Decreasing climate change vulnerability through adaptation with special reference to migration: A study in the Indian Sundarbans

by

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B.A., University of Burdwan, 2010
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Abstract

The Indian Sundarbans is a hotspot of global climate change. This delta harbors 4.3 million people who are mostly dependent on natural resources for their livelihood and are vulnerable to impacts of erosion, salinization of agricultural lands, rainfall variability, and tropical cyclones. This study aims to understand how residents of the coastal areas including deltas and small islands adapt to environmental changes and problems. It specifically focuses on migration as an adaptation. It uses household level primary data collected by interviewing 300 participants from 10 different villages of the eastern and western parts of the Indian Sundarbans. Through a mixed method of data analysis this study examines people's perception of environmental change and its impacts, adaptation practices, particularly the different ways migration is being used as an adaptation, the environmental and non-environmental determinants of adaptive migration, and people's willingness to permanently relocate to environmentally safer places in the future. The results show that residents perceived significant environmental changes and problems in the last 10 years in the Sundarbans. To reduce the impacts of such change they mostly preferred in-situ structural and non-structural adaptation measures but 58% of the households pursued temporary migration as an adaptation strategy. Temporary migration was pursued as a reactive strategy to cope with the economic impacts of natural hazards or disasters, or as a livelihood diversification strategy for present economic security and to prepare for future hazards or as an alternative income source for the households that suffered irrevocable losses of agricultural lands due to erosion. The remittances from migration helped in household consumption and small-scale investments in non-farm economies. This study also revealed that even though remittances reduced the impacts of natural hazards, environmental change and problems were not the determining factors of migration but acted as catalysts of migration by negatively influencing agricultural income. The probability

of migration was greatest among the households that relied on agriculture as the only livelihood and decreased as households shifted to non-farm livelihoods. Among the environmental factors, erosion was found to be the only statistically significant determinant of migration. While labor migration was widely used as an adaptation, 92% of the residents were not willing to permanently relocate away from their native villages in the Sundarbans despite perceiving environmental risk. These residents shared a deep sense of belonging with their birthplaces and communities. They have lived through environmental problems and believed that unpredictability in the potential destination cities is riskier than environmental changes in the Sundarbans. More importantly, they lacked the resources needed to relocate with families. However, a few households—mostly from the erosion affected places—were willing to relocate if the government provided them with free lands and jobs.

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Table of Contents

List of Figures

List of Tables

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Dedication

Dedicated to the people of the Sundarbans.

Chapter 1 - Introduction

Deltas of major rivers such as the Ganges-Meghna-Brahmaputra, Mahanadi, Volta, Mississippi, Yangtze, Pearl, and Chao Phraya are among the most densely populated places in the world. They constitute 5% of the earth's landmass and support over 500 million people in some of the fastest growing megacities, including: Shanghai, Bangkok, Kolkata, and Dhaka (Kuenzer and Renaud., 2012; Lauria et al., 2018). Deltas are natural landforms developed by the accumulation of sediments when a river drains into a lake or an ocean (Becker et al., 2019). They are characterized by a system of channels, low topography and rich biodiversity, and act as active filters and huge reserves of continental materials including carbon (Kuenzer and Renaud., 2012). Soils in the deltaic lowlands are rich in organic matter and nutrients that have allowed major agricultural development throughout history (Vormoor, 2010).

Deltaic lowlands are highly vulnerable to subsidence and flooding due to low topography, natural changes in sediment load, population pressure, and excessive extraction of natural resources coupled with the impacts of sea level rise (SLR) (Tessler et al., 2016; Syvitski, 2008). The situation is increasingly urgent as the rate of sea level rise has increased during the latter half of the twentieth century from thermal expansion of oceanic water and the rapid melting of the Greenland and Antarctic icesheets due to global warming caused by anthropogenic greenhouse gas emissions (Kuenzer and Renaud., 2012). According to the Intergovernmental Panel on Climate Change (IPCC) report (2007; 2019), the average annual rate of sea level rise was 1.8 mm from 1961 to 2003 but increased to 3.1 mm/year between 1993 and 2003, and to 3.6 mm/year between 2006 and 2015. This upward trend is projected to continue through 2050 and beyond (Bhattachan et al., 2018). Such an increase in the level of ocean water—accompanied by geomorphological changes in the deltaic lowlands and adverse human interference—have already intensified coastal

and riverbank erosion, increased salinization of cultivated lands and freshwater fisheries, and even resulted in salinization of groundwater reserves. Additionally, with rising sea level, storm surges associated with tropical storms are likely to intensify which will further aggravate the environmental challenges facing the deltaic and coastal lowlands and put the livelihood of millions of residents at risk (von Storch et al., 2008).

It is also predicted that under the future greenhouse gas emission scenarios, there will be a 50% increase in the surface area impacted by severe floods in these low-lying deltas (Syvitski et al., 2009). Nicholls et al. (1999) showed that sea level rise alone might cause a loss of more than 20% of the area of the coastal wetlands by 2080, and when coupled with adverse human actions the loss might be as high as 70%. This loss of lands, assets, and livelihoods may lead to mass migration of the deltaic, coastal, and small island populations in the future. Asia will face the most serious implications of climate change and sea level rise in the world. This is due to its vast coastlines, a very high population density along the coasts, existence of megacities in the vulnerable deltaic lowlands, poverty, prevalence of subsistence economies among the rural communities, lack of environmental awareness, and less technological development as most of these countries are still in their developing phases (Kuenzer and Renaud., 2012).

Adaptation may be the most feasible option (besides mitigation) towards coping with both long- and short-term impacts of climate change on the lives and livelihoods of communities (Leavy and Greeley, 2011; De Souza et al., 2015). Adaptation refers to certain adjustments made to the natural or human systems in response to actual or expected climate stimuli that "moderate harm or exploit beneficial opportunities" (Toi et al., 2008; McCarthy et al., 2001). The goal of the adaptive strategies is to reduce the overall vulnerability of the system (household/community/society) by limiting exposure of the system to negative changes in the environment, and improving their

adaptive capacities—that is, the ability to deal with such changes and build resilience (Tacoli, 2009; Smit and Pilifosova, 2001). These strategies include in-situ structural engineering measures to protect the coasts from erosion, raised homes to avoid flooding, and in-situ non-structural measures such as use of salinity-tolerant crop varieties, and loans from local micro-credit organizations to set up small, less climate-sensitive businesses (Klein, 2011; Agrawala and Carraro, 2010; Tol et al., 2008).

One of the other prominent strategies is to migrate from these places (Gemenne and Blocher, 2017). Residents may temporarily migrate for work and use remittances to cope with economic losses caused by environmental problems or changes. This promotes capital accumulation, builds resilience, and improves their adaptive capacities at the source (Mallick and Vogt, 2014; Tacoli, 2009; McLeman and Smit, 2006; Gemenne, 2010). Similarly permanent migration to considerably less vulnerable places is likely to serve as adaptation, first, by reducing demographic pressure in the regions of origin and second, by limiting exposure of households and communities to the negative impacts of climate and environmental change (Gemenne 2010). Understanding different forms of adaptation is important in assessing impacts and vulnerability which are fundamental to estimating the costs and risks associated with climate change (Smit and Pilifosova, 2003).

While adaptation strategies may have the potential to reduce household vulnerabilities, the use or practice of these measures depend on several factors including whether and how people perceive environmental changes and problems. People's perceptions largely vary with their economic backgrounds, the socio-cultural environments that they are in, the institutional responses to environmental change, and the types and intensities of climatic stressors they face (Alam et al., 2017; Adger et al., 2009). According to Slegers (2008) vulnerable population tend

to adapt to the perceived environmental problems and changes rather than the physical measurements of the problems and therefore, understanding resident perceptions of environmental problems and changes may aid in developing efficient community-specific adaptation strategies.

The overarching goal of this dissertation research is to identify coastal residents' use of adaptation strategies with a specific focus on the role of human migration as an adaptation. Prior studies investigated the role of migration as an adaptation using conceptual ideas of vulnerabilities, exposure, adaptive capacity, and household resilience (Adger and Helen, 2013; Mc Leman and Smit, 2006; Gemenne and Blocher, 2017; Scheffran et al., 2012; Tacoli, 2009). While these studies made a significant contribution to our understanding of migration as an adaptation, very few studies have evaluated the role of both temporary and permanent migration as an adaptation based on people's perception of environmental change and related economic vulnerability in the coastal areas that are affected by both slow onset and rapid onset hazards. Moreover, it is still unclear if migration is a preferred adaptation strategy among the climate vulnerable coastal residents (Paul, 2005). This study specifically aims to understand the role of temporary migration as an adaptation, environmental and non-environmental determinants of such migration based on coastal population's perception of environmental change. It also aims to understand their willingness to permanently relocate in future as a possible adaptation strategy to environmental change.

This study is conducted in the Indian Sundarban delta, an area that experiences severe impacts from environmental change and problems. The Sundarbans is the tidally active part of the world's largest delta formed by the sediment deposition of the Ganges, Meghna and Brahmaputra Rivers into the Bay of Bengal in South Asia. This region is a hotspot of global climate change where sea level rise (SLR) and its consequences such as erosion, salinity intrusion, rainfall

variability, frequent and intense storms and floods, and land subsidence, are prominently observed (Halder and Debnath, 2014; Ghosh et al., 2014; Raha et al., 2012; Nandy et al., 2011; Roy, 2010; Hazra et al., 2002). It is estimated that the rise in sea level by 45–100 cm can inundate 75 to100% of the Sundarbans delta (IPCC, 2007). According to Sarkhel (2015) and Unnikrishnan and Shankar (2007), the mean tidal amplitude of the Sundarban is between 3.14 and 5.22 mm/year which is much higher than the Indian national average of 1.06 and 1.75 mm/year.

