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Author(English)	Md Sanaul Haque Mondal
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Households‘ Risk and Responses to Flood Disaster: Case of Teesta River, Bangladesh

A Dissertation Presented

by

Md Sanaul Haque Mondal

Supervisors

Professor Takehiko Murayama

Professor Shigeo Nishikizawa

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Department of Trans-Disciplinary Science and Engineering
School of Environment and Society
Tokyo Institute of Technology
Japan

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Abstract

Floods are one of the greatest hazards in Bangladesh. It is assumed that people who reside in a riverine area have adapted to flood pulses. Although recurrent floods cause detrimental impact for the people living in riverine floodplains, households are taking up various risks management measures to deal with them. However, in most cases, household-level risk-reduction strategies are inadequate for ensuring a livelihood resilient to floods. This is because riverine people are exposed to recurrent floods, which increases their vulnerability to floods. In order to formulate effective risk-reduction policies and programs for riverine areas, it is crucial to measure flood risk at the local level.

The overall objective of this study is to assess household-level riverine flood disaster risk to identify corrective risk measures. To achieve this objective, both qualitative and quantitative techniques were used. Using a systematic random sampling technique, 377 households from the right bank of the Teesta River in Bangladesh were interviewed after severe flood in 2017 to characterize flood hazards, exposure to floods, and their vulnerability and capacity to absorb flood risk. The qualitative techniques include documents reviews, focus group discussions and key informant interviews. The collected data from the questionnaire survey were aggregated using a composite index, while comparing the components of flood risk. Descriptive and analytical statistics were also computed. Multivariate techniques (principal component analysis and logistic regression) were also used in order to identify the determinants of households‘ response to flood disaster and perceived preparedness.

The results showed that riverine households from the upstream, midstream, and downstream segments of the right bank of the Teesta River had similar capacity levels, although there were significant differences in their levels of hazard, exposure, and vulnerability. The flood risk was higher in downstream areas, followed by upstream areas and the midstream segments of the Teesta River. The degree of flood risk in these three study locations was significantly different. A significant negative correlation was observed between vulnerability and capacity. No significant associations were found between the exposure and vulnerability components.

The surveyed households adapted different strategies to respond to recurrent flood disasters. The findings revealed that households adopted different post-disaster coping measures which were grouped into five categories: borrowing money, assets disposal, consumption reduction, temporary migration, and grants from external sources. Results from binary logistic regression models suggested that increasing severity of flood reduced households‘ consumption. Exposed households were more likely to borrow money. Consumption reduction and temporary migration were mostly adopted by agricultural landless households. Income from nonfarm sources was found to be an important factor influencing household‘s decisions on coping.

On the other hand, riverine people adapted different risk mitigation measures to reduce risk. These included plinth raise of the house, build homestead on raised earthen mound, modify house with strong materials, precautionary cash saving, precautionary food save, store valuables in a safe place, and collect emergency items. Empirically, it was found that risk perception, perceived preparedness, flooding experience, proximity to river, household‘s head sex, landownership, income sources and membership in social organization significantly influenced households to implement mitigation measures to reduce flood risk.

Furthermore, households that recovered from the last flood disaster seek insurance through their own savings and available physical assets, highlighting the role of disaster preparedness in resilient recovery. Furthermore, the multivariate analysis also suggested that households‘ perceived preparedness was influenced by their ability to respond to floods.

This study calls for the policy intervention at the household-level to enhance the adaptive capacity of riverine households so that people at risk can cope better and recover from flood disaster using their resources. Overall, this study suggests that exposure reduction is the big contributing factor of riverine flood risk reduction in the study area. At the same time capacity development-related interventions (e.g. training) will foster household‘s adaptive capacity to riverine flood disaster. The empirical approach presented in this study could be used to assess household-level flood risk and responses in other regions, especially where data is scarce.

Keywords: Bangladesh, Coping measures, Flood risk assessment, Hazard, Mitigation measures, Northern Bangladesh, Preparedness, Riverine flood disaster risk index, Recovery, Teesta River, Vulnerability.

Publications and Conference Presentation

Peer reviewed articles

[1] Mondal, M.S.H., Murayama, T., & Nishikizawa, S. (2020). Assessing the flood risk of riverine households: A case study from the right bank of the Teesta River, Bangladesh. *International Journal of Disaster Risk Reduction*, 51, 101758. https://doi.org/10.1016/j.ijdrr.2020.101758

[2] Mondal, M.S.H., Murayama, T., & Nishikizawa, S. (2021). Determinants of household-level coping strategies and recoveries from riverine flood disasters: Empirical evidence from the right bank of Teesta River, Bangladesh. *Climate* 2021, *9*, 4. https://doi.org/10.3390/cli9010004

Conference presentation

[1] Mondal, M.S.H., Murayama, T., and Nishikizawa, S. (2018), Does the impact of climate induced disasters hamper to achieve the targets of sustainable development goals? Evidence from Northern Bangladesh. *IAIA's Special Symposium on "The competing challenges of sustainability and economic development: Using impact assessment to achieve the SDGs in Asia"* 1-3 October, 2018 in Kuching, Malaysia. [Oral presentation]

[2] Mondal, M.S.H., Murayama, T., and Nishikizawa, S. (2019), A conceptual framework for flood risk assessment and its application to a case in Northern Bangladesh. *"The Society for Risk Analysis Japan 32nd Annual Meeting"*, 22-24 November, 2019, Tokyo Institute of Technology, Japan. [Poster presentation]

Dedication

I dedicate this dissertation to my late parents, Md Abdur Rouf Mondal and Mst Parul Begum. They had always prayed for Almighty Allah's blessings to pursue my dream to a successful end. Although they did not live long enough to see me through the academic ladder, their prayer for blessings is a living memory. I would forever remember them and may their souls rest in perfect peace.

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I am grateful to all the members of the “Murayama & Nishikizawa laboratory” for their support during my study period. I would like to especially thank Umezawa Shunsuke, Yukiko Iida, and Shingo Takeda for their invaluable support in making a pleasant and memorable stay for myself and my family here in Tokyo, Japan. Without their support, it would be difficult for me to survive in Japan. Also, I wish to convey special thanks to Akiko Morinaka and Natsuka Mochizuki for always being so helpful, providing me non-academic support throughout my student life at Tokyo Institute of Technology.

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Last but not the least, my deepest regards for my parents, whose prayers made it possible to complete this study. I dedicate this work to them.

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List of Abbreviations

BBS	:	Bangladesh Bureau of Statistics
BDT	:	Bangladeshi Taka (currency)
BWDB	:	Bangladesh Water Development Board
CBO	:	Communality Based Organization
CRED	:	Centre for Research on the Epidemiology of Disasters
EM-DAT	:	Emergency Events Database
EWS	:	Early Warning System
FGD	:	Focus Group Discussions
GBM Basin	:	Ganges-Brahmaputra-Meghna Basin
GIS	:	Geographic Information System
HH	:	Household
IPCC	:	Intergovernmental Panel on Climate Change
KII	:	Key Informants' Interviews
NDRCC	:	National Disaster Response Coordination Centre
NGO	:	Non-Governmental Organization
PCA	:	Principal Component Analysis
RFDRI	:	Riverine Flood Disaster Risk Index
RQ	:	Research Questions
SPSS	:	Statistical Package for Social Sciences
TRFB	:	Teesta River Floodplain in Bangladesh
UNDRR	:	United Nations Office for Disaster Risk Reduction
UNISDR	:	United Nations International Strategy for Disaster Reduction
USD	:	United States Dollar (currency)
		[1 USD= 84.25 BDT, as of April 2019 (Source: Bangladesh Bank)]

Glossary

Boro rice	:	*Boro* is the winter-season irrigated rice
Char	:	A *Char* land is a tract of land surrounded by the water of an ocean, sea, lake, or stream
Danger level	:	The danger level of a river refers to the river bankfull stage at which overland flooding may occur
Haor	:	A *Haor* is a bowl or saucer shaped wetland ecosystem
Joystho	:	Bangla calendar month starting from mid-May to mid-June
Kartik	:	Bangla calendar month starting from mid-October to mid-November
Katcha house	:	A *Katcha* house made up of wood, mud, straw, soil, and dry leaves made by the poor, providing little protection from sunlight and rain.
Khas land	:	Government owned land
Mohajon	:	Local moneylenders who give credits with high interest
Union	:	Union is the lowest tier of the local government structure in Bangladesh
Union Parishad	:	Union Parishad is the elected body at the Union
Upazila	:	Upazila functions as sub-district of a district in Bangladesh

Chapter 1: Introduction

1.1 Background

Floods are a part of the natural hydrological system (Vojtek and Vojteková 2016) that have a severe impact on human lives and causes extensive material damage, to such an extent that they overwhelm a community‘s capacity so that they cannot cope without external support. From 1995 to 2015, floods killed more than 157,000 people and affected over 2.3 billion worldwide (CRED and UNISDR 2015). Most of these deaths and devastation occurred in Asia, however, evidence showed that the number of deaths from flooding has increased in many parts of the world (Gotham et al. 2018). For example, in Bangladesh, flood-related death tolls have risen from 223 between 2010–2014 to 435 between 2015–2019 (EM-DAT 2020). The number of people affected and the economic losses caused by floods are also increasing. On the other hand, floods are the primary source of risk to agriculture (Patnaik and Narayanan 2015) in terms of production loss and food shortage (Mondal 2019). Studies found that recurrent flooding also presents severe public health concerns in developing countries (CRED and UNISDR 2015). Therefore, floods are a serious threat to sustainability around the world (Gotham et al. 2018). To address these issues, researchers around the world are now motivated to investigate why and how damage from a flood event occurs and who are at the most risk.

In general, flood risk is a combination of natural and anthropogenic factors (Danumah et al. 2016), and varies according to spatial and temporal context (Nkwunonwo et al. 2016). Among natural hazards, floods are quite distinct because they have both positive and negative effects. For example, a flood is considered a dangerous event when it causes extensive damage to the system, while in the deltaic ecosystem, flooding is considered to be beneficial because it makes agricultural land fertile through the deposition of sediments. Different disciplines use their own approaches to study flood risk (Solin and Skubincan 2013); however, the prime objective of a flood risk study is to protect people, their assets, and the environment from the harmful effects of a flood (Tchórzewska-Cieślak et al. 2018).

The traditional engineering approach of flood management emphasized the capacity of river sections to carry the maximum discharge under a specified probability to limit the scope of river flooding through protecting residential and industrial zones from flood-related damage (Solín et al. 2018). However, quantification of risks by assessing the probability of floods and their consequences will not provide detail input for risk reduction strategies (Figueiredo et al. 2009; Komi et al. 2016). In addition, the increasing trend of frequency and intensity of extreme flood suggest that traditional flood management alone is no longer sufficient (Kotzee and Reyers 2016) to protect people from flood risk. On the other hand, vulnerability is the inseparable part of flood risk management. Therefore, Solín et al. (2018) believes flood risk assessment should include both flood hazard assessment and society's vulnerability assessment. Flood risk can be managed by reducing the probability and intensity of flood hazard, and by reducing vulnerability of exposed people (Komi et al. 2016). However, high-quality data is required for flood hazard assessment (Wang et al. 2011) which is usually scarce for developing countries like Bangladesh. Furthermore, data on flood related damage are not systematically recorded or under-recorded (UNDRR 2019). Considering these issues, a household-level approach will provide a reliable source of information for assessing flood risk for data scarce region. Although floods risk is covariates, the impacts may vary across households and poor households bear the greatest risk of the negative impacts of floods due to their limited capacity (Patnaik and Narayanan 2015). Nevertheless, households employ a set of risk management strategies to mitigate, reduce, or cope with risk (Siegel and Alwang 1999). An understanding of household response measure has relevant implications to design effective risk management policies. The implementation of local adaptation plan will be less effective in absence of adequate information about the level of risk (Yankson et al. 2017).

The Sendai Framework for Disaster Risk Reduction 2015-2030 highlights that disaster risk management strategies should be based on a sound understanding of all the dimensions of disaster risk, including hazard characterization, exposure of people and their assets, vulnerability, and capacity to absorb shocks (UNISDR 2015). Assessing the current risk of flooding is fundamental to understanding how it could change in the future (Poljansek et al. 2017). While risk assessment provides crucial evidence for designing and implementing risk reduction measures, its measurement is very complex. In light of these issues, this research aims to investigate the households' risk and response mechanisms to riverine flood disaster in order to provide a useful source of information for effectively enhancing households' flood disaster preparedness and responses.

1.2 Problem statement

Bangladesh is ranked seventh on the 2020 Global Climate Risk Index in terms of most affected countries due to extreme weather events (such as floods, storms) during 1999-2018 (Eckstein et al. 2019). The country is considered to be one of the most flood-prone countries in the world (Kundzewicz et al. 2014). Flash flood, rainfall induced flood, riverine flood, and storm surge flood are the four major types of floods in Bangladesh (Mirza et al. 2003) and the characteristics of these kinds of floods are different from each other (Raaijmakers et al. 2008). Among these floods, riverine floods are distinct for Bangladesh because the country is located at the lower riparian zone of the Ganges, Brahmaputra, and Meghna (GBM) basin. The country has a complex network of 230 rivers including 57 transboundary rivers and these rivers drain around 1200 billion m^3 of water annually (Ali et al. 2018). River floods are caused by the overflow of riverbanks (Mirza et al. 2003), typically affect the people who reside the near rivers. The spatial and temporal extent of flooding in Bangladesh is determined by the magnitude, synchronization of peak discharges, and duration of floods in the major rivers (Rahman and Salehin 2013), and thus riverine floods are directly related to the amount of rainfall in the upstream catchment and the volume of water carries from the upstream countries. Normal flooding is predictable and people have developed their own risk management strategies, enabling them to withstand and benefit from the flooding (ADPC 2005; Sultana and Thompson 2017). A severe flood can occur when the peak discharges of the major rivers coincide, causing widespread damages. Therefore, riverine flood disaster risk assessment is multi-dimensional and complex in nature.

Between 1971 and 2018, floods accounted for 29% of the country‟s natural disasters (EM-DAT 2020). Flood accounts for the largest share (around 66%) of the country‟s economic losses caused by any type of disasters in the last five decades. During this period, the number of people that were affected and became homeless due to floods was significantly higher than for any other type of disaster. The floods in 1974 killed 28,700 people and affected another 38 million people, with estimated damages of $579.2 million (EM-DAT 2020). The floods of 1988 inundated around 70% areas of the country (Mirza et al. 2003). The 1998 floods resulted in a record amount of damage, totaling around $4.3 billion (EM-DAT 2020) and more than two-third of the country was submerged for three months (Mirza et al. 2003). Although there was shorter term flood in 2004, 2007 and 2008, these impacted millions of people (Webster and Jian 2011).

In August 2017, Bangladesh faced one of the historically devastating river flooding events in its recent history. The northern region (Figure 1.1) of the country was severely affected by the August 2017 flood, impacting around 6.9 million people, destroyed 593,250 houses and claimed the lives of over 114 people (NDRCC 2017). The water levels of major rivers in the northern region crossed their danger levels leading to the inundation of riverine areas. The flood in August 2017 was particularly impactful for the riverine people as it followed two earlier episodes in March and July that year (Philip et al. 2019). The timing and severity of August 2017 flood disrupted this year‟s agricultural production resulted in a record price of rice, affecting food security. Roads, railways and bridges were severely damaged, leaving many areas inaccessible to emergency relief efforts. Thousands of waterborne diseases were reported in the post-disaster period.

The aforementioned statistics indicate the level of flood risk for riverine communities in Bangladesh. Furthermore, the socio-economic impact of flood has been increasing (Webster and Jian 2011) as a result of the growing number of population in riverine floodplains, and increasing the share of crop and property losses (Zhang et al. 2011; Brammer 2016; Ran and Nedovic-Budic 2016). Flood risk will further increase as exposure continues to rise (Kundzewicz et al. 2014). Household lives in floodplain zones are at risk due to exposure to flood hazards as well as their vulnerable conditions. Flood risk assessment for riverine people is thus necessary to understand what makes a household high risk for flood. The focus of flood risk assessment is to reduce flood risk through mitigation efforts and to better prepare for future flood threats. However, little is known what makes people confident about their actual preparedness (McNeill et al. 2018).

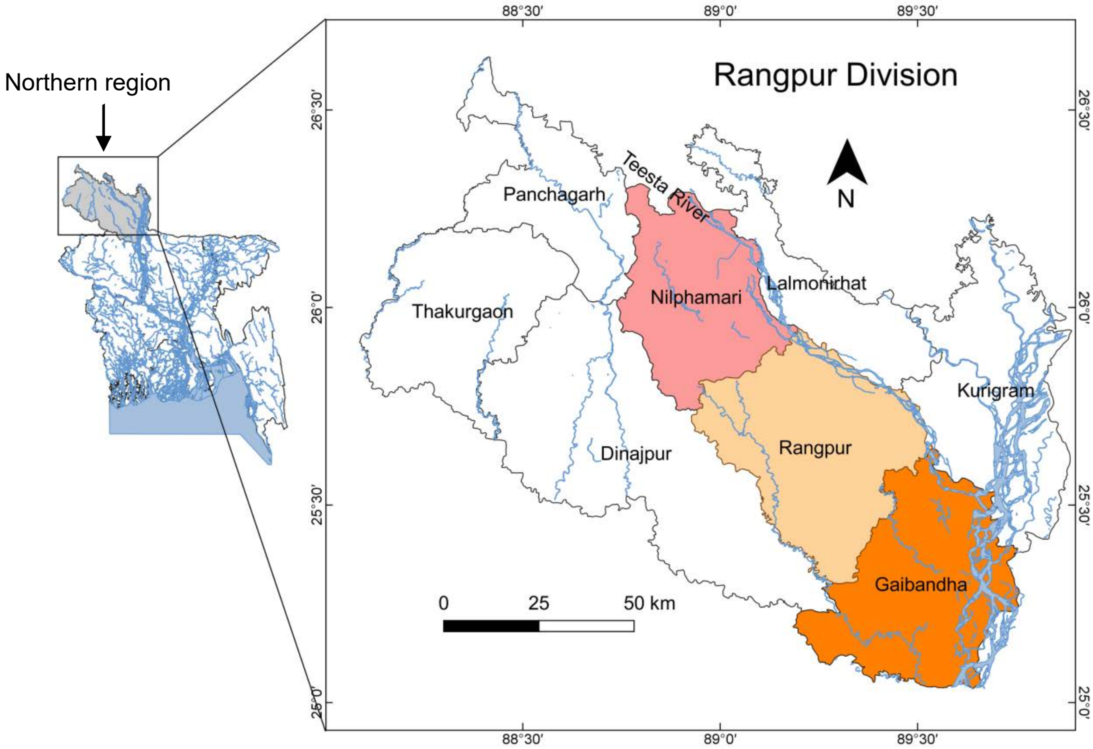

Figure 1 1: Map of the northern region of Bangladesh

Various structural (e.g. embankment, river training) and nonstructural (e.g. zoning, early warning) measures have been adopted in the country to minimize the flood related losses. The country has a long history of building flood embankment alongside the rivers but the maintenance and repair of those embankments are continuing problems resulting in severe floods periodically (Brammer 2016). Despite the nationwide flood warning systems, the dissemination of the warning to the end-users is still a challenge for the country (Chowdhury 2005; Rahman et al. 2013). The economic losses of private households due to flooding are also increasing. As a result, households are motivated to uptake risk reduction measures complementary to public measures (Babcicky and Seebauer 2017) and developed their own level of resilience and adapted their livelihood strategies to the flood pattern. However, severe flood like 2017 exceeds the capacity of people (Gros et al. 2019), undermines household‘s food security and resilience (Smith and Frankenberger 2018). In a post flood period, households respond to flood disasters in a variety of ways (Dercon 2002), which are either supported by themselves or by the civil society and the government (Patnaik et al. 2016). An understanding of why a household chooses different risk reduction measures and whether these measures help them recover from the disaster can guide policymakers in promoting effective flood risk management by identifying target variables.

A number of studies have already been conducted focusing 2017 flood, such as attributing factors of flood (Philip et al. 2019), forecast based cash transfer (Gros et al. 2019), household‘s resilience (Kamal et al. 2018), coping with two successive years floods (2016-2017) (Sultana et al. 2019). However, no study to date has examined risks and responses to flood disaster by the riverine people after facing a historical flood in 2017. This study addresses this gap by investigating household-level riverine flood disaster risks and identifying the key determinants to choose the risk management measures to respond to flood disasters.

In order to understand flood risk at household-level, the right bank of the Teesta River in Bangladesh was chosen for a field study. The riparian people of the Teesta River experience floods almost every year caused by the river overflowing. In addition, the onrush of water from the Gozoldoba barrage (the name of a barrage on the Teesta River in India) is also responsible for uncertain floods in Bangladesh. Floods are also responsible for human casualties and property losses for riparian communities. Therefore, households adopt a variety of measures to manage flood risks. The research employs a case study approach to study riverine households. Data collection from the riverine households includes semi-structured questionnaire survey and informal interviews. To enhance reliability of this study, it also includes interviewing local government bodies (Union Parishad) and focus group discussions with local people.

1.3 Research objectives and research questions

The aim of this study is to assess household-level riverine flood disaster risk to identify corrective risk measures. More specifically, this study will look at the following specific objectives and research questions:

Objective 1:

To assess flood disaster risk of riverine households in Teesta River floodplain in Bangladesh

Research questions:

(1) Who are at higher risk from riverine flood disaster?

(2) How does vulnerability and capacity of riverine households interrelated?

Objective 2:

To examine households‘ response measures to flood disaster and identify the determinants to adopt a particular measure to respond and recover from the impact of a flood disaster.

Research questions:

(3) What risk mitigation and risk coping measures did a household employ to respond to 2017 flood disaster? Which factors influenced households to adapt these measures?

(4) How effective were the coping measures adopted by the household in recovering from flood disaster? Are there any association between the household‘s recovery from flood disaster and adaptation of post-disaster mitigation measures?

(5) What are the key determinants of households‘ perceived preparedness?

1.4 Research scope

This research addresses the need to reduce existing riverine flood disaster risk by identifying corrective risk actions through an empirical study, in a context where people face recurrent riverine flood. The field survey was carried out in 2018 and 2019 after the severe flood in 2017. Riverine flood disaster risk index is developed by incorporating four major components e.g. flood hazard, exposure to flood, socio-economic vulnerability, and capacity to absorb flood shock. This research focuses on riverine flood-affected households residing along the bank of the Teesta River of Bangladesh who is exposed to sudden and recurrent floods and specifically assesses household-level riverine flood disaster risk and response to flood disaster.

1.5 Significance of this study

The results of this study would help clarify the existing risk of riverine households, which will be useful for designing corrective risk measures through mitigating or reducing existing risk (UNISDR 2015). Further, it will explore the determinants of adopting risk reduction measures at household level, allowing risk managers in promoting effective flood risk management through identifying target variables. Finally, this research will contribute to our understanding about individual‘s perceived preparedness using available measures and own capacities which will provide useful insights for designing (actual) preparedness measures.

Chapter 2: Literature Review and Research Methodology

2.1 Introduction

This chapter outlines the conceptual background, literature review and research methodology of this study. The Section 2.2 provides the conceptual background of riverine flood disaster risk assessment. Key concepts underpin this study includes flood risk and its components, households response to flood disaster, perceived preparedness and recovery from flood disaster. The research framework of this study is described in the Section 2.3. The Section 2.4 presents reviewing of scientific literature on flood risk and household‘s response to flood disaster. It also reviews existing literature from Bangladesh on flood risk and household‘s response to flood disaster over the last 20 years. The Section 2.5 describes research methodology. It first presents bio-physical and socio-economic context of the study area. The section also describes the methods used in this study, including data sources, sampling procedures, survey design, and data analysis. This study proposed mixed-method research in a combination of qualitative and quantitative techniques to achieve set objectives.

2.2 Conceptual background

2.2.1 Flood risk and its dimensions

Different disciplines within natural and social sciences have formed their own concepts of risk (Renn and Walker 2008). In general, risk is the potential for a disaster, which is the product of the intensity, severity, and frequency of a hazard and the vulnerability (DHA 1992) of exposed elements (Birkmann 2007), and can be expressed as: *Risk=Hazard X Vulnerability* (Wisner et al. 2004). According to this expression, risk can be zero due to zero vulnerability (Wu et al. 2015). However, the risk may exist where there is no human habitation. Therefore, Maskrey (1989) believed that disaster risk is the coincidence of hazards and vulnerable conditions and can be defined as: *Risk = Hazard + Vulnerability*. The negative consequences of disasters are caused not only by natural events but also may result from a system‘s vulnerability (Solin and Skubincan 2013). Existing vulnerable conditions will thus provide useful information while assessing repeated natural hazards that are usually impossible to prevent. However, disaster risk is not only the probability and severity of a hazard but also about what is exposed to that hazard and how vulnerable that exposure is (Poljansek et al. 2017). This indicates risk is the function of hazard, vulnerability and exposure (Crichton 1999; IPCC 2012). On the other hand, the degree of vulnerability to a particular event depends on the system‘s ability to respond to that event (Alwang et al. 2001). Therefore, some authors include manageability/capacity with hazard and vulnerability to define risk (Carter 2008). This implies that natural disaster risk not only depends on hazard, exposure, and the present vulnerability of the system, but also on the ranges of the capacities and measures present in the system to recover from the disaster‘s impact (Bollin et al. 2003).

This study considered floods as a hazard that affects communities on a regular basis. Households living in floodplain zones are at risk because of their exposure to flooding hazards and their vulnerable conditions. On the other hand, a household‘s capacity helps to reduce the impact of flooding hazard. The resultant flood risk is thus the product of flood hazard, exposure, vulnerability, and capacity (Thywissen 2006; UNDRR 2017), as shown in Figure 2.1. Based on this conceptualization of risk, riverine flood disaster risk can be represented using Equation (2.1).

$$\text{Risk} = \text{f}(\text{hazard}, \text{exposure}, \text{vulnerability}, \text{capacity}) \qquad (2.1)$$

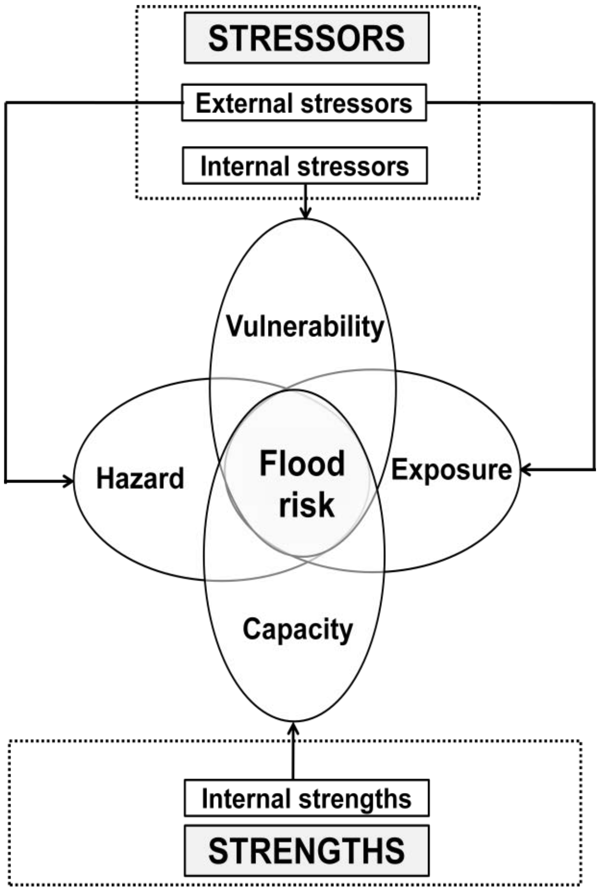

Figure 2 1: Household-level riverine flood disaster risk assessment framework (Source: Own)

There is no common agreement on the mathematical relationships among these components (Thywissen 2006). However, Bollin et al. (2003) suggested the use of linear relations among these components. The present study develops a Riverine Flood Disaster Risk Index (RFDRI) by modifying the Bollin et al. (2003)

approach. The conceptual model of this study qualifies hazard and exposure as external stressors, vulnerability as internal stressors, and capacity as the internal strengths of the household (Figure 2.1). Thus, internal factors that influence flood risk include households‘ vulnerability and capacity, whereas external factors include hazard and exposure to flood.

(i) Flood Hazard

Hazards are events (e.g. flood) that may cause potential harm to natural and social systems, and they are characterized by location, frequency, intensity, and probability (UNDRR 2017). The word ―potential" is used to describe how there may be exposed elements to flood hazard that could, but need not necessarily, be harmed. A riverine flood occurs when a river‘s water level rises and overflows the river‘s banks. Indeed, riverine floods are location specific. Therefore, the characteristics of flood hazard in this study are described in terms of frequency and the intensity of floods (Figure 2.2).

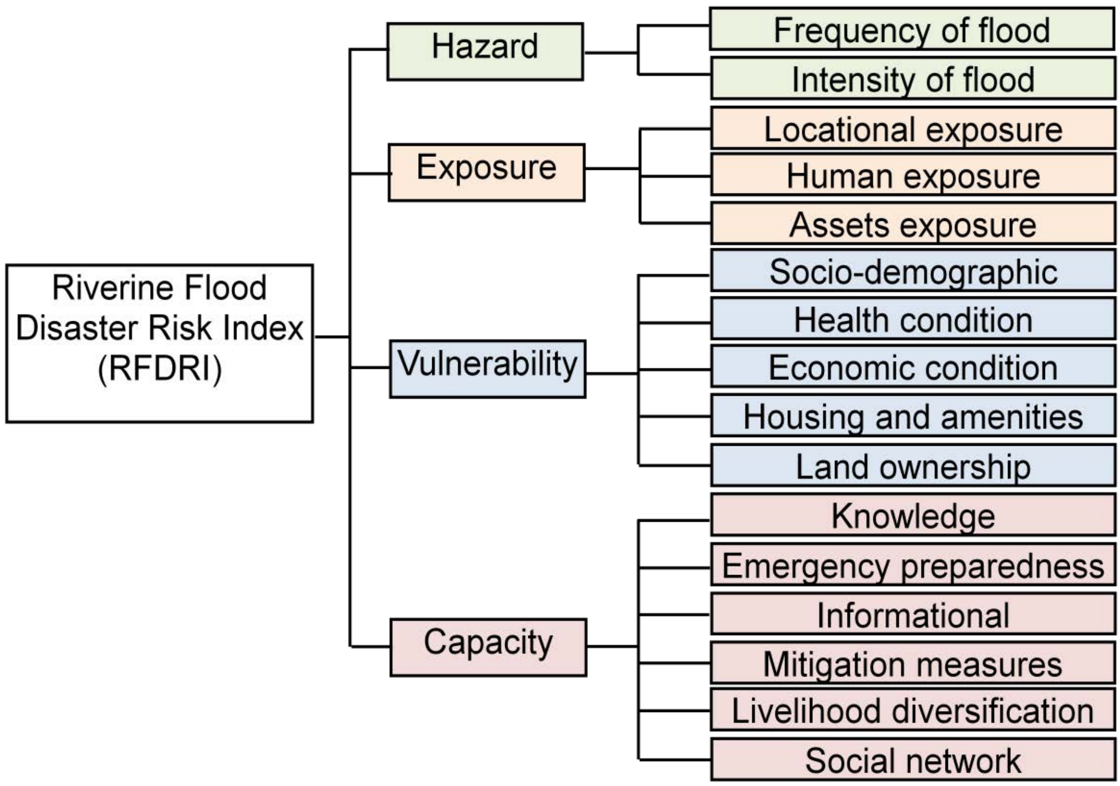

Figure 2 2: Components and subcomponents of flood disaster risk (Source: Own)

(ii) Exposure to floods

Exposure is the number of people or other elements at risk that can be affected by an event (Thywissen 2006). It is the context (location) of the people, infrastructure, housing, production capacities, and other tangible human assets located in hazard-prone areas (UNDRR 2017). However, exposure alone cannot explain risk. Households with a similar level of exposure to an event might have a different level of risk. For example, on an uninhabited island, human exposure is zero; therefore, there is no risk of human loss. On the other hand, when people are not exposed to hazardous events, there is no risk to human life (Pelling et al. 2004). In this study, exposure to floods thus refers to the elements at risk from a flood event (Merz et al. 2010), which include locational, human, and assets exposure (Figure 2.2).

(iii) Socio-economic vulnerability

Vulnerability is multi-dimensional (Vogel and O‘Brien 2004; Birkmann and von Teichman 2010), hazard-specific, and dependent on the context in which specific natural events occur. These conditions are determined by —physical, social, economic, and environmental factors or processes, which increase the susceptibility of an individual, a community, assets or systems to the impact of hazards” (UNDRR 2017). Vulnerability has two sides: (i) the external side, which is described by the context of shocks (e.g. floods), seasonality (e.g. employment opportunities), and critical trends (e.g. demographic, economic); and (ii) the internal side, which is the defenselessness that is caused by the inability to cope with these events (Bohle 2001; Serrat 2017). However, vulnerability and exposure are not similar (IPCC 2012) because vulnerability is influenced by external forces (Turner et al. 2003; Wisner et al. 2004; Willroth et al. 2011). A system may be exposed but may not be vulnerable. For example, for people living in a floodplain, they may not be vulnerable if they have sufficient structural measures with adequate non-structural risk mitigation practices. Moreover, to be vulnerable to a particular hazard, the system also needs to be exposed. For example, riverine floods affect only riparian households, not all the people living in the floodplain. According to Wisner et al. (2004), vulnerability factors may also be generated from international politics and mistrust. For example, riparian peoples‘ vulnerability to floods in downstream areas increases due to the control over transboundary river flow by upstream areas. Therefore, for the purpose of this study, I adopt an integrative definition of vulnerability that considers the social (socio-demographic; health condition), physical (housing and amenities; land ownership), and economic conditions of a household that make it susceptible to the damaging effects of floods (Figure 2.2).

(iv) Capacity to absorb flood shock

Capacity is the combination of all the strengths, attributes, and resources available within an organization, community, or society (UNDRR 2017) that helps them to prepare for, mitigate, respond to, and quickly recover (Bollin et al. 2003) from the impact of a disaster. In this study, the capacity of a household includes all its strengths and resources within the limit of the household that makes it confident enough to absorb the potential impact of a flood. However, capacity to absorb flood shock varies by gender, since men and women possess different levels of assets, access to alternative livelihood strategies and information services, and social relationships (Wisner et al. 2004; Ferdous and Mallick 2019). A system‘s capacity to absorb disaster stresses depend on several factors, including individual-level (household) capacity, community-level capacity, and national-level capacity.

Household-level capacity (internal strengths) helps us understand how people respond to disasters (external stressors). This household-level capacity assessment provides an overview of what kind of capacity households have to reduce flood disaster risk, and based on this assessment, individual measures can be identified to promote successful corrective risk reduction interventions.

It is difficult to separate capacity and vulnerability, since they are closely linked. While vulnerability in this study includes a household‘s internal weaknesses, capacity includes the measures and resources available within the household that helps it to be prepared for mitigating future flood risk in order to better respond and then quickly return to the normal level of functioning following a flood. Therefore, capacity includes measures related to preparedness, mitigation, response, and recovery (Bollin et al. 2003), the four phases of the disaster management cycle.

In this study, the preparedness phase of the disaster management cycle was illustrated through knowledge, emergency preparedness, and the informational subcomponent; the mitigation phase by the mitigation measures subcomponent; and the response and recovery phase by livelihood diversification and the social network subcomponent (Figure 2.2). For the purpose of this study, I only focus on household-level capacity.

2.2.2 Household response to flood disaster

According to UNDRR (2017) response to disaster are the —actions taken directly before, during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected". The post-disaster response starts after a disaster strikes which may encompasses both short-term measures and medium-term measures (Figure 2.3). The effectiveness and efficiency of disaster response depends on the response capacities of individuals, communities, organizations, country and the international community (UNDRR 2017). For the purpose of this study, I only focus on the household-level post-disaster response measures.

Household responses to flood disaster in a variety of ways which can be classified as ex-ante strategies and ex-post strategies, where the foremost includes risk reduction and risk mitigation strategies are taken by the households in pre-hazard periods, while the latter refers to risk coping strategies to recover from disasters in post-disaster periods (Siegel and Alwang 1999). However, post-disaster mitigation measures are also conducted in recognition that similar events are likely in the future (Bullock et al. 2013).

Riverine people are at risk due to exposure to flood hazards and their vulnerable conditions. On the other hand, capacity is the ability of a household to resist or recover from the negative impact of a flood disaster. In the context of vulnerability, capacity is the ability of a household to resist or recover from the negative impact of a flood disaster.

In the post-disaster period, households adopted different coping measures to cope with floods (Figure 2.3). Whether or not a household recover from the impact of a flood disaster, they try to implement some prevention and mitigation measures to the best of their ability, to reduce flood risk. In general, high-risk households less likely to adopt mitigation measures resulting in a higher level of flood risk in future (Figure 2.3).

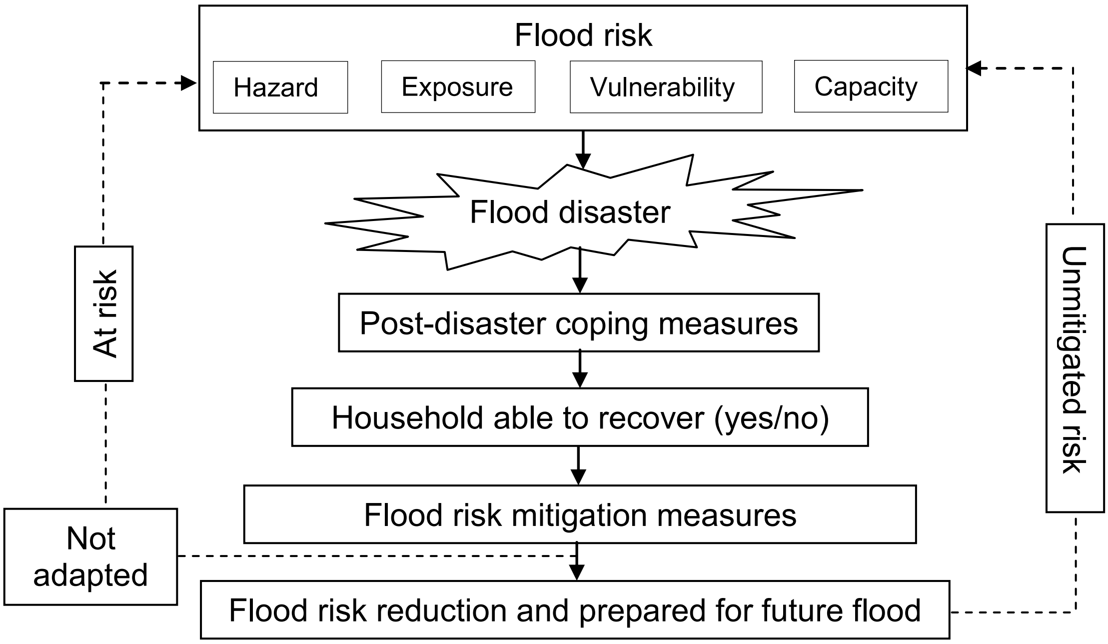

Figure 2 3: Households' response to flood disaster

(a) Post-disaster coping measures

In a post-disaster period, households adopt different coping measures including loan arrangements; sale of assets, livestock, or labor; temporary migration; clearing savings; living on charity; receiving emergency support from external actors; starvation (Ninno et al. 2003; Paul and Routray 2010, 2011; Sultana and Rayhan 2012; Sultana et al. 2019). Coping strategies do not lessen vulnerability; however, understanding the rationale behind coping behaviors might help towards effective targeting of those who are at their greatest risk (Adams et al. 1998). Successful coping may foster households to recover from the impact of a disaster. On the other hand, when coping strategies turn ineffective, households face difficulties in recovering from a disaster. However, the severity of impact may vary across households and most often poor people, who have limited coping capacities, bear the greatest risks (Patnaik et al. 2015). Studies revealed that the adoption of a particular set of coping strategies depends on several factors, including socioeconomic factors, types of shocks, severity of the event, physical location, ability to recover, information on opportunities (Frankenberger 1992; Shoji 2008;

Mavhura et al. 2013; Patnaik et al. 2015; Balgah et al. 2019; Sultana et al. 2019; Rayamajhee and Bohara 2019).

People who live in a recurrent risk area develop their self-insurance strategies to minimize risks on their livelihoods and ensure food security (Corbett 1988). In this study, post-disaster coping measures are defined as the measures employed by a household during or immediately (within one month) after a flood disaster.

(b) Post-disaster mitigation measures

Mitigation measures refer to the actions taken to reduce or eliminate risk to people and their property from flood hazards and their effects (Bullock et al. 2013). Mitigation measures can be divided into structural and non-structural measures. Structural measures are physical construction to reduce or avoid possible impacts (UNDRR 2017). On the other hand, non-structural measures are taken to minimize damage caused by future floods (Neto 2001) which includes knowledge, practice or agreement to reduce disaster risks and impacts (UNDRR 2017). The choice of a particular measure depends on the ability of an individual, a community, or systems. For the purpose of this study, post-disaster mitigation measures are defined as the interventions which are taken by the households to reduce or mitigate future flooding risk after facing 2017 flood.

2.2.3 Recovery from flood disaster

Disaster recovery refers to the return of a disaster-stricken community/household to a state in which the way of life is viewed as —normal” or similar to the level prior to a disaster (Rivera 2019). Recovery from disaster can be categorized as short-term or long-term. In this study, recovery from flood disaster refers to the subjective judgment of a household to build back to their pre-disaster condition.

2.2.4 Household’s perceived preparedness

Household preparedness is the knowledge, capabilities, and actions (UNDRR 2017) used to reduce loss of life, property (Paton 2003), and the psychological impact (Zulch 2019) associated with the occurrence of a disaster (Mabuku et al. 2018). Individuals who are well prepared for a disaster will suffer less than their counterparts when a disaster strikes (Donahue et al. 2014). However, there is limited knowledge on what makes people more prepared (McNeill et al. 2018). Therefore, perceived preparedness can serve as a proxy determinant of an individual‘s confidence in their adopted preparedness measures. However, greater education effort is required to increase understanding of disaster preparedness if individuals who believe they are better prepared than before previous disasters are actually not (McNeill et al. 2018).

In this study, household‘s perceived preparedness is defined as a subjective judgment (household‘s confidence in whether they have adequate measures to prepare for a flood disaster) of a household‘s actual preparedness measures (e.g. saving food, money, a portable cooking stove).

2.3 Research framework

The research framework of this dissertation is presented in Figure 2.4. Starting with the Chapter 1 introduces the background of this research, the problem statement, the overall objectives and specific objectives of this research, the research questions, the research scopes, and the significance of the research.

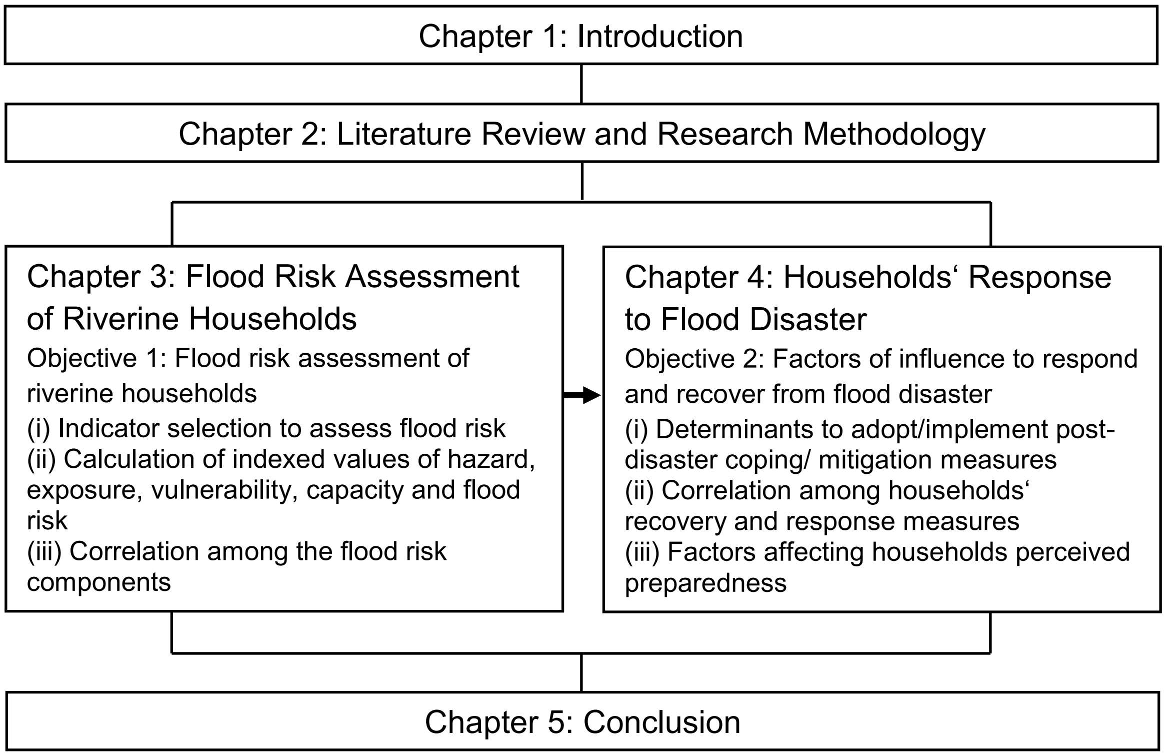

Figure 2 4: Research framework

Chapter 2 starts with the conceptual background. This conceptual model is the entry point for the riverine flood disaster risk assessment. Then, literature review section reviews existing literature on flood risk assessment and response measures to flood disaster and identifies the gap that frame this research. This chapter outlines the methodology of this research.

Chapter 3 introduces steps of riverine flood disaster risk assessment. It reflects the components, subcomponents, and indicators of the riverine flood risk assessment. The score of each indicator is derived from the field survey. The components and subcomponents are aggregated to develop a riverine flood disaster risk index. The risk scores are visualized using a geo-spatial technique. The first research objectives and its corresponding research questions are addressed in this chapter.

Chapter 4 presents empirical findings related to the second objective and its corresponding research questions. Households‘ responses to flood disaster are classified into post-disaster coping measures and post-disaster risk mitigation measures. This chapter provides the results that reflect household-level risk management measures. This chapter also identifies the factors of influence of households‘ perceived preparedness.

Chapter 5 presents the major findings and conclusion of this research. The policy recommendations, study limitations, and future research directions are included in this chapter.

2.4 Literature review on flood risk and household’s response to flood disaster

This section presents a review of the existing approaches of flood risk assessment and household‘s response measures to flood disaster.

A great deal of research has been conducted to understand the risk of floods and associated vulnerabilities on spatial scales using risk mapping. Bio-physical indicators are predominantly used for technical flood risk assessment (Toosi et al. 2019), while some researchers have assessed flood risk by combining spatial data on hazards and vulnerability within a geographic information systems interface (Wang et al. 2011; Danumah et al. 2016; Vojtek and Vojteková 2016; Sharma et al. 2018). To assess flood risk for the Tra Khuc River basin in Vietnam Vu and Ranzi (Vu and Ranzi 2017), hazard maps were combined with damage function. The approach of measuring social vulnerability to flood hazards using a multivariate technique was proposed by Mavhura et al. (Mavhura et al. 2017).

