor Chandrasekhar Krishnamurti, Dr Mafiz Rahman, Dr Rasheda Khanam and Dr Shane Zhen. I would like to extend my special thanks to many friends whom valued accompany made my stay at USQ pleasant, namely, Dr SM Arefin Khan Mamun, Dr Shiduzzaman, Dr Enamul Kabir, Md Salauddin, Md Gaziuddin, Monzur Morshed, Wahid Ferdous, Md Mohsin, Michael and many others. Libby Collett also deserves special thanks for proof reading my thesis.

I have no words to express my gratitude to my family members. My mother Jamila Khatun, wife Nilufa Khatun Akhe, only son Mostakim Alam and my siblings sacrificed a lot and always remained a source of inspiration. I missed them greatly, and all credit for this PhD research therefore goes to them. My late father Kayem Uddin Ahmed who was my teacher and my idol first gave this dream to my mind. He would be the happiest man on about this accomplishment. Therefore, my thesis is dedicated to him. May Almighty Allah keep him in peace!

Finally, I am happy to express my gratitude to all of my teachers from primary to university level, friends, neighbors and all well-wishers for their love, support, encouragement and wishes which enable me to reach in this position. I owe much to my beloved beautiful country Bangladesh forever. Therefore, my commitment is to make all efforts to make them happy.

Warm-hearted thanks to all.

G M Monirul Alam
29 February 2016

ACRONYMS AND ABBREVIATIONS

AHM	Agricultural Household Model
BBS	Bangladesh Bureau of Statistics
BLR	Binomial Logit Regression
BMD	Bangladesh Meteorological Department
BRAC	Bangladesh Rural Advancement Committee
BRRI	Bangladesh Rice Research Institute
CEGIS	Centre for Environmental and Geographic Information Services
Char	Sandbar/island
CLP	*Char* Livelihood Program
CSI	Coping Strategy Index
CSIRO	Commonwealth Scientific and Industrial Research Organization
CVI	Climate Vulnerability Index
DAE	Department of Agricultural Extension
DFID	Department of International Development
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
FSI	Food Security Index
GoB	Government of Bangladesh
GBM	The Ganges, the Brahmaputra, and the Meghna
ha	Hectare
HH	Household Head
HYV	High Yielding Varieties
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IIA	Independence of Irrelevant Alternatives
IPCC	Intergovernmental Panel on Climate Change
IWFM	Institute of Water and Flood Management
Khas land	Governmental Land
LVI	Livelihood Vulnerability Index
MDGs	Millennium Development Goals

MNL	Multinomial Logit
MNP	Multinomial Probit
MOA	Ministry of Agriculture
MOF	Ministry of Food
NFPCSP	National Food Policy Capacity Strengthening Program
NGOs	Non-governmental Organisations
RCI	Resilience Capacity Index
RO	Research Objective
Riparian/Riverine	Riverbank and *char*
SLA	Sustainable Livelihood Approach
Taka (Tk)	Is the Bangladesh currency
UN	United Nations
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNESCO	The United Nations Educational, Scientific and Cultural Organization
UNISDR	United Nations International Strategy for Disaster Reduction
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
USQ	University of Southern Queensland
VGF	Vulnerable Group Feeding
VIF	Variance Inflation Factor
WB	World Bank
WDR	World Disaster Report
WFP	World Food Program
WHO	World Health Organization

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CHAPTER ONE

Introduction

1.1 Background and motivation for the study

Bangladesh occupies an area of only 147,570 km^2 in South Asia, with a population density of about 936 persons/km^2 where more than 35% people live under the poverty line (BBS 2012) (see the map in Figure 1.1 for Bangladesh in South Asia). Bangladesh is widely regarded as one of the world's most vulnerable countries due to its low-lying deltaic geographical position with more than 230 rivers and vast waterways that lead to disaster-proneness, as well as serious socio-environmental concerns including over population[1], poverty, and low economic and technological capacity (WB 2013; GoB 2011; IPCC 2007). The country experiences frequent natural disasters, including extreme climatic hazards, often in the forms of floods, droughts, riverbank erosion, salinity intrusion, water logging, and cyclonic storm surges (see Appendix 1 for specific disaster-prone areas). This causes large-scale loss of life and damage to infrastructure and economic assets, and thus adversely impacts on food, water and energy security, lives and livelihoods of poor people, particularly in the southern coastal areas and in the bank of the large rivers (Jordan 2015; Penning-Rowsell et al. 2013; Thoms et al. 2013; Pouliotte et al. 2009; Huq & Ayers 2008; IPCC 2007; Choudhury et al. 2005).

Food security issues have been a key concern globally over the last four decades. In spite of a reasonable level of food availability in many countries in the world, a substantial number of the globe's 'food insecure' people are the rural poor, who account for around 70% of the world's total of undernourished people (FAO 2010). It is predicted that future climate-induced hazards like floods, cyclones, drought and erosion will have catastrophic consequences on agriculture and food security in many parts of the world, particularly in developing countries (IPCC 2014; FAO 2013b; WB 2013). In this, Bangladesh is not immune to the impacts of these future climate change issues, which the nation is battling, along with the challenge of achieving food security and eradicating poverty.

[1] About 156.6 million people in 2014 (BBS 2014).

Food security is of prime concern in Bangladesh, despite marked improvements in food production and the incidence of poverty since the country's independence in 1971. In the last decade, the country achieved marked GDP growth rate of around 6% despite global economic turmoil in recent years. The rate of poverty decreased from 62% in 1988 to 35% in 2011 (BBS 2012). In contrast, population growth rate reduced from 2.4% in 1970 to 1.47% in 2011 (BBS 2012). Production of rice, the main staple food, increased from 16 million tons in 1970 to more than 50 million tons in 2010 (more than three times) (FAO 2012). This indicates that the country is close to achieving self-sufficiency in food production.

Figure 1. 1: Bangladesh in South Asia

Source: Adapted from http://www.southasiaMaps.php

Despite these successes, the country is regarded as one of the seven countries[2] where two-thirds of the 906 million undernourished people on the globe live (FAO 2010). A report by the USDA (2010) indicates that out of 156 million people in Bangladesh, 33 million were registered as 'food insecure' in 2010 and this is projected to be 37 million by 2020. It is mainly due to the lack of affordability of adequate food for many poor households.

There is a growing recognition that food availability at national level does not essentially assure food security at the household or at the individual level due to a lack of economic access to food by the poorest households (FAO 2012; MacFarquhar 2011; Harrigan 2008; Schmidhuber & Tubiello 2007; Cleaver 1993). For example, Hong Kong and Singapore are 'food secure' although they are not self-sufficient in food production (as in both of these areas, agriculture is non-existent). On the contrary, India is self-sufficient in production, however, a large part of its population is not 'food secure' (Reji 2013; Schmidhuber & Tubiello 2007). The important consideration for food security is whether or not the monetary and nonmonetary resources at the disposal of the population are sufficient to allow them access to adequate quantities of food (Barrett 2010; Schmidhuber & Tubiello 2007). This situation was exacerbated by the soaring price of food in 2008 that pushed many poor households into the vulnerable condition of food insecurity (Anriquez et al. 2013; Swinnen & Squicciarini 2012; FAO 2011; Barrett 2010). Scholars argued that household level food insecurity ultimately threatens food security at a national level, which is ultimately a threat to national security (Alam & Khatun 2012; Akinyele 2009; Bahiigwa 1999). Therefore, households' access to food and their level of vulnerability[3] are becoming more crucial for food security analysis in the changing global market economy (Keating 2013; Quisumbing 2013; WFP 2009).

Given the severe climate-related hazards in the country, the crucial policy agenda for Bangladesh is to identify and to understand the levels of vulnerability and to develop possible adaptation strategies, particularly for marginalised riverine/

[2] In 2010, about 925 million people were undernourished globally of which 906 million (98%) were in developing countries. Two-thirds of these live in just seven countries, namely, Bangladesh, China, Democratic Republic of Congo, Ethiopia, India, Indonesia and Pakistan (FAO 2010).

[3] Food security vulnerability is the probability of an acute decline in access to food or consumption (WFP 2002). This also refers people's propensity to fall, or stay, below a pre-determined food security threshold (Løvendal et al. 2004).

riparian[4] communities (details follow in the next section), that could mitigate the effects of adverse climate change and hazards. For governments to target development programs and initiate appropriate social, economic and environmental policies; it is important that accurate information on livelihood vulnerability is available. Indeed, it has been argued that policy interventions would do little to affect poverty dynamics unless the context of household vulnerability is properly understood (Shah et al. 2013; Hahn et al. 2009; IPCC 2007).

In Bangladesh, a number of studies (e.g., Ahmed 2015; Lein 2010; Zaman 2007, 1991, 1989; Hutton & Haque 2004; Hossain 1993; Elahi et al. 1991; Elahi 1989; Haque 1988; Rogge & Haque 1987; Greenberg 1986; Hossain 1984) have been conducted on riverbank erosion. However, there has been a lack of in-depth empirical research on the impacts of riverbank erosion and other climate change issues on the livelihood vulnerability and food security of the riverine rural households and how they respond to such hazards in order to mitigate immediate livelihood and food insecurity conditions. Therefore, assessing the livelihood vulnerability impacts of riverbank erosion on riparian household food security, along with the appropriate response strategies, is of significant research agenda in Bangladesh.

From an international perspective, this study has unique value since the main focus of the Millennium Development Goals (MDGs) for development agencies is on achieving food security and improving livelihood among the vulnerable rural population (UN 2013). The present study is aimed at generating important policy inputs for a comprehensive understanding of livelihood vulnerability and food security of the riverbank erosion hazard-prone rural households in Bangladesh.

1.2 Statement of the research problem

World Disaster Report (2001) argues that annually one million people are distressed[5] and at least nine thousand hectares of land are lost globally due to climatic hazards including coastal and riverbank erosions. Households in the costal and riverbank areas are more exposed to the impacts of climate change and hazards. Research indicates that a significant portion of households in many countries in the world are

[4] Riverbank and *char*.

[5] A situation in which people do not have enough money and/or food.

affected due to riverbank erosion such as India, Cambodia, Lao PDR, Thailand, Vietnam, Italy and Australia (Das et al. 2014; Hall & Bouapao 2010; Warner & Paterson 2008; Rinaldi 2003).

In Bangladesh, the coastal and riverine households are the most susceptible to the impacts of climate-driven hazards, including riverbank erosion (GoB 2010) and recent models of hydrological impacts of climate change in different climatic zones have shown this to be true across Asia (Eregno et al. 2013). In particular, the hazard of riverbank erosion is a common problem in Bangladesh which contributes to the loss of both physical and material endowments through loss of land, natural resources and employment opportunities of the riverine rural households and thus threatening their food security and livelihoods. Twenty districts out of 64 in the country are prone to the riverbank erosion (CEGIS 2012; GoB 2010); while another study asserted that some parts of 50 districts in Bangladesh are subject to riverbank erosion (Elahi et al. 1991) (see the map in Figure 1.2).

Moreover, resource-poor households in the riverine areas are more prone to the impacts of frequent floods and waterlogging due to their proximity to the river, which also increases their vulnerability. About 8,700 hectares (ha) of homestead and farming land are lost to riverbank erosion, which displaces approximately 200,000 people annually (GoB 2010). Scholars mentioned that the rapid changes in river courses destroy valuable agricultural land, rural settlements, markets and towns, and make the people destitute and landless (Ahmed 2015; Lein 2010; Zaman 2007; Hutton & Haque 2004).

A report by CEGIS (2012) shows that during the period from 1973 to 2011 at least 153,566 ha of cultivable land (1.80% of total land) including 50,339 ha of settlement was eroded by the three major rivers in Bangladesh - the Padma, Jamuna, and Ganges. The Jamuna river erosion rate was around 5,000 ha per year in the 1980s while in recent years the rate is around 2,000 ha per year (CEGIS 2012). The displaced and dispossessed people take shelter in open sky and/or on embankments built along the river. They are pushed into the most vulnerable condition of food insecurity and poverty. Riverine areas are considered to be the most vulnerable areas of persistent poverty in the country (IFAD 2013; Huq & Rabbani 2011).

Despite the fact that damage by riverbank erosion occurs slowly and gradually, however, it has long-term impacts that are irrecoverable (GoB 2010). The

key issue is that riverbank erosion diminishes the total area of arable land every year in a place where arable land is scarce: arable land is 0.05 ha/person in Bangladesh (WB 2015). This contributes to a shortage of aggregate food production and thereby negatively impacts upon the food and livelihood insecurity of the vulnerable riverine people. Erosion also often triggers displacement and intra-country migration in the country. The hazard of riverbank erosion is considered to be one of the important bottlenecks that is preventing Bangladesh from attaining its MDGs, particularly those of eradicating hunger and poverty (GoB 2011).

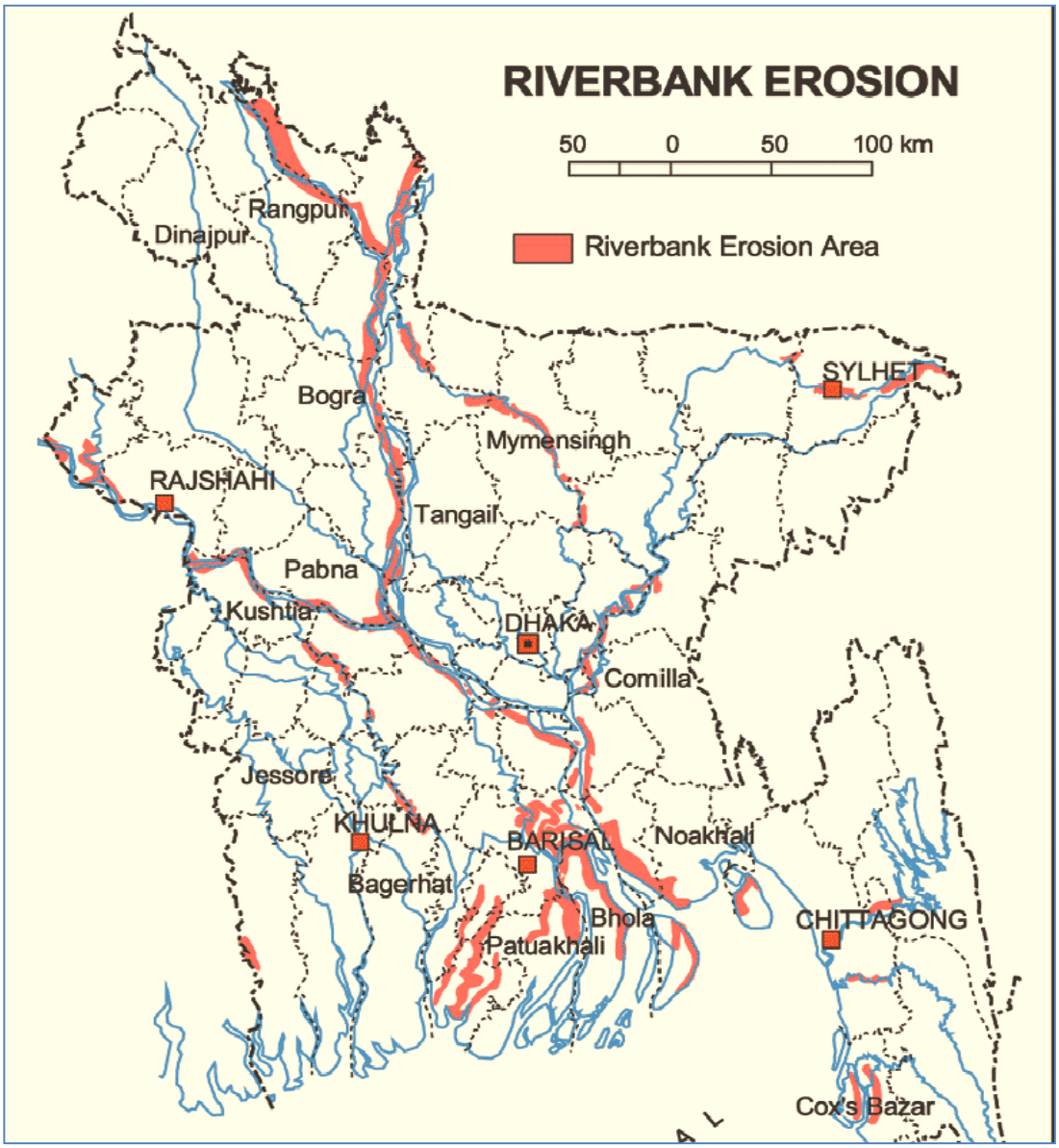

Figure 1. 2: Red colour shows the riverbank erosion-prone areas in Bangladesh

Source: Bangladesh Water Development Board

To make an appropriate policy intervention towards improving food security and the livelihoods of rural people in Bangladesh, policy makers and donor agencies need to know where the vulnerable people are, and to determine what drivers are exacerbating their levels of vulnerability and food insecurity. Although food security is a global concern, empirical evidence on how hazards like riverbank erosion coupled with climate change issues influence rural households' food security and their vulnerability seem to be scarce in the extant literature. This study will contribute to the policy formulation in this field and to the development of more targeted interventions through providing relevant reliable information and thus providing the opportunity to improve the food security and livelihood conditions of the marginalised rural riverine households.

1.3 Specific objectives of the research

The aim of this study is to assess the livelihood vulnerability of the riverbank erosion hazard and its impact on rural households' food security and their coping and adaptation strategies in Bangladesh. The specific objectives are:

i) To assess the livelihood vulnerability of the riparian households;
ii) To assess the food security status of the respondents; and
iii) To identify the response strategies of the vulnerable households in the face of riverbank erosion and other climate change issues.

1.4 Research questions and approach

The following research questions are set to address each of the Research Objective (RO):

Objective 1:

Research questions under this objective are sought as follows:

(i) what are the main drivers of livelihood vulnerability of riparian households to climatic changes and hazards?;
(ii) are households isolated from the mainland more vulnerable to climate change than other riparian households?; and

(iii) does livelihood status serve as a driver of vulnerability for them? and
(iv) what are the factors influencing their resilience capacity?

Objective 2:

The specific research questions under this objective are as follows:

(i) what is the livelihood status of the riverine households?;
(ii) what are the factors influencing households food insecurity?;
(iii) which months the households experience more food shortage (the extent of food insecurity)?;
(iv) what are their coping strategies to address the food shortage? and
(v) what are the policy recommendations to improve food security of these hazards-prone rural households in a sustainable way in Bangladesh?

Objective 3:

The main research questions under this objective are sought as follows:

(i) what are the perceptions of hazard-prone rural households to climate change and variability?;
(ii) what are the perceived impacts of riverbank erosion and other climate change issues on the livelihoods of the households;
(iii) what local adaptation strategies can the resource-poor households adopt to enhance their resilience?;
(iv) what are the barriers to adaptation?; and
(v) what are the determinants influencing adaptation strategies, especially the influence of institutional access and social capital of the resource-poor households?

The study uses both primary (cross-sectional survey) and secondary data. Building on the IPCC framework, this study takes a holistic approach to assessing the two key vulnerability assessments – the Livelihood Vulnerability Index (LVI) and Climate Vulnerability Index (CVI). The study also develops an indicator-based index for assessing resilience capacity of the households, and employs a range of tools and techniques for data analysis such as the binomial logit model for household food security analysis which is based on the theories of consumer demand and

production, popularly known as the Agricultural Household Models. For the analysis of households' choice of adaptation strategies, a multinomial logit model is employed which is based on random utility theory. This study has adopted and extended those approaches in the context of riverine households in Bangladesh.

1.5 Conceptual framework of the study

The livelihood of the majority of rural people in Bangladesh depends on agriculture which is most impacted by climate change. Therefore, riverine rural households in Bangladesh are impacted through climate change issues in general and by the recurrent riverbank erosion hazard in particular. Forecasted climate change impacts may also influence the frequency of flooding (Douglas 2009; Ravi 2008) which escalate the erosion hazard along the rivers (Ahmed 2006; Warrick & Ahmad 1996). The hazard impacts are often referred to as direct or indirect, or first or second order (Kates et al. 1985). Riverbank erosion is contributing to the loss of land, homestead, ponds, crops, trees and other resources of the riverine households, annually (Figure 1. 3).

Loss of land and resources is resulted in reducing their income and employment opportunities. As shown in the Figure 1.3, homeless/displaced people usually take shelter in open space, *khas* land (government land), and embankments or at the homes of relatives. These circumstances make the livelihoods of riverine households vulnerable. Moreover, due to climate change, they are expected to face a projected increase in mean annual temperature, uncertainty in rainfall, likely reduction of cereal crop production, and surges in disease, pest and weed pressure on crops and livestock (Niang et al. 2014; Molua 2009). Due to the proximity to the rivers, they are also prone to frequent flooding and water logging which, together with erosion, create a most volatile environment for them.

Decreased food production and reduced employment opportunities together with fluctuations in food prices contribute to the reduced entitlement to food by the households, particularly for small farmers and landless labourers. Therefore, in a society where most of the households depend on agriculture as in the case of this study, food insecurity will be the main first-order observed impact. At this stage, the riverine households adopt various coping and adaptation strategies to deal with the hazards (Figure 1.3). These adaptation strategies can be farm level (autonomous)

and/ or planned (government policy). It is, however, noted that not all households suffers from climate change and hazards in a uniform way, and therefore, their responses vary depending on their economic position as well as the political and social linkages involved (Paul 1998; Emel & Pett 1989). This means that differential livelihood options and resources for adaptation need to be taken into account to assess the livelihood vulnerability of the riverine households and their food security status.

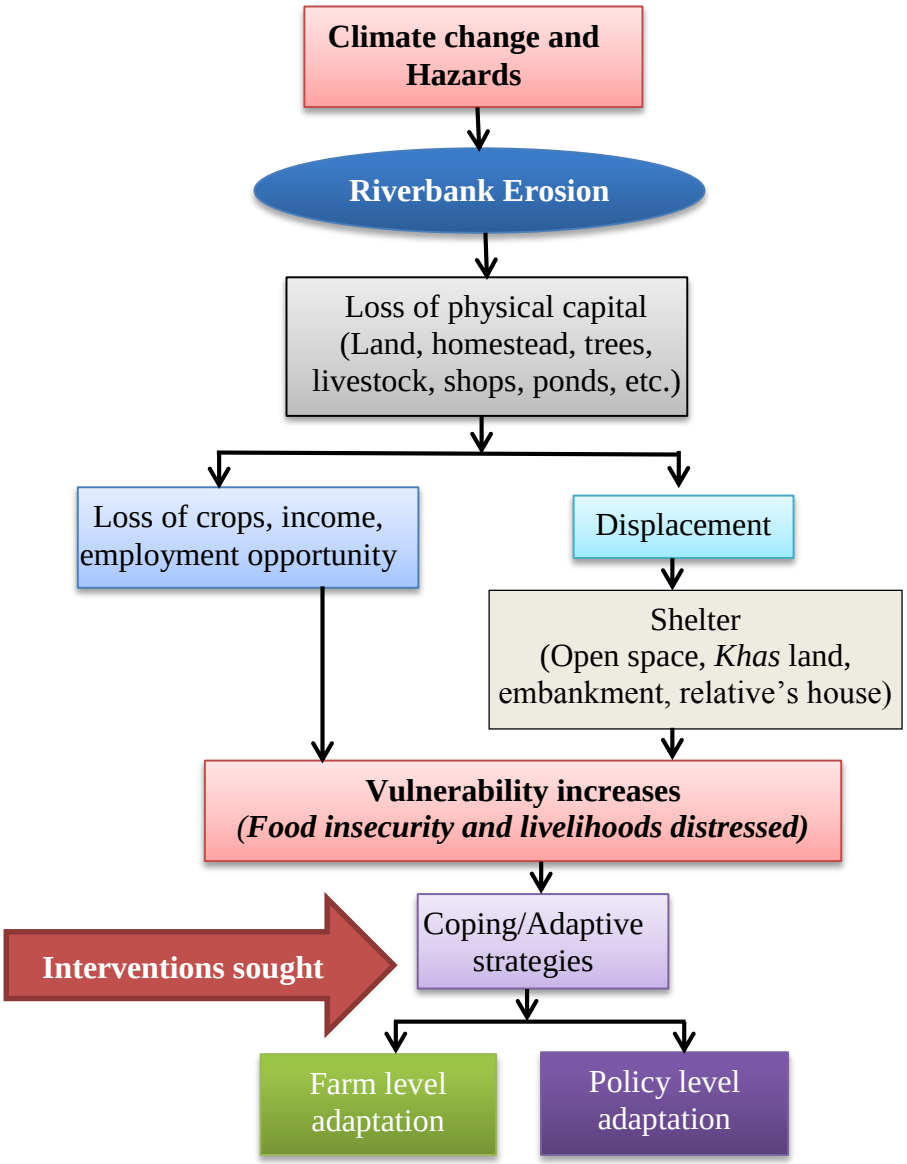

Figure 1. 3: Conceptual framework of the study

This study assesses how the riverine rural households (spatial scale) respond to such hazards and other climate change issues to mitigate immediate livelihood and food insecurity conditions, that often trigger displacement and intra-country

migration using cross-sectional survey data (temporal scale). Understanding the vulnerability of households and their response strategies will assist the policy makers in targeting local adaptation strategies which is considered the key to protect the food insecurity and improving livelihood of poor farmers (IPCC 2014; Lobell et al. 2008; Adger et al. 2005b).

1.6 Scope of the study

There are many vulnerable areas in Bangladesh, however, riverine areas are the most vulnerable (IFAD 2013). Therefore, this study focuses only on riverbank erosion hazards-prone households. The impact of riverbank erosion can occur both at macro (loss of infrastructure and other assets and their impact on food production and national budget) and micro level (loss of land and employment opportunities at household level). This study focuses only on micro level impact. On the other hand, though all components of food security are important but it is not possible to cover all the dimensions (e.g., availability, accessibility and utilisation) due to the time and resource constraints of this study. Maxwell et al. (2013) argued that within food security debate, food availability and accessibility are the most vital components of food security. Therefore, food availability and food accessibility components of the household food security are taken into consideration for the present study. Moreover, food accessibility is considered the key challenge for Bangladesh due to the prevalence of large poor people. The country, on the other hand, did not face greatly the problem of food shortage (availability of food) during the last decade except the global incidence of food crisis in 2008 which also touch Bangladesh.

1.7 Significance of the study

Bangladesh is predominately a riverine country where every year a large portion of rural households are impacted due to riverbank erosion and become vulnerable. Vulnerability and poverty are a related issue, since poor people have the limited resources and opportunities to reduce vulnerability. However, not being poor does not necessarily mean not being vulnerable, and vice versa (Schneiderbauer & Ehrlich 2006). Riverbank issues that affect all surrounding riverine people, are significantly challenging the national goal of eradicating poverty.

There is however, a lack of information on the degree of livelihood vulnerability of the riverine households needed for policy interventions. Therefore, a comprehensive understanding of the drivers of livelihood vulnerability and resilience, and the determining factors of food insecurity today and those will influence in future is crucial to improve marginalised riverine household food security and livelihood over time.

1.8 Contribution of the study

The findings of this study will provide valuable policy inputs towards improving food security and livelihood of the marginalised riparian communities in Bangladesh. This study customised and validated various theories and approaches in the context of riverine households. The analytical approaches developed in this study for assessing vulnerability, resilience, and household food security and adaptation strategies can be replicated in other countries having similar characteristics to Bangladesh due to the flexibility of the methods. The innovation of coping and adaptation strategies by the riverbank erosion prone-vulnerable households could provide new insights and can be shared for other hazards-prone regions in the world.

1.9 Organisation of the thesis

The thesis consists of nine chapters (Figure 1.4) including this introductory chapter. It is important to mention that all the result chapters are presented in a mini thesis format that contains the information of brief introduction and review of the literature, methodology, results and discussions and conclusions.

Chapter 2 presents the reviews of the existing literature globally in general, and Bangladesh, specifically. The first part synchronized the studies on riverbank erosion hazard and other climate change issues covering vulnerability, resilience and adaptation studies. Then studies on food security and livelihood issues are presented and justify the importance of the research through sketching the research gap.

Chapter 3 provides an account of the methodology employed in this study. The theories and procedure of primary (survey) and secondary data collection are discussed here. A brief description of the study areas are also presented in this

chapter. The research design is presented here where the linkages of research objectives, theories and methods are shown.

Chapter 4 assesses the LVI and CVI of the riverine households due to riverbank erosion and other climate change issues. In this chapter a vicious cycle of land access, food security and poverty are also discussed.

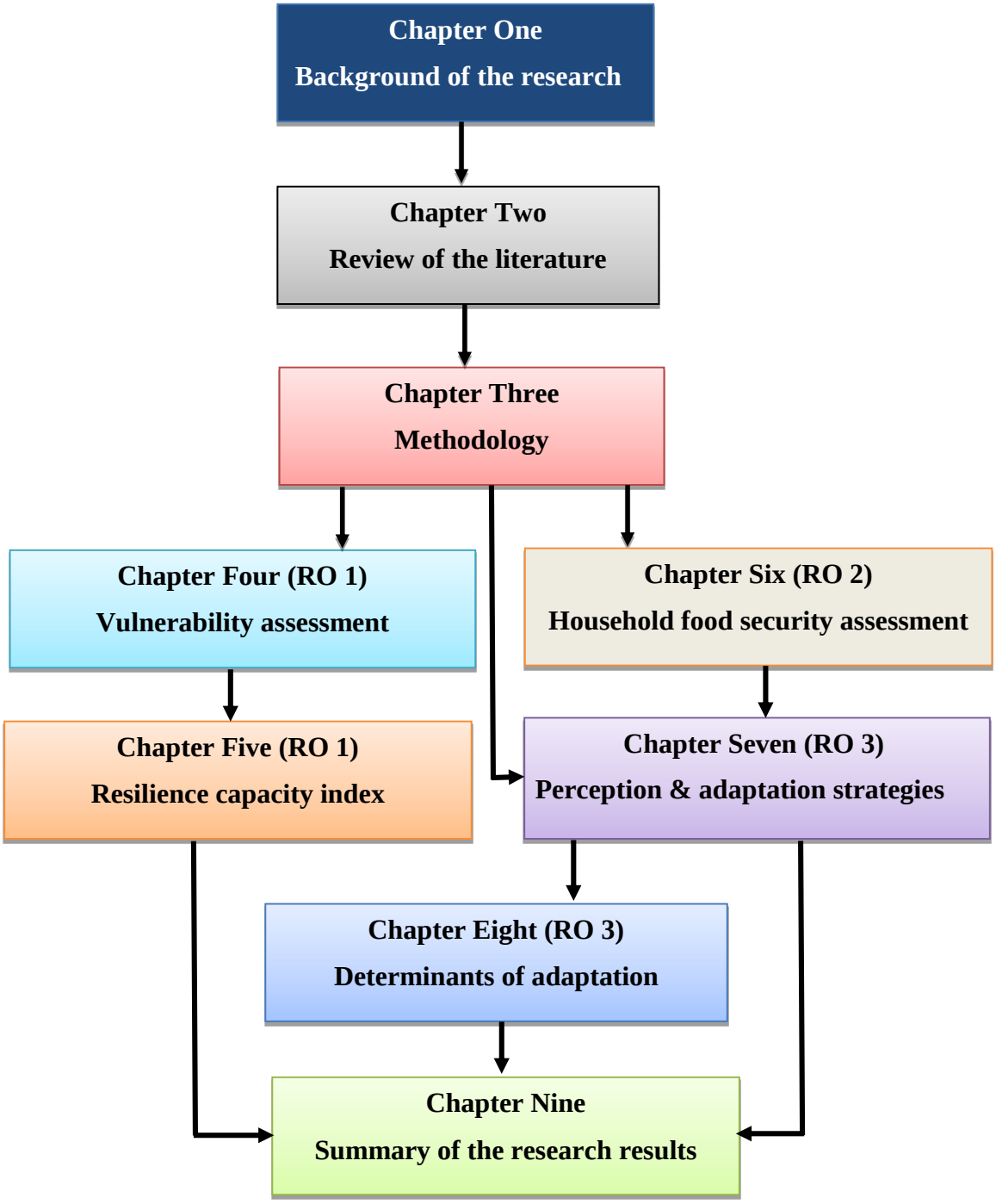

Figure 1. 4: Structure of the thesis

Chapter 5 develops an indicator-based Resilience Capacity Index (RCI) to assess the current resilience activities of vulnerable riverine households resulting from their long-term knowledge, experience and practices.

Chapter 6 examines the effects of riverbank erosion on household food security. Employing a qualitative response model (logistic regression model), the study determine the main influencing factors of households' food security. The stability and robustness of the model is also checked. This chapter also focuses on the coping strategies during the time of food shortages employed/practiced by the households.

Chapter 7 documents households' perceptions about long-term climate change and variability, and perceived impacts of riverbank erosion and other climate change issues on their livelihoods. It also provides information on local adaptation strategies.

Chapter 8 assesses the determinants of households' adaptation choices. A qualitative response model (multinomial logit model) is applied for examining the main factors influencing the households' adaptation strategies, particularly the influence of institutional access and social capital.

Finally, Chapter 9 provides conclusions of the results of the study and suggests policy recommendations and an agenda for future research.

CHAPTER TWO

Literature Review

2.1 Chapter outline

Reviewing the literature is crucially imperative for any research in the sense that it helps to identify prevailing knowledge gaps and assists in developing a sound research design and methodology for carrying out the study, and relates the research findings with past experiences. Keeping this in mind, a thorough review of related literature is performed and presented in this chapter under the following sub-headings: Section 2.2 presents climate change and vulnerability in general. Section 2.3 discusses the disasters in Bangladesh. Sections 2.4 presents the problem of riverbank erosion globally. Section 2.5 presents the concept and assessment techniques of vulnerability, resilience and adaptation; then food security issues are discussed in Section 2.6. Food security measurement techniques are presented in Section 2.7. The gaps in the literature are discussed in Section 2.8 and finally, Section 2.9 contains the summary of this chapter.

2.2 Climate change and vulnerability

The issues of climate change and hazards are ongoing part of human history. However, poor people in developing countries whose subsistence livelihood depend upon the utilisation of natural resources are the first and most affected by the climate change which increases their vulnerability (IPCC 2014; Bardsley & Wiseman 2012; McDowell et al. 2013; Salick et al. 2009; Thomas & Twyman 2005). Scholars argued that climate change can be manifest in four main ways: (i) slow change in mean climate conditions, (ii) increased inter annual and seasonal variability, (iii) increased frequency of extreme events, and (iv) rapid climate changes causing catastrophic shifts in ecosystems (Tompkins & Adger 2004). Nonetheless the impacts of climate change have two dimensions: spatial and temporal. The underline meaning of spatial dimension is that the effects of climate change are heterogeneous, and region and location specific. For example, the issue of climate change – the raising temperature with reduced or abnormal rainfall – has already impacted the natural and physical ecosystem of Bangladesh. The northwest part of the country is

impacted with its recurrent drought and the southwest part through raising soil salinity (Ahsan et al. 2011). It is projected that future climate change will badly impact on agriculture in Bangladesh and thus food security and livelihood of the majority of the population (GoB 2010; IPCC 2007). Projections of the climate change scenarios for Bangladesh are presented in Table 2.1. The table indicates that there will be higher seasonal variations in temperature and reduced rainfall in the coming decades, which might have serious consequences on agricultural production in Bangladesh.

Table 2. 1: Projected climate change scenarios for Bangladesh.

Year	Mean temperature change (°C) (standard deviation)			Mean rainfall change (%) (standard deviation)		
	Annual	DJF	JJA	Annual	DJF	JJA
2030	1.0(0.11)	1.0(0.18)	0.8(0.16)	+3.8(2.30)	-1.2(12.56)	+4.7(3.17)
2050	1.4(0.16)	1.6(0.26)	1.1(0.23)	+5.6(3.33)	-1.7(18.15)	+6.8(4.58)
2100	2.4(0.28)	2.7(0.46)	1.9(0.40)	+9.7(5.80)	-3.0(31.60)	+11.8(7.97)

Source: Adopted from Agarwala et al. (2003)

DJF = December, January and February; JJA = June, July and August

The temporal dimension, on the other hand, refers to the timeframe over which climate change effects are considered. Therefore, vulnerability and associated response strategies need to be assessed along both spatial and temporal scales. Despite the fact that Bangladesh is a hazard-prone country, nevertheless there is limited research focusing on vulnerability. A few studies in the past have been carried out in coping and adaptation mechanisms in coastal Bangladesh mainly focused on hazard warning and evacuation systems (Paul 2010), health security due to disasters (Ray-Bennett et al. 2010), and coastal hazards and community-coping methods (Parvin & Shaw 2012; Alam & Collins 2010; Parvin et al. 2008). Some also focused on the vulnerability issues confronting the coastal and drought prone areas in Bangladesh (Ahsan & Warner 2014; Toufique & Islam 2014). There are hardly any studies that focused on index-based livelihood vulnerability measurement especially for riverbank erosion hazard-prone households in Bangladesh. This assessment is important because vulnerability is context-specific and differs from area to area (Hahn et al. 2009). Therefore, this study assesses location specific

vulnerability (spatial scale) of riverine households using cross-sectional survey data (temporal scale).

2.3 Disasters in Bangladesh

Before going into a discussion on riverbank erosion hazards, this section presents other types of disasters which the nation of Bangladesh has often experienced. In Bangladesh, about 10% of the area is hardly 1m above to the sea level (Huq et al. 1995). The most critical impacts associated with climate change in the country are: (i) drainage congestion (flooding); (ii) reduced fresh water availability; (iii) disturbance of morphological processes (erosion); and (iv) an increased intensity of disasters (Ahmed 2005; WB 2000; Huq et al. 1998). Table 2.2 presents how different sectors are heterogeneously exposed to these climatic hazards in Bangladesh. The table indicates that the most vulnerable sector is crop agriculture on which livelihood of most rural people depends on. Due to erosion, human settlement and infrastructure are also severely affected.

Table 2. 2: Intensity of climate change impacts on various sectors.

	Vulnerability context (climate change and climate events)							
Sectors	Extreme temperature	Drought	Flood		Cyclone & storm surges	Sea level rise		Erosion
			River flood	Flash Flood		Coastal inundation	Salinity intrusion	
Crop agriculture	***	***	*	**	***	**	***	-
Livestock	**	**	*	**	***	**	***	-
Fisheries	**	-	**	*	*	*	*	-
Infrastructure	*	-	**	*	*	**	-	***
Industries	**	-	**	*	*	***	**	-
Biodiversity	**	-	**	-	*	***	***	-
Health	***	-	**	-	**	*	***	-
Human settlement	-	-	-	-	***	-	-	***
Energy	**	-	*	-	-	*	-	-

Source: MOEF, 2005

Notes: ***= Severely vulnerable; **= Moderately vulnerable; *= Vulnerable; - = Not vulnerable

Despite the fact that Bangladesh constitutes only about 7% of the area of the combined catchments of three major eastern Himalayan rivers: the Ganges, the Brahmaputra, and the Meghna (GBM). However, the country drains over 92% of the total annual flow of this GBM system in the region, which is one of the main causes

of erosion in Bangladesh itself. Moreover, Bangladesh has a monsoonal climate that creates frequent, heavy rainfall. It is reported that monsoonal rainfall would increase about 10–15% by 2030 (Jakobsen 2005). The country is frequently faced with over-bank spillages and floods, particularly along the major rivers when monsoon-driven excessive runoff in these rivers combines with local rainfalls. It is predicted that the stronger monsoon rainfall would aggravate flood conditions while catastrophic flood events may occur with higher frequency in Bangladesh (Huq et al. 1996). Increased monsoonal flows will result in an increased sediment transport capacity and morphologic dynamics of the rivers which lead to increase riverbank erosion along the GBM rivers (Warrick & Ahmad 1996; Huq et al. 1998; Ahmed 2006).