The impact of climate change in the delta has been further worsened by its huge population size. The Sundarbans Delta is divided between Bangladesh and India with population densities of 800 and 957 persons/km^2 respectively (Mullick et al., 2019; Dasgupta and Shaw, 2015). The residents of the Sundarbans are mostly subsistence farmers and fishers who are subject to loss of livelihoods due to impacts of climate change such as soil and surface water salinization (Sahana et al., 2019; Hazra et al., 2016). Additionally, the islands of Lohachara, Suparibhanga, Jambu Dwip and New Moore have been obliterated due to sea level rise (Mondal, 2015; Berringer, 2012; Ghosh et.al., 2003) which has forced residents to migrate a mass migration of residents by 2050 is predicted (Rigaud et.al, 2018).

To address such challenges, people have used in-situ adaptation measures such as changing agricultural patterns and constructing local businesses through micro-credit organizations (Chowdhury et al., 2016) and migration (Maharajan et al., 2020). In 2009 a major tropical storm, Cyclone Aila, devastated the Sundarbans causing large-scale temporary migration in search of employment (Mistri, 2013). Remittances from the migrants have since been an important means for survival of the residents in the Indian Sundarbans (Maharajan et al.,2020). To date, most of the studies focusing on adaptation and migration have been conducted in the Bangladeshi Sundarbans whereas there are a very few studies in the Indian counterpart. A higher proportion of residents in

Bangladesh are at a higher risk from climate change than those in India. The mitigation strategies and government policies of the two countries are different and this may influence how people perceive and adapt to environmental change. The Indian Sundarbans is home to millions of people; understanding their perception of environmental problems, in-situ adaptation strategies, and adaptive temporary and permanent migration may facilitate formation of people friendly, climate action plans.

This study has three specific objectives:

1. **To identify the environmental problems and changes perceived by the residents of Indian Sundarbans.**

Understanding resident perception of environmental problems and changes as it dictates their responses to the problems is very important. The descriptions and quantifications of environmental change in the scientific literature are often based on physical measurements. However, resident perceptions about the severity of environmental change or an individual disaster event may not agree with the physical measurements depending upon the socio-economic factors affecting residents. Existing adaptive strategies may also serve as positive feedback (i.e., adequate adaptive strategies may lessen the perceived severity of environmental change) in shaping resident perception about the environmental problems. Therefore, to understand resident responses to such changes, it is necessary to study the perceptions of residents toward environmental challenges and their economic impacts.

2. **To identify the adaptation strategies used by the residents, and to examine the nature of migration as an adaptive response to environmental change.**

The second objective aims to: i) identify the in-situ adaptation strategies; iii–a) examine the different ways residents pursue temporary migration, that is whether as a reactive, concurrent, or

anticipatory response, iii-b) whether temporary migration is practiced for livelihood diversification or for alternative livelihood; and iii-c) the environmental and non-environmental controls of such migratory responses; and iv) resident views on future permanent relocation from the Sundarbans. Through this objective we will understand people's uses of both in-situ and ex-situ adaptations that may help formulate future adaptation strategies including adopting measures which might facilitate inter-state labor migration. Moreover, it is also very important to understand residents' opinions about future relocation from the climate vulnerable islands as it may identify the factors which may be crucial for the governing bodies to consider while formulating plans for a possible mass retreat, to reduce local resistance to such migration.

3. To identify the reasons and determinants of migration.

Objective 3 focuses on examining the factors influencing migration decisions across different environmental zones and across different socio-economic groups. When migration takes place from the environmentally vulnerable areas, the environment might not be the only determining factor of migration. Other factors—economic, political, and demographic—might also contribute to the decision to migrate. These factors might co-produce migration. Therefore, Objective 3 focuses on identifying the relative importance of environmental and the non-environmental determinants of migration from the Indian Sundarbans amid climate change. This objective may identify the immediate and the underlying factors which lead to migration from climate vulnerable places such as the Indian Sundarbans, and which need to be addressed as a part of the government's climate action plan.

After this introductory chapter, the dissertation consists of six chapters. Chapter 2 reviews previous research in this area and provides a background for the current study, which is followed by the discussion of research methods used in data collection and analysis. Chapters 4-

6 present the research findings. The focus of Chapter 4 is the environmental problems in the Indian Sundarbans as perceived by residents. Chapter 5 discusses residents' adaptations to environmental changes and problems in the study area with an emphasis on the roles of migration. Chapter 6 then analyzes the reasons and determinants of temporary migration based on the questionnaire survey data from the Indian Sundarbans. The seventh and final chapter discusses the implications of the research.

Chapter 2 - Literature Review

Adaptation to climate change

Adaptation to climate change refers to any adjustment made in the socio-ecological and economic systems to reduce the adverse impacts of climate change (Smit and Pilifosova, 2003). Since climate change mitigation efforts may take a considerably long time ensuing further delays in reducing global warming, adaptation may be the most viable option towards managing the long- and short-term impacts of climate change on the human society (Weldegebriel, 2016; Adger et al., 2009; 2005 (a) (b)). The goal of adaptation is to reduce a household's or a community's vulnerabilities to environmental change, and to build resilience (Brooks, 2003; Brooks et al., 2005; Smit and Pilifosova, 2003).

Vulnerability is the extent to which climate change may damage a system (household/community/society) and depends on the levels of exposure, sensitivity, and adaptive capacity of the system to change (Smit and Wandell, 2006). Exposure to natural hazards refers to the degree to which a community experiences the impacts of natural hazards (Marshall et al., 2010). Sensitivity is the extent to which the system responds to climate change, and adaptive capacity refers to the ability of the system to adjust to such changes (including climate variability and extremes). Adaptive capacity in turn depends on several factors such as resource distribution, socio-economic and technological developments, human and social capital, and the institutional structure of the society (Tol et al.,2008). For example, coastal lowlands in developing countries such as India, Bangladesh and Sri Lanka lack sufficient protective measures like dams, sea walls, and embankments, and are thus exposed to the impacts of sea level rise. In these areas the poverty stricken rural and predominantly agricultural communities are by far the worst affected by sea

level rise and its associated impacts. Poverty may limit access of these communities to resources and technologies required to reduce their vulnerabilities. Adaptation measures have the potential to reduce vulnerabilities by improving adaptive capacity and limiting the exposure and sensitivities of households/communities/societies to environmental change. Sensitivity can be reduced by reducing dependence on the vulnerable natural resources through measures like diversifying food production and planned conversion of some of the salinized agricultural lands into saltwater fisheries.

People's perceptions of environmental change also largely determine adaptative capacities and their choice of adaptations (Alam et al., 2017). People's perceptions of environmental change and related use of adaptation strategies have been studied in Hong Kong (Ma et al., 2021), USA (Kemp et al., 2015), Kenya (Silvestri et al., 2012), Nigeria (Apata et al., 2009), Ethiopia (Asrat and Simane, 2018), Indian Himalayas (Dey et al., 2017; Negi et al., 2017), and Bangladesh (Alam et al., 2017; Rashid et al., 2014; Anik and Khan et al., 2012; Habiba et al., 2012). People's responses to environmental change are decided by how they perceive such changes rather than the physical measurements of changes. People who perceive local climate risks have a greater probability of pursuing relevant adaptation strategies or lending support to mitigation policies (Niles et al., 2013; Spence et al., 2011; Prokopy et al., 2015). Incorrect perceptions may result in maladaptive strategies that may increase overall vulnerabilities in the long term (Alam, 2017).

Adaptation measures can be either reactive when undertaken after the impacts of a hazard or a disaster, or anticipatory when undertaken in advance to avert the future impacts of climate change (Tol et al., 2008; Fankhauser et al., 1999). However, whether anticipatory or reactive, these adaptation measures are mostly future-oriented and aim towards minimizing the risks associated with future environmental hazards and maximizing benefits (Tol et al., 2008). Protection,

accommodation, and retreat are the three major ways people may try to adapt to environmental changes and problems in the coastal areas (Tol et al., 2008). Protection and accommodation are in-situ adaptation strategies, and retreat of population from the affected places is an ex-situ strategy. Each of these measures has the potential to manage environmental and non-environmental risks, and has its own ecological, economical, and socio-cultural advantages. Some of these measures, such as temporary migration, commercial use of backyard vegetable gardens, and conversion of salinized lands to saltwater fisheries, can be implemented at individual or household levels. Building embankments, infrastructure development, research and development in sustainable agriculture, and promotion of less climate sensitive livelihood options require a community or government action. Each of these strategies can be implemented alone or in combination with the other strategies (Tol et al., 2008).

In-situ adaptation strategies

In-situ adaptations overcome or avert the economic losses that occur due to environmental problems without having to move to new places. These include protecting coasts from flooding and lessening the impacts of environmental problems through a variety of sustainable economic and non-economic activities (Klein et al., 2001).

Protection measures are the engineered structures such as dikes, sea walls, embankments and groins that can protect coasts and riverbanks from erosion, intrusion of saline water and related depletion of natural resources. Planting trees to protect coasts is also a protective adaptation. These measures are meant to be permanent; they are significant for places with a large population as some of these measures have high costs associated with building, maintenance and operation, and additional costs associated with the permanent socio-ecological changes imposed by them. Though highly significant in protecting coasts from physical damages, the structural adaptation measures

come with environmental implications. For example, embankments designed to restrict saltwater from entering lands might trap sediments, increase erosion in the coastal headlands, and damage the ability of the deltaic wetlands to keep pace with sea level rise (Kuenzer and Renaud., 2012; Tol et al., 2008; Donner and Webber, 2014).