Numerous studies used an indicator-based assessment approach, such as for the Shire Valley in Malawi (Mwale et al. 2015), Myjava Basin in Slovakia (Solín et al. 2018), the coastal zone of Odisha in India (Sam et al. 2017), urban areas of Ghana (Yankson et al. 2017), and Pakistan (Rana and Routray 2018), among others. Several studies assessed households‘ vulnerability to flooding by combining variables concerning exposure, susceptibility/sensitivity, and capacity (Mwale et al. 2015; Sam et al. 2017; Yankson et al. 2017; Solín et al. 2018). Flood risk for an urban area was quantified by Rana and Routray (2018) as a function of hazard, exposure, sensitivity, and capacity. Using secondary data, Ntajal et al. (2017) assessed flood risk for the Mono River Basin in Togo. This study (Ntajal et al. 2017) produced useful maps on flood risk, hazard, exposure, vulnerability, and capacity & measures; however, locals‘ voice was missing. Despite the large amount of existing literature, there is still a scarcity of scientific literature on household-level flood risk assessments for riverine areas, which are usually located in hard-to-reach areas. Due to the paucity of data on flood hazards, exposure, and vulnerability, effective riverine flood risk reduction policies and programs cannot be formulated (Sam et al. 2017).

There is a growing body of empirical studies assessing household‘s response to flood disaster and the factors that determine to choose a particular response measure. Patnaik et al. (2016) examined consumption behavior and determinants of coping mechanisms for Indian households. This study found that changes in consumption behavior were associated with the expenditure to deal with post-flood impacts. Balgah et al. (2019) studied the determinants of coping strategies in Cameroon and found that the economic and financial capital had little influence on coping decisions. Using different quantitative techniques, Mabuku et al. (2019) investigated the influence of socioeconomic factors on choosing different coping and adaptation strategies, providing the examples of Namibia and Zambia.

Previous studies reported numerous factors that influenced household‘s choices of implementing mitigation measures. Takao et al. (2004) found flood preparedness depends on ownership of home, perceived fear of flooding, and the amount of damage from previous floods. Previous flood experience also shaped household‘s intention to engage in mitigation measures (Osberghaus 2015; Diakakis et al. 2018). Numerous studies researched on cognitive factors (risk perception and coping appraisal) that motivate households to take precautionary measures (Terpstra 2011; Bubeck et al. 2013; Poussin et al. 2014; Binh et al. 2020). Babcicky and Seebauer (2017) emphasized the role of informal social networks (friends, relatives and neighbors) to make a community resilient against flooding. Recent studies identified different socio-economic factors (age, sex, income, house ownership, marital status) that influenced households to implement mitigation measures (Okayo et al. 2015; Shah et al. 2017; Duží et al. 2017; Mabuku et al. 2019; Ahmad and Afzal 2020). Evidence showed that flood-affected households preferred to take emergency measures instead of relocating their houses in flood-free zones (Arlikatti et al. 2018). This underscores the need to assess household‘s mitigation behavior in order to develop effective flood disaster risk reduction measures. However, a few studies have contributed in the aspect of post-flood mitigation measures adapted by the riverine households who face recurrent floods (Shah et al. 2017; Ahmad and Afzal 2020). Studies suggested that actual flood preparedness may differ according to the local characteristics of flooding (Poussin et al. 2014).

Numerous studies revealed that factors such as household characteristics (Abramson et al. 2010; Chacowry et al. 2018; Akbar and Aldrich 2018), social capital (Akbar and Aldrich 2018), physical assets ownership (Tran 2015) are associated with disaster recovery. Based on a survey in Metro Manila, Philippines Francisco (2014) indicated that access to credit (borrowing) significantly reduce post-disaster recovery time. However, researchers have paid little attention to the post-disaster coping strategies to recover from the disaster.

There are extensive studies focusing on objective preparedness assessment in various natural hazard contexts (Paton et al. 2000; Paek et al. 2010; Kanakis and McShane 2016; Mabuku et al. 2018), but only very few studies investigated perceived (subjective) preparedness (Donahue et al. 2014; Sandanam et al. 2018). Moreover, there is little knowledge about which factors would enhance household preparedness (Donahue et al. 2014). As a result, risk managers face difficulty in designing effective risk reduction measures. Therefore, understanding people‘s perception of their available measures and own capacities are critical, since people act upon their subjective perception rather than objective capacity (Sandanam et al. 2018).

2.4.1 Research on flood risk and household’s response to flood disaster in Bangladesh

This sub-section synthesis the current literatures on flood risk assessment and household‘s response measures to flood disaster focusing on Bangladesh, spanning over last two decades.

(a) Flood characterization and flood risk mapping

Islam and Sado (2000a) carried out flood hazard assessment of Bangladesh using Normalized Difference Vegetation Index (NDVI), land cover category and elevation height and developed ‗flood risk map‘ (Islam and Sado 2000b) and ‗land development priority map for flood countermeasures‘ (Islam and Sado 2002) for the 64 administrative districts of the country. Population density, flood depth, flood frequency, landcover, physiographic features, and drainage network data were combined to prepare land development priority map.

The priority areas for flood mitigation in the southwest region of Bangladesh were mapped by Tingsanchali and Karim (2005). This study conceptualized flood risk as a function of flood hazard and vulnerability. Flooding depth and duration were considered as hazard factor, while vulnerability factor represent the density of population. The flood risk map of southwest region was classified into four risk zones: low risk zone, moderate risk zone, high risk zone and very high risk zone.

Using remote sensing data, Dewan et al. (2007) assessed flood hazard for Dhaka and prepared flood hazard maps for 1998 flood. This study classified the hazard zones from least vulnerable to very high vulnerable and found that around 55.00% areas of Dhaka were located in high to very high hazard zones. This study proposed flood management strategies for Dhaka based on a comprehensive landuse planning.

The relationship between land cover changes and riverflows in Dhaka was studied by Dewan and Yamaguchi (2008). This study estimated inundation areas of Dhaka for the floods of 1988, 1998, and 2004 and identified 47.10% areas were flooded in 1988, while 53.00% areas in 1998 flood and 43.00% areas in 2004 flood.

The findings of this study revealed that rapid changes in land cover played an important role to increase flood intensity of Dhaka.

The study of Islam et al. (2010) examined the feasibility of using MODIS satellite images (low resolution: 500 m imagery) for the floods in 2004 and 2007 to prepare flood inundation maps and compared with a corresponding high-resolution (50 m) RADARSAT satellite images, and found a strong correlation of inundation derived from both sources. This paper contributes to the development of flood risk map using freely available MODIS satellite images. In contrast Hoque et al. (2011) prepared flood hazard map for northeast region (Maghna River Basin) of Bangladesh using RADARSAT inundation maps from 2000 to 2004, GIS data, and damage data. A set of damage maps were also developed using the damage data for 2004.

Masood and Takeuchi (2012) considered flood risk as a function of hazard (average depth of inundation) and vulnerability (percentage of area covered with house/living place and agricultural land) and prepared flood hazard and risk map for mid-eastern part of Dhaka using satellite images. The high-risk zones are almost located adjacent to river and in transitional zone between western built-up area and low-lying area.

The impact of sea level rise on flooding in coastal zone (western and central coastal zones) of Bangladesh was estimated by Bhuiyan and Dutta (2012) by considering flood inundation characteristics, and numbers of affected people and infrastructures by flooding. This study found that the studied regions are highly sensitive to the sea level change and will be aggravated with changes in climate variability.

Gain and Hoque (2013) prepared 100-year return period flood inundation and expected damage (direct economic damages only) maps for the eastern part of Dhaka City using geoprocessing techniques and a hydrodynamic model. This study suggested that changes in land-use and economic value of property can play an important role to minimize property loss due to flood.

Bhuiyan and Al Baky (2014) developed flood vulnerability maps for crops and settlements for Sirajganj Sadar Upazila (a sub-district of Sirajganj District) using satellite image and digital elevation data.

Roy and Blaschke (2015) assessed spatial vulnerability of Dacope upazila (a sub-district of the Khulna district in coastal zone) to floods using GIS weighted overlay. This study conceptualized vulnerability as a function of sensitivity and coping capacity of which sensitivity domains has 9 sub-domains (population and age, livelihood and poverty, health, water and sanitation, housing and shelter, roads and other infrastructure, land use/cover, environment, and gender) with 35 indicators and coping capacity domains has 3 sub-domains (assets, education, and economic alternatives) with 9 indicators. The data were collected from secondary sources and were ranked by 20 local experts using analytic hierarchy process method. The data were then transformed in GIS environment to visualize the vulnerability zone from a range of least vulnerable to most vulnerable zone.

Gusyev et al. (2015) simulate river discharge and flood inundation (Bangladesh portion only) of GBM basin using distributed hydrological Block-wise TOP (BTOP) model and a GIS-based Flood Inundation Depth (FID) model to develop the scenarios for present and future climates. This study found that both flood discharge and inundation areas will increase for the 50- and 100-year floods.

Suman and Bhattacharya (2015) studied on the food characterization of north-east region of Bangladesh and developed an integrated flood index for different return periods to investigate the probability of different flood hazard.

Flood risk of eastern part of Dhaka City was assessed by Gain et al. (2015) considering tangible, intangible, direct, and indirect categories of flood damages. This study adopted integrated approach that considered both physical dimensions (hazard and exposure) and social dimension (vulnerability) of flood risk. GIS and HEC-RAS (Hydrologic Engineering Center- River Analysis System) hydrologic model were used to prepare flood hazard map, whereas vulnerability assessment considered adaptive and coping capacities, and sensitivity. The study found that advanced early warning systems can significantly reduce all categories of damages including number of human injuries and deaths.

Barua et al. (2016) prepared district-wise multi-hazard map for four major disasters of Bangladesh (flood, tornado, earthquake, cyclone) and subdivided the whole country into three zones based on the multi-hazard scores. This study used historical database to develop intensity scales and damage risk levels.

A coastal vulnerability index for multi-hazard was developed by Islam et al. (2016) by using seven physical parameters including geomorphology, coastal slope, shoreline change rate, rate of sea level change, mean tide range, bathymetry, and storm surge height. This study calculates only physical vulnerability of coastal zones to sea level rise and found that 20.1% of the coastline is very highly vulnerable, 17.5% of the coastline is highly vulnerable whilst 21.2% is very low vulnerable.

The study of Ali et al. (2018) determined the characteristics of flood hazard in Sirajganj district and related damage using water level data of river stations, flood inundation map for different return periods and a flood depth versus damage curve.

Islam et al. (2019) investigated inundation pattern inside a polder (Polder 48 in Kuakata) due to dike breaching and generated ―flood risk map" and ―probabilistic flood map" to identify critical locations which are at high risk and where there is a higher probability of flooding. This study developed several worst case scenarios for flood inundation.

The study of Binata et al. (2019) proposed danger levels for pre-monsoon flash flood for northeast haor region by analyzing flood frequency and elevation of the floodplain. This study found remarkable differences between existing monsoon flood danger levels and proposed pre-monsoon flash flood danger levels. This study suggested incorporating their proposed danger levels for flash flood warning to minimize loss and damage of Boro rice cultivation.

Uddin et al. (2019) developed a methodology to map inundated and damaged areas using remote sensing data for floods in 2017. This study determined the extent of cropland damaged by flood which was the highest in August 2017 and the most affected locations were Rangpur and Sylhet division.

Philip et al. (2019) investigated attribution of 2017 flood from meteorological (using precipitation data) and hydrological (using discharge data) perspective in the Brahmaputra basin. The climate models reveal that the risk of high precipitation will increase by more than 1.7 with an increase of temperature of 2 ºC since pre-industrial periods. On the other hand, hydrological models project an increase of high discharge by a factor of 1.5 in a 2 ºC warmer since pre-industrial times.

Using Index for Risk Management (INFORM) framework Haque et al. (2020) assessed risk of natural hazards for coastal districts. The risk was estimated by combining indicators related to hazard and exposure, vulnerability, and lack of capacity derived from the secondary sources.

(b) Research on understanding household's risk and vulnerability

By applying household survey technique at Homna (a sub-district of Comilla district), Brouwer et al. (2007) investigated almost 700 households‘ vulnerabilities and coping strategies to flood risk through measuring households location from river, depth of inundation and cost of economic damage caused by flood. This study tested the effectiveness of existing preventive and adaptive coping strategies in terms of their impact on flood damage costs. They found that poor households were living more closely to river and thus the inundation level was higher that indicates higher level of exposure and inequality which in turn leads to higher flood damage.

Rayhan (2010) examined the complex relationship among poverty, risk (idiosyncratic and aggregate risks) and vulnerability of households to the flood of 2005 by using a sampled data of 600 households from Jamalpur, Sirajganj, Nilphamari and Sunamganj district. This study found that educated people and house owner were less poor and thus less vulnerable to both idiosyncratic risk and aggregated risk. This study suggested that poverty reduction could significantly increase household welfare and reduce vulnerability.

Azad et al. (2013) documented flood related human, social, structural and agricultural vulnerabilities of women in Sirajganj district through employing semi-structured interviews (with 185 individuals), focus group discussions and key informants interview techniques. Using the —Pressure and Release Model”, this study presented the root causes of vulnerabilities of this region.

Younus and Harvey (2013) developed a participatory rapid appraisals technique for flood vulnerability (V) and adaption (A) assessment and tested this method at Islampur upazila (a sub-district of Jamalpur district). Based on the seven-step V&A method, a total of 45 vulnerability issues were identified and further ranked as —high, medium, low and very low vulnerability”, while 40 adaptation issues were classified as –urgent, immediate and low priority”.

Islam et al. (2013a) carried out a multi multi-hazards risk and vulnerability assessment for Matlab municipality by integrating –Seriousness, Manageability, Urgency, and Growth Hazard Priority System” (SMUG) and —United States Federal Emergency Management Agency” (FEMA) models. This study ensured community participation in the risk assessment processes to design possible adaptation measures.

Islam et al. (2013b) conceptualized disaster risk as the sum of hazard and vulnerability and assess the risk of Assasuni upazila of Satkhira district. Hazard index includes frequency and level of devastation, whereas vulnerability index includes social and geographic factors. This study adopted all hazard approach and used the data generated through social survey and secondary sources.

The livelihood vulnerability was calculated by Toufique and Islam (2014) and Alam et al. (2017) through collecting the data on socio-demographics, livelihoods, social networks, health, food and water security, natural disasters and climate variability from 2558 households (saline prone, flood prone, flash floods prone, and droughts prone areas) and 380 households (Char communities and river-bank communities) respectively. Both study computed the livelihood vulnerability index and IPCC vulnerability index. Toufique and Islam (2014) found that flash flood zone was more vulnerable than saline prone, flood prone, and droughts prone zone because this zone is mono-rice cropped area with uncertain and limited livelihood opportunities. Alam et al. (2017) found that Char communities are more vulnerable than river-bank communities. The authors of these two papers were influenced by the methodology developed by Hahn et al. (2009).

Fakhruddin et al. (2015) studied on the community‘s response to flood warning systems in Sirajganj district and developed two flood risk maps of 5-days and 10-days forecast based on probabilistic hydrological models and community consultation. This study found that farmers‘ made decisions on harvesting based on their previous knowledge and scientific probabilistic forecasting helped farmers to verify their knowledge.

Xenarios et al. (2016) investigated households‘ exposure, sensitivity and adaptive capacity to climate change in the droughts prone Rajshahi region and flood-saline prone Barisal region. The vulnerability assessment was computed by combining the indicators of demographic, agro-economic, infrastructural, and bio-physical. This study assessed vulnerabilities of both regions using principal component analysis and identified drought prone zone was more vulnerable to climate change than flood-saline prone zone.

(c) Household's response to reduce flood risk

Thompson and Tod (1998) analyzed the impacts of flood in active floodplains (char land) and households' responses to reduce flood risk. Traditional responses to flood risk in rural areas of Bangladesh includes plinth raise of house, protecting side slopes of plinths with grasses, building raised platform (*macha*) within the home. This study offered potential benefits of small scale structural and non-structural flood-proofing measures to reduce the vulnerability of flood-prone communities especially char lands.

Hutton and Haque (2003) studied on the socio-cultural and psychological aspects of riverbank erosion in Sirajganj district using a questionnaire survey with 238 displaced persons. This study found that capacity of people to respond to environmental disasters is a function of physical forces and traditional socio-cultural belief systems.

Using household-level panel data Khandker (2007) identified that flood affected households adopted various measures such as borrowing cash, selling assets, skipping meals, or migrating from flood-affected areas during the flood in 1998. This study highlighted the role of institutions (public, private, and NGOs) to mitigate the adverse impacts of flood during or after the flood.

Rashid et al. (2006) pointed out that the adoption of coping strategies varies with the income level of the households in Bangladesh. Households with unstable income sources were more prone to adopt coping measures. This study suggested that reliance on ex-post coping measures can be reduced through ex-ante strategy of income diversification.

Mozumder et al. (2009) explored the role of private transfer (gifts) to response to 1998 flood and found that these types of informal insurance mechanisms contributed significantly to reduce household's consumption variability.

Rayhan and Grote (2010) conducted a survey with 1050 households from Nilphamari and Jamalpur district and concluded that crop diversification could reduce flood risk of rural farming households.

Paul and Routray (2010) identified that flood affected households adopted different indigenous preventive and mitigation measures to respond to flood, which were effective for normal floods. This study recommended that along with the indigenous knowledge, effective early warning system, external assistance and social capital can enhance the capacity of households and thus reduce households‘ vulnerability to flood.

Braun and Abheuer (2011) found that regardless of their vulnerability of urban slum dwellers of Dhaka city, mutual help and support during and aftermath of a flood disaster helped them to cope and respond efficiently.

Shah et al. (2012) studied on the farm households‘ responses after getting warning for flood in 2007 in Gaibandha district. This study found that economic factors had greater influence on the responses taken by the farm households.

Sultana and Rayhan (2012) conducted questionnaire survey with flood affected households in the aftermath of 2005 flood and found that households started coping with borrowing money from informal sources after floods, and gradually started emptying cash savings and selling assets as the duration of flood increases.

Choudhury and Haque (2016) assessed adaptive capacity of wetland communities to flash floods and found that household‘s response to reactive, proactive and transformative actions were shaped by local institutions and power structures. While Smith and Frankenberger (2018) identified a strong role of absorptive capacity to minimize exposure of households to the flood and recovering from the impacts in the aftermath of flood in northern Bangladesh.

Using 2010 Household Income and Expenditure Survey data Karim (2018) examined the impacts of recurrent flooding on households‘ income, expenditure, asset, and labor market outcomes. This study compared the impacts of flooding on economic development and found negative impacts on agricultural income and expenditure.

Chowdhooree and Islam (2018) studied on the flood resilience processes of riverside settlements of Bhairab Upazila. This study identified ―coordination and cooperation among government, NGOs and donor agency” and ―awareness on flood vulnerability” act as key factors of flood resilience. The survey respondents identified NGOs as key actors to enhance their resilience to riverine floods.

Kamal et al. (2018) investigated vulnerability and resilience of households of flash flood prone Sunamganj district following the pre-monsoon (March-April) flood in 2017 and identified that poor people were more adaptive to flood than rich and middle-income households. This study further revealed that high-income households tend to be less vulnerable but they are less adaptive. Women are more vulnerable and less resilient to flood disaster. Interestingly, this study identified that households who took a loan from local money lenders (*Mohajon*), relatives, neighbors and other informal sources were found to be more adaptive and tend to migrate to cities to pay back their debts.

In a study conducted by Gros et al. (2019) on forecast-based unconditional cash transfer (BDT 5000) among the flood-prone households in Bogura district and found that households who received cash grants their response was better during or the aftermath of the flood in July 2017 in terms of food access, reduced sales of valuable assets, and lower psychological stress than those who did not receive grants. However, these benefits were not sustained after the second peak in August 2017.

Ferdushi et al. (2019) found fishing, homestead gardening, migration, and changing crop planting time were the most adaptation measures practices by the flash flood prone farm-households of Sylhet district. This study recommended providing government-assisted credit to affected farm households to mitigate losses from flood and to enhance livelihood outcome.

Sultana et al. (2019) investigated household‘s responses for two successive floods (in 2016 and 2017) in northern Bangladesh and found reduced food intake, borrowing cash, sold assets, and migration were the most common coping measures. This study further highlighted the role of embankments, local community-based organizations, and seasonal-migration to enhance the resilience of vulnerable households.

In the context of island Char of Gaibandha district, Sarker et al. (2020) found migration, changing cropping pattern, homestead gardening, and tree plantation were the most common adapted strategies. This study further reported that planned adaptation measures in the Char areas were lower than their expectation.

(d) Summary of literature review

From the above reviews of existing literature in Bangladesh it is found that a number of studies have been carried out on flood risk and vulnerability assessments, including risk mapping using satellite imagery at the national level (Islam and Sado 2000b; Islam et al. 2010); at the regional level, such as the southwest (Tingsanchali and Karim 2005) and northeast regions (Hoque et al. 2011); and at the local level, such as Sirajganj district (Bhuiyan and Al Baky 2014) and Dhaka city (Dewan et al. 2007; Masood and Takeuchi 2016). The risk of floods was also estimated using hydrological and hydrodynamic modeling (Bhuiyan and Dutta 2012; Gusyev et al. 2015). Almost all of these studies were conducted in the southeastern coastal region and the mid-south region of the country.

In Bangladesh, earlier studies researched coping strategies in situations such as riverine floods (Brouwer et al. 2007; Ferdous and Mallick 2019), riverbank erosion (Hutton and Haque 2004). However, a very little research has been carried out on model-based analysis of households‘ coping strategies against flood disaster (Ninno et al. 2003; Rashid et al. 2006). There are several recent studies focused on riverine areas of Bangladesh looking at different issues of households‘ perception and adaptation strategies (Sarker et al. 2020); coping strategies with food insecurity

(Alam et al. 2020); migration decisions due to natural disasters (Islam 2018); livelihood vulnerability (Sarker et al. 2019), and livelihood resilience (Alam et al. 2018), but little is known which factors influence riverine households, especially in the context of transboundary river floods, to adopt post-disaster coping measures.

While a number of studies were carried out in the Teesta floodplain looking at issues of food security (Arfanuzzaman and Ahmad 2015), potential use of the Teesta River water (Islam and Higano 2001; Wahid et al. 2007; Mullick et al. 2013), role of local institutions in the adaption process (Karim and Thiel 2017), and flood adjustment strategies (Mondal and Islam 2017; Ferdous and Mallick 2019), no study to date has examined determinants of household's response to flood disaster. Until now, there is no known study of the Teesta River Floodplain in Bangladesh (TRFB) that assessed riverine flood disaster risk and its components. Keeping in view the current research gaps, this study, therefore, aims to examine flood risk of riverine households and to identify the key determinants to choose the post-disaster coping and mitigation measures.

2.5 Research Methodology

This section describes a detailed methodological consideration of this study. It first presents a description of Teesta River Floodplain in Bangladesh. The geography, hydro-meteorology and socio-economic condition of the study area are also described in this section.

2.5.1 Study area

The Teesta River Floodplain in Bangladesh is located in the northern region of the country. This region is characterized by a higher rate of poverty and seasonal food insecurity (Islam 2016). The TRFB stretches between the old Himalayan piedmont plain on the west and the right bank of the Brahmaputra River on the east, and covers a major portion of Rangpur and its adjoining regions (Figure 2.5). The TRFB covers an area of 10,298 km^2 and includes around 14% of the total cultivated land of the country (Mondal and Islam 2017). The TRFB has low and generally smooth ridges with grey stratified sand and silt and gets flooded in the rainy season. Teesta River, Dudhkumar River, and Dharla River cut through the Teesta floodplain.

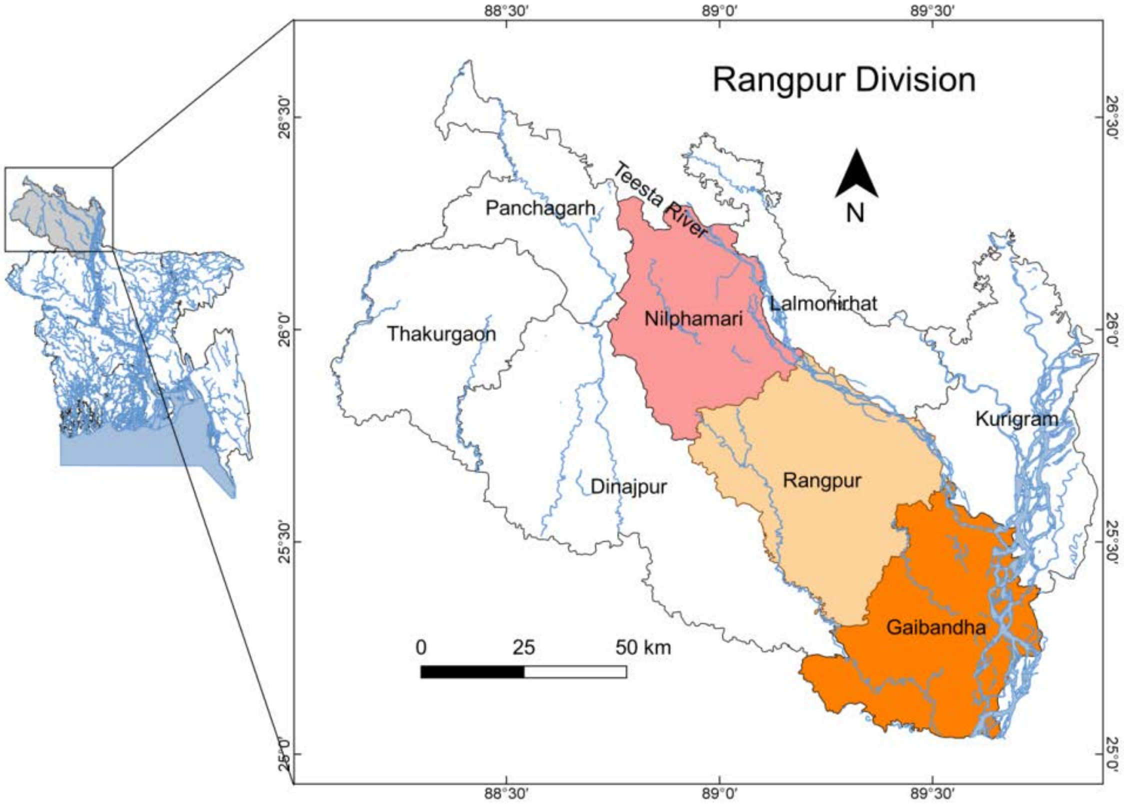

Figure 2 5: Map of Rangpur division and location of the Teesta River in Bangladesh

The Teesta River is the most important river in the TRFB (Figure 2.5), and Bangladesh is located at the lower riparian zone of the Teesta River basin, making it an exemplary case for assessing riverine flood disaster risk in this study. It is the fourth largest transboundary river of Bangladesh after Ganges, Brahmaputra, and Jamuna. The Teesta River originates in Chitamu Lake in the Himalayan range in Sikkim, India at an altitude of about 7,200 m. It is around 414 km long and travels through the highlands in Sikkim, the hills of West Bengal, and the floodplains of West Bengal, India (83% catchment is located in India), and Bangladesh (17% catchment is located in Bangladesh) (Islam 2016; Mondal and Islam 2017). This river enters Bangladesh at the Kharibari border of Nilphamari district, and flowing through the five northern districts of the country (Nilphamari, Lalmonirhat, Kurigram, Rangpur, and Gaibandha districts of Rangpur division) (Figure 2.5).

People lives along the banks of Teesta River are exposed to uncertain floods, bank erosions, and periodic droughts. Among these disasters, floods are the most destructive for the riparian people. Households adopt a variety of measures to manage flood risks. The primary causes of floods in the Teesta River are river overflow, particularly due to the release of water from the barrage, erratic rainfall, riverbank erosion, and poor drainage. The most recent disastrous floods related to the Teesta River were in 1998, 2004, 2008, 2017, 2019, and 2020. The flood in 2017 was particularly devastating, causing severe damage to houses and crops, and more than fifty casualties in those five northern districts (NDRCC 2017). Around 2.5 million people were affected, over 250,000 houses were destroyed, and around 160,000 hectare croplands were damaged (Table 2.1). Roads, bridge, and flood protection embankments were also severely affected.

Table 2 1: Losses and damages in August 2017 flood in the study areas (Source: Compiled from NDRCC, 2017)

Types of damaged	Nilphamari	Rangpur	Gaibandha	Lalmonirhat	Kurigram
Population affected	164936	808555	572731	413600	517076
Houses damaged	23517	NA	122157	9169	88969
Damaged cropland (Hectare)	12895	38815	27167	31400	50031
Reported death (people)	6	6	13	6	23
Schools damaged	111	200	391	323	684
Damaged road (in km)	589	165	630	NA	164
Destroyed bridge/ culverts	140	29	23	NA	23
Embankment damaged (in km)	20	5	43	2	24
Tubewell underwater	1084	1815	3031	8630	12719

NA: Not Available

At Dalia station of Teesta River, the water level crossed the danger level four times and reached at the highest recorded peak (53.05 m) on 13th August 2017. In 2020 there was another recorded flood. This revealed that flood is a regular event for the people who reside along the Teesta Riverbank. Daily water level data of Teesta River at Dalia station in 2017 was plotted in Figure 2.6.

The maximum and minimum monthly average temperature for Rangpur station in 2017 (Figure 2.7) was 30.2°C and 20.9°C, respectively, with a maximum day temperature of 37°C in July and a minimum of 6.6°C in January (Source: Bangladesh Meteorological Department). The average annual rainfall in this region is slightly over 1,900 mm.

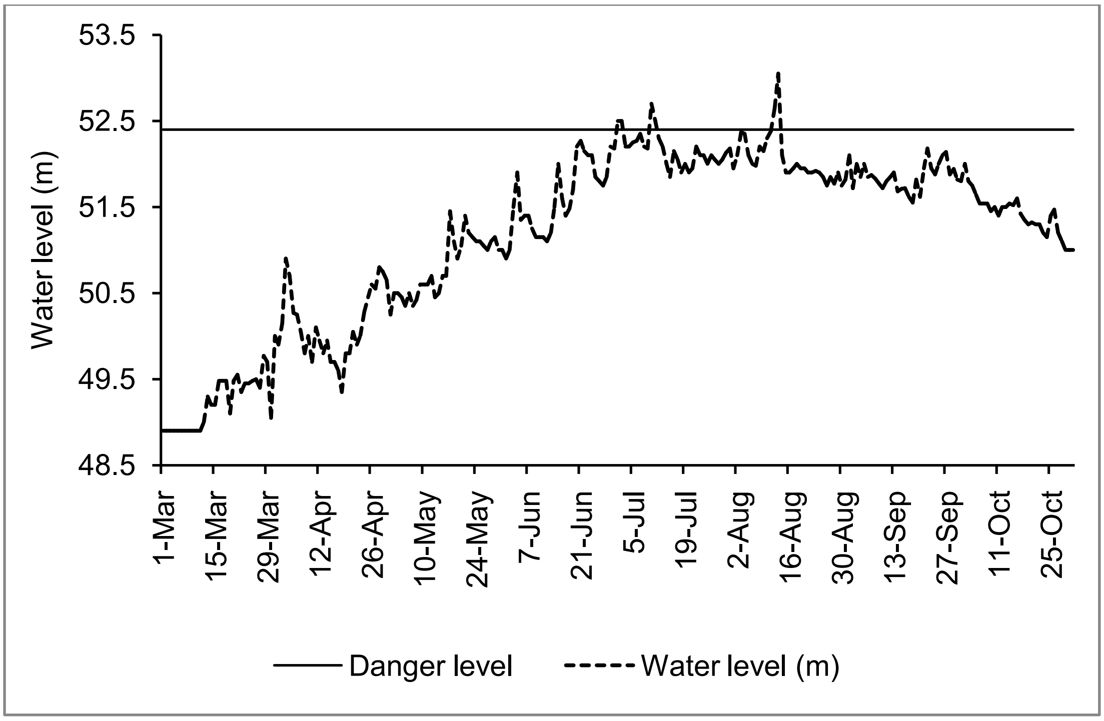

Figure 2 6: Variations in water level of Teesta River at Dalia station in 2017 (Source: Prepared from Bangladesh Water Development Board)

Note: Danger level 52.4 m in 2017

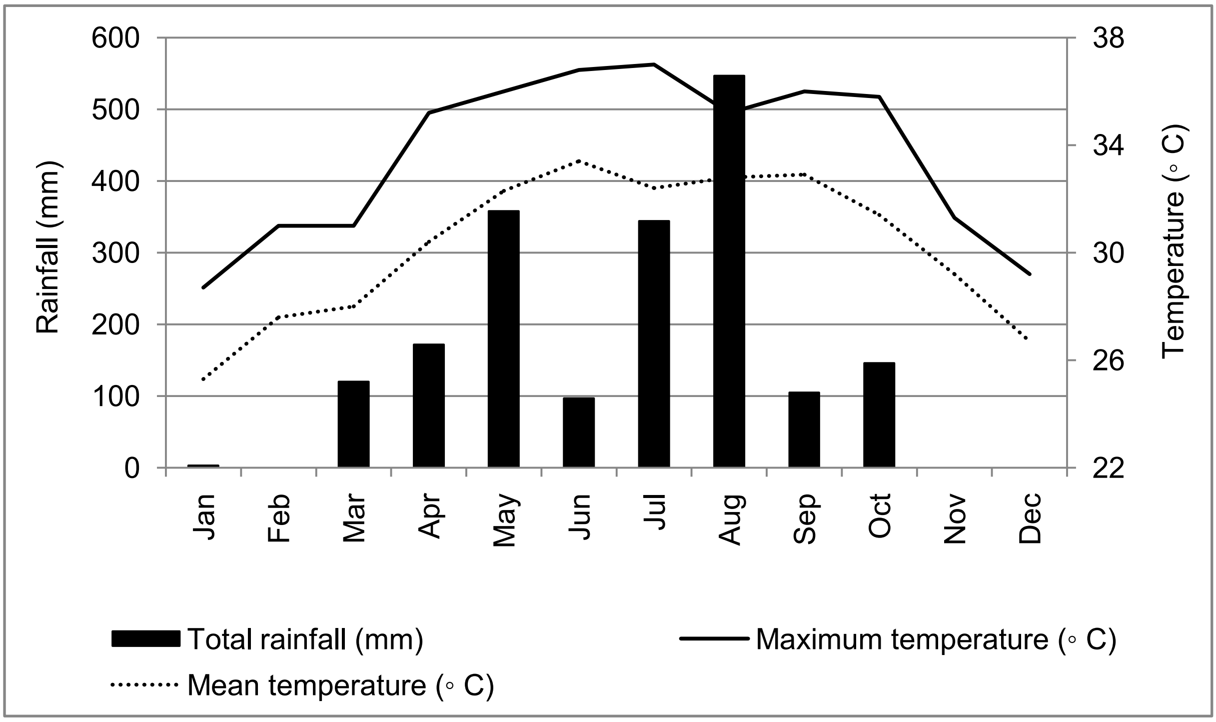

Figure 2 7: Monthly total rainfall (in mm) and monthly maximum and mean temperature in 2017 at Rangpur Station (Source: Bangladesh Meteorological Department)

2.5.2 Data sources

(a) Primary data sources

The primary data sources for this study were the riverine people (semi-structured questionnaire survey, focus group discussions, and in-depth interviews) and local stakeholders (focus group discussions, in-depth interviews).

(b) Secondary data sources

The socio-demographic data used for this study were obtained from the 2011 Population and Housing Census of the Bangladesh Bureau of Statistics (BBS). The temperature and rainfall data were collected from the Bangladesh Meteorological Department, whereas water level data for Dalia Station were collected from the Bangladesh Water Development Board.

2.5.3. Survey locations and sample size determination

(a) Selection of the survey locations

The right bank of the Teesta River in Bangladesh was selected purposively for this study. The reason behind the selection of the right bank was that Brahmaputra River and Dharla River are located on the left bank site of the Teesta River (Figure 2.5). To understand the impact of the Teesta River floods, only the right bank site was chosen. There is no large river on the right bank site. Nilphamari, Rangpur, and Gaibandha districts are located on the right bank of Teesta River. These three districts were considered for the next stage of sampling (Figure 2.8). It is noted that Nilphamari district is located in the upstream, Rangpur district in the midstream, and Gaibandha district in the downstream segments of the right bank of the Teesta River in Bangladesh.

Next, the upazilas of these districts were selected considering two aspects: (i) the upazila is located on the bank of the river, and (ii) it is affected by only the Teesta River. Since only seven upazilas (among 21 upazilas) meet these criteria, three each from Nilphamari district (Dimla, Jaldhaka, and Kishoreganj) and Rangpur district (Gangachara, Pirgacha, and Kaunia), and one from Gaibandha district (Sundarganj) (Figure 2.9) were included for further sampling. From each district, one upazila was chosen. To select the upazila from Nilphamari and Rangpur districts, a single criterion was used: the upazila that is located at the entry point of each administrative district boundary. Finally, Dimla upazila was selected from Nilphamari district, Gangachara upazila from Rangpur district, and Sundarganj upazila from Gaibandha district (Figure 2.9). In the next stage, one union was selected randomly from each sub-district. In order to assess risk from riverine flooding, only unions located along the banks of the Teesta River that are exposed to sudden and recurrent floods from the river were taken into consideration. At the end of this stage, three unions were selected for this study (Figure 2.9): Purbachhatnai union from Dimla upazila, Gajaghanta union from Gangachara upazila, and Belka union from Sundarganj upazila (steps of selecting survey location are given in Figure 2.9).

These three unions - Purbachhatnai, Gajaghanta, and Belka-are located around 65 km, 12 km, and 40 km (on a straight line on Google maps) away from the Rangpur divisional city, respectively. Floods are recurrent in these three unions and mostly caused by the overflow of the riverbank.

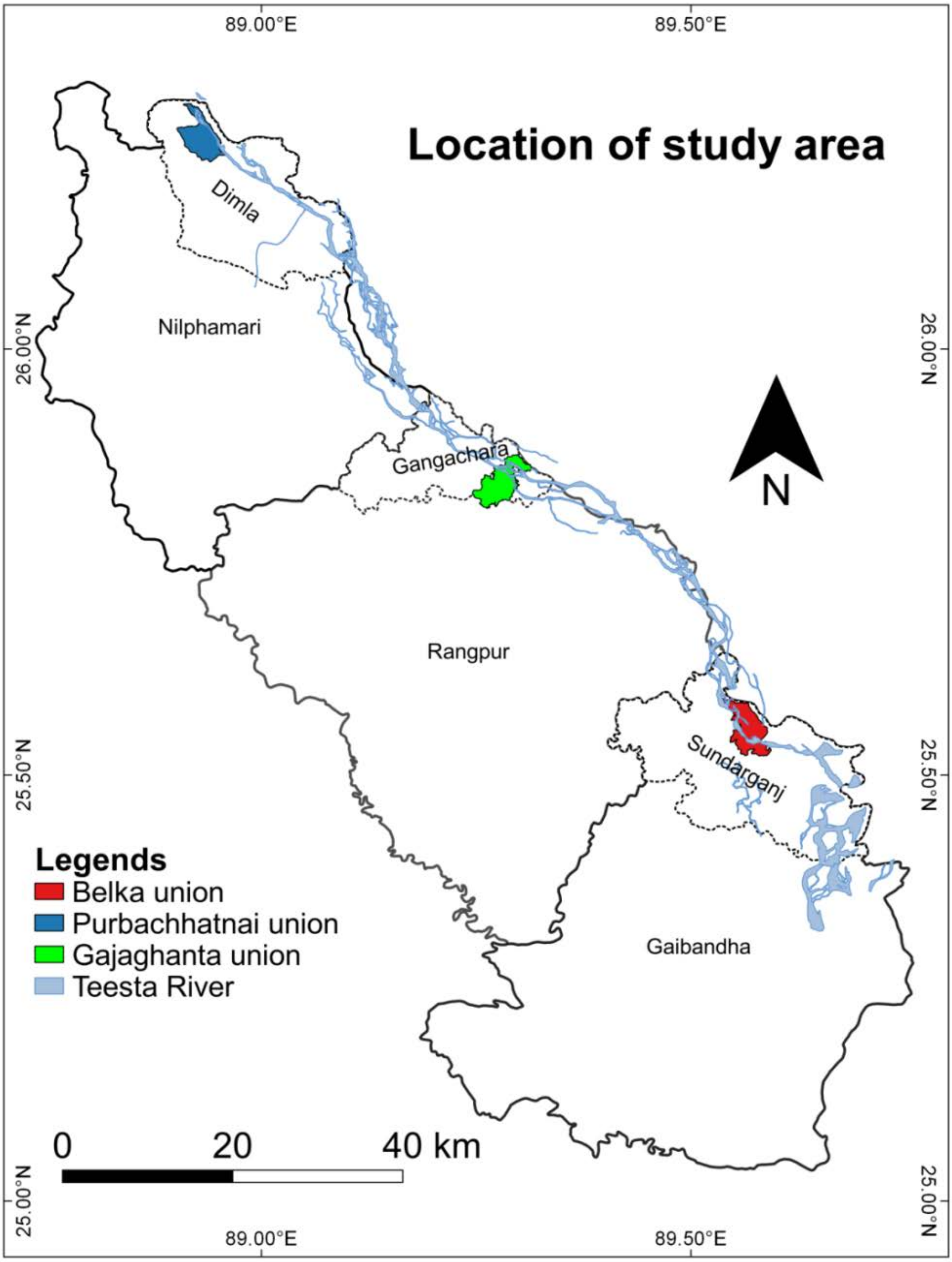

Figure 2 8: Map of the survey locations

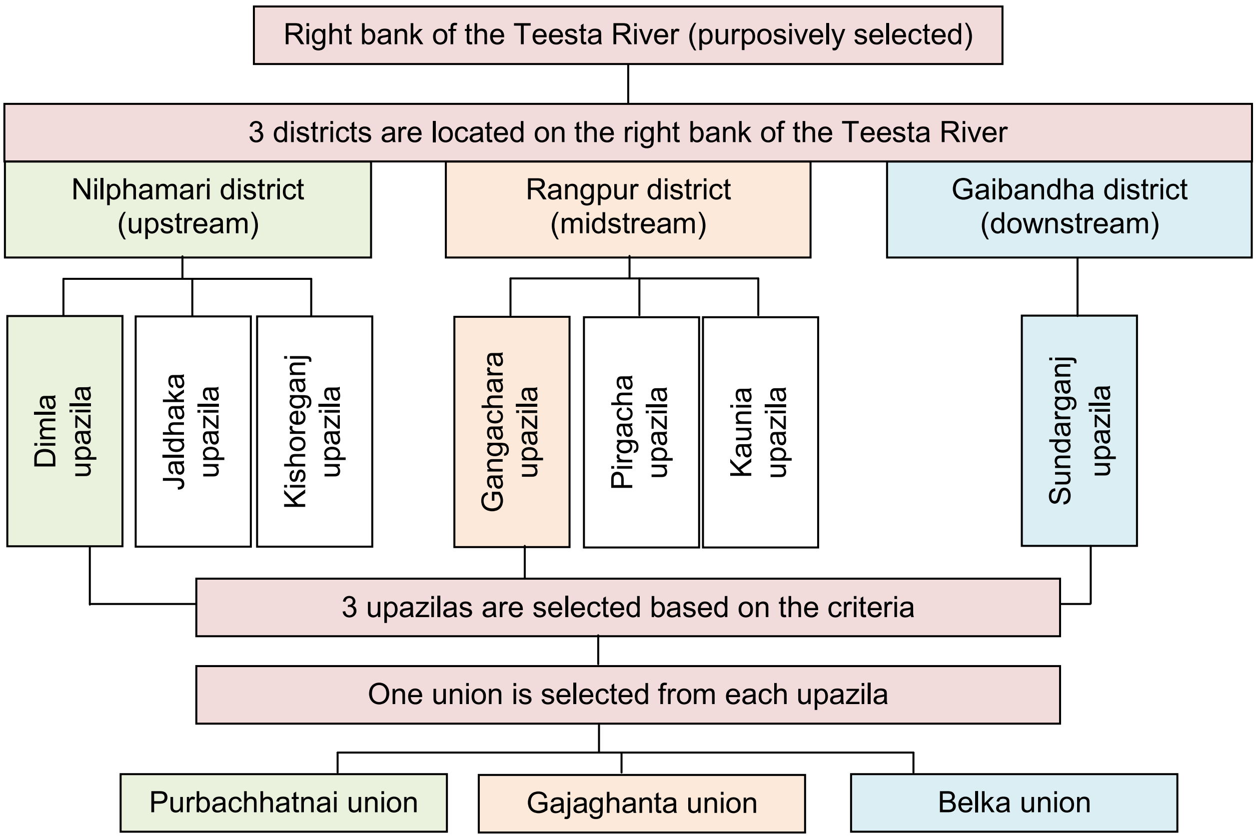

Figure 2 9: Selection of survey locations

(b) Sample size determination

According to the Bangladesh Bureau of Statistics (BBS 2013), the total number of households for these three unions was 18,972 (Table 2.2). Using Cochran‘s Formula (1977) Equations 2.2 and 2.3, the optimum sample size for this study was 377, with a 95% confidence level and 5% margin of error (confidence interval). Subsequently, proportional allocation methods were used to calculate the sample size for each survey locations. Therefore, the optimum sample sizes for each area were: 68 for Purbachhatnai*,* 158 for Gajaghanta, and 151 for Belka (Table 2.2).

$$n_0 = \frac{Z^2 pq}{e^2} \quad (2.2)$$

$$n = \frac{n_0}{1 + \frac{(n_0 - 1)}{N}} \quad (2.3)$$

where,

n= Sample size for a given population

n_o= Sample size for infinite population

N= Population size

Z= Z value (e.g. 1.96 for 95% confidence level)
p = percentage picking a choice expressed as a decimal (0.5 used for sample size needed)
e = confidence interval

Table 2 2: Study area and population size (Source: Bangladesh Bureau of Statistics)

District	Upazila	Union	Total households	Sample households*
Nilphamari	Dimla	Purbachhatnai	3435	68
Rangpur	Gangachara	Gajaghanta	7929	158
Gaibandha	Sundarganj	Belka	7608	151
Total			18972	377

Note: *Calculated using Cochran's Formula

Table 2 3: Key characteristic of the surveyed locations

Category	Purbachhatnai	Gajaghanta	Belka
Area (km^2)	18	19	21
Total population	14482	27065	33275
Total households	3435	7929	7608
Location along the Teesta River	Upstream	Midstream	Downstream
Major disaster[1]	Flood, riverbank erosion	Flood, riverbank erosion	Flood, riverbank erosion
Infrastructure measures[2]	Earthen and concrete embankment, spurs were found during the field visit, some areas were exposed to river	Earthen and concrete embankment, embankment reconstruction was going on during the field survey, few areas are exposed to river due to bank erosion	Exposed to Teesta River, no protection embankment was found in the field survey locations

Note: km^2 = square kilometers; 1 = Based on KII and FGD; 2 = Based on personal observation

According to the 2011 census, the literacy rate in the studied upazila was below the national average (BBS 2013). The sex ratio (number of males per 100 females) for Dimla, Gangachara, and Sundarganj was 101, 102, and 96, respectively. The average household size for Gangachara and Sundarganj was below national average. The highest percentage of population that had access to electricity and sanitation was found in Gangachara (Table 2.4).