In dry season, on the other hand, river flows would further decrease, leading to increase water shortages all over the country and salinisation in the coastal areas (Ahmed 2006; CEGIS 2006; Halcrow et al. 2001; Huq et al. 1996). Reduced winter fresh water flows might aggravate the draw-down of shallow aquifer systems, reducing its potential for drinking and irrigation water, particularly in the western part of the country. Cyclones will be stronger and more frequent due to increases in sea surface temperatures due to warming. Droughts affect many parts of Bangladesh, particularly in the western districts. The projected temperature increase of 2^{o}C and the estimated decrease of 10% of rainfall would result in a decrease in food security (Shahid & Behrawan 2008; FAO 2006). Drought affects rice production heavily in Bangladesh. Yield reduction of different crops varies from 10% to 70% depending on the intensity of drought (Karim 1990). The coastal zone is also affected frequently by cyclones, tidal surges, floods which cause dislocation of households, particularly from the smaller islands (Thoms et al. 2013; Pouliotte et al. 2009).

2.4 Riverbank erosion

In this section research on riverbank erosion is briefly summarised below.

2.4.1 Riverbank erosion: A global perspective

A significant portion of population in the world is likely to be displaced because of climate induced natural hazards including devastating floods, tropical cyclones, coastal and riverbank erosions, as well as storm and sea water surges (IPCC 2007; WDR 2001). The impacts of land loss due to riverbank erosion is permanent and has

long-term consequences on the economy, whereas the impacts of other hazards is temporary.

In terms of the magnitude of devastation of erosion, the Mississippi-Missouri River System of North America, Ganges and Brahmaputra of Bangladesh and India, Mekong Rivers of Asia, Amazon River of South America, and River Nile of Africa are the most prominent (Das et al. 2014). Riverbank erosion is a natural hazard affecting many countries in the world. As for example, Rinaldi (2003) mentioned riverbank erosion as a problem for central Italy. Erosion of Danube river, the second longest river in Europe, creating problems for many European countries (Jones et al. 2007). Warner and Paterson (2008) asserted that flooding and riverbank erosion are the major hazards for people living on or near flood plains of the coastal rivers of New South Wales, Australia. Hall and Bouapao (2010) argued that the Mekong riverbank's erosion had had great impact on the livelihood and food security of the riverine people covering four countries, namely, Cambodia, Lao PDR, Thailand and Vietnam.

2.4.2 Riverbank erosion in Bangladesh

The pattern and severity of riverbank erosion in Bangladesh are unique. Being a densely populated country, a large portion of population live along the bank of rivers (around 230 rivers in total). Moreover, the country drains a huge amount of runoff due to its geomorphological position. The riverbank erosion is a recurring issue in Bangladesh. It has impacted on physical, economic, social and political conditions causing catastrophic impacts on lives and livelihood of the riverine households (Ahmed 2015; Lein 2010; Zaman 2007, 1991, 1989; Hutton & Haque 2004; Chowdury 2000; Hossain 1993, Elahi 1989; Rogge & Haque 1987; Greenberg 1986). Riverbank problem is severe among the landless and impoverished farmers who have least capacity to resist and recover from such natural hazards (Rogge & Elahi 1989; Greenberg 1986). Hossain (1993) estimated that over a 10-year period, the village Bhola lost almost 16 ha of farm land, about 20% of its cultivatable land, and 45% of the households were affected in one way or another due to the bank erosion of the river Kalingonga.

Akhter (1984) asserted that about one quarter of slum dwellers migrated from rural areas to Dhaka, the capital city, because they were uprooted by erosion

disasters. Hossain (1984) in a study of Kazipur rural sub-district recorded that about one-tenth of the riverbank erosion induced displaces moved to urban areas in their attempts to re-establish a livelihood. Haque (1988) found that 43.5% of the displaced people moved family, 9.3% livestock, and 15.5% shifted their belongings from erosion affected areas to comparatively safer places. The riverbank displaces are subject to different hazards notably lack of adequate housing and health facilities, shortage of drinking water and sanitation facilities (Hutton & Haque 2004; Chowdury 2000; Elahi 1989; Rogge & Haque 1987; Greenberg 1986; Islam & Islam 1985). Riverbank erosion affects all the surrounding bank people through eroding land and destroying employment facilities, which the land could provide with them (Romanowski 1987). It is predicted that sea level rise will increase morphological activities in the river, inducing increased river flow which ultimately accelerated river flow and thus will increase river bank erosion too (Alam 2003).

In Bangladesh, riverbank erosion is the topmost disaster concerning the losses (Penning-Rowsell et al. 2013; Makenro 2000). Akter (2009) revealed that on an average 25%, 3% and 2% populations were displaced from different natural calamities like floods and riverbank erosion, droughts and cyclones, respectively in Bangladesh. According to Zaman (2007), environmental disasters were creating acute problems of unemployment in rural areas, urban slums and thereby, worsening the socio-economic conditions of the displaced people. It is therefore clear from the above discussion that riverbank erosion in Bangladesh causing the loss of household production-based entitlement through the reduction of total farm land and, own-labour based entitlement through reducing employment opportunities. This issue deserves the focus of greater research in terms of the future household food security in Bangladesh.

2.5 Concepts of livelihood, vulnerability, resilience and adaptation

In this section the concept of livelihood, vulnerability, resilience and adaptation are discussed.

2.5.1 Livelihood

Households and individuals employ a wide range of activities and invest their limited resources as part of their strategy for improving their livelihood. A person's

livelihood is the combination of a range of farm and non-farm activities that together provide a variety of procurement strategies for food and cash (Drinkater & Rusinow 1999). Livelihoods encompass the assets, activities and the access to these that collectively determine the living gained by an individual of household (Ellis 2000). The issues of improving and sustaining livelihood are considered to be synonymous with poverty alleviation (DFID 1999). Therefore, rural livelihood improvement strategies and policy interventions must be focused on the context in which households operate and create an environment that enables them to improve their conditions. In this study, the vulnerability of households is assessed under a livelihood framework. The livelihood framework presents the main factors that affect people's livelihoods and the typical inter-relationship between these factors. These include human capital, social capital, natural capital, physical capital and the financial capital (DFID 1999).

2.5.2 Vulnerability

There are a cluster of concepts that have developed around the notion of vulnerability over the years. The Intergovernmental Panel on Climate Change (IPCC) defines the term vulnerability as: the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change and variability and extremes (IPCC 2007). Various scholars define vulnerability in different ways. For example, Adger (1999) defines vulnerability as the exposure of a group or individual to stress due to socio-environmental change that disrupts livelihoods. United Nations International Strategy for Disaster Reduction (UNISDR) defines vulnerability as the conditions determined by physical, social, economic, and environmental factors or processes that increase the susceptibility of a community to the impacts of hazards (UNISDR 2004). All communities, however, are not equally vulnerable, and there are differences both spatially and temporally even within the same community (Fraser et al. 2011; Fussel 2010). Past research has revealed that vulnerability depends on a range of factors such as the distance to the city or district headquarters (Pandey & Jha 2012), wealth and well-being and class of households (Gentle et al. 2014; Macchi et al. 2014), gender of households (Arora-Jonsson 2011; Denton 2002; Gentle et al. 2014), and dependency on natural resources and livelihood options (Thomas & Twyman 2005). Scholars have also argued that vulnerability is influenced not only

by internal factors but also by external factors such as government policy (Yeh et al. 2013; Dougill et al. 2010) which makes the issue complex. Therefore, the challenge for vulnerability assessment research is to develop robust and credible measures (Adger 2006).

In recent years, vulnerability research development and consequent adaptation policy have gained top priority (Hinkel 2011). The importance of vulnerability and adaptive capacity has been frequently cited in order to explaining the societal aspects of climate change (Fussel & Klein 2006). There have been a numbers of research endeavours that have tried to assess the vulnerability and adaptive capacity of communities through the development of indices (see, for example, Hahn et al. 2009; Gbetibouo et al. 2010; Pandy & Jha 2012). All of these studies have encountered conceptual and data-related problems while selecting and aggregating relevant indicators in the respective indices. The typical feature of the concept of vulnerability measurement is the level or scale of analysis which ends with an index construction. An index generally deals with the aggregation of a series of observable contributing variables into a scalar variable (Hinkel 2011). Constructions of such indices distinguish between two major ontological approaches: data-driven and theory-driven approaches (Vincent 2007). Selection and aggregation of contributing indicators in the data-driven approach are based on expert judgment and efforts are then made to correlate these with records of previous disasters (Alberini et al. 2006; Brooks et al. 2005). However, the weakness in this approach lies with the limited objectivity of experts and assessment of contributing indicators against a bench-mark of vulnerability (Below et al. 2012).

A theory-driven approach, on the other hand, applies insights from the literature to select and aggregate contributing indicators (Vincent 2007). However, the weakness in normative selection of contributing indicators remains with the associated uncertainties (Below et al. 2012). Considering the limitations, this third group of researchers adopts both theoretical and empirical aspects to select and aggregate the contributing indicators in constructing the index (Hahn et al. 2009; Pandey & Jha 2012). However, the conceptual work on vulnerability and its related theme has yet not resolved the methodological and terminological confusion (Hinkel 2011). Over the years, various researchers have tried to develop vulnerability indices

addressing different set of parameters and their contributing indicators/sub-components which are presented in Table 2.3.

Table 2. 3: Development of vulnerability index.

Author(s) name and year	Name of index	Comments
Turner et al. (2003)	Vulnerability Framework	Based on this framework many researcher developed vulnerability index
Cutter et al. (2003)	Social vulnerability index (SoVI)	Employed principal components analysis in country level socio-economic and demographic data. Some important variables related to exposure to natural hazard were ignored due to data structure
Vincent (2004)	Social vulnerability index (SVI)	Different weights were used for different sub-components in multi-country analysis. There was missing data problem due to usage of secondary data.
Hahn et al. (2009)	Livelihood vulnerability index (LVI)	Problem of secondary data set was removed and diversified components were considered for vulnerability. Flexibility to consider indicators and hence applicable to any area.
Vincent and Cull (2010)	Household social vulnerability index (HSVI)	Five composite sub-indices was used and assigned equal weight. Vulnerability might not affect equally.
Pandey and Jha (2012)	Climate vulnerability index (CVI)	Primary data set was used. Useful tool for assessing scale differences in vulnerability.
Ge et al. (2013)	Social vulnerability index (SVI)	Economic variables (GDP, PCI) were used to assess hazards loss. Absence of exposure indicator(s)
Lee (2014)	Social vulnerability	All indicators showed positive direction to vulnerability. Zero-mean standardized the indicator values.

The social vulnerability index developed by Cutter et al. (2003) and Vincent (2004) has been used by many researchers in different context. However, the method is associated with secondary data driven problem. Later, Hahn et al. (2009) developed an indicator based livelihood vulnerability index which is free from such problem. In this study, indicator based vulnerability analysis approach is adopted

which includes both climatic and non-climatic (socio-economic) indicators (see detailed in Chapter 4).

2.5.3 Resilience

Human populations are concentrated along the bank of rivers and coastal areas which make them more susceptible to the impacts of climatic hazards. The main focus of climate change research is to enhance resilience of such disaster-prone communities. The concept of resilience is aimed at sustaining and enhancing the capacity of social-ecological systems to adapt to uncertainty and surprise (Adger et al. 2005a). It reflects the degree to which a complex adaptive system is capable of self-organisation and the degree to which the system can build capacity for learning and adaptation (Carpenter et al. 2012; Folke et al. 2002). However, there is a lack of standard framework to effectively measure resilience capacity of households (Magis 2010; Manyena 2006). This study attempts to measure the resilience capacity of the households through developing an indicator based index (see detailed in Chapter 5). The findings will enable policy makers to understand the factors that limit the resilience capacity of hazard-prone households and thus effective policy and programs can be formulated.

2.5.4 Adaptation

Globally, mitigation and adaptation are the two major policy responses to climate change. Adaptation has the potential to reduce the adverse impacts of climate change (IPCC 2001). IPCC defines adaptation as the adjustment in human or natural systems in response to climatic or environmental stimuli which buffer harm or exploit beneficial opportunities (IPCC 2001). However, adaptation strategies vary from sector to sector, community to community and place to place (Malone 2009; Smit & Wandel 2006). Scholars argued that all adaptation is not good (Eriksen et al. 2011; Nyong et al. 2007). For example, the adaptation measures that deliver short-term gains and economic benefit can lead to increased vulnerability in the medium or long run (Jones & Boyd 2011). According to Smith et al. (2000), to fully understand adaptation, it is important to know three fundamentals of adaptation such as: adaptation to what, who adapt and how adaptation occurs?

There are few adaptation studies in Bangladesh that mainly focus on drought prone areas in Bangladesh (see, for example, Alam 2015; Alauddin & Sarker 2014; Sarker et al. 2013; Habiba et al. 2012). Few studies focus on low lying and saline-prone areas (Rashid et al. 2014; Anik & Khan 2012). Though these studies provide important policy input, it may not be applicable in other hazards-prone areas due to the variation in socio-economic and climatic conditions. Despite recognition of the need for adaptation, so far there is no study that explores adaptation strategies and the influence of various determinants such as social capital and access to institutional facilities on adaptation decisions for marginalised riparian households which is crucial to making proper climate adaptation policies in the country (see more discussions on Chapter 7 and Chapter 8).

2.6 Food security issues

In this section the food security issues are discussed.

2.6.1 Food security concept

Keating (2013) mentioned that there had been significant revision of the concept of food security in the last 40 years by different scientists and organisations. Hoddinott (1999) reported about 200 definitions and 450 indicators of food security. World Food Summit (1996) defines food security as: "Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO 1996). Household food security is thus referred to as the application of this concept to the family level where individuals within households are the focus of concern. This definition focuses on three[6] distinct but interrelated elements as follows:

Food availability: This refers to having sufficient quantities of food from household production, other domestic output, commercial imports, or food assistance.

[6] Barrett (2010) argued that stability of food refers the availability and access to food.

Food access: This means households having adequate resources to obtain appropriate food for a nutritious diet, which depends in turn on available income, distribution of income in the household, and food prices.

Food utilisation: This element refers to the proper biological use of food that require a diet with sufficient energy and essential nutrients; potable water and adequate sanitation; and knowledge of food storage, processing, basic nutrition, and child care and illness management.

Although this definition mostly refers to 'food', the main concern is with calories (Heald & Lipton 1984). Other issues such as protein, micro-nutrients or more generally, food quality and safety are not considered because when caloric intake is satisfactory, then other needs are usually satisfied (Maxwell & Smith 2006).

Nutrition security, on the other hand, refers to situations in which food security is coupled with a sanitary environment, adequate health services, and proper care and feeding practices to ensure a healthy life for all household members (Horton & Shekar 2010; UNSCN 2010).

2.6.2 Impact of climate change on food security

Climate change has differential impacts on different localities and communities across the planet (Maru et al. 2014). Scholars mentioned that global food distribution system might be affected greatly due to climate change (Poppy et al. 2014; Molua 2009; Schmidhuber & Tubiello 2007; Gregory et al. 2005; Smith et al. 2000). Extreme climate events such as droughts, floods and cyclones severely affects food supplies and thereby food security. Gregory et al. (2005) argued that climate change affects all dimensions of food security directly. However, the impact of climate change on food security varies across regions and over time which depend on country's socio-economic status (Gregory et al. 2005; Stern 2006). Reports indicate that due to climate change issues, achieving/meeting household food demand in the densely deltaic countries in South Asia including Bangladesh will be at risk (Szabo et al. 2015; FAO 2013a). Being a developing country, ensuring household food security is a big challenge for Bangladesh when facing other problems such as climate change, escalating population and poverty. Within the country, food security issues

become acute for the riverine households since they are confronting riverbank erosion and other negative impacts of climate change.

2.6.3 Food security and self-sufficiency

The issue of food security came into focus during the world food crisis of 1972-74 and received momentum after the World Food Conference in 1974 where the FAO Committee on World Food Security were established and a universal declaration on the eradication of hunger and malnutrition was adopted. In the 1970s, food security was considered to be an issue of national and world food supplies, and import stabilisation policies (Maxwell & Salter 2003; Stringer 2000). In the 1980s, the publication of Sen's (1981) influential theory on entitlement (all legal sources of food)[7] influenced food security discussions heavily. He mentioned that famine can occur even if supplies of food are adequate and markets function well. This shifted the focus of the research from the supply side to the demand side issues of food security. In the late 1990s, issues of both availability and stable access to food were also incorporated in the definition (Frankenberger & McCaston 1998).

Food insecurity therefore refers to the lack of food security and also to a state in which households do not have adequate physical, social or economic access to food for an active and healthy life. Schmidhuber and Tubiello (2007) argued that food availability is not the crucial issue of food security in the present world because food could be traded at reasonably low cost. FAO (2010) argued that the most recent increase in hunger was not the consequence of poor global harvests but was caused by the world economic crisis that had resulted in lower incomes and increased unemployment. Adequate access to food is the key to household food security which can be achieved without households being self-sufficient in food production if they have the ability to generate sufficient income or have own production which together can be used to meet food needs (Harrigan 2008; Schmidhuber & Tubiello 2007).

Schmidhuber and Tubiello (2007) asserted that national self-sufficiency is neither necessary nor sufficient to guarantee food security for all of the population, and they cited the example of Hong Kong and Singapore (food-secure without self-

[7] Sen (1981) talked about four types of entitlement to get access to food: 'production-based entitlement' (growing food), 'trade-based entitlement' (buying food), 'own-labour entitlement' (working for food) and 'inheritance and transfer entitlement' (being given food by others).

sufficiency in food production), and India (self-sufficient but much of the population has food insecurity). Aggregate supply of food (i.e. own production plus import) may be a necessary condition but it is certainly not a sufficient condition to be a food secure country (Barrett 2010; Harrigan 2008; Titus & Adetokunbo 2007). Therefore, households or individuals are the appropriate unit of food security analysis (Sen 1981; Dreze & Sen 1989; Ravallion 1997). Scholars, however, argued that individual access to food is associated with households' income and resources (Maxwell 1994; Evans 1991). Households in the developing world also had experienced varying degrees of food insecurity. Anriquez et al. (2013) and MacFarquhar (2011) mentioned that soaring food prices since 2008 had impacted badly upon low income households both in developed and developing countries. This also dramatically changed the focus of food security research by the international organisations that incorporate the vulnerability issue as the backdrop to climate change issues (Quisumbing 2013; Hardley et al. 2011; Lang & Barling 2012; IIbery & Maye 2010). Therefore, this study assesses the vulnerability of households and food security as well.

2.6.4 Food security situation in the world

Food is a basic human right (FAO 2010). Household food security varies across regions, agro-ecological zones and districts (Bahiigwa 1999). Countries like the USA, Canada, and Australia had also faced food security problems due to recent global soaring food price. Among the victims, female-headed households were more vulnerable to food insecurity than other types of households (Quisumbing 2013). In the USA, about 14% of households were food insecure in 2008 and about 14.9% in 2012 (Nord et al. 2008; Jensen et al. 2012). In Canada, 10% of households were food-insecure in 2002 (Che & Chen 2002) and more than 12% in 2011 (Tarasuk et al. 2013). In the case of Australia, more than 5% of the population was food insecure in 2001 (Booth & Smith 2001) and about 4.8% in 2011 (Lockie & Pietsch 2011). FAO (2010) mentioned that the food security situation was not improving in developing countries as expected. Brown et al. (2008) mentioned that the food security situation has improved a little more in the regions like East Asia, South Asia and Latin America as compared to Africa. Brown et al. (2008) stated that food inflation (i.e. increase in food prices) had struck the poor households of Vietnam and India. Krugman (2011) argued that higher prices of cereals impacted

terribly on poor people in developing countries because they spend a major proportion of their income on basic foodstuffs.

The above discussion supports the notion that access to food is the key issue for household food security. Results of the previous studies on the factors affecting household food security both in developed and developing countries are presented in Section 2.6.6.

2.6.5 Food security studies in Bangladesh

The twin objective of Bangladesh after independence in 1971 was to increase food production and eradicate poverty (GoB 2000). Due emphasis has been placed on augmenting food production and thereby ensure food security of the mass population in the country. A significant number of research have been carried out on food security, funded by the donors, particularly the WB, USAID, FAO and IFPRI (Ahmed et al. 2004 & 2007; Murgai & Zaidi 2005; WB 2006). Few studies are highly dominated by the field of economics which provides an economic explanation of food security in Bangladesh (see, for instance, Mishra et al. 2015; Islam 2014; Chowdhury et al. 2010; Faridi & Wadood 2010; Hossain 2010; Shahabuddin 2010; Deb et al. 2009; Hossain & Deb 2009; Ali et al. 2008; Ahmed et al. 2007). However, food security at household level is relatively unexplored, particularly for riverine households when they are confronting the problem of land loss and other climate change issues.

2.6.6 Determinants of household food security

There are many reasons to believe that incidences of food insecurity vary between the rural households that are affected by riverbank erosion. This study can thus hypothesise that households are not equally vulnerable to food insecurity and its different forms. Their socio-economic variables along with other variables play vital role here. Keeping these assumptions in mind, this study attempts to find out which household and community level characteristics can influence food insecurity and its different forms. In this section findings of the previous studies on the determinants of household food security are summarised:

Age of the household head was found to have a significant impact on the determinants of household food security by different studies. A study by Bashir et al. (2010) in Pakistan found that the presence of a household head aged over 35 years reduced the chances for food security by 83%. They employed the multinomial logistic regression model (MLR) for their analysis. Titus and Adetokubo (2007) in their study in Nigeria using descriptive statistics revealed that increases in the age of the household head contributed positively to food insecurity and the level was the highest for the age group of 61-70. In the USA, Onianwa and Wheelock (2006) applying binomial logistic regression model (BLR) found that the increase in household heads' age reduced the chances of becoming food secure by 2%. Family size was found to be an important factor in determining household food security by different studies (Bashir et al. 2010; Sindhuet et al. 2008; Amazaet et al. 2006). Households with large numbers of family members were likely to be more food insecure than households with small numbers of family members in Bangladesh (Alam et al. 2010). In India, Sindhu et al. (2008) revealed that one additional family member would increase the chance to be food insecure by 96%. In Nigeria, an increase of one family member would decrease the probability of food security by 1.5% (Amaza et al. 2006). Bashir et al. (2010) found that households with a nuclear (husband and wife) family system were 5 times more food insecure than households with joint family system in Pakistan. Household heads who have education levels of eight years of schooling and those who had attained graduation level increased the probabilities for their families to become food secure by 6% and 20%, respectively (Bashir et al. 2010).

Ojogho (2009) revealed by employing BLR that probability of food insecurity would decrease with the increase of education level from primary to secondary and to tertiary level by 78% and 92%, respectively, in Nigeria. Mariara et al. (2006) by using simple regression found that the level of education of the mother in the household would increase the likelihood to become food secure by 0.05 % in Kenya.

In the USA, Kaiser et al. (2003) applying BLR revealed that chances of food insecurity would decrease by 29% with the higher level of education of mother in the family. Increases in household income contributed positively towards household food security. Households' monthly income increase by 1000 Rupee contributes to

reduce food insecurity by 30% in India (Sindhu et al. 2008). Increase in households' annual income, both with and without children, would reduce the chances of becoming food insecure by 6% and 5%, respectively (Onianwa & Wheelock 2006). Che and Chen (2002) applying BLR revealed that upper middle income households were 7.29 times less food insecure than households with lower income in Canada. Alam et al. (2010) employing BLR found that probability of household food security would increase by 0.03% for a one hundred decimal increase in farm size in Bangladesh. They also revealed that the probability of household food security would increase by 0.35% with the increase of household off-farm income (income from outside agriculture) of Tk[8] 100 thousand per year (see more on Bangladesh context in the Chapter 6). Households with two milking cows were found 37 times more food secure than the households with no milking cow in Pakistan (Bashir et al. 2010). Amaza et al. (2006) in their study by applying BLR revealed that households having bullock would increase the likelihoods of becoming food secure by 5% in Ethiopia (see more in Chapter 6).

2.7 Measurement of food security

There are various methods or indicators for food security measurement that differ significantly (Carletto et al. 2013; Maxwell et al. 2013; Perez-Escamilla & Segall-Correa 2008). Scholars argued that a variety of measurement is required for its analysis due to the multidimensional nature of food security (Carletto et al. 2013; FAO 2013b; Maxwell et al. 2013; Coates et al. 2010; Perez-Escamilla & Segall-Correa 2008; Kennedy 2002). The most common food security measurements are – Dietary Intake assessment (DIA) (Alam 2010; Bashir et al. 2010; Feleke et al. 2005), Household Food Insecurity Access Scale (HFIAS) (Chatterjee et al. 2012; Che & Chen 2002), Anthropometry measure (Mariara et al. 2006; Sharif & Merlin 2001) and Household Expenditure Survey Method (HESM) (Titus & Adetokubo 2007; Charlton & Rose 2002).

Maxwell et al. (2013) opined that the combination of Coping Strategies Index (CSI) and Food Consumption Score (FCS) could provide reliable and acceptable results for food security analysis. Recently, Self-assessment Food Security Measures (SAFS) have been used by Heady and Oliver (2013) and Headey (2011). Maxwell et

[8] Taka (Tk) is the Bangladesh currency, US$1 = Tk 76.21 as on 2 September, 2015.

al. (2013) asserted that SAFS questions are well-correlated to other measures of food security. However, DIA method is commonly used for household food security measurement. The main reason is that this method often used as proxy for all nutritional requirements for health which is the last part of food security definition of FAO. Since there is no unique approach to measure food security, therefore, this study applies various methods including DIA method, CSI and HFIAS for comprehensive understanding of riverine household food security status.

2.8 Gaps in the existing literature

The discussion above indicates that climate change and hazards such as riverbank erosion have had serious impacts on food security and livelihood of the rural riverine households in Bangladesh. Notwithstanding, there have been studies to address climate change, food security and adaptation in Bangladesh. However, an assessment of vulnerability, food security and response strategy for hazards-prone people has yet to be made. This study has, therefore, made an attempt to fill this gap. The following gaps are revealed from the literature review:

- There are few studies on livelihood vulnerability on global scale. So far, there is no study that focused on index-based livelihood vulnerability measurement, especially for marginalized riparian households in Bangladesh. Therefore, applying the standard methodological framework of determining livelihood vulnerability, this study intends to bridge the gap between community necessity and priority at the policy level.

- Although resilience is an ongoing research thrust, however, there is a lack of well accepted framework to measure resilience. In order to explore the factors affecting resilience capacity of the households, this study develops and indicator based resilience capacity index.

- There are many studies on food security, however, to the best of researcher's knowledge, no study has yet examined the determinants of food security of the riverbank erosion hazard-prone rural households.

- The extent of household food security is also relatively unexplored which is important for targeted policy interventions. This study, developing an index, examines the experience of household's food insecurity over the year.

- There is hardly any study that explores the perception of climate change and hazards of marginalised households which is crucial for supporting their autonomous adaptation. Therefore, this study explores hazards-prone households' perception of climate change and their local adaptation strategies.

- There are inadequate studies on the factors affecting adaptation choices of households. This study goes beyond simply examining the determinants of adaptation, it also focuses on the influence of social capital and institutional access on adaptation choices for the resource-poor households.

2.9 Summary

This chapter provides a brief review of existing literature pertinent to the research topic under discussion. First, climate change impacts in general are discussed. Then the riverbank erosion hazard, vulnerability and food security issues are discussed. The chapter clearly sketches out some gaps in the existing literature. This research is proceed to fill up these gaps in the following chapters. The next chapter discusses the various theories and methodologies used for analysing and making a meaningful presentation of the results of this study.

CHAPTER THREE

Methodology

3.1 Chapter outline

This study employs a range of tools and techniques for analysis of the data. Thus, the purpose of this chapter is to illustrate the relevant theories and methodologies employed in this study including description of the study areas. A brief overview of some selected characteristics of the study households is also presented. However, some descriptive results and analysis techniques which are more pertinent to the specific objective are presented in the respective chapter. This chapter is divided into six sections as follows: theoretical framework is presented in Section 3.2. Section 3.3 outlines the methods of descriptive statistics. A description of the study areas followed by survey methods is presented in Section 3.4. Section 3.5 presents a description of the data including common socio-economic characteristics. Section 3.6 then contains the summary of the chapter.

3.2 Theoretical and analytical framework

This study uses a number of theories and models as per the requirements of the study objectives. These theories are the customised approach in the context of vulnerable riverine households in Bangladesh. The relevant theories and approaches are discussed in this section as follows:

3.2.1 Household food security analysis

Household food security analysis is based on the theories of consumer demand and production that is widely known as the Agricultural Household Models (AHMs) (Bashir et al. 2012; Aromolaran 2010; Shaikh 2007; Fleke et al. 2005; Straus 1983; Yotopoulos 1983; Barnum & Squire 1979). In this model, households take the decision both as a producer and a consumer. For a short-run production cycle (i.e., up to one year), the households are assumed to maximise their utility function specified as:

$$U = U(Fh, Fm, I, Dm) \quad \text{(i)}$$

where, F_h = consumed goods by the household produced at home

Fm = consumed food commodities purchased from the market

I = leisure,

Dm = demographic characteristics of the household

A household, both as producer and consumer, is assumed to maximise its utility from the consumption of these goods subject to farm production, income and time constraints as follows *(Production Constraint):*

$$G(Qi, L, R^o A^o K^o) = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(ii)}$$

where, G is the implicit production function; Qi is the quantities of the goods produced on-farm; L is the total labour input to the farm; R^o is the farm technology fixed in short term; A^o is the household's fixed quantity of land; K^o is the fixed stock of capital. If we consider the consumption and income constraint of the households[9], we can write the function as:

$$P_i(Q_i - F_h) - PmFm - w(L - L_f) + N = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(iii)}$$

Where, Pi= price of the goods i, $(Q_i - F_h)$ = Marketed surplus of the goods i, W= Wage rate, L_f = Household labour suply for nonfarm use, N= Total non-farm income which adjusts to ensure the equation (3) is equal to zero.

Time constraint:

$$T = L_f + I \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(iv)}$$

T= Total time available for the household to allocate between work and leisure. The income and time constraints on household behaviour can be combined into a single equation by incorporating (4) into (3) as:

$$P_i(Q_i - F_h) - PmFm - w(L - T + I) + N = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(v)}$$

After rearranging the above equation it stands as:

$$P_i F_h + P_m F_m + wI = P_i Q_i + wT - wL + N \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(vi)}$$

The left-hand side shows the household expenditure (consumption) on food and leisure. This includes purchase of the own farm-produced goods $i(P_i F_h)$, the goods households purchased from the market $(P_m F_m)$ and the household's purchase of its

[9] In the short run, a household assumed to have fixed amount of land, capital and technology so these variables are considered constant.

own leisure time (wI). The right hand-side of the equation is income of the households. It consists of the value of total agricultural production (P_iQ_i), the value of the household's time (wT), the value of labour derived from both farm and hired labour (wL), and non-farm income, N. The lagrangian is:

$$Max\ \psi = U(F_h, F_m, I) + \lambda[(P_iQ_i + wT - wL + N) - (P_iF_h + P_mF_m + wI)] + \mu[(Qi, L, R^oA^oK^o)] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(vii)}$$

The first order conditions of the relationship between production and consumption can be establish as:

$$\left(\frac{\partial U}{\partial I} \Big/ \frac{\partial U}{\partial F_h}\right) = \frac{w}{Pi} = \left(\frac{-\partial P}{\partial L} \Big/ \frac{\partial P}{\partial Qi}\right) = \frac{\partial Qi}{\partial L} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(viii)}$$

Household being a consumer tries to maximise its utility by equating the marginal rate of substitution between food and non-food commodities to the marginal product of labour. If household has more production than consumption, it can offer to sale in the market. Similarly, if household is short supplied of labour it hires additional labour. Since it is assumed that household has no leisure time, they offer labour to other farmers and businesses if they have free time. Given the assumption of 'separability' one can derive the production side equation and consumption side equation separately (Fleke et al. 2005; Straus 1983) as:

$$L^* = L^*(Pi, w, R^oA^oK^o) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (ix) \text{ and}$$

$$Qs^* = Qs^*(Pi, w, R^o, A^o, K^o) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (x)$$

Once the optimum level of labor is selected, the value of full income when profits have been maximised can be obtained by substituting equation (9) and (10) into the right hand side of the income constraint equation (6) as:

$$Y^* = P_iQ_i{}^* + wT - wL^* + N \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(xi)} \quad \text{And}$$

$$Y^* = wT + \pi^*(P_i, w, R^o, A^o, K^o) + N \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(xii)}$$

Where, Y^* is the full income under the assumption of maximized profit π^*. These first order conditions for consumption demand can be solved in terms of prices, wage rate, and income as follows:

$$F_k = F_k\left(P_{i,}P_m, w, Y^*\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(xiii)}$$

Where, k= i, m. The three equations (i.e., 9, 10 and 13) give a complete picture of the economic behaviour of the farm household. They are combined through the profit effect. In semi-subsistence farming, household's income is determined by production activities that imply changes in factors influencing production which ultimately affects income, which in turn stimulates consumption behaviour. Incorporating demographic factors D_m, the demand for food indicated in equation (13) can be written as:

$$F_k = F_k\left[P_{i,}P_m, w, Y^*(w, R^o, A^o, K^o, N), D_m\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(xiv)}$$

The logistic regression model of food security can be written as

$$Ln\left(\frac{\emptyset_i}{1-\emptyset_i}\right) = \beta_0 + \sum_{j=1}^{n=k} \beta_j X_{ij} + \varepsilon_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(xv)}$$

Where, $\emptyset_i$ is the conditional probability of food security and β_j's parameters to be estimated and $X_{ij}'s$ are the independent variables (Results of the analysis are discussed in Chapter 6).

3.2.2 Analysis of adoption of adaptation strategies

The econometric analysis of household adaptation is based upon the random utility theory. Households' adaptation decisions are based on their perceived utility of the different adaptation measures in response to climatic hazards. These decisions are guided by their utility (or profit) maximisation behaviour[10]. The households' choice of adaptation strategies is discrete and mutually exclusive. There is no natural ordering in the preferred strategies and the relationship between the underlying latent or unobservable variable is linear that justifies the use of random utility framework model (Verbeek 2004). The farmers in this study are assumed to select from the 15 alternatives those which have the highest utility.

Assuming U_h and U_k are the utility of household i, who chooses between any two alternatives, the random utility model can be written as:

$$U_{ih} = V_{ih} + \varepsilon_{ih} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(i)}$$

$$U_{ik} = V_{ik} + \varepsilon_{ik} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(ii)}$$

[10] A contrary opinion is that farmers' strategic responses are not explained entirely by profit-maximization behavior but also by farmers' attitudes and values (Marshall et al. 2012; Gasson & Errington 1993).

where, U_{ih} and U_{ik} are an individual household's utility (i) of choosing option h and k, respectively, and V_{ih} and V_{ik} imply the deterministic (observable or explainable) or systematic component of utility. Whereas, ε_{ih} and ε_{ik}represent the stochastic (random or unexplainable) element that stands for unobservable influences on individual choices and measurement error, and are assumed to be independently and identically distributed (Greene 2012). According to utility maximisation behaviour, a household will only choose an option h if $U_{ih}>U_{ik}$ for all h ≠ k.

The deterministic components V_{ih} or V_{ik} represent an attribute vector x, i.e., $V_{ih} = x'_{ih}\beta$ or $V_{ik} = x'_{ik}\beta$. However, utility is not directly observable; rather, a household's choice of adaptation strategies can be observed. When there are many choices, the likelihood of alternative adaptations can be expressed as a probability:

$$Pr[Y_i = h|x| = P\ [U_{ih} > U_{ik}] = \Pr\ [x_i\beta_h + \varepsilon_{ih} - x_i\beta_k - \varepsilon_{ik} > 0|x|]$$
$$= \Pr\ [x_i(\beta_h - \beta_k) + \varepsilon_{ih} - \varepsilon_{ik} > 0|x|] = \Pr\ [x_i\beta + \varepsilon > 0|x|] \ldots\ldots\ldots\ldots\ldots\text{(iii)}$$

where, β is a vector of unknown coefficients and x is the vector of the explanatory variables influencing the choice of adaptation and ε is a random error term. For a given x the probability that a household will choose an alternative h is given as follows:

$$\Pr(Y_i = h/x) = \frac{e^{\beta_h x_i}}{1+\sum_{k=1}^{m} e^{\beta_k x_i}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(iv)}$$

Equation (iv) can be estimated by choice models (Greene 2012). To obtain unbiased and consistent parameters in the model, the assumption of Independence of Irrelevant Alternatives (IIA) must be fulfilled (Cameron & Trivedi 2009). It indicates that the probability of adopting a particular adaptation strategy by a given farm household requires independence from the probability of selecting another adaptation strategy.

Different choice models – multinomial probit (MNP) or multinomial logit (MNL) – can be constructed based upon the assumed distribution of the random disturbance terms. MNL provides a more precise estimation than the MNP (Kropko 2007). Moreover, estimation of MNL is simpler and interpretations of parameter estimates are easier (Cameron & Trivedi 2009; Long 1997). MNL is widely employed in climate adaptation research (e.g., Alam 2015; Alauddin & Sarker 2014; Sarker et al. 2013; Deressa et al. 2009).

The estimated parameters of MNL only show the direction of the impact of the explanatory variables on the dependent variable and do not provide the extent of change or the probabilities. Marginal effects, however, measure the impact on the probability of observing each of several outcomes rather than the impact on a single conditional mean and are more meaningful and interpretable (Cameron & Trivedi 2009; Long 1997). To compute the marginal effects of different exogenous variables, we differentiate equation (iv) with respect to N explanatory variables as follows:

$$\frac{\partial Pr_m}{\partial x_n} = Pr_h(\beta_{hn} - \sum_{h=1}^{H-1} Pr_h\, \beta_{hn}) \dots\dots\dots\dots\dots\dots\dots\dots\dots..(v)$$

Marginal effects measure the likelihood of change in the probability of the adaptation of a particular choice with respect to a unit change in an explanatory variable (Greene 2012). The MNL model can be regarded as simultaneously estimating binary logits for all possible comparisons among the outcomes. With Z outcomes, only Z-1 binary logits need to be estimated (see results of the analysis in Chapter 8).

3.2.3 Vulnerability analysis

This analysis is based on the vulnerability theories which suggest that households are particularly vulnerable if they have low adaptation capacity (IPCC 2007). According to IPCC (2007) vulnerability is a function of three dimensions as follows:

$$\text{Vulnerability} = f(\text{Exposure, sensitivity, adaptive capacity})$$

Exposure refers to the environment/location of people that could be adversely affected by physical events and which, thereby, are subject to potential future harm, loss, or damage (Gasper 2010). This also indicates the magnitude and duration of the climate-related events such as change in precipitation or a flood. Whereas sensitivity is the degree to which the system is affected by the exposure, and adaptive capacity refers to the system’s ability to withstand or recover from the exposure (Ebi et al. 2006). Exposure, sensitivity and adaptation are composed of various indicators. In recent years, index based vulnerability measurement method is widely employed in many parts of the world (see, for example, Aryal et al. 2014; Toufique & Islam 2014; Shah et al. 2013; Hahn et al. 2009). This study also adopted index based vulnerability analysis method. Detailed derivation of the approach is discussed in Chapter 4.

3.2.4 Resilience analysis

There is a growing interest among the policy makers about an understanding of how far the affected communities are resilient in order to be able to provide best support to them to cope and adapt to climate change and hazards. This analysis is based on the resilience theories which is the function of sensitivity and adaptive capacity (Malone & Brenkert 2008) as shown below:

$$\text{Resilience} = f(\text{Sensitivity}, \text{adaptive capacity})$$

The results of the analysis will help to understand how resilient the study households are and what are the factors influencing their resilience capacity so that necessary interventions can put in place (see detailed in Chapter 5).