Accommodative adaptation refers to the practices that allow people to operate in vulnerable places without physical attempts to prevent hazards or disasters (Buitrago et al., 2018). These include storm shelters, elevated homes, drainage modifications, use of salinity-tolerant crop varieties, converting the freshwater fisheries and already saline agricultural lands into saltwater fisheries, opting for less climate sensitive economic activities, building effective pumping stations, bioswales, artificially injecting stormwater in the aquifers to increase the level of groundwater and offset the pressure of saline water due to sea level rise and a prohibition on human activities on the coasts that have a long-term detrimental effect on the ecosystem (Almedia and Mostafavi, 2016). Examples of human activities include the filling of wetlands, destruction of mangrove forests, and expansion of human settlements in the erosion prone areas.

These accommodative measures are economically beneficial as they can revive some of the damaged economic and ecological systems (like conversion of salinized farmlands to aquaculture). However, it requires careful planning at all levels to ensure the adaptability of the measures to future anticipated environmental and socio-economic changes. Additionally, awareness, technical assistance and education are required to reduce the economic and socio-cultural implications of the adaptation practices (Kuenzer and Renaud., 2012; Tol et al., 2008). For instance, Wamsler et al. (2012) found that with formal education people can better assess environmental risk and access information on risk reduction measures more efficiently.

Ex-situ adaptation strategies

Ex-situ adaptation measures refer to either permanently migrating to comparatively less environmentally vulnerable places or temporarily migrating in search of work (*Mc Leman and Smit, 2006; Foresight, 2011; Tacoli, 2009*). The next section highlights the different aspects of permanent migration as an adaptation. This is followed by a review of literatures on mass migration in the era of climate change and review of the different case studies on migration from climate vulnerable places around the world. Next, different aspects of temporary migration is discussed followed by a review of literatures on the multicausality of migration.

Permanent household relocation

Relocating from vulnerable environments may have beneficial effects both for the affected households and the source area. While relocation to safer places may limit a household's exposure to environmental problems, it may also reduce population pressure from the limited resources at the source which in turn may revive the natural ecosystems that have been disturbed due to human interference and resource exploitation (Adams and Adger, 2013; Gemenne, 2008). This can be achieved through government-supported community retreat that may include planned abandonment of developments in the areas under risk, withdrawal of government support, prohibition of reconstruction of damaged properties, and declaration of coastal areas as natural reserves (Gibbs, 2016). The decision to migrate as an adaptive strategy against environmental problems and changes can also be taken at the household level when members of households plan such relocations to destinations with comparatively good environmental conditions and where they can utilize their skills to earn a living that is less likely to be impacted by natural hazards (Adams and Adger, 2013).

In the latter half of the 20th century, migration associated with environmental changes and problems gained significant attention in the literature. In 1985 mass migration of populations due to environmental change emerged as a major issue when El-Hinnawi coined the term "environmental refugee" to refer to the population displaced by negative forces in the natural environment and recognized the roles of both slow onset hazards and rapid onset disasters as major causes of mass displacements in the era of global warming induced climate change. Later Jacobson (1988) also recognized environmental hazards and disasters as factors inducing mass migration. The IPCC (1991) also highlighted the significance of environmental factors in human migration and anticipated future social instability and disruptions of settlement patterns due to mass migration because of climate change. Subsequently, British environmentalist Norman Myers set forth an alarming estimate of 250 million migrants worldwide by 2050 and ranked it as 'the foremost human crisis of our times' (Myers, 1993, 2002, 2005).

Several international organizations backed the claims of a future mass migration and came up with their own number of migrants. According to the Almeria Statement (1994), 135 million people were at risk of being forcibly displaced due to desertification. Similarly, the UNHCR in 2007 estimated that 24 million people had already escaped their ancestral places due to floods and other environmental hazards. The International Organization for Migration (IOM) estimated 200 million people will be displaced due to deteriorating environments by 2050, and after 2050, there could be as many as 700 million such migrants worldwide (Christian Aid, 2007). With these predictions, the systematic re-settlement of vulnerable populations was called for, and refugee status was demanded for the present and potential migrants (Biermann and Boss, 2008; Conisbee and Simms, 2003).

These predictions received severe criticism from the scientific community. Warner et al. (2010) mentioned that the considerable range in the estimated numbers of future migrants raised questions about their empirical validity, and these predictions seemed to be grounded in the deterministic idea that environmental change causes outmigration of people without considering the possibilities of adaptation. Black (2001) questioned the terms environmental refugees and environmental migrants and demanded more empirical and theoretical research on the issue for these migrants to be considered potential recipients of international assistance.

Concerns were also raised about the determining factors of human migration from environmentally vulnerable places. Massey et al. (1993), Castels (2002), McLeman and Smit (2006), and Hulme et al. (2008) among others identified several determining factors which were considered valid even while evaluating climate induced migration. It was pointed out that even in places that are extremely vulnerable to environmental change, human migration is generally a result of socio-economic, political factors as opposed to one single cause like environmental change (Black, 2011) (Fig 2-1). Environment may play the major role in migration if there is a permanent loss of habitable land due to inundation or extreme erosion. For example, farmers in Australia and Northern Ethiopia may suffer environmental problems of the same intensities but unlike the farmers in Ethiopia the Australian farmers may not migrate as they do not suffer hunger comparable to those from Northern Ethiopia. This suggests that migration from Northern Ethiopia is primarily caused due to poverty while environmental change acts as a trigger (Webber and Barnett, 2009; Meze-Hausken, 2000). Similarly in Bangladesh, economic reasons were the primary motivations for rural to urban migration, and environmental factors were found to be secondary. Households that had better access to land, more human capital, transferable skills, and weak rural ties were more prone to migrate than the others. Environmental factors such as distance

from the coast or a major river, loss of arable land, land submergence and resultant lack of agricultural work increased the probability of migration. Yet these were relatively less important when compared to economic factors (Brenzen et al., 2019; Mallik and Vogt, 2014). According to Warner and Buffet (2009) understanding the role of slow-onset environmental change in producing migration is difficult because of the socio-economic factors of migration at sources and destinations which may or may not be intricately related to the environmental factors.

Migration after rapid onset or extreme environmental events also results from a combination of factors with disasters as the immediate cause of migration. Large scale migration was reported from Honduras after Hurricane Mitch in 1998, but studies suggest that poverty, unemployment, and less provision for in-situ adaptation strategies in Honduras determined the islanders' decisions to migrate, and the storm served as an immediate push factor (Wrathall, 2012 and Alscher, 2011). Therefore, considering the possibilities of a mass migration, it will be premature to ignore the non-environmental determinants of migration and highlight the role of the environment as the sole cause. Moreover, migration may not always be forced. It can also be pursued a 'transformational livelihood strategy' or as a coping or adaptation strategy to increase household resilience after failure to adapt in the source region due to environmental and non-environmental reasons (Mallick and Vogt, 2014).

Despite of detailed discussion in the literature on migration being used as adaptive strategies, it is still unclear whether migration is a favored adaptation response among the populations experiencing environmental changes or problems. Paul et al. (2020) suggested that there is seldom a linear relationship between permanent migration and environmental degradation. Factors like place attachment, natural and social capital at the source areas, and unpredictability and unfamiliarity of living and working conditions at the destinations demotivate people from

migrating (Firdous, 2019). Moreover, relocation is a resource intensive option. When smallholder households suffer considerable economic losses due to environmental change, they cannot afford settling somewhere else away from their native places (Mendelsohn et al., 2006).

A study in Bangladesh by Chen and Mueller (2018) found that extreme soil salinity in the coastal areas of Bangladesh resulted in a decrease in the rates of long-term international migration due to the relative lack of resources required for moving when extreme salinity compromised crop production. These people might be 'trapped' in the environmentally challenged places and suffer double vulnerability, firstly because they live in vulnerable environments and second, they do not have enough resources to escape from these places (Foresight 2011).