Table 2 4: Upazila-wise socio-demographic and physical characteristics (Source: Bangladesh Bureau of Statistics)

Category	Bangladesh	Dimla	Gangachara	Sundarganj
Literacy rate (%)	51.5	42.2	43.2	40.6
Sex ratio (number of male per 100 female)	100.3	101	102	96
Average household size (in persons)	4.44	4.46	4.02	3.77
Access to electricity (%)	56.1	24.9	31.8	22.2
Sanitary toilet facilities (%)	63.5	27.7	42.0	27.5
Disable people	1.44	1.30	1.60	1.40
Distance between district headquarter and upazila by road (in km)	-	42	8	35
Length of embankment road (in km)	-	60.0	31.0	3.7
Total areas (in km^2)	-	326.74	269.68	369.85
Riverine areas	-	12.60	9.09	49.26

2.5.4 Questionnaire design

Three types of questionnaires were used for this study: households-level questionnaire (Appendix A), checklist for key informants interview (Appendix B), and check list for focus group discussion (Appendix C). The qualitative interviews (FGD and KII) focused on the characteristics (frequency, intensity) of flood, vulnerability and capacity of the riverine people. Information collected through these qualitative tools (FGD and KII) and through extensive reviews of empirical studies was incorporated to prepare the first draft the household level questionnaire, which was pre-tested and further revised. This pre-tested questionnaire was used to conduct face-to-face interviews with 377 households (Appendix A).

The survey questionnaire consisted of factors pertaining to flood hazard, exposure to flood, socio-economic vulnerability, capacity to absorb flood shock, and perception of the household. The questionnaire had twelve sections: (a) Demographic information, (b) Occupation, (c) Dwelling information, (d) Water and sanitation, (e) Means of transportation and communication, (f) Health status, (g) Energy sources, (h) Land ownership, (i) Food availability, (j) Social network, (k) Coping strategies during flood, and (l) Household preparedness and perception on flood risk (questionnaire framework presented in Appendix D, Figure 2). The questionnaire was designed with both closed and open questions. The original version of the questionnaire was developed in English and was translated into Bengali.

2.5.5 Primary data collection method

This study used a mixed method research design. Primary data were collected through a household-level questionnaire survey, focus group discussions, and key informants‘ interviews.

(a) Data collection through focus group discussion

In total three FGDs, one from each union, were conducted with the local inhabitants in June 2018. The respondents for the FGDs were selected purposively using a snowball sampling technique. These FGDs explored in detailed about the characteristics of Teesta River flood and their experiences to living with floods. The FGDs also investigated vulnerability profile and their available capacities to absorb the shocks from flooding.

The FGDs were more flexible and respondents were given more room to engage in the process to share their stories without any mislead or bias responses. The discussions were held in open space for a comfortable environment. Participation in the discussion session was also voluntary. In total, one discussion lasted between 60 minutes to 90 minutes. Total 31 respondents participated in the three discussion sessions. The age of the FGD respondents were in between 30 and 90 year.

(b) Data collection through key informants' interview

A total of twelve KIIs were conducted. Among them six KIIs were conducted prior to the household-level questionnaire survey with the local inhabitants in June 2018 in order to piece together a generalized picture of the flood risk in the targeted survey locations. The rest six were conducted during the post-household-level questionnaire survey, with the local leaders in April to May 2019, in order to obtain more in-depth information which is difficult to capture using structured questionnaire survey. The average duration of each interview was between 40 minutes to 60 minutes.

(c) Data collection through structured household questionnaire survey

A face-to-face interview is the best technique for collecting household-level data from rural areas of Bangladesh, which allows for a higher response rate compared to other tools (e.g. postal survey). The face-to-face interviews were conducted in April to May of 2019, with the assistance from ten university students (having academic background in disaster management), who were familiar with the geographical and socio-economic contexts of the study area. The research assistants were received four days of training before conducting the questionnaire survey. The households for the door-to-door surveys were selected using the systematic random sampling technique. Initially, the survey team went to the riverbank of each union from where the administrative boundary of a union begins. Each administrative union is composed of several villages. This study was conducted in those villages of sampled unions that lie along the bank of the Teesta

River. When the team arrived at the river bank (where the current flow of river begins) of each union, one member from the study team threw a pen in the air to get the direction of the first house to be surveyed.

To assign an interviewer for the first house selected, the name of each interviewer was alphabetized by their first name and each member of the team was assigned a unique identification number based on the alphabetical order of their name. The interviewer who received —ID_01" was assigned to collect data from the first sampled house. The next interviewer (ID_02) selected his starting point by choosing the fifth or sixth house from the first house along the river bank. In this way, all the interviewers identified their starting points to be surveyed along the river bank. Then each interviewer continued the survey on the vertical paths, moving to the third or fourth house next. On an average, one interviewer conducted a maximum of 10 household surveys on vertical paths. The rule of the thumb to select a house for the interview was to ask an anonymous person near the potential house to be surveyed whether this locality is exposed to flood hazard or not. If a house is empty or the resident is unwilling to participate in the survey, the interviewer moved to the next house and the next thereafter, following the same principles stated above. Although this study planned to conduct the interview with the head of the households, the study team noticed the difficulty of getting the household head in the randomly selected houses, even though the survey was conducted on holidays or weekends. To expedite the interview process, the study team continued interviewing the male or female head of the household or the elderly. Therefore, the survey was conducted in three unions and data collected from 377 households. The interviews were conducted in Bengali and the average duration of each door-to-door interview was 30 minutes.

2.5.6 Methods of data analysis

(a) Qualitative data analysis

I used a digital voice recorder to record the discussion (KIIs and FGDs) with the permission from the respondents. I also informed the respondents that the discussions will be translated to English. The recorded discussions were transcribed in Bengali at first, and then translated to English with cautions to maintain the originality of the emotions, expressions and feelings. The data were categorized into different themes and sub-themes and then illustrated with quotes to support detail insights on the discussions.

(b) Quantitative data analysis

Data collected through the structured questionnaire were coded and then analyzed using the Statistical Package for Social Sciences (SPSS, version 25). The Chi-square test of independence, bivariate correlation, principal component analysis (PCA), and logistic regression techniques were employed for the answers to the given research questions. The Chi-square test of independence was applied to determine the association between two nominal variables. The maps were prepared using Quantum GIS (free and open-source) platform.

The principal component analysis is a multivariate statistical technique used to examine correlation structure of groups of variables (Saisana and Tarantola 2002). This technique decomposes an original set of variables into a smaller number of linear combinations to produce principal components (Saisana and Tarantola 2002; Field 2013).

Binary logistic regression was used to examine the relationship between response measures and explanatory variables. I preferred logistic regression for the following reasons (Azen and Walker 2011; Stoltzfus 2011):

- First, logistic regression technique is suitable when the dependent variable is dichotomous in nature.
- Second, logistic model can accommodate different types of variables, including continuous, categorical, and ordinal.
- Third, logistic models are suitable for non-normally distributed data.

In the logistic regression model, the dependent variable becomes the natural logarithm of the odds when a positive choice is made (Ndamani and Watanabe 2016). In this study, the functional form of logistic regression as presented by Azen and Walker (2011) was used (Equation 2.4).

$$\mathrm{Logit}(\pi) = \ln\frac{\pi}{1-\pi} = \alpha + \beta X \qquad (2.4)$$

Where,
α = constant term;
β = a vector containing all regression coefficients and
X =a vector containing all of the predictor variables.

The model fitness was checked using Hosmer and Limeshow test value. The non-significant (*p* value >.05) Hosemer and Lemeshew chi-square test indicates a good fit for the logistic regression model (Azen and Walker 2011; Stoltzfus 2011). The results of the independent variables used in the logistic models are reported as odds ratio with 95% confidence intervals (Stoltzfus 2011). Multicollinearity among the independent variables was verified using a correlation analysis.

2.5.7 Response rate

Six households from Gajaghanta and four households from Belka were unwilling to participate in the interview. There were two withdrawal cases: one from Gajaghanta and another from Purbachhatnai. For the first case, the respondent was the newcomer at his current location, while for second case; the interview session had to stop at middle because he received the message that one of his relatives was died. Around 3% households did not participate in the study and were replaced with other households. Thus, the response rate for the questionnaire survey was 97%.

2.5.8 Ethical consideration

At the very beginning of the interview, the respondents were informed about the objective of the study and were asked whether they were interested in participating in the interview. Each of the interviews was conducted only after receiving verbal consent from the respondent. This study was approved by the Tokyo Institute of Technology Human Ethics Committee.

2.6 Chapter summary

This chapter reviewed relevant literature on flood risk and households' response to flood disaster and identified the current research gaps on riverine flood disaster risk. The practical details of data collection including technical and ethical issues were also described.

Chapter 3: Flood Risk Assessment of Riverine Households

3.1 Introduction

The purpose of this chapter is to assess flood risk of riverine households using empirical data. Documents reviews, focus group discussions, and key informants interview technique were used to identify potential indicators of flood risk assessment. A household-level questionnaire survey was conducted with the participation of 377 households in three selected unions from the right-bank of the Teesta River of Bangladesh. The indicators were aggregated to develop a composite riverine flood disaster risk index. Bivariate statistics was used to describe the relationships between two variables. Qualitative insights were included as quotes in the discussions.

This chapter is divided into several sub-sections. Following Section 3.1 “Introduction”, Section 3.2 discusses steps of riverine flood disaster risk assessment. The calculation of riverine flood disaster risk index is described in Section 3.3. The socio-demographic profile of the surveyed households describes in Section 3.4. The empirical findings of riverine flood disaster risk assessment are presented in Section 3.5 to Section 3.7. Section 3.8 summarizes the chapter outcomes.

3.2 Steps of riverine flood disaster risk assessment

There are two dominant paradigms through which risk is perceived: subjective (perceived) view and objective (statistical) view (Smith 2003). Assessment could be done probabilistically, scenario-based, or by composite indexing. The probabilistic risk assessment is characterized by inherent uncertainties that could provide good information on future disasters through providing the likelihoods and impacts of all possible scenarios (Kheradmand et al. 2018). Unfortunately, more high-quality data is required for probabilistic assessments, which are difficult to obtain in a developing country (Wang et al. 2011) like Bangladesh. On the other hand, the composite indicator-based method can summarize multi-dimensional concepts (OECD 2008), which are easy for decision makers to understand and interpret (de Brito et al. 2017). The indicator-based assessment approach also facilitates the targeting of interventions and allocation of scare resources, as well as enables the monitoring of the progress of policy interventions. Yet, there is difficulty in choosing the indicators (de Brito et al. 2017), which are usually selected based on previous studies and thus overlook local conditions (Rufat et al. 2015) that put people at risk of flooding (Mwale et al. 2015). There are a number of disaster risk assessment frameworks, such as the Disaster Risk Index, National Disaster Hotspot, INFORM index, and so on. However, national or regional scale data are aggregated and difficult to generalize on a micro-scale.

Given the objectives of this study and practicality of data availability, I adopted a composite index technique to calculate household-level riverine flood disaster risk for Teesta River floodplain in Bangladesh, which is the unique contribution of this study. A composite index is a mathematical combination of a set of indicators used to summarize the characteristics of a system (Saisana and Tarantola 2002).

Indicators for each subcomponent were selected based on information collected through the preliminary survey in 2018 and an extensive review of previous literature. In total, 47 indicators were selected to assess flood disaster risk for riverine people of Teesta River floodplain in Bangladesh (Table 3.1). In Table 3.1, I justified selecting individual indicators and the potential limitations of respective indicators. However, it did not include why other indicators were not included which are available in the literature. Initially, I selected the indicators through an extensive review of literature related to risk and vulnerability measurement. Finally, potential indicators were selected considering the local context. It is worth mentioning here that the indicators of hazard component were collected based on the subjective assessment of each household which represents ―characteristics of historical flood".

Figure 3.1 shows the stepwise flood risk assessment processes used in this study.

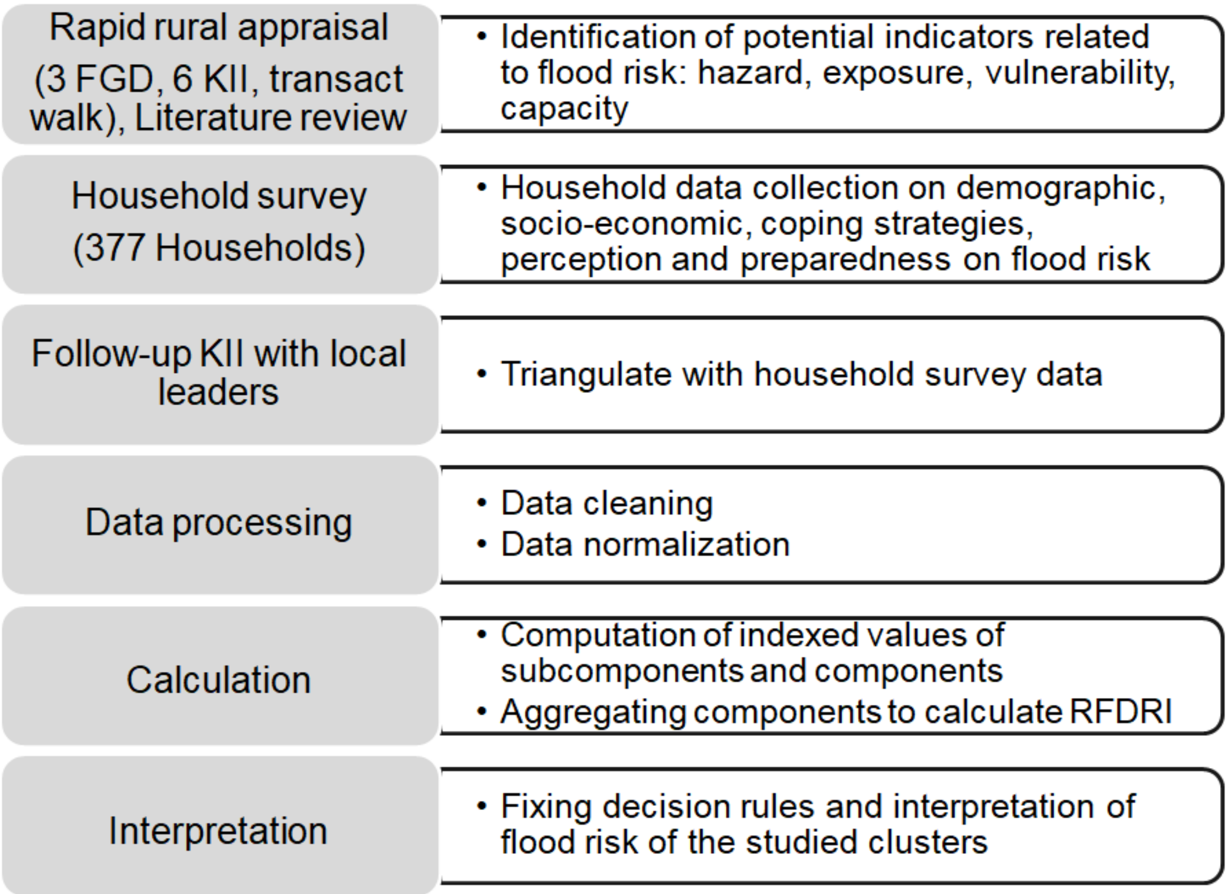

Figure 3 1: Step-wise flood risk assessment processes

Table 3 1: Indicators for RFDRI developed for Teesta River Floodplain in Bangladesh

Subcomponents	Indicators	Scales	Interpretation of indicators	Assumed functional relationships	Limitation	Source
Frequency of flood	Frequency of floods in the community in last 5 years	In numbers	Number of floods experienced by a household in the last 5 years while living in the Teesta floodplain.	Past flood events show that the area is prone to flood hazards. Higher number of flood events in past, higher risks of floods.	Recall bias, respondents could memorize the most severe floods only	[1–4]
	Frequency of home inundation in a year	In numbers	It is the maximum number of home inundation in a year experienced by a household in the last five years.	Inundation of homestead verifies the frequency of floods. Higher frequency of home inundation implies higher flood risk.	Recall bias; subjective definition of inundation	[4,5]
Intensity of flood	Duration of floodwater inside the home	Number of days	Maximum number of days a house was underwater in the last five years.	Longer duration of home inundation indicates severity of flood.	Recall bias	[5]
	Height of floodwater inside the home	In feet	Maximum height of floodwater inside their living room.	The higher the floodwater depth inside a home, the more severe is the flood.	Recall bias; reliance on subjective measurement of water depth	[5]
	Height of floodwater outside the home measured from the local roads	In feet	Maximum height of floodwater outside the home.	The higher the floodwater depth outside a home, the more severe is the flood.	Recall bias; reliance on subjective measurement of water depth	[5]
	Time to rise of floodwater	In hours	It is the lag-time which was reported by respondent as the time between their observed water level of the river and the time when the water level of the river overflowing its banks and inundates neighboring lands. Used as ordinal scale: 1 = more than/equal to 48 hours; 2 = 24 to 48 hours; 3= 13 to 24 hours; 4= 7 to 12 hours; 5= less than/ equal to 6 hours	A rapid rise of floodwater implies the higher intensity of flood.	Subjective definition of water rise period, recall bias	

Subcomponents	Indicators	Scales	Interpretation of indicators	Assumed functional relationships	Limitation	Source
Locational exposure	Location of home within 1000 meters from the riverbank	1=Yes, 0= No	Household who reported their house was situated within: 100 m of riverbank, 100 to 500 m of riverbank, or 500 to 1000 m of riverbank.	Exposure to flood increases with the proximity of human settlements to the riverbank.	Reliance on self-reported distance from the river	[5]
	Location of home in between levee and riverbank	1=Yes, 0= No	Household who reported their house was situated: in between levee and riverbank without raised platform; in between levee and riverbank with raised platform; outside of embankment.	Exposure to flood is higher for the houses which are located in between levee and riverbank than those located outside of flood protection embankment	Confusion about the definition of levee and raised platform	[5]
Human exposure	Family members infected by communicable disease or injured in the last 5 years due to flood	1=Yes, 0= No	These included water-borne/ vector-borne diseases such as cholera, typhoid, fever, jaundice, skin infections, gastric, etc or injured by underwater flooding objects, fragile building materials, snake/other insects‘ bites.	Injured or infected by communicable diseases due to previous flood implies that household is exposed to flood disaster.	Confusion about the classification of communicable disease, recall bias	[1,4–6]
Assets exposure	Damage of home in the last 5 years due to flood	1=Yes, 0= No	Household who reported their house was either completely destroyed or partially damaged due to flood.	Damages of house from previous flood indicate that household is exposed to flood.	Subjective definition of damage	[1,4,5]
	Lost household goods in the last 5 years due to flood	1=Yes, 0= No	Household who reported their household assets such as furniture, electric equipments, fuel wood, kitchen stuff, or clothing were damaged by flood.	Loss of household goods from previous flood indicates the house is exposed to flood.	Recall bias of the lost items	[4]
	Lost standing crops in the last 5 years due to flood	1=Yes, 0= No	Household who reported their standing crops were completely or partially destroyed by flood	Inundation of agricultural lands and loss of crops indicate exposure to floods	Confusion about the floods and flooding, recall bias	[1,2]

Subcomponents	Indicators	Scales	Interpretation of indicators	Assumed functional relationships	Limitation	Source
Socio-demography	Female headed household	1=Yes, 0= No	Self-explanatory	Female-headed households are more vulnerable than male-headed households because of limited assets ownership.	Confusion about the definition of household head where male member works outside or multiple wage earner	[1,2,6]
	Ratio of female population in the house	Ratio	It is the ratio of female members to the total members of the house	Women are more vulnerable than male because of their limited mobility, physical strength and other social norms	Confusion who are the members of the family for a large extended family	[3–7]
	Age dependency ratio	Ratio	It is the ratio of the members <15 years and >65 years to the members 16-64 years	Higher dependency indicates higher vulnerability of the household because children and elderly people are more vulnerable than adult and young people	Confusion who are the members of the family for a large extended family	[1,2,7–9]
	Illiterate household	1=Yes, 0= No	Highest level of education of a household was not above the primary level.	Households without formal education are vulnerable because of their limited understanding of information and communication	Reliance on self-reported data, not verify the level of education	[1,3,8,10]

Subcomponents	Indicators	Scales	Interpretation of indicators	Assumed functional relationships	Limitation	Source
Health condition	Chronically ill member(s) in the house	1=Yes, 0= No	Household who reported they had at least a member with chronic illness.	Chronic illness takes away resources from households that could have been used to reduce vulnerability.	Confusion about the definition of chronic disease, reliance on own judgment of respondents	[1,2,5,11]
	Disabled member(s) in the house	1=Yes, 0= No	Household who reported they had at least a member with disability.	Household with disable people are more vulnerable than household with no disabled people. Disable people also requires special assistance in the case of emergency.	Confusion about the classification of disability	[11,12]
Economic condition	Monthly income of the household less than national average*	1=Yes, 0= No	Household who have an income of below 13,353 Bangladeshi Taka.	Households living below the poverty level are more vulnerable and require more time to recover.	Difficult to verify self-reported income. Respondents may hide their actual income	[1,5,13, 14]
	Household has debt to payback*	1=Yes, 0= No	Household who reported they had debt to payback from the following sources: individual local lender, NGOs, banks, neighbors, friends, or relatives.	Households that have loans to pay back are more vulnerable to an unforeseen flood disaster.	Difficult to proof the debt status with pledge documents	[1,5,6]
	Household without access to any form of financial institutions	1=Yes, 0= No	Access to formal financial institutions includes ownership of account in banks or micro-credit organizations.	Vulnerability of a household increases due to the inaccessibility to financial institutes.	Household may not receive support when they need	[1]

Subcomponents	Indicators	Scales	Interpretation of indicators	Assumed functional relationships	Limitation	Source
Housing and amenities	Thatched/mud-made (*Katcha house*)	1=Yes, 0= No	Household who reported their houses were made up of the following material: thatches, wood, mud, soil, or dry leaves.	*Katcha* houses are more vulnerable and can be easily destroyed by floods than those made by corrugated iron sheet or bricks.	Confusion when several types of material are used in a same house	[3–5]
	Household without tubewell	1=Yes, 0= No	Self-explanatory	Vulnerability of household increases without a tubewell.	Tubewell water may be contaminated with other impurities (excessive iron, arsenic)	[3,4]
	Household without sanitary toilet	1=Yes, 0= No	Only sanitary latrine and ring slabs latrines were considered as sanitary.	Vulnerability of household increases without access to a sanitary toilet.	Reliance on self-reported data, some persons in a household may not use sanitary toilet	[2,4,5]
	Household without electricity (solar panel)	1=Yes, 0= No	Household who reported they did not have either access to electricity or rooftop solar panel.	Vulnerability of household increases without access to electricity.	In rural area, electricity facilities are not consistent even in regular period	[3–5]
Land ownership	Household does not have agricultural lands	1=Yes, 0= No	Household who reported they did not have lands to be used for agricultural purposes.	Agricultural land supports the recovery process.	Reliance on self-reported information, not verify	[1,3]
	Housing tenure	1=Yes, 0= No	Household reported that their house was currently located in rented/government/relatives‘ land.	Households living in rented/government/relatives‘ land have fewer options or less willingness to fortify their house, thus increasing vulnerability.	Reliance on self-reported information, difficult to understand types of agreement	[4,5]

Subcomponents	Indicators	Scales	Interpretation of indicators	Assumed functional relationships	Limitation	Source
Knowledge	Household has at least one member who received training on flood disaster management	1=Yes, 0= No	Household who reported at least one member from their family received training on disaster from government, NGOs, or other social organizations.	Knowledge and attitude towards disaster risk will be enhanced by receiving training from experts.	Reliance on self-reported data, not verify the outcome of the training program	[1,10]
	All adult family members know how to swim	1=Yes, 0= No	Self-explanatory	Swimming will increase capacity as it will help save lives and household items during a flood disaster.	Reliance on self-reported data, not verify	[5,15]
	Household has a good understanding of flood disaster warning*	1=Yes, 0= No	Household who rated their level of understanding on flood disaster as moderate to high.	Households who understand flood warning systems will be more aware about the onset of a flood	Confusion about the level, reliance on self-reported level of understanding	[5,11]
Emergency preparedness	Household has precautionary crop savings	1=Yes, 0= No	Household who reported they have either save crops or seeds to be used for future.	Households who save crops are more capable of absorbing flood disaster shocks.	Confusion about the purpose of saving crop/seed	[1,6]
	Household has emergency planning	1=Yes, 0= No	Household reported they have knowledge and understanding on what to do after getting warning.	Households who have emergency planning are considered better prepared than those without plan.	Reliance on self-reported level of understanding	[3]
	Household has a portable cooking stove	1=Yes, 0= No	Household who reported they have a portable cooking stove in their house to be used during flood emergency period.	Portable stoves are very useful when a house is underwater or for taking shelter outside the house.	Reliance on self-reported data, functionality of the stoves not check	[1]
	Household has precautionary money savings	1=Yes, 0= No	Households who reported they have cash savings in the following places: banks, NGOs or house.	Savings will increase capacity to cope with a flood and thus help in recovery.	Reliance on self-reported data, household may hide this information, confusion about the purpose of savings	[5]

Subcomponents	Indicators	Scales	Interpretation of indicators	Assumed functional relationships	Limitation	Source
Informational	Household received last flood disaster warning	1=Yes, 0= No	Household who reported they received flood warning for the last flood from the following sources: government official, local leaders, miking, mobile phone, TV, radio, newspaper, mosque, young people of house, NGO staffs, relatives, or neighbors.	If a household received warning in the last flood, means that there is a possibility of getting warning of coming flood.	Recall bias, most severe events are most likely to be remembered	[1,4–6]
	Household has mobile phone/ TV set/ radio at home	1=Yes, 0= No	Household who reported they owned the following information devices: mobile phone, television, or radio.	Ownership of communication devices, such mobile phone/ TV set/ radio can facilitate receiving early flood warnings or other useful information from friends/relatives.	Blackout may disrupt the usability of these electronic equipments	[1,5]
	Household has owned at least one vehicle*	1=Yes, 0= No	Household who reported they owned the following vehicles: bi-cycle, motor cycle, rickshaw-van, or auto-rickshaw.	Households with vehicles are more able to mobilize during evacuation and recovery.	Vehicle may dysfunction during disaster	[3,5]
Mitigation measures	Household has taken at least one structural mitigation measure to prevent a flood disaster	1=Yes, 0= No	Household who reported they implemented at least one structural mitigation measures such as raising the plinth of house, building home on natural levee, modification of house with strong materials after last flood.	Households who implement mitigation measures after the last flood are more capable to absorb flood shocks in future.	Confusion which mitigation measures will actually lessen risk, do not consider maladaptation	[4]

Subcomponents	Indicators	Scales	Interpretation of indicators	Assumed functional relationships	Limitation	Source
Livelihood diversification	Household has their family member(s) working outside of the flood prone area and sending remittance*	1=Yes, 0= No	Households who reported they are receiving remittance regularly from their family member(s) who works in urban areas. Only rural-urban migration was identified.	Regular remittance from outside of flood-prone zones builds confidence of household to absorb shocks.	Reliance on self-reported data, confusion about the type of residence of remitters	[1,2,5,6]
	Household has a non-farm income source	1=Yes, 0= No	Nonfarm income includes income from non-agricultural sources, such as petty trade, transport, construction, tailoring, services and others.	Agriculture is likely to be more affected by flooding than non-agricultural income. Income diversification through nonfarm income sources is associated with greater capacity.	Confusion on primary and secondary sources of income.	[5,6]
	Household has more than one earning member	1=Yes, 0= No	Household who reported they have multiple earning members in their family.	Having multiple earning members in a family is associated with increased capacity, since even if one income is cut off due to a flood, these households can survive on another	Confusion about the amount of income, family with one earning member can earn more than a family with more than one earning members	[3,5,10]
	Household with livestock	1=Yes, 0= No	Household who reported they owned the following animals: chicken, duck, cattle, or goats.	Owning livestock may help in the recovery process by selling or lending them, selling milk, or using them for agricultural purposes.	In most cases household requires to sell their livestock at a reduced price at the onset/ during disaster	[3]
	Household was able to recover from last flood disaster using their own resources	1=Yes, 0= No	Household who reported they were able to recover from the impact of last flood using their own resources and did not seek assistance either from government or NGOs.	Households who were able to recover from the last flood using their own resources are considered more capable.	Subjective judgment of recovery from the 2017 flood	[6]

Subcomponents	Indicators	Scales	Interpretation of indicators	Assumed functional relationships	Limitation	Source
Social network	Household has lived in the community (current house) for more than 5 years*	1=Yes, 0= No	Household who reported they have been living in their current house for more than 5 years.	Households living in their community for a longer time will be aware of evacuation routes and the geography of their locality, and also have a strong network with neighbors.	Reliance on self-reported data	[5,7,14]
	Household has received help from their community during a flood disaster response	1=Yes, 0= No	Household who rated community/neighbor cooperation during the last flood disaster as moderate to high.	Good cooperation from neighbors/ community helps household to cope better with floods.	Recall bias, reliance on self-reported data,	[5,10]
	Household exchanged goods or services with their neighbor in the last year	1=Yes, 0= No	Household reported they exchanged goods/services such as give fertilizer, provide transport support, take care of children, connect important people etc to their neighbors in the last year.	I assume that a household that exchanged goods/ services with their neighbors might have a stronger social network than who do not and are more capable.	Reliance on self-reported data, considers on bartering, it is a crude measure	[1,2,6]
	Household is affiliated with any organization	1=Yes, 0= No	Household who reported at least one member from their family is an active member of an NGO, CBO, government project or any other social organizations.	Affiliation with any organization gives more confidence in building a network and eventually increases household's capacity by getting more information and support from extended networks.	Confusion which organization could help to recovery	[1,10]

Note: * Indicator was modified based on the local context

1: Huong et al. 2018
2: Toufique and Islam, 2014
3: Yadav and Barve, 2017
4: Yankson et al. 2017
5: Rana, and Routray, 2018
6: Hahn et al. 2009
7: Cutter et al. 2003
8: Gain et al 2015
9: Szlafsztein and Sterr 2007
10: Nhuan et al. 2016
11: Ahsan and Warner, 2014
12: Balica et al. 2012
13: Holand et al. 2011
14: Walker et al. 2014
15: Jonkman and Kelman, 2005

3.3 Calculation of riverine flood disaster risk index

According to the conceptual framework, RFDRI consisted of four components, 16 subcomponents (Figure 2.2), and 47 indicators (Table 3.1). Each of the subcomponents is combined with several indicators (Table 3.1). Initially, indicators were grouped into various subcomponents to calculate the sub-indices of hazard, exposure, vulnerability, and capacity components. The indicators of different subcomponents were measured on different scales, and hence, it was mandatory to standardize the values to calculate an index for each subcomponent. Different techniques are available to normalize the data such as standardization (z-score), categorical rescaling, minimum-maximum (min-max) normalization (OECD 2008). Around 83% indicators (39 indicators) were dichotomous (yes/no) and rest of the indicators were continuous (5 indicators), categorical (1 indicator), and ratio (2 indicators) scale. The z-score normalization is suitable to avoid the extreme outliers in the data. Categorical rescaling assigns a score to each responses of an indicator with a defined range. These two normalization methods are not suitable for this study. The min-max normalization is appropriate if the data has no extreme outliers and guarantees that all features of the dataset will have the exact same scale. Considering the issues, I adopted a min-max method (Equation 3.1) to normalize indicators. The equation that I used here for conversions was adopted from the calculation of life expectancy in the Human Development Index (UNDP 2007). The min-max rescaling transformation has a range of zero (least) to one (most). Such approach is widely used by the other studies (Hahn et al. 2009; Toufique and Islam 2014; Yadav and Barve 2017; Huong et al. 2018).

$$\mathrm{Index, X_d} = \frac{\mathrm{X_{vd}} - \mathrm{X_{min}}}{\mathrm{X_{max}} - \mathrm{X_{min}}} \qquad (3.1)$$

Here, Index, X_d refers to the indexed value of a variable, X_{vd} is the original variable of a surveyed union d, X_{max} and X_{min} are the maximum and minimum values, respectively, for each variable among all the surveyed unions. The dichotomous variables (No/Yes) were assigned 0 and 1 based on the logic of the indicator. After the normalization of each indicator, the subcomponents were averaged using Equation 3.2.

$$\mathrm{S_d} = \frac{\sum_{\mathrm{i=1}}^{\mathrm{n}} \mathrm{IndexX_{di}}}{\mathrm{n}} \qquad (3.2)$$

Here, S_d= subcomponent value (for example, flood frequency, flood intensity, human exposure, assets exposure, etc.) for surveyed union d; $IndexX_{di}$ refers to the indicators, indexed by *i*, that make up each subcomponent; and n represents the number of indicators in each subcomponent.

Using the above method (Equations 3.1 and 3.1), the normalize values of each subcomponent for all surveyed unions were calculated. Subsequently, the components (hazard index, exposure index, vulnerability index, capacity index) of each union were averaged using Equation 3.3. In this study, I adopted a balanced weighting approach to calculate the index scores (Sullivan 2002; Hahn et al. 2009; Toufique and Islam 2014; Yadav and Barve 2017; Huong et al. 2018) of hazard, exposure, vulnerability, and capacity, assuming that all subcomponents of each component contribute equally to those components.

$$\mathrm{CI_d} = \frac{\sum_{i=1}^{n} \mathrm{W_{mi}} * \mathrm{S_{di}}}{\sum_{i=1}^{n} \mathrm{W_{mi}}} \qquad (3.3)$$

Where CI_d refers to the index value of a component for a union d, S_{di} are the subcomponents for a union d, W_{mi} is the weight of each subcomponent mi (W_{mi} equals the number of indicators in sub-component *mi*), and n is the total indicators in each component. It is noted that the composite index for each component lies between 0 and 1. In their study to calculate disaster risk, Bollin et al. (2003) summed up the index score of hazard, exposure, and vulnerability, and subtracted the index score from the capacity measures, as shown in Equation 3.4:

$$\mathrm{Risk} = (\mathrm{wHH} + \mathrm{wEE} + \mathrm{w\,VV}) - \mathrm{w\,CC} \qquad (3.4)$$

Where H, E, V, and C refers to the scores of Hazard, Exposure, Vulnerability and Capacity & Measures; *w* is the constant coefficient.

In my study, the components were aggregated by modifying the approach given in Bollin et al. (2003). Since the capacity to absorb flood shock contributes negatively to the overall index and reduces overall risk, the inverse value was used *(1-Capacity Index)* (Krishnamurthy et al. 2014) in this study. Once the index value of hazard, exposure, vulnerability, and capacity (thereof ―lack of capacity") were calculated, the resulting normalized values were averaged to calculate the RFDRI using Equation 3.5. Note that the inverse value of capacity was used during the calculation of aggregated RFDRI.

$$\mathrm{RFDRI} = \frac{\mathrm{Hazard_{Index}} + \mathrm{Exposure_{Index}} + \mathrm{Vulnerability_{Index}} + \mathrm{Lack\ of\ Capacity_{Index}}}{4} \qquad (3.5)$$

The RFDRI value ranges between 0 (least) and 1 (most). Through this way, the risk will not get any negative value. Using the same procedure, the flood risks of individual households were calculated. The range of RFDRI values were then categorized into three different groups using the tertiles method: low risk (Q1), medium risk (Q2), and high risk (Q3). Using the same tertiles method, the degree of hazard (thereof ―characteristics of historical flood"), exposure, vulnerability, and capacity were also calculated. The Pearson‗s Chi-square (χ^2) test was used to determine the differences among the studied areas for each index (hazard, exposure, vulnerability, capacity, and risk).

3.4 Socio-demographic profile of the surveyed households

Table 3.2 summarizes the descriptive statistics on socio-demographic profiles of the 377 households. The age of the household head ranged from 22 to 90 years, with a mean age of 49 years (SD=14.2). The majority of the households were male headed (95%). The average household size was 4.8, which was higher than the national average (4.4 persons). In this study, a household was considered illiterate if the highest level of education in that household was at or below the primary level. It was found that 34% households were illiterate. The percentage of illiterate people was lower in Gajaghanta compared to the other regions. In all areas, agriculture (63%) was the dominant source of livelihood, followed by daily wage labor (23%). Around one-third of the households had income from nonfarm sources. Among the agricultural occupants, 24% (58 out of 238) had nonfarm income sources. Almost 84% of the sampled households in Gajaghanta were living on their own land, the highest in the region. According to BBS (BBS 2017), the average monthly income of rural households in Bangladesh is 13,353 Bangladeshi Taka (BDT) [1 USD= 84.25 BDT, as of April 2019 (Source: Bangladesh Bank)]. The average monthly income per households was 8,977 BDT (SD=5113; range 1000 BDT to 40,000 BDT) at the time of the interview which was below the national average. Around 85% of households reported an income that was lower than the national average. Around 48% households did not have any agricultural lands. The majority of the agricultural landless households‘ (44%) income was less than the national level. The majority of the surveyed households (85%) were located within 1000 m from the riverbank. Most of the households (97%) reported that their houses were inundated in 2017 flood.

Table 3 2: Descriptive statistics of socio-demographic variables (Source: Field survey 2019)

Socio-demographic profile	Purbachhatnai % (n=68)	Gajaghanta % (n=158)	Belka % (n=151)
Sex of household head			
Female	14.7	4.4	2.0
Male	85.3	95.6	98.0
Highest education within household			
Illiterate	30.9	27.2	42.4
Secondary (6 to 12)	66.2	67.7	51.7
Tertiary (13+)	2.9	5.1	5.9
Employment of household head			
Agriculture	60.3	60.1	67.6
Wage labor	29.4	22.2	20.5
Business	2.9	10.1	4.6
Service	1.5	1.3	2.7
Others	5.9	6.3	4.6
Construction material of house			
Katcha (all thatched)	5.9	3.8	9.3
Corrugated iron (CoI)	69.1	77.2	80.1
Thatches with CoI	20.6	7.6	8.6

Socio-demographic profile	Purbachhatnai % (n=68)	Gajaghanta % (n=158)	Belka % (n=151)
Semi wall	4.4	11.4	2.0
Ownership of land where house is located			
Own land	69.1	84.2	51.7
Relative land	25.0	10.1	33.1
Government (*Khas*) land	4.4	1.9	1.3
Rented land	1.5	3.8	13.9
Monthly average income of the household			
Less than national average	79.4	79.8	92.7
Greater than national average	20.6	20.2	7.3

3.5 Flood risk assessment

3.5.1 Indexed value of components and subcomponents

The indexed value of flood risk and its components are described in this section. The indexed values of 16 subcomponents are shown in Figure 3.2. The normalized score of each indicator is presented in Table 3.3 (details are in Appendix E, Table 1).

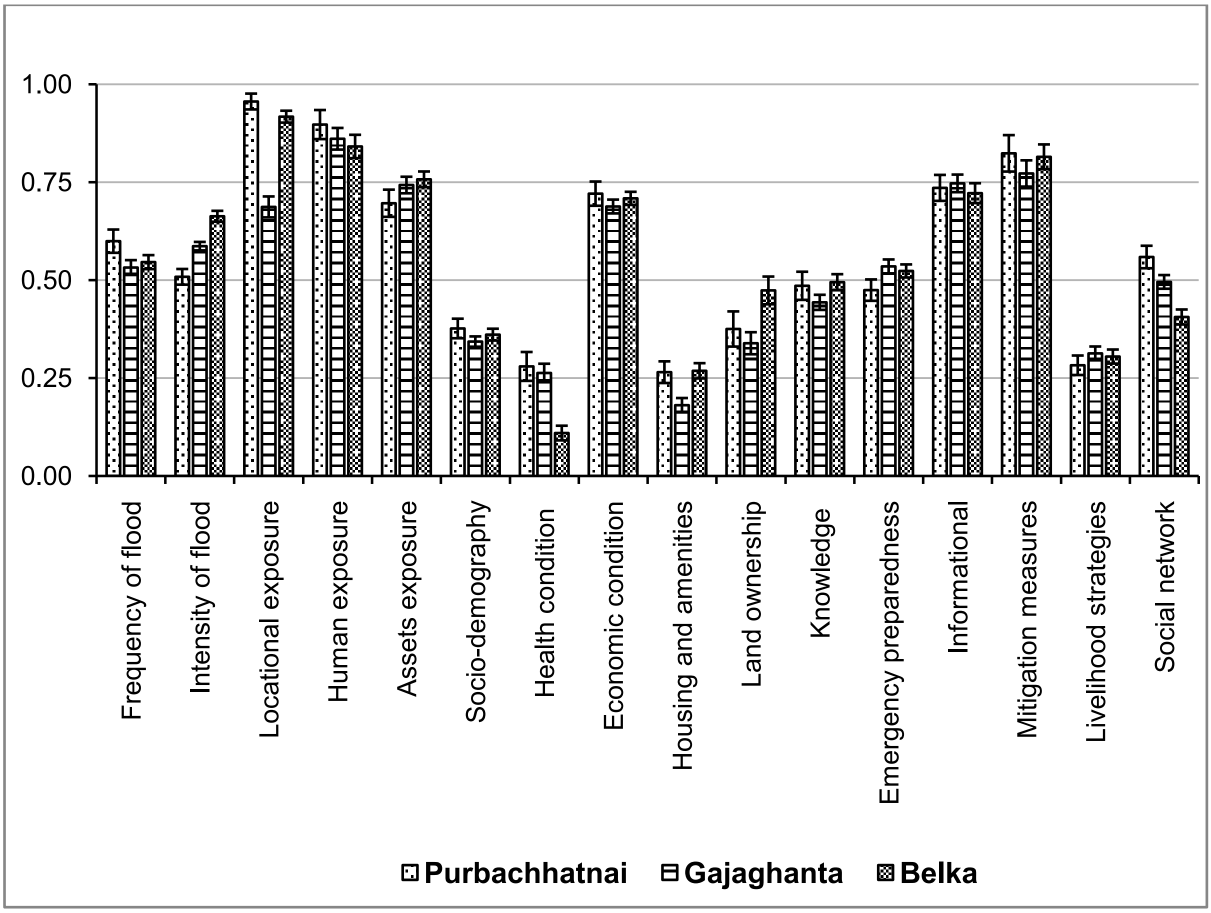

Figure 3 2: Subcomponent wise index value (with standard error bar) (Source: Prepared from Field Survey 2019)

Table 3 3: Indexed score of subcomponents and variables (Source: Prepared from Field Survey 2019)

Subcomponents	Indicators	PU	GU	BU
Frequency of flood	Frequency of floods in the community in last 5 years	0.669	0.488	0.597
	Frequency of home inundation in a year	0.529	0.576	0.495
	Averaged subcomponent score	***0.599***	***0.532***	***0.546***
Intensity of flood	Duration of floodwater inside the home	0.230	0.331	0.644
	Height of floodwater inside the home	0.379	0.578	0.548
	Height of floodwater outside the home measured from the local roads	0.512	0.607	0.681
	Time to rise of floodwater	0.912	0.831	0.778
	Averaged subcomponent score	***0.508***	***0.587***	***0.663***
Locational exposure	Location of home in between levee and riverbank	0.927	0.576	1.000
	Location of home within 1000 meters from the riverbank	0.985	0.798	0.834
	Averaged subcomponent score	***0.956***	***0.687***	***0.917***
Human exposure	Family members infected by communicable disease or injured in the last 5 years due to flood	0.897	0.861	0.841
	Averaged subcomponent score	***0.897***	***0.861***	***0.841***
Assets exposure	Damage of home in the last 5 years due to flood	0.779	0.886	0.868
	Lost household goods in the last 5 years due to flood	0.677	0.817	0.801
	Lost standing crops in the last 5 years due to flood	0.632	0.525	0.603
	Averaged subcomponent score	***0.696***	***0.743***	***0.757***
Socio-demography	Female headed household	0.147	0.044	0.020
	Ratio of female population in the house	0.532	0.512	0.444
	Age dependency ratio	0.518	0.543	0.555
	Illiterate household	0.309	0.272	0.424
	Averaged subcomponent score	***0.376***	***0.343***	***0.361***
Health condition	Chronically ill member(s) in the house	0.456	0.424	0.179
	Disabled member(s) in the house	0.103	0.101	0.040
	Averaged subcomponent score	***0.279***	***0.263***	***0.109***
Economic condition	Monthly income of the household less than national average	0.794	0.798	0.927
	Household has debt to payback	0.574	0.608	0.457
	Household without access to any form of financial institutions	0.794	0.658	0.742
	Averaged subcomponent score	***0.721***	***0.688***	***0.709***
Housing and amenities	Thatched/mud-made (*Katcha house*)	0.265	0.114	0.179
	Household without tubewell	0.044	0.025	0.060
	Household without sanitary toilet	0.559	0.392	0.523
	Household without electricity (solar panel)	0.191	0.190	0.311
	Averaged subcomponent score	***0.265***	***0.180***	***0.268***
Land ownership	Household does not have agricultural lands	0.309	0.158	0.483
	Housing tenure	0.441	0.519	0.464
	Averaged subcomponent score	***0.375***	***0.339***	***0.474***

Subcomponents	Indicators	PU	GU	BU
Knowledge	Household has at least one member who received training on flood disaster management	0.147	0.019	0.053
	All adult family members know how to swim	0.735	0.709	0.821
	Household has a good understanding of flood disaster warning	0.574	0.601	0.609
	Averaged subcomponent score	***0.485***	***0.443***	***0.495***
Emergency preparedness	Household has precautionary crop savings	0.294	0.279	0.252
	Household has emergency planning	0.897	0.886	0.815
	Household has a portable cooking stove	0.382	0.722	0.834
	Household has precautionary money savings	0.324	0.253	0.192
	Averaged subcomponent score	***0.474***	***0.535***	***0.523***
Informational	Household received last flood disaster warning	0.941	0.848	0.735
	Household has mobile phone/ TV set/ radio at home	0.794	0.848	0.874
	Household has owned at least one vehicle	0.471	0.544	0.556
	Averaged subcomponent score	***0.735***	***0.747***	***0.722***
Mitigation measures	Household has taken at least one structural mitigation measure to prevent a flood disaster	0.824	0.772	0.815
	Averaged subcomponent score	***0.824***	***0.772***	***0.815***
Livelihood strategies	Household has their family member(s) working outside of the flood prone area and sending remittance	0.221	0.146	0.053
	Household has a non-farm income source	0.427	0.386	0.238
	Household has more than one earning member	0.338	0.329	0.318
	Household with livestock	0.397	0.563	0.729
	Household was able to recover from last flood disaster using their own resources	0.029	0.139	0.185
	Averaged subcomponent score	***0.282***	***0.313***	***0.305***
Social network	Household has lived in the community for more than 5 years	0.912	0.823	0.483
	Household has received help from their community during a flood disaster response	0.427	0.127	0.285
	Household exchanged goods or services with their neighbor in the last year	0.647	0.779	0.748
	Household is affiliated with any organization	0.250	0.253	0.106
	Averaged subcomponent score	***0.559***	***0.495***	***0.406***

Note: PU: Purbachhatnai union; GU: Gajaghanta union; BU: Belka union

(a) Level of flood hazard (thereof "characteristics of historical flood")

The hazard index for individual households ranges from 0.17 to 1.00. Almost 60% of the respondents claimed that their localities had flooded more than 10 times in the last five years. A majority of the respondents (74.3%) informed that their houses remained flooded for more than four days. Over 90% of respondents from Belka, 76% from Gajaghanta, and 29% from Purbachhatnai faced inundation for four or moredays. All but 4% of the respondents from Purbachhatnai claimed that the river water rises within 12 hours, compared to 82% respondents from Gajaghanta and 75% from Belka. More than half of the respondents (58%) reported that floodwater rose four feet or more inside or outside their houses. Overall, the flood frequency for Purbachhatnai was found to the highest among all surveyed areas; in contrast, the intensity of the flood hazard was higher in Belka compared to Gajaghanta and Purbachhatnai (Figure 3.2).