3.3 Descriptive statistics

Statistical analyses including descriptive statistics such as mean and percentages, moving average, standard deviation, coefficient of variation, simple t-test and post-hoc are used to ensure meaningful presentation of the data. Moreover, a linear trend analysis is also employed to detect the changes in climate variables.

3.4 Description of the study areas and data collection

This section provides the information of the study areas and the procedure of data collection.

3.4.1 The approach

The study applies a mixed method approach for collection of data (quantitative and qualitative data). The methods of data collection were included the survey method (face-to-face interviews of the household head), focus group discussion and the key informants' interviews. One focus group discussion was conducted in each village with a group of 10 to 12 household heads. Moreover, discussions were also conducted with academics, agriculture officers, environmentalists and Non-Government Organisations' (NGOs) workers. The underlying purposes of the discussions were to shape the survey questionnaires and to obtain views on various climatic and socio-economic variables. These opinions were then used to cross-validate the information obtained from the surveys and the key informant interviews.

To fulfill the objectives and research questions of this study, data were gathered from both primary and secondary sources. The procedure of primary data collection (survey design) are described below:

3.4.2 Selection of the study areas

A multi-stage sampling technique was employed to collect data from riverbank erosion hazard-prone rural households[11] in Bangladesh. The riverbank erosion-affected districts, upazilas[12] and riverine villages were selected based on the degree of severity of erosion that was identified through a review of the literature, reports in newspapers and in consultation with experts. Within each village, respondents were selected randomly. For the field survey, the Chauhali Upazila of the Sirajgonj district and the Nagarpur Upazila of the Tangail district were selected, as they represent the most riverbank erosion-affected riparian environments in Bangladesh. The area is about 200 km north of Dhaka, the capital of Bangladesh. The Jamuna River[13], which is reported to cause erosion of around 2,000 ha per year (CEGIS 2012), crosses the study area. Data were collected from six riverine villages, namely; Kashpukuria, Moradpur, Kairat, Datpur, Kashkawalia and Atapara (Figure 3.1). Some pictures of Jamuna riverbank erosion and livelihoods are presented in Figure 3.2.

3.4.3 Unit of analysis

Selection of the units of analysis is considered as the entry point in social science research. The unit of analysis influences greatly to the decision of research design, data collection and data analysis (Silverman & Solman 1998). In this study, the unit of analysis was households and for data collection, the household head (either male or female) was the survey participant. A household (economic agent) is a domestic unit with autonomous decision-making regarding production and consumption (Ellis 1988). In Bangladesh, household heads have the power to exercise decision-making over household's resources and setting strategies.

[11] Riparian (riverbank and *char)* communities.

[12] Lower administrative unit of government; below district level but above village level.

[13] Bangladesh is composed of the floodplains and deltas of three main rivers, the Padma (Ganges in India), the Jamuna and the Meghna (Brahmaputra in India).

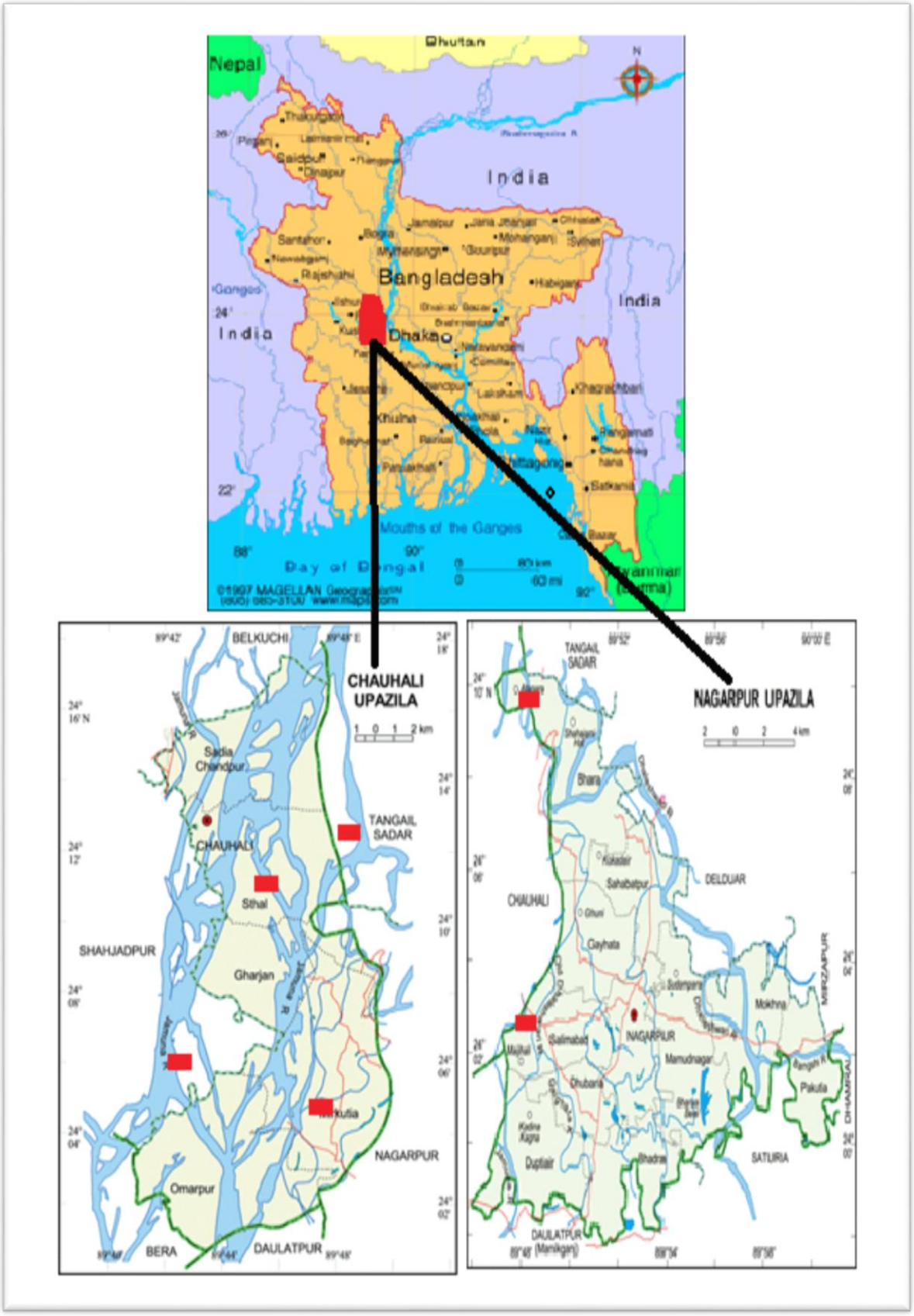

Figure 3. 1: The study areas: the Nagarpur and Chauhali Upazilas

Source: http://www.banglapedia.org/httpdocs/HT/G_0144.HTM

Riverbank erosion damage ***Char* land under cultivation**

Figure 3. 2: Riverbank erosion (Jumuna river) and livelihood in the study areas

Source: Field survey

3.4.4 Sample size

In survey research, it is a vital issue to determine the representative same size which will be yielded sound results to fulfill the research objectives. Some argued that a minimum sample size of around 30 is required for statistical analysis (Champion 1970). Perry (1998) suggested that a sample size of 350 is the optimal size for a structured interview in quantitative research. On the other hand, Bartlett et al. (2001) suggested that 5% of the population is considered to be adequate for the cross-sectional household survey.

Therefore, for this study 15% of the household heads from each village were interviewed, which gave a sample size of 380 households for the study. It is worthy to mention that there were relatively small number of households which varies across the villages. Moreover, rural households in Bangladesh virtually face analogous socio-economic, environmental and climate conditions (i.e. low education attainment and income, relatively high birth rate and high dependence on agriculture for livelihoods) which validates the use of a small sample size that can be typical of the whole population (Blaikie 2010; Gilbert 2008). To do that a complete list of riverine households of the selected villages was first collected from the Department of Agricultural Extension (DAE). The distribution of sampling is given in Table 3.1.

Table 3. 1: Sample size for the survey.

Village	Households	Sample size (15% of the population)
Kashkawalia	650	97
Kashpukuria	750	112
Moradpur	270	41
Kairat	315	47
Datpur	250	38
Atapara	300	45
Total	2535	380

3.4.5 Sampling technique and non-response

Random sampling technique is an important way to make sure that the sample is representative of the population under study (Neuman 2006). To ensure randomness

in sampling, this study employed a computer-generated random number table to the list to select 380 households.

The issue of non-response is unavoidable in cross-section household survey. Scholars, however, argued that when the sample is truly random, non-response does not represent a bias (Fowler 2009; Henry 2009). This study did not face the non-response issue greatly rather received good cooperation from the households. Unavailability of respondents or refusal to answer questions were mainly by the female-headed households, which cover less than 2% of the actual samples. In the case of non-response, the interviewers simply proceeded to the next household until the required number of respondents for a particular village was reached.

3.4.6 Questionnaire and data collection

The researcher developed a structured survey questionnaire containing both open-ended and closed-ended questions. Based on the review of the literature and discussions with the experts, a draft questionnaire was prepared to achieve the research objectives. The first part of the questionnaire contains the information on households' socio-economic condition such as household demographic information, income and expenditure. The second part covers the information that relates to household livelihood status and food security issues. The third part includes the information on their perception of climate change and hazards, and response strategies (see Appendix 1 for the complete questionnaire). Moreover, different semi-structured interview schedules were also prepared for conducting FGDs and Key Informant Interviews. Since 'Bengali' was the target language, therefore, back translation of the questionnaire was done following Sperber (2004). It allowed the researcher and the enumerators to collect the precise and reliable data easily.

Prior to the final survey, the questionnaire was pilot-tested with 20 respondents to ensure adequacy of the information obtained and avoid ambiguity of questions. Expert opinion was also shared and their suggestions were incorporated to modify the questionnaire. At this stage, the questionnaire was ready to conduct the survey and the author along with three trained enumerators implemented the survey. Educated enumerators were chosen from the study areas and trained properly. Due to their known environment and familiarity with the people, the selection of households was relatively stress-free. The work of enumerators were supervised by the

researcher and where necessary, clarification of the issues and further instructions were provided.

The face-to-face interviews were conducted between January and May 2014 to collect the data. However, the observation of changes in the study areas particularly the infrastructure (road, institutions) changes was continued in time interval over the whole PhD study period: the study areas experienced massive riverbank erosion in 2015 for which the upazila complex and the only public hospital of Chauhali upazila were disappeared.

Other survey methods including mail and telephone surveys were not possible due to the low education level of the respondents and unavailability of such technology. Moreover, the in-person interview method helps to build rapport between the respondent and interviewer to get more information.

3.4.7 Validity and reliability

Validity and reliability are the two very important issues in research. These issues are related with the characteristics of measurement and its precision. In the questionnaire survey, it is hard to measure accurately which is often resulted in measurement error (Singh 2007; Williams 2003). Validity implies to how conceptually close the variables are to what it intends to measure[14]. In other words, validity ask the question: are we measuring what we want to measure? (Muijs 2010). Reliability, on the other hand, implies the consistency of the measures that able to provide identical results in repeated measurements (Blunch 2008; Singh 2007). Reliability of the questionnaire can be achieved by internal consistency (Williams 2003).

In this research, the validity and reliability of the survey question were ensured through adopting various techniques such as appropriate wording in the questionnaire, piloting of the questionnaire, extensive review of the questionnaire by more than six academic experts, and collection of the data through local trained enumerators under close supervision of the researcher. During face-to-face interviews, respondents were asked the questions in more than one way and tested consistency in responses which was relatively easy for the local enumerators for their

[14] For instance, if child nutrition status are taken into account to measure food insecurity rather than considering the number of nights the family members have gone to bed hungry, then it will not be valid measure for this study.

known environment. These together contributed to building rigorous assessment of survey instrument's validity. Moreover, extended analysis of socio-economic characteristics of study households and drawing comparisons with local and national data, and various statistical measures also established the validity and reliability of the research which yielded sound results (for more on this, see the discussion in the proceeding chapters).

3.4.8 Data entry and cleaning

The trained enumerator thoroughly checked the filled questionnaires at the end of everyday data collection. If they found any inconsistencies, they went to the household the next day and made the required changes. They also converted local units of data into standard units. Therefore, in the first stage the filled survey questionnaires were cleaned and validated at the field level. Then the collected data were tabulated into Excel spreadsheet (Excel 13). Once the data entry was completed, the file was thoroughly edited for cleaning the data by producing frequency table for each question and checking the outliers. Thus, the data entry, cleaning and validation were done very vigilantly which made the data reliable. At this stage, the data was ready for statistical analysis. For regression analysis, the Excel data was imported in the Stata (see Chapters 6 and 8). Table 3.2 present the major statistical tools and software used in this study along with their purposes.

Table 3. 2: Statistical techniques, purpose of use and software.

Statistical tools	Purpose of use	Link to research objectives	Software
Descriptive statistics such as mean, percentage, frequencies	To analysis the socio-economic profile of households	All research objectives	Excel 2013
Graphs such as pie charts and line charts	To observe the trend in climate variables, farmers' adoption strategies and barriers to adoption	Objective 3	Excel 2013
Pearson chi-square test and independent sample t-test	To compare the relationship between two categorical variables and continuous variables	Objective 1	SPSS 22
Logit model	To analysis the	Objectives 2 and	STATA 12

	determinants of household food security and household adaptation choices	3 (Research question (ii) under objective 2 and research question (v) under objective 3)	
Breusch-Pagan test	To check the problem of heteroscedasticity	-do-	STATA 12
Variance Inflation Factor	To check the presence of multicollinearity	-do-	STATA 12
Hausman test	To test the assumption of IIA for the Multinomial logit model (MNL) for adaptation	-do-	STATA 12
Endogeneity test	To make sure that the model has no endogeneity problem	-do-	STATA 12

3.4.9 Secondary data

To support the results of the primary data, relevant secondary data were also collected and compared. This data were mainly collected from various reports of Bangladesh Bureau of Statistics (BBS), Food and Agriculture Organization (FAO), and World Bank (WB).

3.4.10 Research ethical issues

Research ethics is an important aspect in research (David & Resnik 2011). The approval of the USQ Human Research Ethic Committee is mandatory for PhD research before launching the data collection and stick to this up to 5 years after completion the research. The author enrolled in the PhD program at USQ in July 2013. After conformation of the PhD candidature, the author received the ethical approval from the University of Southern Queensland (H13REA244) in November 2013 to collect the survey data from the study areas in Bangladesh.

The ethical standard was maintained during the periods of data collection in Bangladesh by all the enumerators. Before each interview, the purpose of the research and the confidentiality of the data were described, and then their consent to provide information voluntarily were taken. Same procedure was also maintained in FGDs. Most of the respondents cooperated nicely and the author is highly grateful to

all of them who provided information and suggestions for this research. Moreover, ethical issues also maintained in presented the results of this thesis in various scientific journals.

3.5 Data description

In this section, some descriptive statistics of the data are illustrated as follows:

3.5.1 Socio-economic characteristics

The information of household socio-demographic and economic characteristics are very useful to get an insight into the profile of the study households and to formulate effective policy interventions. This information can be served as the delimitation of the study so that whatever findings or outcomes derived from this study can be described within the domain of this profile. Socio-economic characteristics of the study households are presented below:

As seen in Table 3.3 that half of the household heads belong to the age group of 46 to 60 years. Average age of the household heads is around 45 years. Currently, the life expectancy at birth in Bangladesh is 70.3 years (UNESCO 2015). The majority of household heads is male (88%) as against women of 12%. The average family size of 5.21 is relatively large compared to the national average of 5.0 (BBS 2012). More than 46% of households had six members or more. The mean education level of the household was below primary level (3.17 years). More than 29% of respondents did not attend school. In Bangladesh, the estimated literacy rate was 61.5 percent in 2015 (UNESCO 2015). Majority of the household heads had education level between primary and secondary level. Only 9% had more than secondary education level.

Households' farm size is relatively low since all household had experienced loss of some of their land. Therefore, the study households were categorized as: large farm household (12%) (>2.5 acres), medium farm household (28%) (1.5–2.49 acres), small farm household (33%) (1.49–0.5 acres) and landless (27%) (<0.5 acres). Household occupation groups are classified according to the main source of income (i.e., >50%) (Table 3.3). As expected, most of the households in the study areas depend on agriculture (71%) which is relatively higher than national

statistics (BBS 2012). Service holders or affluent households usually live in nearby town or other places that are free from erosion problems.

Table 3. 3: Some selected socio-economic characteristic of the study households.

Characteristics/Variables	Number	Percentage
Age of HH head (Mean :45; Range:25-65)		
≤30 years	36	10
31-45 years	134	35
46 -60 years	191	50
61-65 years	19	5
Gender of HH head		
Male	335	88
Female	45	12
HHs family members (Mean :5.21; Range:3-11)		
3	31	8
3-5	174	45
≤ 6 members	175	46
Religion		
Muslim	337	89
Others	43	11
Education (Mean : 3.17 years; Range: 0-16)		
Illiterate	109	29
Primary (level 1-5)	137	36
Secondary (level 6-10)	104	27
Higher secondary (level 11-12)	21	6
< Higher secondary (level 12-16)	9	2
Employment status		
Agriculture	271	71
Business + Agriculture	75	20
Services + Agriculture	34	9
HHs yearly income (Tk) (Mean:35, 000 Tk; Std. 38456)		
≥ 35,000	39	10
36, 000-60,000	137	36
61,000-150,000	151	40
≤151,000	53	14
Farm category (Average farm size: 0.56 acres *)*		
Large farm (>2.5 acres)	45	12
Medium farm household (1.5–2.49 acres)	107	28
Small farm household (1.49–0.5 acres)	127	33
Landless (<0.5 acres)	101	27

Note: Household = HH

Since most of the farmers depend on agriculture, therefore their income level is also low. More than 50% of households belong to the income level of Tk 60,000

(see Gini coefficient in the next section). Road and transport communication is also inadequate in the areas. Farmers mainly use vans, bicycles, rickshaws, scooters, and tempo driven by small machines to market their products.

3.5.2 Income inequality among the households

In order to show the inequality of income among the households, we estimated the Gini coefficient and the Lorenz curve. The Gini coefficient was calculated by using the formula of Rodrigue et al. (2009):

$$G = \left| 1 - \sum_{k=1}^{k=n-1} (X_{k-1} - X_k)(Y_{k+1} + Y_k) \right|$$

Where, Xs are the proportion or share of households and Ys are the proportion of their corresponding income.

The Gini coefficients are aggregate inequality measures and can vary anywhere from 0 (perfect equality) to 1 (perfect inequality) (Todaro & Smith 2005). The estimated Gini coefficient of 0.511 is higher than Bangladesh's national income Gini coefficient of 0.458 (BBS 2010). This means that income distribution among the sample households is relatively skewed. We also draw a Lorenz curve to show the degree of inequality in income of the respondents (Figure 3.3).

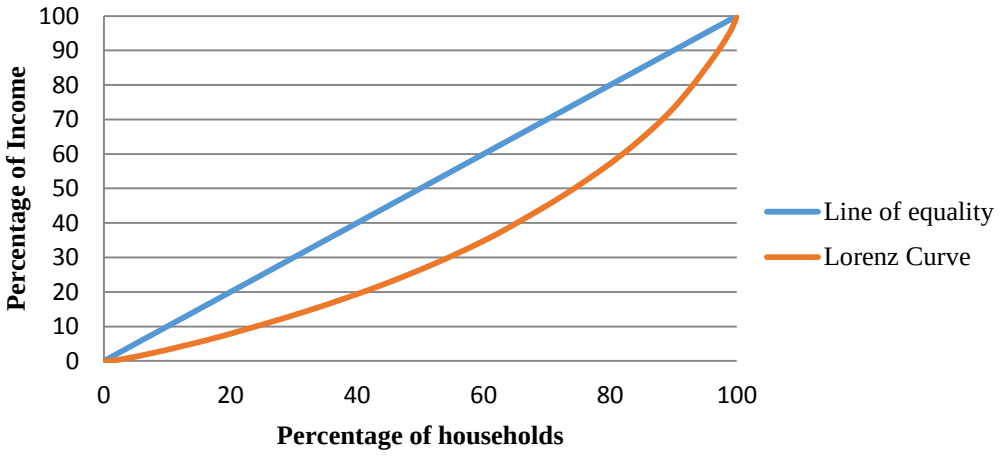

Figure 3. 3: Lorenz curve of income of the study households

This indicates that the bottom 80% of the sample households had only 60% of the total income whereas the top 20% had about 40% of the total income. This

indicates that a huge income inequality exists among the households included in the study. This result is not quite unexpected in the context of rural Bangladesh. In 2010 the income share of the top 5% of the households was 24.61% whereas it was 0.78 for the bottom 5% of the households (BBS 2010).

3.6 Research design: An overview

The below diagram (Figure 3.4) links the research objectives, theories and approaches, data requirements, and major methods of analysis in this study.

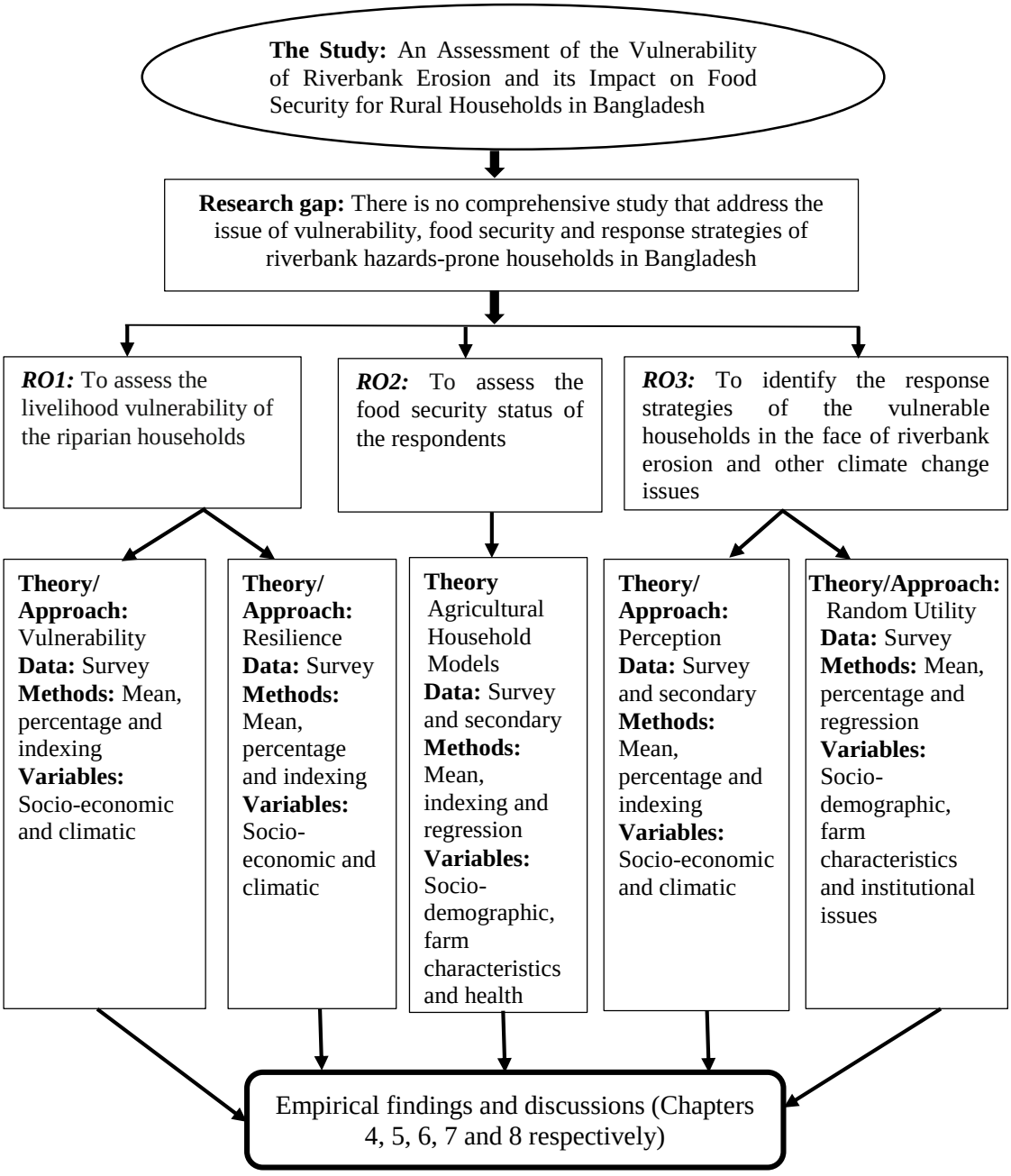

Figure 3. 4: Research design

The study has set three objectives based on three close interlinked aspects (i.e., vulnerability, food security and response strategies of the households). Under the first objective – the livelihood vulnerability and resilience capacity due to riverbank erosion and other climate change issues are assessed. In the second stage, the impacts on household food security are analysed. Finally, how the households are responding in such settings is discussed.

3.7 Summary

This chapter discusses various theories and approaches to be used in this thesis. It provides descriptions of the study areas and methods of data collection. This chapter also explains how different statistical methods and software are used to achieve the objectives of the research. A brief overview of some selected characteristics of the study households are presented in this chapter.

A multistage sampling technique was employed to collect the survey data from riverbank erosion-prone households' covering six villages of the Chauhali upazila of the Sirajgonj district and the Nagarpur upazila of the Tangail district in Bangladesh. A total of 380 households head were interviewed. For better understanding of their livelihood and difficulties, discussions were also held with the key informants and other experts in all the study locations. The remaining chapters (Chapter 4 to Chapter 8) are based upon the results of the analysis of the data. The result chapters are organised in a mini thesis format where all sections such as introduction, review of the literature, methodology, results and discussions and conclusions are presented. Relevant descriptive statistics to the specific objective is presented in the respective chapters. The next chapter discusses the vulnerability of households due to riverbank erosion and other climate change issues.

CHAPTER FOUR

Vulnerability of Riverine Rural Households to Climate Change and Hazards

4.1 Chapter outline

Rural riverine households in Bangladesh are confronted with many climate-driven hazards, including riverbank erosion, which results in loss of productive land and other natural resources, and thus threatens their livelihoods and food security. To improve their situation in a sustainable way, it is crucial to have critical information on the livelihood vulnerability of these households, and this information is currently unavailable. Therefore, this chapter assesses the livelihood vulnerability of the riverbank erosion-prone rural households. The findings will allow the stakeholders to understand the complex set of factors that contribute to the vulnerability of the households. The chapter is organised as follows: the background of the study is presented in Section 4.2. Section 4.3 presents the brief methodology of the study. The results are discussed in Section 4.4; and Section 4.6 contains the conclusions of the chapter.

4.2 Introduction

Global environmental research has projected that climate change will intensify over the coming decades and emphasised the need to develop suitable adaptation strategies to address the potential impacts of unavoidable climate change (IPCC 2014). The identification of suitable adaptation strategies needs to start with an assessment of vulnerability (O'Brien et al. 2009; Ford & Smit 2004), which is the condition determined by physical, social, economic and environmental factors and processes that increase the susceptibility of a community/system to the impacts of hazards (UNISDR 2004). There are a number of benefits that vulnerability assessments can offer – for example, vulnerability indicators can be used as an instrument for evaluating development policy frameworks (Eriksen & Kelly 2007); it can provide information for developing adaptation and mitigation plans (Gbetibouo et al. 2010); it allows comparison of different contexts, and monitoring of

vulnerabilities over time and space; and enables the setting of priorities in resource allocations for adaptation and mitigation (Preston et al. 2011). Therefore, it has been suggested that there is a need for place-specific and context-specific assessments of vulnerability, since it is driven by many local factors which vary with space and time (Wood et al. 2014; Fraser et al. 2011; Fussel 2010; Cutter et al. 2003). This study assesses the vulnerability of the most susceptible riparian households in Bangladesh.

Although the country experiences frequent events of extreme climatic hazards, riverbank erosion is the disaster that accounts for the largest losses (Penning-Rowsell et al. 2013; Makenron 2000). Damage from riverbank erosion occurs gradually and has long-term impacts which are naturally irrecoverable. About 8,700 hectares (ha) of land are lost each year due to riverbank erosion, which displaces approximately 200,000 people annually and pushes them into vulnerable conditions of food insecurity and poverty (IFAD 2013; Huq & Rabbani 2011; GoB 2010). Due to the dynamics of erosion and accretion in the rivers, some *char* land (sandbars/sand and silt landmasses) has emerged as islands within the river channel or as land attached to the riverbanks in Bangladesh. Households in the *char* areas are the poorest of the poor and are the most vulnerable (Islam & Hossain 2013; CLP 2010), and they are marginalised from the benefits of mainland people due to their poor communication networks (Sarker et al. 2003; Thompson 2000). According to the estimates of EGIS (2000), the *char* area covers about 5% of the total land area of the country and is home to around 6.5 million people (5% of the total population). Households in the riverine areas are also prone to frequent flooding and water logging due to their proximity to the rivers which together with erosion, create a most vulnerable environment for them.

There are several indicators which suggest that riparian (river bank and *char*) households are more vulnerable to riverbank erosion and other climate-induced hazards, however, critical information on the degree of their livelihood vulnerability is not available; this information is crucial for the development of appropriate social, economic and environmental policies. The Government of Bangladesh (2011) has also acknowledged information gap regarding the likely impacts of climate change and has highlighted the need to identify most vulnerable sectors and geographical areas. Scholars have opined that policy interventions would do little to affect poverty dynamics unless the vulnerability context is properly understood (Shah et al. 2013;

Hahn et al. 2009; IPCC 2007). This study aims to fill this gap by integrating the LVI and the CVI utilising the IPCC vulnerability framework. The study frames the following research questions to achieve this aim: (i) what are the main drivers of livelihood vulnerability of the riparian households to climate change and hazards?; (ii) are households isolated from the mainland more vulnerable to climate change than other riparian households? and (ii) does the livelihood status serve as a driver of vulnerability to climate change of these hazard-prone rural households in Bangladesh? The next section provides the methodology for vulnerability analysis.

4.3 Data analysis method

As discussed in Chapter 3, a multistage sampling technique was employed for this study to collect the data from riverbank erosion prone areas. Here the vulnerability assessment method is discussed.

The study households were divided up based on the location into two groups, namely, 'riverine mainland households' (from now on 'riverbank households') and '*char* households' (from now on '*char* dwellers'). Although riverine mainland households and *char* dwellers are both affected by riverbank erosion and other climatic hazards, they have different location identity with respect to the river and therefore suffer differently in terms of livelihood vulnerability. Households in the *char* lands are isolated from the mainland by the river and are deprived of all standard government services, whereas riverine mainland households are relatively better off, being better connected to transport and other services. The *char* villages studied were Moradpur, Datpur and Kairat, and the riverbank villages studied were Atapara, Kash Pukuria and Kash Kawalia.

4.3.1 Developing an index for vulnerability analysis

The IPCC (2007) suggests that vulnerability is characterised as a function of three dimensions – exposures, sensitivity and adaptive capacity, as follows:

$$\text{Vulnerability} = f(\text{Exposure}, \text{sensitivity}, \text{adaptive capacity})$$

This relationship is essentially determined by the local circumstances. According to Ford and Smit (2004), vulnerability is a positive function of the system's exposure and sensitivity, and a negative function of the adaptive capacity. According to Adger

(1999), vulnerability is considered as an exposure to a group or individual stress due to a change in social and environmental conditions that disrupt livelihoods. Vulnerability assessment reflects the social process and material outcomes within the system and identifies who and what are more or less sensitive to climate risks (Ford et al. 2010; Adger 2006).

Based on the IPCC definition of vulnerability, Turner et al. (2003) developed a vulnerability framework and later Hahn et al. (2009) developed an indicator-based vulnerability assessment that has been used by many scholars in different contexts (see, for example, Panthi et al. 2015; Aryal et al. 2014; Toufique & Islam 2014; Etwire et al. 2013; Shah et al. 2013; Pandey & Jha 2012). This study adopted and extended the Livelihood Vulnerability Index (LVI) proposed by Hahn et al. (2009) and the Climate Vulnerability Index (CVI) proposed by Pandey and Jha (2012) to measure and compare livelihood vulnerability in the context of the riparian households and to assess the relative magnitude of contributing indicators within the concerned vulnerability-dimension under the IPCC framework. The LVI approach is preferred over the Sustainable Livelihood Approach (SLA), developed by Chambers and Conway (1992), which only considered five types of household assets – natural, social, financial, physical and human capital – but failed to integrate the issues of sensitivity and adaptive capacity to climate change. The LVI approach focuses on quantifying the strength of current livelihoods and health and water resource characteristics as well as the capacity of communities to alter these strategies in response to climate-related exposures (Hahn et al. 2009). The study therefore develops a weighted-balance integrated approach to the calculation of the LVI and CVI that incorporates local and indigenous knowledge into the selection of indicators.

The LVI is composed of seven major components – socio-demographic profile, livelihood strategies, social networks, health, food and water, natural disaster and climate variability. Each component comprises several sub-components or indicators. Due to the flexibility of the methods, they study included additional relevant indicators, which are based on a critical review of relevant literature, local circumstances and consultation with experts. Table 4.1 presents the major components and the indicators included in vulnerability analysis in this study along with the explanation of the reason of inclusion.

Table 4. 1: Major components and sub-components comprising the Livelihood Vulnerability Index (LVI) in the study areas.

Major components	Sub-components or indicators	Explanation of sub-components	Expected relationship
Socio-Demographic profile (SDP)	Dependency ratio	Population ratio under 15 and above 65 years of age to the population over 15 and below 65 years of age	Positive (It is expected that higher dependency ratio increases household vulnerability)
	Percentage of female headed HHs	Female member percentage to total household members	Positive (higher proportion of household female members increases vulnerability)
	Percentage of HHs where head of the HHs has not attend school	Percentage of households where the heads of household have zero years of schooling	Positive (Higher education level of households head decrease vulnerability)
	Average number of family members in the HHs	Average number of family members in the households	Positive (higher numbers of family members increases vulnerability)
	Percentage of HHs where a women family members are not allowed to work outside	Percentage of women family members to total family members	Positive (higher the numbers, higher is the vulnerability)
Livelihood strategies (LS)	Average livelihood diversification index	The inverse of (the number of agricultural livelihood activities)	Positive (More agricultural livelihoods reduce vulnerability)
	Percentage of HHs with the family member (migrate) working in a different community	Percentage of households to total households	Positive (higher the numbers, higher is the vulnerability)
	Percentage of HHs solely dependent on agriculture and livestock as a source of income	Percentage of households to total households	Positive (higher the numbers, higher is the vulnerability)
	Ratio of non-agricultural income to total income	Ratio of non-agricultural income to total income	Inverse is considered (higher the ratio, lower the vulnerability)
Health	Average time to	Total time to reach	Positive (higher the

	health facility (at least with MBBS doctor)	health facilities	distance, higher is the vulnerability)
	Percentage of HHs with family members with chronic ill	Percentage of households that report family members chronically ill	Positive (higher the numbers, higher is the vulnerability)
	Percentage of HHs not going to doctors (local doctor) during illness	Percentage of households to total households	Positive (higher the numbers, higher is the vulnerability)
	Percentage of household without sanitary latrine	Percentage of households to total households	Positive (higher the numbers, higher is the vulnerability)
	Percentage of households where a family member missed work or school due to illness in the past two weeks	Percentage of households that report family members missed out work or school	Positive (higher the numbers, higher is the vulnerability)
Food	Average number of months HHs struggle to find food	Average number of months households struggle for food	Positive (higher the numbers, higher is the vulnerability)
	Average crop diversity index	The inverse of (the number of crops grown by households +1)	Positive (higher the index, higher is the vulnerability)
	Percentage of households that do not get food from the family farm	Percentage of households to total households	Positive (higher the numbers, higher is the vulnerability)
	Percentage of household losing their agricultural land	Percentage of households to total households	Positive (higher the numbers, higher is the vulnerability)
	Percentage of households not practicing homestead gardening	Percentage of households to total households	Positive (higher the numbers, higher is the vulnerability)
Water	Percentage of HHs reporting water conflicts	Percentage of households that report conflicts over water in their area	Positive (higher the numbers of conflicts, higher is the vulnerability)
	Percentage of households use unsafe drinking water (River, pond,	Percentage of households to total households	Positive (higher the numbers of households unsafe drinking water, higher is the

	hole, arsenic contaminated water)		vulnerability)
	Average time to get safe drinking water source	Total distance to reach in safe drinking source	Positive (higher the distance, higher is the vulnerability)
Social Network	Percentage of HHs received assistance from social networks	Percentage of households that report receiving assistance	Positive (more assistance reduce vulnerability)
	Percentage of HHs provided assistance to others	Percentage of households to total households	Positive (more sources of assistance provider reduce vulnerability)
	Percentage of HHs borrowing money from others	Percentage of households to total households	Positive (more sources of borrowing money reduce vulnerability)
	Percentage of households lending money to others	Percentage of households to total households	Positive (more sources of lending money reduce vulnerability)
	Percentage of households receiving assistance/aid from Government and NGOs	Percentage of households to total households	Positive (more sources of assistance reduce vulnerability)
Natural disaster and climate variability	Average number of flood, drought, and cyclone events in the past 10 years	Total number of disasters reported by the households	Positive (higher the numbers of disasters , higher is the vulnerability)
	Percentage of HHs with an injury or death as a result of natural disasters in the last 10 years	Percentage of households that reported either injury or death	Positive (higher the numbers an injury, higher is the vulnerability)
	Percentage of HHs with an injury or death to their livestock as a result of natural disasters in the last 10 years	Percentage of households that reported either injury or death of their livestock	Positive (higher the numbers of injury or death of livestock, higher is the vulnerability)
	Percentage of HHs with losses to physical assets (homestead/agril. equipment/ machinery) due to riverbank erosion and other disasters	Percentage of households that reported losses of physical assets of their households	Positive (higher the numbers of losses, higher is the vulnerability)
	Percentage of HH that do not receive a warning before a	Percentage of households that did not receive warning	Positive (higher the numbers of households not receiving warning,

	natural disaster	about any severe disasters	higher is the vulnerability)
Climatic variability	Perception index of summer temperature	Percentage of households reported change in summer temperature	Positive (changes in summer temperature increase vulnerability)
	Perception index winter temperature	Percentage of households reported change in winter temperature	Positive (changes in winter temperature increase vulnerability)
	Total rainfall perception index	Percentage of households reported change in total rainfall	Positive (changes in total rainfall increase vulnerability)
	Perception index of monsoon rainfall	Percentage of households reported change in monsoon rainfall	Positive(changes in monsoon rainfall increase vulnerability)
	Perception index of winter months rainfall	Percentage of households reported change in winter month rainfall	Positive (changes in winter rainfall increase vulnerability)
	Perception index of frequency of floods/riverbank erosion	Percentage of households reported change in the frequency of floods	Positive (changes in the frequency of floods increase vulnerability)

The interpretation of the results of the method demand some caution, since the results expressed in this methodology are in relative terms, rather than absolute, and are assessed at the scale of 0 (least vulnerable) to 1 (most vulnerable). It is very useful for cross-comparison of intra- and inter-group vulnerability and also to identify the most and least vulnerable groups.

In the LVI, each sub-component contributes equally to the overall index, even though each major component is comprised of a number of sub-components. Since all sub-components were measured on a different scale, they were required to be standardised as an index using the following equation:

$$\text{Index}k_a = \frac{k_v - k_{min}}{k_{max} - k_{min}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (i)$$

where k_a is the original sub-component for an area a, and k_{min} and k_{max} represent the minimum and maximum values for each sub-component, respectively. These minimum and maximum values were then employed to transform this indicator into a

standardized index. For variables that measure frequencies – such as 'percentage of female-headed households' and 'percentage of households where the household head has not attended school' – the minimum value was set at 0 and the maximum at 100.