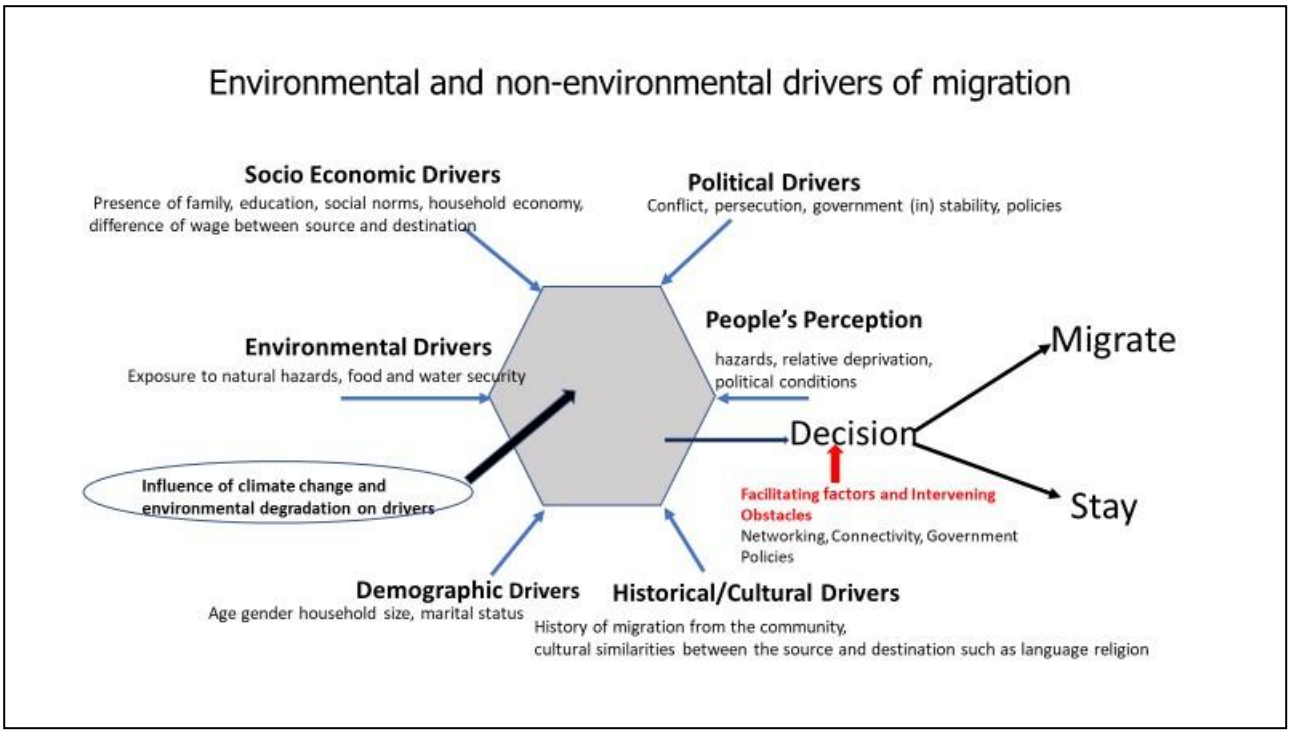

Figure 2-1. Environmental and Non-environmental drivers of migration. By author after Black (2011)

While poor household economy hinders migration, provision of resources and employment at the source in the form of relief and aid may also act as anchoring forces after a hazard or a disaster. Paul (2005) investigated migration responses in coastal Bangladesh after a cyclone in 2004. All the respondents suffered damage due to the cyclone, 5% of the respondents reported deaths due to the cyclone in their households, and 65% of the respondents reported injuries. However, no migration was reported from any of the affected villages. Instead, after the storm there was an influx of people into the cyclone-affected villages from outside.

Skilled laborers such as carpenters temporarily migrated to these villages to participate in the post-disaster reconstruction of buildings. People from distant places also in-migrated with the intention of receiving disaster aid and relief. Even after experiencing huge losses, these villagers continued staying in the vulnerable places as they received prolonged post-disaster aid and agricultural assistance from the government. Others stayed due to the creation of jobs in the construction sector that provided them with economic security in their villages.

Economics is, however, not the only major factor that determines a person's willingness to migrate from these vulnerable places. Sometimes residents do not perceive enough risk to abandon their native places (Paul, 2005). They usually prefer adapting to the environmental problems and changes with in-situ strategies and remittances from outside (Rahman et al., 2015; Koubi et al., 2012). Mortreux and Barnett (2009) and Kelman et al. (2019) investigated whether the residents of the islands of Tuvalu and the Maldives wanted to relocate to environmentally safer places as their islands are at an extreme risk of inundation due to sea level rise. Their studies revealed that only a few residents wanted to relocate; for the others, sea level rise and its associated impacts were not threatening enough to consider moving. The people of Maldives preferred in-situ adaptation options against relocation.

In Tuvalu, climate change was not a matter of concern for most of the islanders. Some islanders did not notice any immediate impacts of climate change other than tidal surge; they believe that God will protect them in case there is an extreme environmental situation. Some younger respondents even considered climate change as a rumor, which suggests that they might not have spent enough time in Tuvalu to experience the slow impacts of climate change. Less environmental awareness, a strong faith in God, the future-oriented impacts of slow-onset changes like sea-level rise, the uncertainty and pace of such changes, and the fact that as these islanders have already lived through difficult environmental and socio-economic situations, the impacts of climate change did not seem concerning enough to initiate relocation.

Similar results were found in the studies that examined the possibility of mass migration after rapid onset disasters. For example, Rahman et al. (2015) examined the possibility of migration as a response to a sudden storm surge that created 20 ft. high tidal waves and inundated parts of the Bangladeshi island of Kutubdia. According to their results, 92% of the respondents suffered property damage due to the event, but only 5% of them wanted to migrate. Much like the findings in Tuvalu, Rahman et al. (2015) explain that the people of Kutubdia have lived through such disasters and have gradually adapted to extreme situations.

Behavioral and socio-psychological factors also determine a resident's willingness to relocate from these vulnerable places (Adams, 2016). The behavioral aspects of migration can be explained with theories such as stress threshold, place utility and residential dissatisfaction at the source, and mobility potential (Speare, 1974; Wolpert, 1966; Brown and Moore, 1970). These theories suggest that the decision to migrate partly depends on the level of satisfaction a person experiences at the source. When a person is satisfied with the amenities at the source, she/he will generally not migrate even when other locations have the potential to provide a better life. The

person might want to migrate when the threshold of dissatisfaction is crossed, but factors like family obligations, attachment to place and community, perception about the potential destinations, and lack of suitable destinations might also influence the persons' willingness to migrate (Adams, 2016). According to Adams (2016) many of these factors determine a person's mobility potential. They may be 'self-imposed' and prevent people from considering better living conditions in other places. People generally trade off wellbeing in the potential destinations with locational well-being at the source despite perceiving environmental risk and dissatisfaction.

There is evidence of permanent relocation conducted after rapid onset events and from places experiencing slow-onset changes. The town of Spencer in South Dakota had a tornado touchdown in 1998. This event led to population migration, and only half of Spencer's population returned by 2001 (Cross, 2001). Population migration was also documented after the 2001 tornado in Hoisington, Kansas where 70 families relocated because of the tornado (Brooke and Paul, 2003). Relocation of population also occurred after devastating earthquake events in El Salvador and in the Indian state of Gujarat in 2001 (Ibrahim, 2003). Population migration was also reported from Bangladesh after Cyclone Aila in 2009. Saha (2017) reports that a considerable number of people relocated from coastal Bangladesh after the storm due to the destruction of homes, permanent damage to croplands, decreased access to food, increasing dependence on loans to survive, and lost capacity to repay money borrowed before Aila.

The willingness of residents to permanently migrate due to slow-onset environmental events was reported from the Pacific Island of Kiribati where it was found that most of the studied population were willing to relocate or temporarily migrate as a response to the threat of inundation of large parts of Kiribati due to sea level rise. Eighty-two percent of them previously migrated temporarily for work to different places outside of their island. Unlike the residents of Tuvalu, the

Maldives and Bangladesh, these islanders were willing to relocate as they were aware of the threats consequent to climate change due to their prior experiences with temporary migration, and the migration-friendly policies of the Government of Kiribati (Allgood and McNamara, 2017).

Temporary labor migration as an adaptation

Many studies have shown that vulnerable population temporarily migrate for work to adapt to slow onset changes and cope with the rapid onset environmental problems they experience in their source areas, instead of permanently relocating from their places. As a response to slow onset changes labor migration is generally pursued as a livelihood diversification strategy as was seen in Nepal, parts of Bangladesh and in Ethiopia (Shrestha et al., 2007; Chen and Muller, 2019; Kartiki, 2011; Penning et al., 2013; Weldegebriel and Prowse, 2017; Radel et al., 2018). According to Weldegebriel and Prowse (2017) such livelihood diversification practices can promote accumulation of capital and secure smallholders from losses due to climate variabilities, and act as effective adaptation. Labor migration can be circular if undertaken several times by the same households or non-circular. Studies from Bangladesh suggest that such migration is commonly practiced as a response to economic losses that are recoverable as opposed to permanent relocation practiced mostly when economic losses at the source are irrevocable (Penning Rowsell et al., 2013; Joardar and Miller, 2013). Sometimes labor migration is also undertaken as a future risk minimization strategy or an anticipatory adaptation strategy at the household level as suggested by the Theory of New Economics of Labor Migration (Stark, 1984; Stark and Levhari, 1982). Connecting this theory to environment-induced migration, we can infer that households anticipating environmental risks at the source might send a few members to work elsewhere while the others continue working at the source. In case of market failure in the source, the households rely on the remittances earned by the migrant members.

Environmental degradation gradually wears away a household's and society's adaptive capacity which in turn increases their vulnerability to environmental change. Remittances help restore the gradually eroding adaptive capacity in different ways, ultimately promoting effective adaptation to climate change. Remittances may be used in the reconstruction of properties after a hazard: in building stronger homes to reduce impacts from future hazards; setting up diversified economies at the source through investments in less-climate sensitive non-farm business; or sustainable agriculture (threats (Perch Nielson, et al., 2008; Piguet, 2008; Gemenne and Blocar, 2017 ;Maharajan et al., 2020; Findlay and Geddes, 2011; Foresight, 2011; Piguet et al., 2011; Gemenne, 2010; Webber and Barnett, 2010; Tacoli, 2009; McLeman and Smit, 2006).). Remittances can contribute to poverty alleviation, the promotion of economic development and sustainability amid climate shocks in the place of origin, and through a stable flow of capital.

Remittances also increase a household's or community's ability to withstand environmental stress, that is, increases resilience to the environmental stressors at the source (Tacoli, 2009). According to Foresight (2011), proactive migration in combination with robust in-situ adaptation measures will ultimately help communities to continue staying in their native places instead of requiring them to relocate elsewhere (except for extreme situations like island inundation). Further, migrants help in the transfer of resources and advanced knowledge from developed societies, and in gathering tangible and intangible assets that ultimately assist in capacity building and risk mitigation at the source (Gemenne and Blochar, 2017; Scheffran et al., 2011).