Significant differences (χ^2 = 21.6, df = 4, p < .01) in the level of hazard was found among the sampled communities (Appendix E, Table 2). Around 43% of households from Belka were living in a high hazard zone, compared to 19% in Purbachhatnai (Figure 3.3).

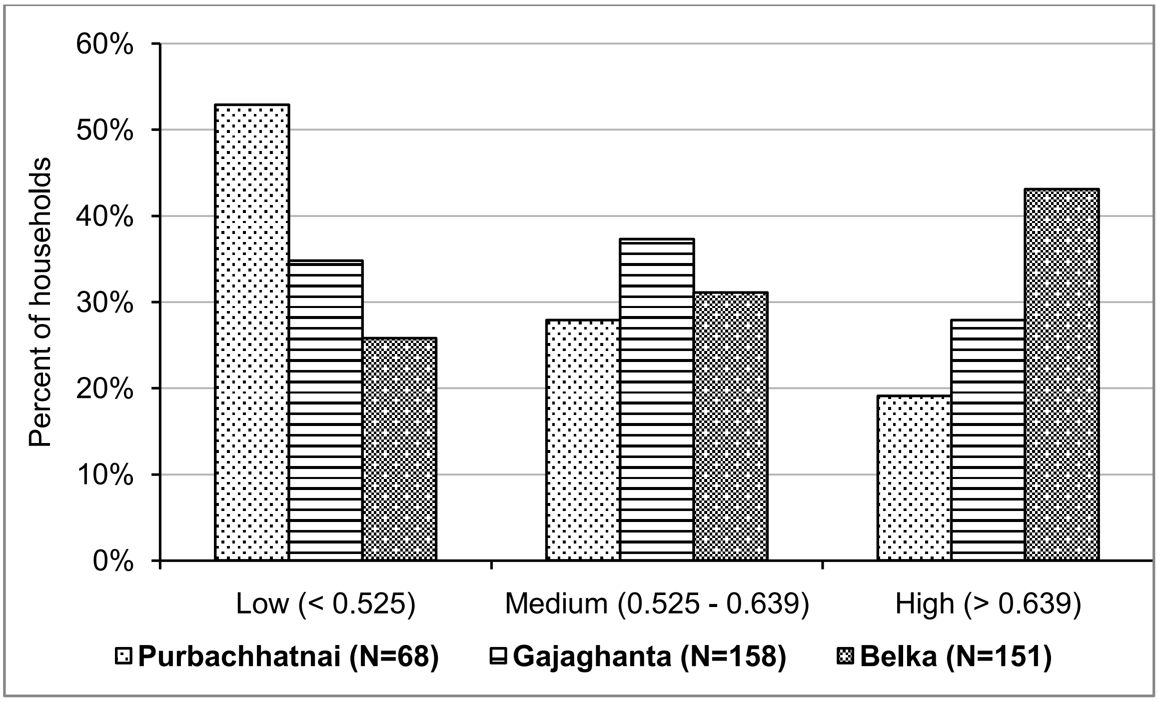

Figure 3 3: Level of flood hazards in the study area

(b) Level of flood exposure

The exposure index of individual households varied from 0.17 to 1.00. The index value for locational exposure was found to be higher in Purbachhatnai and Belka, compared to Gajaghanta (Figure 3.2). Four-fifths of the respondents' houses were located between the levee and the river bank. Around 85% (n=319) were living within 1,000 meters of the river bank, and a majority of them (n=271) suffered from communicable diseases or were injured due to the flooding in the last five years. Therefore, the index value for human exposure (>0.840) was found to be very high for all the locations studied (Figure 3.2). On the other hand, the index value of assets exposure was found to be higher in Belka than Purbachhatnai and Gajaghanta (Figure 3.2).

Significant differences (χ^2 = 11.5, df = 4, p = .02) were observed in the level of exposure among the floodplain communities (Appendix E, Table 3). Only 18% of households from Gajaghanta reported a higher exposure to river flooding, compared to 34% from Purbachhatnai and 33% from Belka (Figure 3.4).

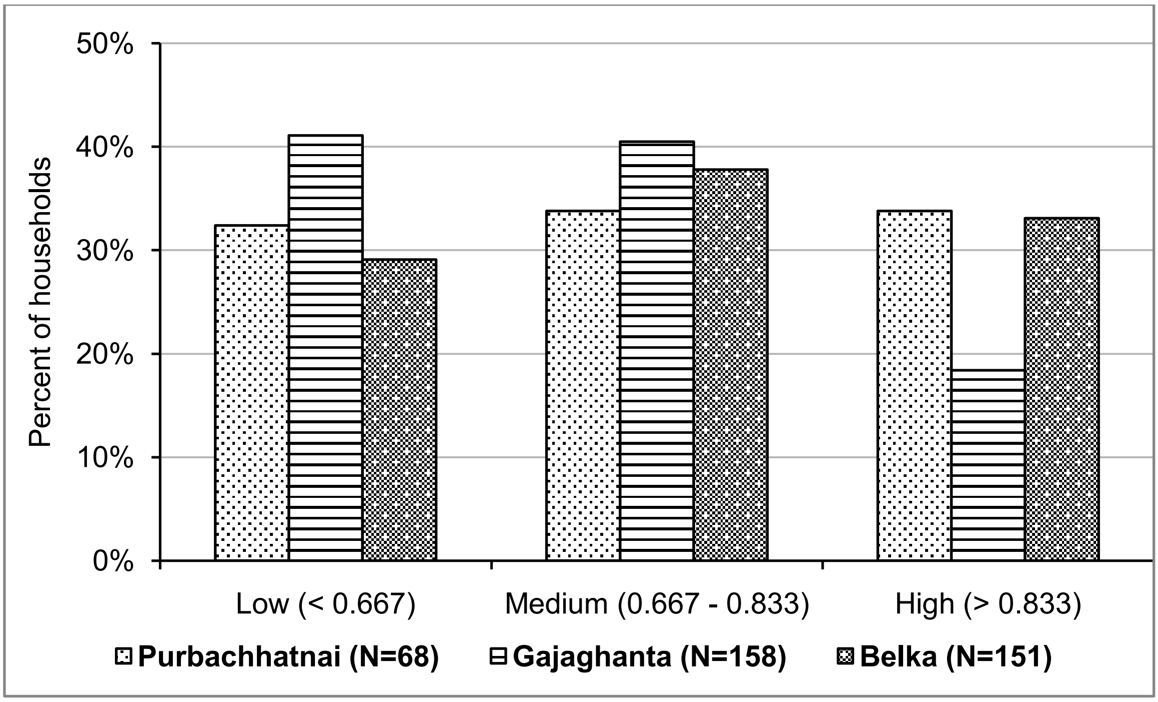

Figure 3 4: Level of exposure to flood in the study area

(c) Level of vulnerability

The vulnerability index score for individual households ranged from 0.01 to 0.82. Purbachhatnai (score: 0.38 ± 0.21) had relatively higher socio-demographic vulnerability compared to Gajaghanta and Belka. A majority of the households (95%) were male-headed. Female-headed households (14% of households) and the ratio of the female population (53% of households) in the households were found to be higher in Purbachhatnai than in the other two study areas. The age dependency ratio was similar throughout the study area. Belka had the highest percentage (42%) of illiterate households, compared to 31% for Purbachhatnai and 27% for Gajaghanta. Health vulnerability was found to be the lowest in Belka (score: 0.11 ± 0.23) compared to Purbachhatnai (score: 0.28 ± 0.30) and Gajaghanta (score: 0.26 ± 0.30) (Figure 3.2). Chronic illness was reported by 46% of households in Purbachhatnai, 42% in Gajaghanta, and 18% in Belka. Overall, around 8% of all households had disabled members.

More than one-fourth of households from Purbachhatnai (27%) reported that they were living in *Katcha* houses, compared to 11% from Gajaghanta and 18% from Belka. A majority of the households (96%) had tubewells in their house. However, the sanitation facilities of more than half of the households from Purbachhatnai (55.9%) and Belka (52.3%) were poor. A higher proportion of households from Belka (31%) than Purbachhatnai (19%) and Gajaghanta (19%) reported that they did not have electricity (solar panel) in their house. Although the respondents from Belka did not have any access to electricity, around 69% (n=104) of households had a rooftop solar panel. Overall, households in Purbachhatnai and Belka were more vulnerable than those in Gajaghanta with regards to the housing and amenities subcomponents (Figure 3.2).

A higher percentage of Belka (48%) households reported that they did not have agricultural lands compared to those in Purbachhatnai (31%) and Gajaghanta (16%).The overall, the land ownership score for Belka (score: 0.47 ± 0.43) was higher than Purbachhatnai (score: 0.38 ± 0.37) and Gajaghanta (score: 0.34 ± 0.36). Almost half of the surveyed households (48.3%) did not own agricultural land. The highest percentage of households from Belka (48%) constructed their house on rented, government, or relatives' land. In contrast, most households in Gajaghanta (84%) owned their houses.

Purbachhatnai (score: 0.72 ± 0.26) was an economically vulnerable region. Belka had the highest percentage of households (92.7%) that did not have an income greater than the national average, whereas this rate was similar in Purbachhatnai (79.4%) and Gajaghanta (79.8%). The average monthly income per household was BDT. 8977 (SD=5113) at the time of the interview, and around 67% of the households did not have any non-farm income sources. More than 80% of the households had borrowed money to compensate for flood damages and losses within the last five years, of which 49.3% still had debt to pay back. A majority of households (71.6%) did not have access to financial institutions.

Significant differences ($\chi^2 = 11.1$, df = 4, $p = .03$) were observed in the level of vulnerability among floodplain communities (Appendix E, Table 3). Around 40% households from Purbachhatnai were highly vulnerable, compared to 25% in Gajaghanta (Figure 3.5).

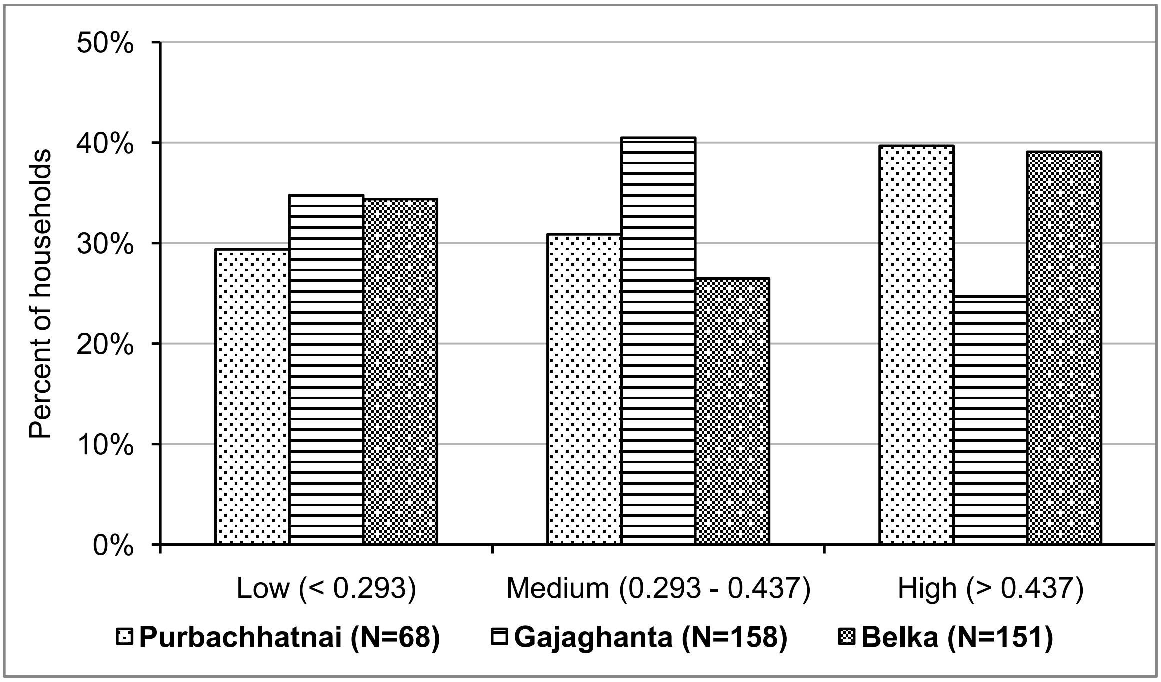

Figure 3 5: Level of vulnerability of households in the study area

(d) Level of capacity

The individual household-level capacity index ranged from 0.10 to 0.85. The results showed that only 6% (n=21) of households received flood disaster-related training and significantly higher proportion of households from Purbachhatnai received training (χ^2 = 14.86, df = 2, p = .001). On the contrary, 86% (n=324) of the households were aware of what to do after receiving a flood warning, and all the adult family members in 76% of households knew how to swim. With regards to emergency preparedness, only 27% of households had precautionary crops saved, and 86% of households had an emergency plan. A smaller percentage of Purbachhatnai households (38%) reported storing a portable cooking stove, compared to 83% for Belka and 72% for Gajaghanta (χ^2 = 46.46, df = 2, p < .001). A relatively higher percentage of households from Purbachhatnai (32%) reported precautionary money saving, compared to 25% from Gajaghanta and 19% from Belka. About 80% of households had implemented at least one structural mitigation measure to reduce flood disaster risk.

The index scores for the informational subcomponent were similar for the three study areas. Over 94% of households in Purbachhatnai, 85% in Gajaghanta, and 74% in Belka reported that they received the last flood disaster warning (χ^2 = 14.96, df = 2, p = .001). About 85% of households reported owning a mobile phone/ television/ radio and 54% of households owned at least one vehicle.

Among all the subcomponents of the capacity component, livelihood strategies received the lowest scores (Figure 3.2). Only 32.6% (n=123) of households had multiple earning members in their families. Over 70% (n=110) of households sampled from Belka had livestock in their house, compared to 39.7% (n=27) in Purbachhatnai and 56.3% (n=89) in Gajaghanta (χ^2 = 22.93, df = 2, p < .001).

Social networks were found to be stronger in Purbachhatnai. More than half of the households (52%) from Belka had been living in their present location for less than five years, while this figure was much lower in Purbachhatnai (8.8%) and Gajaghanta (17.7%) (χ^2 = 59.91, df = 2, p < .001). Community cooperation during a deluge was found to be significantly higher for Purbachhatnai compared with Gajaghanta (χ^2 = 25.44, df = 2, p < .001). However, only 19.4% (n=73) of households were affiliated with any voluntary or social service-related organization and was significantly higher percentage from Gajaghanta (χ^2 = 12.40, df = 2, p = .002).

There were no significant differences (χ^2 = 0.9, df = 4, p = .93) in capacity levels among the riparian households (Appendix E, Table 5). Around 42.4% (n=160) of the households‘ capacities were categorized as low (Figure 3.6).

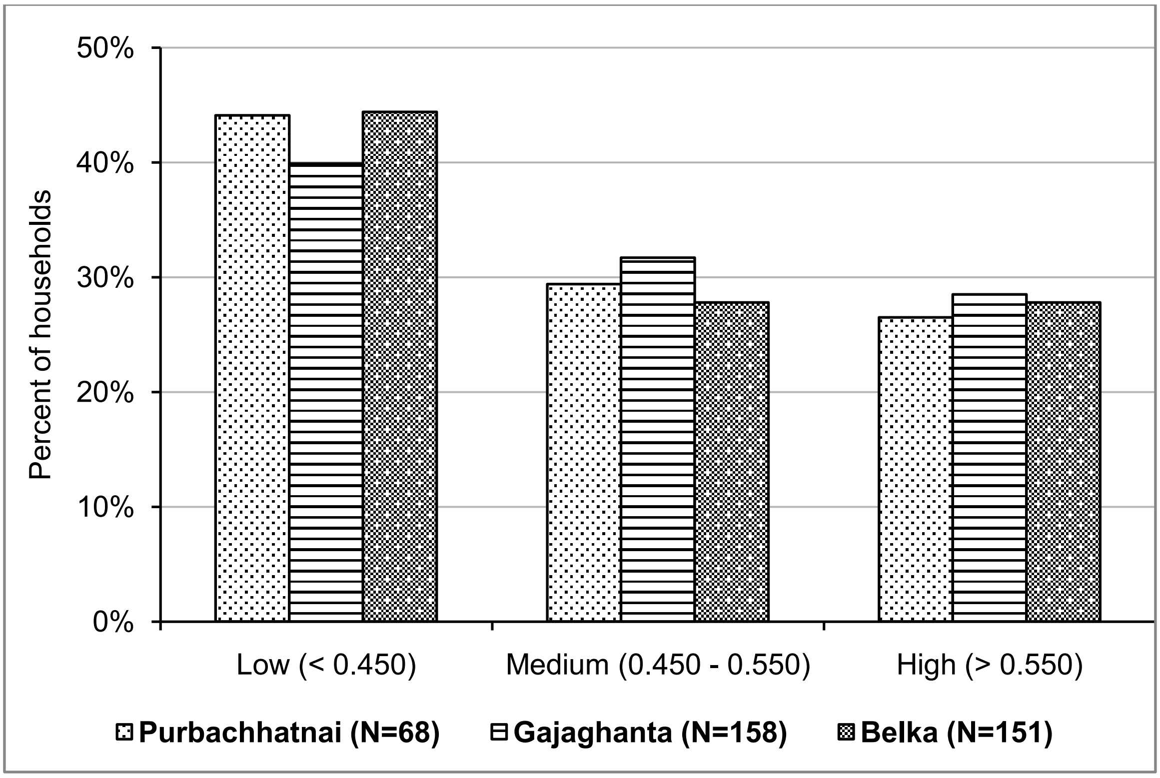

Figure 3 6: Level of capacity of households in the study area

(e) Level of flood disaster risk

The flood risk of riverine communities was calculated using Equation 3.5. The capacity index value was subtracted from 1 to calculate the ―lack of capacity.” The aggregated value for flood disaster risk was 0.56 (SD=0.09) for Purbachhatnai, 0.54 (SD=0.09) for Gajaghanta, and 0.59 (SD=0.10) for Belka (Figure 3.7).

Overall, the indexed value of hazard (score: 0.62 ± 0.15) and exposure (score: 0.83 ± 0.16) were found to be higher for Belka, whereas the vulnerability (score: 0.40 ± 0.15) and capacity (score: 0.50 ± 0.13) indices were found to be higher for Purbachhatnai when compared to the other study areas. On the contrary, Gajaghanta had the lowest exposure (score: 0.74 ± 0.21) and vulnerability (score: 0.36 ± 0.14) indices (Figure 3.7).

A Chi-square test of independence was performed to examine the differences among the study areas in terms of degree of risk. Highly significant differences (χ^2= 27.3, df = 4, p < .01) in the level of flood risk were observed among the households of three different study areas (Appendix E, Table 6). Nearly half of the households (46.4%) from Belka reported a high flood risk, compared with 35.3% of households in Purbachhatnai and 20.3% in Gajaghanta (Figure 3.8). Around 33.4% of the households from the study area were at a high risk. Overall, Belka was more at risk than Purbachhatnai and Gajaghanta (Figure 3.8). The spatial distributions of household-level riverine flood risks are shown in Figure 3.9 to Figure 3.11.

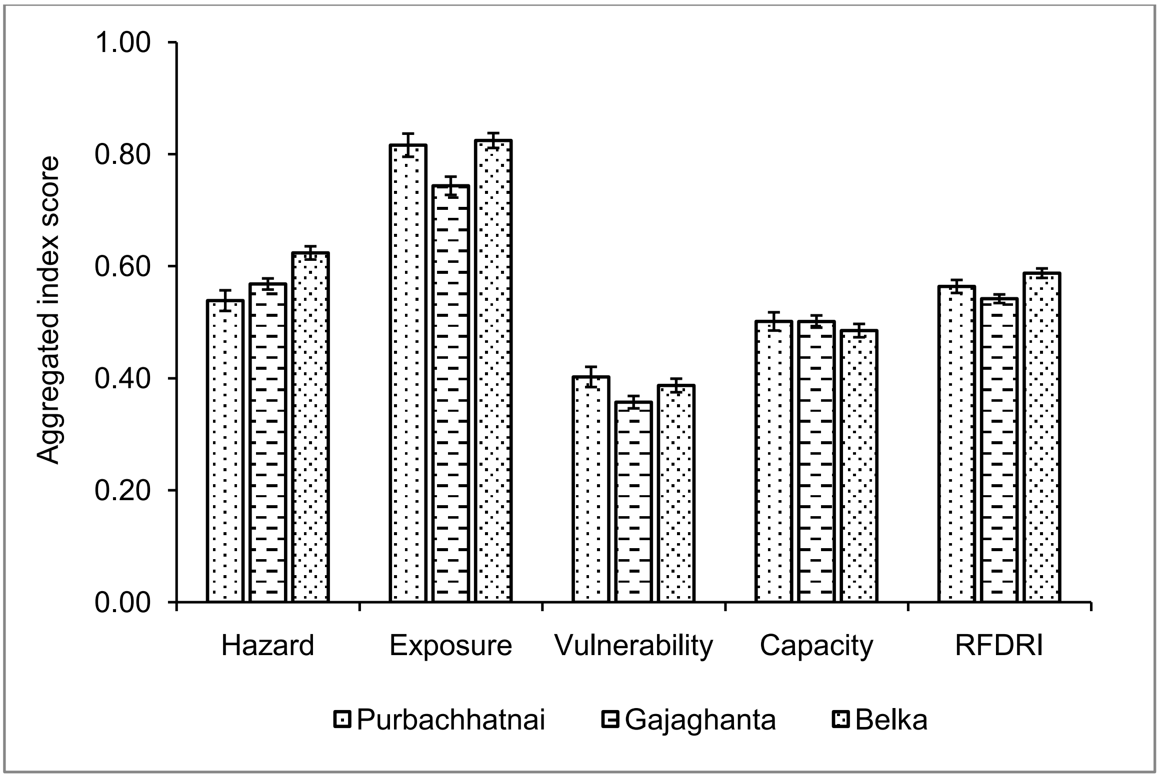

Figure 3 7: RFDRI and index score of hazard, exposure, vulnerability, and capacity

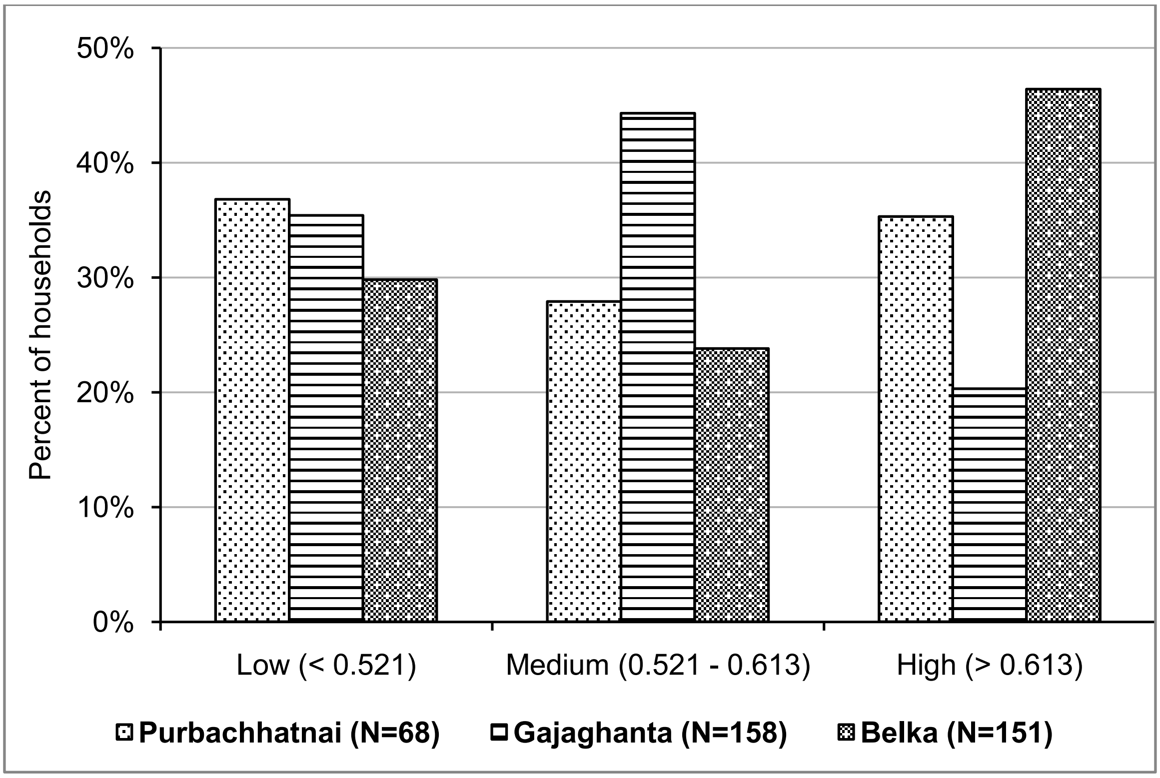

Figure 3 8: Level of flood risk of households in the study area

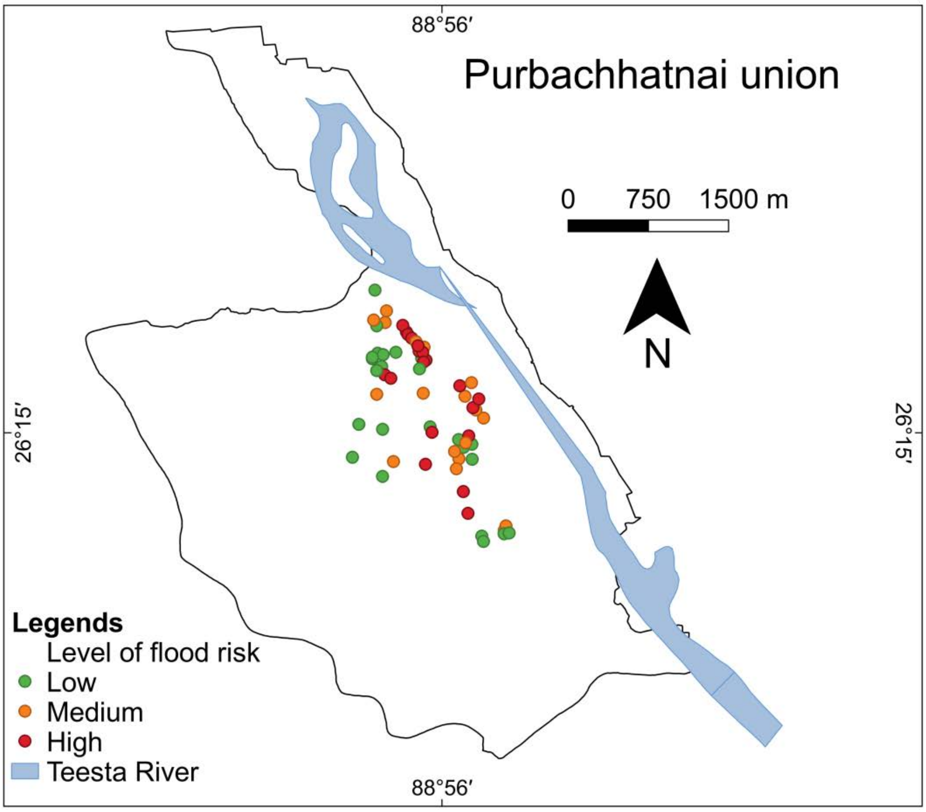

Figure 3 9: Risk map of Purbachhatnai union (prepared from RFDRI values)

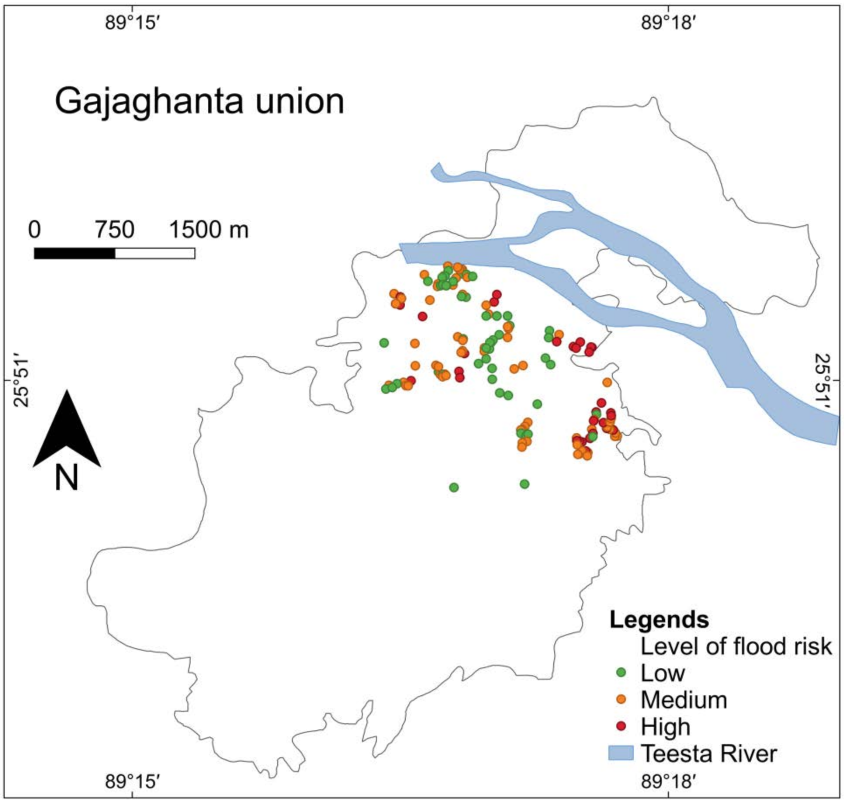

Figure 3 10: Risk map of Gajaghanta union (prepared from RFDRI values)

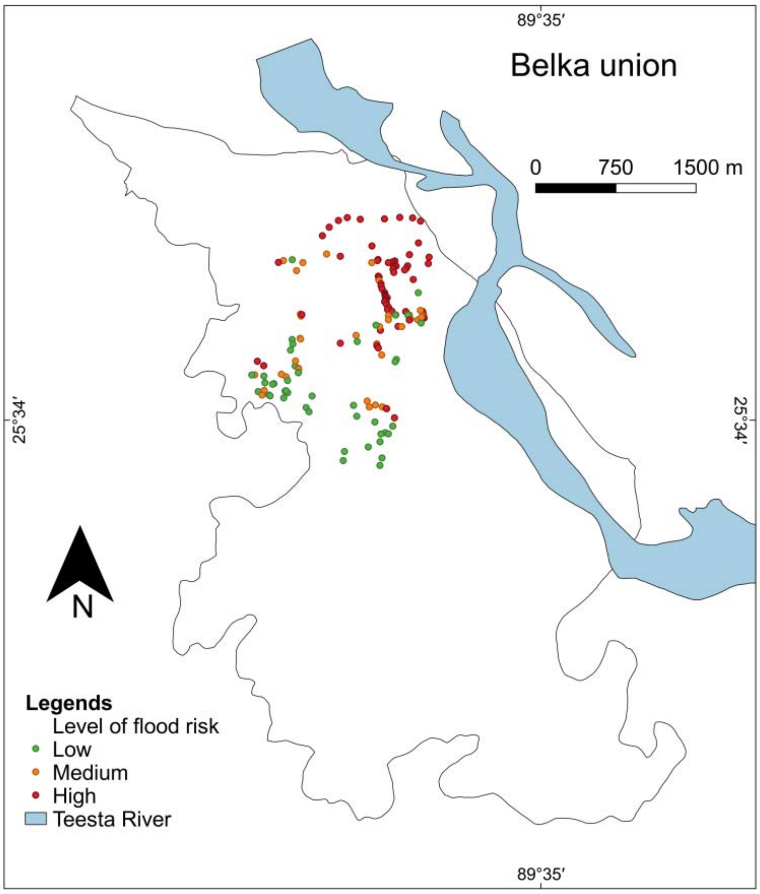

Figure 3 11: Risk map of Belka union (prepared from RFDRI values)

3.5.2 The relationships among the risk components

Pearson's correlation analysis was employed to identify the relationships among different components of flood risk (Table 3.4). The results revealed that the capacity component was statistically significant and negative to the vulnerability (r = -.53, p = .01) and hazard (r = -.33, p = .01) components. However, the relationship of exposure to vulnerability and capacity was not significant. On the contrary, a significantly weak correlation was found between hazard and exposure (r = .28, p = .01), and hazard and vulnerability (r = .32, p = .01).

Table 3 4: Correlation among the flood risk components

Components	Hazard	Exposure	Vulnerability	Capacity
Hazard	1	.28**	.32**	-.33**
Exposure		1	.07	-.05
Vulnerability			1	-.53**
Capacity				1

**Correlation is significant at the 0.01 level (2-tailed).

A series of Chi-square tests were performed to understand the associations among the variables (Appendix E, Table 7 to Table 29). The higher level of vulnerability was significantly associated with households whose members were injured or infected with communicable diseases (χ^2=11.5, df=2, $p < .01$), had damaged homes (χ^2 = 16.9, df = 2, $p < .01$), and who had lost household goods (χ^2 = 16.1, df = 2, $p < .01$). However, the vulnerability levels of the households were not associated with the house's distance from the river bank (χ^2 = 1.1, df = 2, $p = .57$).

A lower level of capacity was significantly associated with female-headed households (χ^2 = 13.6, df = 2, $p < .01$), those with a higher age dependency ratio (χ^2 = 27.8, df = 10, $p < .01$), illiterate households (χ^2 = 20.5, df = 2, $p < .01$), those with a monthly income lower than the national average (χ^2 = 33.8, df = 2, $p < .01$), those without access to financial institutions (χ^2 = 56.2, df = 2, $p < .01$), those without ownership of agricultural land (χ^2 = 38.4, df = 2, $p < .01$), and those without housing tenure (χ^2 = 37.5, df = 2, $p < .01$). Furthermore, households' level of capacity was not influenced by the location of their house, whether it was inside or outside an embankment (χ^2 = 4.3, df = 2, $p = .11$), its proximity to the river bank (χ^2 = 0.4, df = 2, $p = .83$), the presence of disabled (χ^2 = 0.1, df = 2, $p = .96$) or chronically ill (χ^2 = 1.4, df = 2, $p = .50$) members in the house, debt (χ^2 = 5.5, df = 2, $p = .06$), or housing built of fragile construction materials (χ^2 = 4.3, df = 2, $p = .11$).

3.6 Uncertainty and sensitivity analysis

Uncertainty and sensitivity analysis were performed to determine the influence of choices of flood risk components/ indicators and normalization techniques on the index output. The effect of choosing of indicator/ hazard component used was tested by including or excluding of "frequency of floods in the community in last 5 years" indicator and hazard component. Regarding normalization technique, it included testing of normalization effects by computing index score using z-score normalization of indicators and comparing it to the min-max normalized index. The risk index scores for both normalization schemes were then ranked and compared.

3.6.1 Choice of indicator/component and its impacts on the risk index

The sensitivity of RFDRI to the inclusion and exclusion of "frequency of floods in the community in last 5 years" indicator and hazard component were assessed and summarized in the Table 3.5. The calculated risk index for these two configurations was renamed: RFDRI-2 (exclusion of "frequency of floods in the community in last 5 years" indicator) and RFDRI-3 (excluding hazard component).

Table 3 5: Riverine flood disaster risk including/excluding indicator and hazard component

Location	Risk calculation	Mean	Std. Deviation	Minimum	Maximum
All study area (377 HHs)	RFDRI	0.5642	0.1014	0.1842	0.8278
	RFDRI-2	0.5652	0.1010	0.1842	0.8232
	RFDRI-3	0.5572	0.1073	0.1739	0.8444
Purbachatnai (68 HHs)	RFDRI	0.5639	0.0956	0.2892	0.7229
	RFDRI-2	0.5574	0.1005	0.2558	0.7389
	RFDRI-3	0.5723	0.1025	0.2744	0.7741
Gajaghanta (158 HHs)	RFDRI	0.5420	0.0967	0.1842	0.7958
	RFDRI-2	0.5460	0.0967	0.1842	0.7917
	RFDRI-3	0.5332	0.1056	0.1739	0.7811
Belka (151 HHs)	RFDRI	0.5876	0.1041	0.3343	0.8278
	RFDRI-2	0.5889	0.1013	0.3571	0.8232
	RFDRI-3	0.5755	0.1070	0.2939	0.8444

Note: RFDRI-2 refers to the exclusion of ―frequency of floods in the community in last 5 years" indicator
RFDRI-3 refers to the exclusion of ―hazard component"

(a) RFDRI-2 (exclusion of "frequency of floods in the community in last 5 years")

The inclusion/exclusion of ―frequency of floods in the community in last 5 years" indicator has varying effects on risk scores in all study areas. The index scores of RFDRI-2 for the 377 households range from 0.1842 to 0.8232 with an average of 0.5652 and a standard deviation of 0.1010 (Table 3.5). The exclusion of this indicator showed an increase of risk scores except Purbachatnai. The Spearman‗s rank correlation revealed a strong and positive monotonic correlation between RFDRI and RFDRI-2 (r_s = .99, n = 377, p < .001). Exclusion of ―frequency of floods in the community in last 5 years" indicator was resulted an increase in the hazard scores for Gajaghanta and Belka. The index score for ―frequency of floods in the community in last 5 years" indicator was higher for Purbachatnai compared with Gajaghanta and Belka. However, Belka is still at high risk followed by Purbachatnai and Gajaghanta. The analysis showed that households from Gajaghanta (Figure 3.15) and Belka (Figure 3.17) experience big variations in their rankings, while the variations in rankings were lower for Purbachatnai (Figure 3.13).

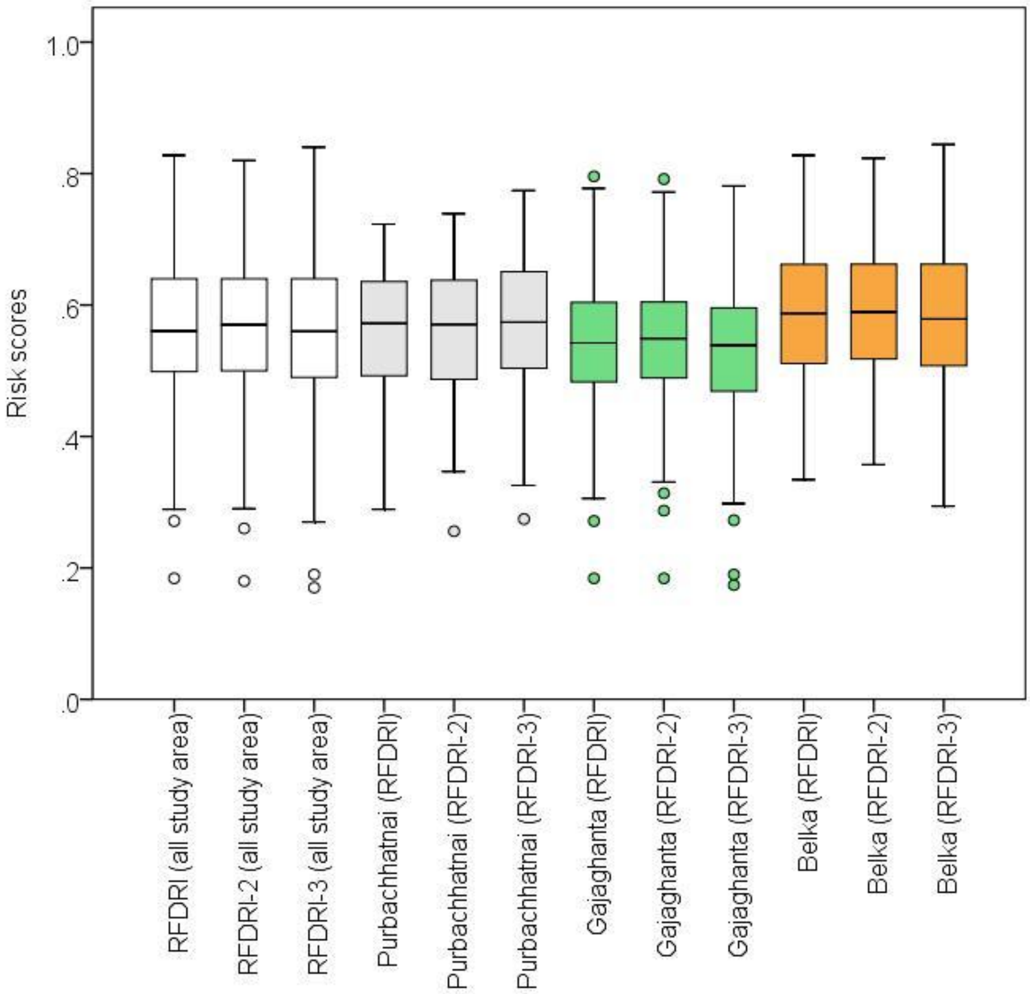

Figure 3 12: Summary of the riverine flood disaster risk index (RFDRI) values using all indicators and components (all study area), excluding ―frequency of floods in the community in last 5 years" indicator (RFDRI-2), excluding ―hazard component" (RFDRI-3).

(b) RFDRI-3 (exclusion of "hazard component")

The index scores of RFDRI-3 for the 377 households range from 0.1739 to 0.8444 with an average of 0.5572 and a standard deviation of 0.1073 (Table 3.5). The exclusion of indicators related to hazard component was resulted a decrease in the average risk scores except Purbachatnai. The reason to increase the overall risk score (RFDRI-3) for Purbachatnai were attributed by the higher level of vulnerability and exposure. The Spearman‘s rank correlation revealed a strong and positive monotonic correlation between RFDRI and RFDRI-3 ($r_s = .95$, n = 377, $p < .001$). In this case, Belka is still at the highest risk region followed by Purbachatnai and Gajaghanta. However, exclusion of hazard component showed a greater dispersion of risk scores, with a downward shift in the minimum values for all three study areas (Figure 3.12). Some households from Gajaghanta (Figure 3.16) and Belka (Figure 3.18) experience big variations in their rankings, while the variations in rankings were lower for Purbachatnai (Figure 14).

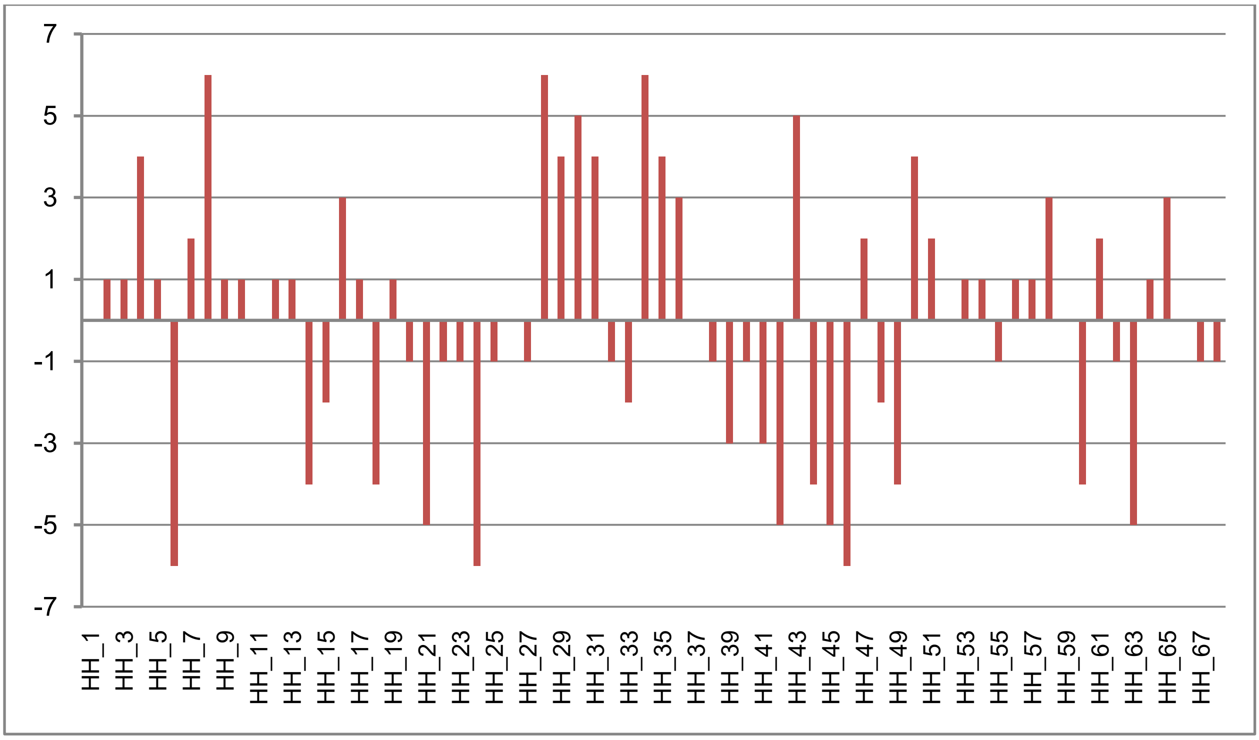

Figure 3 13: Shifts in rank between original RFDRI and RFDRI-2 in Purbachatnai. Horizontal axis is ordered by the code of individual households in Purbachatnai (HH_1 to HH_68).

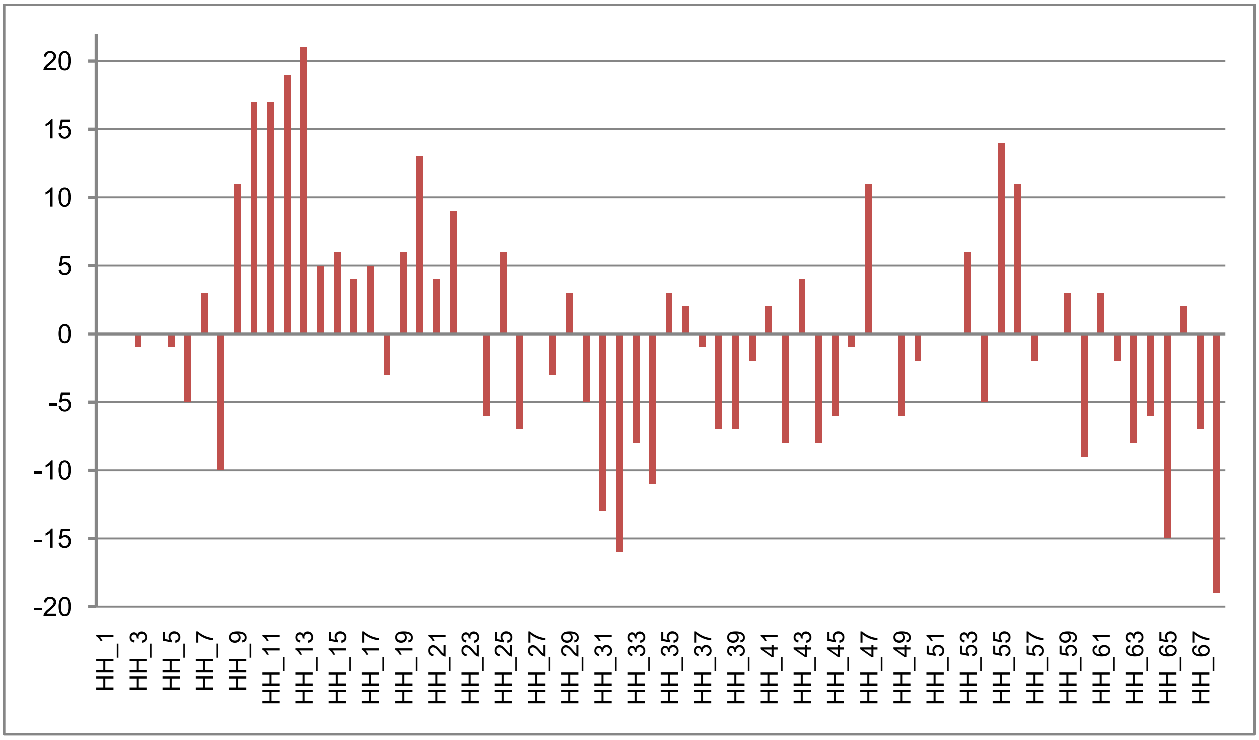

Figure 3 14: Shifts in rank between original RFDRI and RFDRI-3 in Purbachatnai. Horizontal axis is ordered by the code of individual households in Purbachatnai (HH_1 to HH_68).