The sub-components were averaged after being standardised using Equation (ii) to calculate the value of each major component:

$$M_a = \frac{\sum_{i=1}^{n} IndexKa_i}{n} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (ii)$$

where M_a is one of the seven major components for an area *a*, $IndexKa_i$ represents the sub-components, indexed by *i*, which make up each major component, and *n* indicates the number of sub-components in each major component.

Once the values for each of the seven major components were calculated, they were then averaged using Equation (iii) to obtain the LVI, using:

$$\mathrm{LVI}_a = \frac{\sum_{z=1}^{7} \mathrm{W_{M_z}}\,\mathrm{M_{az}}}{\mathrm{WM_z}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (iii)$$

Equation (iii) can also be presented in the following way:

$$\mathrm{LVI_a} = \frac{\mathrm{W_{SDP}SDP_a}+\mathrm{W_{LS}LS_a}+\mathrm{W_{SN}SN}_a+\mathrm{W_H H_a}+\mathrm{W_F F_a}+\mathrm{W_W W_a}+\mathrm{W_{NDC}NDC_a}}{\mathrm{W_{SDP}}+\mathrm{W_{LS}}+\mathrm{W_{SN}}+\mathrm{W_H}+\mathrm{W_F}+\mathrm{W_W}+\mathrm{W_{NDC}}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (iv)$$

where LVI_a is the LVI for an area *a*, which equals the weighted average of the seven major components. The weights of each of the major components (*WMz*) were determined by the number of sub-components that make up each major component. Weights were included so that all sub-components contribute equally to the overall LVI.

The index for exposure (*Exp*) includes natural disaster (*ND*) and climate variability (*CV*) and was calculated as follows:

$$Exp = \frac{W_{exp1}ND + W_{exp2}CV}{W_{exp1} + W_{exp2}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (v)$$

where W_{exp1} and W_{exp2} represent the weight for natural disasters and climate variability, respectively. It was equal to the number of sub-components.

The index of sensitivity (*Sen*) was calculated as follows:

$$Sen = \frac{W_{sen1}H_{+}W_{sen2}F + W_{sen3}W}{W_{sen1} + W_{sen2} + W_{sen3}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (vi)$$

where $W_{sen1}, W_{sen2} and\ W_{sen3}$ are the weight of major components health, food and water, respectively.

The adaptive capacity (*AdaCap*) index was calculated as follows:

$$AdaCap = \frac{W_{ad1}SD + W_{ad2}LS + W_{ad3}SN}{W_{ad1} + W_{ad2} + W_{ad3}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (vii)$$

where W_{ad1}, W_{ad2} and W_{ad3} represent the weight of the socio-demographic profile, livelihood strategies and social networks, respectively.

The index value for exposure, sensitivity and adaptive capacity were combined for the weightage of CVI as follows:

$$CVI = 1 - \left|\left\{\frac{N_1 Exp - N_2 Ada.cap}{(N_1 + N_2)}\right\}\right| * \left\{\frac{1}{Sen}\right\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (viii)$$

where N_i is the number of major components in the i^{th} dimensions of vulnerability. The value of each dimension will attain a maximum value of 1 and minimum of 0.

4.3.2 IPCC framework approach

The LVI is also calculated based on the IPCC vulnerability definition. The IPCC approach aggregates the seven major components into three dimensions – exposure, sensitivity and adaptive capacity – for vulnerability analysis. Exposure comprises natural disasters and climate variability; sensitivity comprises food, water and health; and adaptation includes socio-demographic profile, livelihood strategy and social networks. Once the value of these three dimensions was calculated, the three contributing factors were combined using the following equation:

$$LVI - IPCC_a = (Exp - AdaCap) * Sen \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (ix)$$

where $LVI - IPCC_a$ is the LVI for community a expressed using the IPCC vulnerability framework. The minimum value for $LVI - IPCC$ was scaled to a minimum of -1 (least vulnerable) and a maximum of 1 (most vulnerable).

4.3.3 Limitations

A major problem associated with vulnerability analysis is choosing robust and sound indicators (Etwire et al. 2013; Adger 2006). However, an extensive review of the literature and consultations with the subject experts that were carried out during this study expected to yield sound results. The important issue is that the methodology of the present study – for example, the index values – are free from the limitations of secondary data-driven methods and missing data problems. Moreover, the indicators or sub-components index value may be useful in assessing the impact of a policy or a program to see whether or not the planned activities contribute to reducing vulnerability of the households.

4.4 Discussion of the findings

This section explains the results of the vulnerability analysis in different phases. In the first stage, the results of the major components and sub-components contributing to each of the major components are presented in Table 4.2, along with their overall LVI. The spider diagram of major components of the LVI is illustrated in Figure 4.1. The second stage deals with the estimated values for the different dimensions (sensitivity, exposure and adaptive capacity) of CVI, with results presented in Table 4.3; and Figure 4.2 presents a vulnerability triangle diagram of the dimensions of the CVI.

4.4.1 Livelihood vulnerability index

Households in both the study areas were found to be vulnerable to climate change issues. However, the overall LVI of 0.478 was a little higher for the *char* dwellers compared to that of the riverbank households (0.417) ($p < 0.004$) (Table 4.2). This indicates that *char* dwellers are more vulnerable than riverbank households.

The study found a small difference in the estimated index value for different socio-demographic profiles for the study sites. However, there was considerable variation observed between the sub-components. As seen in the Table 4.2, the dependency ratio and percentage of female-headed households were higher for *char* dwellers; this is largely due to the fact that many of the husbands who migrate to

major cities as their seasonal coping mechanism to find employment do not return to their families, leading to a high rate of divorce.

Table 4. 2: Indexed value of major components and sub-components comprising the LVI (HHs = households).

Major components	Indexed value of each component		Sub-components or indicator	Indexed value for each sub-component (indicator)	
	Char dwellers	Riverbank household		*Char* dwellers	Riverbank households
Socio-demographic profile	0.291	0.270	Dependency ratio	0.147	0.125
			Percentage of female-headed HHs	0.131	0.075
			Percentage of HHs where head of HH has not attended school	0.451	0.257
			Average number of family members in the HH	0.456	0.429
			Percentage of HHs where female family members are not allowed to work outside the home	0.270	0.465
Livelihood strategies	0.324	0.343	Average livelihood diversification index	0.128	0.153*
			Percentage of HHs where family members migrate to work in a different community	0.525	0.414
			Percentage of HHs solely dependent on agriculture and livestock as their source of income	0.635	0.799*
			Ratio of non-agricultural income to total income	0.007	0.004
Health	0.470	0.309	Average time to health facility (at least with qualified doctor)	0.464	0.266 [b]**
			Percentage of HHs with family members who are chronically ill	0.337	0.198 [a]**

			Percentage of HHs who do not attend a local doctor during illness	0.549	0.386
			Percentage of HHs without sanitary latrine	0.332	0.133 [a]***
			Percentage of HHs where a family member missed work or school due to illness in the past two weeks	0.343	0.217
Food	0.757	0.628	Average number of months HHs struggle to find food	0.815	0.506 [b]**
			Average crop diversity index	0.437	0.850 [b]**
			Percentage of HHs that do not get food from the family farm	0.873	0.368 [a]**
			Percentage of HHs losing their agricultural land	1.000	1.000
			Percentage of HHs who do not practice homestead gardening	0.662	0.412 [a]*
Water	0.287	0.188	Percentage of HHs reporting water conflicts	0.251	0.117
			Percentage of HHs using unsafe drinking water (river, pond, water hole, arsenic-contaminated)	0.555	0.374
			Average time to safe drinking water source	0.054	0.072 [a]*
Social network	0.373	0.344	Percentage of HHs who receive assistance from social networks	0.572	0.357
			Percentage of HHs who have provided assistance to others	0.166	0.541 [a]**
			Percentage of HHs borrowing money from others	0.742	0.314 [a]**
			Percentage of HHs lending money to others	0.111	0.373

			Percentage of HHs receiving assistance/aid from Government and NGOs	0.273	0.136 [a]**
Natural disaster and climate variability	0.645	0.562	Average number of reported flood, drought and cyclone events in the past 10 years	0.821	0.743
			Percentage of HHs with an injury or death as a result of natural disasters in the last 10 years	0.135	0.067 [a]**
			Percentage of HHs with an injury or death to their livestock as a result of natural disasters in the last 10 years	0.217	0.152
			Percentage of HHs with losses of physical assets (homestead/ agricultural equipment and machinery) due to riverbank erosion and other disasters	0.795	0.743
			Percentage of HHs that do not receive a warning before a natural disaster	0.612	0.542
Climatic variability	0.555	0.562	Perception index of summer temperature	0.59	0.58
			Perception index of winter temperature	0.57	0.57
			Total rainfall perception index	0.53	0.54
			Perception index of monsoon rainfall	0.56	0.58
			Perception index of winter months rainfall	0.46	0.51
			Perception index of frequency of floods	0.62	0.59
Overall livelihood vulnerability index:					
Char* dwellers: 0.478, Riverbank households: 0.417 **					

***p<0.001, **p<0.05 and *p<0.10

[a] Fisher's exact test.

[b] T-statistics for mean difference test.

The index value of 'livelihood strategies' was lower for *char* dwellers (0.324) than for riverbank households (0.342). The index value for 'social network' differed slightly across sites. The index values of 'food' and 'water' were the highest for *char* dwellers, at 0.757 and 0.287, respectively, against 0.628 and 0.188, respectively, for riverbank households (Table 4.2). The index value for 'natural disasters' was the highest for *char* dwellers, whereas both sites were almost similar for 'climate variability'. The results of major components are presented in the spider diagram (Figure 4.1).

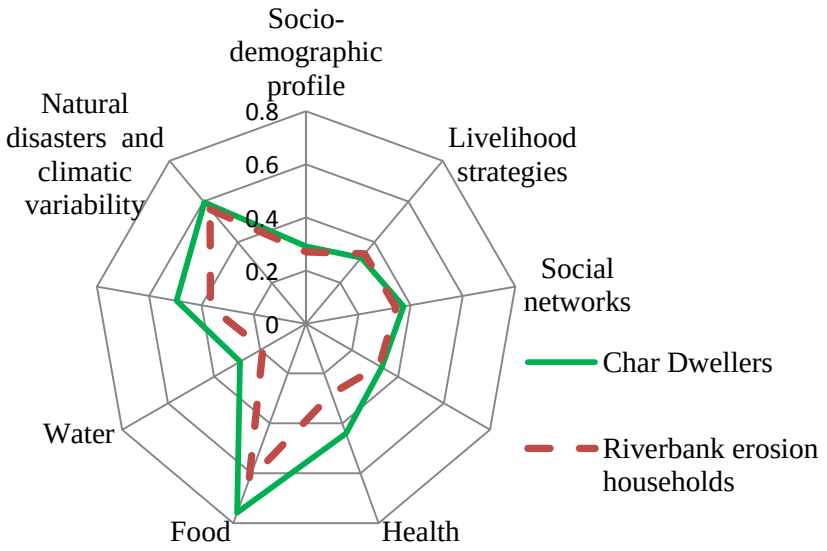

Figure 4. 1: Spider diagram of major components of the LVI

4.4.2 Climate vulnerability index

The various dimensions of vulnerability are presented in Table 4.3.

Table 4. 3: Indexed dimensions of climate vulnerability of char dwellers and riverbank households.

Contributing factors to vulnerability	*Char* dwellers	Riverbank households
Adaptive capacity (Socio-demographic profile, livelihood strategies and social network)	0.330	0.317
Sensitivity (Health, food and water)	0.538	0.403
Exposure (Natural disaster and climate variability)	0.596	0.562
Climate vulnerability index (CVI)	0.924	0.915
LVI-IPCC	0.143	0.099

The CVI was 0.924 and 0.915 for *char* dwellers and riverbank households, respectively, which indicates that households in both areas are vulnerable to climate change and variability. The vulnerability triangle that plots the scores of contributing factors for exposure, sensitivity and adaptive capacity are shown in Figure 4.2. It is evident from the figure that *char* dwellers are more exposed (0.596) to climate change than riverbank households (0.562).

In terms of sensitivity, riverbank households are less sensitive than *char* dwellers. The results of the LVI-IPCC estimation do not change the ranking of vulnerability. The *char* dwellers have come out as the most vulnerable with a score of 0.143, in contrast to riverbank households with a score of 0.099.

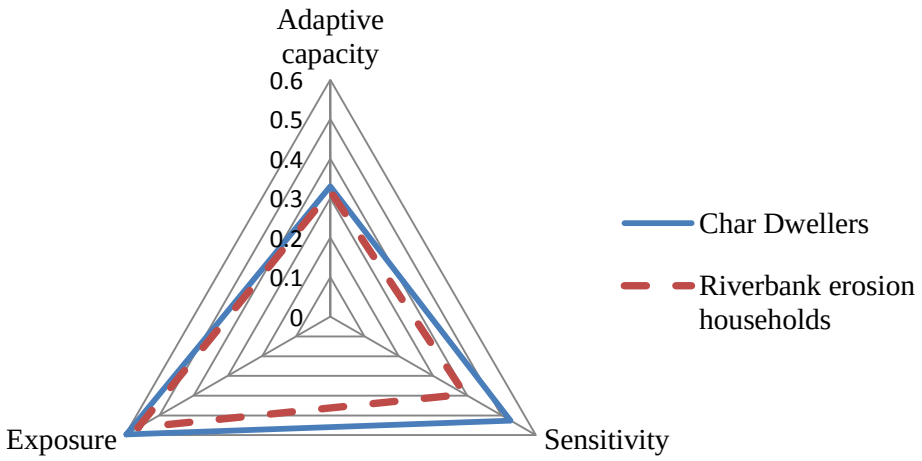

Figure 4. 2: Vulnerability triangle diagram of the dimensions of the CVI

4.4.3 Discussions

The following discussions are based on the information presented in Tables 4.2 and 4.3. Table 4.2 shows the components and sub-components of the LVI that are the major contributing factors for the highest and lowest vulnerability in each site. The variations in the value of both LVI and CVI across sites indicate that the vulnerability of riparian households varied both overall and in relation to the particular components and sub-components.

The most influential factors for the variation in the LVI were ‘food’, ‘water’ and ‘health’. The value of the LVI for ‘food’, ‘water’ and ‘health’ was the highest for *char* dwellers, at 0.757, 0.287 and 0.470, respectively, than for riverine mainland

households (0.628, 0.188 and 0.309, respectively). The contribution of the 'food' component to increasing livelihood vulnerability of *char* dwellers is likely due to the reason that they have to struggle more to manage their food, and local agricultural production is limited and can feed them for only a few months of the year. Crop cultivation is inadequate due to poor soils (sandy soils) and limited land ownership. The contribution of livestock to food is also limited. Furthermore, *char* dwellers experience more natural disasters than others, which also results in loss of livestock. During the rainy season, *char* dwellers normally move to a safer place, mainly in nearby embankments or open spaces. In such a situation, they typically sell their livestock at a low price and in some cases actually lose their livestock due to poor health. The component 'water' had an even larger influence on vulnerability in the *char* area. Households in this area use unsafe drinking water mainly from the river; although there are several tube-wells, most of them were found to be contaminated with arsenic. Households are aware of the danger of drinking arsenic-contaminated water, however, they have no choice but to drink it. In order to get arsenic-free water, they would have to travel more than 1 km and sometimes become involved in conflict with others.

The *char* dwellers are more vulnerable in terms of access to health facilities. The contribution of the 'health' component in the *char* area to increasing livelihood vulnerability can be explained by the fact that they have to travel a longer distance (more than 2.5 km) to reach the health and veterinary centres. Since they are not part of the mainland and boat is the main form of transport to the mainland, it naturally takes longer to reach the canters. Besides, many of the households still believe in their traditional system to recover from sickness rather than going to the local doctor. The number of chronically ill people is the highest for the *char* area. They are deprived of all kinds of standard government services. They have a low level of education and awareness and, coupled with their traditional beliefs, make them more vulnerable. Such social barriers affect vulnerability and adaptive capacity of a particular community (Jones & Boyd 2011). Notably, in Bangladesh, overall public spending on sanitation and drinking water, and expenditure on health care are the lowest in the world (WHO 2012). *Char* dwellers are more dependent on agriculture and livestock-related activities, and this dependency on agriculture-based activities increases the vulnerability of the households who do not diversify (Mirza 2003).

However, it is encouraging to find that households are cultivating in the emerging *char* lands, which remained fallow previously due to the lack of crop varieties suitable for such land.

Although these major components are found to be the highest for *char* dwellers, the index values are also high for riverbank households. This high index values indicate that the components 'food', 'water' and 'health' facilities also act as primary drivers to increase the vulnerability of the riverbank households, coupled with natural disasters. Previous literature also showed that displaced riverbank households are subject to different hazards, notably lack of adequate housing and health facilities, and shortage of drinking water and sanitation facilities (Lein 2010; Zaman 2007; Choudhary et al. 2005; Hulton & Haque 2003). The remaining major components such as 'socio-demographic profile', 'social network' and 'climate variability' have contributed to a more or less similar extent in determining the LVI of both sites, as there was insignificant variation. However, households in both locations reported poor access to governmental or formal financial institutions, including NGOs. This is mainly due to their poor economic conditions where the possibility of financial institutions recovering their credit is somewhat uncertain. In addition, because the addresses of riverbank households often change due to changes in homestead position as a result of erosion, their social network – the key to social capital – was found to be limited. They reported to have less farmer-to-farmer contacts and the contact with the extension service providers from whom they can get advice related to agriculture and rural development.

The study households are not only vulnerable to riverbank erosion but also to other climatic hazards. The climate change vulnerability index value of the three dimensions – adaptive capacity, sensitivity and exposure – contributed to the CVI of the communities. It is evident from the results in Table 4.3 that the highest sensitivity and exposure value contributed to the highest CVI for *char* dwellers. The indicators of 'food', 'water' and 'health' were comparatively higher for *char* dwellers than for riverbank households. The riverbank households showed relatively more adaptive capacity due to many reasons, such as higher opportunities to diversify their income sources, comparatively less dependence on agriculture, low dependency ratio, higher level of education and being better connected to transport and other services. The

above discussions indicate that access to ‘food’, ‘water’ and ‘health’ facilities are the main drivers of the livelihood vulnerability of the study households.

4.4.4 The vicious cycle of land loss and poverty

The riverbank erosion hazard is an age-old problem in Bangladesh which causes the loss of riverbank households’ entitlement every year due to the loss of production-based entitlement (the loss of farm land) and labour-based entitlement (reduced employment opportunities in farming). It has serious consequences in the study areas where the majority of the people depend on wage earnings and other non-farm activities for their livelihoods. Thus, all levels of households are impacted severely by riverbank erosion and are forced into a low livelihood status. Good health is also very important because it enables people to pursue different farm and non-farm activities efficiently and helps them to achieve their livelihood objectives. It was observed in the study areas that farmers’ physical health status influences their access to farm and non-farm activities. If the household members become sick mainly due to inadequate calorie intake and lack of proper health facilities, they will no longer be able to perform their farming jobs and ultimately become vulnerable and a burden to the family and society. Ironically, this is a common phenomenon in the study areas as an impact of recurring riverbank erosions and other climate change issues.

The study revealed that livelihood conditions of the study households follow a cycle which starts with low livelihood status and ends in poverty, as shown in Figure 4.3. Due to their existing low livelihood conditions, their opportunities to earn income from both agricultural and non-agricultural activities become limited. This limited income has resulted in low household food intake, as the main source of household food supply is either from domestic production or from market purchase. Due to loss of farmland as a result of riverbank erosion, their food production is less, and low income reduces their purchasing power to obtain necessary food items from the market. Therefore, it is inevitable that they take less food than is required, which has forced them into becoming food insecure. Lack of food means lack of required calories to remain active for doing farm and non-farm jobs which, when coupled with limited access to health services, gradually pushes household members to become susceptible to many diseases and poorer health. Diseases such as fever,

cough, skin infections and diarrhoea are common in the areas. These pose another obstacle for the households through missed work and by affecting their job opportunities; this increases their vulnerability and ultimately pushes them into the vicious cycle of poverty.

It will be difficult for a developing country such as Bangladesh to bring all those inactive people into the social safety net program and thus achieve the MDGs of eradicating poverty and enhancing food security. This is mainly due to the nature of the economy, which is characterised as a poor economy confronted with many other problems such as climate change issues, natural disasters, high population growth and poverty. Therefore, the existing low livelihood status of the households is also a driver of their vulnerability in the context of future climate change issue. It is also reported that the poor households have less ability to cope with climate change (Szbo et al. 2015; Jordan 2015; Prowse & Scott 2008; Adger 2006). This demands more targeted policy interventions for improving the livelihood status of these segments of the population – it is these interventions with the aim of improving and sustaining the livelihoods of these households which are the key to alleviation of poverty (DFID 1999; UNDP 2005).

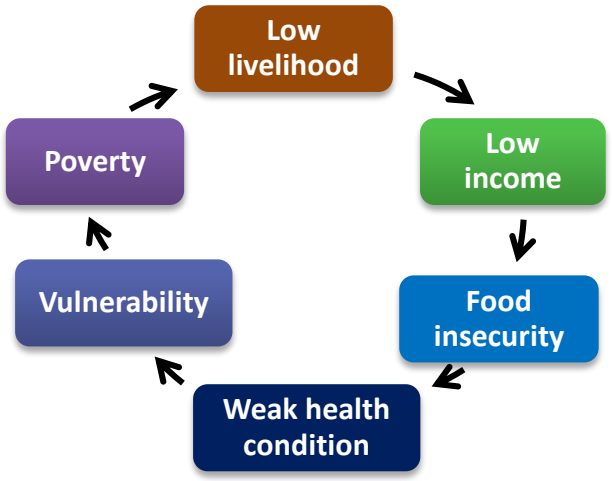

Figure 4. 3: The livelihood cycle driven by hazards in the study areas

In this vulnerability analysis, a wide range of sub-components were used where each indicator under each major component has the potential to influence that major component; in the same way, each major component under each dimension has the potential to influence that dimension. Variations in vulnerability according to location were also found in previous studies (see, for instance, Hahn et al. 2009;

Aryal et al. 2014; Toufique & Islam 2014; Pandey & Jha 2012) and within male and female groups (Shah et al. 2013). The assessments of vulnerability as well as individual dimensions (exposure, sensitivity and adaptive capacity) of climate change of such hazard-prone rural households provide insights into identifying those dimensions that require interventions to reduce overall climate change vulnerability and improve livelihoods.

4.5 Summary of the chapter

In every country, there are many areas that are at a risk of being affected by various natural hazards such as floods, droughts, cyclones and erosion. People living in these areas have relatively limited capacity to cope with shocks and, consequently, natural disasters may have persistent effects on their lives and livelihood welfare. This chapter presented the results of the assessment of the vulnerability of the most vulnerable riparian households in Bangladesh: such information is crucial for enhancing vulnerable households' resilience in the face of hazards and for coping with climate change and variability. The vulnerability assessment in this study is a customised approach to the calculation of the LVI and CVI in the context of riverine households in Bangladesh. It incorporates local and indigenous knowledge into the selection of sub-components and indicators. It supports the notion that vulnerability to climate change does not exist in isolation from wider socio-economic and bio-physical attributes of the communities.

The differences in overall CVI, as well as dimensions of CVI, indicate that vulnerability to climate change differs even within the groups of people adopting similar livelihood activities. The index values of the LVI and LVI-IPCC, which are related methods, provide evidence that riparian households in both the sites are vulnerable, particularly in the areas of food, health and livelihood strategies. Furthermore, low livelihood status of the households appears to be a driver of vulnerability in the future climate change perspective, which can lead to a vicious cycle of poverty. Therefore, special attention needs to be given to these hazard-prone rural households in order to seek improvement in the areas of food availability and access to health, water and sanitation and to reduce the hazard sensitivity of these households. In order to enhance the adaptive capacity of these households, more focus needs to be given to strengthening the socio-demographic profile, social

networks and diversification of their livelihood activities. For example, women can be engaged in other income-generating activities such as tailoring, handicrafts or embroidery, which should be facilitated through proper training. Planned adaptation strategies such as access to institutions and credit facilities, and a package of technologies through agro-ecological based research, particularly for the emerging *char* land, might help to cope with challenges. Development of communication and transport networks and infrastructure is important in order to support alternative livelihoods of the households and improve their access to services. The findings of this study will help in formulating effective policies and programs to improve and sustain the site-specific coping and adaptation strategies for the resource-poor riparian households, and thus assist with incorporating these strategies into the wider climate change policies. The next chapter discusses the factors influencing the resilience capacity of the households.

CHAPTER FIVE

Resilience of the Riverbank Erosion-Prone Households

5.1 Chapter outline

Despite the increasing recognition of the need for building resilience of the poor farmers in the face of changing climate issues, there is a lack of information on the factors influencing resilience capacity. This chapter develops an indicator-based resilience capacity index to understand the factors influencing resilience capacity of resource-poor riverbank erosion-prone rural households in Bangladesh. The rest of the chapter is organised as follows: Section 5.2 contains the introduction of the study. The conceptual framework is presented in section 5.3. Section 5.4 describes the methodology for assessing the resilience capacity. The focus of the paper then shifts to the survey results followed by discussions in section 5.5. Section 5.6 concludes the chapter and provides some policy guidelines.

5.2 Introduction

Although Bangladesh is one of the most vulnerable countries due to climate change and hazards; not all communities within the country are uniformly affected due to differential livelihood options and resources for adaptation. The coastal and riverine households in Bangladesh are the most susceptible to the impacts of climate-driven hazards including riverbank erosion (GoB 2010). Moreover, due to climate change, they are expected to face projected increases in mean annual temperatures, uncertainty in rainfall, a likely reduction of cereal crop production, and surges in disease, pest and weed pressure on crops and livestock (Niang et al. 2014).

In such unavoidable circumstances, there is increasing recognition for the need for resilient agricultural practices and building resilience capacity for the poor farmers to cope with increasing climatic hazards by many government and non-government agencies globally (IPCC 2014; UN 2013; IFPRI 2010; DFID 2009; WB 2009; UNEP 2008). However, there has been a lack of information around the factors influencing such household resilience, particularly socio-economic resilience of the disaster-prone communities (Akter & Mallick 2013; Cutter et al. 2008). The

resilience of a household is understood by its capacity to absorb shocks while still maintaining its core functions. Scholar argued that the more resilient a household, the greater its ability to absorb shock and disturbances (Traerup 2012). Livelihoods of resource-poor rural households in developing countries like Bangladesh is generally dependent on natural resources and their capacity to cope and adapt with the compounding influence of climate change and hazards which are largely uncertain (WB 2013; Stokes & Howden 2009; Dessai et al. 2007; IPCC 2007). A loss of resilience of a natural resource-dependent community contributes to an increase in its vulnerability to shocks which could have previously been absorbed (Kasperson & Kasperson 2001). One of the principal objectives of disaster risk mitigation strategies is to achieve disaster-resilient communities (UN/ISDA 2005). Policy makers are interested in knowing what affected communities can do for themselves and how to best support the capacity of resource users to cope and adapt to climate change and hazards (Kulig et al. 2013; Wilson 2012; Nelson 2011; Nelson, et al. 2007; IFRC 2004; Walker et al. 2004; Gunderson et al. 1999).

It is therefore, crucial to better understand riparian households resilience strategies resulting from their long-term knowledge, experience and practices which will enable policy makers to ensure interventions are targeted to appropriate climate adaptation processes to mitigate the effects of an adverse climate and hazards in the country (Marshall 2010; Tompkins & Adger 2004). This chapter focuses on assessing the resilience of vulnerable riverine households from socio-economic perspectives through developing an indicator based resilience capacity index (RCI). The research questions used here to seek those answers are: (1) whether the riverine mainland households are more resilient than c*har* households to river bank erosion and other climate change issues?; and (ii) what are the factors influencing their resilience capacity? In the next section the conception framework of this study is described.

5.3 Conceptual framework

In this section the conceptual linkages between climate change, vulnerability and resilience are first explored and then the study proceeds to answer the research questions. Resilience is an evolving concept applicable to climate adaptation which has been routinely applied in numerous disciplines, especially in the field of disaster

management (Manyena 2006). One of the important aims of employing resilience theory to empirical studies is to assess the current state of the socio-ecological system and make predictions about whether or not the system is resilient (Gilbert 2010; Marshall 2010; Cumming et al. 2005; Berkes & Folke 1998). In the climate change literature, resilience is often used to describe a system characteristic that determines how the impacts of climate change will be experienced (Adger 2000; Peterson 2000). Resilience denotes the ability of a system to return to an earlier (meta-) stable state after a perturbation (Fussel 2007) and to adapt to change or retain its essential functions irrespective of the changing conditions that it experiences (Wilson 2012; Perrings 2006). It is also described as a mechanism of self-organisation, the capacity to learn from experience, to process information and adapt accordingly (Cutter 2008; Marshall & Marshall, 2007; Gallopin 2006; Folke 2006; Klein et al. 2003). There is, however, debate surrounding the nexus between vulnerability and resilience.

The IPCC defines the term vulnerability, resilience and adaptation as follows: Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change and variability and extremes. Resilience, on the other hand, is the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change. Adaptive capacity is the ability of a system to adjust to climate change and variability and to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (IPCC 2007). Scholars have mentioned resilience as a positive adaptive response[15] to adversity (Luthar et al. 2000; Masten et al. 1990). Vulnerability, on the other hand, is often denoted as the antonym, i.e. flip side of resilience (Folke et al. 2002). Researchers referred vulnerability as a combination of sensitivity, exposure and adaptive capacity (Paavola 2008; IPCC 2007; Gallopin 2006; McCarthy 2001). Resilience, unlike vulnerability, does not include exposure to a disturbance (Gallopin 2006). Nelson et al. (2007) argued that vulnerability and resilience are considered to be linked to one another via response capacity. Some scholars (see, for example, Adger 2006; Smit & Wandel 2006) use these two terms synonymously. However, some viewed vulnerability and resilience are two distinct

[15] Though some response may increase resilience in short period but can create great vulnerability in the long-term (Maru et al. 2014).

concepts with some components in common (Sapountzaki 2012; Cutter et al. 2008). Some scholars have taken a different approach, by treating resilience as an isolated concept in their disaster analysis. They focused on some specific strategies such as microfinance, and migration to rebound after disaster (Mallick & Vogt 2012; Mohapatra et al. 2012; Parvin & Shaw 2012). Perez et al. (2015) considered fostering resilience as an equivalent to building an on-going adaptive capacity of individuals and social organisations. Given the limitation of a widely accepted framework of resilience assessment, this study adopted resilience as a function of sensitivity and adaptive capacity proposed by Malone and Brenkert (2008), Brenkert and Malone (2005) and Moss et al. (2001) as follows:

$$\text{Resilience} = f(\text{Sensitivity}, \text{adaptive capacity}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (i)$$

Sensitivity and adaptive capacity are, in turn, composed of different components. Every element is composed of various indicators. In the sensitivity dimension the components included are food, water and health. The adaptation capacity consists of the components of household socio-demographic profile, livelihood strategies and social networks (Figure 5.1). Exposure includes natural disaster and climate variability (Shah et al. 2013; Pandey & Jha 2012; Hahn et al. 2009; IPCC 2007).

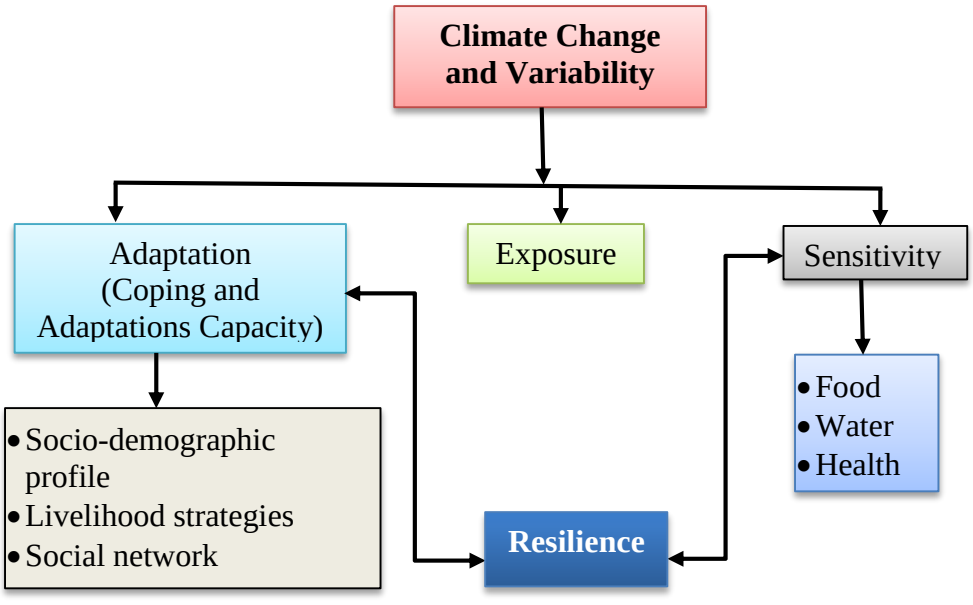

Figure 5. 1: Conceptual framework for resilience assessment

In resilience assessment, it is often difficult to quantify in absolute terms since the techniques are quantitative and use selected indicators or variables as proxies (Schneiderbauer & Ehrlich 2006). The quantitative indicator approach

though, celebrated several criticisms including subjectivity regarding variable selection and weighting, lack of availability of certain variables, problems with aggregation to different scales, and difficulties in validating the results (de Leon & Carlos 2006; Luers et al. 2003). However, the usefulness of quantitative indicators for reducing complexity, measuring progress, mapping, and setting priorities makes them an important tool for policy makers (Cutter et. al. 2008).

Based on this discussion and the author's proposed conceptual framework for this study (Figure 5.1), the rationale of selecting indicators is the relevance of indicators to the local conditions resulting from the review of literature, consultations with the local experts, and field experience. It can be, however, argued that the indicators are not representative enough to assess the resilience. This issue is not uncommon in any indicator set; see, for example, Wellbeing Index (Prescott-Allen, 2001); Environmental Sustainability Index (YCELP & CIESIN 2002); Livelihood Vulnerability Index (Hahn et al. 2009).

5.4 Data analysis method

A description of study areas, sampling and data collection procedure have already been discussed in Chapter 3. This section mainly focuses on development of the resilience index. The study households were divided into 'riverine mainland households' and '*char* households' based on the location (see more in Section 4.3.1).

5.4.1 Developing resilience index

A resilience capacity index (RCI) is constructed, driving from previous equation (i) sensitivity (the potentially negative impact of climate change) and adaptive capacity (the capability to maintain, minimise loss of, or maximise gains in welfare) of the study households. The indicators included in the sensitivity and adaptive capacities are illustrated in Table 5.1. These indicators were selected on the basis of their relevant contribution to each component.

Table 5. 1: Components and indicators comprising the Resilience Capacity Index (RCI) developed for the study areas (HHs = Households).

Components	Indicators	Score/Values	Possible limitations/Comments
Socio-demographic profile	Dependency ratio?	If 1:3, then score =1 , if more = 0	Higher dependency will increase the vulnerability. One earning member can lead a family of 3 members properly. It was considered standard after consultation with local people in the area.
	Education level?	Illiterate = 0, Level 1-5,= 1, 5-10= 2, 10-12= 3, above 12 = 4	Education level of household head can increase family income and enhance resilience capacity.
	Do you adopt any contraceptive method?	Yes = 1, No = 0	If no, it means chances of increase family members which reduce their capacity to cope with any shocks.
	Does your family send children to school?	Yes = 1, No = 0	Some household heads (HHSs) engage their children in some income earning activities due to their family need. However, it ultimately reduces his/her future scope to enter the informal job market and thus more income.
Health issues	Does your family use sanitary toilet?	Yes = 1, No = 0	This is related to good health as well as an environmental issue. In the study areas, the HHs physical health condition has influence in terms of access to farm and non-farm activities.
	Do you have any family members with chronic illness?	Yes = 1, No = 0	HHs members with chronic disease will increase the vulnerability.
	Access to health services?	Yes = 1, No = 0	Access to health services can contribute to remaining fit and healthy and thus reduce

			vulnerability.
	Current health condition of the household head? (based on observation and asking about physical health)	Good=2, Poor =1, Sick= 0	Good health is important for doing farm and non-farm jobs. If the HH head possesses an underprivileged or sick category of health, it may mean he/she might not get employment and thus become less resilient.
Water	Does your family use tube-well water?	Yes = 1, No = 0	Use of unsafe drinking water acts as a source of many diseases.
	Distance the source of safe drinking water?	Within 5 minutes' walk = 1, more than=0	A greater distance from a safe drinking water source will increase vulnerability. HH's agreed that they would walk up to five minutes to collect safe drinking water.
Food	Household food secure or not? (self-ranked)	Yes = 1, No = 0	Current food security status can reduce vulnerability.
	Do you adopt zero-tillage cultivation?	Yes = 1, No = 0	This practice can enhance HHs resilience capacity. Improved agricultural practices can contribute to a reduction in vulnerability.
	Do you adopt new cropping practice?	Yes = 1, No = 0	This practice can increase overall food production and enhance HHs resilience capacity.
	Do you adopt improved management of weeds?	Yes = 1, No = 0	This practice can improve HHs resilience capacity.
	Do you adopt improved management of manure?	Yes = 1, No = 0	This practice can enhance HHs resilience capacity. This is important for the poor farmers in the face of increasing prices for chemical fertilizer.
	Do you adopt IPM?	Yes = 1, No = 0	This practice can improve HH resilience capacity.
	Do you cultivate multiple crops?	Yes = 1, No = 0	Scope and practices of cultivating multiple crops will reduce vulnerability and improve resilience.
	How many months	No. of	Households' ability to

	can you provide food from your family farm?	months	supply food from their own produce will reduce vulnerability and enhance resilience.
	Do you practice homestead gardening?	Yes = 1, No = 0	This is expected to contribute to the increase in HHs food supply and income earnings.
Livelihood strategies	What is your main profession? (Agriculture=1)	If, Agri = 1, Agril + Livestock = 2, Agri+ Petty business = 3, Service = 4	Dependence on agriculture increases vulnerability and reduces resilience.
	Do you receive remittance from family member migrated to cities?	Yes = 1, No = 0	Remittance can help to improve the livelihood and thus resilience.
	Do you practice tree plantation?	Yes = 1, No = 0	Tree planting can contribute to an increase in family income and reduce erosion.
	Do you allow your family women members to work outside the home?	Yes = 1, No = 0	Women members having working opportunities outside of the home can contribute to an increase in household income and enhance resilience.
Social network	Are you a member of any cooperative society?	Yes = 1, No = 0	Involvement in social organizations can reduce vulnerability and improve resilience.
	Have you any saving accounts?	Yes = 1, No = 0	In the face of any disaster HHs are able to rely on this.
	Have you received any training in your profession?	Yes = 1, No = 0	It enables HHS to better manage farming activities and increase production/ income.
	Do you explore and utilize information technology for professional, health and family planning activities?	Yes = 1, No = 0	Access to and use of information technology can contribute to the reduction of the overall vulnerability and improve resilience.
	Do you get cooperation from other village people in case of your	Yes = 1, No = 0	Normally, lower economic households get less help from others. More sources of support can reduce

	need?		vulnerability and enhance resilience.
	Do you allow women in decision-making process	Yes = 1, No = 0	This is important for effective resource planning within households. It can contribute to enhancing resilience.
	Are your family members a member of cooperative society?	Yes = 1, No = 0	It can increases the potentiality of getting assistance and help in case of necessity.