Much like understanding the relation between environmental change and permanent relocation, it is difficult to analyze the relative importance of the environmental and non-environmental factors of labor migration from the environmentally vulnerable places. Sustained

environmental change or extreme events generally influence migration by influencing the non-environmental drivers of migration in different intensities. This may vary with the types and severity of natural hazards being experienced at the source and the socio-economic conditions of the households or communities.

Many theories have been put forth to characterize labor migration from different places. Labor migration can be considered a profit maximization or risk minimization approach by an individual or a household (Massey et al., 2013). It may be a result of differences of wages and availability of labor between two regions where people migrate from low wage and labor surplus regions to high wage labor scarce regions (Harris and Todaro, 1970; Todaro, 1976). Regions with fast developing economies often have a continuous demand for skilled and unskilled labor which also induces labor migration from surrounding areas that are not necessarily low wage and labor surplus (Piore, 1979). These theories provide a framework for understanding the drivers of labor migration from environmentally vulnerable areas.

Several drivers of labor migration have been identified in prior studies. Since labor migration is often a household decision, the nature of the household economy at the place of origin plays a decisive role in such migration (Massey et al., 1993). For instance, households that survive on subsistence economies such as small-scale agriculture, wood collection and fishing may be particularly vulnerable to the impacts of environmental change and may need to migrate for work as they often fail to afford effective in-situ adaptation strategies (Shrestha and Bhandari, 2007; Hunter, 2005). Other indicators of household economies are total assets owned by the household including agricultural landholding. According to Van Wey (2003) “land can impact migration in four ways: as wealth, as employment, as investment opportunities and through inequality in ownership.” However, mixed results were found in studies regarding land as a determining factor

of migration. Bandari (2004), Van Wey (2003), Massey and Espinosa (1997), and Mukherji (1895) found a negative relationship between landownership and migration indicating that households with less access to landholdings have greater probabilities of migrating for work to generate alternative incomes. In other cases, a positive relationship was found that indicated households earning substantial income by means of their higher landholdings may migrate more, as they can afford the cost of migration and associated risks (Van Wey, 2005; Davis et al., 2002; Zhao, 1999; Durand and Massey, 1992). Bilsborrow et al. (1987) found a curvilinear effect of landholdings on migration. According to Winters de Janvry and Sadoulet (2001), the size of landholdings has a positive effect on migration for households that own up to 15 hectares of land, and beyond that it showed a negative impact. Other studies indicated that households with more fertile and well-irrigated landholdings tend to have sufficient income from agriculture, and therefore they do not tend to migrate for work (Dustmann, 2011; Davis et al., 2002; Zhao, 1999; Massey and Espinosa, 1997; Rigg, 1988).

Demographic characteristics of residents such as age, gender, household size, marital status, and education also influence the household's decision to migrate. For example, males between 20–35 years old were found to be the most mobile, whereas mobility decreased in adults older than 35 years (Mahinchai, 2010; Clark, 1986). Household size (number of family members) and their marital status are inversely related with the probability of labor migration from that household (Sandefur and Scott,1981).

Labor migration may be in the form of skilled and unskilled laborers where the education of the resident plays an important role. Prior studies have found that the chances of migration are highest among the most and the least educated individuals; the educated individuals would migrate

in search of skilled jobs, while least educated individuals would seek unskilled labor (Zimmerman, 2014; Mahinchai, 2010; Becker, 1975).

The social connections of residents in potential destination areas, including prior migrants and relatives, ethnic contacts, and people with linguistic similarities also increase the probability of labor migration as such social connections provide necessary feedback and guidance, and facilitate migration (Kalter and Will, 2016; Seddon et al., 2002). In case of rural-urban migration, wages in the destinations are much higher than in the residents' native villages. This positive difference in wages also leads the household to migrate for work (Bernzen et al., 2019; Istiaque et al., 2013; Istiaque and Ullah, 2013; Massey et al., 1993; Mabogunje, 1970).

Similarly, perception of relative deprivation can also influence a household's decision to migrate. In predominantly agricultural communities with very less migration there may be less economic differences among households. When migration starts, income inequality may increase among the migrant and the non-migrant households. This may create a sense of relative deprivation among the non-migrant households and encourages more migration. Moreover, the migrants get introduced to industrial and urban life, consumer products that can unlikely be obtained simply with a rural subsistence income. This in turn generates more trips (*Massey et al., 1993; Mabogunje, 1970*).

Environmental factors including slow and sudden disasters and natural hazards have been linked with labor migration globally (Foresight, 2011; Tacoli, 2009). However, whether environmental factors alone can induce labor migration is still unclear. In most environmentally vulnerable places economies are so dependent on the environment that these two factors are practically inseparable. Therefore, environmental factors may be one of the many drivers of

migration, or act as a catalyst rather than a sole cause of migration (Black et al., 2011; Foresight, 2011; Catteno et al., 2019).

While environmental, economic, and social factors exist, the migration decision also greatly depends upon how residents perceive these factors. Perceptions of risk due to environmental or non-environmental (economic and social) factors plays a key role in migration decision making (Fordham, 1992). Some households may perceive that their present economies are at risk due to environmental change and migrate to diversify livelihoods. Some may migrate as an anticipatory adaptation strategy to cope with the future perceived environmental and related economic risks. Others may not anticipate enough economic risks and continue to earn their incomes in native places (Peacock and Girard, 1997; Dynes and Quarantelli, 1976).

Previous studies have highlighted how people's perceptions of environmental change and problems shape their choice of adaptations. These studies were mainly conducted in agricultural communities in different parts of the world (Silvesti et al., 2012; Apata et al., 2009; Asrat and Simane et al., 2018; Li et al., 2017; Alam et al., 2012, 2017; Rashid et al., 2014). While these studies provide meaningful insights into the link between human perceptions of climate impacts and related use of adaptation, their recommendations might not be relevant universally due to the varying intensities of environmental hazards, the socio-economic backgrounds of the households, and the varying institutional responses to environmental change (Malone, 2009; Alam et al., 2017).

Prior studies have also investigated the role of migration as an adaptation using conceptual ideas such as vulnerabilities, exposure, adaptive capacity, and household resilience (Adger and Adams, 2013; Mc Leman and Smit, 2006; Gemenne and Blocher, 2017; Scheffran et al., 2012; Tacoli, 2009), or in the context of political ecology (Radel et al., 2018; Wrathall et al., 2014). Some studies identified migration as a common post-disaster response (Mistri, 2013; Kartiki, 2011;

Alscher, 2011) but Paul et al. (2005) challenged the inevitability of such responses. Researchers also examined if vulnerable residents would consider permanent relocation to environmentally safer places in the future but reported mixed findings (Paul et al., 2020; Mortreux et al., 2009; Allgood and McNamara, 2017). Scholars have analyzed the effects of environmental and non-environmental factors on migration from vulnerable environments though their concern is usually not on migration as a form of adaptation (Bernzen et al., 2019; Ishtiaque et al., 2017; Ishtiaque and Ullah, 2013).

While these studies made a significant contribution to our understanding of the role of migration as an adaptation, very few studies have evaluated the role of both temporary and permanent migration as an adaptation from places that are affected by both slow onset and rapid onset hazards. This research, conducted in the Indian Sundarbans specifically asks: Do residents of the Indian Sundarbans perceive the impacts of environmental change? What are the adaptation strategies used in the Indian Sundarbans? What are the different ways residents use migration as an adaptation (alternative source of income, additional source of income, livelihood diversification strategy)? Do socio-economic and environmental factors influence the different ways they use migration? Is permanent relocation considered an adaptation strategy by the residents? What is the relative importance of the environmental and non-environmental factors in generating migration from the Indian Sundarbans?

The present study also aims to overcome some of the methodological limitations in prior studies from different places. Some of the prior studies focused on the receiving communities (destination areas) to characterize migration, and consequently ignored the non-migrant population from the sending communities (source areas) (Ishtiaque and Nazim, 2017; Ishtiaque and Ullah, 2013). Many studies used secondary data to study migratory behavior or focused on migratory

responses only after specific natural disasters or assessed migration without separately assessing the temporary and permanent migratory responses (Chen and Mueller, 2018; Mallick and Siddiqui, 2015; Ishtiaque and Ullah, 2013; Ishtiaque and Nazim, 2017; Paul, 2005). These limitations often failed to provide a comprehensive understanding of why some of the residents migrate while others do not despite facing similar environmental problems. The present study uses household-level primary data collected by surveying migrants as well as non-migrant households of the Indian Sundarban delta. This study considers both environmental and non-environmental factors that may control the types of migration across different environmental zones of the delta across a 10-year time scale.

Chapter 3 - Methods

This research uses household level primary data and mixed methods of data analysis (qualitative and quantitative) to examine adaptation to environmental change in the Indian Sundarbans based on people's perception of environmental changes and problems. Conceptually this research considers migration as one of the important adaptations to environmental changes and problems (McLeman and Smit, 2006). This chapter provides stepwise information about the research's conceptual framework, geographical information about the study area, the pre-field, field and post-field investigation techniques, and the methodological limitations.