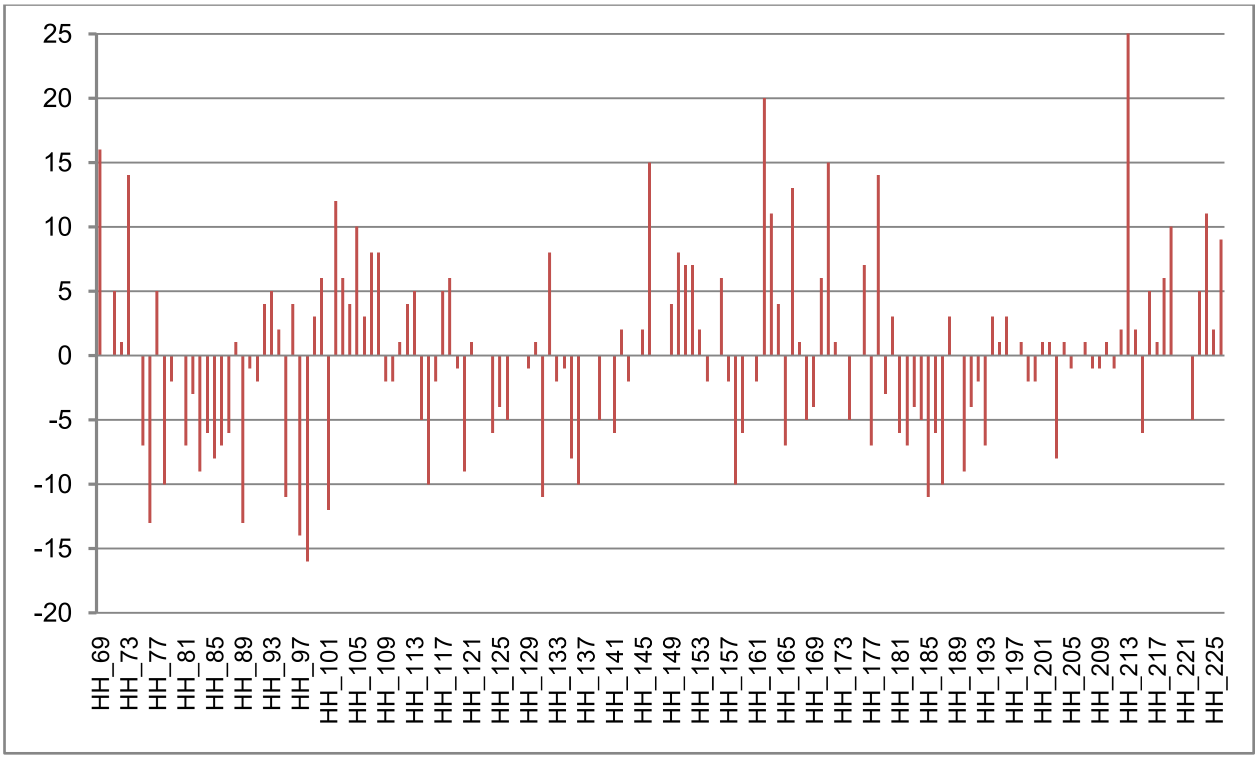

Figure 3 15: Shifts in rank between original RFDRI and RFDRI-2 in Gajaghanta. Horizontal axis is ordered by the code of individual households in Gajaghanta (HH_69 to HH_226).

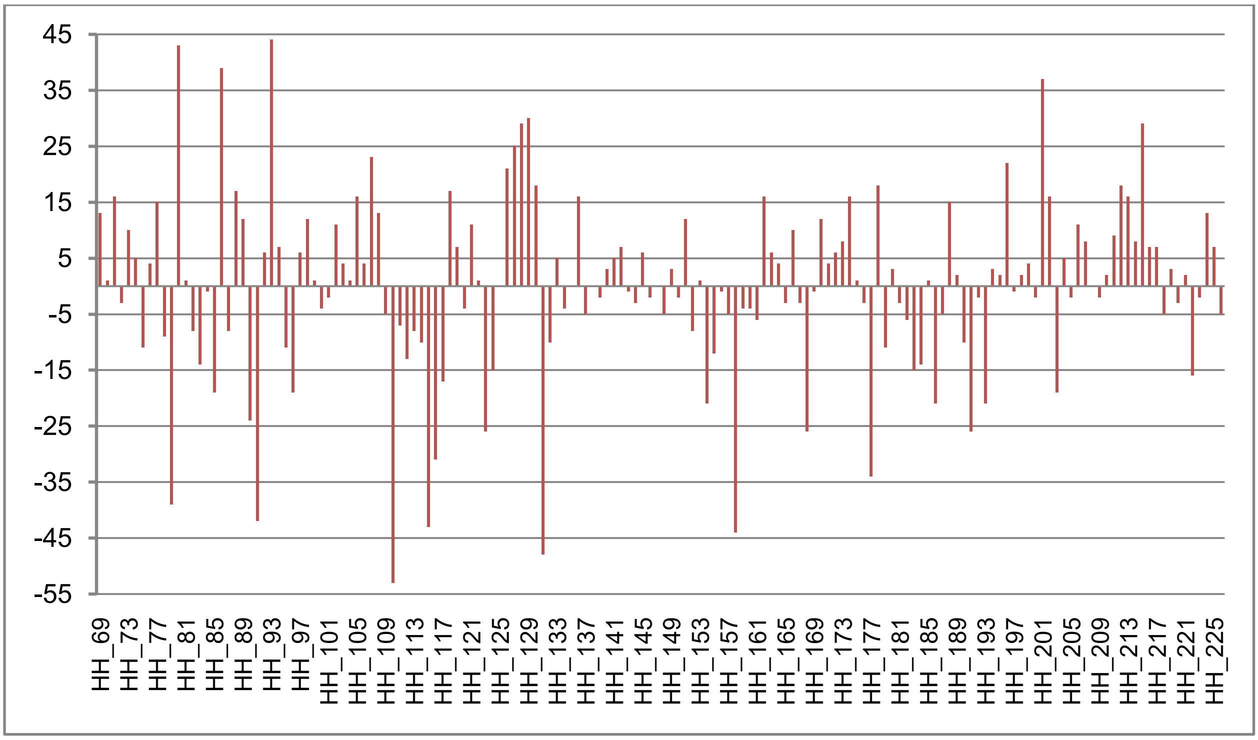

Figure 3 16: Shifts in rank between original RFDRI and RFDRI-3 in Gajaghanta. Horizontal axis is ordered by the code of individual households in Gajaghanta (HH_69 to HH_226).

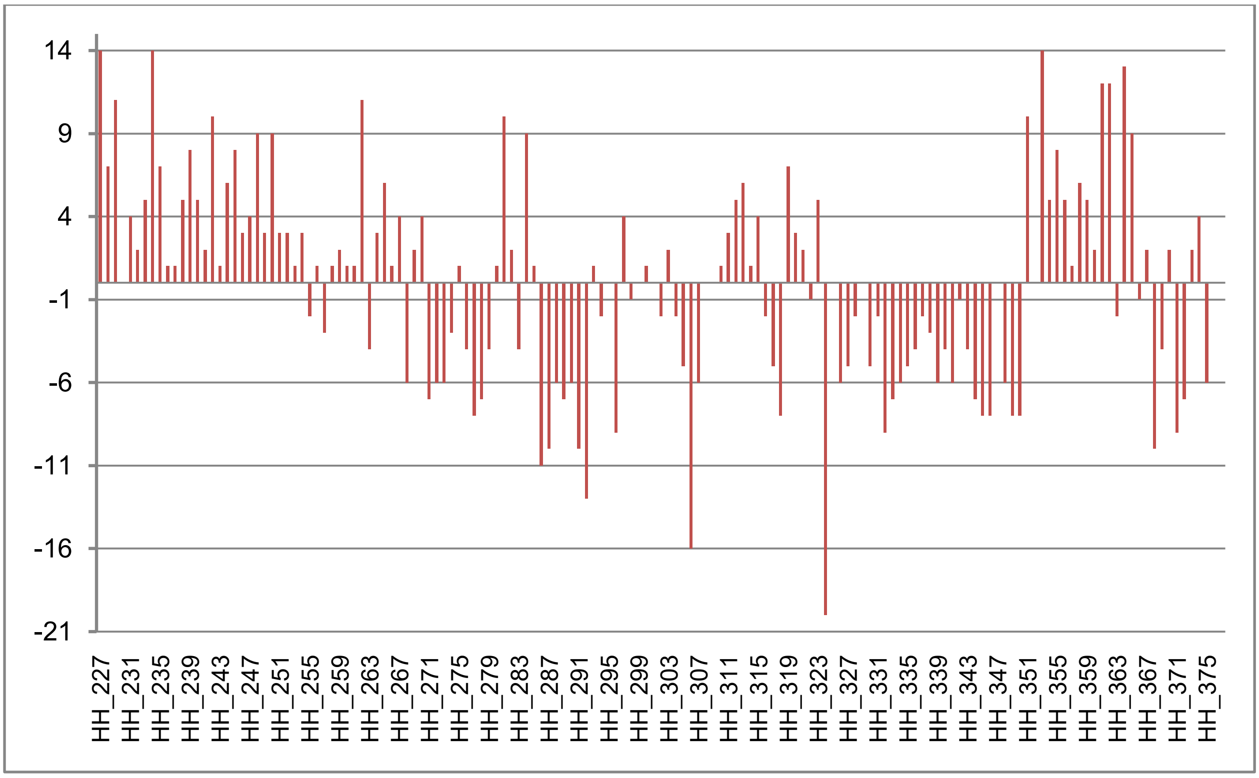

Figure 3 17: Shifts in rank between original RFDRI and RFDRI-2 in Belka. Horizontal axis is ordered by the code of individual households in Belka (HH_227 to HH_377).

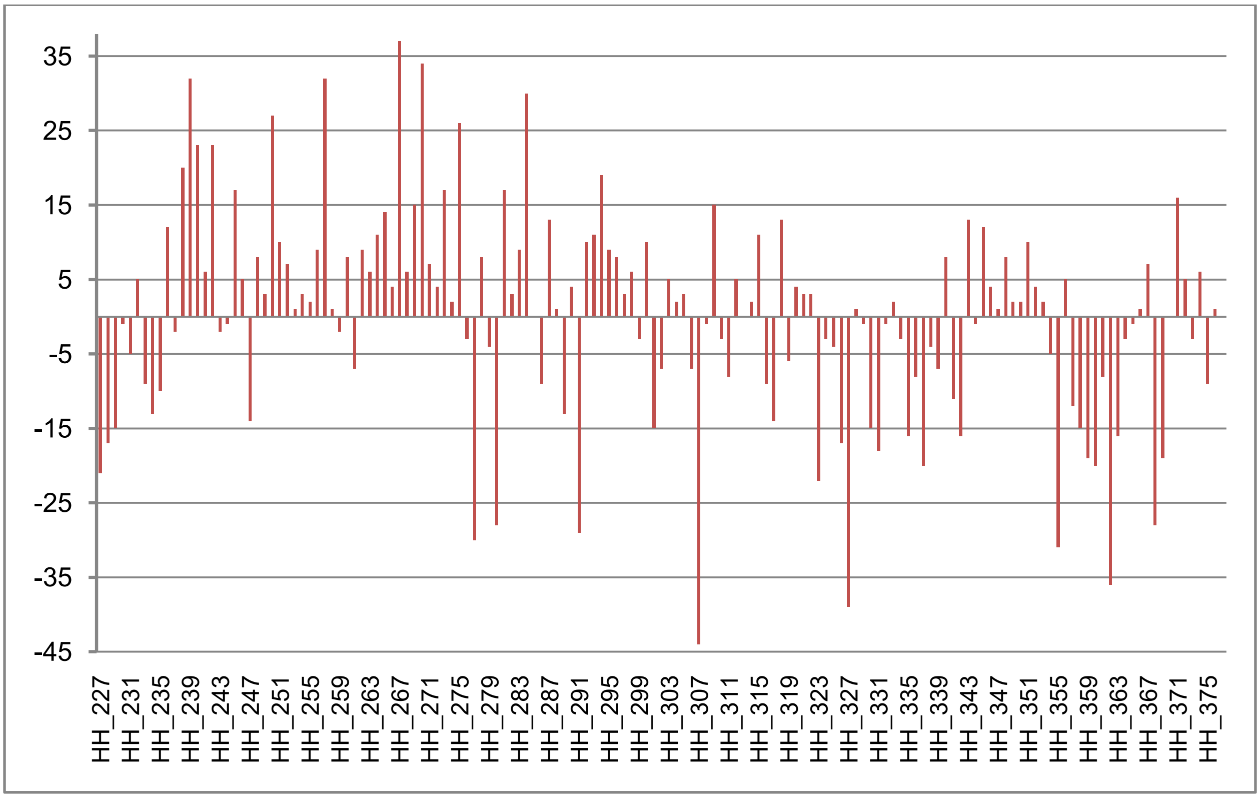

Figure 3 18: Shifts in rank between original RFDRI and RFDRI-3 in Belka. Horizontal axis is ordered by the code of individual households in Belka (HH_227 to HH_377).

3.6.2 Normalization techniques and its impacts on RFDRI

Risk index for two normalization schemes (min-max and z-score) are summarized and compared in Table 3.6. Table 3.6 showed a marked difference in the average scores of the RFDRI for two normalization options. However, the ranking of the study locations remained unchanged computed with both normalization techniques. Results also showed a strong positive correlation in the output obtained for the two normalization techniques ($r = .984$, $p < .001$).

Table 3 6: Summary of the RFDRI scores computed at three survey locations, computed with min-max and z-score normalization techniques (N=377)

Survey locations	RFDRI: min-max transformation		RFDRI: z-score transformation	
	Average score	Rank	Average score	Rank
Belka	0.5876	1	0.3080	1
Purbachatnai	0.5639	2	0.2356	2
Gajaghanta	0.5420	3	0.2008	3

3.7 Discussion on the results

3.7.1 External factors of flood risk

Purbachhatnai is characterized as a flash flood-prone zone and suffers frequent flooding with sharp increases in water level (score: 0.91) and rapid recession of water (score: 0.23) (Mondal and Islam 2017). In contrast, the intensity of flooding increased gradually from upstream to downstream (Figure 3.2). Because of Belka's low and flat topography, flood water levels rise slowly (score: 0.78) and dissipate slowly (score: 0.64). The higher intensity of flooding in Belka was also associated with higher asset exposure (Figure 3.2). During the data collection, it was noticed that river banks were almost protected by earthen or concrete embankments in the sampling areas of Purbachhatnai and Gajaghanta. Indeed, no such protective measures were found in Belka. According to a local leader from Belka, —we are living in the highly-exposed areas, since there is no embankment in our community." Thus, the index scores of the hazard and exposure components were comparatively higher in Belka (Figure 3.7). Overall, the exposure component received the highest score amongst all the components of risk. The most important reason behind the higher level of exposure is the proximity of human settlements and their agricultural lands to the river. The question may arise: why do so many people in Bangladesh live in floodplains? Flood risk can be substantially reduced if people and their assets are moved outside of the floodplain zone. However, it is impractical not to allow settlements in floodplains in Bangladesh because of the scarcity of land (Brammer 1992). Moreover, people who have lost their land to bank erosion try to stay near their lost land in hopes of reclaiming it when it accretes (Mamun 1996). Additionally, the net economic benefits derived from settling on floodplains outweigh the average losses caused by floods (Smith 2003). The FGD participants from Purbachhatnai informed that —we do not want relief from the government, but rather request that the government help us protect ourselves and our agricultural lands from the floods. If we are able to reap our crops (e.g. maize, nuts) successfully, we will be able to improve our economic conditions without external supports."

The findings showed that flooding is associated with the risk of communicable disease/ injuries in the post-flood period throughout the whole study area (Alderman et al. 2012; Sultana et al. 2019). This is because most of the tubewells and toilets become submerged, which increase the risk of spreading water- and vector-borne diseases during or immediately after a flood (Chanda Shimi et al. 2010). One respondent from Belka reported that —we suffer from diarrhea, fever, running nose, gastric disease, skin diseases, and many more during a flood. The government distributes some water purification tablets or oral saline, which are insufficient. Hospitals are far away. As the communication system here is very poor, we have to hire boats to go to a health center during floods, which is expensive for us. In most cases, we purchase medicines from local pharmacies without any consultation with physicians."

3.7.2 Internal factors of flood risk

The vulnerability and capacity of households were not influenced by their house's location relative to the riverbank. This finding is slightly different from other studies (Brouwer et al. 2007; Paul and Routray 2010) where they found that vulnerability increases with the house's proximity to the river bank. The negative but significant correlation between vulnerability and capacity demonstrated that household capacity may help to reduce vulnerability. This finding was supported by Jamshed et al. (2019) and Bergstrand et al. (2015), who confirmed that capacity was negatively correlated with vulnerability, i.e. households with higher vulnerability had a lower capacity and vice versa. Although Purbachhatnai was more vulnerable than Gajaghanta and Belka, it showed a higher capacity score in absorbing flood risk. This is due to the fact that Purbachhatnai households had good knowledge, undertook mitigation measures, and had better social networks. This study confirmed the findings in Cutter et al. (2000) that the most vulnerable places do not always overlap with the most vulnerable populations.

The findings of this study have demonstrated that vulnerability to flood hazard in riverine areas is associated with complex dimensions of socio-economic conditions, such as higher dependency ratio, lower levels of income, limited access to financial institutes, poor sanitation, and landlessness, which led to the increased vulnerability of riverine households. These findings confirmed that higher age dependency was associated with lower capacity (Brenkert and Malone 2005) and thus an increased flood risk. This study also revealed that female-headed households were less capable than male-headed households. The finding is consistent with Kamal et al. (2018) which identified female were more vulnerable to flood. The findings also confirmed that illiterate households were less capable than educated households. The results revealed that households who reside in rented, government owned, or /relative‘s land were less capable than households living on their own land.

The economic conditions of the surveyed households were very poor. The findings revealed that households with lower incomes were less capable of absorbing the shock of flooding, compared to those with higher incomes. Interestingly, a majority of the households (72%) did not have access to financial institutes, but they did have loans to payback. This indicates that people mostly rely on informal sources for borrowing money. This finding is consistent with other empirical studies that have indicated the high financial vulnerability of riverine people (Sarker et al. 2019).

Knowledge on hazard and vulnerable elements helps in identifying appropriate risk reduction measures, such as planning for emergency situations (Merz et al. 2010) or implementing proactive risk mitigation strategies. As riparian people, the majority of the households adopted at least one structural mitigation measure to reduce flood risk. Indeed, these household-level mitigation measures helped individuals protect their assets from flooding. One respondent from Gajaghanta said that ―around 20-25 years ago, the majority of the houses in here were made of straw. But now you will rarely find straw-made houses here. Even people who are day laborers have their corrugated iron tin-made houses. Although the initial investment for straw houses is low, it requires regular repair and can be washed away if a severe flood hits. On the other hand, corrugated tin houses are durable, require minor repair for upto 15 to 20 years, and we can easily dismantle them when we need to.”

This study‘s findings showed that only a small percentage of households reported precautionary saving of money and crops. This could be explained by the fact that these households have lower income levels, a lack of access to financial institutions, and limited knowledge. Another reason may be related to their recurrent experience of flood disasters, which has reduced the chance of experiencing negative outcomes in future disaster (Fox Gotham et al. 2017). Interestingly, only a small proportion of Purbachhatnai households had a portable cooking stove when compared to households in Gajaghanta and Belka. This is probably due to the flashy nature of floods in Purbachhatnai, where water recedes within few days. Therefore, people are reluctant to have a portable stove, and instead prefer to have precautionary money and crops saved. However, a vast majority of the households did not receive any form of disaster-related training. As a result, these riverine people are less aware of recent developments in terms of flood risk reductions measures.

There was little variation in the index score of the informational subcomponent in the studied clusters. Although more than four-fifths of respondents received a flood warning, the lead-time was less than six hours, which restricted people‘s ability to move their belongings to a safer place. This is because the abrupt release of water from the Gozoldoba Barrage resulted in uncertain floods in Bangladesh (Mondal and Islam 2017). The percentage of people who received an early warning gradually decreased from upstream (94%) to downstream (74%), suggesting that risk communication systems are not uniform across the whole study area.

Livelihood diversification is a risk mitigation strategy through which households construct a diverse portfolio of activities for diverse income sources (nonfarm, livestock, remittance flow), which helps improve livelihood security and thus reduces risk (Davies and Hossain 1997). Although households in Belka reported having limited livelihood diversification options (such as limited remittance flow outside of flood-prone areas, limited non-farm income sources, a lower number of multiple earning members in households), a higher percent of people from this area engaged in livestock and poultry rearing. Cattle are the most common and key livestock assets, and the vast availability of lowland pastures (mostly open access) motivates people to rear cattle, as reported by key informants in Belka. On the other hand, people from Purbachhatnai have limited interest in cattle or goat rearing. According to an in-depth interview, flash flood-prone Purbachhatnai has limited grazing land, and therefore, people there have a greater interest in poultry rearing rather than in cattle or goats. A higher percent of households from Belka reported that they were able to recover from the last flood disaster using their own resources as compared to the percent in Purbachhatnai. This indicates that physical asset ownership, such as livestock, can serves as precautionary savings for liquidity purposes during a disaster (Siegel and Alwang 1999).

The analysis showed that duration of living in one place had a strong influence on receiving cooperation from neighbors during a disaster. The key informants from Purbachhatnai reported, ―Some people from our community are organized to provide voluntarily assistance to those families who are in need of dismantling their houses on realizing that their homes will be eroded by floods or riverbank erosion, or even to rebuild their houses.*"* Surprisingly, a lower percent of Gajaghanta households received help from their neighborhoods during the disaster, even though they had lived there for an extensive period of time. This might be partly due to the urban influence on people‘s mindset in that area.

3.8 Chapter summary

This chapter assessed the flood disaster risk of riverine households from the upstream (Purbachhatnai), midstream (Gajaghanta), and downstream (Belka) segments of the right bank of the Teesta River using a multi-dimensional composite index (RFDRI). The riverine flood risks were measured by combining four vital components of risk into one framework, confirming that risk is a function of hazard, exposure, vulnerability, and capacity (UNDRR 2017). The findings from this study indicated that the frequency and intensity of flood hazards were high, meaning that people and their assets were highly exposed to floods, but vulnerability was not as high as hazard or exposure. The non-significant differences of capacity levels suggested that people living in the riverine floodplain are similarly adapted to flooding hazards (Brammer 2016). The degree of flood risk was different among the communities. The aggregated RFDRI score for Belka was higher than for Purbachhatnai and Gajaghanta. This is because external stressors for flood risk (hazard and exposure) were dominant in Belka, and the highest percentage (46.4%) of people from this regions were at high risk. This area was also characterized by non-diversified income sources with limited livelihood strategies. Additionally, people from Belka are also largely excluded from services offered by the government and private sectors because of Belka‘s geographical remoteness. On the other hand, the aggregated RFDRI was the lowest in Gajaghanta among the studied areas. This can be attributed to the fact that Gajaghanta is located within a 12 km periphery of the Rangpur metropolitan area. People living in Gajaghanta have greater access to services and other basic facilities and can commute frequently to the divisional city. Spatial analysis provided further insights into the geographic distribution of riverine flood risk across the study area and visualized the locations of risk-prone households.

Chapter 4: Households' Response to Flood Disaster

4.1 Introduction

The purpose of this chapter is to examine households‘ response measures and identify the determinants to choose a particular measure to respond and recover from the impact of a flood disaster. Logistic regression and principal component analysis techniques were used to identify the determinants of households‘ response to 2017 flood. Chi-square test was used to describe the relationships between households‘ response measure and recovery from flood disaster.

The remainder of this chapter is divided into six sections. The results are presented in four sections. Section 4.2 and 4.3 investigates the determinants of households‘ response to flood disaster. Section 4.4 examines the relationships between recover from flood disaster and households‘ response measures. Section 4.5 explores the determinants of perceived preparedness. Section 4.6 presents the discussion on the results and Section 4.7 summarizes the chapter outcome.

4.2 Post-disaster coping measures and its determinants

This section aims to examine post-disaster coping measures adopted by the individual household and identify the determinants to adopt a particular coping measure to respond to a flood disaster.

4.2.1 Variables selection

(a) Dependent variables

To assess post-disaster coping measures adopted by the households, the respondents were asked whether or not they adopted 21 measures during or immediate (within one month) after the 2017 flood. These coping measures (Table 4.1) are classified into five groups: namely, borrowing money; assets disposal; consumption reduction; temporary migration; and grants from external sources (detail description of each category is in Appendix F, Table 1).

Table 4 1: Grouping of post-disaster coping measures

Groups	Measures
Borrowing money	Borrowed money from NGOs
	Borrowed money from local money lenders
	Borrowed money from relatives
	Borrowed money from friends
	Borrowed money from banks
	Borrowed money by selling labor in advance
	Borrowed money by selling crops in advance
Assets disposal	Sold poultry (livestock)
	Sold cattle (livestock)
	Sold goats (livestock)

Groups	Measures
	Sold household's goods (household assets)
	Sold/leased out jewelry (household assets)
	Sold/leased out lands (household assets)
	Sold crops (household assets)
	Sold trees (household assets)
	Spent previous savings
Consumption reduction	Starvation/meal skipping during flood
Temporary migration	Temporary migration for work
Grants from external sources	Received emergency support from NGOs
	Received emergency support from government
	Received emergency support from local elites

(b) Explanatory variables

A multitude of factors influences coping measures, and there is no agreed framework for choosing explanatory variables. A household's choice of a particular set of strategies and their timing depends on the complex dimensions of vulnerability (Davies 1993). First, all the indicators of flood risk were included in the logistics models. Then the non-significant indicators were excluded one by one from the logistic regression models until only statistically significant variables remains for all models (Stoltzfus 2011). Finally, depth of floodwater (EXPERIENCE), location of house (LOCATION), affected by disease (ILLNESS), age (AGE), female (FHH), agricultural landless (LAND), crop save (CROP), mobile phone (MOBILE), mitigation measures (MITIGATION), and nonfarm income (NONFARM) and two regional variables (GAJAGHANTA, BELKA) were included in the models (Table 4.2).

Table 4 2: List of variables used for the logistic regression model to identify the determinants of post-disaster coping measures

Variables	Description
Floodwater depth	Height of floodwater inside the home (continuous)
Location of house	Location of home within 1000 m from the riverbank: yes=1, otherwise=0
Affected by disease	Family members infected by communicable diseases/ injured in the last 5 years due to flood: yes=1, otherwise=0
Age	Age of household head (in years)
Female	Female headed household: yes=1, otherwise=0
Agricultural landless	Household does not have agricultural lands: yes=1, otherwise=0
Crop save	Household has precautionary crop savings: yes=1, otherwise=0
Mobile phone	Household has informational device at home: yes=1, otherwise=0
Mitigation measures	Household has taken at least one structural mitigation measure to prevent a flood disaster: yes=1, otherwise=0
Nonfarm income	Household has a non-farm income source: yes=1, otherwise=0
Gajaghanta	Household lived in Gajaghanta: yes=1, otherwise=0
Belka	Household lived in Belka: yes=1, otherwise=0

(c) Regression model

The dependent variable is whether a household adopted a particular coping measure or not after 2017 flood. Since the dependent variable is dichotomous (yes and no), a binary logistic regression was used to model the influence of explanatory variables on adopting different coping measures. The logistic model (Equation 4.1) provides the odds of dependent variables, which are the ratio of probability of adopting coping measure vs not adopting it and can be written as follows:

$$\text{Logit}(P_x) = \log\frac{P_x}{1-P_x} = \beta_0 + \beta_1\ \text{EXPERIENCE} + \beta_2\ \text{LOCATION} + \beta_3\ \text{ILLNESS} + \beta_4\ \text{AGE} + \beta_5\ \text{FHH} + \beta_6\ \text{LAND} + \beta_7\ \text{CROP} + \beta_8\ \text{MOBILE} + \beta_9\ \text{MITIGATION} + \beta_{10}\ \text{NONFARM} + \beta_{11}\ \text{GAJAGHANTA} + \beta_{12}\ \text{BELKA} \quad (4.1)$$

Where,

P_x = Probability of adopting a coping measure
$1 - P_x$ = Probability of not adopting coping measures
β_0 = Probability constant
$\beta_1, \beta_2, \beta_3 \ldots\ldots\ldots\ldots\ldots\ \beta_j$ = Coefficient of the explanatory variables

4.2.2 Household-level coping measures

Households adopted a mix of coping measures to respond to flood disaster. Table 4.3 provides a combination of five major categories of coping measures employed by households to respond and recover from the impact of the last flood. The majority of the households adopted two or three measures. Adopting four or five measures were less common. When adopting one measure, assets disposal was the most preferred, while temporary migration was the least preferred option.

Table 4 3: Combination of five major post-disaster coping measures (Source: Field Survey, 2019 [N=377])

Coping measures	Number of coping measures																										% of HHs
	1				2								3								4				5	0	
BOMO	✓				⊙	⊙	⊙	⊙					⅄	⅄	⅄	⅄	⅄			⅄	✦	✦	✦	✦	★		85%
ASDI		✓			⊙				⊙	⊙	⊙			⅄			⅄	⅄	⅄	⅄	✦	✦		✦	★		73%
CORE			✓			⊙			⊙			⊙			⅄	⅄	⅄	⅄				✦	✦	✦	★		29%
TEMI							⊙			⊙			⅄			⅄			⅄	⅄	✦		✦		★		23%
GRES				✓				⊙			⊙	⊙	⅄	⅄	⅄			⅄	⅄		✦	✦	✦	✦	★		34%
Number of HHs	15	22	4	2	98	23	9	11	4	7	7	3	9	49	12	8	28	2	1	24	12	9	1	5	9	3	

Note: BOMO: Borrowing money; ASDI: Assets disposal; CORE: Consumption reduction; TEMI: Temporary migration; GRES: Grants from external sources. HHs: Households

Coping measures within the borrowing category had mixed outcomes (Figure 4.1). Among the respondents, 16% borrowed money from formal sources (NGO/bank), 66% took interest-free loans from their friends or relatives, and 27% borrowed money from local money lenders. In extreme situations, some of the households borrowed money either by selling labor in advance (9%), selling crops in advance (9%), or both (2%). Further investigation found that the majority (72 out of 73) of households that adopted these kinds of erosive measures faced inundation of their houses during the last flood. Households with higher vulnerability were found to borrow money from local money lenders ($\chi^2 = 23.13$, df = 2, $p < .01$). There is also a sequence of adopting a particular coping measure (Corbett 1988), as FGD participants from the Belka informed: —we first use up our own savings. When we finish our savings, we try to ask our relatives for help. If we fail to get assistance from our friends, relatives, or neighbors, we then approach the local money lender to borrow money from them. Sometimes, we take loans from NGOs but we rarely seek a bank loan." Regardless of the source, 85% of the households borrowed money from at least one in order to cope with flood (Table 4.3).

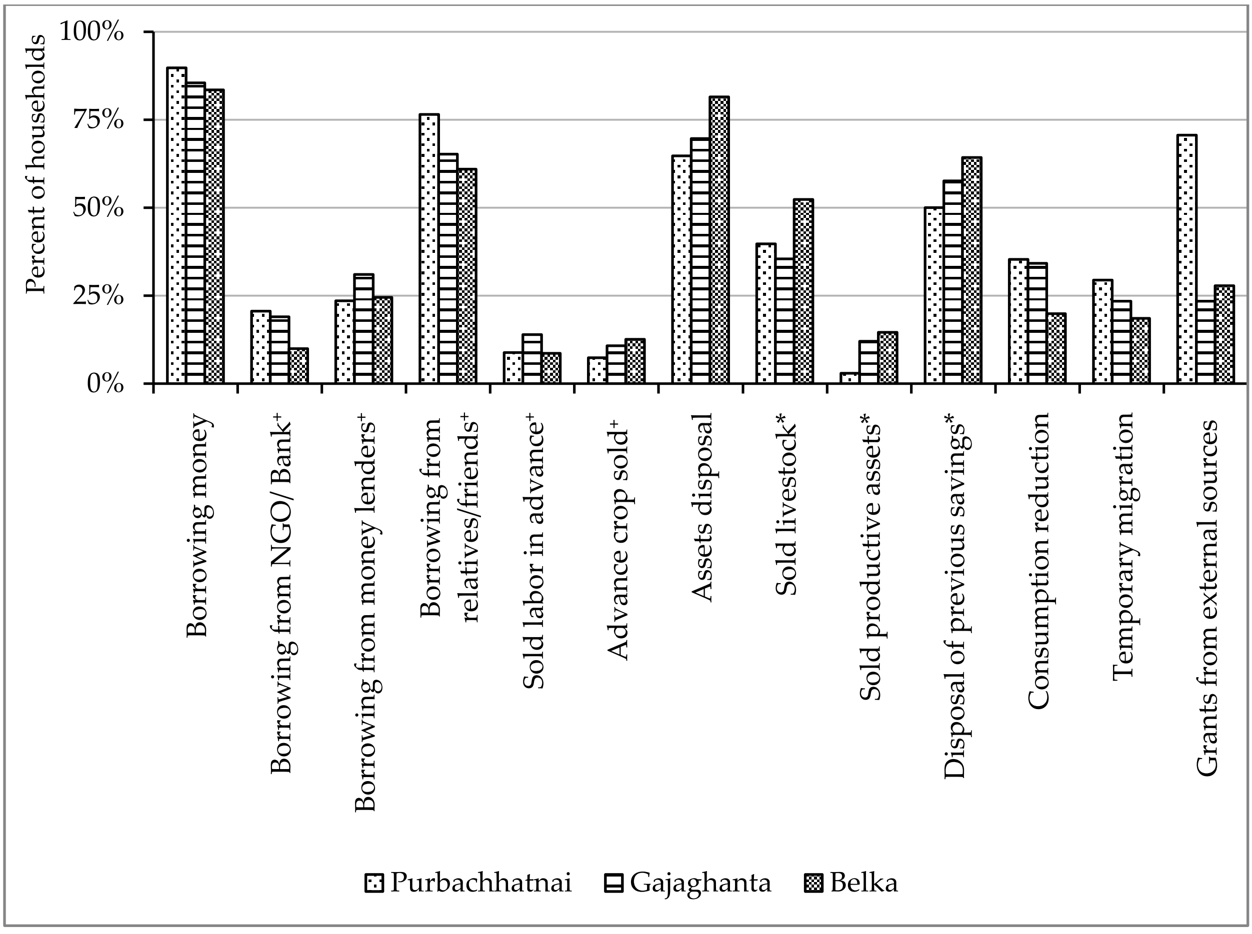

Figure 4 1: Geographical variations of post-disaster coping measures in the study areas (Source: Field Survey, 2019)

Note: +Coping measures within borrowing money category; *Coping measures within assets disposal category

Around 73% of the households adopted at least one assets disposal measure to cope with flood (Table 4.3). In this case, 43% of the households sold their livestock and around 11% sold their productive assets (Figure 4.1). More than half of the respondents (59%) spent their savings to cope with flood. Around 29% of the households reduced their daily consumption through starvation or meal skipping and 34% received grants from external sources (Table 4.3). However, a higher proportion of households from Purbachhatnai received external support compared to other regions (Figure 4.1). In the context of temporary migration of male members outside of flood-prone regions, 23% of the households adopted this measure (Table 4.3). I also conduct further analysis to know whether there was any association between post-disaster borrowing money and temporary migration. The analysis showed that post-disaster temporary migration was not significantly associated with borrowing money from NGO/bank (χ^2 = 2.54, df = 1, p = .111), from local money lenders (χ^2=1.23, df=1, p=.270), or from relatives/friends (χ^2 = 2.68, df = 1, p = .102). However, a significantly higher proportion of household who were adopted temporary migration, they had debt at the time of interview (χ^2 = 8.82, df = 1, p = .003).

I explored the association between coping measures and level of risk (Table 4.4). The results showed that there was significantly higher proportion of households from low risk group adopted assets disposal strategy. In contrast, a higher proportion of households from the high risk group adopted consumption reduction strategy.

Table 4 4: Associations between coping measures and level of risk

Coping strategies	**Risk categorization**			*p* value
	Low risk	Medium risk	High risk	
% of HH borrowed money	82.5	89.6	84.1	*p*=.251
% of HH disposed assets	86.5	72.0	61.9	*p*<.001
% of HH reduced consumption	11.1	25.6	49.2	*p* <.001
% of HH migrated temporarily	22.2	25.6	19.8	*p*=.548
% of HH received grants from external sources	31.0	39.2	31.0	*p*=.280

4.2.3 Factors affecting post-disaster coping measures at household-level

The results of the logistic regression models are presented in Table 4.5 (details are in Appendix F, Table 2 to Table 6). Prior to the analysis, multicollinearity among the independent variables was verified using a correlation analysis (correlation matrix presented in Appendix F, Table 7).

The results indicated that increasing floodwater depth increases the probability of adopting consumption reduction strategy. The likelihood of borrowing money and receiving grants were higher for the houses located within 1000 m from the riverbank than those farther away. The odds for borrowing money and temporary migration were positive and significantly higher for the households who were infected by communicable diseases due to flood. Age and sex of household‘s head were statistically significant and negatively associated with borrowing money.

Table 4 5: Determinants of post-disaster coping measures

Explanatory variables	**Dependent variable**				
	Borrowing money	**Assets disposal**	**Consumption reduction**	**Temporary migration**	**Grants from external sources**
Floodwater depth	n.s	n.s	(2.25)***	n.s	n.s
Location of house	(1.09)***	(-.86)*	n.s	n.s	(.85)*
Affected by disease	(.99)*	n.s	n.s	(1.28)*	n.s
Age	(-.03)*	n.s	n.s	(-.02)*	n.s
Female	(-1.62)**	n.s	n.s	n.s	n.s
Agricultural landless	n.s	(-1.12)***	(1.00)***	(.95)***	n.s
Crop saves	n.s	n.s	(-1.76)***	(.84)***	n.s
Mobile phone	(.89)*	n.s	n.s	(1.07)*	n.s
Mitigation measures	n.s	n.s	(-.80)**	(.92)*	n.s
Nonfarm income	(-1.06)***	(.77)**	n.s	n.s	n.s
Gajaghanta	n.s	n.s	n.s	n.s	(-1.86)***
Belka	n.s	(1.18)***	(-1.53)***	n.s	(-1.67)***
Constant	(2.31)*	(2.20)*	(-1.26)	(-3.28)***	(-.55)

Note: Unstandardized coefficients in parenthesis
―n.s” denotes non-significant
***, **, * imply significance at 0.1%, 1%, and 5% levels, respectively
Source: Calculated based on Field Survey, 2019 (N= 377)

Agricultural landless was significant and positively associated with consumption reduction and temporary migration. The significant negative relation between agricultural landless and asset disposal suggested that agricultural landless households were less likely to dispose their assets to cope with flood. In contrast, the odds of assets disposal were higher among the households who have income from nonfarm sources. Precautionary crop-save had a significant positive relation with temporary migration and a negative relation with consumption reduction.

The coefficient of location dummies indicated that households from Belka were more likely to adopt assets disposal strategy rather than borrowing money, consumption reduction and temporary migration. The results also indicated that if a house was located within 1000 m from the riverbank and in Gajaghanta and/or Belka there was a lower chance to get support from external sources.

4.3 Post-disaster risk mitigation measures and its determinants

This section aims to examine risk mitigation measures adopted by the individual household and identify the determinants that influenced households' to adopt risk mitigation measures after 2017 flood.

4.3.1 Variables selection

(a) Dependent variables

The household-level mitigation measures included plinth raise of the house; building homestead on raised earthen mounds; modify house with strong materials; precautionary money savings; precautionary crop savings; store valuables household goods safer place; and collect emergency items (detail description of each category is in Appendix F, Table 8). Each respondent were asked whether they implemented these mitigation measures after experiencing severe flood in 2017 in order to reduce future flood risk. These mitigation measures are grouped as structural and nonstructural measure (Table 4.6). Structural and nonstructural measure was the dependent dummy variable. To determine the dummy, a value of "1" was assigned to those households that had implemented at least one structural measure and "0" for those that had not implemented. Similar process was repeated to determine the dummy value for nonstructural measure. The dependent variable for assessing post-disaster mitigation measures is whether a household implemented a particular mitigation measures or not after 2017 flood.

Table 4 6: List of variables used for the logistic regression model to identify the determinants of post-disaster risk mitigation measures

Groups	Measures
Structural measures	Plinth raise of the house
	Build home on raised earthen mounds
	Modify house with strong materials
Nonstructural measures	Household has precautionary money savings
	Household has precautionary crop savings
	Store valuables household goods safer place
	Collect emergency items

(b) Explanatory variables

I repeated similar procedure of post-disaster coping measures to select explanatory variables. In addition, two perception variables were included to model risk mitigation measures. Finally, perception of flood probability (PROBABILITY), perceived preparedness (PREPARATION), floodwater depth (EXPERIENCE), location of house (LOCATION), living duration (DURATION), membership (AFFILIATION), age (AGE), female (FHH), earning member (EARNERS), education (EDUCATION), nonfarm income (NONFARM), agricultural land (LAND) and two regional variables (GAJAGHANTA, BELKA) were included in the models.

Table 4 7: List of variables used for the logistic regression model to identify the determinants of post-disaster mitigation measures

Variables	Indicators and description
Perception of flood probability	Probability of a flood like 2017 within next 10 years: yes=1, otherwise=0
Perceived preparedness	Household who reported they are better prepared than for previous flood: yes=1, otherwise=0
Floodwater depth	Height of floodwater inside the home (continuous)
Location of house	Location of home within 500 m from the riverbank: yes=1, otherwise=0
Living duration	Duration of living in the community (in years)
Membership	Household is affiliated with any NGOs: yes=1, otherwise=0
Age	Age of household head (in years)
Female	Female headed household: yes=1, male=0
Earning member	Number of earning members (continuous)
Education	Illiterate household (binary variable): yes=1, otherwise=0
Agricultural landless	Household does not have agricultural lands: yes=1, otherwise=0
Nonfarm income	Household has a non-farm income source: yes=1, otherwise=0
Gajaghanta	Household lived in Gajaghanta: yes=1, otherwise=0
Belka	Household lived in Belka: yes=1, otherwise=0

(c) Regression model

The dependent variable is whether a household implemented mitigation measures or not after 2017 flood. Since the dependent variable is dichotomous (yes and no), a logistic regression was used to model the influence of explanatory variables to implement mitigation measures. The logistic model (Equation 4.2) provides the odds of dependent variables, which are the ratio of probability of implemented mitigation measures vs not implemented it and can be written as follows:

$$\begin{aligned}\mathrm{Logit}(\mathrm{P_x}) = \log\frac{\mathrm{P_x}}{1-\mathrm{P_x}} &= \beta_0 + \beta_1\ \mathrm{PROBABILITY} + \beta_2\ \mathrm{PREPARATION} \\ &+ \beta_3\ \mathrm{EXPERIENCE} + \beta_4\ \mathrm{LOCATION} + \beta_5\ \mathrm{DURATION} \\ &+ \beta_6\ \mathrm{AFFILIATION} + \beta_7\ \mathrm{AGE} + \beta_8\ \mathrm{FHH} + \beta_9\ \mathrm{EARNERS} \\ &+ \beta_{10}\ \mathrm{EDUCATION} + \beta_{11}\mathrm{LAND} + \beta_{12}\ \mathrm{NONFARM} \\ &+ \beta_{12}\ \mathrm{GAJAGHANTA} + \beta_{12}\ \mathrm{BELKA}\end{aligned} \tag{4.2}$$

Where,

P_x = Probability of implementing mitigation measure

$1 – P_x$ = Probability of not implementing mitigation measure

β_0 = Probability constant

β_1, β_2,β_3 …………… β_j = Coefficient of the explanatory variables

4.3.2 Household level risk mitigation measures

Figure 4.2 and Figure 4.3 provides an overview of the extent of adaption of structural and nonstructural measures. The majority of the households (83%) adapted at least one mitigation measure. The results showed that 56% households raised the plinth of their house (living room) at a height above the levels recorded in the last flood. On the other hand, 47% households built homesteads on a raised earthen mound to protect themselves from flood. All of the surveyed households were single story and majority (77%) of them was made of corrugated iron sheets for both roofing and walls. However, due to the huge cost of building materials, only 26% households modified their houses with strong materials. Around 10% (n=39) households reported that they adapted three structural measures together after the last flood. Further investigation revealed that majority of the households who reported they adapted three structural measures, their houses were destroyed in the last flood (n=31).

As many as 55% (n=209) households adapted at least one nonstructural measure in the form of precautionary cash saving (n=91), precautionary food save (n=102), collect emergency items (n=45), and store valuables in a safe place (n=97).