The next crucial issue is to allocate a score to each indicator. Eakin and Bojorquez-Tapia (2008) note that equal weighting makes an implicit judgment about the degree of influence of each indicator and propose a logic-based weighting method as a more objective approach. Vincent (2004, 2007) and Sullivan et al. (2002) suggest expert opinions and stakeholder discussions to determine weighting schemes. In this study, we assigned weight to each contributing indicator rather than any of the dimensions as a whole. This score is based on the knowledge of the local experts and scholars with an emphasis on the inductive approach[16]. The simple arithmetic functions such as weighted mean index and aggregated mean index were used to calculate the scores for indicators and dimension of resilience capacity, respectively (Mazummder & Lu 2015; Habiba et al. 2011). In RCI, each component contributes differently to the overall index, since each component is comprised of a different number of indicators.

First the index value of each indicator was calculated using the equation as follows:

$$Index_{In_a} = \frac{\sum SIn_{a_i}}{n} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (ii)$$

Where, In_a is one of the indicators for an area a, $SIna_i$ represents the total score of each indicator, indexed by *i*, and n indicates the number of observations. After getting an index value of indicators, the next step was to estimate the index value of each component which was calculated using the equation as follows:

$$C_a = \frac{\sum index_{In_{C_i}}}{\sum S_{C_i}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (iii)$$

[16] Please see Goddard and Melville (2004) for further details.

Where, C_a is the index value of one of the components for an area a, $index_{In_{C_i}}$ represents the value of indicators in each component, indexed by i, and S_{C_i} indicates the value of indicators in each component.

Once the index value of each component was calculated, they were then used to calculate the index value of sensitivity and adaptive capacity.

The index value of sensitivity (Sen) was calculated as follows:

$$Sen = \frac{W_{sen1}Health_{+}W_{sen2}Food + W_{sen3}Water}{W_{sen1} + W_{sen2} + W_{sen3}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (iv)$$

Where, $W_{sen1}, W_{sen2} and\ W_{sen3}$ are the weight (one for each) of the components health, food and water, respectively.

The index value of adaptive capacity (AdaCap) was calculated as follows:

$$AdapCapty = \frac{W_{ad1}SD + W_{ad2}LS + W_{ad3}SN}{W_{ad1} + W_{ad2} + W_{ad3}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (v)$$

Where, $W_{ad1}, W_{ad2}\ and\ W_{ad3}$ represent the weight (one for each) of the component of socio-demographic, livelihood strategies and social networks, respectively. Each dimension will attain a maximum value of 1 and minimum of 0.

Then the index value for sensitivity and adaptive capacity are combined to calculate the RCI as follows:

$$RCI = \{Senvity - Adap.capty\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (vi)$$

The higher the value of the RCI, the higher the resilience capacity and vice versa. Some caution needed to be taken in interpreting the results, since the results are expressed in relative terms, rather than absolute, and are assessed at the scale of 1 (most resilient) to 0 (least resilient).

5.5 Results and discussions

In this section, the results are described in different phases. In the first stage, the results of the RCI components along with the indicators contributing to each of the

components are presented in Table 5.2. The spider diagram of major components of RCI is illustrated in Figure 5.2. The results are discussed in the later stage.

5.5.1 Resilience index

The overall RCI of 0.299 for riverine mainland households was found to be significantly higher as compared to the c*har* households (0.204) ($p < 0.04$) (Table 5.2). This indicated that riverine mainland households were relatively more resilient than c*har* households. However, both of them had a low index value that indicated a truncated resilient capacity of the communities to climate change and hazards.

Table 5. 2: Indexed value of components and indicators comprising the resilience capacity index.

Components	Index value of each component		Indicators	Indexed value for each indicator	
	Char household	Riverine mainland household		*Char* household	Riverine mainland household
Socio-demographic profile	0.397	0.503	Dependency ratio?	0.168	0.373[a]**
			Education level?	0.894	1.242[b]***
			Do you adopt any contraceptive method?	0.905	0.941
			Does your family send children to school?	0.873	1.000[a]*
Health issues	0.494	0.823	Does your family use sanitary toilet?	0.913	0.987
			Do you have any family members with chronic illness?	0.863	0.943[a]*
			Access to health facilities?	0.000	0.778[a]***
			Current health condition of the household head?	0.692	1.407[b]**
Water	0.775	0.938	Does your family use tube-well water?	0.963	1.000[a]*
			Distance the source of safe drinking water?	0.586	0.876[a]**
Food	0.230	0.515	Household food	0.412	0.688[a]**

			secure or not?		
			Do you adopt zero-tillage cultivation?	0.681	0.795[a]**
			Do you adopt new cropping practice?	0.342	0.89[a]***
			Do you adopt improved management of weeds?	0.114	0.769[a]**
			Do you adopt improved management of manure?	0.123	0.743[a]**
			Do you adopt IPM?	0.045	0.623[a]**
			Do you cultivate multiple crops?	0.051	0.813[a]**
			How many months can you provide food from your family farm?	2.12	4.513[b]***
			Do you practice homestead gardening?	0.712	0.471[a]*
Livelihood strategies	0.379	0.430	What is your main profession?	1.178	1.663[b]*
			Do you receive remittance from a family member who has migrated to the city?	0.167	0.375[a]**
			Do you practice tree plantation?	0.457	0.492 [a]*
			Do you allow your family women members to work outside home?	0.854	0.482[a]*
Social network	0.111	0.446	Are you a member of any cooperative society?	0.078	0.421[a]***
			Have you any saving accounts?	0.014	0.753[a]**
			Have you received any training in your profession?	0.047	0.218[a]*
			Do you explore and utilize information technology for	0.034	0.337[a]***

			professional, health and family planning activities?		
			Do you get cooperation from other village people in case of your need?	0.274	0.612[a]*
			Do you allow women in decision- making process?	0.114	0.342[a]**
			Are your family members a member of cooperative society?	0.213	0.436[a]**
Overall resilience capacity index:				**0.201**	**0.297****

***p<0.001, **p<0.05 and *p<0.10

[a] Fisher's exact test.

[b] T-statistics for mean difference test.

The study also found quite a large difference in the estimated index value for the components of health, food, and social networks between the study sites. The index values for health, food, water and social network were the highest for mainland households which were 0.823, 0.515, 0.938 and 0.446, respectively as against 0.494, 0.775, 0.230 and 0.111 for c*har* households, respectively (Table 5.2). The highest index values demonstrated relative higher resilience capacity of mainland community in those areas than the c*har* community (Figure 5.2). The index value for the component of socio-demographic and livelihood strategies varied slightly across sites.

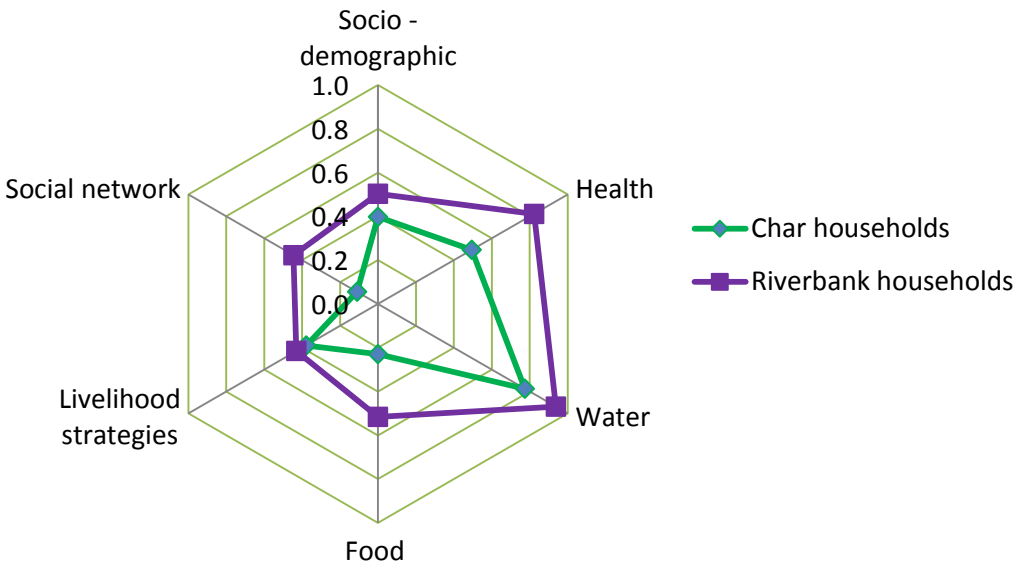

Figure 5. 2: Index value of the major components

A considerable variation was observed between the indicators. For instance, level of education (0.894, as against 1.242), access to health facilities (0, as against 0.778), adoption of new agricultural practices (0.261 as against 0.764), ability to supply food from own production (2.12, as against 4.513), access to familial and kinship networks (0.188 as against 0.499) were low for the c*har* households which contributed to limiting their resilience capacity. The index value for the dimension of sensitivity and adaptation were significantly higher for the mainland households which were 0.499 and 0.759, and 0.296 and 0.460 for mainland households and c*har* households, respectively (Figure 5.3).

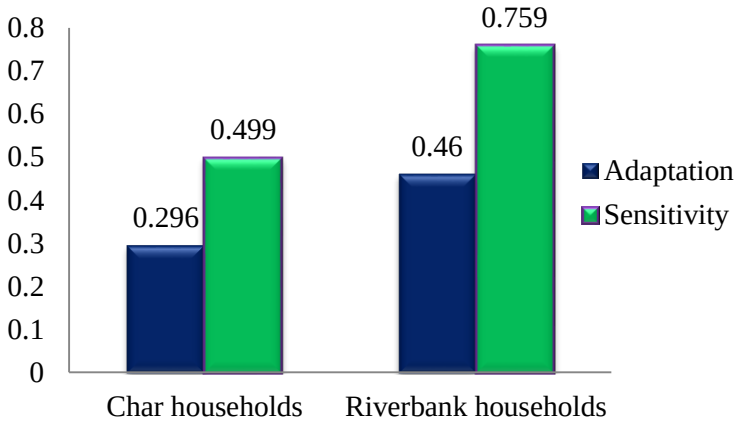

Figure 5. 3: Index dimension of resilience

5.5.2 Discussions

The index values for the underlying components and indicators of RCI analysis provided evidence that limited the resilience capacity of the study households. The variation in RCI indicates that resilience capacity of hazard-prone households vary across locations, both overall and more radically in relation to the particular components and indicators.

Access to health facilities is one of the important limiting factors for resilience capacity of c*har* households. The c*har* area is isolated from the facilities of the riverine mainland. The main form of transport for them is boat which naturally takes more time to reach the health and veterinary centre. Their low income profile and the unavailability of health services are also preventing many households to visiting local doctors. Low income means cutting back their minimum consumption requirements to pay for health care services. Basically they are deprived of many standard government services. They have limited human resources in terms of formal education (below the primary level) and skills which limit their options when seeking employment opportunities in the non-farming sectors. It is reported that human capital development is an important pathway to enhance resilience capacity (Magis 2010; Alam et al. 2004).

There are a lack of primary education facilities in the c*har* areas. Children in this area need to go to the mainland area to access education facilities. The confluence of low level of education and awareness coupled with their traditional belief in recovery from sickness makes c*har* households more vulnerable and reduces their resilience capacity. *Char* households have limited scope to diversify their livelihood activities. The irony of this fact is that most of the c*har* households are dependent on agriculture which is most vulnerable to climate change and hazards and thus limit their resilience. However, some households are found to adopt livestock and poultry rearing, engaging them in small businesses to be more resilient and risk adversity towards natural hazards. Therefore, the enabling role should be ensured by both the government and NGOs. For example, government organizations and NGOs can provide them with livestock support or credit for having livestock since lower income households lack capital. This can serve as an important source of supplementary income.

The low resilience capacity of the communities can also be explained by the limited access to food. The situation is worse for c*har* households than mainland households. The contribution of the 'food' component to reduce resilience capacity for c*har* households is likely for two reasons: they have to struggle more to manage their food and local agricultural production is limited only being able to feed themselves for a few months. The crop cultivation is limited to very few crops due to poor soil condition (sandy soils) and land ownership (small farm size mainly due to erosion). The contribution of livestock to food security is also limited. Furthermore, they experience more natural disasters than other areas resulting in a loss of livestock and poultry. During the rainy season, they used to move to a safer place mainly in nearby embankments or an open place. They then have to sell their livestock at a lower price and in some cases lose their livestock completely due to sickness. Despite the above mentioned limiting factors of resilience, the households in the c*har* area are increasingly adopting resilient activities such as homestead gardening, tree plantation, new cropping practices, and allow women to work outside. Many of them also found to use safe drinking water and a sanitary toilet which might be regarded as a positive move to enhance their resilience capacity.

The low resilience capacity of the households is also due to the existing low level of social networks. Due to poor socio-economic conditions and inadequate road transportation facilities, their social network, the key to social capital, was also found to be limited. Communities which have strong risk-sharing informal networks have proved to be more resilient to idiosyncratic shocks since risks can be transferred across members and time (Tompkins & Adger 2004; Narayan 1997; Moser 1996). Such informal networks typically include women's groups, religious groups and cooperative farming groups which are currently lacking in the study areas. Households in the c*har* areas have inadequate access to financial institutions. The existence of governmental or formal financial institutions including NGO activities is insufficient. Lack of such access can limit the potential to enhance resilience of the underprivileged in a range of ways. For example, this can limit their ability to obtain the resources and technologies they might need for adaptation. After any disaster, households need financial capital to meet their basic needs. Since the c*har* households have limited access to familial and kinship networks to gain capital during hazards, they are forced to borrow money from informal money lenders with

high interest rates. To pay the loan, sometimes they need to sell their economic assets such as livestock which otherwise can provide income support and food. This ultimately contributes to reducing the resilience capacity of households. Islam and Walkerden (2015) also maintained that households' links with NGOs can promote resilience.

The households in the riverine mainland area, on the other hand, have relatively more education level, more opportunities to diversify their livelihood strategies, better access to food, health and safe drinking water, and are quick in adopting new agricultural practices due to their easy access to agricultural extension services. They enjoy easy access to financial institutions owing to the existence and proximity of such service providers, have better use of information technology for various purposes and relatively strong social networks. Altogether these factors allow them to show somewhat more resilient capacity than the c*har* households. However, it is important to mention that all riverine households have experienced loss of some of their land and other natural resources. That reduces their production potential and employment opportunities in farming consequently increasing vulnerability. They were able to supply food from their own production to feed family members only for a few months. They experienced more food insecurity during the months of Ashar to Agrahyon (mid-June to mid-November) (see more on Chapter 6). These months mainly cover the rainy seasons in Bangladesh when opportunities for both farming and non-farming activities are reduced significantly. Due to loss of many market places and inadequate road and transport facilities as a result of erosion hazards, residents are required to travel some distance places to sell their products. Moreover, traders were not able to go to local markets, which reduced their chances of obtaining the right price of products for riverine households.

5.5.3 Limitations

The main challenge in resilient assessments is to develop robust and sound indicators and providing scores for the assessment due to the multidimensional nature and complexity of the concept (Cumming et al., 2005). Which variables should be measured in a given study of resilience is a crucial question. This study attempts to overcome this issue through extensive review of the literature and multilevel consultation with the local experts which expected to yield sound results.

The methodology of this study can be applied to estimating and comparing the resilience capacity of other rural communities due to the flexibility of the method which allows the changes of indicators and provides scores according to the circumstances of a given condition of a region, sector or community. Furthermore, the method used the household level primary data which does not suffer from the limitation of secondary data-driven methods and missing data problems. The assessment can provide potential insights and guidance in the area of impacts, adaptation and societal behaviour. Socio-economic factors are a useful guidance to decision-makers about climate change. In determining the resilience capacity, the role of socio-economic changes such as switching profession to livestock and poultry rearing, tree plantation, cultivation of new crops in the emerging c*har* land, homestead grading, and overseas labour migration are recently boosting in those areas and cannot be overlooked. Indicators representing such changes are incorporated in the index developed in this study. It can provide a better understanding on how to build resilience to adapt to climatic change hazards through the decision-making process. The information will enable policy makers to know where policies need to be directed to build resilience and reduce vulnerability of the households.

5.6 Summary of the chapter

This chapter enhances our understanding of the socio-economic factors affecting the resilience capacity of hazard-prone rural households in Bangladesh, through developing an indicator based index. The RCI is a relative measure and the value ranges between 0-1, where the higher the value the higher the resilience capacity. The assessment method includes several features of the communities such as the socio-demographic profile, livelihood strategies, social networks, and access to food, water and health facilities that helps to identify linkages of social factors and climate change impacts, and accompanying coping and adaptation responses. Although the *char* households show relatively less resilience capacity than riverine mainland households, however, both have a low RCI value indicating their inability to demonstrate resilience. In other words, this underpins the need of strong intervention and supports from both the government and NGOs to cope, and adapt with climate change and hazards. This study identifies that access to food, water, and health

facilities, livelihood strategies and level of education have contributed to limiting the resilience capacity of the households.

The strategies for improving access to food, water and health will contribute to reduce sensitivity whereas strengthening the socio-demographic profile, diversification of livelihood activities and access to social networks will enhance adaptive capacity of the communities. Interventions need to be targeted to promote community capacity development in the area of human capital, social capital and organizational capacity that are likely to contribute to enhancing the resilience of the disadvantaged communities. Moreover, development of communication and transport networks and infrastructure is also vitally important in order to support alternative livelihoods of the households and improve their access to available services. The next chapter discusses household food security conditions due to the impacts of erosion hazard and other climate change issues.

CHAPTER SIX

Policy Options for Improving Access to Food for Vulnerable Rural Households

6.1 Chapter outline

This chapter is linked to research objective two and the results are divided into two sections. In the first part, the key factors that derive vulnerable rural household food insecurity and the pathways in which these affect are discussed. In the second part, households coping strategies and the allocation of intra-households resource distribution are discussed. The rest of the chapter is organised as follows: Section 6.2 provide introduction. Section 5.3 presents methodology including theoretical and empirical model for analysis. Results and discussions are presented in section 6.4. Section 6.5 provides some policy guidelines. In the second part, the impact of riverbank erosion on different sectors is presented in Section 6.6. Technique of developing household food security index is discussed in Section 6.7. The coping strategies of the households are illustrated in Section 6.8. The issue of intra-household food distribution is discussed in Section 6.9. Section 6.10 discusses the vulnerability of households to food security and Section 6.11 contains the conclusions of this chapter.

6.2 Introduction

Food security is still a prime concern in Bangladesh, even though the country has made significant improvements in food production and eradicating poverty over the last 45 years. In regards of poverty reduction, the country also showed marked progress. The rate of poverty decreased from 62% in 1988 to 35% in 2011 (BBS 2012). In contrast, population growth rate reduced from 2.4% in 1970 to 1.47% in 2011 (BBS 2012). In regards of food production particularly rice, the main staple food of Bangladesh, impressive progress has also been made in spite of frequent climatic hazards. Recent statistics showed that the rice production in Bangladesh has increased more than three times: from 16 million tons in 1970 to more than 50

million tons in 2010 (FAO 2012). This gives an indication that the country is close to achieving self-sufficiency in food production.

There remains, however, an argument that self-sufficiency in food production, i.e. availability of food at national level does not essentially assure food security at household or individual level due to unaffordability of large poor households (MacFarquhar 2011; Harrigan 2008; Schmidhuber & Tubiello 2007; Cleaver 1993). To be food secured, households' monetary and nonmonetary resources should be sufficient to get access to adequate quantities of food (Barrett 2010; Schmidhuber & Tubiello 2007). The issue of food insecurity exists largely as a consequence of limited resources, a problem affecting many households globally and in Bangladesh. Therefore, better understanding of household food security dynamics from a resource-poor rural perspective is becoming more crucial in the changing global market economy.

In Bangladesh, growing concern among the policy makers is that certain groups within the country do not have access to food needed for active and healthy life (GoB 2011). This food insecurity due to lack of access has negative consequences on people's health, productivity and well-being which can deepen poverty situation (Harrigan 2008; Chavas et al. 2005). Stiglitz (1976) argued that the likelihood of getting job and efficiency wage rate depend on the job seeker's health condition. Scholars pointed out that less consumption of calories can be a key risk factor in many chorionic diseases of late life (Wichstrom et al. 2013; Telema et al. 2005). Less consumption of calories contributes to increases people's vulnerability to sickness and infectious diseases which resulted in missed out work (Rice et al. 1985). Moreover, important aspect of human development also depends on food security (Hamelin et al. 1999).

In Bangladesh, most of the food security studies have been conducted at national level (For instance, Mishra et al. 2015; Rich et al. 2015; Akter & Basher 2014; Muniruzzaman 2013; Dorosh & Rashid 2013; Ahmed et al. 2012; Alam & Khatun 2012; Alam et al. 2010; Hossain 2010; Faridi & Wadood 2010; Shahabuddin 2010; Ali et al. 2008; Yusuf et al. 2008; Ahmed et al. 2007; Talukder 2005, among many) and household context is relatively unexplored. There is a lack of information on the factors influencing household food security especially for the vulnerable population in the country. This research addresses this limitation using cross-

sectional survey data and provides new insights on the determinants of households' food security and their livelihood status. Furthermore, this study for the first time also explores how household heads' physical health status impacts on rural households' food security. Motivation comes through the field experience that physical health status has influence on access to both farm and non-farm job in the study areas where majority of the people depend on wage earnings and other non-farm activities for their livelihoods. The research questions seek to answer are: (i) what is the livelihood status of the riverine households?; (ii) what are the factors influencing households food insecurity especially the influence of household heads' physical health status? and (iii) what are the policy options to improve food security of these hazards-prone vulnerable rural households in Bangladesh?

Although designing and implementing food policy is a challenge in developing countries like Bangladesh, evidence-based food security analyses are conducive to resource allocation, equity and sustainability of household as well as national level food security. The result will provide an informed basis to identify the factors contributing to food insecurity of particular vulnerable segments of population in the country and thus enable policy makers to formulate various effective intervention plans and policies to reduce geographical disparity of household food security.

6.3 Data analysis method

In Bangladesh, riverine households are among the poorest of the poor and most vulnerable to food insecurity and poverty (IFAD 2013; GoB 2010). Therefore, riverbank erosion affected areas were selected purposively (see Chapter 3 for details). In case of econometric analysis, the study households were not divided based on location since the results of separate analysis of riverbank households and *char* households did not provide significant difference.

Food consumption data was collected at household level through asking about the quantity of different food items (approximately 35 items) consumed over the last three days[17] along with their unit price and sources (home supplied and/or

[17] The accuracy of food consumption data reduces with the length of recall period (Bouis 1994). Hence, we used three day recall method which is common in the literature (Alam 2010; Reddy 1997).

purchased). Several issues were taken into consideration to estimate the available per capita household calories:

- Firstly, food supply at household level was determined by both household supply and purchase. It was converted into calories using the Food Conversion Table of the FAO (Shaheen et al. 2013) to measure the available calories for each household.
- Secondly, available calories were converted into adult equivalent (AU) ratios and the values were then comparable across households of different sizes. Household family members and guest were both excluded and included in AU depending on their availability during the recall period. Household members under the age of six were considered as children and two children were considered as one adult member in this study (Alam et al. 2010; Omotesho et al. 2006).
- Thirdly, 2, 122 kcal per person per day (GoB 2000) were set as desirable and cut off point of calories requirement (demand) to enable an adult to live a healthy and moderate active life (food secure). Finally, the difference between calories available and calories demand by a household was used to determine the food security status of households. If the households' per capita calories were found to be greater than their demand then they were considered food secure and assigned a score 1. On the other hand, those households experiencing a calorie deficit were regarded as food insecure and scored 0.

6.3.1 Empirical model

This study applied calorie intake[18] method to determine the household food security (Rahman et al. 2012; Aromolaran 2010; Bashir et al. 2010; Kazal et al. 2010; Alam et al. 2010; Sindhu et al. 2008). To compute the availability of calories (C_i), the Food Calorie Conversion Table was used. A household is considered to be food secure (C_i*) if the difference between calorie consumption and recommended daily calorie needs (γ_i) is greater than or equal to 0.

[18] It is often used as proxy for all nutritional requirements for health though there may be serious deficiencies in other nutrients required for health (Aromolaran 2010).

C_i*=$C_i - \gamma_i$, where, C_i*≥ 0 indicates that the household is 'food secure' and if C_i*< 0 the household is to be considered 'food insecure'. Assuming a liner function, household food security status can be written as:

$$C_i * = \sum_{j=1}^{n=k} \beta_j X_{ij} + \varepsilon_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(i)}$$

Where, X_{ij} are explanatory variables and ε_i is the error term which is assumed to be uncorrelated with the explanatory variables. The observed variable is food security, where Z_i= 1 when C_i*≥ 0 and Z_i= 0 when C_i*< 0 for ith household. Since the observed dependent variable, Z_i, is binary/discrete in nature, the food security model can be framed as a response model (logit or probit) of qualitative variable, where $\emptyset_i$ is the probability of food security specified as:

$$\emptyset_i = \text{Prob}\ (Z_i = 1) = \text{Prob}\ (\sum_{j=1}^{n=k} \beta_j X_{ij} + \varepsilon_i > 0) \ldots\ldots\ldots\ldots \text{(ii)}$$

Now, the logistic regression can be applied to this model because it directly estimates the probability of an event occurring for more than one independent variable, that is, for k independent variables (Hailu & Nigatu 2007; Fleke et al. 2005; Demaris 1992). The logistic regression model of food security can be written as:

$$Ln\left(\frac{\emptyset_i}{1-\emptyset_i}\right) = \beta_0 + \sum_{j=1}^{n=k} \beta_j X_{ij} + \varepsilon_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(iii)}$$

Where, $\emptyset_i$ is the conditional probability of food security and β_j's are parameters to be estimated and $X_{ij}{}'s$ are the explanatory variables.

In equation (iii), the dependent variable – food security – is in log odds, the results of the logistic regression can be interpreted in terms of conditional probabilities instead of log odds or odds using the formula as:

$$\emptyset_i = \frac{e^{\left(\hat{\beta}_0 + (\Sigma_{j=1}^{n=k} \hat{\beta}_j X_{ij}\right)}}{1 + e^{\left(\hat{\beta}_0 + (\Sigma_{j=1}^{n=k} \hat{\beta}_j X_{ij}\right)}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(iv)}$$

However, the estimated parameters only show the direction of the impact of the explanatory variables on dependent variable and do not provide the extent of change or probabilities. Marginal effects, on the other hand, measure the impact on the probability of observing each of several outcomes rather than the impact on a single conditional mean and are more meaningful and interpretable (Cameron & Trivedi 2009; Long 1997). Therefore, the results of marginal effects are presented in the model after testing the stability and robustness of the results.

6.3.2 Specification of the variables

The selection of variables is based on the review of the literature and field experience. The author assumed household food security to be a function of households' socio-economic and farm characteristics such as household heads' age, gender and educational attainment, size of household, adoption of livestock, and access to market and safety net program. Also included were cultivated land size[19] and access to non-farm income, as a proxy of household income. Due to limited agricultural land a large number of households depend on wage earnings or other non-farm income to maintain their livelihoods. Therefore, the study also included household heads' physical health status in the model as dummy since it has influence on access to farm and non-farm jobs, where good and poor health conditions are coded as 1 and 0, respectively. To provide a score, a few techniques were adopted to minimise self-reported biased since health status is unobserved or latent variable. For example, instead of asking about respondents' health status directly, we asked whether they are fit for farm and non-farm works regularly throughout the year. The answer were then checked with how many days they were absent from the work due to sickness. If it is less than one week[20] then the score is 1 and 0 otherwise. Detailed description of these variables and the summary statistics are presented in Table 6.1.

The specific model for household food security takes the form as follows:

$$Y_i = \beta_0 + \beta_1(HHAg)_i + \beta_2(HHG)_i + \beta_3(HS)_i + \beta_4(HHEd)_i + \beta_5(HLS)_i + \beta_6(HNFI)_i + \beta_7(HLO)_i + \beta_8(ASN)_i + \beta_9(AMkt)_i + \beta_{10}(HHHelth)_i + \varepsilon_i$$

Where, Y_i= Probability of the ith household to become food secure; (Male = 1, Female 0), β_0= Constant, β_{1-10}= Parameters to be estimated, ε_i= Error term, HHAg = Household head age, HHG = Household head gender, HS = Household size, HHEd = Household head education, HLS = Household land size, HNFI = Household non-farm income, HLO = Household livestock ownership, ASN = Access to safety net, AMkt = Access to market, HHhealth = Household head health status.

[19] Many households have large farm size but practically most of the land are in the grip of river and not suitable for cultivation therefore excluded in estimation.

[20] Based on the consultation with local physician one week absent from the work was considered as normal. Diseases such as fever, cough, skin infection and diarrhoea are found common in the area.

Table 6. 1: Summary statistics and description of model variables.

Explanatory variables	Description	Mean	Std.	Expected sign
Age of household head	Years (Continuous)	45.12	14.43	+/-
Gender of household head	Dummy, 1 = male, 0 otherwise	0.95	0.22	+
Education of household head	Years of schooling (Continuous)	3.17	4.63	+
Household size	Number (Continuous)	5.21	3.35	-/+
Cultivated land size	Decimal (Continuous)	0.56	0.88	+
Adoption of livestock	Dummy, = 1 if households have livestock; 0 otherwise	0.84	0.36	+
Access to non-farm income	Dummy, = 1 if households have access; 0 otherwise	0.63	0.31	+
Access to safety net	Dummy, = 1 if households have received; 0 otherwise	0.04	0.20	+
Household head's physical health condition	Dummy, = 1 represent good health and 0 represent poor health	0.57	0.49	+
Household food security	Dummy, 1= secure, 0= insecure)	2048	975	

6.3.3 Econometric consideration

The issues of multicollinearity, heteroskedasticity and the effect of outliers in the variables were taken care of which are the inherent characteristics of cross-sectional survey data. Before proceeding with model estimation, the study tried to identify multicollinearity using the correlation matrix with all the explanatory variables after running an ordinary least square regression. The correlations are found relatively low, below 0.43 in all cases. Typically, correlation coefficients of 0.7 or higher are considered as high (Kennedy 1998). Thus, correlation problems between explanatory variables can be ruled out. In order to explore potential multicollinearity which presence in the model can lead to imprecise parameter estimates (Gujarati 2003), the Variance Inflation Factor (VIF) for each of the explanatory variables were also calculated. The VIFs ranges from 1.17 to 1.71 which does not reach convectional thresholds of 10 or higher used in regression diagnosis (Maddala 1992). The Breusch-Pagan/Cook-Weisberg test confirms that the model has no heteroskedasticity problem (The null hypothesis of homokedasticity is accepted; Chi-square 13, $p>0.131$). The Ramsey-RESET test was also performed in order to test the accuracy of the models. The result rejected the null hypothesis of incorrect functional

form that indicates relevant variables have not been omitted. In order to be sure that household health status is exogenous, Hausman endogenity was employed to verify that error term is uncorrelated with household heads' health status. The test result rejects the null hypothesis that household heads' health status is endogenous (F (1, 23); p> 0.110).

6.4 Results and discussions

The results of the study are presented in two phases: riparian households' livelihood conditions and the econometric results for the determinants of household food security.

6.4.1 Livelihood conditions

Better understanding of the overall livelihood status of the households can provide information about potential policy interventions and thus make an improvement towards household livelihood and food security. The status of households' socio-economic and livelihood conditions are summarized below:

The study revealed that 39% and 55% of households had lost their homestead more than three times and at least once, respectively, during the last 10 years. More than 93% of households had reported to loss of employment opportunities and income from agriculture due to the hazards. Due to loss of many market places and inadequate road and transport facilities, residents go to distance places to sell their products. Moreover, traders were not able to come to local markets which reduces the chance of getting right price of their products.

In case of hygienic issues, more than 21% households were without sanitary latrine facilities whereas 47% had no safe drinking water facilities although many of them have tube-well facilities but with arsenic contamination. The distance of nearest safe drinking water source was more than 1 km. The households were also found deprived from many standard government services. About 46% households were without any electricity facility. In case of health issue around 63% of household heads fall into the category of poor health condition. Poor health condition limits their opportunities to find job in farm and non-farm sectors. Availability of health facilities was also found limited in the study areas. They had to travel a longer

distance (more than 2.5 km) to reach the nearest health and veterinary canters including public hospitals where they are supposed to get free health care.

Moreover, the existence of governmental or formal financial institutions including NGOs activities in the areas were reported to have inadequate. About 69% households reported to have no access to government financial institutions and 64% have no access to NGOs from where they can get credit. This is mainly due to their poor economic conditions where the possibility of getting back the credit is somewhat uncertain. Because riverine households' address are often changed due to change in homestead position as a result of erosion. Moreover, most of the female-headed households (83%) in the study areas are found widowed or divorced[21]. They are vulnerable in all aspects of livelihood characteristics in rural Bangladesh (Mallick & Rafi 2010). Field experience suggest that their opportunities to work in farming and non-farming are limited and still are not well accepted in the society, inferring gender inequalities in the labour market. This contributes to an increase in the vulnerability of female-headed households to food security.

6.4.2 Status of household food security and expenditure

In case of household food security, more than half (56%) of households fall into the food insecure category with an average per capita calorie consumption of 1867 kcal/day which is about 12 percent less than the standard minimum daily requirements. Whereas food secure household exceeded the minimum calorie requirements by 5 percent (2229 kcl/day). This shortfall of 12% substantially understates the energy deficiency of the poor. The standard deviation of the calorie demand variable is fairly high that indicates a wide range of variability across sample.

Furthermore, about 70% of their total expenditure are spent on food items and the rest for non-food items including farming and livestock (15%) and house building and/or repairing (6%) (Table 6.2). Expenditure on health care is the less priority area where they spent less than 2% of their earnings. It is mainly due to their low income and the unavailability of health service facilities in the areas. Their low

[21] This area has one of the highest rural-urban migrations in Bangladesh. Many of the husbands who migrate to major cities as their seasonal coping mechanisms to find job did not return to their families, leading to high rate of divorce.

income prevent them to cut back their minimum consumption requirements to pay for the health care services. After fulfilling consumption demand their target is to invest in farming and house building and/or repairing.

Table 6. 2: Household expenditure.

Expenditure head	Percentage	Food expenditure head	Percentage
Food	70	Rice/ Wheat	78
Farming and livestock	15	Fish and Meat	4
Children education and Clothing	7	Egg and Milk	1
Health care	>2	Pulse, species and oil	11
House building/repairing	6	Vegetables and fruits	6
Total	100	Total	100

The market purchase of the total value of food consumed at home stands at 75%. This indicates the vulnerability of the households on price shocks. It is reported that the lower the share of household expenditure on food, the easier it is for household to cope with price increases and shocks (Economist 2015). In case of food expenditure, the households spent about 78% on rice/wheat, the main source of carbohydrate. Therefore, it is crucial from the policy perspective to keep the price of rice/wheat reasonable so that poor people can afford. Increasing adoption of livestock and poultry by the resource-poor households not only supplement their income but also provide eggs, milk and meat for their consumption.

6.4.3 Econometric results

The results of the regression analysis (logit)[22] are presented in Table 6.3. To test the stability and robustness of the results, four alternative specifications of the model have been estimated. In the first model, core variables are included and subsequently added other relevant variables in models 2 to 4. In model 3, the non-significant variables are dropped which do not increase the coefficients of the remaining variables substantially. Goodness of fit of the models (given by McFadden Pseudo R^2) does not increase substantially from models 1 to 4 and indicates a reasonable explanatory power of the model (Table 6.3). The last specification (model 4) represents all variables and shows the best model fit in terms of the expected sign

[22] STATA 12 was used to estimate the model.

and significance level. The likelihood ratio statistics (Chi-square of 342.137) indicate the strong explanatory power of the model. In other words, it rejects the joint null hypothesis that all coefficients of independent variables in the model are zero ($p<0.00$). The signs and degree of statistical significance of the variables do not change substantially across the different estimates hence the estimated results are stable and robust (follow discussions below):

Educational attainment

This study found as expected a significant positive relationship between household heads' educational attainment and food security (1.134, $p<0.001$). Past result also yielded the same results (Anik 2013; Alam 2010). It is expected that household heads with more education have wider access to non-farm jobs and the capacity to adopt better adaptation strategies in their farming which in turn increase their production and contribute to become food secure. It is reported that household heads' education level is associated with adoption of modern agricultural technology, fertiliser and better agronomic management which is key to offsetting the negative effects of changing climate (Gebrehiwot & van der Veen 2013; Deressa et al. 2009; Lin 1991). The marginal effect of education implies that a one unit (year) increase in participants' level of education will increase the probability of household food security by 1.134 while the effect on the remaining options is negligible. The same interpretation holds true for other variables.

Age of household head

The study found negative association between household head's age and food security (–0.091, $p<0.10$). Similar results were also found in past research (Balagtas et al. 2014; Mannaf & Uddin 2012). It is mainly due to their inability to do relatively hard work in farm and non-farm sector with the increase of age. In the study areas most of the farmers particularly small and landless farmers used to migrate to cities for few months to improve their livelihood. However, this type of migration is less likely for an aged household head which increases their vulnerability.

Table 6. 3: Regression results for the likelihood determinants of food security.

Variables	Maximum likelihood estimates (coefficient)				Marginal effect of model 4	
	Model 1	Model 2	Model 3	Model 4	Coeff.	Std error
Age of household head (years)	-0.217** (0.103)	-0.215** (0.102)	-0.211** (0.098)	-0.213** (0.101)	-0.091*	0.048
Gender of Household head (dummy)		0.101 (1.402)		0.105 (1.027)	0.071	0.874
Household size (AE)	1.316*** (0.470)	1.312*** (0.463)	1.317*** (0.468)	-1.310*** (0.461)	-1.041***	0.379
Education of household head (year)	1.725*** (0.572)	1.723*** (0.570)	1.728*** (0.575)	1.721*** (0.569)	1.134***	0.402
Cultivated land size (decimal)	1.197*** (0.411)		1.216*** (0.407)	1.192*** (0.402)	1.082***	0.371
Access to non-farm income (dummy)	1.151*** (0.413)	1.148*** (0.411)	1.153** (0.415)	1.150*** (0.410)	1.013***	0.375
Livestock ownership (dummy)	-	1.165*** (0.410)	1.167*** (0.413)	1.163*** (0.431)	1.087**	0.513
Access to safety net (dummy)	-	0.139 (0.345)	-	0.102 (0.647)	0.074	0.023
Access to market (dummy)	-	0.023 (0.109)	-	0.016 (0.103)	0.010	0.093
Household head physical health condition (dummy)	1.210*** (0.371)	-	1.237*** (0.376)	1.211*** (0.349)	1.110***	0.391
Constant	10.587***	11.451***	11.461***	11.563***		
Prob > χ^2	0.000	0.000	0.000	0.000	0.000	
Goodness of fit (Pseudo R^2)	0.721	0.727	0.729	0.730		
Log likelihood	-80.129	-81.514	-81.461	81.921		
LR (chi-square)	337.07	341.142	341.512	342.137		
Degrees of freedom	06	08	07	10		
Number of observations	380	380	380	380		

Note: Dependent variable: Food security.

***p<0.001; **p<0.05 and *p<0.10.

Household size

The study found inverse relationship between family size and food security (–1.041, $p<0.001$). This result is consistent with previous findings (Feleke et al. 2005; Bashir et al. 2010). Households with more family members tend to have lower food security. However, households endowed with more earning members are more likely to be food secured. In this study, large family size includes mainly the members who are not able to earn income such as children and aged people. The young people with income sources were often found to be separated from their family. Higher numbers of children were found for the households who had less education and not adopted contraceptive methods. Despite a tremendous progress in reducing population growth in Bangladesh, this finding sought more pragmatic role of family planning activities among this vulnerable communities.