Conceptual framework

The conceptual framework (Figure 3-1) of this study provides a nexus between environmental change, related economic losses, and decisions to migrate as an adaptation. According to the framework, environmental changes, and problems impact livelihoods of residents in the low-lying coastal and deltaic communities (Hauer et al., 2020; Nunn, 2013). The residents cope with economic losses and try to decrease overall vulnerabilities through different adaptive practices, both in-situ and migration. Adaptive migration can be both temporary circular and non-circular migration for work, and permanent household relocation. Temporary migration is considered an adaptation as remittances may increase household adaptive capacity and provide an economic security against market risks at the source (Tacoli, 2009; Stark and Bloom, 1985). The places impacted by environmental change mostly belong to some of the poorest parts of the world that have a surplus of labor relative to capital (Hansen et al., 2019, Carter et al., 2007). Migration generally takes place from these labor rich, capital constrained places mostly to the urban centers that require labor to operate (Harris and Todaro, 1970). Additionally, household demographic and economic factors, environmental risk perception at the source, the nature intensities of

environmental problems, networking with the employers at the destination, and a sense of relative deprivation among the non-migrants also determine the decision to migrate for work (Below et.al. 2012; Hulme 2008; Mc Leman and Smit 2006; Castels 2002; Massey et.al., 1993). On the other hand, permanent migration entails relocation to less environmentally vulnerable places and therefore limits household exposure to environmental change. However, this decision is often treated as a last resort when all other adaptation strategies are exhausted and depends on people's perception of environmental risk, residential satisfaction at the source, ability to withstand stress at the individual or household level, presence of resources to migrate, place attachment, and presence of social capital at the destination (Adams, 2016; Speare, 1974). These factors in turn are partly shaped by environmental changes the place is facing.

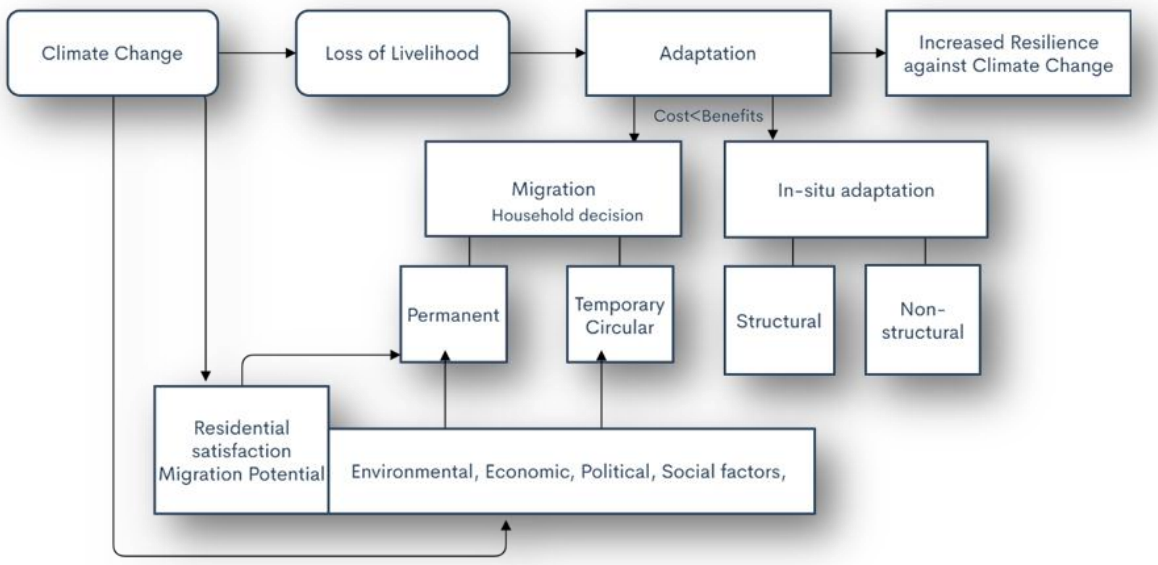

Figure 3-1 Conceptual framework of the study

Study area

The Sundarban delta (Figure 3-2) is the world's largest coastal wetland (Chatterjee et al., 2015) formed by the hydrologic discharge of the rivers Ganga, Meghna and Brahmaputra in the Bay of

Bengal. In magnitude this discharge is second only to the discharge by the Amazonian river system and is driven by the Southwest Indian monsoons. The delta occupies the Bengal Basin that lies at the confluence of the Indian, Burmese and the Asian tectonic plates (Wilson and Goodbred, 2015). It stretches 10,000 km^2 with 38% in India and the remaining 62% in Bangladesh (Bandyopadhyay et al., 2018; Ghosh et al., 2014; Rahman et al., 2011). The Indian part of the Sundarbans stretches from 21°32′N to 22°40′N in latitude and from 88°05′E to 89°00′E in longitude, and is bounded by the River Hooghly (Map Figure 3-3) in the west, the Icchamati-Raimangal river system in the east, the Dampier Hodges line (northern-most limits of estuarine zones affected by tidal fluctuations) in the north, and the Bay of Bengal in the south (Banerjee et al., 2013). The delta is characterized by a network of anastomotic river channels, islands, and mudflats (Ghosh et al., 2015; Gopal et al., 2006; Rudra, 2014).

The Sundarbans (both in India and Bangladesh) is considered one of the seven most important wetlands globally due to its biological diversity (Junk et al., 2006). It is the world's largest continuous belt of mangrove ecosystem that occupies more than 4000 km^2 (Naskar, 2004; Joshi and Ghose, 2014). The 'Sundarban' is named after the 'Sundari tree', which is the dominant mangrove species of this region, and the name literally means 'beautiful forest' (sundar = beautiful, ban = forest). Besides mangrove, the Sundarbans is home to 200 more plant species, 400 species of fish, 300 species of birds, 57 species of reptiles and 42 species of mammals which include the Royal Bengal Tiger, Panthera tigris (Ghosh et al., 2015; Gopal and Chauhan, 2006; Mandal and Nandi, 1989). It was declared as World Heritage Site by UNESCO in 1997(Rahman, 2016).