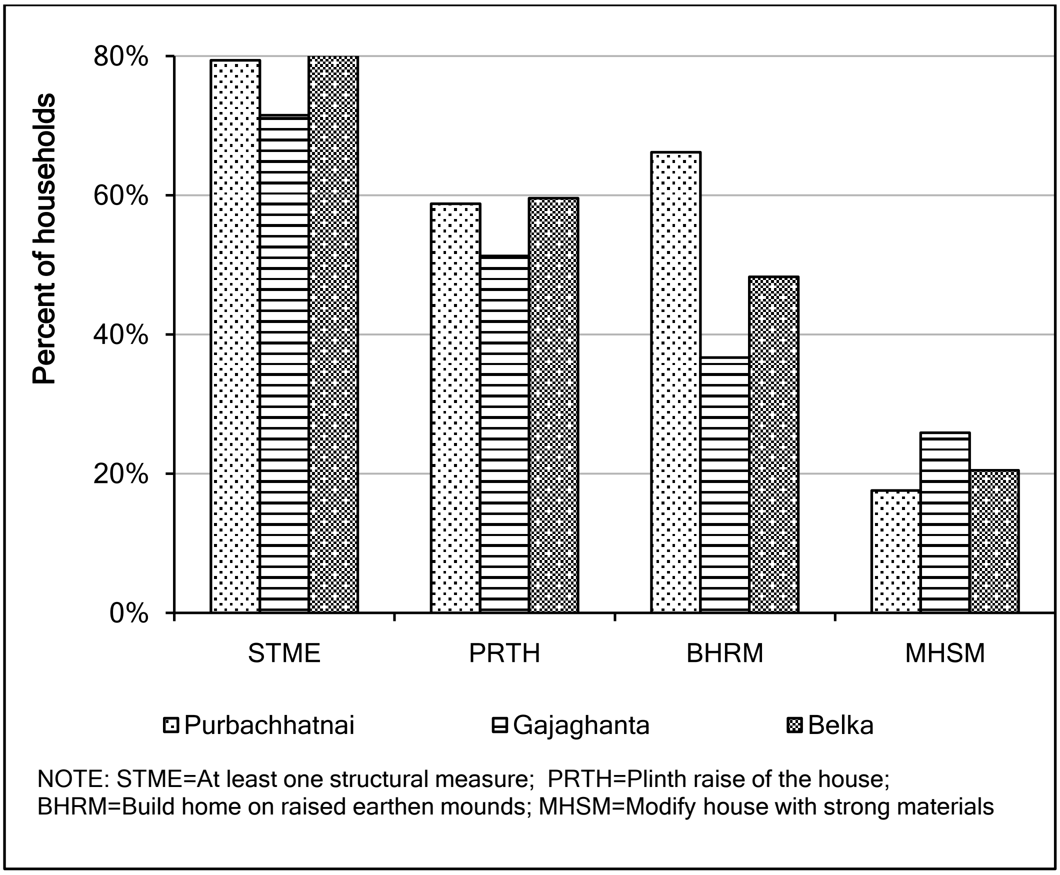

Figure 4 2: Extent of implemented structural mitigation measures in the study areas

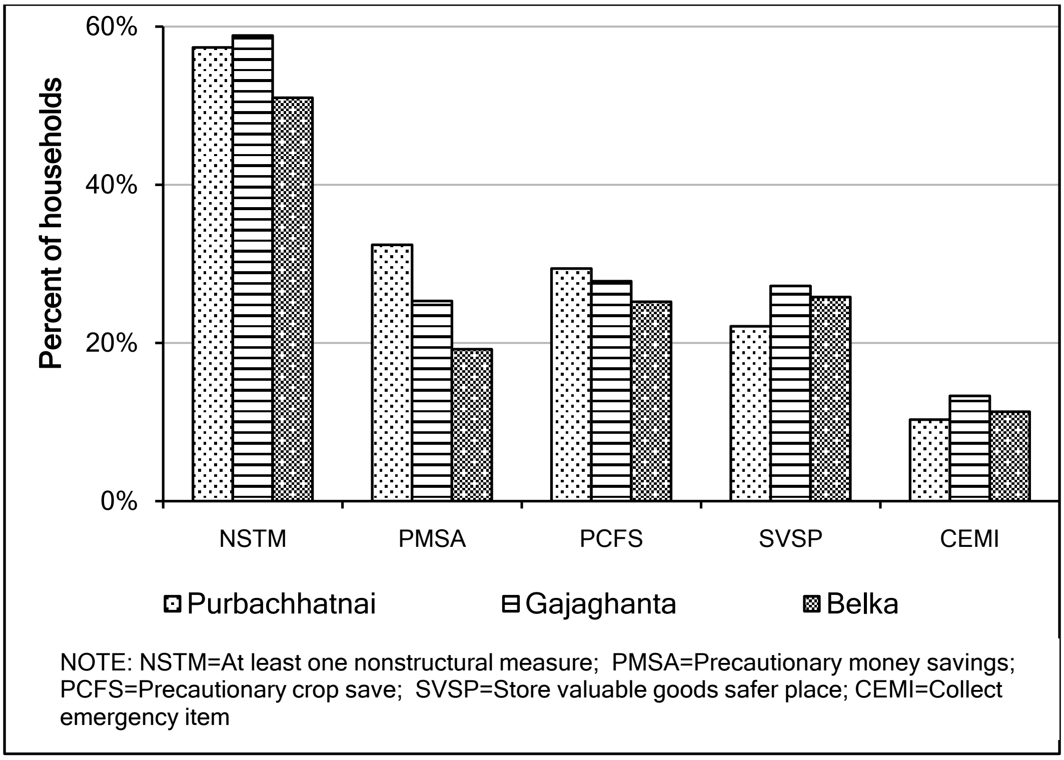

Figure 4 3: Extent of implemented nonstructural mitigation measures in the study areas

I also explored the association between mitigation strategies and level of risk (Table 4.8). The results showed that there was significantly higher proportion of households from low risk group adopted structural and nonstructural mitigation measures.

Table 4 8: Associations between mitigation measure and level of risk

Risk mitigation measures	**Risk categorization**			***p* value**
	Low risk	**Medium risk**	**High risk**	
At least one structural measure (%HH)	89.7	77.6	61.9	$p < .001$
% HH raised plinth of the house	65.1	53.6	49.2	$p = .032$
% HH built home on raised mounds	64.3	41.6	34.1	$p < .001$
% HH modified house with strong materials	38.9	16.0	11.9	$p < .001$
At least one nonstructural measure (%HH)	66.7	63.2	36.5	$p < .001$
% HH has stored valuables goods in safe	26.2	30.4	20.6	$p = .207$
% HH has collected emergency items	15.9	12.0	7.9	$p = .151$
% HH has precautionary crop savings	38.1	24.8	18.3	$p < .001$
% HH has precautionary money savings	37.3	28.8	6.3	$p < .001$

4.3.3 Factors affecting post-disaster mitigation measures at household-level

To assess post-disaster mitigation behavior of households, four different models were developed. Among these four models, Model 1 and Model 3 included risk perception variables, while risk perception variables were excluded from Model 2 and Model 4 (Table 4.9).

The results of the logistic regression models are presented in Table 4.9 (details are in Appendix F, Table 9 to Table 12). Prior to the analysis, multicollinearity among the independent variables was verified using a correlation analysis (correlation matrix presented in Appendix F, Table 13).

Table 4 9: Determinants of risk mitigation (structural/nonstructural) measures

Explanatory variables	Dependent variable:			
	Structural measures		Nonstructural measures	
	Model 1	Model 2	Model 3	Model 4
Perception of flood probability	(.76)**		(.25)	
Perceived preparedness	(1.02)**		(.16)	
Floodwater depth	(-.10)*	(-.11)**	(-.03)	(-.04)
Location of house	(-.14)	(-.21)	(-.85)***	(-.86)***
Living duration	(-.85)	(-.94)	(.03)	(-.02)
Membership	(.05)	(.21)	(.92)**	(.94)**
Age	(.46)	(.34)	(-.17)	(-.19)
Female	(-1.05)*	(-1.01)	(-.81)	(-.81)
Earning member	(-.30)	(-.17)	(.18)	(.20)
Education	(-.35)	(-.31)	(.21)	(.21)
Agricultural landless	(-.74)*	(-.74)**	(-.99)***	(-.99)***
Nonfarm income	(.63)*	(.66)*	(.71)**	(.72)**
Gajaghanta	(-.56)	(-.48)	(-.19)	(-.17)
Belka	(.56)	(.56)	(-.12)	(-.11)
Constant	(1.60)*	(2.76)***	(.75)	(1.04)
Nagelkerke R Square	.199	.137	.210	.206

Note: Unstandardized coefficients in parenthesis
***, **, * imply significance at 0.1%, 1%, and 5% levels, respectively
Source: Calculated based on Field Survey, 2019 (N= 377)

The results showed that perception of flood probability and self-efficacy significantly influenced the adaptation of structural mitigation measures. Experience of flooding had a negative and significant effect on the implementation of structural measures. The negative and significant coefficient of house location in the model about the implementation of nonstructural measures implied that proximity to riverbank discourage households to uptake mitigation measures. Mixed effects were found in the case of duration of living to implement mitigation measures and none of these relationships were statistically significant. The significant positive coefficients of the membership variable for the nonstructural measures showed those households affiliated with social organizations were more likely to implement nonstructural measures.

Gender had negative and significant effects on the adaptation of structural measures meaning that female were less likely to implement structural mitigation measures. Age, earning members and education were not significant to any of the models. The agricultural landownership and nonfarm income significantly influenced households to adapt mitigation measures. The location variables did not produce any significant association.

4.4 Association between household's response to flood disaster and post-disaster recovery

This section examined the association between household's response to flood disaster (coping measures and mitigation measures) and post-disaster recovery. Recovery from the flood disaster was investigated by asking households whether they were able to recover from the losses and damages incurred from the last flood disaster. Only 14% of the households (52 out of 377) reported that they were able to recover from the impact of the last flood in 2017. Pearson's chi-squared test was used to investigate these relationships. A household's recovery from flood disaster was coded as 1 for yes, 0 for no.

$$Y_r \begin{cases} 1 = & \text{If a household was able to recover from the last flood disaster} \\ 0 = & \text{If a household was not able to recover from the last flood disaster} \end{cases}$$

Where, Y_r is the subjective judgment of household's recovery status from the impact of 2017 flood.

4.4.1 Association between post-disaster coping measures and recovery from flood disaster

The results revealed that the proportion of households who borrowed money was lower among those who recovered than those not recovered (26.9% versus 94.8%) (Table 4.10). Similarly, 13.5% households who recovered adopted consumption reduction measure, versus 31.1% in other group (p =.008, OR=.35). However, temporary migration and grants from external sources had no significant association with recovery from flood.

Table 4 10: Comparison of post-disaster coping measures and recovery from flood

Coping measures variables	Recovered from last flood disaster		
	Yes (N=52)	**No (N=325)**	**OR [CI] (N=3377)**
% of households borrowed money	26.9	94.8	.02* [.01-.05]
% of households disposed assets	94.2	70.2	6.95* [2.12-22.84]
% of households reduced consumption	13.5	31.1	.35* [.15-.79]
% of households migrated temporarily	15.4	23.7	.60 [.26-1.30]
% of households received grants from external sources	25.0	35.1	.62 [.32-1.20]

* p value significant (<.01) using Chi-square test; OR=Odds Ratio; CI=Confidence Interval

In contrast, households who recovered was higher among those who disposed assets (p <.001, OR=6.95). Surprisingly, the majority of the households (49 out of 52) reported to have recovered resorting to either assets disposal or a combination of assets disposal with other coping measures (Figure 4.4). It is apparent from Figure 4.5 that most of the households reporting recovery adopted either SAVE or combination of SAVE and other measures. However, the households that adopted only the PASSET measure were unable to recover.

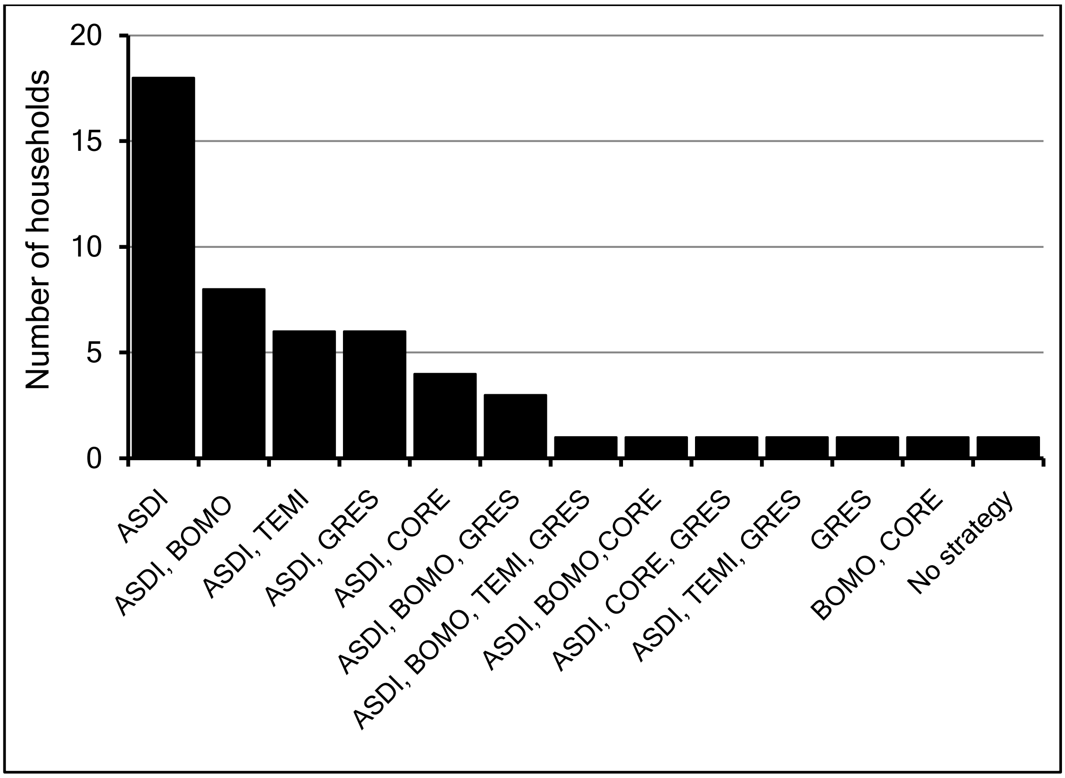

Figure 4 4: Recovered from last flood and adopted post disaster coping measures (n=52).

Note: BOMO: Borrowing money; ASDI: Assets disposal; CORE: Consumption reduction; TEMI: Temporary migration; GRES: Grants from external sources

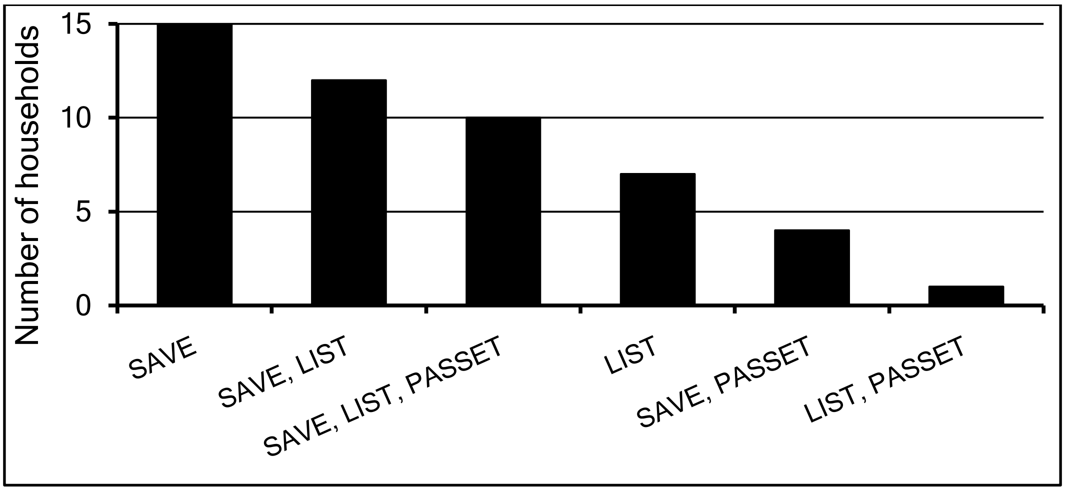

Figure 4 5: Recovered from last flood and assets disposal category (n=49).

Note: SAVE: Disposal of previous savings; LIST: Sold livestock; PASSET: Sold productive assets

4.4.2 Association between post-disaster mitigation measures and recovered from flood disaster

This section examines whether there was any association between recover from flood disaster and implementation of structural/nonstructural mitigation measures. I did not find any association between recovered from flood disaster and structural measures (*p*=.16) or recovered from flood disaster and nonstructural measures (*p*=.88) (Table 4.11).

Table 4 11: Comparison of risk mitigation measures and recovery from flood disaster

Post-disaster risk mitigation measures	Recovered from last flood disaster		
	Yes (N=52)	**No (N=325)**	**OR [CI] (N=3377)**
% of households adopted structural measures	84.6	75.1	1.83 [0.83-4.04]
% of households adopted nonstructural measures	53.9	55.7	0.93 [0.52-1.67]

Chi-square test; OR=Odds Ratio; CI=Confidence Interval

4.5 Determinants of perceived preparedness to flood disaster

Households' perceived preparedness was assessed by asking every household a single question: ―Do you think you are better prepared now than for previous floods?" A household's perceived preparedness was coded as 1 for yes, 0 for no. Multivariate analysis using principal component analysis and logistic regression was employed to evaluate the role of flood risk subcomponents in explaining households' perceived preparedness.

$$Y_p \begin{cases} 1 = & \text{Yes: Do you think you are better prepared now than for previous floods?} \\ 0 = & \text{No: Do you think you are better prepared now than for previous floods?} \end{cases}$$

Where, Y_p is the subjective judgment of household's actual preparedness measures

4.5.1 Results of multivariate analysis

PCA was undertaken using the 16 subcomponents of flood risk (frequency of flood, intensity of flood, locational exposure, human exposure, assets exposure, socio-demographic, health condition, economic condition, housing and amenities, land ownership, knowledge, emergency preparedness, informational, mitigation measures, livelihood strategies, and social network) (Figure 2.2). A Varimax rotation with Kaiser Normalisation was applied to the component matrix. The robustness of the model was checked using Kaiser-Meyer-Olkin (KMO) of sampling adequacy and the Bartlett's Test of Sphericity. The KMO value was 0.729, which was above the recommended minimum (0.6) (Table 4.12). The Bartlett's Test of Sphericity was highly significant (df =120; Sig. =.000) (Table 4.12), suggesting that the data were appropriate for principal component analysis. The PCA extracted five components

(Eigenvalue >1), which explained 51.9% of the variance (Table 4.13) (details are in Appendix F, Table 14). After rotation, the first component explained 15.4% of the variance. Land ownership and economic condition variables were scored highly on component one, with negative loading for the social network variable (Table 4.13). The first component was a reasonable representation of the socio-economic unsafe condition (SEUC). The second component accounted for 9.9% of the variance. Knowledge, mitigation measures, emergency preparedness, and information were highly loaded on the second component and were classified as the ability to respond (ATRE). For the third component, asset and human exposure variables showed positive loadings. The third component explained 9.8% of the variance and was interpreted as impact magnitude (IMMA). The fourth component accounted for 9.0% of the variance and explained the variations of locational exposure and flood characteristics. This component was a reasonable representation of proximity to flooding (PROF).

Table 4 12: KMO and Bartlett's test

KMO and Bartlett's Test[a]		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.729
Bartlett's Test of Sphericity	Approx. Chi-Square	822.79
	df	120
	Sig.	.000

[a] Based on correlations

Table 4 13: Rotated component matrix with Eigenvalues

	Component				
	1 (SEUC)	**2 (ATRE)**	**3 (IMMA)**	**4 (PROF)**	**5 (HEST)**
Social network	**-.747**	.020	-.208	.156	-.021
Land ownership	**.719**	-.127	-.236	.166	.037
Economic condition	**.558**	-.048	.007	.101	-.140
Socio-demography	**.449**	-.236	.063	.243	.052
Housing and amenities	**.411**	-.168	.109	.369	.299
Knowledge	.068	**.710**	-.235	.084	.441
Mitigation measures	-.069	**.567**	.030	-.077	-.129
Emergency preparedness	-.294	**.565**	.220	-.012	-.107
Informational	-.463	**.466**	-.116	-.133	-.281
Assets exposure	-.192	.145	**.784**	.113	.020
Human exposure	.120	-.085	**.592**	.030	.079
Intensity of flood	.496	-.009	**.586**	-.043	-.033
Locational exposure	.106	.152	.026	**.727**	-.245
Frequency of flood	-.002	-.115	.020	**.695**	.182
Livelihood diversification	-.300	.205	-.087	**-.353**	.167
Health condition	-.068	-.103	.103	-.064	**.839**
Eigenvalues	3.182	1.530	1.298	1.201	1.091
% of Variance	19.88	9.563	8.113	7.505	6.819

Note: Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. The highest loadings variables for each component are highlighted in bold.

The fifth component, labeled as health status (HEST), accounted for 7.8% of the variance. It is noted that the first and second components represent internal factors (vulnerability and capacity), whereas the third and fourth components explain the variables related to external factors (hazard and exposure), as shown in Figure 2.1.

The means scores of four principal components are plotted in Figure 4.6 and Figure 4.7. PC 1 and PC 2 in Figure 4.6 clearly separated lower capacity area Belka (e.g. informational, emergency preparedness) from lower vulnerable area Gajaghanta (e.g. land ownership, economic condition, socio-demography, housing and amenities). On the other hand, Purbachhatnai was separated from other two areas because of higher mean scores of PC 4 (higher locational exposure, higher frequency of flood) and lower means scores of PC 3 (lower assets exposure, lower intensity of flood) as shown in Figure 4.7.

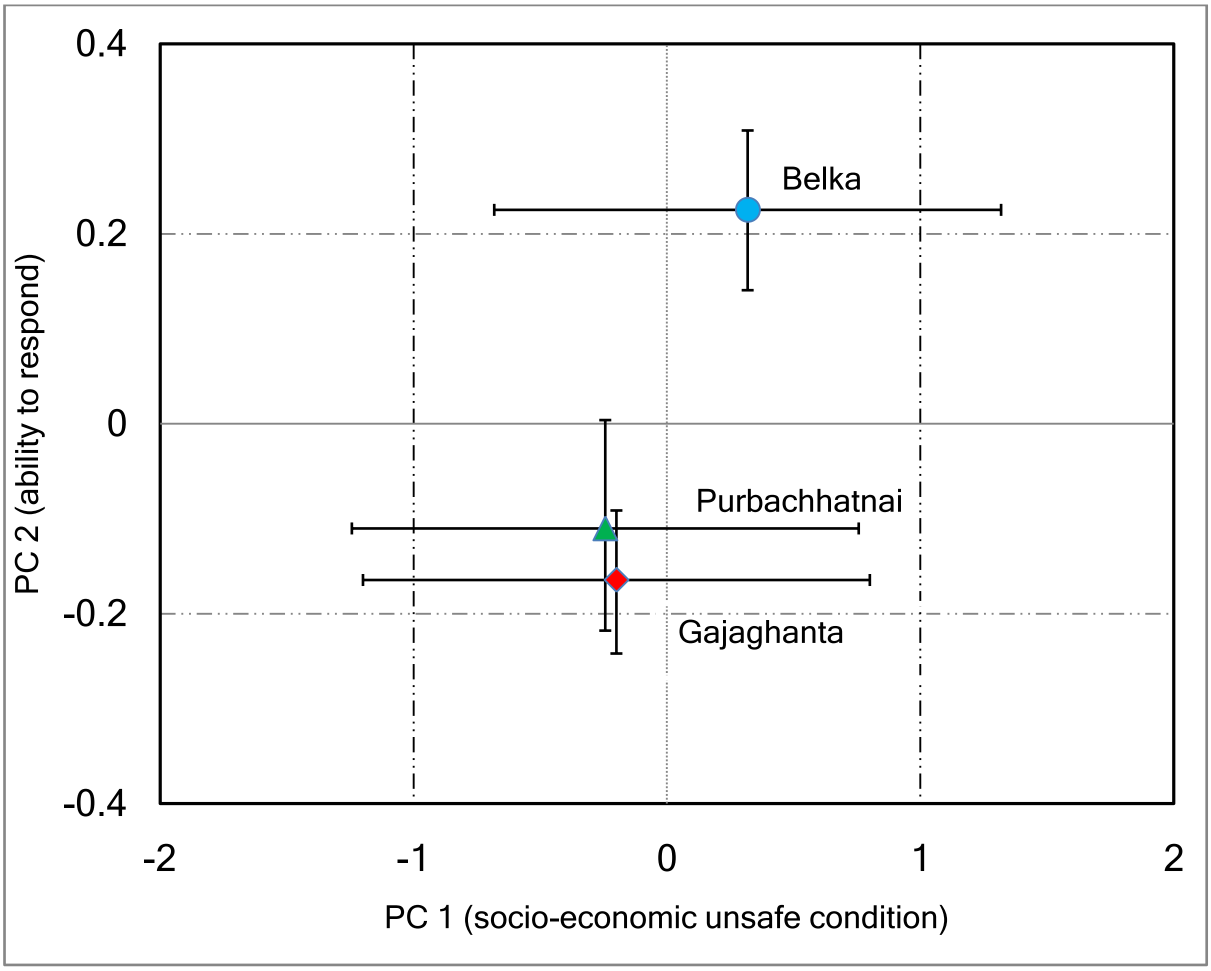

Figure 4 6: Location wise mean and standard error of PC1 and PC2

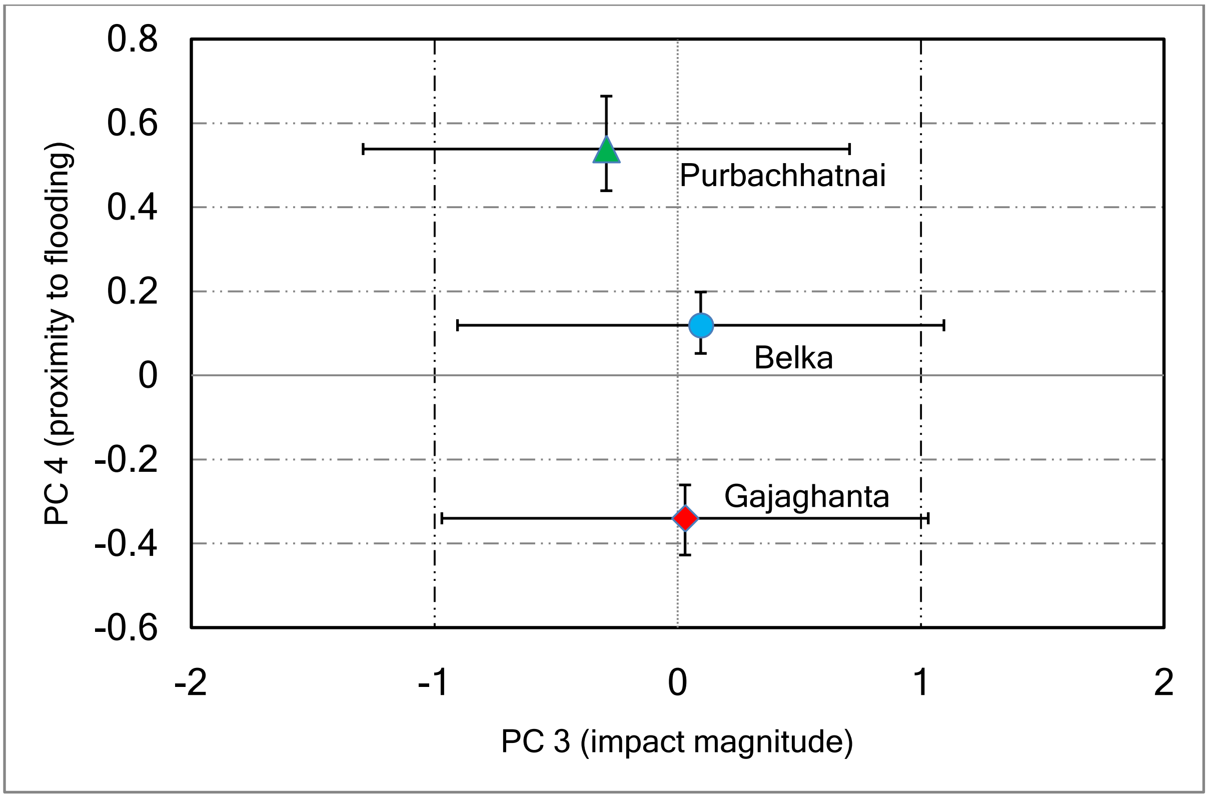

Figure 4 7: Location wise mean and standard error of PC3 and PC4

Next, the logistic regression model was used to identify the factors that determine households' perceived preparedness on flood disaster. The dichotomous variable on perceived preparedness (Yes=1, No=0) was used as a dependent variable in the model. The extracted factor scores of five principal components (SEUC, ATRE, IMMA, PROF, HEST) were considered independent variable. Prior to the analysis, the bivariate correlation test was applied to omit insignificant variables from the model (details are in Appendix F, Table 15). The HEST component was removed from the logistic regression model since it had no significant relation with the dependent variables. The equation of the logistic model to analyze household's perceived preparedness can be rewritten as:

$$\log \frac{P_x}{1 - P_x} = \beta_0 + \beta_1 SEUC + \beta_2 ATRE + \beta_3 IMMA + \beta_4 PROF \quad (4.3)$$

Where,

β_0 = Probability constant
SEUC = Socio-economic unsafe condition
ATRE = Ability to respond
IMMA = Impact magnitude
PROF = Proximity to flooding

This logistic model provides the odds of dependent variables (perceived preparedness) which are the ratio of probability of perceived well prepared than previous vs no prepared. The results of logistic regression are presented in Table 4.14.

Table 4 14: Determinants of perceived preparedness

Explanatory variables	B	S.E.	Wald	df	Sig.	Odds ratio	95% C.I.for EXP(B)	
							Lower	Upper
SEUC	-.42	.17	6.32	1	.01*	.66	.48	.91
ATRE	.84	.17	24.69	1	.00**	2.31	1.66	3.21
IMMA	-.70	.21	11.52	1	.00**	.50	.33	.74
PROF	-.40	.18	4.90	1	.03*	.67	.47	.96
Constant	2.33	.21	120.40	1	.00**	10.23		

Notes: N = 377; CI=Confidence Interval
Dependent variable = Do you think you are better prepared now than for previous floods? (Yes=1, No=0).
-2 Log likelihood= 248.65, Nagelkerke R^2=.23.
Significance level: *, and ** indicates statistical significance at 5% and 1%, respectively.

4.6 Discussion on the results

4.6.1 Post-disaster coping measures

The findings showed that high risk households were more prone to reduce their consumption. However, regardless of their level of risk, households adopted borrowing money and temporary migration measure. Contrary to the results of Kamal et al. (2018), the variable post-disaster temporary migration had no association with the sources of borrowing money. One possible explanation for this may be related to the use of previous savings by the households. In fact, households adopt a particular coping measure based on the impact level of the disaster and the availability of an individual‘s networks.

Floodwater depth had significant relation with consumption reduction. This may be due to the reduced livelihood opportunities during flood. Indeed, when floods hit, the ability of a wage laborer household to purchase food decrease as a result of wage reduction (Mavhura et al. 2013; Sakai et al. 2017). Another reason might be related to limited dry places for cooking or to wet firewood, exemplified by the majority of the respondents (72%), who said that their firewood was wet due to floodwater, and by one female respondent from Gajaghanta, who stated ―when flood water enters our room, we cannot cook our food due to the unavailability of dry places in our house. Therefore, we need to skip one or two meals a day". This finding was supported by other studies (Paul and Routray 2010; Sultana and Rayhan 2012; Ferdous and Mallick 2019), which reported that flooded households have to starve, skip meals, or eat less food during flood. However, the relationship between borrowing money and depth of flood was negative and insignificant. This findings contradict the results of Sultana and Rayhan (2012) which found positive and significant relation between borrowing decisions and height of flood.

Proximity of house was found to be positive and significant for borrowing money. This may be because proximity to river is associated with an increased level of flood risk, which may result in higher flood damage (Brouwer et al. 2007; Mavhura et al. 2013). This finding was partially consistent with Hyder and Iqbal (2016), who reported that people living near the riverbank were more prone to borrowing. Apart from borrowing, the probability of receiving grants from external sources increased with the house proximity to the riverbank than their counterparts. The findings were supported by previous research, which indicated that emergency aid was targeted to those households who were exposed to flooding in 1998 in Bangladesh (Paul 2003). However, a vast majority of the households from the study areas were still out for getting grants from external sources during emergency. As one respondent from Belka shared, —My house was flooded for around 15 days, but I did not receive any support either from the government or NGOs." This may be because road communication systems in the study area are not well-developed and they inundate, causing many places to become hard to reach without a boat. Previous research by Mallick et al. (2011) reported that people residing near marketplaces received more external support after a cyclone than those living far away, in the coastal zone of Bangladesh. During the interview, when I asked the respondents whether they received grants from external bodies, a vast majority claimed that, without a good connection with the Union Parishad representative, it was difficult for them to receive grants. Some of the respondents mentioned that they did not receive grants as they were unable to give bribes to the local government personnel. However, none of the respondents who received grants disclosed whether they had to offer bribes in order to receive grants. In their study, Kamal et al. (2018) also reported that emergency relief were not distributed properly among the flood affected people during 2017 flood in Sunamganj district.

On the other hand, disposal of assets was negatively associated with location of house, which implies that households located within 1000 m were less likely to dispose their assets compared to their counterparts. This may be because these households had limited cash saving to be used during disaster.

Floods generate a vicious cycle of impacts on the exposed people. For example, in flood-affected areas food prices increase, while job opportunities for wage laborers reduce. In this complex situation, if a family member suffers from a disease, households have to adopt a variety of coping strategies. The results suggested that having ill members affected by diseases in the family increased the probability of adopting borrowing money and temporary migration than who were not affected. This highlights their risk-averseness, as illness entails the need of immediate cash for the preventive and curative care of people struck by illness. These findings are consistent with Rashid et al. (2006) where they reported that household who experienced disease were more likely to adopt current adjustment (e.g., adjustment to meals, migrate to sale labor) and unsecured borrowing (e.g., borrow from relatives/moneylenders) measures. In a study conducted by Rayamajhee and Bohara (2019), on choices of post-earthquake coping responses in Nepal, it was found that household that experienced health damage was engaged in borrowing cash and advance labor sale as a compensation strategy.

Age increasing gradually reduces the physical capacity and thus increases the vulnerability of the household. A negative and significant coefficient of age implies that increase in household head‘s age reduced the likelihood of borrowing money. Previous studied also reported that borrowing was a less practiced coping option among aged people (Paul and Routray 2011; Sultana and Rayhan 2012; Hyder and Iqbal 2016). One respondent in his 80s from Gajaghanta shared his experience of why he did not borrow money: —I am an aging person with limited income. Nobody wants to lend me money as I might not be able to return it.” A related finding was also reported by Patnaik et al. (2015) with reference to flood in rural India, where they found that older people are less willing to depend on monetary transfers from relatives and friends, as compared to younger. Post-disaster temporary migration was also found lower among aged people. This is due to the level of functional fitness, which decreases with age (Tomás et al. 2018), making elderly people very cautious in taking decisions on temporary migration. Moreover, the demand for youths in urban labor markets discourages aged people in making migration decisions in Bangladesh (Hutton and Haque 2004). One respondent in his 70s shared that —when I was young, I went outside of this flood-prone area to find employment. However, now I do not search for jobs outside this area, because my physical conditions do not permit me to go outside for work”.

The negative coefficient of female presented that female headed households (FHH) were less likely to borrow money as compared to male headed households. This may be because majority of FHH in this study had insufficient assets, such as being landless (80% of FHH), unable to save crops (95% of FHH), lacking cooperation from their neighborhood during flood (90% of FHH), and limited access to financial institutions (90% of FHH). Existing literature suggested that FHH rely less on borrowing (Sultana and Rayhan 2012; Tran 2015; Bhattacharjee and Behera 2018) since people assess women as having limited capabilities of repayment (Ferdous and Mallick 2019). Furthermore, FHH were less likely to receive grants from external sources and preferred to reduce their consumption rather than employing asset disposal and temporary migration. However, these relationships were insignificant.

Agricultural land is an important natural asset for rural households. The results indicated that landless had a negative and significant relationship with asset disposal. This is true in the sense that majority of the surveyed household head‘s were employed in agricultural sector and thus flood become a way of living for them.

This finding was partially supported by Bhattacharjee and Behera (2018) that reported households who owned land were more likely to sell their productive assets to cope better disaster. The probability of consumption reduction and temporary migration were significantly greater for the agricultural landless households than their counterparts. A possible explanation of these findings could be illustrated by the vulnerability of the households. In rural areas of Bangladesh, landless households have limited precautionary money savings and possess fewer productive assets with no cultivable lands. Since rural areas have limited job opportunities, landless people temporarily migrate outside of flood prone areas to provide for their household consumption. These findings were in the line with the finding of Bhattacharjee and Behera (2018), where they reported that agricultural landholders were less likely to migrate to city/town. In a study undertaken by Paul and Routray (2011) on cyclones and storm surges in Bangladesh, it was found that landless households reduced their consumption and had fewer assets to dispose. However, I did not find any significant relation between land ownership and borrowing, as reported by Patnaik et al. (2015).

The result showed that households that saved crops were less likely to reduce their consumption. One informant narrated, ―I faced financial problems after the last flood. However, I could easily recover since I had nuts on the land. After the flood water receded, I harvested nuts and sold them in the market, which provided me with instant cash to purchase food for our family." However, the likelihood of temporary migration was significantly greater for the households that saved crops than their counterparts, implying that households that saved crops were risk averse. Therefore, instead of reducing consumption, they preferred temporary migration in response to disaster. The findings however contradict the studies of Paul and Routray (2010), who claimed that migration is the last option for the flood affected people.

Mobile phone improves information flow and communication among the members of a family or of a social network. In this study, we found ownership of mobile phone had significant positive relationships with borrowing money. This could be because mobile phone seems to be an important factor to keep touch with friends/relatives and ask for financial assistance at the time of disaster. For instance, majority of the households who possess mobile phone borrowed money from their relatives/friends (219 out of 320). Similarly, ownership of mobile phone significantly and positively influenced households' decision on migration. This may be because mobile phone facilitates to have a social connection with migrants who are living in their targeted destinations (Sultana et al. 2019), which, in turn, helps them take decisions on migration. Consistent with the findings of this study, Boas (2020) reported that mobile phones are helpful to make decisions on migration in a more coordinated way.

Households that undertook mitigation strategies were less likely to reduce their consumption than their counterparts. This may be due to the fact that household who had precautionary crop save they implemented mitigation measures. On the contrary, a positive significant relationship between mitigation strategies and temporary migration indicated that households that implemented mitigation strategies preferred to choose temporary migration. Regardless of the socio-economic status, the majority of the households (78.39%) that suffered damage in the last flood implemented mitigation strategies.

The results suggested that having income from nonfarm sources reduced a probability of borrowing money and increased a probability of assets disposal. This may be due to the fact that agriculture is likely to be more affected by floods as compared to the non-agricultural income (Hahn et al. 2009), and thus nonfarm income ensures consistent cash flow for the households. Among the surveyed households, nonfarm income was mostly concentrated whose income was more than 10,000 BDT per month. This means nonfarm income is linked with economic well-being and precautionary savings. These findings were partially consistent with Bhattacharjee and Behera (2018) who reported that household‘s with income from non-agricultural sources were more prone to sell their livestock during emergency. Previous research by Sakai et al. (2017) found that nonfarm income provided effective insurance to the typhoon affected households in Philippines.

The location dummies showed that assets disposal were higher among the households from Belka. This may be due to the fact that majority of the households from Belka (72.8%) have shown their interest to rear livestock which serves as a precautionary saving for liquidity purposes during a flood disaster.

4.6.2 Post-disaster mitigation measures

The results showed that the inclusion of risk perception variables was useful to obtain insights into the factors that influence households‘ mitigation behavior in a post-disaster period.

Flood risk perception is often found in the literature to positively influence households‘ risk mitigation behavior (Terpstra 2011; Bubeck et al. 2013; Binh et al. 2020). The results showed that perception of flood probability had strong influence to the adaptation of structural mitigation measures. Similarly, riverine households had a strong belief (perceived preparedness) in the effectiveness of structural mitigation measures in preventing or reducing future flood risk. However, none of these perception variables influenced households to adopt nonstructural measures. The possible explanation for these findings may be either because of higher flood frequency in the study areas which influence household‘s confidence of being better protected through structural measures or they are less aware about the benefit of nonstructural measures. The qualitative interviews revealed that being flooded is a part of the respondents‘ life and they do not care flood which is normal and blessing for their livelihoods.

The findings indicated that as the floodwater increased in the house, the likelihood of adapting structural measure decreased. This is particularly true because households who faced damage they need investment to implement structural measures which can be expensive for the poor people with insufficient financial means (Brouwer et al. 2007). The result of this study was similar with Takao et al. (2004) which revealed that households' preparedness for future flood did not depend on previous flood experience. Similarly, in a study by Duží et al. (2017) in the Czech Republic found that experiencing more floods and damages in the past did not necessarily mean that household would implement more risk reduction measures. But the finding of this study was different from Ref. (Bubeck et al. 2013; Osberghaus 2015; Diakakis et al. 2018), which reported that previous experience was an important factor for flood mitigation intention.

Location played an important role to implement mitigation measures in riverine areas. This is true in the sense that when people face recurrent occurrence of risk, they tend to accept it as a part of their life and less likely to adapt mitigation measures (Martin et al. 2009; Binh et al. 2020). Another possible explanation is that active Teesta floodplain is highly erosion prone zone which discouraged households to invest money in the fear of being washed away by the river. This finding was in the line with Ref. (Okayo et al. 2015; Binh et al. 2020), although Ref. (Shah et al. 2017; Ahmad and Afzal 2020) reported that households living near the river in Pakistan preferred to implement more structural measures.

Duration of living did not influence the implementation of risk mitigation measures. One reason may be related to the place attachment that has reduced the notion of experiencing negative outcomes in future disaster (Fox Gotham et al. 2017). As one informant from Purbachhatnai stated, ―There was a severe flood in 2017. Now we forget the impact of last year flood. We are living with flood. If we memorize the impact of flood, we will not be able to live in here. We have countless memories on flood disaster in here. When flood arrive, we become flooded; and when flood recedes, we forget what happened due to flood." The findings of our study were different from Mabuku et al. (2018) that found sense of community positively influenced household's preparedness in Zambia and Namibia.

The positive relationship between membership and nonstructural measures may be directly related to the transfer of knowledge on how to cope with flood, as well as, indirectly, the adaptation of risk mitigation measures. These findings were in the line with Binh et al. (2020).

The variable age did not have a significant impact on the adoption of mitigation measures. As the coefficient of age variable was positive for structural measures, although not significant, it may be inferred that a relatively older household's head is more likely to adopt structural measures due to their long-term experience to live in riverine areas. The positive effect of age to adopt structural mitigation measures was reported by Poussin et al. (2014). In contrast, relatively older household's head were less likely to adopt nonstructural measures. Similarly, the variable of earning member was not a significant predictor for determining the mitigation measures behaviors. This may be because agricultural was the main occupation for majority of the surveyed households.

The results suggested that female headed households (FHH) were less likely to implement structural mitigation measures. This is because only 20% of the FHH had their agricultural lands and majority (95%) their monthly income was below BDT. 10,000. These findings were in the line with previous study of Shah et al. (2017), who found that male headed households tend to implement structural measures to safeguard their properties over FHH. However, Bubeck et al. (2013) reported non-significant relations between gender and mitigation behavior models.

Education had no influence to uptake risk mitigation measures. The result was similar with the study of Ref. (Bubeck et al. 2013; Diakakis et al. 2018) but different from Ref. (Okayo et al. 2015; Shah et al. 2017). This signifies that irrespective of their level of education, the studied communities have a demand for knowledge and skills related to flood disaster management.

Agricultural landownership was an important indicator in this study as it affects both mitigation measures significantly. This may be because among the agricultural occupants, only 69% had agricultural lands and majority of their income was below BDT 6,000. In contrast, households with income from nonfarm sources implemented more mitigation measures as compared with others. Nonfarm income sources are less susceptible to floods which provide consistent cash flow for the households. Among the surveyed households, nonfarm income was mostly concentrated whose income was more than 10,000 BDT per month. This means nonfarm income is associated with higher income and savings that can readily help households to adapt multiple risk mitigation measures.

4.6.3 Households response measures and recovery from flood

The findings of this study revealed that there was significantly lower proportion households who borrowed money were unable to recover from the impacts of last flood disaster. This could be because households that already had debt during the interview (192 out of 204), adopted borrowed money measure as a mean of coping, thus becoming trapped in a ―vicious cycle of borrowing" (Paul and Routray 2011) which, in turn, reduced the capacity to recover from flood disasters. The positive relationship between assets disposal and recovered from last flood disaster may be therefore partly related to the long-term adaptation and accumulative learning to survive with repeated flood events of the surveyed households. One of the informants from Belka shared his strategy to cope with flood: ―I used to sell a cow after a flood. I usually purchase cows in *Kartik* (October to November) and raise them till *Joystho* (May to June). In *Joystho*, there is plenty of grass in here, which helps fatten cows. For example, I purchase a cow at BDT

30,000 and, after eight months of fattening, I can sell it for BDT 50,000. Sometimes, I need to sell tress, even nuts and paddy to cope with the flood”. Tran (Tran 2015) argued that coping strategies often help poor households recover better from the losses. Regarding post-disaster mitigation measures, the findings indicated that whether or not a household recover from the impact of 2017 flood, they implemented at least one mitigation measures (either structural or nonstructural measures) to the best of their ability to reduce or mitigation flooding risk in future.

4.6.4 Factors affecting households' perceived preparedness

Results from the multivariate analysis demonstrated that households‘ perceived preparedness was negatively correlated with (Table 4.14) socio-economic unsafe conditions and the impact magnitude and proximity to flooding, and positively correlated with their ability to respond to a flood disaster. This finding partially supported Sandanam et al. (2018), who reported that households‘ perceived preparedness for a cyclone disaster in the Wet Tropics, Australia was influenced by psychological flexibility rather than social network and individual adaptive capacity. The results revealed an important role of the ―ability to respond” (i.e. knowledge, mitigation measures, informational and emergency preparedness) in increasing the perceived preparedness of riverine households. This implies that a higher level of knowledge of flood disasters, adopting structural mitigation measures, dissemination of warning messages, and ownership of communication devices, as well as effective emergency preparedness, helps improve households‘ confidence in their actual preparedness. On the other hand, findings suggested that increasing socio-economic unsafe condition (SEUC), impact of flood (IMMA) and proximity to flooding (PROF) were associated with the reduction of household‘s perceived preparedness.

4.7 Chapter summary

This chapter analyzed the complex relationships between flood risk components and household‘s response measures through identifying the determinants of both post-disaster coping and mitigation measures and their role in recovering from the impact of flood.

The findings indicated that the majority of households adopted a combination of post-disaster coping measures. While borrowing money was used by the exposed households to cope with floods, they (borrowing money) were not preferred choices by the demographically vulnerable households especially if the head of the household was aged person or female. Assets disposal was preferred by the households who had income from nonfarm sources; however, vulnerable households were less likely to dispose of their assets. Households that recovered from 2017 flood disaster seek insurance through their own savings and available physical assets (e.g., livestock, plants). However, grants from external sources did not have significant effects on household‘s recovery from the flood disaster.

The findings indicated that the majority of the households implemented at least one mitigation measure after facing severe flood in 2017. However, a higher proportion of households adapted structural measures as compared to nonstructural measures. The results showed that perceived probability of flood influenced households to uptake structural mitigation measures, while exposure (proximity) to flood did not translate into the adaptation of risk structural measures. Households affiliated with social organizations were more likely to implement nonstructural measures. The results of the socio-economic characteristics of the households were mixed. In determining the choice of mitigation measures, landownership and income from nonagricultural sources plays an important role in the study area. The determinants of perceived preparedness were further analyzed through multivariate analysis. Results from the multivariate analysis supplied further insights on perceived preparedness, which was positively influenced by households‘ ability to respond to flood disasters.

Chapter 5: Conclusion

5.1 Introduction

The conclusion chapter starts with the summary of this study. This chapter presents an assessment of this study to understand its value and its success in addressing the research objectives. The policy implications for flood management in Bangladesh, study limitations and future research are also described in this chapter.