Cultivated land size

Access to land – the most important natural resources – is considered the key determinant of the livelihood strategies of the rural poor. Rural households' income mainly derives from land. Though 32% of households in the study areas are found landless. The study found significant positive relationship between cultivated land size and food security (1.082, $p<0.001$). In Bangladesh, positive relationships between farm size and household food security are well registered (Faridi & Wadood, 2010; Kazal et al. 2010). The important policy intervention is required for the emerging *char* lands which was fallow previously. Scientists need to respond to develop and improve crop varieties and production technologies suitable for the emerging *char* lands in the riverbank erosion affected areas.

Livestock ownership

Furthermore, the study found livestock adoption as a significant positive impact on household food security (1.087, $p<0.05$). The result is in line with the findings of Rahman and Poza (2010), and Amaza et al. (2006). Livestock serves as an important source of supplementing their family income. It is indeed encouraging that households in the areas are switching their profession towards livestock, poultry and duck rearing. However, many farm households were found to use animal power for agricultural purposes including cultivation of land. This indicates their backwardness as well as inability to adopting modern agricultural practices.

Access to non-farm income

Access to non-farm income offers an important pathway to food security. It indicates the income diversification opportunities of households. This study found a significant positive association between non-farm earnings and food security (1.013, $p<0.001$) which supports the previous findings (Murungweni et al. 2014; Reardon 1997). However, all households do not have equal access to non-farm income. It is reported that the poor and uneducated households, and others lacking social ties rarely enjoy the access to remunerative opportunities in non-farm earnings (Barrett et al. 2010). The public services such as education and credit facilities, and communication and transport infrastructure are crucial to participate in non-farm activities which found inadequate in the study areas. Households' limited access to institutional facilities coupled with limited agricultural activities due to land loss serve as substantial barriers to participate in non-farm activities.

Household heads' physical health condition

This study found significant positive impact of household heads' health status on household food security (1.110, $p<0.001$). Marginal effect suggests that household heads' good health would result in an improvement in the likelihood of household food security by 0.822. It is reported elsewhere that households with ill health are more likely to be food insecure (Bernell et al. 2006). The reason behind this is that health status has effects on labour supply and productivity, farm output, and earnings (Fisher & Lewin 2013; Chavas et al. 2005). This issue is curial for the households who are mainly dependent on agriculture as in the case of this study. Poor health prevents households to participate into farm and non-farm jobs. Scholars have pointed out a range of negative health outcomes due to food insecurity including less consumption of calories such as iron deficiency anemia, obesity, poor physical and mental health (Carter et al. 2010; Stuff et al. 2004; Vozoris & Tarasuk 2003; Che & Chen 2001). Therefore, it can be said that if the observed food insecurity situation (less calorie intake) prolonged, the households will lose their productive capacity and thus fall into the victim of food insecurity leading to increased vulnerability of poverty. In other words, it could lead an unfortunate vicious cycle of poverty which starts with food insecurity (low consumption of calories leading to poor health condition leading to poor access to farm and non-farm job leading to poor income leading to poor consumption and finally drop into poverty). This issue will in turn be

the main hurdle to attain long-term food security in the country unless appropriate policy put in place.

It is important to note that previous research, for example, Kazal et al. (2010) indicates the effectiveness of safety net program on household food security. Estimates of this study, however, show positive but insignificant relationship even at 10% level of significance. This statistical insignificance can be attributed due to a few number of households (4%) included in the safety net program. It might have important policy implications for household food security which underpins the coverage of safety net program in the study areas. Contrary to this, Ahmed et al. (2012) argued that access to microfinance is more effective than safety nets in helping poor households to cope with the shocks. Households in the erosion-prone areas, however, reported to have limited access to financial institutions that needs attention.

6.5 The pathways

A broad range of actions are necessary to improve and sustain the food security of these particular vulnerable communities. First, since these resource-poor households have limited access to food due to loss of productive land and subsequent effects on income and other resource endowment, direct food transfer through food aid program is one mechanism to boost access to food in the short-term. The coverage of safety net program in the study areas seems to be inadequate. Therefore, a targeted food policy intervention is yet to be developed for these vulnerable communities. Households headed up by women should get priority since they have fewer opportunities to enter into farm and non-farm jobs which make them more vulnerable to food insecurity. Intervention through income generating activities such as tailoring, handicraft, embroidering where women can be engaged need to be facilitated through proper training.

The findings of this study clearly show that education has a significant impact on household food security. In the riverbank erosion-prone area, many educational institutions have been found eroded coupled with fragile road communication limit their access to education. Targeted programs are sought to boosting primary school enrolments and human capital development in the areas.

Livestock ownership by the resource poor households emerged as one of the important way forward to address household food insecurity. Since the crop production environment in the erosion affected areas is somewhat unfavourable, hence livestock rearing should be encouraged with enabling policy support. For instance, government organisations and NGOs can provide them with livestock support or credit for having livestock since the poor households have lack of capital. This can serve as an important source of supplementary income.

Health status of household heads critically affects household food security which could lead vicious cycle of poverty that underpins important policy implication. It is really a big challenge to the policy makers to improve the health condition of the rural households by ensuring access to food and health care. The consequences, if the farm households become sick mainly due to inadequate calorie intake and a lack of access to health service, will be for them that they develop an inability to perform farm and non-farm jobs which will, in turn, make them vulnerable and they will become a burden to the family and country as well. The question is whether the government will be able to bring all those inactive people into a social safety net program to overcome its food security challenge. The answer should definitely be negative due to the nature of the economy which is characterised as a poor economy (developing country) confronting with various other problems such as natural disasters, climatic change issues, high population growth and poverty. Therefore, access to health services should get top policy priority in parallel to access to food in order to achieve and sustain long-term solutions to the food security challenge in Bangladesh. Providing community health services which are currently not in place, is one option to ensure their access to health service. Poor households are supposed to get free health care from public hospital. Both the government and NGOs can set out mobile health (m-health) service in the study areas along with their microcredit program. It was found that most of the households (more than 89% households) have had mobile phone ownership which raises the opportunities to provide them variety of information related to agriculture and health services easily. For instance, BRAC, the largest NGO in Bangladesh, has introduced the use of smartphones in its ‘Manoshi’ project for improving slum dwellers’ access to maternal and child health program (BRAC 2013).

Poor institutional support including lack of credit, extension services, inadequate marketing facilities, and poor transportation facilities limit vulnerable riverine households' ability to cope with the food insecurity situation. Properly targeted income transfers and credit programs along with infrastructure and human development programs in the riverbank erosion affected areas across the country may have very high payoffs to improving food security and reducing poverty in the long run. The critical issue is to generate income and employment opportunities for these vulnerable rural households in order to ensure their access to food and other basic needs which demand well-targeted policy interventions.

6.6 Sectorial impacts of riverbank erosion on food security

Riverbank erosion has impacted various sectors of the local economy in a varying degrees which are discussed below:

6.6.1 Impacts on various sectors

Based on the empirical findings, discussion with the experts and field observations, this study sketches out (Figure 6.1) that different sectors are affected in varying degrees which together impacting on food security and livelihood of the study households.

The agriculture sector and infrastructure are severely impacted by the erosion hazard. These resulted in a decrease of employment opportunities both in farming and non-farming sectors. Education, health, water and sanitation, and fisheries sectors also experienced moderate impacts. Although the livestock sector is relatively low impacted by erosion, however, it has a great impact on household food security. All these have serious consequences on overall household food security and livelihood (Figure 6.1).

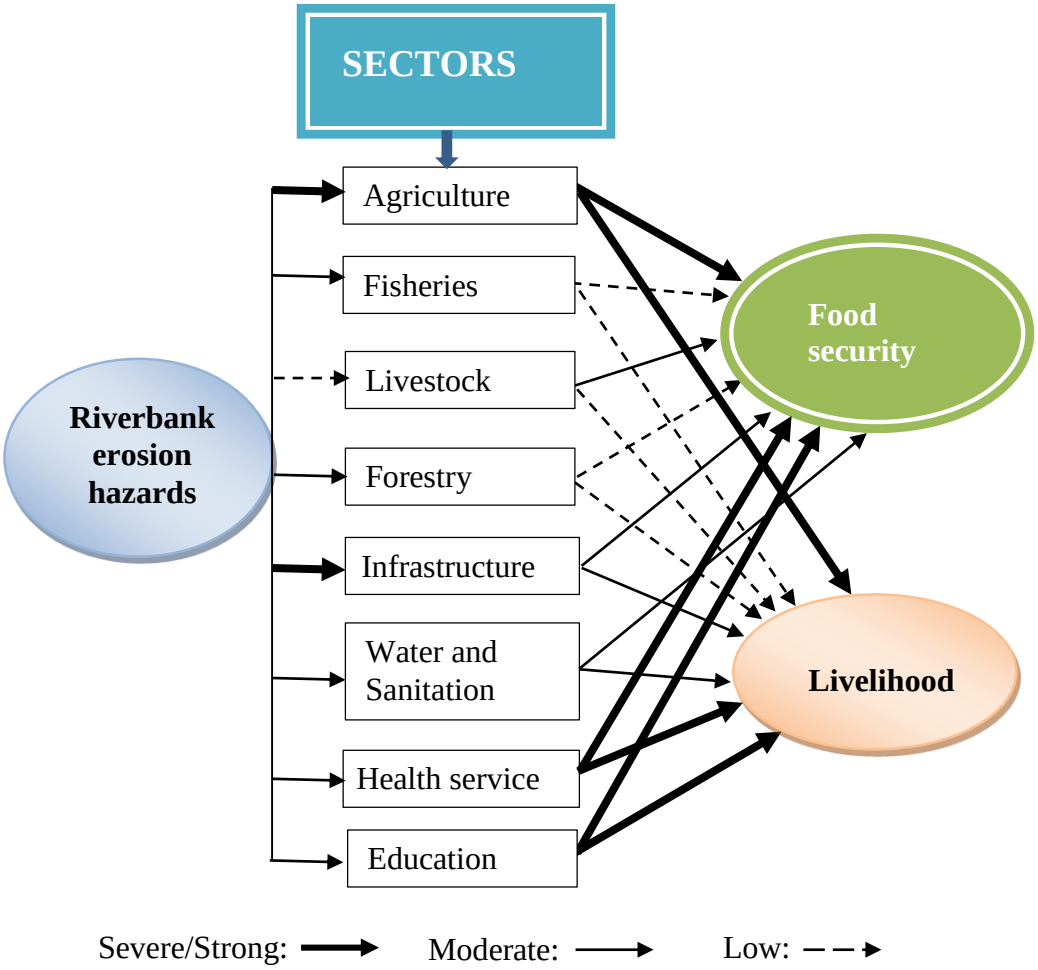

Figure 6. 1: Severity of impacts of riverbank erosion on various sectors

6.6.2 Impacts on farm sizes and household food security

Riverbank erosion and other climate change issues have great impacts on household food security of the riverine households. Since most of the households depend on agriculture for their livelihood so changes in farm size obviously has great impact on household food security. Therefore, a change in farm size is discussed first and then impact on households' food security.

This study revealed that over the years, all households have experienced loss of land that has led to changes in their farming status – these changes in farming status on the basis of land ownership are presented in Table 6.4. Results indicate that out of 39 large farm households, about 21%, 35%, 31% and 13% have become medium, small, marginal and landless farm households, respectively, during the past 10 years. In addition, out of 158 medium farm households, about 34%, 27% and 15% have become small, marginal and landless farm households, respectively. Of 123

small farm households, about 49% and 36% have become marginal and landless farm households, respectively, during the same period (Table 6.4).

Table 6. 4: Changes in farming status due to riverbank erosion.

Land ownership (acres)	No. of households 10 years before (Percentage)	At present (2014)	Percentage change
Large farm (> 7.50)	39 (10)	Medium farm Small farm Marginal farm Landless	21 35 31 13
Medium farm (2.51 to 7.49)	158 (42)	Medium farm Small farm Marginal farm Landless	24 34 27 15
Small farm (1.51 to 2.49)	123 (32)	Small farm Marginal farm Landless	15 49 36
Marginal (0.50 to 1.49)	43 (11)	Marginal farm Landless	26 74
Landless (>0.50)	17 (4)		32

Average land holdings of households are 0.56 acres[23] (small farm size is a common feature in Bangladesh), and about 32% of households are registered as landless in the study areas. Results also indicate that during the past 10 years, another 28% of households have dropped into the category of landless. In terms of land loss, farmers of large and medium sized farms are the worst affected. Farmers of small and marginal plots have also been badly impacted since agriculture is their main source of livelihood. Evidence of this can be found in the low food index value discussed below:

6.7 Household food security index

For better understanding of household food security and formulate need based policy intervention a household food security index is also developed which is discussed below:

[23] Arable land is 0.123 acres/person in Bangladesh (WB 2015).

According to Pinstrup-Anderson (2009) household-level food security can be defined and measured in different ways. A household is considered to be food secure if it has the ability to acquire the food needed by its members; however, it does not necessarily mean that individual members are food or nutritionally secure (Pinstrup-Anderson 2009). In this study, a Food Security Index (FSI) was developed to understand the household food security status throughout the year. This index was based on the Household Food Insecurity Access Scale (HFIAS) – whether all household members are able to take food three times a day (food secure) or not (food insecure) (Chatterjee et al. 2012; Coates et al. 2007). The respondents were asked three Likert scale questions regarding food security status. To develop the index, the scale 'adequate', 'inadequate' and 'scarce' were given scores of 3, 2 and 1, respectively.

'Adequate' indicates households are getting a meal three times a day without any difficulties – they are considered food secure. Households are normally not worried or bothered about taking the required calories recommended for an active and healthy life; rather, the households keep themselves busy and direct all their efforts to fulfilling the food demand of their family members, typically three times a day. 'Inadequate' represents households that take food normally twice a day and sometimes three times. They find it difficult to manage sufficient food for their family members three times a day – it is assumed that the daily total calories they consume are less than their requirements. 'Scarce' represents households that take food less than twice a day. They find it very difficult to fulfil their household food requirements, and it is assumed that the daily total calories they consume are less than their requirements. This measurement of food security will enable policymakers to understand in which months the households experience more food shortage, and thus needs-based policy intervention can be formulated.

The FSI value ranges between 3 and 1, where 3 indicates food secure and 1 least food secure. The overall FSI was estimated to be 2.06, indicating households' inability/hardship to manage family food requirements throughout the year to be regarded as 'food secure'. These households can usually manage food twice per day for their family members. There were, however, large differences in the estimated FSI of various months throughout the year. As seen in Figure 6.2, on average, households experience more food insecurity for the six months from Ashar to

Agrahyon (mid-June to mid-November). These months mainly cover the rainy seasons in Bangladesh when opportunities for both farming and non-farming activities are reduced significantly. It was observed that the study areas also experiences more riverbank erosions during this period.

Moreover, the households experience severe food insecurity during the period from Bhadra (1.83) to Ashwin (1.91) (mid-August to mid-October). The situation starts improving marginally from the month of November when the cultivation of Boro rice starts and, as a result, the scope of employment in farming expands. In the month of Falgun (February–March), households begin harvesting crops that contribute to improving their food security situation further (2.81) (Figure 6.2). Most of the households, on average, are able to manage their family food demands nearly three times a day during that period. During food shortage they practice some coping strategies which are discussed in the next section:

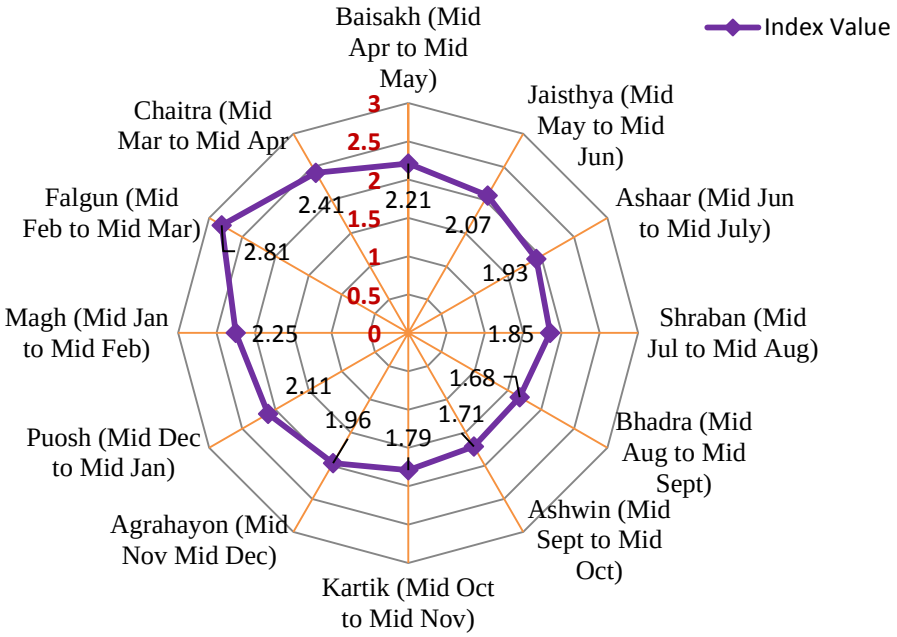

Figure 6. 2: Household food security situation throughout the year

6.8 Coping strategy index

The frequency and severity of coping strategies can be considered as an alternative indicator of food insecurity and vulnerability. According to Berman et al. (2015) coping strategies can shape the availability of future adaptation options. Therefore,

there is a need to identify and analyse coping strategies for the most vulnerable riverine rural households in Bangladesh to mitigate the effects of climate change and hazard shocks and their effects on household nutritional status.

Households in the study areas were able to supply food for their families from their own production only for a few months: on an average 3.2 months. Most of the households depend on the market to purchase their necessities, and this is affected by their income-earning capacities. Households' income earning capacities, on the other hand, become limited at certain times due to lack of employment opportunities. These circumstances trigger them to adopt some sort of coping strategies based on their experience, knowledge and asset position to reduce the food shortage. According to Maxwell et al. (2003) there are mainly two types of coping strategies: one is consumption based which is related to food consumption today or tomorrow, and another is non-consumption which is linked to sale of assets and so on.

For this study, coping strategy questions were constructed through literature review, focus group discussions and pre-testing of the interview schedule. Finally, there were 13 questions related to coping strategy and households used at least one of these strategies. The respondents were asked about the frequency of use of these strategies based on 4–point Likert scale (Likert 1932). The scale was frequently, occasionally, rarely and not use. To rank the household coping strategies a Coping Strategies Index (CSI) was developed. The corresponding value of the scale 'frequently', 'occasionally', 'rarely' and 'not use' were 3, 2, 1 and 0, respectively. The CSI was constructed as follows:

$$CSI = \frac{X_{i\,F_i} + \text{------} + X_{n\,F_n}}{N}$$

Where, Xi = Scale value at the ith priority of the strategy, Fi = Frequency of responses on the strategy, n = Number of strategies in the parameter, N = Number of respondents, i = 1, 2, ---n.

Considering the consequences of these strategies, this study was categories the index value into three groups, namely, consumption base, borrowing and selling. As shown in Table 6.5, the most common coping strategy was to rely upon less expensive or less preferred food (2.36), followed by migration (1.65) and rely on casual labour for food (1.42).

Table 6. 5: Coping strategies to address food shortages.

Sl. No.	Coping strategy	Index value	Category
1	Reduce amount of food per meal	1.31	Consumption based
2	Reduce number of meals per day	0.80	
3	Go bed without food	0.38	
4	Rely upon less expensive or less preferred food	2.36	
5	Reduce buying children food (i.e. milk) from market	1.18	
6	Purchase food on credit	1.40	Borrowing
7	Borrow money from NGOs/GB/money lenders	1.09	
8	Borrow from relatives/friends and neighbours	0.43	
9	Rely on casual labour for food	1.42	Selling
10	Sell labour in advance	0.83	
11	Sell cattle/livestock/land and other assets	1.02	
12	Spend money from deposit	0.70	
13	Migrate to city or other area	1.65	

The consequences of these coping practices are manifold. For instance, reduction in consumption base coping strategies might have long-term negative impacts on their health and wellbeing: they may no longer be able to keep themselves fit and healthy for farm and non-farm jobs and ultimately become a burden on society. Selling assets mainly includes selling livestock and poultry which are important sources of household income, and this can have negative impacts on sustainability of future household food security. However, selling assets is a common practice by the poor farmers in Bangladesh during times of hardship. Paul (1998) also found it to be a coping practice of drought victims in North Bengla, Bangladesh. Borrowing strategies might be conducive to meet up their food demand in short-term. However, it could be detrimental effects of borrowing money from money lenders: they usually charge higher interest rates. This trap sometimes make them compelled to sell their valuable assets such as land with low price to make a payment of loan.

6.9 Intra household food distribution

Although most of the study households had experienced food insecurity situation during a certain period of a year. However, all household members within the family were not equally treated to get access to food. This discrimination was mainly the result of long-practiced culture in the society in Bangladesh. Women in the areas are

usually the last person in the family to eat and they consume the least amount so as to ensure food security for other family members in their household. These people sometimes go for days without food. As a result, they become more vulnerable to malnutrition. In household food distribution, the first priority goes to the male members, in other words, who earn income. Among women, aged women who have no income nor included in the social safety net programs become the last person to get access to food. However, some families where women are educated and have access to income sources are found to get equal access to household food.

6.10 Vulnerability to food security

Loss of land is a recurrent phenomenon in the riverine areas. Therefore, the households who depend on agriculture will be the most vulnerable to food security. Apparently, large and medium farmers are not in vulnerable group due to their land position that enables them to produce to meet up their family consumption. Considering the current trend of erosion, it can infer that all the farm households (large, medium and small) will fall into the vulnerability group within a passage of time due to erosion which is out of their control. They can also loss land for many other socio-economic reasons, but erosion is the main cause. Previous discussion indicates that all households in the study areas have experienced loss of land that has led to changes in their farming status and thus contributes to increase their vulnerability.

Another vulnerable group are the households who have little or no education and possess poor health. These qualifications prevent them to take the opportunity to seasonal migration to improve their food security and livelihoods, since there is lack of employment opportunities. The aged people who are neither able to do work nor included in the safety net programs are another vulnerable group in the society.

The women headed households are also most vulnerable groups. They have relatively limited scope to get employment both farming and non-farming. Many of them do not get any support from their absent husband to maintain their family that pushed them most vulnerable situation.

Scholars argued that the options to improve the household food security were either to create employment opportunities to increase per capita income and/ or

ensure that households have the resources and capacity to produce their own food through farming (Musemwa et al. 2015). However, the latter option is not feasible for many households in the study areas due to recurrent land loss. Therefore, creating employment opportunities is crucial to improve their access to food especially during rainy seasons when there was limited scope of employment both farming and non-farming. Government social safety net program such as food for work, vulnerable group feeding (VGF) might be appropriate options in such a situation.

6.11 Summary of the chapter

The first objective of this chapter was to determine the factors influencing vulnerable rural household food insecurity in Bangladesh. The analysis of survey data of 380 households using logit model has provided a better understanding of the key factors that derive vulnerable rural household food insecurity in Bangladesh. The study reveals that the riverbank erosion-prone areas are poor in a number of areas such as infrastructure, assess to education and health services, access to market and non-farm activities and availability of public utilities like electricity and safe-drinking water which contribute to increase their vulnerability. The study has found several factors serve as a driver of households' food insecurity such as household heads' level of education, household size and cultivated land holdings, livestock ownership and access to non-farm income. Study also found new evidence which suggest that physical health status of household head is a key significant influencing factor for household food security. The rest of the variables are not statistically significant but have the expected sign.

The second objective was to develop a household food security index based on HFIAS. The information is crucial for potential policy interventions and thus make an improvement towards household food security and livelihood. The overall FSI value of 2.06 out of 3 indicating households' inability to manage family food requirements throughout the year to be regarded as 'food secure'. The households experience severe food insecurity during the month of Bhadra (1.83) to Ashwin (1.91) (mid-August to mid-October). Important coping strategies include reduction of food consumption and household expenditure, borrowing money and selling assets. Government interventions such as a safety net program, which presently covers only 4% of households, need to be increased to improve the food gap. Therefore, in the

short-term, a targeted food policy intervention needs to be developed for these vulnerable communities to boost access to food, particularly in the most food insecure months. This empirical evidence enables the policymakers to formulate well-targeted food policies to improve food security and the livelihoods of vulnerable riverine households across Bangladesh. The next chapter discusses the response strategies of the households in the face of changing climate and hazards.

CHAPTER SEVEN

Climate Change Perceptions and Local Adaptation Strategies of Hazard-Prone Households

7.1 Chapter outline

This chapter is linked to research objectives number three. In this chapter, households' perceptions of climate change and variability and their adaptation responses are discussed. The information will enable policy makers to identify local adaptation strategies and to incorporate them in sectoral and other planning activities. The intervention strategies could thus assist the community in adopting effective, logical and sustainable adaptation practices that will enhance their resilience. The chapter is organised as follows: Section 7.2 describes the introduction of the chapter. Section 7.3 presents the literature review. Section 7.4 presents the methodology. The results are illustrated in Section 7.5 and Section 7.6 contains the conclusions of the chapter.

7.2 Introduction

The livelihood of resource-poor rural households in developing countries such as Bangladesh depends largely on agriculture but this is most vulnerable to climate change and variability. The households' capacity to adapt to the compounding influences of climate change, which can affect households' resources and resilience, is uncertain due to poor socio-economic conditions (Wood et al. 2014; Lobell et al. 2008; IPCC 2007; Adger & Vincent 2005). Therefore, adaptation measures are important to help the local communities to cope with extreme weather conditions and associated climatic variations (Niles et al. 2015; Gandure et al. 2013; Rosenzweig et al. 2013; Adger et al. 2003). Adaptation strategies are context specific and change over time from area to area and even within particular societies (Malone 2009; Smit & Wandel 2006). This chapter focuses on perceptions of climate change and local level knowledge of adaptation of the study households: such knowledge is important for enhancing vulnerable households' resilience in the face of hazards and for coping

with climate change and variability. The IPCC has placed local knowledge of adaptation in the centre of discussions to formulate adaptation options (IPCC 2007).

The livelihoods of riparian rural households are severely affected because the erosion increases their vulnerability to food insecurity and reduces their ability to alleviate poverty (IFAD 2013; Huq & Rabbani 2011; GoB 2010; Lein 2010; Hutton & Haque 2004). Scholars have argued that the vulnerability of rural households depends on access to and use of livelihood capital, namely, natural, physical, financial, human and social (DFID 1999; Carney 1998; Chamber & Conway 1992). The linkages between households vulnerability context and livelihood capital enables policy makers to understand of which assets are most affected by the vulnerability context and how better way people can be supported to build up their livelihood assets and become more resilient. Therefore, it is crucial from policy perspective to identify and to understand vulnerability and possible adaptation strategies of marginalised riparian communities, which could mitigate the effects of an adverse climate.

This chapter addressed the following research questions: (i) what are the perceptions of hazard-prone rural households to climate change and climatic variability?; (ii) what are the perceived impacts of riverbank erosion and other climate change issues on the livelihoods of the households; and (iii) what local adaptation strategies can the resource-poor households adopt to enhance their resilience?

7.3 Review of literature

The brief outlines of the existing research on households' perception of climate change and adaptation strategies are summarised here. 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 realise potential opportunities (Wheeler et al. 2013; Smit et al. 2000; IPCC 2001). Climate change affects countries, regions and communities in different ways and thus they differ in terms of their adaptive strategies. The factors responsible for the variation in adaptive responses across regions are the agro-ecological system, socio-economics, climatic impact, and existing infrastructure and capacity (Brulle et al. 2012; Fraser et al. 2011; Adger et al. 2009; Berry et al. 2006). The adaptation process

requires the capacity to learn from previous experience to cope with the current climate, and to apply these lessons to cope with future climate change (Adger et al. 2005b).

Perception and the adoption of adaptation strategies are the two key components of adaptation process (Maddison 2007). Farmers first need to perceive the impact of changes in the climate in order to take appropriate adaptive strategies to mitigate their vulnerability and to enhance the overall resilience of the agro-ecological systems (Arbuckle et al. 2013; Bryan et al. 2009; Reid et al. 2007). Misleading perceptions can induce inappropriate adjustment measures (Taylor et al. 1988). Farmers who perceive the potential consequences of climate change are more likely to support policies that aim to address it (Arbuckle et al. 2013; Niles et al. 2013; Gordon et al. 2013).

Numerous research has indicated that any attempts to elicit adaptive behaviour should come through an understanding of how climate variability is perceived by farmers and what shapes their perception (Weber 2010; Mertz et al. 2009; Slegers 2008; Shisanya & Khayesi 2007; Maddison 2007). Scholars have mentioned that adaptive capacity is influenced by factors such as knowledge of and perception about climate change, assets, and access to appropriate technology, institutions and policies (Brulle et al. 2012; Haden et al. 2012; Hisali 2011; Mertz et al. 2009; IFAD 2008; Adger et al. 2003). The significant link between the perception of climatic variability and the adaptation process has been examined in several countries; for example, in the USA (Arbuckle et al. 2011), Canada (Bryant et al. 2000), Australia (Wheeler et al. 2013), Vietnam (Dang et al. 2014; Schad et al. 2012), India (Vedwan & Rhoades 2001), Malaysia (Alam et al. 2012), Sri Lanka (Esham & Garforth 2013), The Philippines (Predo 2010), Nigeria (Apata et al. 2009), Tanzania (Slegers 2008), Tunisia (Mertz et al. 2009), Ethiopia (Deressa et al. 2011) and South Africa (Gandur et al. 2013).

Studies in Bangladesh in this context are limited. Most adaptation studies are drought focused (see, for example, Alam 2015; Alauddin & Sarker 2014; Sarker et al. 2013; Habiba et al. 2012; Shahid & Behrawan 2009; Ahmed & Chowdhury 2006; FAO 2006). Few studies focus on low lying and saline-prone areas (Rashid et al. 2014; Anik & Khan 2012; Hossain et al. 2012; Rawlani & Sovacool 2011; Ayers & Huq 2008). All these studies provide useful indicators for adaptation policy.

However, these might not be effective and applicable to other hazard-prone communities due to the heterogeneity of the impact of the various hazards and the socio-economic conditions of the households and therefore their responses vary. This is particularly important for the most vulnerable riparian communities who are poorly resourced. There are studies on displacement and the socio-economic impact of riverbank erosion in Bangladesh (see, for example, Ahmed 2015; Lein 2010; Hutton & Haque 2004, 2003; Zaman 1991, 1989; Makenro 2000; Elahi 1989; Rogge & Haque 1987; Greenberg 1986; Hossain 1984). However, there is a lack of in-depth empirical research on how the resource-poor hazard-prone households perceive climate change and variability and how their perceptions are linked to their local adaptive responses. Scholars have argued that local level adaptation knowledge is a key to promoting the resilience of vulnerable communities (Hiwasaki et al. 2014; Alexander et al. 2013; Green & Raygorodetsky 2010; Ellen 2007; Nyong et al. 2007). In terms of policy making, farmers' local knowledge of adaptation strategies will have immense significance if they are supported by relevant government organizations, NGOs and research for the overall sustainability of the adaptation process in the country.

7.4 Data analysis method

Detailed description of the study areas and sampling have been presented in Chapter 3. Here the data collection techniques of perception of climate change and adaptation strategies are discussed.

Perceptions of change in various climatic variables were collected using a 4 point Likert scale (Likert 1932): increase, decrease, remaining same and don't know. In the case of the perceived impact of climate change and of hazards, a respondent's self-elicitation status was considered: the replies to the questions ranged from high to low impact. In the case of adaptation strategies, the respondents were asked about their range of practices. The rainfall and temperature data for the observation station nearest to the study areas was obtained from the Bangladesh Meteorological Department (BMD 2014).

7.4.1 Data analysis

Statistical analyses such as descriptive analysis and a 5-year moving average for the temperature and rainfall data were conducted to compare these with household perceptions about climate change parameters. General linear regression was performed to obtain the mean rainfall and temperature trends. A non-parametric Chi-square test was performed to identify differences between the farming groups when selecting adaptation strategies.

7.5 Results and discussions

7.5.1 Households' perception of climate change and variability

The respondents indicated that they observed changes in the climate and in the extreme events over time (Table 7.1). In the case of the annual mean temperature and rainfall over time, 91% of the respondents believed that the former had increased and 89% believed that the latter had decreased (Figure 7.1). None of the respondents perceived an increase in rainfall and a decrease in temperature. They observed abnormalities in rainfall timing and distribution which has serious consequences for their production plans. These perceptions are consistent with macro-level evidence of climate change and variability in Bangladesh (WB 2013; IWFM 2012).

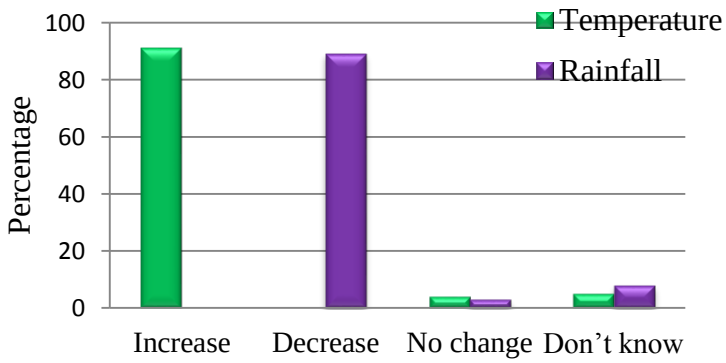

Figure 7. 1: Households' perception of the annual mean temperature and rainfall

As well, 83% and 81% of the household heads suggest that the frequency of flooding and cyclones respectively had increased. A similar response was also observed in regards to droughts – more than 91% of the household heads believed the frequency of droughts had increased. However, only 67% and 87% of household heads reported a decrease in the availability of groundwater and surface water,

respectively. Winter and summer periods were perceived to have increased and decreased by 90% and 93% of households, respectively. Finally, 96% of household heads said that the severity of riverbank erosion had increased (Table 7.1).

Table 7. 1: Perception of climate change parameters.

Climate parameters	Respondents' response			
	Increase (%)	No change (%)	Decrease (%)	Don't know (%)
Drought	91	5	0	4
Availability of groundwater	0	7	67	26
Availability of surface water	0	4	87	9
Severity of riverbank erosion	96	0	0	4
Frequency of flood	83	10	0	7
Frequency of cyclones	81	7	10	2
Winter period	2	2	90	6
Summer period	93	5	0	2

Household perceptions of climate change and variability were also supported by the observed scientific data. An upward trend of annual mean temperature from 1980 to 2014 was found in the study areas (Figure 7.2). The Institute of Water and Flood Management reported an increasing trend in mean temperature during the same period in Bangladesh (IWFM 2012).

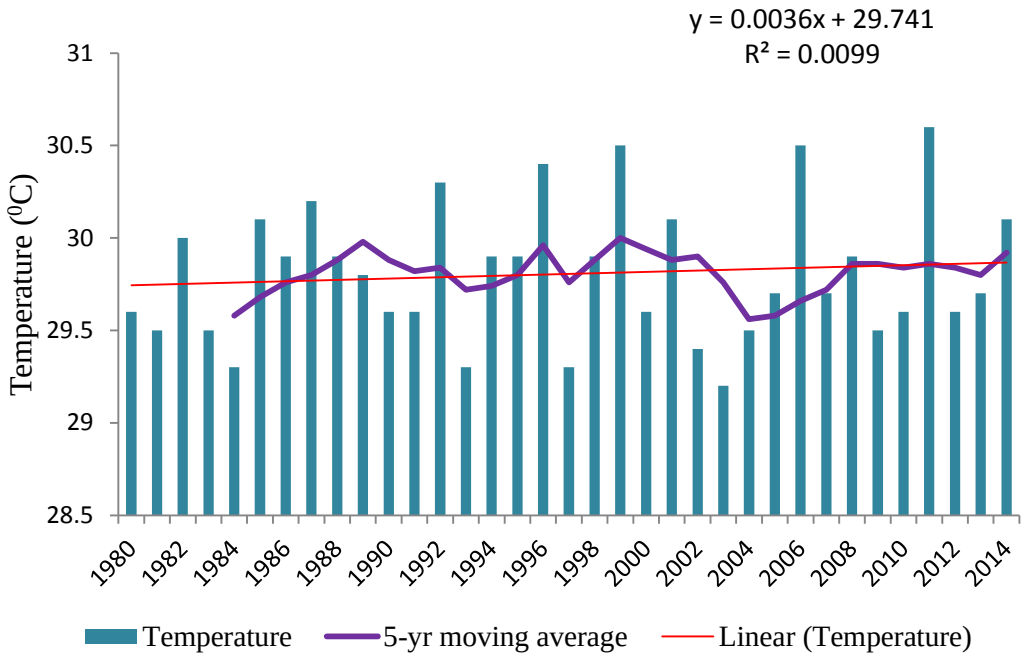

Figure 7. 2: Annual mean temperature in the study area

Mean rainfall data, however, showed a slightly decreasing trend over the same period which is consistent with households' perception (Figure 7.3). IWFM (2012) indicated that rainfall in the pre-monsoon and post-monsoon seasons had increased in Bangladesh, but it decreased in the monsoon season.

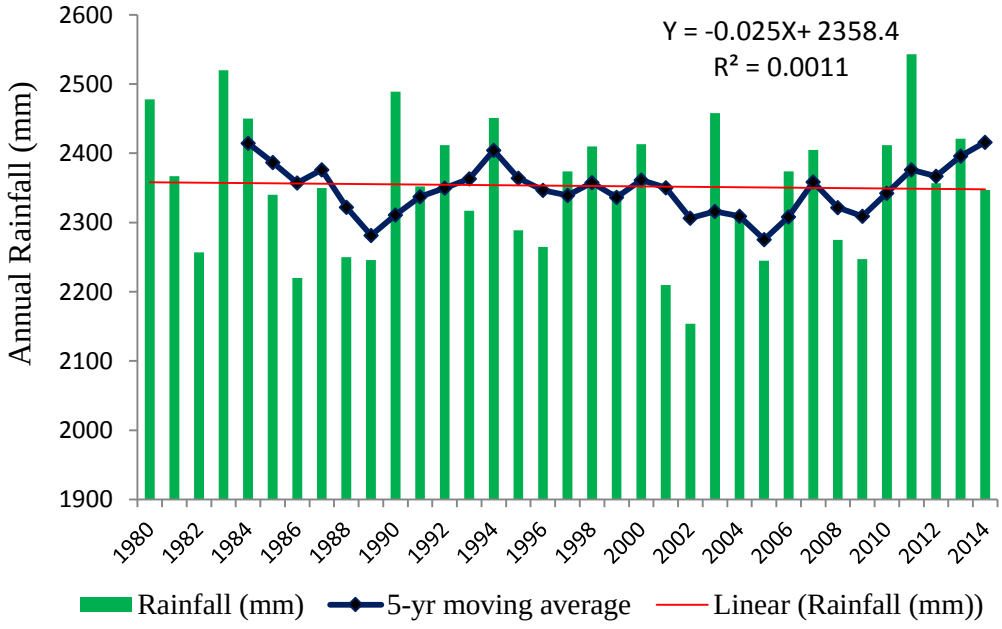

Figure 7. 3: Annual mean rainfall in the study areas

It should be noted that the annual mean temperature and rainfall in Bangladesh are about 26°C and 2540 mm, respectively. The maximum summer temperatures vary between 38°C and 41°C (BBS 2012). The discussion above indicates that households in the study areas are conscious of local climatic changes and variability which ultimately guide them to adopt adaptation strategies in order to minimize the adverse effects of various climatic changes and hazards, including riverbank erosion.

7.5.2 Perceived impacts of climate change and hazards

The perceived impacts of riverbank erosion hazards and other climate change issues are broadly characterized based on the capital assets on which the households' livelihood depend, namely, natural, physical, financial, human and social (Table 7.2). It is, however, important to note that successful adaptation processes to mitigate the adverse effects of climate change and climatic variability depend largely on access to and the judicial use of these capital assets.