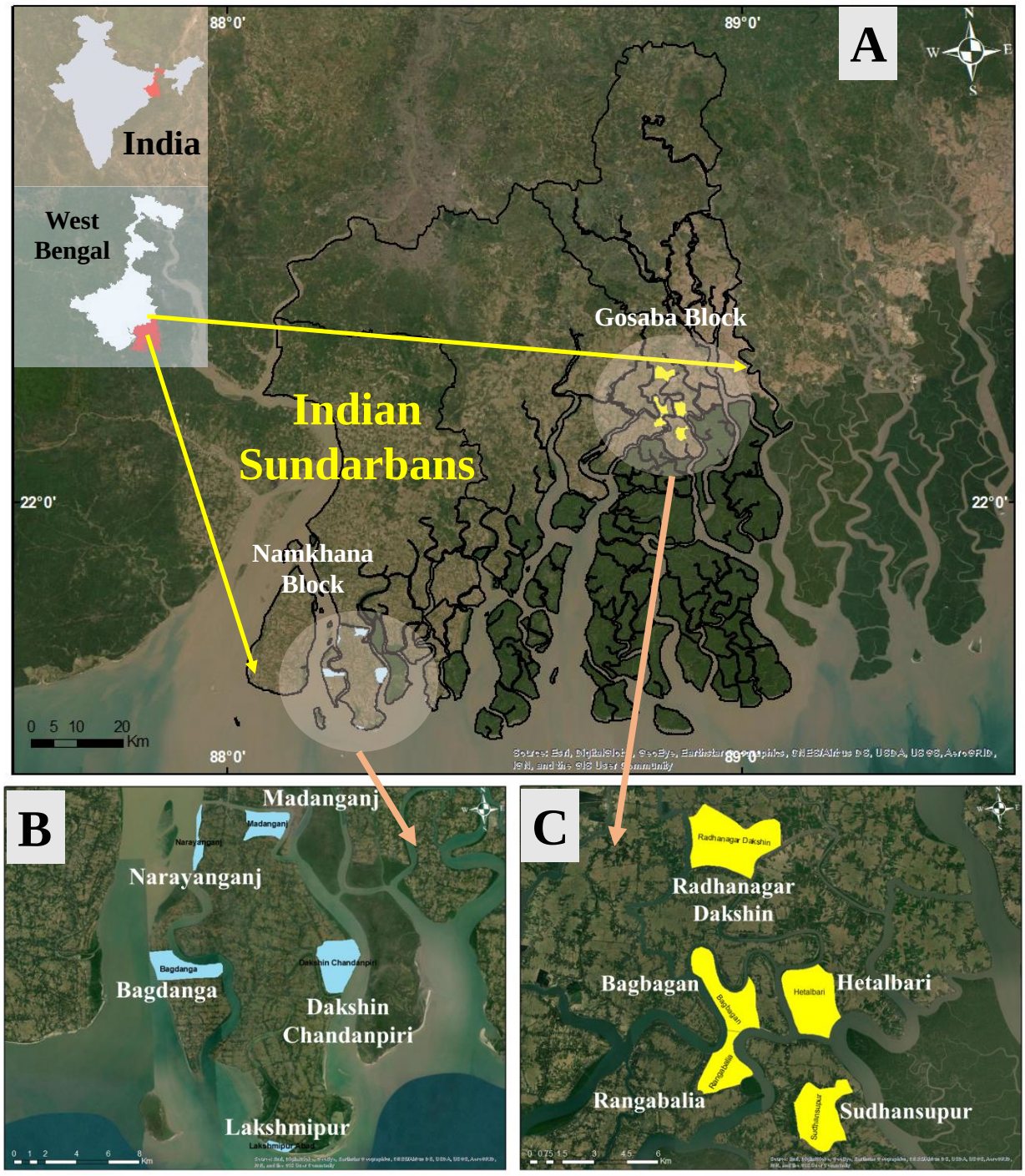

Figure 3-2 Map of the study area and sample villages

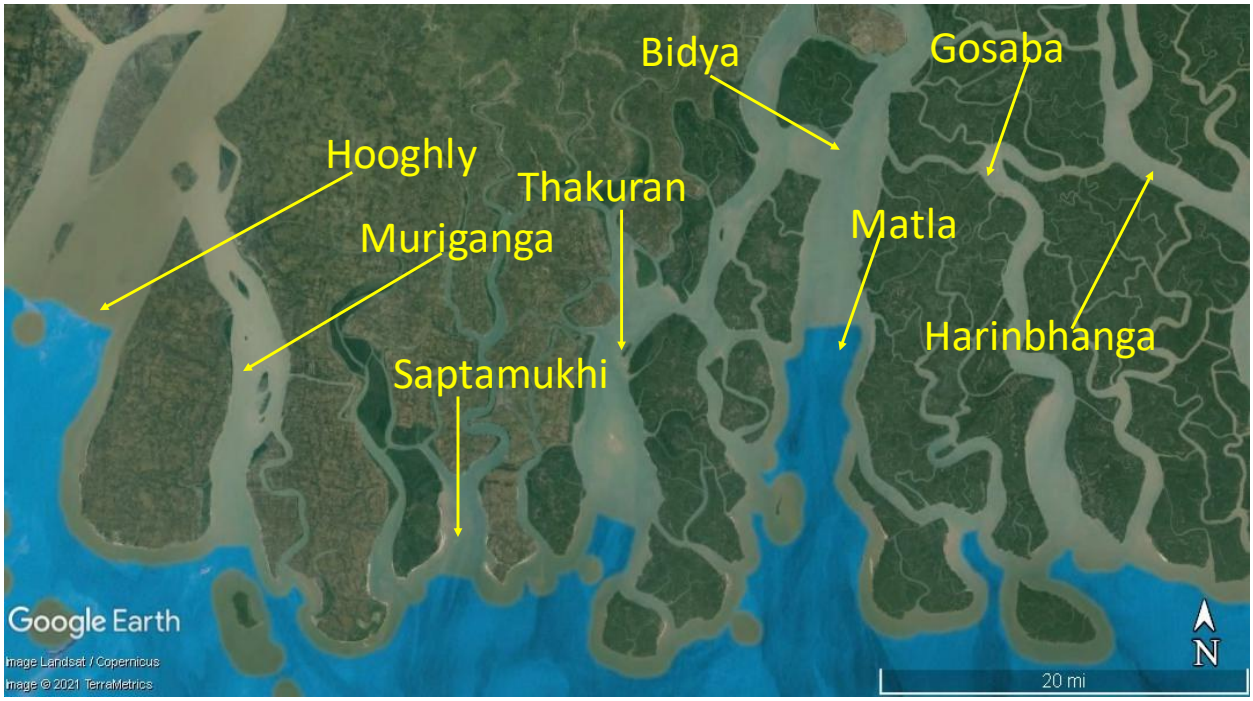

Figure 3-3 Major rivers in the study area

The Indian Sundarbans has a subtropical climate according to Köppen–Geiger climate classification system (Debnath, 2018), with most precipitation in the summer. The average annual temperature of this region is 35ºC (95ºF). The summer or the pre-monsoon season extends from April to June followed by the monsoon that extends from July to September. The month of October marks the beginning of the post-monsoon season. This is followed by winter from November to January. The months of February and March mark the spring season (Mitra et al., 2009). The average annual rainfall ranges between 1662 mm to 1805 mm (65" to 71") with maximum rainfall in the summer monsoon months consequent to the southwesterly winds. Heavy rainfall with hail and thunderstorms, commonly called nor'westers, are experienced in the pre-monsoon. These thunderstorms often develop into cyclonic storms causing disruptions to the life and livelihoods of the residents. (Gopal and Chauhan, 2006).

The Indian Sundarbans is in the state of West Bengal in India (Fig 3-2 A). The state has 23 administrative districts, each district is divided into several sub-divisions, and each sub-division is divided into several community development (CD) blocks (see Appendix). Each CD block comprises a few villages (moujas) where the village is the lowest administrative unit. The Indian Sundarbans is comprised of 19 CD blocks, 13 in South 24 Paraganas (a Paragana means a group of towns) district and six in North 24 Paraganas district, respectively (Hazra et al., 2002; Danda, 2007). There are 106 islands of which 54 are inhabited by 4.37 million people with a population density of 957/km^2. The residents are mainly engaged in subsistence agriculture, subsistence and commercial fishing, and honey collection from the forests. According to the Census of India (2011), the population of the Sundarbans has grown 18% between 2001–2011, 14% more than that of the state of West Bengal. Most of the people are dependent on subsistence monocropping for survival and 55% of these farmers are poor, landless laborers. They suffer from extreme poverty due to dependence on subsistence agriculture and the underdevelopment of the non-agricultural economic sectors. Forty-seven percent of the population is considered marginalized (scheduled class according to the Census of India, 2011) (Ghosh et al., 2018).

The Sundarbans is one of the hotspots of global climate change (De Souza et al., 2015; Chand et al., 2012). It is severely affected by sea level rise, the rate of which is more than the Indian national average, salinity intrusion, increasing sea-surface temperature, rainfall variability, storm surges, increased frequency of river flooding, storms, over siltation of the rivers, soil erosion, and island subsidence (Halder and Debnath, 2014; Ghosh et al., 2014; Raha et al., 2012; Nandy et al., 2011; Roy, 2010; Hazra et al., 2002).

The Northern Indian Ocean has been rising at a relatively high rate compared to the other oceans and the Bengal delta has been subsiding at a mean annual rate of 15-50 mm/year due to over-exploitation of resources and sediment trapping in the upper reaches of the rivers in the reservoirs and sea level rise (Mikhailov and Dotsenko, 2007, Stanley and Hait, 2000; Syvitski et al., 2009; Rahman et al., 2011). Given the huge population in this part of the world, coupled with the present rise in the sea level, and the present rate of sinking, the Bengal delta is likely to face the largest potential impact of sea level rise (Ericson, 2006). Measurements taken at the Diamond Harbor Gauge Station in the western part of the Indian Sundarbans suggested a relative rise in sea level (RSL) of 5.22 mm/year (INCCA 2010). This RSL was much higher than the national sea level rise of 1.88 mm/year (Unnikrishnan and Shankar, 2007). According to projections by the Intergovernmental Panel on Climate Change (IPCC), the sea level in the northern Bay of Bengal will possibly rise 0.3 m (1 foot) to 0.6 m (2 feet) by 2100, but due to differential rates of local subsidence, the rate of sea level rise might differ regionally (Kay et al., 2015). The IPCC also projected that 75% of the Sundarbans will be inundated with a sea level rise of 45 cm and a rise in 1 m can inundate the entire region. Chatterjee et al. (2015) reported that the eastern and western parts of the Indian Sundarbans have lost 80 km^2 (31 square miles) of land in the last 32 years. Some islands like Ghoramara, Bhangaduani, Bulchery, Jambudweep have lost more than 30% of landmass in this period, and Lohachara, Suparibhanga, New Moore islands were completely inundated (Karmakar et al., 2019; Mondal, 2015; Berringer, 2012 Ghosh et al., 2003). Long-shore current patterns, tidal height and velocity, sea level rise, position of islands (distance from the Bay of Bengal) several oceanographic, geologic, and atmospheric factors, coupled with the growing population and unplanned exploitation of natural resources,

collectively contributed to this rapid shoreline modification of the delta (Ganguly et al., 2006; Chatterjee et al., 2015).

Salinization of estuarine water in the Indian Sundarbans also varied regionally with a decreasing trend in the western sector and an increasing trend in the eastern sectors (Mitra et al., 2009). This difference was because the major rivers in the western sectors like the Hooghly River are still fed by Himalayan freshwater, whereas the major rivers of the eastern sectors like the Bidyarthi River are heavily silted and cut-off from the Himalayan freshwater source. The saline water of the estuaries enters agricultural fields during high tides and storm surges through river channels and tidal inlets. A study conducted by Halder and Debnath (2014) showed that vast areas of the Indian Sundarbans had a soil salinity as high as 20 parts per million. Their study also found that this salinity was higher during the post monsoon season and decreased with an increasing distance from the coast. Their study also showed that since the tropical storms of 2009, parts of the eastern Indian Sundarbans experienced a rapid rise in soil salinity. Increase in soil salinity followed by untimely a monsoon rendered agricultural lands completely infertile for years.

In addition to the salinity of estuarine water, pH, turbidity, and dissolved oxygen (DO) content of water also showed regional variation. In general, the pH of surface water of the Indian Sundarbans (8.25 to 8.33) is higher than that of the global average (8.17) (Mitra et al., 2009). However, pH in the western rivers is lower and shows a decreasing trend compared to that of the eastern rivers. On the contrary, the DO level in the surface water of the western rivers was higher than that of the rivers in the eastern sector. While the low pH in the western rivers was related to ocean acidification and increasing industrial waste generated from the nearby Haldia Industrial Complex, the high level of DO in the same sector was due to an influx of freshwater from the

Hooghly River system. Unlike pH and DO, transparency of surface water showed a constant downward trend for the rivers of both the eastern and the western sectors. This was due to an influx of load from the Himalayan rivers mostly in the western sector and embankment erosion in both sectors of the Sundarbans (Mitra et al., 2009). Besides these slow onset changes in surface water, soils and overall morphology of the islands that adversely impact residents' livelihoods, and rapid onset disasters like tropical cyclones result in a loss of lives and livelihoods and cause damage to properties and assets.