5.2 Synthesis of the findings

This research was set to assess household‘s risk and response measures to riverine flood disaster to identify corrective risk measures. I collected data from the right bank of Teesta River in Bangladesh by interviewing 377 households on demographic, housing, landownership, drinking water sources, sanitation condition, means of transportation, means of communication, health condition, energy sources, food availability, social network, coping strategies during flood, experience with flooding, exposure to flood, preparedness for future flood risk, and perception on flood risk. I also conducted key informants interviews and focus group discussion with the local residents. The richness of the collected data is an asset of this study. The study has addressed two objectives and corresponding five research questions. The key findings of this study are organized below under the five research question.

Research question 1: Who are at higher risk from riverine flood disaster?

Chapter 3 assessed flood risk of riverine households. It answers the first research question to identify the household who are at risk from riverine flood. To assess flood risk of riverine households, I started with a review of different theories and frameworks that are useful to understand risk assessment and its processes. After that I developed a conceptual framework for household-level riverine flood risk assessment (Figure 2.1). This framework combines four vital components of risk into one framework: hazard, exposure, vulnerability, and capacity. I classified the dimensions of flood risk into internal and external factors. The characterization of flood risk also included ―stressors and strengths" which clearly separate ―households‘ capacity" (strengths) from the stressors (Figure 2.1). I tested the framework by executing social survey with the riverine people in Bangladesh who faces recurrent river flooding. The RFDRI provides a reliable support for flood disaster risk reduction efforts and summarizes a great deal of information on hazard (characteristic of historical flood events), exposure, vulnerability, and capacity in a way that is easy to understand, visualize, and facilitate comparison between and among the components and subcomponents.

The findings from this study indicated that the frequency and intensity of historical events (hazards) were high, meaning that people and their assets were highly exposed to floods. Overall, households from the Belka union (downstream) were found to be at higher risk because external stressors were dominated (hazard, exposure) in here. The analysis suggested that household with female headed, income below national level, illiterate, agricultural landless, no access to finance, lives in rented lands, fragile construction materials of house were found as higher risk households for flood disaster. High risk households were located close to river and were affected by diseases and experienced more damage by historical flooding.

Research question 2: How does vulnerability and capacity of riverine households interrelated?

In the Chapter 3, I examined the association among the flood risk components. This chapter also answered the second research question to see the correlation among the flood risk components. Bivariate correlation was used (Pearson‘s correlation and Chi-squared test) to establish the associations among the components.

A household‘s vulnerability and capacity to absorb shock were negatively correlated. There was no significant relationship between exposure to flooding with household‘s vulnerability and capacity to absorb flood shock. Among the study areas capacities to absorb flood shock were found to be similar but vulnerability patterns demonstrated a dissimilar pattern.

Research question 3: What risk mitigation and risk coping measures did a household employ to respond to 2017 flood disaster? Which factors influenced households to adapt these measures?

Chapter 4 examined households‘ response to flood disaster assessed flood risk of riverine households. Section 4.2 and Section 4.3 answered the third research question.

Households employed different coping measures to respond to 2017 flood including borrowing money, assets disposal, consumption reduction, temporary migration, and grants from external sources, to cope with flood. Results from logistic regression models suggested that increasing severity of flood reduced households‘ consumption. Exposed households were more likely to borrow money. Consumption reduction and temporary migration were mostly adopted by agricultural landless households. Income from nonfarm sources was found to be an important factor influencing household‘s decisions on coping.

On the other hand, most of the households implemented at least one mitigation measure either from structural or nonstructural categories after 2017 flood. Binary logistic regression models provide useful insights into the determinants to the implementation of two categories of flood risk mitigation measures (structural or nonstructural). The results showed that the perceived probability of flood, perceived preparedness, flood experience, exposure to flood, membership, household head‘s sex, income source, and landownership significantly influenced households to implement mitigation measures in the post-disaster period. However, education, duration of living, age of household‘s head, and multiple earning member did not significantly influence a household to implement mitigation in a post-disaster period in the study area.

Research question 4: How effective were the coping measures adopted by the household in recovering from flood disaster? Are there any association between the household’s recovery from flood disaster and adaptation of post-disaster mitigation measures?

This research question has been addressed in Section 4.4 of Chapter 4. Pearson‘s chi-squared test was used to find the associations. The findings from this study revealed that households that recovered from a flood disaster seek insurance through their own savings and available physical assets (e.g., livestock, plants). However, I did not find any association between post-disaster mitigation measures and recover from flood disaster which proved the assumptions that whether or not a household recover from the impact of last flood disaster, people try to implement mitigation measures to the best of their ability to reduce or mitigation flooding risk in future.

Research question 5: What are the key determinants of households’ perceived preparedness?

Section 4.5 of Chapter 4 identified the determinants of households‘ perceived preparedness for flood disaster. Multivariate techniques (PCA and binary logistic regression) were employed to answer this research question. Perceived preparedness was lower among the high risk households. The findings suggested that households‘ perceived preparedness was influenced by their ability to respond to a flood disaster (knowledge, mitigation measures, emergency preparedness, and information).

5.3 Policy Recommendation

The findings of this study provide useful insights as to how disaster risk reduction interventions at household-level can be developed and improved. The following recommendations are made from the findings of this study:

Living with riverine flood is very costly for the studied communities and therefore to ensure a secure and resilient livelihood for the riverine people, it is necessary to reduce the exposure of riverine communities through public protection measures such as earthen embankment.

Capacity building interventions should be designed in a way so that it not only promotes knowledge and preparedness for flood disasters but also enhance understanding of livelihood diversification, which will ultimately help at-risk people especially who have limited financial capacity to prepare themselves using their available resources and knowledge. It is also necessary to aware and motivates studied people about the benefits of nonstructural measures to reduce flood risk. The diversification of livelihoods can be promoted via livestock rearing, self-employment in nonfarm activities, together with increased access to financial institutions. However, any policies and programs on livelihood strategies for reducing flood risk should be designed based on the local context and the community's interests, especially for vulnerable segments of the community. Targeted interventions are required for the vulnerable group particularly female-headed households, ageing people, and agricultural landless. Post-disaster relief should be given to those vulnerable households that experience greater losses and are unable to recover without support from external sources. Emphasis should be given to ensure the minimum food intake and provide adequate public health support to the destitute people during the emergency period. There is a need to develop post-disaster recovery plans for a speedy recovery because a majority of the households were unable to recover using their existing resources.

5.4 Limitations of the study and future research

This study attempted to assess and compare flood risk of riverine households in the upstream, midstream, and the downstream segments of the Teesta River in Bangladesh. However, it had some limitations. The followings are limitations and future research directions:

While the indicators used to develop the RFDRI concentrated on the household level, relevant indicators on community- and national-level governance arrangements can be included in future investigations. Incorporating bio-physical and hydro-meteorological (e.g. river discharge, river water level, temperature, rainfall) indicators in future research may provide more integrative risk assessment. The reason behind the exclusion of those important parameters is that of the nonexistence of local hydro-meteorological stations in those studied locations. Nevertheless, these parameters can fit well in hazard and exposure characterization components.

The capacity of a system to absorb the stresses depends on several factors, including individual (household) level capacity, community level capacity, and national level capacity. However, this study did not consider community capacity as well as government intervention (external strengths such as hard infrastructure measures) that help to reduce risk and promote resilient development. Future research may consider all available resources and strengths to assess riverine flood disaster risk.

The selected indicators for each subcomponent were based on the understanding of the local context of the study area and complemented by previous studies which may only be suitable for a similar geographical context. The categorization of risk and its subcomponents (low, medium, high) was subjective and needs to be adjusted depending on the context. The relationships among the flood risk components can be verified further with larger samples. Besides, balanced weighting scheme was another limitation of this study which could be further improved through statistical modeling or expert judgments.

This research did not explore in detail why at-risk people preferred to borrow from local money lenders (although with a high-interest rate) than formal sources. Factors that determine choices of borrowing from formal and informal sources should be examined in the future. Another limitation is the self-reported measures of the recovery indicator, which may be a potential source for response bias. Recovery from disaster can be categorized as short-term or long-term. However, the research did not explore in detail the recovery status of the individual household. Future research may consider objective data for recovery assessment to foster the adaptive capacity of households. The relationships between actual and perceived preparedness can also be examined in future studies.

This empirical study collected data from the households who reside along the right bank of the Teesta River in Bangladesh, which may not be representative for the whole region/country. Therefore, caution is required before the results can be generalized for the whole TRFB/country. This is a cross-sectional study just addressed one point of time and therefore the examined relationships do not necessarily claiming the causality. There was another flood in 2020. Replication of this study in the same location might provide useful information about how repeated flooding events influence household‘s adaptive capacity.

In summary, the contribution of this research is to simplify household level riverine flood risk assessment technique that could be adopted in other regions, especially where data is scarce, in order to set corrective risk measures and reduce existing risk.

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Appendices

Appendix A: Questionnaire for household level survey

QUESTIONNAIRE FOR HOUSEHOLD SURVEY

Title: Community perspective on flood risk in Teesta River floodplain in Bangladesh: Exploring the implications on flood risk management

Researcher: Md Sanaul Haque Mondal, PhD researcher, Tokyo Institute of Technology
Supervisor: Prof. Takehiko Murayama, Tokyo Institute of Technology, Japan
Prof. Shigeo Nishikizawa, Tokyo Institute of Technology, Japan

Questionnaire code: I_____I_____I_____I_____I_____I_____I

District:

Upazila:

Union:

Village:

Date of interview: I_____I_____I Day I_____I_____I Month

Interview start time: I_____I_____I Hours I_____I_____I Minutes

Interview end time: I_____I_____I Hours I_____I_____I Minutes

Name of interviewer:

Remarks:

Title: Community perspective on flood risk in Teesta River floodplain in Bangladesh: Exploring the implications on flood risk management

Researcher: Md Sanaul Haque Mondal, PhD researcher, Tokyo Institute of Technology, Japan

Supervisor: Prof. Takehiko Murayama, Tokyo Institute of Technology, Japan

Prof. Shigeo Nishikizawa, Tokyo Institute of Technology, Japan

Hello, this is Md. Sanaul Haque Mondal from the Tokyo Institute of Technology, Tokyo, Japan. I am a PhD student, doing a research work on the flood risk assessment in the Teesta River floodplain. To fulfill my research objective, I need to collect data from different stakeholders including local community, local administration, academicians, local school teachers, and experts of relevant sectors. As a part of the research work, I would like to conduct an interview to learn from you about your experiences on flood risk. If you choose to participate in this research study, I would like to schedule a 60 minutes interview with you, at which time I will ask you about your experience on flood risk in this locality. Your participation is totally voluntary and your identity will not be used in anywhere for any purpose.

Do you have any questions about this research study or the information I just provided? ☐Yes ☐No

Are you willing to participate in 60 minutes interview? ☐Yes ☐No

If ‗Yes': Continue and ask his/her available schedule.
If ‗No': End here by saying
―Thank you for your time. Have a nice day. Goodbye."

If you need you can contact me by mobile phone at +88-01735-622426 (in Bangladesh) or by email at mshaquem@gmail.com

- [**Study objective**: The objective of this research work is to assess the risk of flood in the Teesta River floodplain of Bangladesh.

- [**Disclosure**: The information you will provide us will be fully confidential and will be used only for research purposes. Whether you will participate in the discussion or not will completely depend on your personal will. If you are unwilling to answer any of the questions or feel embarrassed to answer, you may stop the discussion anytime you want or you can refrain from answering that specific question(s). At the end of the study, we will prepare a report (thesis/journal paper) and share the findings with different stakeholders engaged in disaster management, but we will not identify your name and will not disclose to anybody who said what. Please feel free to ask me any questions now, or at any point of during the interview, or after the interview.]

- ―Do you have any questions before we continue?" ☐Yes ☐No

Yes: Provide information what they ask
No: Continue interview……………….>>>

A. Basic Household Information:

1. Could you please tell us the information of your family members (who eat and sleep in this house)?

Serial	Age (years)	Sex (Male =1/ Female=2)	Education	Remarks
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

Please identify respondent as ‗R' and household head as ‗HH' in remarks column

Enumerator portion	Age of HHH	Sex of HHH	Family members		Age structure		
			Male	Female	Age ≥ 14	Age 15-65	Age ≤ 65

2. Are you (your family) living in this community since birth?

Yes	Since birth	Skip to 3 question
No, Ask, how many years?	I______I______I	

2.1. Why did you migrate in your current location?

I lost my house by flood and migrate current location	1
I lost my house by river bank erosion and migrate current location	2
Other____	3

2.2. How many times you dislocate your house in your lifetime?

1 time	1
2 times	2
3 times	3
Others__________________ times	4

B. Occupation and Income Information:

3. What is the main occupation of household head?

Agriculture	1
Sharecropper	2
Daily labor	3
Business	4
Government service	5
Private service	6
Housewife	7
Unemployed	8
Others______________________	9

4. What are the sources of income in your family? (Multiple answers are accepted)

Source	**Primary source**	**Secondary source**
1. Agriculture (crops & vegetables)		
2. Livestock (poultry & cattle)		
3. Fisheries		
4. Sharecropper		
5. Daily labor		
6. Seasonal labor		
7. Small trade		
8. Business		
9. Private service		
10. Government service		
11. Remittance (local/foreign)		
12. Others ________________		

Please draw circle in each respective cell where applicable

5. How many earning members do you have in your family?

1 member	1
2 members	2
3 members	3
Others_________________	4

6. Do you or your family members' works outside of flood prone zones? (Who are listed in Q 1)

Yes	1
No	2

6.1. Is there any member from your family who permanently works outside of this community?

Yes	1	
No	2	Skip to 7 question

6.2. Are they sending remittance regularly?

Yes, they send remittance regularly	1
Yes, they send remittance when we need	2
No, they never send remittance	3

7. Could you please tell us about the income and expenditure of your family on a monthly basis? (In Bangladeshi Taka, BDT)

Average family expenditure (monthly)	I___I ___ I___ I___I I___ I___I
Total income (primary and secondary sources)	I___I ___ I___ I___I I___ I___I

8. Does any member of your household have an account in a bank or micro-credit organization?

Yes, in a bank	1
Yes, in an NGO	2
No	3

9. Do you save money?

Yes	1	
No	2	Skip to 10 question

9.1. Where do you usually save or deposit money? (Multiple answers are accepted)

Bank	1
NGO	2
In house	3
Others ___________________________	4

10. Do you have any debt to pay back?

Yes	1	
No	2	Skip to 11 question

10.1. Where or whom to pay back your debt?

Individual local lender (*Mohajon*)	1
NGO	2
Bank	3
Neighbors/ friends/ relatives	4

11. Do you (your family) have any type of insurance?

Yes	1	
No	2	Skip to 12 question

11.1. What kind of insurance do you (your family) have? (Multiple answers are accepted)

Flood insurance	1
Crop insurance	2

Health insurance	3
Life insurance	4
Others ___________________________	5

C. Information on dwellings:

12. Could you please tell us the construction materials of your house?

Katcha (all thatches)	1
Earth-wall	2
All corrugated iron (CI)	3
Thatches with CI roof	4
Semi-wall (brick wall & CI)	5
Pakka (brick)	6
Others______________________	7

13. Where is your house located?

In between levee and riverbank without raised platform	1
In between levee and riverbank with raised platform	2
Outside of the embankment	3
Others____	4

14. How far (in meters) is your house from the river bank?

On the river bank (<100 meters)	1
100 to 500 meters	2
500 to 1000 meters	3
More than 1 kilometer	4

15. How many times has this village been affected by floods in the last 5 years?

Never inundated	1
1 time	2
2 times	3
3 times	4
Others_____________________	5

16. How frequently you face inundation of your homestead?

Never inundated	1	Ask next questions (16.1 & 16.2) for conformation
Once in a year	2	
Twice in a year	3	
Three times in a year	4	
Others____________________	5	

16.1. How long (maximum days) flood water stayed in your room/house in the last 5 years?

1 day	1
2 days	2
3 days	3
4 days	4
Others ________________ days	5

16.2. What was the highest depth (in feet) of floodwater in your room/house in the last 5 years?

Around 1 feet	1
Around 2 feet	2
Around 3 feet	3
Around 4 feet	4
Others _________________ feet	5

17. What was the highest depth (in feet) of flood water outside of your house?

Not inundated	1
Around 1 feet	2
Around 2 feet	3
Around 3 feet	4
Around 4 feet	5
Others _________________ feet	6

18. How long it does usually takes to rise the flood water?

≥48 hours	1
24 to 48 hours	2
13 to 24 hours	3
7 to 12 hours	4
≤6 hours	5

19. Did your house damaged by flood in the last 5 years?

Yes	1	
No	2	Skip to 20 question

19.1. What was the extent of damage of your homestead?

Partially damaged rooms	1
Completely destroyed	2

20. Did your household assets damaged by flood in the last 5 years?

Yes	1	
No	2	Skip to 21 question

20.1. List down the lost assets (Multiple answers are accepted)

Furniture	1
Electric equipments (e.g. Fridge/TV/ fan)	2
Fuel wood	3
Kitchen Stuff	4
Clothing	5
Other____________________	6

D. Water and sanitation:

21. Do you have consistent pure drinking water supply round the year?

Yes	1
No	2

22. What is the primary source of drinking water in your family?

Tubewell water	1
River water	2
Pond water	3
Other______________________	4

23. Do you have a tubewell in your house?

Yes	1
No	2

24. Do you have a sanitary toilet in your house?

Yes	1
No	2

E. Transportation and communication:

25. Does your family belong to any means of transport?

Yes	1	
No	2	Skip to 26 question

25.1. What kind of transport do you have? (Multiple answers are accepted)

Bi-cycle	1
Motor cycle	2
Rickshaw-van	3
Auto-rickshaw	4
Others______________	5

26. Do you (your family members) have the following means of communication devices? (Multiple answers are accepted)

Devices	Yes	No
Television	1	2
Radio	1	2
Mobile phone	1	2

(Please check all devices options) Please draw circle for Yes or No in each rows

F. General Health information:

27. Is there any member in your family who is chronically ill?

Yes	1
No	2

28. Is there any disabled person in your family?

Yes	1
No	2

29. Did you or your family members were infected by communicable diseases or injured due to flood in the last 5 years?

Yes	1	
No	2	Skip to 30 question

29.1. What kind of diseases you/ your family members were face due to the flood? (Multiple answers are accepted)

Diarrhea	1
Fever	2
Gastric diseases	3
Weakness	4
Cold	5
Died	6
Others___________________	7

29.2. How did you / your family members injured? (Multiple answers are accepted)

Underwater flooding objects	1
Fragile building materials	2
Snake/other insects‘ bites	3
Others__________________________	4

G. Energy sources:

30. Do you have electricity supply in your house?

Yes, we have electricity connection	1
Yes, we have a solar power panel	2
No	3

31. Do you have a portable stove to be used during emergency period?

Yes	1
No	2

31.1. Do you preserve fuel wood to face flood situation?

Yes	1
No	2

H. Land processions of the household:

32. Who belongs to the land where your house is currently located?

It is our own land	1
We rented land from a private owner	2
This belongs to government, we need to pay	3
This belongs to my relatives, we don‘t need to pay	4
It is government land, we don‘t need to pay (*Khas* land)	5
Others_______________________	6

33. Do you have agricultural land?

Yes	1	
No	2	Skip to 34 question

33.1. Could you please tell us the size of your agricultural land? I______I______I local unit/ hectares /acres/

Landless(<0.2 ac)	1
Marginal (0.21-1 ac)	2
Small (1.01-2.5 ac)	3
Medium (2.51-5 ac)	4
Large(>5ac)	5

[Do not ask the information presented in the table]

33.2. Are the lands productive?

Yes	1
No	2

33.3. How frequently you face inundation of your agricultural land?

No. Our lands are located in flood free zones	1	Ask next question (35.1) for conformation
Once in a year	2	
Twice in a year	3	
Thrice in a year	4	
Others ________________	5	

33.4. Did you lost your standing crops by flood?

Yes	1	
No	2	Skip to 36 question

33.5. What was the extent of damage of your agricultural crops?

Partially damaged	1
Completely destroyed	2

34. Do you have any land/house outside of the flood prone zones?

No	1
Yes, We have land outside of the flood prone zones	2
Yes, We have house outside of the flood prone zones	3
Yes, We have both	4

I. Food security aspect:

35. Does your family have adequate supply of food round the year?

Yes, we have consistent food supply throughout the year	1	Ask 37.1 question
No, we do not have sufficient food supply	2	Ask 37.2 question

35.1. Do you save crops/seeds?

Yes, We save seeds	1
Yes, We save crops	2
Yes, We save both	3
No, We do not save anything	4

35.2. How many days/ months in a year does your family have the trouble to get adequate food?

I______I______I days/ months

J. Coping and adaptation strategies of the household:

36. What were sources of help during flood or recovery phase? (Multiple answers are accepted)

- Financial coping strategies:

Strategies	Sources	
Borrow money	From NGOs	1
	From local people	2
	From relatives	3
	From friends	4
	From banks	5
Sell or leased out assets	Lands	6
	Poultry	7
	Cattle/goats	8
	Plants	9

K. Social networking:

	Dwelling	10
	Business	11
	Jewelry	12
Sell household assets	Crops	13
	Household goods	14
	Jewelry	15
Others	___________________	16

36.1. Did you receive any support from the government/ NGOs during or after the flood?

No	1
We were able to recover using our own resources	2
Yes, We received support from government	3
Yes, We received support from NGOs	4
Yes, from both government and NGOs	5

36.2. What were the immediate strategies (reactive coping strategies) to recover from flood? (Multiple answers are accepted)

Spent previous savings	1
Sold advance labor	2
Sold crops in advance	3
Starvation/ meal skipping	4
Temporary out- migration for work	5
Insecurity	6
Withdrawal of child education	7
Others___________________	8

37. How to you rate support/ cooperation from your community during disaster response?

Very low	1
Low	2
Moderate	3
High	4
Very high	5

38. Did you lost your job during the flood?

Yes	1
No	2

39. Are you (your family) a member of any organization / NGO groups?

Yes	1	
No	2	Skip to 42 question

39.1. What kind of organization is it?

NGO/CBO	1
Government Project (BRDB, BADC, etc.)	2
Others__________________	3

40. Have you (your family members) received any training related to disasters?

Yes	1	
No	2	Skip to 43 question

40.1. Who provides the training?

NGO	1
Government project	2
Others____________________	3

40.2. What kind of training was that? ____________________________________

41. In the last one year, did you (or your family) and your neighbor/ your relatives help each others? Please check all the options provided in the below table. [Note: These kinds of assistance are voluntary]

Type of assistance	Given	Received	
1. Give clothes			
2. Give fertilizer			
3. Give food (rice/vegetable)			
4. Give seeds			
5. Give some medicines			
6. Provide care for family when someone sick			
7. Provide psychological support			
8. Provide transport support			
9. Connect important people			
10. Find information about something			
11. Help to find goods			
12. Construct or dismantle house			
13. Help to sell or purchase product			
14. Rescue during flood/ emergency			
15. Take care of children			
16. Take care of crops/ animals/ fishery			
17. Take shelter in house			
18. Others________________			

Please draw circle in the respective cells where applicable

42. In the last 2 years, have you or your family members gone to the local government for assistance?

Yes	1
No	2
We do not need	3

L. Preparedness and perception related:

43. What are the reasons of flooding in your locality? (Multiple answers are accepted)

Excessive rainfall in our locality	1
Drainage congestion	2
Overflow of river water	3
Low topography	4
Release water from barrage	5
Others ___________________________	6

44. How could you expect that flood may occur? (Multiple answers are accepted)

I have no idea	1
I have personal experience of the locality	2
I could predict seeing weather phenomenon	3
I could predict seeing cloud formation	4
I could predict seeing rainfall trend	5
I could gauge seeing the river flow	6
Availability of verbal information	7
Others______________________________	8

45. Are all the members from your family know how to swim?

Yes	1	Skip to 48 question
No	2	

45.1. Who does not know how to swim? (Multiple answers are accepted)

Female	1
Children (6-15 years)	2
Others_________	3

46. How do you rate your (your family members') level of understanding on flood warning?

Very low	1
Low	2
Moderate	3
High	4
Very high	5

46.1. Do you know what to do after getting warning? (emergency planning)

Yes	1
No	2

47. Did you receive early warning on last flood?

Yes	1	
No	2	Ask next question (47.1) for conformation

47.1. How did you receive the last flood warnings? (Multiple answers are accepted)

Government official	1
Local leaders	2
Miking	3
Mobile phone (Call/ SMS/ IVR)	4
Neighbors	5
Newspaper	6
TV	7
Radio	8
Relatives	9
NGO staff	10
Young people of house	11
Others________________	12

47.2. How many hours before the flood did you receive flood warning?

≤6 hours ago	1
6 to 12 hours ago	2
13 to 24 hours ago	3
24 to 48 hours ago	4
≥48 hours ago	5

48. Where do you usually take shelter during disaster? (Multiple answers are accepted**)**

We do not go outside of my house	1
Flood shelter	2
In school building	3
On embankment	4
In neighborhood house	5
We have no idea where to take shelter	6
Others___________________	7

49. How far (approximately) is your house from the following service points? (in kilometers/ meters)

Facility centers	Time (Minutes)
School building	I______I______I
Hospital/clinic center	I______I______I
Shelter center	I______I______I
Union Parisad	I______I______I

50. Does the community have land use policy?

Yes, we have	1
No, we do not have	2
I have no idea on it	3

50.1. Do you have the knowledge where to build house or not?

Yes	1
No	2

50.2. Do you have the knowledge when and where not to cultivate crops considering uncertainty of flooding?

Yes, I have	1	
Yes, I have but taking the risk	2	
No	3	Ask next question for conformation

50.3. Have you ever avoided crop cultivation with the fear of being flooded?

Yes	1
No	2

51. What are the measures do you take to reduce flood risks? (proactive coping) (Multiple answers are accepted**)**

Raising the plinth of the house	1
Building home on natural levee	2
Modification of house with strong materials	3
Store valuables household goods safer place	4
Collect emergency survival items	5
Make a plan how to act if a flood is	6
Others	7
Do not know what to do	8
Do not have sufficient income to implement planned measures	9

52. Do you think you are now better prepared than previous?

Yes	1
No	2

53. Do you think severity and frequency of floods has increased or decreased?

Frequency has increased	1
Frequency has decreased	2
Severity has increased	3
Severity has decreased	4
No changes observed	5
I do not know	6

53.1. Why do you think severity and frequency of floods have increased/decreased?

____

____

____

54. Do you think frequency of flood will increase in the next 10 years?

Frequency will increase	1
Frequency will decrease	2
Severity will increase	3
Severity will decrease	4
No changes will observe	5
I do not know	6

54.1. Do you think flood like 2017 may visit in the next 10 years?

Yes	1
No	2
I do not know	3

Do you have any comments? (Respondent)

____

____

____

____

Thank you very much for your time and information

Remarks from data collector:

____

____

____

____

Appendix B: Check list for Key Informants Interview

KEY INFORMANTS INTERVIEW: LOCAL LEADER

Title: Community perspective on flood risk in Teesta River floodplain in Bangladesh: Exploring the implications on flood risk management

Researcher: Md Sanaul Haque Mondal, PhD researcher, Tokyo Institute of Technology
Supervisor: Prof. Takehiko Murayama, Tokyo Institute of Technology, Japan
Prof. Shigeo Nishikizawa, Tokyo Institute of Technology, Japan

Hello, this is Md. Sanaul Haque Mondal from the Tokyo Institute of Technology, Tokyo, Japan. I am a PhD student, doing a research work on the flood risk assessment in the Teesta River floodplain. To fulfill my research objective, I need to collect data from different stakeholders including local community, local administration, academicians, and experts of relevant sectors. As a part of the research work, I would like to conduct an interview to learn from you about your experiences on flood risk. If you choose to participate in this research study, I would like to schedule a 30-40 minutes interview with you, at which time I will ask you about your experience on flood risk in this locality. Your participation is totally voluntary and your identity will not be used in anywhere for any purpose.

Do you have any questions about this research study or the information I just provided?	☐Yes ☐No

Are you willing to participate in 30-40 minutes interview?		☐Yes ☐No
	If ‗Yes': Continue and ask his/her available schedule.	
	If ‗No': End here by saying ―Thank you for your time. Have a nice day. Goodbye."	

If you need you can contact me by mobile phone at +88-01735-622426 (in Bangladesh) or by email at mshaquem@gmail.com

- [**Study objective**: The objective of this research work is to assess the risk of flood in the Teesta River floodplain of Bangladesh.
- [**Disclosure**: The information you will provide us will be fully confidential and will be used only for research purposes. Whether you will participate in the discussion or not will completely depend on your personal will. If you are unwilling to answer any of the questions or feel embarrassed to answer, you may stop the discussion anytime you want or you can refrain from answering that specific question(s). At the end of the study, we will prepare a report (thesis/journal paper) and share the findings with different stakeholders engaged in disaster management, but we will not identify your name and will not disclose to anybody who said what. Please feel free to ask me any questions now, or at any point of during the interview, or after the interview.]
- [**Recording of the discussion**: We would also like to use a voice recorder to record our discussion to make sure that your views are accurate captured and reflected. These audio clips will not be shared with anybody except within the research team. Your voice will be translated into another language (in English). We will destroy those audio clips upon

finishing our research.] - [**Photographs of the discussion**: We would also like to take some photographs of our discussion. We want to use and share those pictures for research purposes only. We will not share them to any third party or sell them to anybody.] - [**Consent**: Do you consent to participate in this discussion?] ☐Yes ☐No

Date of interview:	I_____I_____I Day I_____I_____I Month
Interview start time:	I_____I_____I Hours I_____I_____I Minutes
Interview end time:	I_____I_____I Hours I_____I_____I Minutes

Name of the interviewee:		
Occupation:		
Sex of the interviewee:		
Age of the interviewee:		
Address	Village:	Union:
	Upazila:	District:

1. Could you please describe in details about the exposure and vulnerability of flood of this union /village (for example, number of floods in the last 5 years, severity of flood, time to increase flood water, socio-economic vulnerability, etc)? What are the major reasons of flood in this community?
2. Is there any disaster management committee in your locality? If yes, how does it work?
3. Does the community have any ‗disaster emergency plan'? If available, are these plans circulated among the communities?
4. Does the community have any landuse zone policy? If available, how does it work? Are communities following these landuse policies? Do the communities need any permission to build house in the floodplain?
5. Could you please tell us in detail about the condition of community critical infrastructures (e.g. embankments, roads, bridges)? How those critical infrastructures are maintained?
6. Is there any disaster shelter in this union (community)? If yes, can you please tell us about it (location, convenience, internal environment, satisfaction, occupancy, etc.)?
7. Are there any public awareness campaigns organized by the Union Parisad (for example, drill) for reducing risk and increasing awareness?
8. Could you please tell us the role of the Union Parisad before, during and after the flood disasters?

Thank you very much for sharing your experience with us

Appendix C: Check list for Focus Group Discussion

FOCUS GROUP DISCUSSION (PRE-SURVEY)

Title: Community perspective on flood risk in Teesta River floodplain in Bangladesh: Exploring the implications on flood risk management

Researcher: Md Sanaul Haque Mondal, PhD researcher, Tokyo Institute of Technology
Supervisor: Prof. Takehiko Murayama, Tokyo Institute of Technology, Japan
Prof. Shigeo Nishikizawa, Tokyo Institute of Technology, Japan

- [**Welcome**: Welcome and thank you for volunteering to take part in this discussion.]

- [**Objective**: The objectives of this focus group discussion are to hearing and learning from your experiences on disasters. The main aspect of the study is to assess the community level disaster risk in the Teesta River floodplain of Bangladesh.]

- [**Disclosure**: The information you will provide us will be fully confidential and will be used only for research purposes. Whether you will participate in the discussion or not will completely depend on your personal will. If you are unwilling to answer any of the questions or feel embarrassed to answer, you may stop the discussion anytime you want or you can refrain from answering that specific question(s). Your participation is totally voluntary and your identity will not be used in anywhere for any purpose. Your opinion and cooperation is very important for this study. It will be helpful for us if you kindly spare some of your valuable times for this discussion session. At the end of the study, we will prepare a report (thesis/journal paper) and share the findings with different stakeholders engaged in disaster management, but we will deidentify your name and will not disclose to anybody who said what. Please feel free to ask me any questions now, or at any point of during the discussion, or after the discussion.]

- [**Time of the discussion**: The discussion will take no more than 1.5-2 hours.]

- [**Recording of the discussion**: We would also like to use a voice recorder to record our discussion to make sure that your views are accurate captured and reflected. These audio clips will not be shared with anybody except within the research team. Your voice will be translated into another language (in English). We will destroy those audio clips upon finishing our research.]

- [**Photographs of the discussion**: We would also like to take some photographs of our discussion. We want to use and share those pictures for research purposes only. We will not share them to any third party or sell them to anybody.]

- [**Consent**: Do you consent to participate in this discussion?] ☐Yes ☐No

FGD serial no.

Date of FGD:	
Time:	to

Location:	Village:	Ward no.:	Union:
	Upazila:	District:	
	Geocode:		

Section 1: Identifying hazard (hazard assessment): **[30-40 minutes]**

Opening question:

How long have you been living in this community? How many of you have the experience on disasters?

Probing question: *Tell them what does disaster mean?*

Engagement question:

This section will allow identifying the hazard of the community. Ask the communities about the common hazard in their locality. List all the hazards and then ask them to rank the hazards (significant). Then ask them about the history, frequency, severity, duration, location and trends of the disaster.

Table 1: Identification of hazard

Questions	Hazard 1	Hazard 2	Hazard 3
Type of hazard			
Significant			
History			
Frequency			
Causes			
Severity			
Duration			
Location			
Warning sign			
Trends			

Probing question: *(this section must seek the answers of the following questions, check whether the discussion is align with the following questions or not. If not, ask the remaining questions.)*

- ***Type of hazard:*** What are the different types of natural hazard that commonly affect your community?

- ***Significant:*** Which one do you consider the most sever hazard (in terms of impact) in your community?
- ***History:*** What was the last significant disaster that affects your community? When it hit your community?
- ***Frequency:*** How frequently does this hazard occur (e.g. once in a year, twice in a year, etc.)?
- ***Causes of disaster:*** What are the major causes of disaster?
- ***Severity:*** How severe the hazard was (e.g. for flood: max depth of water/flow of water/ presence of water/ duration of rain or for drought: number of days/ weeks with not rainfall/ damage)? Could you please compare the impact of this disaster with a normal year?
- ***Duration:*** How long does the hazard persist in your community (e.g. hours/ days/ weeks/ years)?
- ***Location:*** Which part of your locality are the worst affected?
- ***Warning sign:*** Do you receive any early warning of the hazard? How do you receive the warning signs? How quickly (or slowly) does the hazard appear?
- ***Trends:*** Do you find any changes to the frequency, severity and duration (increased/ decreased) of the hazard? Could you please specify those changes?

Section 2: Vulnerability and capacity assessment **[40-50 minutes]**

Engagement question:

This will allow identifying the existing vulnerabilities and available capacities of the communities. Ask the communities to identify the impact caused by the main disaster. This assessment will be made based on the five livelihood matrix (individual/ social/ physical/ natural and economic). Summarize the discussions using the following table 2.

Table 2: Vulnerability and capacity assessment

Category	Impact of hazard	Vulnerabilities	Capacities
Individual			
Social			
Physical			
Natural			
Economic			

Probing question: *(this section must seek the answers of the following questions (as presented in* ***Table 4),*** *check whether the discussion is align with the following questions or not. If not, ask the remaining questions.)*

Engagement question:

During disaster, what sort of strategies (coping mechanisms) do you take to recover from that situation?

Probing question: This portion will deal the different types of support from different sources during disaster.

Section 3: Risk treatment (prioritizing the impacts and risk reduction option)

[20-30 minutes]

In the last two sections, we identify hazards, impacts, vulnerabilities and capacities of your locality. In this section, we will prioritize the impacts (ranking) and your suggestions to reduce those impacts.

Table 3: Risk treatment

Prioritizing impacts	Vulnerability	Capacity	Suggested risk reduction option

[Note that the suggested risk reduction strategies should reflect the vulnerability and capacity.]

Probing question: *(What can be done to make you better prepared to reduce the risk? Who will be responsible for those risk reduction measures?)*

4. Final section: Are there any issues you would like to discuss?

____

____

____

____

Thank you very much for your kind cooperation

Appendix D: Details on hydrological data at Dalia station of Teesta River

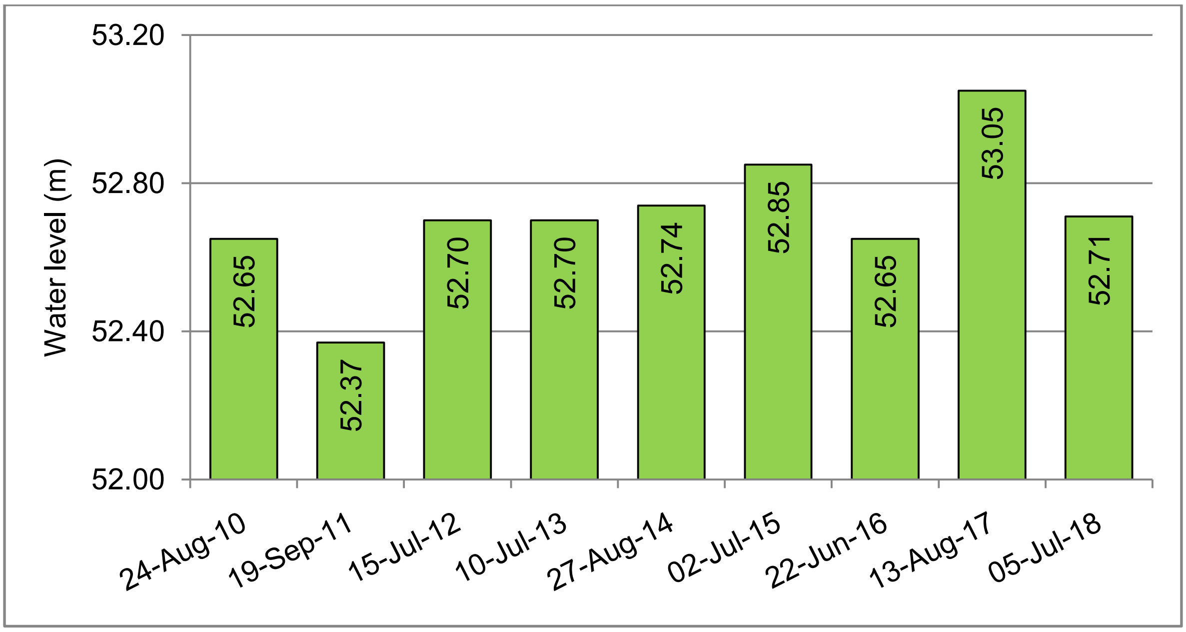

Figure 1: Peak water level of the year at Dalia Station

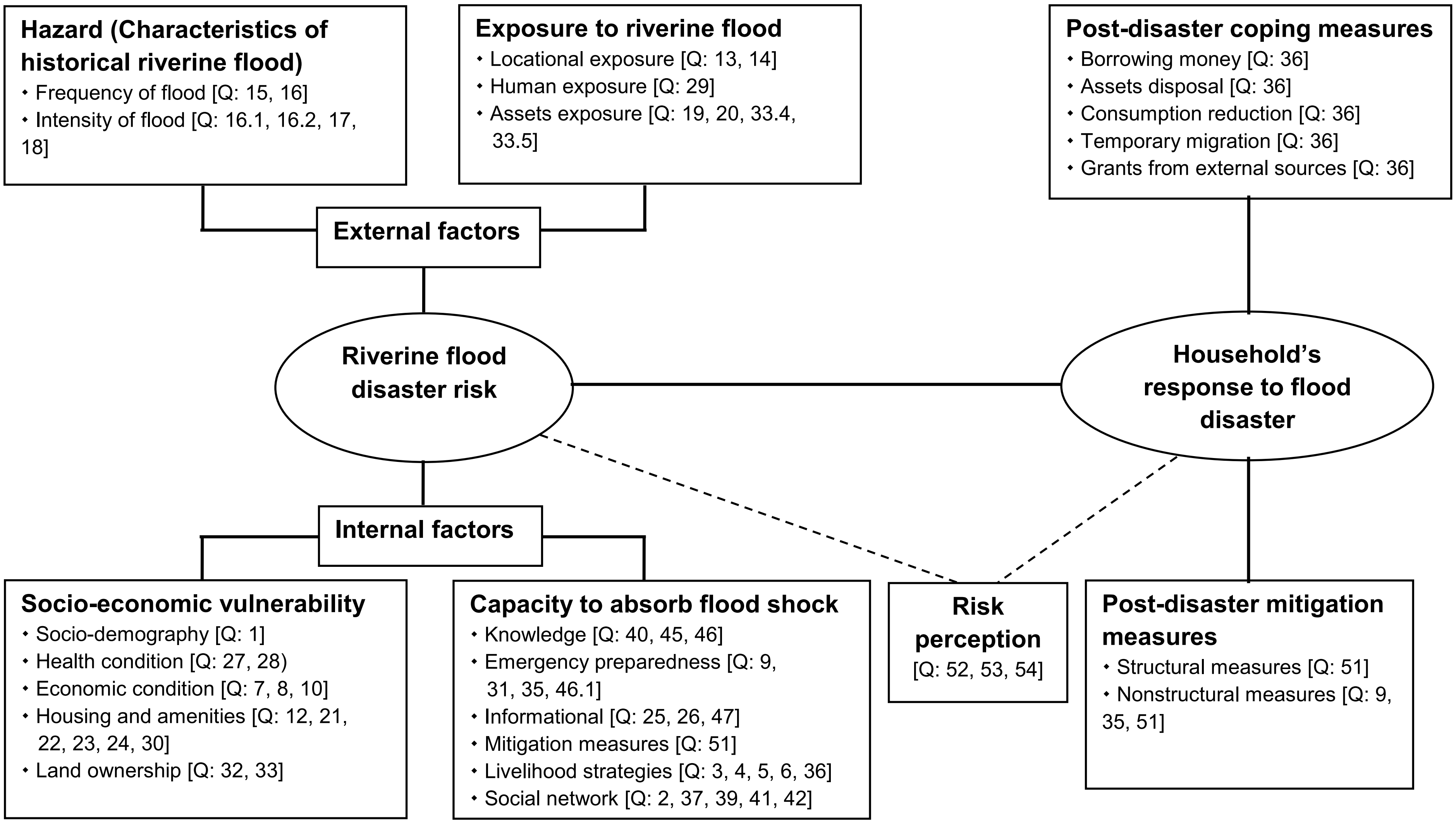

Figure 2: Questionnaire framework

Appendix E: Statistical analysis related to flood risk assessment

Table 1: Summary statistics of the indicators used for flood risk assessment

Indicator name	***Mean***	***Std.dev.***
Frequency of floods in the community in last 5 years (in numbers)	9.77	3.87
Frequency of home inundation in a year (in numbers)	1.64	.78
Duration of floodwater inside the home (number of days)	6.58	4.43
Height of floodwater inside the home (in feet)	2.12	1.03
Height of floodwater outside the home measured from the local roads (in feet)	3.72	1.36
Time to rise of floodwater (in hours)*	4.30	1.10
Location of home in between levee and riverbank (1=Yes, 0= No)	.81	.39
Location of home within 1000 meters from the riverbank (1=Yes, 0= No)	.85	.36
Family members infected by communicable disease in the last 5 years due to flood (1=Yes, 0= No)	.86	.35
Damage of home in the last 5 years due to flood (1=Yes, 0= No)	.86	.35
Lost household goods in the last 5 years due to flood (1=Yes, 0= No)	.79	.41
Lost standing crops in the last 5 years due to flood (1=Yes, 0= No)	.58	.49
Female headed household (1=Yes, 0= No)	.05	.22
Ratio of female population in the house (Ratio)	.49	.17
Age dependency ratio (Ratio)	.54	.33
Illiterate household (1=Yes, 0= No)	.34	.47
Chronically ill member(s) in the house (1=Yes, 0= No)	.33	.47
Disabled member(s) in the house (1=Yes, 0= No)	.08	.27
Monthly income of the household less than national average (1=Yes, 0= No)	.85	.36
Household has debt to payback (1=Yes, 0= No)	.54	.50
Household without access to any form of financial institutions (1=Yes, 0= No)	.72	.45
Thatched/mud-made (*Katcha house*) (1=Yes, 0= No)	.17	.37
Household without tubewell (1=Yes, 0= No)	.04	.20
Household without sanitary toilet (1=Yes, 0= No)	.47	.50
Household without electricity (solar panel) (1=Yes, 0= No)	.24	.43
Household does not have agricultural lands (1=Yes, 0= No)	.48	.50
Housing tenure (1=Yes, 0= No)	.32	.47
Household has at least one member who received training on flood disaster management (1=Yes, 0= No)	.06	.23
All adult family members know how to swim (1=Yes, 0= No)	.76	.43
Household has a good understanding of flood disaster warning (1=Yes, 0= No)	.60	.49
Household has precautionary crop savings (1=Yes, 0= No)	.27	.44
Household has emergency planning (1=Yes, 0= No)	.86	.35
Household has a portable cooking stove (1=Yes, 0= No)	.71	.46

Indicator name	*Mean*	*Std.dev.*
Household has precautionary money savings (1=Yes, 0= No)	.24	.43
Household received last flood disaster warning (1=Yes, 0= No)	.82	.39
Household has mobile phone/ TV set/ radio at home (1=Yes, 0= No)	.85	.36
Household has owned at least one vehicle (1=Yes, 0= No)	.54	.50
Household has taken at least one structural mitigation measure to prevent a flood disaster (1=Yes, 0= No)	.80	.40
Household has their family member(s) working outside of the flood prone area and sending remittance (1=Yes, 0= No)	.12	.33
Household has a non-farm income source (1=Yes, 0= No)	.33	.47
Household has more than one earning member (1=Yes, 0= No)	.33	.47
Household with livestock (1=Yes, 0= No)	.60	.49
Household was able to recover from last flood disaster using their own resources (1=Yes, 0= No)	.14	.35
Household has lived in the community for more than 5 years (1=Yes, 0= No)	.70	.46
Household has received help from their community during a flood disaster response (1=Yes, 0= No)	.24	.43
Household exchanged goods or services with their neighbor in the last year (1=Yes, 0= No)	.74	.44
Household is affiliated with any organization (1=Yes, 0= No)	.19	.40

Notes: N = 377
* Used as ordinal scale: 1 = More than/equal to 48 hours; 2 = 24 to 48 hours; 3= 13 to 24 hours; 4= 7 to 12 hours; 5= less than/ equal to 6 hours

Table 2: Level of flood hazards in the study area (Chi-square test)

Level of hazard	**Purbachhatnai**	**Gajaghanta**	**Belka**	**Pearson's χ^2**
	N=68	N=158	N=151	
Low (< 0.525)	36 (52.9%)	55 (34.8%)	39 (25.8%)	χ^2=21.6
Moderate (0.525 - 0.639)	19 (27.9%)	59 (37.3%)	47 (31.1%)	df=4
High (> 0.639)	13 (19.1%)	44 (27.9%)	65 (43.1%)	*p* value<.01

Table 3: Level of exposure to flood in the study area (Chi-square test)

Level of exposure	**Purbachhatnai**	**Gajaghanta**	**Belka**	**Pearson's χ^2**
	N=68	N=158	N=151	
Low (< 0.667)	22 (32.4%)	65 (41.1%)	44 (29.1%)	χ^2= 11.5
Moderate (0.667 - 0.833)	23 (33.8%)	64 (40.5%)	57 (37.8%)	df=4
High (> 0.833)	23 (33.8%)	29 (18.4%)	50 (33.1%)	*p* value=.02