Table 7. 2: Perceived impacts of climatic change and hazards.

Types of assets	Impact/risk	Description	Farm category			
			Large (N= 45)	Medium (N= 107)	Small (N= 127)	Landless (N= 101)
Human capital	Food security and malnutrition	Food insecurity and malnutrition increased due to low production and income	x	x	xxx	xxx
	Unemployment	Employment opportunities reduced mainly for the small and landless farmers	-	x	xxx	xxx
	Disease/health condition	Due to food insecurity and limited access to health facilities, small and landless farmers are prone to many sicknesses and possess poor health	x	x	xx	xx
	Migration	Induced seasonal migration to cities and other places due to a lack of employment	-	x	xx	xxx
Social capital	Educational institutions	Many educational institutions have been damaged or eroded	xx	xx	xx	xx
	Religious institutions	Religious institutions damaged	x	x	x	x

	Medical facilities	Access to health services reduced	x	x	xx	xx
	Farmers to farmers co-operation	Limited co-operation among farmers' groups. Small and landless farmers hardly get help from affluent farmers	-	x	xx	xxx
	Organizational involvement	Limited involvement with different organizations	-	x	xx	xxx
Financial capital	Credit facilities	Access to formal and non-formal sources of credit reduced	-	x	xxx	xxx
	Market access	Access to market reduced	xx	xx	xx	xx
	Income from agriculture	Income from agriculture reduced due to loss of land, crops and yield	xxx	xxx	xxx	xxx
	Savings	Reduced the ability of savings	xx	xx	xxx	xxx
Physical capital	Homestead	Loss of homestead property	xx	xx	xx	xxx
	Latrine facility	Deteriorated latrine facilities	-	-	xx	xx
	Transport	Deteriorated transport facilities	xx	xx	xx	xx
	Electricity	Deteriorated electricity facilities	x	x	xx	xxx
	Market place	Loss of market places	x	x	x	x
	Embankment	Damage to embankment	x	x	x	x
Natural capital	Land	Land loss	xxx	xxx	xxx	xxx
	Water	Reduced availability of safe drinking water	x	x	xx	xx
	Livestock	Shortage of fodder and poor animal health	xx	xx	xx	xx
	Fisheries	Reduced pond areas	xx	xx	xx	xx
	Forestry	Loss of trees	xxx	xxx	xx	xx
	Soils	Soil quality deteriorated except emerging '*char* land' where no agriculture was possible previously.	x	x	x	x

Note: xxx = high impact, xx = medium impact, and x = low impact

Agricultural production depends mainly on physical and natural capital, which experienced varying degrees of impact. Households' human capital in terms of education and skills, social capital in terms of access to health facilities, social bonding and organisational involvement, and financial capital in terms of access to NGOs and government financial institutions were found to be affected. This could limit their coping ability and push them further into vulnerable conditions.

The impact on human capital in terms of reduced food security and a decline in employment were registered as high mainly by the small and the landless farmers as these induced them to migrate to cities and other places to improve their livelihoods. Many institutions such as schools and hospitals were found to be eroded.

Residents have to travel a longer distance to reach the school and health centre. Access to education and health facilities is one of the limiting factors of enhancing resilience of households. Therefore, investing in education and health facilities in the study areas should be in top policy priority.

All farming groups perceived a high impact of riverbank erosion and other climate change issues on agriculture which is the main source of their livelihood. To increase their resilience, appropriate adaptation in agriculture is necessary. The most important perceived impacts mentioned by the small and the landless farmers were a loss of land and homestead which increase their vulnerability. They also perceived a high impact in access to credit and market. The organisational involvements by bodies such as NGOs were found to be limited. NGOs are not interested in providing them with credit because many of them had no permanent residence. All farming groups perceived that climate change impacts on crop and yield loss, causes a decline in soil fertility and creates a scarcity of safe drinking water which all affect their livelihood (Table 7.2). However, they consider the new '*char* land' as a blessing for them since the advent of new crop varieties and technology has enabled agricultural activities where such land remained fallow previously.

7.5.3 Households' adaptive responses

The study revealed that, despite the apparent difficulties of riverbank erosion and climate change issues, all the resource-poor households were attempting to sustain and to improve their livelihoods through a range of adaptation strategies. The study identified 15 farming and non-farming adaptation strategies which were practiced by the respondents based on their long-term knowledge and perceptions of climate change (Table 7.3).

Most of the households adopted more than one strategy. Based on the respondents' main choice, the most common adaptation practices are changing plantation time, cultivation of pulses, cultivation of spices and oil seeds, homestead gardening, tree plantation and migration (Table 7.3).

Table 7. 3: Adaptation strategies of the households in the study areas.

Adaptive measure	Responses * (%)	Farm category				Comments
		Large	Medium	Small	Landless	
Agricultural adjustment						
Change planting time	8	x	x	x		ILA
Cultivation of pulses	11	x	x	x		ILA
Cultivation of wheat and other crops	4	x	x	x		ILA
Tree plantation	6	x	x			ILA/PA
Cultivation of spices and oil seed	10	x	x	x	x	ILA/PA
Cultivation of local Aman rice	5	x	x			ILA
Cultivation of vegetables	6	x	x	x	x	ILA
Cultivation of HYV rice varieties (e.g., BRRI-28, 29)	8	x	x	x		ILA
Livestock rearing	7	x	x	x	x	ILA/PA
Poultry rearing	5		x	x	x	ILA/PA
Duck rearing	3			x	x	ILA/PA
Homestead gardening	5			x	x	ILA/PA
Non-agricultural						
Migration	12			x	x	ILA
Off-farm work (van, rickshaw, tempo driving)	7			x	x	ILA
Petty business	3			x	x	ILA

*According to main adaptation strategies although there were multiple options.

ILA = Individual level adaptation based on experience and knowledge.

PA = Individual level and planned adaptation supported by government organizations and NGOs.

Adaptation strategies were, however, shaped by farming category. A Chi-square test was conducted to see whether there were differences between the farming groups in the adaptation strategies adopted. A significant difference was found (χ^2-test, $p<0.003$). In the second stage, we conducted a post-hoc analysis to see the location of the difference. The result indicates that non-agricultural adaptation was practiced mostly by small and landless farm households ($p<0.001$) while agricultural adjustments were practiced mainly by large and medium farms. This indicates that wealthier farmers are in a better position to respond to the challenges posed by climate change and variability through adopting different strategies in agriculture whereas small and landless farmers have few choices. Households received relatively

little technical and financial supports from government organisations and NGOs for some adaptation practices (Table 7.3).

Crop cultivation was found to be diversified in the study areas. In the past, farmers rarely cultivated horticultural and cereal crops, and large parts of their farmland remained fallow in the dry season. Farmers with cultivable land were found to be adopting the HYV rice and wheat varieties as part of their response to the changing climatic conditions. In particular, they were cultivating spices and oil seeds in the newly formed *char* lands which had remained fallow due to the unavailability of crop varieties suitable for such land previously. In responding to the adverse effects of climate change, households were changing the planting times of their crops. Most of the land in the *char* areas and/or near to the river is subject to water logging and flooding during the rainy seasons. But the crops are now cultivated in a way that enables harvesting to be done before a hazard can arise. This adjustment evolved from long-term local knowledge and perceptions about the climate. Vegetable cultivation appeared to be the most common adaptation strategy in the study areas: for example, small and landless farmers cultivated different types of short duration winter and summer vegetables.

The continuous loss of land through riverbank erosion is the main problem for the households. In order to ensure the sustainable use of the available land, households were practicing homestead gardening and tree plantation, particularly the small and landless farmers (Table 7.3). Homestead gardening provides a continuous supply of nutrients in the food chain and can be an important source of income. Both government organisations and NGOs play an enabling role in this regard by providing improved technologies and skills as well as encouraging households to adopt this strategy. However, the small and the landless farmers have limited access to financial institutions and extension services. They were undertaking small businesses such as grocery shops, a tea stall and retail sales that require less capital. Many of them had taken up driving as their occupation in the face of diminishing employment in farming. Government organisations and NGOs can play an enabling role in improving their livelihoods by providing training and financial support in this regard.

Migration, both seasonal and permanent, was also found to be an important adaptation strategy, especially for the small and the landless farmers. Households

with limited agricultural land used to migrate in search of alternative livelihoods for a few months. This temporary migration is very common in the study areas, especially during the rainy seasons when there is limited scope for farming and non-farming employment. However, it is encouraging to find that households are adopting different activities such as livestock, poultry and duck rearing on their land to secure their livelihood by supplementing their income. This local level knowledge of adaptation is crucial for policy makers to support and promote adaptation strategies, and to turn them into effective and sustainable action. Eriksen and Lind (2009) argued that in order to be effective, an adaptation must take place at the local level rather than being a nationally imposed option.

It is not necessary for all of the strategies to relate directly to climate change. For example, the adoption of new crop varieties might be introduced simply as a way to increase production and household income. Besides, there might be other external factors that stimulate adaptation strategies such as scientists responding with new crops and varieties suitable to local conditions like the BRRI-28, BRRI-29 and BRRI-45 rice varieties, and government and NGOs disseminating information to farmers. However, since these resource-poor hazard-prone rural households are responding to climatic events and other opportunities (e.g., cultivation in the *char lands*) by adopting strategies which are based on their local knowledge and experience guided by climate change perceptions, they can be treated as climate change adaptation strategies. Scientists will continue to develop crop varieties, high-value crops and technologies suitable to local conditions, especially in the *char* lands, to accelerate the adaptation process. The Bangladesh Government should strengthen the existing extension network to provide information on successful adaptation strategies and other agricultural services to the grass roots stakeholders through its extension service.

7.5.4 Access to information and adaptation

Access to Information and Communication Technology (ICT) can play a vital role in providing information to the vulnerable households in the study areas where road and transportation communication system is inadequate. It is reported that access to climate information can be effective and contribute to reduce vulnerability of rural livelihoods to climate variability (Troy 2008; Patt et al. 2007; Ziervogel 2004; Patt &

Gwata 2002). Availability of climate information is important as it could contribute to improve management of climate variability and change, and thus, adaptive capacity (Matarira et al. 2012). Scholar argued that information assists farmers in deciding which agricultural technologies and adaptation mechanisms may be most useful in responding to weather variability and change (Ziervogel & Ericksen 2010). Thus, it is important for the policy makers and the development practitioners to understand the kind of ICT that rural households have access to; in order to determine appropriate ways of providing cost-effective information services to rural households.

7.5.5 Access to and uses of ICT by the study households

Exploring access to common ICT equipment by rural households in the study areas involved TV (both colour, and black and white), radio, computer, the Internet and mobile phone (Figure 7.4).

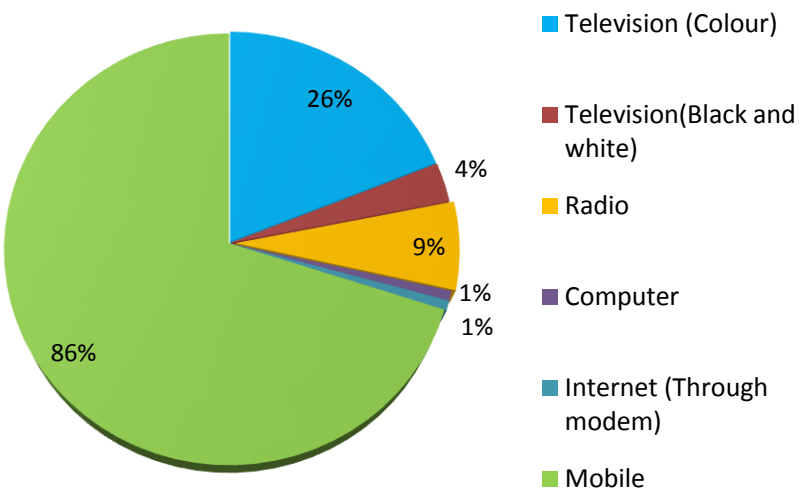

Figure 7. 4: Possession of ICT devices by rural households (multiple options)

Figure 7.4 shows that a mobile phone was the most common ICT device possessed by the rural households (86%). Only 1% of the households had access to a computer with a modem for the Internet access. The study by Ullah (2010) in the coastal areas of Bangladesh found that around 41% of households had access to a radio in 2006: this was used mainly to receive warning and forecasting information. In this study household access to a radio was only 9%, ranking it third of the ICT devices. Most strikingly, the figure shows an extreme inequality of access to ICT

when the mobile phone is excluded. In other words, this represents a digital divide for the rural households. Therefore, mobile phones contribute to reducing the digital gap (between the haves and the have nots) among the study rural households. The results indicate that more than half of the rural households (58%) had more than one mobile phone with about 2% having five or more mobile phones.

The households in the study had less contact with the agriculture extension officers and had less farmer-to-farmer contacts and less involvement with different organizations from which they can receive information and assistance. Hence, they need information and communication sources that can meet their demand for necessary information. Most households in the study areas possessed mobile phones, however, they were not receiving information related to agriculture and rural development through it. This study suggests that mobile phone can be a viable way of disseminating information easily relating to agricultural production, market prices, weather forecasts, climatic hazards and health issues for large rural farm households than other ICT where households have heterogeneous access.

7.6 Summary of the chapter

Despite the recognition of the need for policies and programs to implement and facilitate adaptation strategies, there is still a lack of information about local measures that can reduce households' vulnerability. This chapter has presented local level adaptation strategies in relation to hazard-prone resource-poor rural households' perception of climate change and climatic variability. All of the households perceived changes in the climate and extreme events, particularly abnormal rainfall in terms of timing and distribution which has serious consequences on production plans. Climate data also supported households' perception of climate change and climatic variability. The households perceived the various impacts of erosion hazard and other climate change issues on livelihood capitals, including loss of land, crops and yield, homestead, pond areas, trees, access to education and health facilities, and infrastructure resulting in an increase of livelihood vulnerability. Households respond through adopting farming and non-farming adaptation strategies to build resilience based on their local knowledge, climate change perception and farming status. Significant differences are observed among farm household groups when choosing adaptation strategies: small and landless farm households adopt non-

farming adaptation practices mostly. The important strategies include adopting new crop varieties, changing plantation time, homestead gardening, tree plantation, migration and changing profession to livestock, poultry and duck rearing.

This information will enable policy makers to identify local adaptation strategies and to incorporate them in sectoral and other planning activities. The intervention strategies could thus assist the households in adopting effective, logical and sustainable adaptation practices that will enhance their resilience. The next chapter describes the factors affecting adaptation strategies and the barriers to adaptation of the study households.

CHAPTER EIGHT

Determinants of and Barriers to Adaptation by Resource-Poor Households

8.1 Chapter outline

Farm level adaptation strategies are the key to reducing climate change impacts on agriculture, food production and the vulnerability of rural households. In this chapter, the determinants of and barriers to adaptation of the resource-poor households are illustrated using economic techniques. The information will enable policy makers to identify the factors that influence household adaptation choices so that effective intervention policies can be formulated to enhance their resilience. The reminder of the chapter is organised as follows: after introduction in Section 8.2, a review of relevant empirical evidence is presented in Section 8.3. Section 8.4 presents the brief methodology of the study. The results are discussed in Section 8.5 and Section 8.6 provides a conclusion of this chapter.

8.2 Introduction

Bangladesh is most vulnerable to climate change (WB 2013; IPCC 2007) which poses a major risk to the lives, livelihoods and food security of 64% of the rural population who depend on agriculture (BBS 2012). Scholars have put a high importance on the adaptation to climate change as one policy option for reducing the adverse effects of climate change so as to protect the livelihood and food security of poor farmers (IPCC 2014; Gandure et al. 2013; Wheeler et al. 2013; WB 2013; Lobell et al. 2008; Adger et al. 2005b).

Farmers' adaptation strategies and responses vary, however, between the different agro-ecological contexts and are unevenly distributed depending on socio-economic and institutional factors, climatic impact and infrastructure (Brulle et al. 2012; Adger et al. 2009; Bryan et al. 2009; Deressa et al. 2009; Maddison 2007; Berry et al. 2006). It is suggested that adaptation options need to be assessed at household and community levels in order to meet the development goals of poverty alleviation and food security (Thornton et al. 2010). Adaptation strategies can be

classified in different forms such as planned and autonomous (spontaneous), structural and non-structural, and hard and soft (IPCC 2001). Planned adaptation requires intervention by government and/or regional, national and international organisations to support and/or enhance responses by farmers and organisations (Shaw et al. 2013). Autonomous adaptation actions are those undertaken by the affected people without planned intervention (IPCC 2007; Smit et al. 2001). These generally occur through private agents such as farmer or agricultural organisations (Shaw et al. 2013; Seo 2011). Poor households' autonomous adaptation strategies are often overlooked in international and national efforts to manage the impact of climate change (Christoplos et al. 2009). But these strategies can be influenced by a range of factors and that information is crucial for identifying appropriate options for enhancing adaptation. A lack of successful adaptation will make the households more vulnerable to poverty and food insecurity.

Farmers in Bangladesh have experienced a range of climatic hazards, including riverbank erosion, and have made adaptation decisions. Some argued that adaptation research should focus on the most vulnerable groups or those with the least adaptive capacity (Hulme et al. 2011; IPCC 2007). However, the factors influencing hazard-prone resource-poor households' adaptation strategies and the barriers to adaptation have not been explored so far. These are crucial to formulating and implementing an effective and sustainable adaptation policy in Bangladesh. Moreover, recent literature has indicated that farmers' access to various institutions (Alam 2015; Alauddin & Sarker 2014) and their social capital (i.e., social connection) play crucial roles in their adaptation decisions (Wolf et al. 2010; Deressa et al. 2009). These issues have particular importance for the resource-poor rural riparian communities where the availability of institutional services and social connection among farmers seems to be limited due to the fragile infrastructure and low livelihood status. Action like government intervention is crucial in ensuring sustainability of farm-level autonomous adaptations (Stringer et al. 2009; Maddison 2007; Smit & Pilifosova 2001).

This research using cross-sectional survey data provides new insights on the determinants of the households' choice of adaptation and the barriers to their adaptation. The research questions posed to investigate this are: (i) what are the main adaptation strategies that the resource-poor households adopt?; (ii) what are the

barriers to adaptation?; and (iii) what are the determinants influencing adaptation strategies, especially the influence of institutional access and social capital of resource-poor households in the study areas?

8.3 Review of literature

This section provides a summary of the existing research on climate change adaptation and the factors influencing adaptation. Scholars mentioned that adaptation is one of the key policy options that determine the severity of the impact of climate change on agriculture (Green & Raygorodetsky 2010; Kurukulasuriya & Mendelsohn 2008; Lobell et al. 2008; Brooks et al. 2005; Adger et al. 2003). Understanding the determinants of adaptive capacity is crucial to explaining the local autonomous adaptation process. This knowledge assists policy development by strengthening adaptation through investing in these factors (Yohe & Tol 2002).

Empirical evidence from outside Bangladesh indicates that the most common adaptation strategies are using new crop varieties, diversifying crop varieties, adopting mixed crop and livestock farming systems, changing planting dates, planting trees, irrigation, soil conservation, and switching from farm to non-farm activities (Gebrehiwot & van der Veen 2013; Deressa et al. 2011; Deressa et al. 2009; Molua 2009; Kurukulasuriya & Mendelsohn 2008; Nhemachena & Hassan 2007). The ability and capacity to adapt are influenced by system characteristics (e.g., agro-ecological) that are called the 'determinants of adaptation' (Smit et al. 2000). The determinants of adaptation choices can be broadly categorized as:

- Household and farm characteristics, including household head's age, gender, education, farming experience, household income, farm size and tenure status (Gebrehiwot & van der Veen 2013; Bryan et al. 2013; Deressa et al. 2009; Hassan & Nhemachena 2008).
- Social capital encompassing farmer-to-farmer extension and organizational involvement (Deressa et al. 2009).
- Institutional variables comprising access to climate information, extension services, credit facilities, markets, irrigation, and off-farm employment opportunities (Gebrehiwot & van der Veen 2013; Bryan et al. 2009; Deressa et al. 2009; Kurukulasuriya & Mendelsohn 2008).

Although the impact of climate change and hazards in Bangladesh is not limited to the occurrence of droughts, most of the adaptation strategies are drought focused (see previous Chapter 7). Previous studies have been identified various determinants of adaptation strategies using a multinomial logit model (MNL). For example, Alam (2015) indicated that farmers with more experience of farming, better schooling, and access to electricity and institutional facilities would have an increased likelihood of adopting alternative adaptation strategies in the drought-prone Rajshahi district. Alauddin and Sarker (2014) showed a household head's education level, farm size, access to climate information, electricity for irrigation, agricultural subsidies and severity of drought were significant factors underpinning the farmers' decision to adopt adaptation strategies in drought-prone areas in Bangladesh. Sarker et al. (2013) found that the household head's gender, age, education, household income, farm size, farmer-to-farmer extension, and access to credit, subsidy and electricity were the main determinants of an adaptation strategy in the Rajshahi district.

Empirical results suggest that riverbank erosion has catastrophic impacts on the lives and livelihood of riverine households in Bangladesh (Penning-Rowsell et al. 2013; Lein 2010; Hutton & Haque 2004, 2003; Haque 1997). So far there is no in-depth empirical research on the factors influencing the local adaptation of hazard-prone resource-poor rural households and the barriers to adaptation. Place-based climate adaptation studies have received much theoretical discussion in recent years (Groulx et al. 2014; Fresqe-Baxter & Armitage 2012). Eisenack (2009) argued that local autonomous adaptation is not sufficient to reduce the risk of climate change. The factors that contribute to the adaptive capacity of households could allow government intervention to target the right groups of people and to formulate and implement an effective and sustainable adaptation policy in the country.

8.4 Data analysis method

As procedure of data collection and empirical model are discussed detailed in Chapter 3. Here, only the specifications of the variables are discussed.

8.4.1 Specification of variables

The selection of explanatory variables in this study is based on the review of the literature, the focus group discussions and field experience. The author has assumed household adaptation strategies are a function of a household's socio-economic and farm characteristics such as the age, gender and education of the household head, household income and farm size, access to climate information and other institutions, and social capital.

Some authors have argued that social capital and access to various institutions have crucial roles in enabling households to adjust their management practices (Wood et al. 2014; Deressa et al. 2009; Hassan & Nhemachena 2008; Smit & Wandel 2006). Jordan (2015) argued that social capital can increase a household's resilience and can be used for more forward-looking adaptations. Therefore, indices of social capital and access to various institutional facilities were constructed. The components of the institutional access index are: (i) access to market (input and output), (ii) financial institution for credit, (iii) agricultural extension services, (iv) information on climate and weather conditions, and (v) off-farm employment opportunities. The social capital index includes farmer-to-farmer extension, organisational involvement of the household heads and women members. The respondents replied 'yes' or 'no' to the questions on these components and the score as provided to make the index[24]. The higher the index value the higher the likelihood of the adoption of that particular adaptation strategy.

The specific model for the determinants of adaptation strategies stands as follows:

$$Y_i(DCV, HG, TP, DIS\ and\ Mi) = \beta_0 + \beta_1(\mathrm{HHAg})_i + \beta_2(\mathrm{HHG})_i + \beta_3(\mathrm{HI})_i + \beta_4(\mathrm{HHEd})_i + \beta_5(\mathrm{LF})_i + \beta_6(\mathrm{MF})_i + \beta_7(\mathrm{SF})_i + \beta_8(\mathrm{LL})_i + \beta_9(\mathrm{IAc})_i + \beta_{10}(\mathrm{SCa})_i + \varepsilon_i$$

Where, $Y_i(DCV, HG, TP, DIS\ and\ Mg)$ = Probability of the ith household to adopt the adaptation strategies, β_0= Constant, β_{1-10}= Parameters to be estimated, ε_i= Error term, DCV = Diversifying crops and varieties, HG = Homestead gardening, TP = Tree plantation, DIS = Diversifying income sources, Mg = Migration, HHAg = Household head age, HHG = Household head gender, HI = Household income,

[24] No weighting was used to treat the facilities equally. Weighting can be inherently biased (Wheeler et al. 2013; Hoffmann et al. 2009).

HHEd = Household head education, LF = Large farm, MF = Medium farm, SF = Small farm, LL = Land less, IAc = Access to Institutions, SCa = Social capital. The variables and summary statistics are presented in Table 8.1.

Table 8. 1: Summary statistics.

Explanatory variables	Description	Mean	Std.
Age	Years (continuous)	45.12	14.43
Education	Years of schooling (continuous)	3.17	4.63
Gender	Dummy, 1 = male, 0 = female	0.95	0.22
Average household income	Bangladeshi Taka (continuous)	35000	38456
Large farmer (N = 47)	Dummy, 1 = large farmer, 0 = otherwise)	0.23	0.32
Medium farmer (N = 119)	Dummy, 1 = medium farmer, 0 = otherwise)	0.44	0.33
Small farmer (N = 131)	Dummy, 1 = small farmer, 0 = otherwise)	0.63	0.46
Landless (N = 83)	Dummy, 1 = small farmer, 0 = otherwise)	0.68	0.48
Institutional access index	Continuous	1.36	0.89
Social capital index	Continuous	0.67	0.45

8.4.2 Model diagnosis

The problems of multicollinearity, heteroskedasticity and the effect of outliers in the variables are usually associated with cross-sectional survey data. This study examined collinearity using the correlation matrix with all the explanatory variables. The correlations are found to be relatively low (<0.39) in all cases which is less than the typical range of 0.7 (Kennedy 1998). Thus, correlation problems between explanatory variables can be ruled out. The effects of a possible collinearity between variables were not large. In order to explore the potential multicollinearity in the model, the VIF for each of the explanatory variables were calculated which range from 1.07 to 1.53. This does not reach to the conventional thresholds of 10 or higher used in regression diagnosis (Gujarati 2003). The robust standard errors were used to tackle the problem of heteroskedasticity. The Ramsey-RESET test was also performed to test the accuracy of the models. The result rejected the null hypothesis of incorrect functional form that indicates relevant variables have not been omitted.

Endogeneity can also be a problem as its presence in the model creates bias estimates and limits the ability to make inferences about the characteristics (Wooldridge 2006). However, this issue has so far received relatively little attention in climate change adaptation studies (notable exceptions are Alam 2015; Wheeler et al. 2013; Di Falco et al. 2012). The education variable in the model could be argued to be a potential endogenous variable due to the influences of some external confounding factors, namely the Compulsory Primary Education Policy of the government of Bangladesh (Alam 2015). The endogeneity problem of the education variable in the model is examined by employing an augmented Durbin–Wu–Hausman test. Using the total educated numbers in the family as a proxy for the government policy intervention, the test result rejects the null hypothesis that the education variable is endogenous (F value 1, 1.05; Prob >0.2).

8.5 Results and discussions

8.5.1 Households' main adaptation strategies

The households were found to adopt different strategies based on their long-term knowledge, experience and perceptions in the face of the riverbank erosion hazard and other climate change issues. All of the households responded positively to undertaking adaptation measures to address these adverse effects. Households adopted at least one form of adaptation from the various adaptation options to sustain their farming and livelihood. An initial 15 adaptation strategies were identified through the focus group discussions. However, these failed to generate statistically significant parameters in the logit estimation. Therefore, following Alam (2015), Alauddin and Sarker (2014), Gebrehiwot and van der Ven (2013), and Sarker et al. (2013), the adaptation strategies were reorganized by grouping closely related choices into the same category based on the best practices in the field and expert opinions for the model estimation. Thus, diversifying crops and varieties included the cultivation of pulses, spices and oil seed, and the cultivation of wheat and HYV rice varieties (e.g., BRRI-28, BRRI-29). Adjusting planting time and techniques included the cultivation of Aman and Aus varieties of rice, as well as vegetables. Diversifying income sources included livestock, poultry and duck rearing, small business and off-farm employment. Small and landless farmers were found to adopt seasonal migration, especially during the rainy seasons when there was limited scope of both

farming and non-farming employment to improve their livelihood and food security. Tree plantation was practiced mainly by large and medium farmers who had sufficient land. The adaptation strategies of the households resulted in six main outcomes which are unordered and discrete (Figure 8.1).

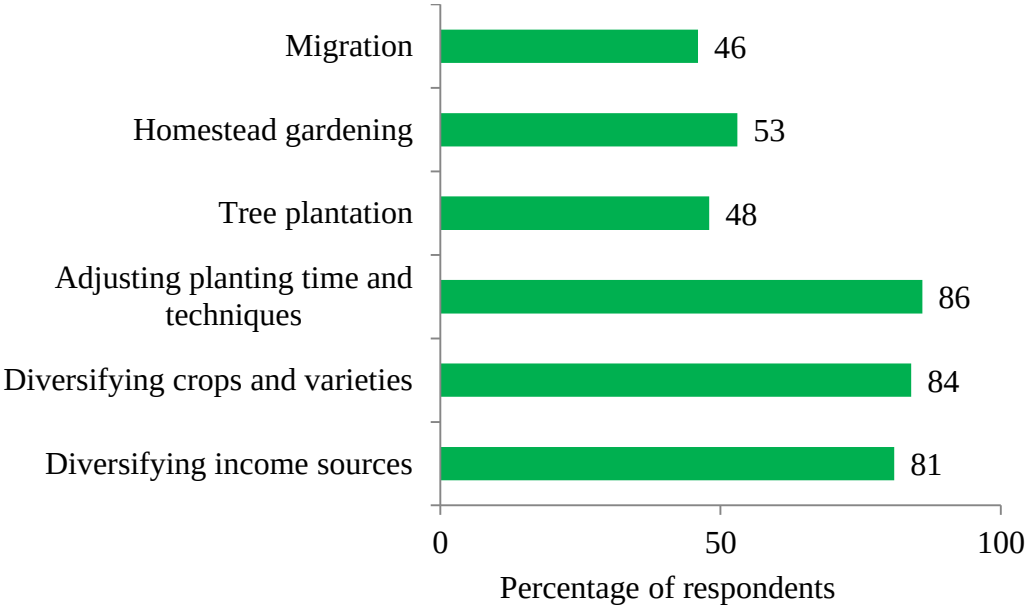

Figure 8. 1: Main adaptation strategies of households

8.5.2 Barriers to adaptation

Although the households were adopting adaptation strategies, they reported some barriers that prevented them from adapting successfully. The main barriers were the lack of information about riverbank erosion and related climate issues, one's own land for cultivation, appropriate crop varieties, knowledge of appropriate adaptation and credit facilities (Table 8.2). Also mentioned were other post-production related problems such as a lack of storage facilities, marketing and transportation facilities which are crucial for policy intervention.

However, the barriers were felt heterogeneously among the farming groups. For example, the main barriers to adaptation for households with relatively less land ownership were the lack of credit, own land and knowledge about appropriate adaptation: the lower average land size among these households was highly significant ($p<0.007$) compared to the households who did not mention these as a main barrier (independent sample t-test). The lack of storage and marketing facilities were mentioned mainly by the large and medium farmers as these might prevent

them from getting the best price for their products (Table 8.2). Connecting the small farmers to supermarkets could be a strategic option for both government and NGOs who are working to improve the livelihoods by enabling them better access to market.

Table 8. 2: Perceived barriers to adaptation measures.

Barriers to adaptation	Response by farm category			
	Large	Medium	Small	Landless
Lack of information about riverbank erosion and related climatic issues	xx	xx	xx	xx
Lack of appropriate variety of crops	xx	xx	xx	–
Lack of knowledge concerning appropriate adaptation strategies	x	x	xx	xx
Lack of credit/money/saving	–	x	xx	xx
Lack of suitable land for cultivation	–	–	xx	xx
Lack of own land	–	–	xx	xx
Lack of storage facilities	xx	xx	–	–
Lack of marketing facilities	xx	xx	xx	–
Lack of transportation facilities	x	x	x	–

Where, xx= main barriers, x = barriers

They also mentioned a lack of knowledge about appropriate adaptation strategies and transport facilities as barriers. A lack of credit is appeared to be the main barrier for small and medium farmers. A lack of institutional access and credit can limit their ability to get the resources and technologies they might need for adaptation. Since the small and landless farmers have resource limitations, access to financial institutions is crucial for them to undertake adaptation.

8.5.3 Econometric results

Table 8.3 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–213.43) indicate the strong explanatory power of the model. In other words, the joint null hypothesis that all variables are jointly significant is accepted. Goodness of fit of the model given by the McFadden pseudo R^2 of 0.29 also indicates reasonable explanatory power of the model (Table 8.3). We also tested the IIA by employing the Hausman test. The test results failed to reject the null hypothesis of IIA at the 5% level (p value of 0.231). This indicates that the estimated model meets the asymptotic assumption of the test. Moreover, most of the explanatory variables in the model and their marginal values were found to be statistically significant with an expected sign (see discussion below).

Level of education

It is expected that household heads with more education are more likely to adopt better adaptation strategies. The study found a significant positive relationship on the adoption of diversifying crops and varieties (0.112, $p<0.05$), homestead gardening (0.019, $p<0.10$), tree plantation (0.123, $p<0.05$) and diversifying income sources (0.034, $p<0.10$). It implies that a one unit (year) increase in a respondent's level of education will increase the probability of adopting diversifying crops and varieties by 0.112 relative to the base category while the effect on the remaining options is negligible. The same interpretation holds true for the other variables. 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 & van der Veen 2013; Deressa et al. 2009) and in Bangladesh (Alam 2015; Alauddin & Sarker 2014).

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 factor on adopting diversifying crops and varieties (0.012, $p<0.10$) and negative factor in adopting a migration decision (–0.105, $p<0.05$). 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. Households with low income and resources tend to migrate for few months to improve their livelihood and

food security. However, temporary migration is less likely for an aged household head (negative impact) as it represents their vulnerability. This finding is consistent with previous adaptation studies (Alam 2015; Hisali et al. 2011; Deressa et al. 2009).

Gender of household head

This study found a significant relationship between adopting the strategies of diversifying crops and varieties (0.002, $p<0.05$) and a migration decision (–0.021, $p<0.05$) for male-headed households. This result is in accordance with the field experience. But the opinion that male-headed households in an African context are more likely to take up climate adaptation strategies is mixed: Deressa et al. (2009) opposed the findings of Nhemachena and Hassan (2007).

Household income

Household income was a significant positive factor in adopting the strategies of diversifying crops and varieties (0.101, $p<0.05$) and tree plantation (0.007, $p<0.10$) and a negative factor in adopting a migration decision (–0.103, $p<0.001$). Modern agriculture is capital intensive: more capital is required when adopting new crops and varieties, agricultural technologies and fertiliser management. This opportunity is somewhat limited for small and marginal farmers unless they get access to credit. Previous studies found a positive relationship between income and adaptation also (Alam 2015; Alauddin & Sarker 2014; Gebrehiwot & van der Veen 2013).

Table 8. 3: Estimated results from MNL model.

Explanatory variables	Adaptation strategies (Dependent variable)									
	Diversifying crops and varieties		Homestead gardening		Tree plantation		Diversifying income sources		Migration	
	Coefficient	Marginal effect	Coefficient	Marginal effect	Coefficient	Marginal effect	Coefficient	Marginal effect	Coefficient	Marginal effect
Constant	–5.31** (2.441)		–3.41* (2.201)		–1.75* (0.905)		–1.23 ** (0.571)		–2.65 * (1.361)	
Age	0.125** (0.051)	0.012* (0.013)	0.141 (0.112)	0.025 (0.017)	0.130* (0.077)	0.019 (0.031)	0.102* (0.052)	0.037 (0.025)	–0.321*** (0.121)	–0.105** (0.047)
Education	0.313** (0.124)	0.112** (0.053)	0.065* (0.037)	0.019* (0.011)	0.071** (0.033)	0.123** (0.061)	0.093** (0.043)	0.034* (0.018)	0.071 (0.032)	0.006 (0.012)
Gender	0.011** (0.004)	0.002** (0.001)	0.017 (0.014)	0.009 (0.021)	0.061 (0.047)	0.015 (0.012)	0.023 (0.013)	0.009 (0.011)	–0.131*** (0.041)	–0.021** (0.01)
Average household income	0.135** (0.061)	0.101** (0.047)	0.023 (0.021)	0.001 (0.000)	0.013* (0.007)	0.007* (0.004)	0.013 (0.006)	0.002 (0.000)	–0.211*** (0. 056)	–0.103*** (0. 031)
Large farmers	1.128*** (0.331)	0.231*** (0.083)	0.017 (0.102)	0.005 (0.014)	0.193** (0.065)	0.074** (0.026)	0.011 (0.104)	0.000 (0.000)	–0.171*** (0.051)	–0.103*** (0.035)
Medium farmers	0.122*** (0.039)	0.101*** (0.029)	0.023 (0.142)	0.007 (0.105)	0.103** (0.035)	0.045** (0.022)	0.027 (0.204)	0.003 (0.093)	–0.112*** (0.036)	–0.073** (0.026)
Small farmers	0.118 (0.103)	0.072 (0.041)	0.191*** (0.061)	0.108** (0.045)	0.076 (0.045)	0.012 (0.014)	0.213*** (0.067)	0.112*** (0.036)	0.172*** (0.054)	0.094** (0.035)
Landless farmers	0.105 (0.076)	0.051 (0.031)	0.115** (0.041)	0.073** (0.025)	0.114 (0.102)	0.065 (0.073)	0.059** (0.021)	0.023** (0.011)	0.237*** (0.067)	0.113*** (0.037)
Institutional access index	0.511*** (0.183)	0.191*** (0.072)	0.130** (0.064)	0.071** (0.034)	0.028** (0.014)	0.011** (0.005)	0.106** (0.045)	0.013** (0.006)	0.014 (0.045)	0.005 (0.012)
Social capital index	0.215*** (0.073)	0.102*** (0.04)	0.251** (0.097)	0.127** (0.055)	0.151 (0.312)	0.016 (0.145)	0.113** (0.051)	0.031* (0.017)	0.153*** (0.053)	0.119*** (0.041)
Log likelihood	–227.12									
Pseudo R^2	0.29									
LR (Chi-square)	213.43 (p<0.02)									

N= 380. ***p<0.001; **p<0.05 and *p<0.10. Adjusting planting time and techniques is used as base category. Robust standard errors are indicated in parentheses.

Farm status

Land ownership plays a key role in the livelihood of most of the rural households and this was expected to be a factor in increasing adaptation in farming. Farmers of large and medium land holdings are relatively well resourced and more likely to adopt strategies earlier than farmers with small plots, and landless farmers. This study found a significant positive relationship in adopting diversifying crops and varieties (0.231, $p<0.001$ and 0.101, $p<0.001$) and tree plantation (0.074, $p<0.05$ and 0.045, $p<0.05$), and a significant negative relationship in the case of a migration decision (–0.103, $p<0.001$ and –0.073, $p<0.05$) for farmers of large and medium land holdings, respectively. It is understandable that households with sufficient land are not likely to migrate. By contrast, farmers of small plots and landless farmers migrate seasonally frequently (0.094, $p>0.001$ and 0.113, $p>0.001$ for small and landless farmers, respectively). They cannot generate enough income to sustain their livelihood mainly due to the lack of employment opportunities in farming. They are more likely to adopt homestead gardening (0.108, $p>0.05$ and 0.073, $p>0.05$ for small and landless farmers, respectively) for the effective and sustainable use of their limited land resources. This strategy provides nutrients in their food chains and is an important source of subsequent income throughout the year. The significant positive relationship between farm size and adaptation are consistent with previous studies (Alauddin & Sarker 2014; Sarker et al. 2013; Deressa et al. 2009).