Table 4: Level of vulnerability of households in the study area (Chi-square test)

Level of vulnerability	**Purbachhatnai**	**Gajaghanta**	**Belka**	**Pearson's χ^2**
	N=68	N=158	N=151	
Low (< 0.293)	20 (29.4%)	55 (34.8%)	52 (34.4%)	χ^2= 11.1

Moderate (0.293 - 0.437)	21 (30.9%)	64 (40.5%)	40 (26.5%)	df=4
High (> 0.437)	27 (39.7%)	39 (24.7%)	59 (39.1%)	*p* value= .03

Table 5: Level of capacity of households in the study area (Chi-square test)

Level of capacity	Purbachhatnai	Gajaghanta	Belka	Pearson's χ^2
	N=68	N=158	N=151	
Low (< 0.450)	30 (44.1%)	63 (39.9%)	67 (44.4%)	χ^2=0.9
Moderate (0.450 - 0.550)	20 (29.4%)	50 (31.7%)	42 (27.8%)	df=4
High (> 0.550)	18 (26.5%)	45 (28.5%)	42 (27.8%)	*p* value= .93

Table 6: Level of flood risk of households in the study area (Chi-square test)

Flood risk level	Purbachhatnai	Gajaghanta	Belka	Pearson's χ^2
	N=68	N=158	N=151	
Low (< 0.521)	25 (36.8%)	56 (35.4%)	45 (29.8%)	χ^2= 27.3
Moderate (0.521 - 0.613)	19 (27.9%)	70 (44.3%)	36 (23.8%)	df=4
High (> 0.613)	24 (35.3%)	32 (20.3%)	70 (46.4%)	*p* value< .01

Table 7: Crosstab between level of vulnerability and location of home in between levee and riverbank (Chi-square test)

Level of vulnerability	Location of home in between levee and riverbank		Pearson's χ^2
	Yes	No	
Low (< 0.293)	97 (31.8%)	30 (41.7%)	χ^2= 6.2
Moderate (0.293 - 0.437)	98 (32.1%)	27 (37.5%)	df=2
High (> 0.437)	110 (36.1%)	15 (20.8%)	*p* value=.04

Table 8: Crosstab between level of vulnerability and location of home within 1000 meters from the riverbank

Level of vulnerability	Location of home within 1000 meters from the riverbank		Pearson's χ^2
	Yes	No	
Low (< 0.293)	104 (32.6%)	23 (39.7%)	χ2= 1.2
Moderate (0.293 - 0.437)	108 (33.9%)	17 (29.3%)	df=2
High (> 0.437)	107 (33.5%)	18 (31.0%)	*p* value=.57

Table 9: Crosstab between level of vulnerability and family members infected by communicable disease in the last 5 years due to flood

Level of vulnerability	Family members infected by communicable disease in the last 5 years due to flood		Pearson's χ^2
	Yes	No	
Low (< 0.293)	102 (31.5%)	25 (47.2%)	χ2=11.5
Moderate (0.293 - 0.437)	104 (32.1%)	21 (39.6%)	df=2
High (> 0.437)	118 (36.4%)	7 (13.2%)	*p* value= .003

Table 10: Crosstab between level of vulnerability and damage of home in the last 5 years due to flood

Level of vulnerability	Damage of home in the last 5 years due to flood		Pearson's χ^2
	Yes	No	
Low (< 0.293)	98 (30.2%)	29 (54.7%)	χ2= 16.9
Moderate (0.293 - 0.437)	107 (33.0%)	18 (34.0%)	df=2
High (> 0.437)	119 (36.7%)	6 (11.3%)	*p* value<.001

Table 11: Crosstab between level of vulnerability and lost household goods in the last 5 years due to flood

Level of vulnerability	Lost household goods in the last 5 years due to flood		Pearson's χ^2
	Yes	No	
Low (< 0.293)	90 (30.4%)	37 (45.7%)	χ2=16.1
Moderate (0.293 - 0.437)	93 (31.4%)	32 (39.5%)	df=2
High (> 0.437)	113 (38.2%)	12 (14.8%)	*p* value<.001

Table 11: Crosstab between level of vulnerability and lost standing crops in the last 5 years due to flood

Level of vulnerability	Lost standing crops in the last 5 years due to flood		Pearson's χ^2
	Yes	No	
Low (< 0.293)	109 (50.2%)	18 (11.3%)	χ2=73.7
Moderate (0.293 - 0.437)	67 (30.9%)	58 (36.3%)	df=2
High (> 0.437)	41 (18.9%)	84 (52.5%)	*p* value<.001

Table 12: Crosstab between level of vulnerability and female headed household

Level of capacity	Female headed household		Pearson's χ^2
	Yes	No	
Low (< 0.450)	16 (80.0%)	144 (40.3%)	χ2=13.6
Moderate (0.450 - 0.550)	4 (20.0%)	108 (30.3%)	df=2
High (> 0.550)	0 (0.0%)	105 (29.4%)	*p* value=.001

Table 12: Crosstab between level of capacity and illiterate household

Level of capacity	Illiterate household		Pearson's χ^2
	Yes	No	
Low (< 0.450)	73 (57.0%)	87 (34.9%)	χ2=20.5
Moderate (0.450 - 0.550)	35 (27.3%)	77 (30.9%)	df=2
High (> 0.550)	20 (15.6%)	85 (34.1%)	*p* value<.001

Table 13: Crosstab between level of capacity and chronically ill member(s) in the house

Level of capacity	Chronically ill member(s) in the house		Pearson's χ^2
	Yes	No	
Low (< 0.450)	56 (44.8%)	104 (41.3%)	χ2=1.4

Moderate (0.450 - 0.550)	39 (31.2%)	73 (29.0%)	df=2
High (> 0.550)	30 (24.0%)	75 (29.8%)	p value=.50

Table 14: Crosstab between level of capacity and disabled member(s) in the house

Level of capacity	Disabled member(s) in the house		**Pearson's χ^2**
	Yes	**No**	
Low (< 0.450)	13 (44.8%)	147 (42.2%)	χ2=.09
Moderate (0.450 - 0.550)	8 (27.6%)	104 (29.9%)	df=2
High (> 0.550)	8 (27.6%)	97 (27.9%)	*p* value=.96

Table 15: Crosstab between level of capacity and monthly income of the household less than national average

Level of capacity	**Monthly income of the household less than national average**		**Pearson's χ^2**
	Yes	**No**	
Low (< 0.450)	154 (48.1%)	6 (10.5%)	χ2=33.8
Moderate (0.450 - 0.550)	92 (28.7%)	20 (35.1%)	df=2
High (> 0.550)	74 (23.1%)	31 (54.4%)	*p* value<.001

Table 16: Crosstab between level of capacity and household has debt to payback

Level of capacity	**Household has debt to payback**		**Pearson's χ^2**
	Yes	**No**	
Low (< 0.450)	81 (39.7%)	79 (45.7%)	χ2=5.5
Moderate (0.450 - 0.550)	56 (27.5%)	56 (32.4%)	df=2
High (> 0.550)	67 (32.8%)	38 (22.0%)	*p* value=.06

Table 17: Crosstab between level of capacity and household without access to any form of financial institutions

Level of capacity	**Household without access to any form of financial institutions**		**Pearson's χ^2**
	Yes	**No**	
Low (< 0.450)	139 (51.5%)	21 (19.6%)	χ2=56.2
Moderate (0.450 - 0.550)	84 (31.1%)	28 (26.2%)	df=2
High (> 0.550)	47 (17.4%)	58 (54.2%)	*p* value<.001

Table 18: Crosstab between level of capacity and thatched/mud-made (*Katcha house*)

Level of capacity	**Thatched/mud-made (*Katcha house*)**		**Pearson's χ^2**
	Yes	**No**	
Low (< 0.450)	29 (46.0%)	131 (41.7%)	χ2=4.3
Moderate (0.450 - 0.550)	23 (36.5%)	89 (28.3%)	df=2
High (> 0.550)	11 (17.5%)	94 (29.9%)	*p* value=.11

Table 19: Crosstab between level of capacity and household without tubewell

Level of capacity	**Household without tubewell**		**Pearson's χ^2**
	Yes	**No**	

Low (< 0.450)	12 (75.0%)	148 (41.0%)	χ2=7.7
Moderate (0.450 - 0.550)	3 (18.8%)	109 (30.2%)	df=2
High (> 0.550)	1 (6.3%)	104 (28.8%)	*p* value=.02

Table 20: Crosstab between level of capacity and household without sanitary toilet

Level of capacity	Household without sanitary toilet		Pearson's χ^2
	Yes	No	
Low (< 0.450)	92 (51.4%)	68 (34.3%)	χ2=12.4
Moderate (0.450 - 0.550)	49 (27.4%)	63 (31.8%)	df=2
High (> 0.550)	38 (21.2%)	67 (33.8%)	*p* value=.002

Table 21: Crosstab between level of capacity and household without electricity (solar panel)

Level of capacity	Household without electricity (solar panel)		Pearson's χ^2
	Yes	No	
Low (< 0.450)	59 (65.6%)	101 (35.2%)	χ2=34.1
Moderate (0.450 - 0.550)	25 (27.8%)	87 (30.3%)	df=2
High (> 0.550)	6 (6.7%)	99 (34.5%)	*p* value<.001

Table 22: Crosstab between level of capacity and household does not have agricultural lands

Level of capacity	Household does not have agricultural lands		Pearson's χ^2
	Yes	No	
Low (< 0.450)	106 (58.2%)	54 (27.7%)	χ2=38.4
Moderate (0.450 - 0.550)	45 (24.7%)	67 (34.4%)	df=2
High (> 0.550)	31 (17.0%)	74 (37.9%)	*p* value<.001

Table 23: Crosstab between level of capacity and housing tenure (lives rented land)

Level of capacity	Housing tenure		Pearson's χ^2
	Yes	No	
Low (< 0.450)	75 (63.0%)	85 (32.9%)	χ2=37.5
Moderate (0.450 - 0.550)	32 (26.9%)	80 (31.0%)	df=2
High (> 0.550)	12 (10.1%)	93 (36.0%)	*p* value<.001

Table 24: Crosstab between level of capacity and location of home in between levee and riverbank

Level of capacity	Location of home in between levee and riverbank		Pearson's χ^2
	Yes	No	
Low (< 0.450)	135 (44.3%)	25 (34.7%)	χ2=4.3
Moderate (0.450 - 0.550)	92 (30.2%)	20 (27.8%)	df=2
High (> 0.550)	78 (25.6%)	27 (37.5%)	*p* value=.11

Table 25: Crosstab between level of capacity and location of home within 1000 meters from the riverbank

Level of capacity	Location of home within 1000 meters from the riverbank		Pearson's χ^2
	Yes	No	
Low (< 0.450)	137 (42.9%)	23 (39.7%)	χ2=.38
Moderate (0.450 - 0.550)	95 (29.8%)	17 (29.3%)	df=2
High (> 0.550)	87 (27.3%)	18 (31.0%)	*p* value=.83

Table 26: Crosstab between level of capacity and disabled member(s) in the house

Level of capacity	Disabled member(s) in the house		Pearson's χ^2
	Yes	No	
Low (< 0.450)	13 (44.8%)	147 (42.2%)	χ2=.09
Moderate (0.450 - 0.550)	8 (27.6%)	104 (29.9%)	df=2
High (> 0.550)	8 (27.6%)	97 (27.9%)	*p* value=.96

Table 27: Crosstab between level of capacity and chronically ill member(s) in the house

Level of capacity	Chronically ill member(s) in the house		Pearson's χ^2
	Yes	No	
Low (< 0.450)	56 (44.8%)	104 (41.3%)	χ2=1.3
Moderate (0.450 - 0.550)	39 (31.2%)	73 (29.0%)	df=2
High (> 0.550)	30 (24.0%)	75 (29.8%)	*p* value=.5

Table 28: Crosstab between level of capacity and household has debt to payback

Level of capacity	Household has debt to payback		Pearson's χ^2
	Yes	No	
Low (< 0.450)	81 (39.7%)	79 (45.7%)	χ2=5.5
Moderate (0.450 - 0.550)	56 (27.5%)	56 (32.4%)	df=2
High (> 0.550)	67 (32.8%)	38 (22.0%)	*p* value=.06

Table 29: Crosstab between level of capacity and thatched/mud-made (*Katcha house*)

Level of capacity	Thatched/mud-made (*Katcha house*)		Pearson's χ^2
	Yes	No	
Low (< 0.450)	29 (46.0%)	131 (41.7%)	χ2=4.3
Moderate (0.450 - 0.550)	23 (36.5%)	89 (28.3%)	df=2
High (> 0.550)	11 (17.5%)	94 (29.9%)	*p* value=.11

Appendix F: Statistical analysis related to households' response to flood disaster

Table 1: Description of the post-disaster coping mitigation measures

Group	Description
Borrowing money	The term borrowing includes all kinds of measures that a household employed to take loans from others. The formal sources include banks and non-governmental organizations (NGOs), whereas informal sources include local money lenders, friends, relatives, or neighbors. In extreme situations, some people borrow money by selling labor or field crops with an advance payment. Households that employed one or a combination of these measures were grouped in this category.
Assets disposal	Disposable items include financial and physical assets. The physical disposable assets are comprised of livestock (poultry, cattle, goats), household utensils, jewelry, trees, crops, land. On the other hand, financial assets include household savings (deposits). If a household sold any physical assets or used up its savings in response to flood, it was classified in this category.
Consumption reduction	Food scarcity is common in disaster-affected areas. Households adopt numerous measures to cope with shocks, including consumption smoothing, resorting to cheap foods, wild foods collection (Paul and Routray 2011). In this study, consumption reduction implies a household reducing their consumption in response to a flood disaster, in the form of meal skipping or starvation.
Temporary migration	Migration to cities or other flood-free areas is a common measure to compensate losses incurred from flood. If a family member from a household migrated outside of the flood prone area (study area) for income and then returned to their houses within six months, the household was labeled in this category.
Grants from external sources	Grants from external sources are vital for short-term survival. It helps flood disaster victims to compensate their losses (Mavhura et al. 2013). Grants are distributed among flood victims by the local/national government, NGOs, local elites, or a host of other organizations. In this study, if a household received grants from external sources (e.g., government, NGOs, or local elites), it was classified in this category.

Table 2: Logistic regression for borrowing money model

Explanatory variables	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
							Lower	**Upper**
Floodwater depth	-.97	.70	1.96	1.00	.16	.38	.10	1.48
Location of house	1.09	.39	7.97	1.00	.00	2.98	1.40	6.36
Affected by disease	.99	.43	5.34	1.00	.02	2.68	1.16	6.18
Age	-.03	.01	5.37	1.00	.02	.97	.95	1.00
Female	-1.62	.59	7.42	1.00	.01	.20	.06	.64
Agricultural landless	.12	.34	.13	1.00	.72	1.13	.58	2.22
Crop save	-.22	.37	.36	1.00	.55	.80	.39	1.66
Mobile phone	.89	.43	4.35	1.00	.04	2.44	1.06	5.63
Mitigation measures	.08	.41	.04	1.00	.85	1.08	.49	2.40
Nonfarm income	-1.06	.34	9.87	1.00	.00	.35	.18	.67
Gajaghanta	-.36	.57	.41	1.00	.52	.70	.23	2.12
Belka	-1.05	.57	3.41	1.00	.06	.35	.12	1.07
Constant	2.31	1.10	4.41	1.00	.04	10.07		

Log Likelihood	:	266.31
Wald Chi Square	:	$\chi 2$= 46.981, df=12, p value < .001
Cox & Snell R Square	:	.117
Nagelkerke R Square	:	.208
Hosmer and Lemeshow Test	:	$\chi 2$=7.98, df=8, p=.436

Table 3: Logistic regression for assets disposal model

Explanatory variables	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
							Lower	**Upper**
Floodwater depth	-.94	.55	2.89	1.00	.09	.39	.13	1.15
Location of house	-.86	.43	4.12	1.00	.04	.42	.18	.97
Affected by disease	-.80	.46	2.99	1.00	.08	.45	.18	1.11
Age	.00	.01	.03	1.00	.86	1.00	.98	1.02
Female	-.24	.52	.21	1.00	.65	.79	.28	2.19
Agricultural landless	-1.12	.28	16.08	1.00	.00	.33	.19	.56
Crop save	.48	.33	2.10	1.00	.15	1.62	.84	3.11
Mobile phone	.28	.34	.65	1.00	.42	1.32	.67	2.59
Mitigation measures	.28	.31	.87	1.00	.35	1.33	.73	2.42
Nonfarm income	.77	.31	6.34	1.00	.01	2.16	1.19	3.94
Gajaghanta	.34	.37	.86	1.00	.35	1.41	.68	2.92
Belka	1.18	.40	8.82	1.00	.00	3.25	1.49	7.08
Constant	2.20	.93	5.66	1.00	.02	9.03		

Log Likelihood	:	317.096
Wald Chi Square	:	$\chi 2$= 65.077, df=12, p value < .001
Cox & Snell R Square	:	.159
Nagelkerke R Square	:	.231
Hosmer and Lemeshow Test	:	$\chi 2$=9.233, df=8, p=.323

Table 4: Logistic regression for consumption reduction model

Explanatory variables	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
							Lower	Upper
Floodwater depth	2.25	.58	15.11	1.00	.00	9.46	3.05	29.36
Location of house	.35	.41	.75	1.00	.39	1.42	.64	3.17
Affected by disease	.77	.46	2.74	1.00	.10	2.15	.87	5.32
Age	-.01	.01	1.53	1.00	.22	.99	.97	1.01
Female	.08	.55	.02	1.00	.89	1.08	.37	3.20
Agricultural landless	1.00	.29	12.10	1.00	.00	2.71	1.55	4.75
Crop save	-1.76	.42	17.35	1.00	.00	.17	.08	.39
Mobile phone	-.02	.36	.00	1.00	.96	.98	.49	1.97
Mitigation measures	-.80	.31	6.61	1.00	.01	.45	.25	.83
Nonfarm income	-.47	.31	2.26	1.00	.13	.63	.34	1.15
Gajaghanta	-.53	.40	1.79	1.00	.18	.59	.27	1.28
Belka	-1.53	.43	12.79	1.00	.00	.22	.09	.50
Constant	-1.26	.93	1.83	1.00	.18	.28		

Log Likelihood	:	345.51
Wald Chi Square	:	$\chi 2$= 105.77, df=12, p value < .001
Cox & Snell R Square	:	.245
Nagelkerke R Square	:	.350
Hosmer and Lemeshow Test	:	$\chi 2$=6.15, df=8, p=.631

Table 5: Logistic regression for temporary migration model

Explanatory variables	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
							Lower	Upper
Floodwater depth	-.26	.57	.21	1.00	.65	.77	.25	2.35
Location of house	.06	.37	.02	1.00	.88	1.06	.51	2.21
Affected by disease	1.28	.52	6.16	1.00	.01	3.59	1.31	9.87
Age	-.02	.01	4.22	1.00	.04	.98	.96	1.00
Female	-.37	.70	.27	1.00	.60	.69	.18	2.75
Agricultural landless	.95	.28	11.35	1.00	.00	2.58	1.49	4.47
Crop save	.84	.29	8.34	1.00	.00	2.31	1.31	4.09
Mobile phone	1.07	.49	4.75	1.00	.03	2.92	1.11	7.63
Mitigation measures	.92	.41	5.07	1.00	.02	2.50	1.13	5.55
Nonfarm income	-.09	.29	.10	1.00	.75	.91	.52	1.61
Gajaghanta	-.34	.38	.78	1.00	.38	.71	.34	1.51
Belka	-.77	.40	3.72	1.00	.05	.47	.21	1.01
Constant	-3.28	1.06	9.53	1.00	.00	.04		

Log Likelihood	:	354.186
Wald Chi Square	:	$\chi 2$= 48.25, df=12, p value < .001
Cox & Snell R Square	:	.120
Nagelkerke R Square	:	.183
Hosmer and Lemeshow Test	:	$\chi 2$=6.88, df=8, p=.549

Table 6: Logistic regression for grants from external sources model

Explanatory variables	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
							Lower	Upper
Floodwater depth	-.48	.52	.84	1.00	.36	.62	.23	1.71
Location of house	.85	.39	4.67	1.00	.03	2.34	1.08	5.07
Affected by disease	.53	.38	2.03	1.00	.15	1.71	.82	3.56
Age	.01	.01	.52	1.00	.47	1.01	.99	1.02
Female	-.16	.57	.08	1.00	.77	.85	.28	2.57
Agricultural landless	-.08	.25	.09	1.00	.77	.93	.56	1.53
Crop save	-.21	.28	.57	1.00	.45	.81	.46	1.41
Mobile phone	-.22	.36	.38	1.00	.54	.80	.40	1.62
Mitigation measures	.46	.32	2.04	1.00	.15	1.58	.84	2.97
Nonfarm income	-.20	.27	.53	1.00	.46	.82	.49	1.39
Gajaghanta	-1.86	.36	26.93	1.00	.00	.16	.08	.31
Belka	-1.67	.36	22.10	1.00	.00	.19	.09	.38
Constant	-.55	.88	.39	1.00	.53	.58		

Log Likelihood	:	421.07
Wald Chi Square	:	$\chi 2$= 60.689, df=12, p value < .001
Cox & Snell R Square	:	.149
Nagelkerke R Square	:	.206
Hosmer and Lemeshow Test	:	$\chi 2$=7.08, df=8, p=.528

Table 7: Correlation among the post-disaster coping measures and explanatory variables

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. BOMO	1	-.04	.05	.08	.06	-.08	.14**	.09	-.13*	-.17**	-.02	-.02	.14**	.02	-.17**	.001	-.05
2. ASDI		1	-.297**	-.064	-.06	-.14**	-.11*	-.12*	.004	-.13*	-.26**	.15**	.17**	.15**	.12*	-.07	.15**
3. CORE			1	-.019	-.005	.24**	.06	.12*	-.04	.14**	.27**	-.28**	-.18**	-.25**	-.11*	.10*	-.16**
4. TEMI				1	.05	-.05	.001	.13*	-.11*	-.04	.11*	.17**	.12*	.13*	.02	.02	-.078
5. GRES					1	-.13*	.16**	.08	.04	.06	-.04	-.03	-.04	.08	-.01	-.19**	-.10*
6. Floodwater depth						1	-.04	.19**	-.001	.09	.10	-.06	-.21**	-.15**	-.12**	.16**	.058
7. Location of house							1	-.07	-.04	.07	.00	-.07	.01	-.03	.02	-.12*	-.027
8. Affected by disease								1	.07	.03	.04	.01	-.09	.01	-.10*	.003	-.043
9. Age									1	.04	-.07	.04	-.08	.01	.11*	.136**	-.16**
10. Female										1	.15**	-.12*	-.23**	-.09	.06	-.033	-.12*
11. Agricultural landless											1	-.17**	-.23**	-.19**	.01	.062	-.031
12. Crop save												1	.17**	.16**	.14**	.015	-.035
13. Mobile phone												.17**	1	.14**	.05	-.002	.058
14. Mitigation measures														1	.10*	-.056	.033
15. Nonfarm income															1	.093	-.17**
16. Gajaghanta																1	-.69**
17. Belka																	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Note: BOMO: Borrowing money; ASDI: Assets disposal; CORE: Consumption reduction; TEMI: Temporary migration; GRES: Grants from external sources

Table 8: Description of the Post disaster risk mitigation measures

Group	Description
A. Structural measures	
Plinth raise of the house	Plinth of the house (individual hut) raised above the height of the recent recorded flood.
Build home on raised earthen mounds	Homestead area including main-house, kitchen, latrine, tube-well, cattle-shed, and courtyard are constructed on a raised earthen mounds with a plinth level at a height of the recent recorded flood so that the whole homestead area do not over-top.
Modify house with strong materials	Increasing resistance of the house based on the ability of the people which includes foundation strengthening with wood or bamboo framework/poles; construction of walls and/or roof with corrugated iron sheet; or construction of brick walls with corrugated iron sheet for roofing.
B. Nonstructural measures	
Household has precautionary money savings	Household has precautionary cash savings for flood days in their house.
Household has precautionary crop savings	Household has precautionary food/crop stocks for flood days in their house.
Store valuables household goods safer place	Store available valuables goods and food stocks above the flood level.
Collect emergency items	Household is equipped with emergency items such as flash light, firebox, first aid kits, medicines, water purification tablets, plastic containers, and others which can be used during the flood.

Table 9: Logistic regression model for structural risk mitigation measures (Model 1)

Explanatory variables	**B**	**S.E.**	**Wald**	**df**	**Sig.**	**Exp(B)**	**95% C.I.for EXP(B)**	
							Lower	**Upper**
Perception of flood probability	.76	.27	8.05	1.00	.00	2.14	1.26	3.61
Perceived preparedness	1.02	.34	8.90	1.00	.00	2.77	1.42	5.41
Floodwater depth	-.10	.04	6.21	1.00	.01	.91	.84	.98
Location of house	-.14	.30	.23	1.00	.63	.87	.48	1.56
Living duration	-.85	.57	2.22	1.00	.14	.43	.14	1.31
Membership	.05	.37	.02	1.00	.89	1.05	.51	2.18
Age	.46	.72	.41	1.00	.52	1.58	.39	6.45
Female	-1.05	.53	3.94	1.00	.05	.35	.12	.99
Earning member	-.30	.21	1.93	1.00	.17	.74	.49	1.13
Education	-.35	.29	1.45	1.00	.23	.70	.40	1.25
Agricultural landless	-.74	.29	6.37	1.00	.01	.48	.27	.85
Nonfarm income	.63	.31	4.15	1.00	.04	1.89	1.02	3.47
Gajaghanta	-.56	.41	1.89	1.00	.17	.57	.26	1.27
Belka	.56	.50	1.27	1.00	.26	1.75	.66	4.62
Constant	1.60	.75	4.58	1.00	.03	4.96		

Log Likelihood : 358.57
Wald Chi Square : $\chi 2$= 53.51, df=14, p value < .001
Cox & Snell R Square : .132
Nagelkerke R Square : .199
Hosmer and Lemeshow Test : $\chi 2$= 6.88, df=8, p=.549

Table 10: Logistic regression model for structural risk mitigation measures (Model 2: without perception variables)

Explanatory variables	**B**	**S.E.**	**Wald**	**df**	**Sig.**	**Exp(B)**	**95% C.I.for EXP(B)**	
							Lower	**Upper**
Floodwater depth	-.11	.04	7.89	1.00	.00	.90	.84	.97
Location of house	-.21	.29	.55	1.00	.46	.81	.46	1.42
Living duration	-.94	.55	2.90	1.00	.09	.39	.13	1.15
Membership	.21	.36	.32	1.00	.57	1.23	.60	2.50
Age	.34	.70	.24	1.00	.63	1.40	.36	5.52
Female	-1.01	.52	3.80	1.00	.05	.36	.13	1.01
Earning member	-.17	.21	.65	1.00	.42	.85	.57	1.27
Education	-.31	.28	1.21	1.00	.27	.73	.42	1.28
Agricultural landless	-.74	.29	6.70	1.00	.01	.48	.27	.84
Nonfarm income	.66	.30	4.72	1.00	.03	1.93	1.07	3.48
Gajaghanta	-.48	.39	1.48	1.00	.22	.62	.29	1.34
Belka	.56	.48	1.36	1.00	.24	1.75	.68	4.49
Constant	2.76	.67	17.07	1.00	.00	15.83		

Log Likelihood : 376.04
Wald Chi Square : $\chi 2$= 36.03, df=12, p value < .001
Cox & Snell R Square : .091
Nagelkerke R Square : .137
Hosmer and Lemeshow Test : $\chi 2$= 6.44, df=8, p=.598

Table 11: Logistic regression for non-structural risk mitigation measures (Model 3)

Explanatory variables	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
							Lower	Upper
Perception of flood probability	.25	.23	1.15	1.00	.28	1.28	.81	2.03
Perceived preparedness	.16	.34	.22	1.00	.64	1.17	.61	2.26
Floodwater depth	-.03	.03	1.11	1.00	.29	.97	.91	1.03
Location of house	-.85	.26	10.47	1.00	.00	.43	.26	.72
Living duration	.03	.49	.00	1.00	.95	1.03	.39	2.69
Membership	.92	.33	7.91	1.00	.00	2.51	1.32	4.76
Age	-.17	.61	.08	1.00	.78	.84	.25	2.79
Female	-.81	.55	2.18	1.00	.14	.44	.15	1.30
Earning member	.18	.19	.94	1.00	.33	1.20	.83	1.73
Education	.21	.25	.66	1.00	.42	1.23	.75	2.03
Agricultural landless	-.99	.25	15.54	1.00	.00	.37	.23	.61
Nonfarm income	.71	.26	7.74	1.00	.01	2.04	1.23	3.38
Gajaghanta	-.19	.34	.30	1.00	.59	.83	.42	1.63
Belka	-.12	.39	.10	1.00	.76	.89	.41	1.92
Constant	.75	.65	1.33	1.00	.25	2.11		

Log Likelihood	:	453.78
Wald Chi Square	:	$\chi2$= 64.39, df=14, p value < .001
Cox & Snell R Square	:	.157
Nagelkerke R Square	:	.210
Hosmer and Lemeshow Test	:	$\chi2$=5.34, df=8, p=.721

Table 12: Logistic regression for non-structural risk mitigation measures (Model 4: without perception variables)

Explanatory variables	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
							Lower	Upper
Floodwater depth	-.04	.032	1.421	1	.233	.962	.903	1.025
Location of house	-.86	.261	10.990	1	.001	.421	.253	.702
Living duration	-.02	.487	.002	1	.961	.977	.376	2.535
Membership	.94	.325	8.373	1	.004	2.564	1.355	4.852
Age	-.19	.608	.096	1	.757	.829	.252	2.727
Female	-.81	.548	2.198	1	.138	.444	.151	1.299
Earning member	.20	.186	1.188	1	.276	1.225	.851	1.763
Education	.21	.254	.676	1	.411	1.232	.749	2.027
Agricultural landless	-.99	.249	15.749	1	.000	.372	.228	.606
Nonfarm income	.72	.256	8.027	1	.005	2.064	1.250	3.407
Gajaghanta	-.17	.342	.241	1	.624	.845	.432	1.654
Belka	-.11	.393	.077	1	.781	.896	.415	1.938
Constant	1.04	.560	3.468	1	.063	2.838		

Log Likelihood	:	455.21
Wald Chi Square	:	$\chi2$= 62.95, df=12, p value < .001
Cox & Snell R Square	:	.154
Nagelkerke R Square	:	.206
Hosmer and Lemeshow Test	:	$\chi2$=5.21, df=8, p=.734

Table 13: Correlation among the post-disaster risk mitigation measures and explanatory variables

Variables	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1. At least one structural measure	1	.29**	.15**	.20**	-.10*	.01	-.04	.05	.00	-.12*	.00	-.09	-.18**	.10*	-.10	.07
2. At least one non-structural measure		1	.08	.10	-.12*	-.16**	.12*	.21**	.05	-.12*	.10*	-.07	-.23**	.18**	.06	-.07
3. Perception of flood probability			1	.09	-.09	-.03	-.03	.04	.01	.02	.04	-.01	.00	.06	.06	-.07
4. Perceived preparedness				1.00	-.05	-.08	-.01	.10	-.02	-.08	.13**	-.06	-.10	.05	.01	.01
5. Floodwater depth					1.00	-.09	-.29**	-.15**	-.12*	-.05	.02	.14**	.13*	-.16**	-.31**	.57**
6. Location of house						1.00	-.12*	-.01	-.12*	.07	-.04	.05	-.05	-.04	-.24**	.04
7. Living duration							1.00	.17**	.34**	-.07	.04	-.15**	-.19**	.10	.29**	-.36**
8. Membership								1.00	-.02	-.09	.04	-.08	-.07	.21**	.13*	-.18**
9. Age									1.00	.04	.26**	.01	-.07	.11*	.14**	-.16**
10. Female										1.00	-.05	.06	.15**	.06	-.03	-.12*
11. Earning member											1.00	-.17**	-.17**	.06	.01	-.03
12. Education												1.00	.28**	-.04	-.12*	.15**
13. Agricultural landless													1.00	.01	.06	-.03
14. Nonfarm income														1.00	.09	-.17**
15. Gajaghanta															1.00	-.69**
16. Belka																1.00

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 14: Total variance explained by the 16 variables (Source: Authors)

Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	3.18	19.88	19.88	2.47	15.44	15.44
2	1.53	9.56	29.45	1.58	9.89	25.32
3	1.30	8.11	37.56	1.56	9.74	35.07
4	1.20	7.51	45.07	1.44	9.02	44.09
5	1.09	6.82	51.88	1.25	7.79	51.88
6	1.00	6.25	58.13			
7	.94	5.87	64.00			
8	.90	5.63	69.63			
9	.78	4.85	74.48			
10	.76	4.76	79.23			
11	.70	4.37	83.60			
12	.65	4.04	87.64			
13	.57	3.54	91.18			
14	.53	3.33	94.51			
15	.47	2.92	97.43			
16	.41	2.57	100.00			

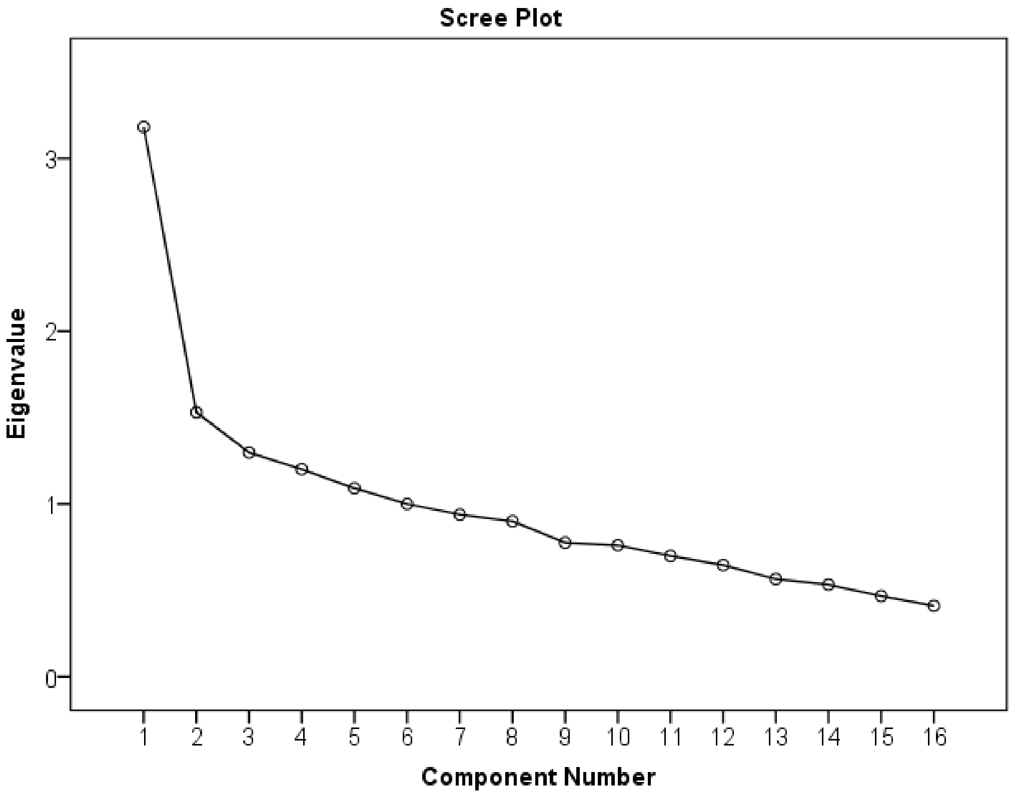

Figure 1: Scree plot of 16 variables

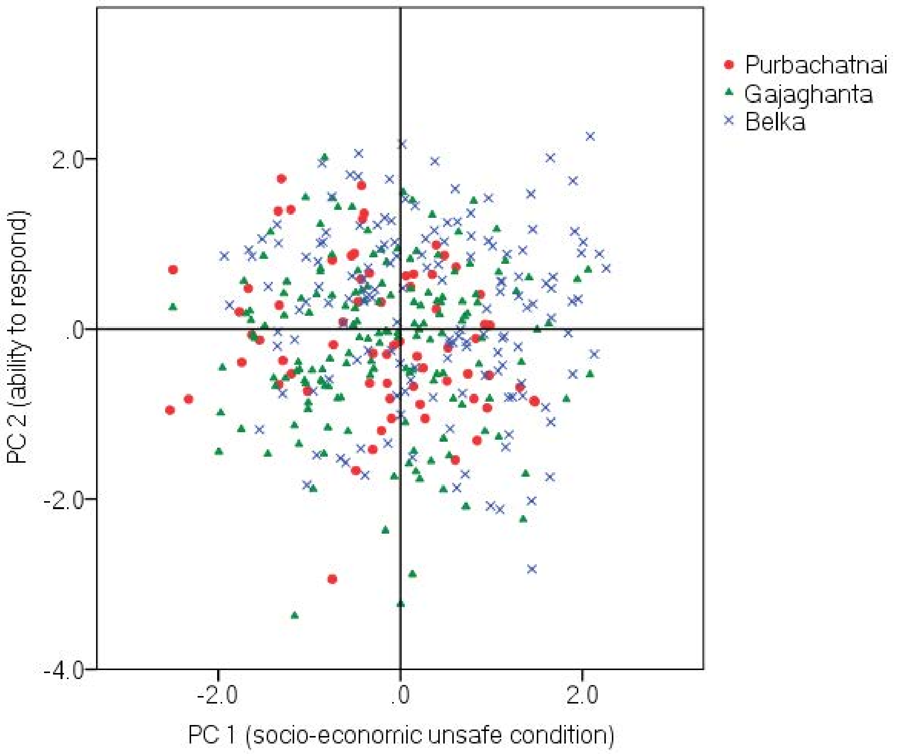

Figure 2: Distribution of PC1 and PC2 of 377 households

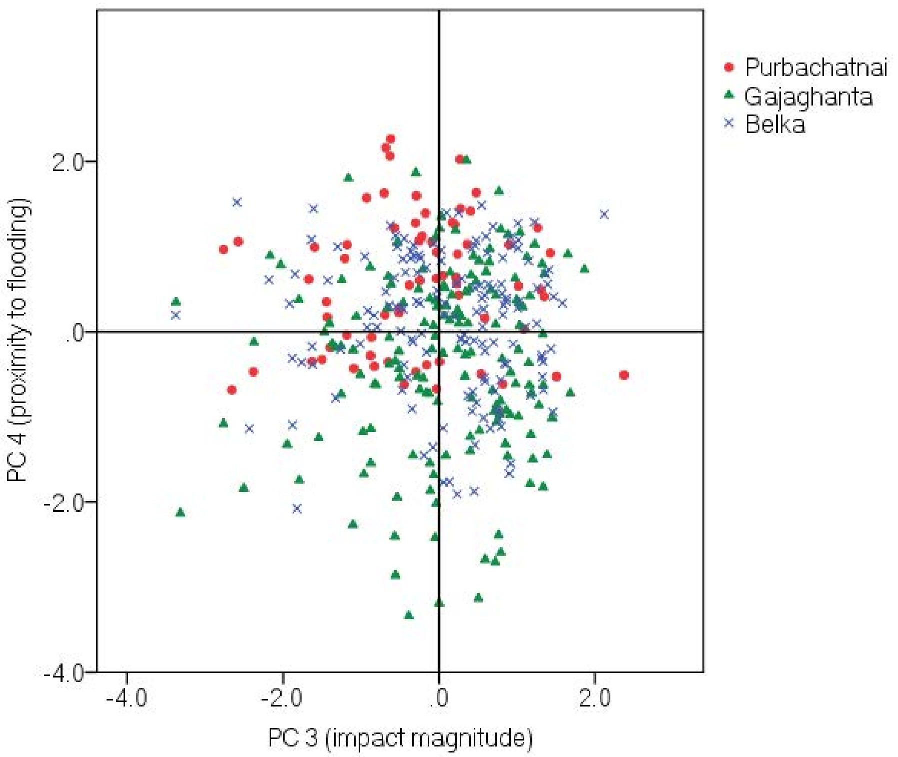

Figure 3: Distribution of PC3 and PC4 of 377 households

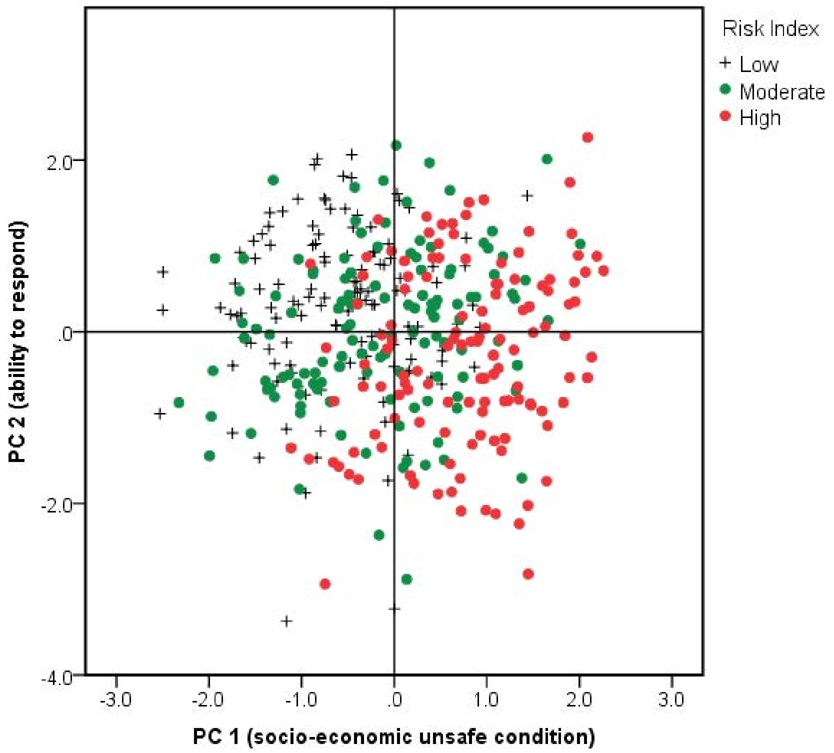

Figure 4: Distribution of PC1 and PC2 based on risk index category

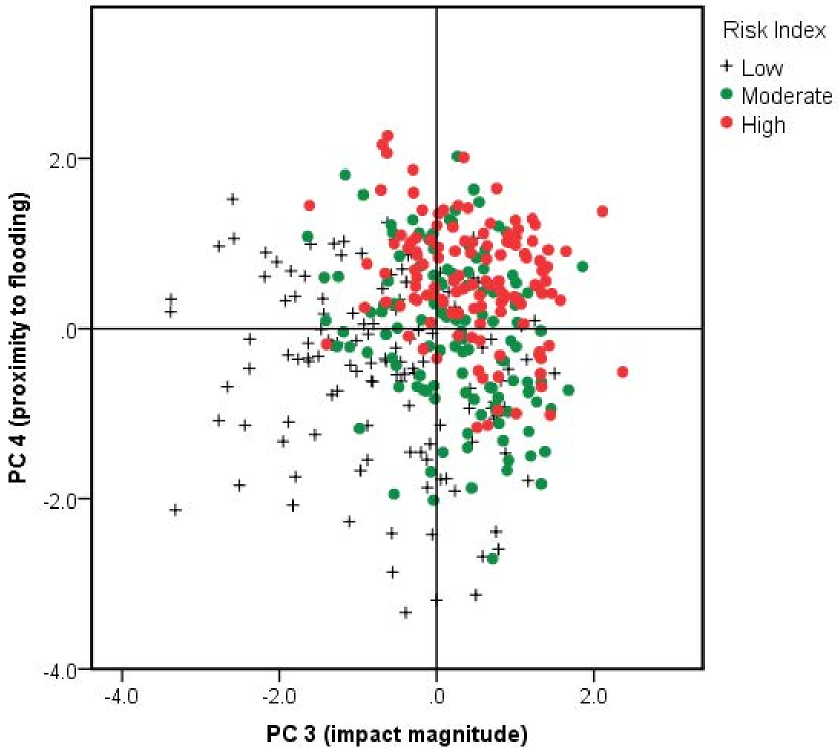

Figure 5: Distribution of PC3 and PC4 based on risk index category

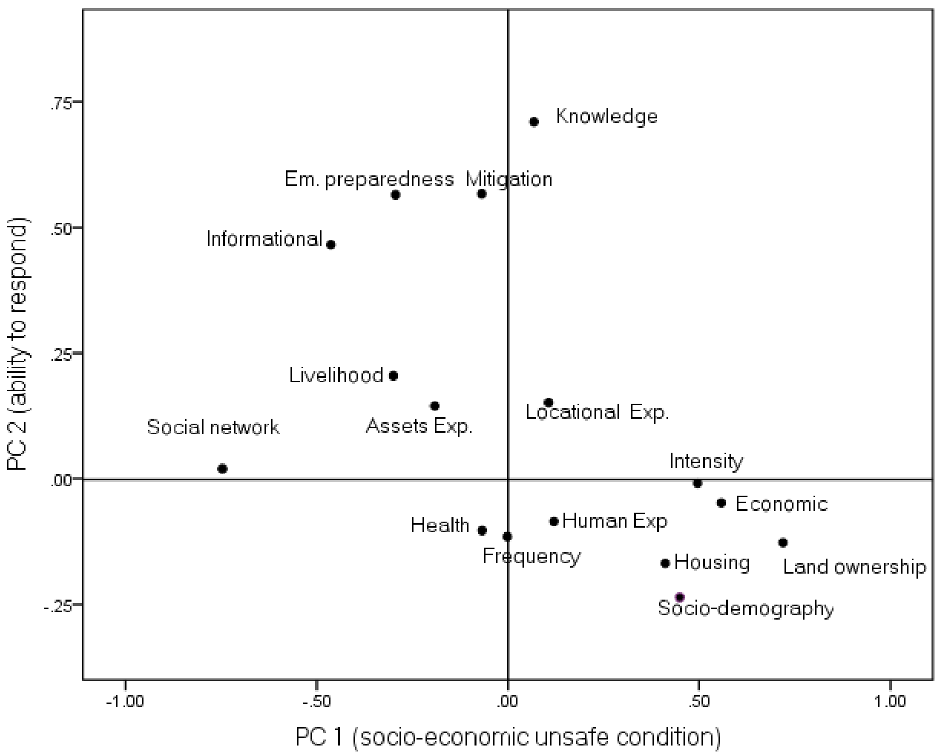

Figure 6: Distribution of PC1 and PC2 (based on rotation component matrix)

Table 15: Correlation between perceived preparedness and five components extracted from PCA

	PEPR	SEUC	ATRE	IMMA	PROF	HEST
PEPR	1	-.120*	.265**	-.163**	-.107*	.047
SEUC		1	.000	.000	.000	.000
ATRE			1	.000	.000	.000
IMMA				1	.000	.000
PROF					1	.000
HEST						1

Notes:

*, ** imply correlation is significant at the 0.05 level (2-tailed) and 0.01 level (2-tailed)

PEPR= Perceived preparedness; SEUC = Socio-economic unsafe condition; ATRE = Ability to respond; IMMA = Impact magnitude; PROF = Proximity to flooding; HEST: health status