Institutional access

This study found evidence that suggests a household's access to institutional facilities greatly influences the likelihood of adopting adaptation strategy. The marginal results of the probability of adopting adaptation strategies such as diversifying crops and varieties (0.191), homestead gardening (0.071), tree plantation (0.011) and diversifying income sources (0.013) were found significant at the 5% level. The availability of information can promote adaptation through better management of crops, land, fertilizer and climate variability. Access to credit has been reported to have a significant positive impact on adaptation decisions (Alauddin & Sarker 2014; Bryan et al. 2009; Deressa et al. 2009). Gebrehiwot and van der Veen (2013) mentioned that access to markets can serve as a platform for providing information for farmers. Information on climate change can create awareness among farmers and increase the probability of adopting adaptation strategies (Alam 2015;

Deressa et al. 2009; Maddison 2007). Field experience suggests that farmers with small plots and landless farmers have limited access to institutional facilities, especially in terms of access to credit and extension services, which limits their scope to adopt adaptation strategies. Access to institutional facilities was also mentioned as a main barrier to adaptation by the small and landless farmers (section 8.5.2). Strong government intervention is required to ensure these households' access to institutional facilities.

Social capital

The study results show a highly significant role of social capital on the likelihood of adaptation strategy adoption. Social capital increases the probability of implementing the strategy of diversifying crops and varieties (0.102, $p<0.001$), especially for large and medium farmers. Small and landless farmers benefit through adopting the strategies of migration (0.119, $p<0.001$), homestead gardening (0.127, $p<0.05$) and diversifying income sources (0.031, $p<0.10$). This result is consistent with the findings that the presence of a strong kinship network can increase the adaptive capacity of farmers by providing economic, managerial and psychological help (Smit & Wandel 2006). Deressa et al. (2009) found a highly significant negative relationship between social capital and no adaptation decision. Households have reported that access to farmer-to-farmer extension and government extension services stimulated them to cultivate in the new *'char* land*'* which was fallow in the past. Households which adopted homestead gardening and changing profession towards livestock, poultry and duck rearing reported a positive contribution for adopting such strategies through their involvement in different organizations and NGOs. However, informal social networks typically include women's groups, religious groups and cooperative farming groups which is the key to form social capital is found limited existence in the study areas. This is mainly due to the fragile environment and low livelihood status of the households. Small and landless farmers expressed an opinion that sharing and exchanging information and views with each other helped them to take the seasonal migration decision to improve their livelihood and food security.

8.6 Summary of the chapter

This chapter has highlighted the factors influencing local adaptation strategies and the barriers to adoption by hazard-prone resource-poor households. The MNL model passes the assumptions of the IIA and does not suffer from multicollinearity, heteroskedastacity and endogeneity problems as confirmed by the statistical tests. The study reveals that all of the sample households have responded at least somewhat to the hazards and other climate change issues through adopting a range of adaptation strategies depending on their socio-economic and household characteristics, and access to institutional facilities and social capital. Migration appears to be an important adaptation strategy for small and landless farmers in particular while other important adaptation strategies are diversifying crops and varieties, diversifying income sources, adjusting plantation time and techniques, planting trees and homestead gardening. The important barriers to adopting the adaptation strategies include a lack of information about riverbank erosion and related climatic issues, a lack of knowledge about appropriate strategies, unsuitable crop varieties, the limitations of one's own land and limited access to credit.

Analyses of marginal effects indicate that household characteristics such as household heads' level of education and age, farm status and household income have significant impacts on which adaptation strategies are decided upon. Thus, investment in education and a supply of high yielding crops and varieties suitable to local conditions can be effective options for reducing the adverse impacts of climate change and hazards, and be means to improve their livelihoods. The study also reveals that access to institutional facilities and social capital are the key factors influencing the adoption of adaptation strategies by the households. This underscores the need for strengthening the extension services in the study areas and providing rural households with better information on production techniques, agronomic and land management practices, and climate change issues. Access to financial institutions and the creation of off-farm employment opportunities in riverine rural areas are also crucial to support the households in adapting to climate change at the farm level. Government organisations and NGOs can play a greater role by helping to form social organizations/clubs with the farmers (e.g., an Integrated Pest Management club) or assisting cooperative farms in these poorly resourced

communities so that the adoption of adaptation strategies is likely to contribute to their successful continuation.

Adaptation strategies and intervention policies which are centralised in nature in Bangladesh need to consider local circumstances when developing new crop varieties, high-value crops and technology suitable for the emerging *char* land in order to accelerate the effective and logical autonomous adoption of adaptation processes. This will enhance the resilience of vulnerable households in riparian areas across Bangladesh. The next chapter summarises the findings of the study.

CHAPTER NINE

Conclusions and Recommendations

9.1 Chapter outline

This chapter summarises the whole thesis. After describing the brief background of the research in Section 9.2, the chapter is organised as follows: the main findings of the research as per set objectives are presented in Section 9.3. Relevant policy recommendations based on the findings are presented in Section 9.4. The contribution of this research to the literature is enlightened in Section 9.5. The acknowledgement of the limitations of this research is presented in Section 9.6. Further research directions are provided in Section 9.7 and the Section 9.8 contains the conclusions of the study.

9.2 Introduction

Bangladesh is most vulnerable to climate change due to its low-lying deltaic topography dominated by major rivers, population density, limited land area and poverty. It is situated in the interface of two environments – the Bay of Bengal to the south and the Himalayas to the north. This geographical position makes the country more exposed to the impacts of frequent events of extreme climatic hazards including riverbank erosion. A large part of Bangladesh are subject to recurrent riverbank erosion. This causes significant loss of land and displaces thousands of people annually, and pushes them into vulnerable conditions of food insecurity and poverty. Forecasted climate change impacts may also influence the frequency of flooding which accelerate the erosion.

The most vulnerable communities are those marginalised rural groups who seek to make a living along riverbanks and on sand bars in the shifting channels and sediment-laden tributaries where land is available, albeit, temporarily. People living in these areas have relatively limited capacity to cope with climate-induced shocks and consequently natural disasters are likely to have persistent effects on their lives, livelihoods, health and welfare. The crucial policy agenda of Bangladesh is to identify and to understand vulnerability and possible adaptation strategies,

particularly for marginalised riparian communities which could mitigate the effects of an adverse climate change and hazards and improve food security and livelihood. Until now, no study had systematically addressed this issues. Therefore, this study has assessed the livelihood vulnerability of riverbank erosion and its impact on riparian rural households' food security and their coping and adaptation strategies.

The study uses both primary (cross-sectional survey) and secondary data. For the field survey, the Chauhali upazila of the Sirajgonj district and the Nagarpur Upazila of the Tangail district were selected. Survey data were collected randomly from 380 households using a structured survey questionnaire with face-to-face interviews. Moreover, focus group discussion was also conducted to obtain views on various climatic and socio-economic variables, and these opinions were then used to cross-validate the information obtained from the surveys and the key informant interviews.

9.3 Summary of findings

The study employs a range of standard tools and techniques to analysis the data which are expected to yield sound results. This section briefly narrated the major findings under the set objectives of this study.

9.1.1 Research objective 1

To assess the livelihood vulnerability of the riparian households.

To fulfill the objective, the following research questions are set: (i) what are the main drivers of livelihood vulnerability of riparian households to climatic change and hazards?; (ii) are households isolated from the riverine mainland more vulnerable to climate change than other riparian households?; (iii) does livelihood status serve as a driver of vulnerability?; and (iv) what are the factors influencing their resilience capacity?

Building on the IPCC framework, this study adopts a holistic approach to assessing the livelihood vulnerability of rural riparian households from *char* and riverine mainland communities in Bangladesh. Both communities are affected by the riverbank erosion and other climatic hazards; however, they have different locational

identity with respect to the river and therefore, suffer differently in terms of livelihood vulnerability and have different response strategies. Two key vulnerability assessment approaches – the Livelihood Vulnerability Index (LVI) and Climate Vulnerability Index (CVI) – are customized to incorporate local and indigenous knowledge into the selection of sub-components and indicators. The LVI and CVI values are found to be different between *char* and riverbank communities. The *char* dwellers are the most vulnerable and have less adaptive capacity than riverbank mainland households who have a greater diversity in income sources, comparatively less dependence on agriculture, low dependency ratio and a higher level of education. The main drivers of vulnerability are found to be livelihood strategies and access to food, water and health facilities. However, riparian households were also found to be vulnerable due to their relative inaccessibility and low livelihood status. These coupled with climate impacts on river morphology driving erosion and loss of land with consequent decrease in economic potential, creates a vicious cycle of poverty. The vulnerability theory supports the notion that climate change vulnerability does not exist in isolation from wider socio-economic and bio-physical attributes of the communities.

Resilience theory is also applied in this study which is the function of adaptation capacity and sensitivity components of climate change. For this, an indicator based Resilience Capacity Index (RCI) is developed for better understanding of riparian households' resilience activities from socio-economic perspective which is resulting from their long-term knowledge, experience and practices. This will enable policy makers to ensure more targeted and appropriate climate adaptation policies to mitigate the effects of an adverse climate and hazards in the country. Results reveal that they have adopted a range of resilient activities such as homestead gardening, tree plantation, new cropping practices, allowing women to work outside, using safe drinking water and sanitary toilet which might be regarded as a positive move to enhance their resilience capacity. However, the RCI values in both the locations are low that infer households' inability to keep peace or cope with, and adapt to the increasing impacts of climate change and hazards. Their lower level of education, social networks and access to food, water and health services are the important limiting factors for their resilience capacity.

9.1.2 Research objective 2

To assess the food security status of the respondents.

The following research questions are sought to fulfill the objective: (i) what is the livelihoods status of the riverine households?; (ii) what are the factors influencing households food insecurity?; (iii) which months the households experience more food shortage (the extent of food insecurity)?; (iv) what are their coping strategies to address the food shortage? and (v) what are the policy options to improve food security of these hazards-prone rural households in a sustainable way in Bangladesh?

The determinants of household food security are basically based on the theories of consumer demand and production that is widely known as the Agricultural Household Models. Both calorie intake method and Household Food Insecurity Access Scale are used to determine the household food security. The study indicates that riverine households' lack of access to many basic necessities and services such as food, safe drinking water, education and health results in increased vulnerability to food insecurity. More than half (56%) of the households fall into the food insecure category, with an average per capita calorie consumption of 1,867 kcal/day, which is about 12% less than the standard minimum daily requirement. The standard deviation of the calorie demand variable is fairly high, which indicates a wide range of variability across sample. Study also reveals that about 73% of the households' total expenditure is on food items and less than 2% on health care. The total market purchase value of food consumed at home stands at 75%: this indicates the vulnerability of the households to price shocks. Employing logit model after addressing data related problems including endogeneity, the study has found several factors served as a driver of households' food insecurity such as household heads' education, household size, adoption of livestock and access to non-farm earnings. Study also found new evidence which suggests that physical health status of the household heads is a key significant factor influencing household food security.

To understand the household food security status throughout the year a household Food Security Index (FSI) is developed. The FSI value ranges between 3 and 1, where 3 indicates food secure and 1 least food secure. The overall FSI was estimated to be 2.06, indicating households' hardship to manage family food requirements throughout the year to be regarded as 'food secure'. These households

can usually manage food twice per day for their family members. Households, on an average, experience food insecurity for the six months from Ashar to Agrahyon (mid-June to mid-November). These months mainly cover the rainy seasons in Bangladesh when opportunities for both farming and non-farming activities are reduced significantly. The households experience most food insecurity situation during the month of Bhadra (1.83) to Ashwin (1.91) (August to October). The situation starts improving little bit from the month of November when the cultivation of Boro rice started i.e. scope of employment in the farming started. The households were able to supply food only for a few months to feed family members from their own production: on an average 3.2 months. To reduce the food shortage they adopt some sort of coping strategies. Therefore, a Coping Strategies Index (CSI) was developed to rank the household coping strategies. The most common coping strategies are to rely upon less expensive or less preferred food, reduce number of meals per day and purchase food on credit.

9.1.3 Research objective 3

To identify the response strategies of the vulnerable households in the face of riverbank erosion and other climate change issues.

The findings of this objective are described in two parts. The first part is concerned with the evidence of local knowledge of adaptation in response to perceived changes in the climate and the impact of riverbank erosion and other climate change issues. The second part analyse the factors that influence household adaptation choices using Multinomial Logit (MNL) model and the barriers to adaptation. Despite the recognition of the need for policies and programs to implement and facilitate adaptation strategies, there is a lack of information about local measures that can reduce households' vulnerability. The research questions set to understand the first part are: (i) what are the perceptions of hazard-prone rural households to climate change and hazards?; (ii) what are the perceived impacts of riverbank erosion and other climate change issues on the livelihoods of the households; and (iii) what local adaptation strategies can the resource-poor households adopt to enhance their resilience?

Using descriptive and non-parametric statistical techniques the results indicate that all the households perceived changes in the climate and extreme events, particularly abnormal rainfall in terms of timing and distribution which has serious consequences on their production plans. Climate data also supported households' perception of climate change and climatic variability. The households perceived the various impacts of erosion hazard and other climate change issues on livelihood capitals, including loss of land, crops and yield, homestead, pond areas, trees, access to education and health facilities, and infrastructure resulting in an increase of livelihood vulnerability. Agricultural production depends mainly on physical and natural capital, which experienced varying degrees of impact. Households' human capital in terms of education and skills, social capital in terms of access to health facilities, social bonding and organisational involvement, and financial capital in terms of access to NGOs and government financial institutions are found to be affected. They have to travel a longer distance to reach the school and health centre. Altogether might limit their coping ability and push them further into vulnerable conditions.

Households are found responding through adopting farming and non-farming adaptation strategies to build resilience based on their local knowledge, climate change perception and farming status. Significant differences are observed among farm household groups when choosing adaptation strategies: small and landless farm households adopt non-farming adaptation practices mostly. The important strategies include adopting new crop varieties, changing plantation time, homestead gardening, tree plantation, migration and changing to livestock, poultry and duck rearing.

The second part address the following research question: (iv) what are the barriers to adaptation?; and (v)what are the determinants influencing adaptation strategies, especially the influence of institutional access and social capital of the resource-poor households? The results of the second part indicates that all of the sample households have responded at least somewhat to the hazards and other climate change issues through adopting a range of adaptation strategies depending on their socio-economic and household characteristics, and access to institutional facilities and social capital. The important barriers to adaptation strategies include a lack of information about riverbank erosion and related climatic issues, a lack of knowledge about appropriate strategies, unsuitable crop varieties, the limitations of

one's own land and limited access to credit. Analyses of marginal effects indicate that household characteristics such as household heads' level of education and age, farm status and household income have a significant impact on which adaptation strategies are decided upon. The study also reveals that access to institutional facilities and social capital are the key factors influencing the adoption of adaptation strategies by the households.

9.4 Policy implications

The finding of this study has several policy implications. Based on the results, the following specific recommendations are made. Both the government and NGOs should strengthen their activities in different capacities to improving household food security and to reduce vulnerabilities in the areas.

9.4.1 Public sector role

- To ensure access to food, a targeted food policy intervention is yet to be developed for these vulnerable communities. In short-term, direct food transfer through food aid program can boost access to food, since these resource-poor households have limited access to food. The coverage of safety net program in the study areas seems to be inadequate which need to be expanded significantly.
- Development of improved communication, transportation and access to markets and services also vitally important to support existing and alternative livelihoods for individuals and households.
- Interventions need to be targeted to promote community's capacity development in the area of human capital, social capital and organisational capacity that are likely to contribute to enhance resilience of the disadvantaged communities.
- Targeted programs are sought to boosting primary school enrolment and other skills development program in the areas. Many educational institutions have been found eroded coupled with fragile road communication which limit their access to education.
- More investment in agricultural research and development is required. Scientists need to continue to develop crop varieties, high-value crops and technologies

suitable to local conditions, especially in the emerging *char* lands, to accelerate the adaptation process.

- Existence of government financial institutions are limited in the study areas. Therefore, poor farmers' access to credit should be ensured. This will enable them to obtain the resources and technologies they might need for adaptation.
- Adaptation strategies and intervention policies which are centralised in nature in Bangladesh need to consider local circumstances when developing new crop varieties, high-value crops and technology in order to accelerate the effective and logical autonomous adoption of adaptation processes. This will enhance the resilience of vulnerable households in riparian areas across Bangladesh.
- In the long run, the construction of river embankments and the protection, and further planting of riparian forests would help to reduce bank erosion. Therefore, government investment is required which often hardly possible for the government due to the magnitude of the cost. The homeless households can be relocated in the *khas* land and providing them with the facilities of house, school, hospital and other basic facilities to build long-term adaptive capacity.

9.4.2 Role of private sector and NGOs

- Activities of NGOs should be strengthen which seem to be inadequate in the study areas. They need to be extended their credit programs significantly so that poor farmers' access to credit is ensured.
- NGOs also need to expand their safety net programs in the areas. NGOs should spread their education program in the remote *char* areas. Both the NGOs and private sector can launch various training programs to improve their skills to be fit for the non-farm sectors.
- They should come forward to disseminate various information including successful adaptation among farmers and stimulates them to adopt with appropriate support such as credit and technical support.

9.4.3 Community involvement

Strengthening capacity of local institutions and communities in the riverine areas is vitally important to cope with the present and future climatic hazards. Access to resources, awareness raising, sharing knowledge and skills, access to information, and local planning process can ensure greater community participation which will ultimately contribute to raise the capacity of autonomous adaptation of the poor farmers.

9.4.4 Public-Private-NGOs partnership

Coordination between the government's various sectors and other stakeholders including NGOs is required in order to make the efforts effective to reduce vulnerabilities. Public-private-NGOs partnerships can play vital role to improve their livelihood in the following areas:

- Health status of household head critically affects household food security which call attention for important policy implication. Household members with poor health, mainly due to inadequate calorie intake and unavailability of health services, will be incapable to perform farm and non-farm jobs which in turn make them vulnerable and burden to the family and country as well. This demand for policy priority of access to health services in parallel with access to food in order to achieve and sustain long-term food security in Bangladesh. Provision of adequate community health services, which are currently lacking, is one option to ensure households' access to health care: poor households are actually supposed to get free health care from the public hospital. Both the government and NGOs could set up mobile health (m-health) services in the areas along with their microcredit programs. Since most of the households have mobile phone, which enhances the opportunity to provide them with a variety of information related to agriculture and health services. Hospital can be built in the areas through public-private partnership where option for poor people to get access to health service free and/ or stumpy cost should be in place.
- Livestock adoption by the resource poor households emerged as one of the important way forward to address household food insecurity. Therefore, livestock rearing should be encouraged with enabling policy support. For example, government organizations and NGOs could provide households with

livestock support or credit for having livestock, as the poor households suffer from a lack of capital.

- Since the households are deprived of getting right price of their products due to the lack of storage and marketing facilities in the areas. Therefore, making storage facilities available in the areas is one of the important policy tasks where private sectors can play a vital role. They can come forward to establish storage facilities through public private partnership. Connecting small farmers to supermarkets, on the other hand, might ensure right price of their products. Both private sector and NGOs who are working to improve the livelihoods by enabling them better access to market should be considered this option.
- Lack of institutional access and social capital underpins the need for strengthening the extension services in the study areas and providing rural households with better information on production techniques, agronomic and land management practices, and climate change issues. Government organisations and NGOs can play a greater role by helping to form social organisations/clubs with the farmers (e.g., an Integrated Pest Management club) or assisting cooperative farms in these poorly resourced communities so that the adoption of adaptation strategies is likely to contribute to their successful continuation.

9.5 Contribution

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

9.5.1 Contributions to the knowledge

The primary specific contribution of this thesis is that for the first time it generated detailed insights from the vulnerability and resilience analyses of most vulnerable riparian households in Bangladesh. The policy implication of this is that policy makers will be enable to formulate targeted social, economic and environmental policies to overcome the increasing climate change vulnerabilities to improve food security and livelihood of these marginalised communities.

This study has provided a better understanding of the key factors that derive household food insecurity and the pathways in which these factors affect vulnerable

groups and households in Bangladesh. This study also explores the new dimension of how household heads' physical health status impacts on rural households' food security and found a significant impact. Policy implication of this is that health care facilities also need policy support in parallel with improved access to food to achieve and sustain long-term food security in Bangladesh. The development of food security index will contribute to understand the most food deficit months the households' experience and thus need-based policy interventions can be formulated.

This study has provided local level knowledge of adaptation which is important for enhancing vulnerable households' resilience in the face of hazards and for coping with climate change and variability. This study also explores the influence of new dimension of social capital and access to institutional facilities in adapting adaptation strategies at the farm level. This information is crucial as a way forward to support and sustain local adaptation process of these vulnerable resource-poor households.

9.5.2 Methodological contribution

The methodological contribution is that this study develops an index for assessing resilience, household food security and coping strategy. This study also modified the livelihood vulnerability index in the context of hazard-prone households. It is expected that these methods can be used in other sectors, regions or rural communities in the world for assessing and comparing vulnerability, resilience and household food security due to the flexibility of the methods. The methods allow to change or replace indicators or sub-components as per the local conditions. Furthermore, the methodologies are free from the limitations of secondary data-driven methods and missing data problems. On the other hand, indicators or sub-components index values might be very handy in assessing the impact of a policy or a program by substituting the value of indicators which is likely to change and re-estimating the overall vulnerability and resilience. Similarly, future vulnerability and resilience under some policy or program interventions could be calculated in order to see whether the planned activities contribute to reduce the vulnerability and enhance the resilience. The conceptual framework developed in this study can be used in future hazard, food security and adaptation research for Bangladesh in particular and other hazards-prone rural communities in general.

9.5.3 Contribution to the theory

The contribution in theory is that this study has adapted the theory of consumer demand and production that is widely known as the Agricultural Household Models, the theory of random utility and the theory of vulnerability to a new and important setting. This study has validated the wider application of these theories in the context of individual household responses to riverbank erosion hazard and other climate change issues and adaptation.

9.6 Limitations of the study

Although, the data of this study is reliable and representative to understand the livelihood vulnerability and food security of the riverine households. However, the results should be judged in light with the *caveat* that it is based on specific areas: relatively closest to the capital of Bangladesh which enables the households to take the opportunities of seasonal migration to the cities. Involving more areas (e.g., Padma and Meghna riverbank erosion-prone areas) would have contributed to a better understanding of their vulnerability, food insecurity and response strategies and thus strong generalization of the results. This is, however, impractical for an individual researcher due to time and funding constraints (Blaikie 2010; Gilbert 2008). Noteworthy, rural households in Bangladesh virtually face analogous socio-economic, environmental and climate conditions (i.e., low educational attainment and income, relatively high birth rate and high dependence on agriculture for livelihoods) which validates the use of a small sample size that can be typical of the whole population.

Another limitation is that one can argue that the indicators used for assessing vulnerability and resilience are not representative enough. This study overcome this issue through extensive review of the literature and multilevel consultation with the experts which expected to yield sound results.

9.7 Future research directions

This research focuses on the most severe riverbank erosion-prone areas in Bangladesh. However, the literature indicates that vulnerability is context specific, and different sectors and communities are impacted unequally due to climate change

and hazards. This warrants area and sector specific research to generate a more complete picture of the impacts of climate change and hazards and their response strategies. Therefore, future research can be undertaken in the drought, flood, cyclone and salinity affected areas of Bangladesh. This then may provide an avenue for policy makers to devise area specific adaptation policies which will have potential to address the adverse effects of climate change and hazards more effectively.

Seasonal migration is a common features in the riverine areas. This issue can be investigated more in-depth for understanding the linkages of migration and riverine households' food security.

Household's hazards responses differ as per the location, time and magnitude. Therefore, more research needs to be conducted in other riverbank erosion-prone areas to better understand their resilience activities and provide support to turn them into actions.

Further research can investigate farmers' adjustment in cropping patterns based on environmental and climate variability, and livelihood strategies to better understand of their response strategies. The perceived changes and possible impacts of climate change and hazards to the riverine households need to be monitored scientifically over time.

Successful adaptation strategies of these households can help to better adapt with higher degree of climate change whereas others can be maladaptive. Therefore, the effectiveness of local adaptation strategies of vulnerable riverine households to climate change and hazards needs to be scientifically tested and prioritized.

9.8 Conclusions of the study

This study has comprehensively examined challenging issues facing rural households in Bangladesh in the form of rising water levels, land erosion near the riverbanks, and the subsequent loss of arable land. This in turn has pushed these households into food insecurity and together, these factors are major obstacles to economic and social progress in the nation of Bangladesh. Moreover, this study did field research to seek answers directly from the households themselves about the extent to which this crisis

is affecting them, the extent of their food insecurity, and the nature of any adaptation strategies that they may have deployed to offset these challenges.

In bringing together this analysis, the researcher has produced credible findings employing standard tools and techniques for comprehensive understanding of the livelihood vulnerability and food security status of the riverbank erosion hazard-prone rural households in Bangladesh. It has been found that a lack of institutional support including lack of credit, extension services, inadequate marketing facilities, and poor transportation and communication facilities in combination with the effect of land loss, limit their ability to cope with the food insecurity situation and thereby increases the level of their vulnerability. Properly targeted income transfers and credit programs along with infrastructure and human development programs in the riverbank erosion affected areas across the country may have significant positive impact to improve food security and reduce poverty in the long run. What is urgently needed in Bangladesh to circumvent this slow spiral into poverty and hunger is to generate income and employment opportunities for the rural poor people in order to ensure their access to food and other basic needs. Without offsetting hunger and poverty, Bangladesh's capacity for economic and social development will remain stymied.

It is therefore recommended that new policy interventions are needed, focusing on improved access to food, health, water, sanitation and education for these vulnerable communities across Bangladesh that inhabit and make a living from the shifting rivers that comprise the Ganges-Brahmaputra-Jamuna delta, to break the vicious cycle of economic deprivation and poverty. This study further recommends that without addressing household vulnerability, interventions to improve poverty dynamics of such households will be ineffective.

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APPENDICES

Appendix 1: Types of disasters and their impacts in specific disaster prone areas.

Types of Disaster	Areas Affected	Impact
Flood	Floodplains of the Brahmaputra-Jamuna, the Ganges-Padma and the Meghna river system	Loss of agricultural production, disruption of communication and livelihood system, injury, damage and destruction of immobile infrastructure, disruption to essential services, national economic loss, evacuation, and loss of human lives and biodiversity, displacement and sufferings of human population and biodiversity
Cyclone and Storm Surge	Coastal areas and offshore islands	Loss of agricultural production, disruption of communication and livelihood system, damage and destruction of immobile infrastructure, injury, national economic loss, loss of biodiversity and human lives, need for evacuation and temporary shelter
Tornado	Scattered areas of the country	Loss of human life and biodiversity, injury, damage and destruction of property, damage of cash crops, disruption in lifestyle, damage to essential services, national economic loss and loss of livelihood
Drought	Almost all areas, especially the northwest region of the country	Loss of agricultural production, stress on national economy and disruption in life style
Flash Flood	Haor Basins of the north-east region and south-eastern hilly areas	Damage of standing crops, disruption in life style, evacuation and destruction of properties
Hail Storm and Lightning	Any part of the country	Damage and destruction of property, damage and destruction of subsistence and cash crops and loss of livelihood
Riverbank Erosion	River banks of the Brahmaputra-Jamuna, the Ganges-Padma and the Meghna	Loss of land, displacement of human population and livestock, disruption of production, evacuation and loss of property
Landslide	Chittagong and Chittagong Hill Tracts	Loss of land, displacement of human population and livestock, evacuation, damage of property and loss of life
Earthquake	Northern and central parts of the country	Damage and destruction of property, loss of life and change in geomorphology

Source: UNEP 2001

Appendix 2: Questionnaire (Back translation of the questionnaire was used)

ID	

1. General information:

Upazila: **Union:** **Village:**

Name of the household head:

Total Population: Male- Female- Children- Old (65)- Earning members-

2. Family type: ☐Unit or Nucleus ☐Joint ☐Other (specify)

3. Information of household members/human resources

Sl. No.	Relationship with HH Head	Age	Sex(M/F)	Marital Status	Education level	Earning members (Yes=1, No=0)	Staying with family (Yes=1, No=0)	Profession	
								Main	Secondary
1	Self								
2									
3									
4									
5									
6									
7									

HH Head = 1, Spouse = 2, Father = 3, Mother = 4, Brother = 5, Sister = 6, Son =7, Daughter = 8, Daughter-in-law = 9, Grandson =10, Granddaughter = 11, Others = 12 (specify)…….. ,
Marital Status: Unmarried =1, Married = 2, Widow = 3, Divorced = 4, Other = 5 (specify)

4. Land property

Types of land	Amount (in decimal)
Own cultivable land	
Rented-in	
Rented-out	
Mortgage in	
Mortgage-out	
Homestead land	
Orchard/Garden	
Pond	
Fellow land	

5. Household yearly income (Tk.)

Income from agricultural sources		Income from non-agricultural sources	
Items	Total Taka (Tk.)	Items	Income (Tk.)

Rice		Service	
Wheat		Business	
Spices / pulses / oil seed crops		Pension	
Fruits and vegetables		Remittance	
Livestock and poultry		Other occupation (selling labour, rickshaw pulling, boat, handicrafts etc.)	
Fisheries		Safety net (VGD/VGF, food for work etc.) allowance	
Others (if any)		Charity (*fitra, jakat*, help etc.) and begging	
		Others (if any)	

6. Household yearly expenditure (Tk.)

Expenditure head	Total expenditure	Expenditure head	Total expenditure (Tk/Month)
Crop farming		Food (1)	
Clothing		Rice	
Children education		Wheat	
Health care		Fish	
House making/repairing		Meat	
Festivals		Egg	
Livestock rearing		Milk	
Poultry keeping		Pulses	
Other costs		Species & Oil	
		Fruits & Vegetables	

7. Household wealth

Items	Quantity	Value	Items	Quantity	Value
TV			Rickshaw/van		
Mobile phone			Tempo		
Radio			Furniture		
Camera			Cassette player		
VCD/DVD			Iron		
Computer			Refrigerator		
Laptop			STW		
Motor cycle			Generator/motor		
Cycle			Sewing machine		
Torch light			others		

8. Livestock resources

Type of livestock	Number	Present value
1. Bull/Ox		
2. Cow		

3. Calf		
4. Pig (adult)		
5. Pig (calf)		
6. Goat (adult)		
7. Chicken(adult)		
8. Other (please specify)		

9. Overall livelihood status of the households

Questions on livelihood status	YES	NO	If NO, why ?
Does your family use sanitary toilet?			
Does your family use tube well water?			
Does your family use electricity?			
Does your family buy new clothes during festivals?			
Does your family offer gifts to relatives during different social events?			
Do you use any contraceptive method?			
What type of doctors do you normally visit while you are sick?	(a) MBBS, (b) Village doctor (c) Homeopathic, (d) Quack		
Does your family send children to school?			
Are you a member of any cooperative society?			
Do you have any saving accounts?			
Are your family members a member of cooperative society?			
Do you explore and utilise information technology for professional, health and family planning activities?			
Have you received any training in your profession?			
Do you get cooperation from other village people in case of your need?			
Do you adopt zero tillage cultivation?			
Do you adopt new cropping practice?			
Do you adopt improved management of weeds?			
Do you adopt improved management of manure?			
Do you adopt IPM			
Do you cultivate multiple crops?			
Do you allow women to participate in decision making processes?			
Current health condition of the household head (observing physical health)?	(a) Good =1 (b) Poor = 0		
How many days you were absent from the work due to sickness?			
How many years have you had working in your main profession?	……Years		

10. Household food security situation throughout the year

Months	Level of food availability		
	Adequate	Inadequate	Scarce
Baisakh (mid-April to mid-May)			
Jaisthya			
Ashaar			
Shraban			
Bhadra			
Ashwin			
Kartik			
Agrahayon			
Puosh			
Magh			
Falgun			
Chaitra (mid-March to mid-April			

11. Household food insecurity situation (Perception)

Food Insecurity Status	Yes=1, No=0	If yes, how many times did these happen?		
		Most of the time	Sometimes	Sudden
a) Were members of your household anxious about the lack of sufficient food during the last three months?				
b) Were you or any member of your household bound to eat fewer than three meals in a day due to the unavailability of sufficient food during the last three months?				
c) Did you or any other member of your household go to bed hungry due to lack of sufficient food during the last three months?				

12. Availability of food from own production

Type of food	No. of months cover	Type of food	No. of months cover
Rice		Pulse	
Wheat		Species	
Fish		Oil	
Meat		Fruits	
Egg		Vegetables	
Milk			

13. Food Consumption in Last 3 Days

Food Items	Unit	Yesterday		Day before yesterday		Two days before	
1. Cereals		Quantity	No. of people (Adult+ Child)	Quantity	No. of people (Adult + Child)	Quantity	No. of people (Adult + Child)
Rice	kg						
Chira	gm						
Muri & Khai	gm						
Wheat/Flour	gm						
Samai/Sugi	gm						
Bread/Biscuit	gm						
Cake	gm						
Others	gm						
2. Pulses							
Masoor	gm						
Khesari	gm						
Moog	gm						
Boot	gm						
Kalai	gm						
Others	gm						
3. Spices & Oil							
Onion	gm						
Garlic	gm						
Oil	gm						
Chili & ginger	gm						
Salt	gm						
Other spices	gm						
4. Fruits							
Banana	gm						
Coconut	gm						
Papaya	gm						
Apple	gm						
Others	gm						
5. Vegetables							
Potato	gm						
Brinjal	gm						
Radish	gm						
Bean	gm						
Cabbage/	gm						

Cauliflower							
Others							
6. Meat& Egg							
Cow& Buffalo	gm						
Goat	gm						
Hen/Poultry	gm						
Duck	gm						
Egg	gm						
Others	gm						
7. Fish							
Small Fish	gm						
Medium Fish	gm						
Big Fish	gm						
Shutki	gm						
8. Milk & others	litre						
Milk	litre						
Other milk products	litre						
Sugar	litre						
Molasses	litre						
Others	litre						

14. Please rank the following questions

In your household, who get food first, then second and so on during a severe food crisis?

Types	Rank	Types	Rank
Husband		Siblings	
Wife		Daughter	
Son		Old-age person	
Pregnant wife		All have equal chance	

15. Local orientation

Were you affected by riverbank erosion?	☐Yes ☐No
☐ If you are not affected by riverbank erosion, move on to Question 18	
How were you affected by riverbank erosion? (tick all those that apply)	☐ Loss of farm land ☐ Homestead land ☐ Pond ☐ Loss of employment opportunities ☐ Trees ☐ Other:
How many times were you affected by riverbank erosion during last 10 years? -----	

In which year did the most recent riverbank erosion event occur? ----------
Was your household food secure before the first riverbank erosion? ☐ Yes ☐ No ☐ Not sure/ Don't know
Distance of homestead from the river bank (m) ----------
Amount of land within ½ km of river bank (decimal)----------
Housing condition-☐ Tin ☐ House with only roof with tin ☐ Hut

16. Impact of river bank erosion on different household indicators

Items	After riverbank erosion	Reasons
Housing condition (No change=0, deteriorate = 1, improve=2)		
Occupation opportunities of household members (No change=0, reduce = 1, improve=2)		
Working hours of the household members (Average hours) (No change=0, reduce = 1, improve=2)		
Income of the household (No change=0, reduce = 1, improve=2)		
Education facilities (No change=0, reduce = 1, improve=2)		
Health facility (No change=0, reduce = 1, improve=2)		
Electricity (No change=0, reduce = 1, improve=2)		
Sources of drinking water (No change=0, reduce = 1, improve=2)		
Sanitary (toilet) conditions (No change=0, reduce = 1, improve=2)		
Transport facilities (No change=0, reduce = 1, improve=2)		
Communication facilities (No change=0, reduce = 1, improve=2)		
NGO services (No change=0, reduce = 1, improve=2)		
Institutional credit facilities (Bank) (No change=0, reduce = 1, improve=2)		
Mechanised agricultural instruments (Number) (No change=0, reduce = 1, improve=2)		
Household assets (No change=0, reduce = 1, improve=2)		
Food security condition (No change=0, reduce = 1, improve=2)		
Availability of labour (No change=0, reduce = 1, improve=2)		

Marketing facilities (No change=0, reduce = 1, improve=2)		
	At present	**Before riverbank erosion**
Land size (in decimal – square metres)		
Land use patterns (major)		
Occupation of the household head		
Do you earn more income than your previous occupation? (If your occupation has changed)	☐**Yes** ☐**No**	
Main source of household income (Remittance=1, Agriculture=2, Job=3, Business=4, Labour Sale=5, Non-agriculture=6, others=7)		
Wage of day labour (amount/day)		
Income of the household		
Changes in livestock numbers (no.)		
Changes in poultry and ducks (no.)		

17. Perceptions about riverbank erosion hazards/ and climate change

(a) Have you noticed/ perceived any change to the climate in your locality over the last 20 years?
☐Yes ☐No ☐ Not sure/Don't know

(b) If yes, identify which of the climate variables you think have changed and describe how they have changed.

Climate components	Time period	Increased	Decreased	No change/ same	Don't know
Temperatures	Annual				
	Winter				
	Summer				
Rainfall	Annual				
	Winter				
	Summer				
Extreme events such as drought	Annual				
Availability of groundwater	Annual				
Availability of surface water	Annual				
Severity of cold wave	Annual				
Severity of heatwave/hot days	Annual				
Severity of riverbank erosion	Annual				
Frequency of flood	Annual				
Frequency of cyclones	Annual				
Winter period	Annual				

Summer period	Annual				
Others, if any (please specify)	Annual				

18. Coping strategies towards food security during stress situation

SL. No.	Food security strategies	Degree of responses			
		Regularly	Occasionally	Rarely	Not at all
1.	Reduce amount of food per meal				
2.	Reduce number of meals per day				
3.	Go bed without food				
4.	Rely upon less expensive or less preferred food items				
5.	Reduce buying children food(i.e. milk) from market				
6.	Purchase food on credit				
7.	Borrow money from NGOs/GB				
8.	Borrow from money lenders				
9.	Migrate to city or other area				
10.	Rely on casual labour for food				
11.	Sell cattle/livestock				
12.	Spend money from deposit				
13.	Borrow money or food from friends/relatives				
14.	Sell land and other asset (specify)				
15.	Sell labour in advance				

Regularly = 3; Occasionally = 2; Rarely = 1; Not at all = 0

19. Government/NGO programs for food security in the area

a) Are you or family members are under any safety net programs available in your locality from government sector? ☐Yes ☐No

b) If yes, for how many years?---

c) Please describe the nature of that support (amount and months): ----- …….TK.

d) What is your opinion about the impact of these programs on your household food security? ☐ Adequate ☐Inadequate

e) Is there any NGOs program towards food security? ☐Yes ☐No

f) If yes, please describe-

g) What is your opinion about their support to ensure food security? ☐ Adequate ☐Inadequate

20. Adaptation to riverbank erosion hazards/climate change

Have you made any changes to your farm operations due to riverbank erosion or changes in climate attributes in order to reduce the adverse impacts?

☐Yes ☐No

21. What adaptive measures (adjustments) do you practice in your farming system?

Adaptive measures	Please put 1 for main measure and tick (□) for others that you practice
Change planting time	
Cultivation of pulses	
Cultivation of wheat and other crops	
Tree plantation	
Cultivation of spices and oil seed	
Cultivation of local Aman rice	
Cultivation of vegetables	
Cultivation of HYV rice varieties (e.g., BRRI-28, 29)	
Livestock rearing	
Poultry rearing	
Duck rearing	
Homestead gardening	
Migration	
Off-farm work (van, rickshaw, tempo driving)	
Petty business	
No adaptation	
Others (please specify)	

22. What are your barriers in taking adaptive measures?

Barriers to adaptation	Please put 1 for main measure and tick (□) for others that you practice
Lack of information about riverbank erosion and related climatic issues	
Lack of appropriate variety of crops	
Lack of knowledge concerning appropriate adaptation strategies	
Lack of credit/money/saving	
Lack of suitable land for cultivation	
Lack of own land	
Lack of storage facilities	
Lack of marketing facilities	
Lack of transportation facilities	
Others (please specify)	

--Thank you for your cooperation---