Cyclonic storms over the Bay of Bengal are noted for their high surface pressure gradient, heavy precipitation, strong winds, and large oceanic waves (Sarthi et al.,2015). Frequency and intensity of tropical storms were predicted to increase as the planet warms (Knutson et al., 2010; IPCC,2007). Cyclonic storms produce storm surges or waves of large wavelength. According to Unnikrishnan et al. (2011), storm surges have a catastrophic effect on the coastal areas, especially on the coasts of the Bay of Bengal due to high winds during a tropical storm and population density along the coasts (Shankar and Behra, 2019). The May 25, 2009, cyclone Aila hit the coast of the Indian Sundarbans and killed 137 people in India (Saha, 2015; Gupta, 2009), mostly in the Indian Sundarbans. The cyclone affected seven million people in the state of West Bengal in India, damaged over 700,000 homes, more than 40,000 hectares of cropland, and 415 miles of embankments along the coast (Mukhopadhyay, 2009). Since it hit the Sundarbans during high tide, the cyclone caused very high waves up to 22 ft and inundated vast parts (105,075 ha) of lands (Mukhopadhyay, 2009; International Agencies, 2009). Inundation following stagnation of saline tidal water for months rendered huge areas of the Indian Sundarbans infertile for agriculture and this severely compromised the livelihoods of people, mostly the subsistence farmers. In the years that followed, delayed monsoons further complicated the situation (Halder and Debnath, 2014).

While previous research identified some of the environmental problems and changes in the Indian Sundarbans, this research will examine adaptation decisions based on how residents perceive these changes and their economic impacts. This is important because the response of residents to environmental problems, including their ways of adaptation, often depend on how they perceive environmental change rather than on the physical and meteorological measurements of change (Berkes et al., 2001).

As a response to the impacts of environmental degradation on residents' lives and livelihood, past research identified some of the adaptation strategies and even predicted mass migration from the Sundarbans (Maharajan et al., 2020). The World Bank predicted that more than a million people would leave the Sundarbans of Bangladesh and India (Rigaud et al., 2018) and similar predictions were featured in the July 2019 issue of the National Geographic Magazine. Myers (1993) also predicted a mass migration of 'environmental refugees' from these places as a response to the environmental hazards and disasters. At present however, the residents of the Indian Sundarbans have responded to the loss of livelihood due to environmental hazards by using in-situ strategies such as bringing changes in the agricultural patterns, constructing local business through self-help-groups and tourism on the one hand, and circular labor migration on the other (Dutta et al., 2011). While such measures were identified as adaptation strategies, the nature of such adaptations is still unclear. This study will evaluate the nature of migration as an adaptation to environmental changes and problems in this area. This will also examine whether the residents are willing to permanently abandon the Indian Sundarbans in the context of the predictions of future mass migrations by various researchers and international bodies.

Survey methods

This section provides information about the pre-field, field, and post-field stages of the investigations for the dissertation research. The pre-field investigation stage includes sampling of the blocks, villages, and number of households from each village in the Sundarbans. The field investigation stage includes a pilot study, participant selection in the villages, the main survey and the researcher's positionality statement. This is followed by post-field investigation stage that includes data transcription, coding, and analysis.

Sampling strategies

Adaptation to environmental changes and problems is determined by several factors such as socio-economic, demographic, types and intensities of natural hazards and people's perception to environmental change and problems (Deressa et al., 2011). As this research focuses on various aspects of adaptive migration, we decided to select two different Community Development blocks (CD Blocks) from the Indian Sundarbans with differences in the types and intensities of environmental hazards using a purposive sampling technique. These were the western block of Namkhana and the eastern block of Gosaba. While excessive erosion was the major environmental issue in Namkhana, soil and water salinization were reported from Gosaba (the two blocks are separately described in the next section). Next, we selected five villages each from these two blocks using simple random sampling (RAND function in Microsoft Excel) to remove sampling bias and to ensure that different parts of the CD blocks have an equal probability of being selected. Based on the population of each selected village, the selection of households to be surveyed was done using probability proportional to size of the villages to ensure proportional representation of the households as well as an equal probability of the socio-economic groups to be selected within the villages (Rosen,1997).

The selected Community Development Blocks

Namkhana Block

Namkhana is the southernmost block of the Indian Sundarbans (Figure 3-1 B). It has 34 inhabited villages on two main islands, Namkhana and Mousini. The main island of Namkhana is bounded by the rivers Hooghly in the west and Saptamukhi in the east with numerous other channels cutting through the island (Bandyopadhyay et al., 2014). A study on the decadal shifts in the shoreline patterns (Chatterjee and Mitra, 2015) depicted a 4.37% land loss in the northwest, south and southwest of the island between 1979 and 2011. The island of Mousini also exhibited ~~the~~ land loss of 12.6% in the northwest, north and west. The shoreline erosion and cyclonic storms together resulted in surge flooding and devastation of livelihoods in many of the villages (Dasgupta and Shaw, 2015). While bank failures and flood frequency continued to increase in this area, soil salinity over the last decade has decreased, possibly because of the discharge from Farakka Barrage (~380 km north of Namkhana) and higher run-off from other streams (Halder and Debnath, 2014; Banerjee, 2013). From this block five villages were selected using random sampling. They are Lakshmipur, Bagdanga, Dakshin Chandanpiri, Madanganj and Narayanganj (Fig 3-2)

Gosaba block

The Gosaba CD block (Figure 3-1 C) is in the eastern part of the Indian Sundarbans. This block is surrounded by the Bidyarthi River which experiences extreme siltation and has been cut off from the Himalayan freshwater river sources from the north. A majority of the surface water bodies including the Bidyarthi River channel are only fed by estuarine brackish water and are therefore subjected to high levels of salinity (Halder and Debnath, 2014; Banerjee, 2013). Recently, there has been an increase in the frequency of rainfall and in the duration of the monsoon season, increase in breaching of the embankments mainly due to tidal bores, as well as an increase

in the frequency of flooding (Bera, 2013). In addition, during Tropical Storm Aila in 2009, there was a massive embankment failure due to very high storm surge. This resulted in an intrusion and stagnation of saline water in the agricultural fields rendering them infertile for years. It was also observed that increasing levels of surface water salinity in different parts of the block and increased acidification of the land mainly due to decomposition of biomass in the waterlogged agricultural fields for months after the Cyclone Aila have caused failure in growing even high salinity tolerant rice varieties (Halder and Debnath, 2014). These environmental hazards coupled with a very high population density (831.89 /km^2) have led the Indian Meteorological Department to designate the Gosaba CD Block a high-risk zone (Halder and Debnath, 2014). For this study five villages were randomly selected from Gosaba Block. They are Rangabelia, Dakshin Radhanagar, Sudhangshupur, Bagbagan and Hetalbari.

Sampling of the households

In this study, migration was considered a household decision-making process as opposed to an individual decision as mentioned by Huy et al (2015), Tsegai (2007), and Agesa and Kim (2001). A probability proportional to size random sampling based on the percentage of households from the 10 different villages was done (Rosen, 1997). In this sampling, selected numbers of households from each village were proportional to its share of households in the village to the total number of households of all the selected villages. A total number of 300 households were selected as a sample size considering the time and funds available. Moreover, a sample size of 300 for a large population gives us a 5–6% margin of error at 95% confidence level which is acceptable (0.98/ √300) and falls before the point of diminishing returns (Hunter, 2016)

Table 3-1. Selected villages from Namkhana and Gosaba community development (CD) blocks.

Community Development (CD) Block	Villages	Total Households	Selected Households	% Of Selected Households
Namkhana	Lakshmipur	282	10	3.33
	Bagdanga	901	33	11
	Dakshin Chandanpiri	1224	45	15
	Narayanganj	338	13	4.33
	Madanganj	719	27	9
Gosaba	Rangabelia	857	31	10.33
	Hetalbari	945	35	11.66
	Bagbagan	791	29	9.66
	Sudhangshupur	1047	39	13
	Dakshin Radhanagar	1031	38	12.66

Field investigation

Pilot survey

Before conducting the survey in the selected villages, a small pilot survey was conducted in the village of Pakhirala in the Indian Sundarbans to avoid overlooking errors in the main survey interviews (Connelly, 2008). A total of 15 households were selected for the pilot survey. This village was chosen because it faced similar environmental problems as the other villages (Roy and Guha, 2013). The questionnaire that was designed for the study was tested on the pilot households before the main survey. This survey provided an idea of residents' perceptions of the issue of environmental change, use of adaptation, practice of migration and views on permanent relocation. The pilot survey revealed that the residents often could not distinguish between the natural and the built environment. When asked about the natural environmental problems, the residents often talked about the lack of hospitals, roads and transportation, and inflation. Therefore, for the main survey, specific environmental problems were specified to them. For example, the pilot survey asked residents ~~asked~~ whether they identified environmental problems, but the main survey gave

actual examples such as floods and rainfall to make it easier for them to understand the environmental aspect.

Preparation for field survey

The field investigation was carried out from May 2017 to August 2017 and in January 2018. The field investigations started with visiting the respective village *Panchayat* offices (local government office). Each village (*mouza*) is divided into neighborhoods called *para*. Information about the number of households in each neighborhood was gathered from the *Panchayat* office. The total number of sampled households in each village was divided by the number of *paras* in the village. The resultant number of houses were chosen from each para. For example, the target number of sample households in Sudhangshupur was 39. Sudhangshupur is divided into four different paras. 39/4 = 9.75. Therefore, 10 Households were selected from each para approximately. The households were selected based on *paras* to ensure an equal representation of the entire village. However, the examination of data entailed a village level analysis and not a para or neighborhood level analysis. A systematic random sampling was carried out to select the households for the survey. This was done considering the size of each *para*. For example, in a *para* consisting of 20 households, if the target number of households is four, one in every five households was selected. In the Indian Sundarbans households follow both linear and scattered settlement patterns. The households in a linear pattern could be systematically selected, but the ones that followed a scattered pattern had to be chosen randomly. A part of the survey was conducted during the nursery season of rice in Gosaba (May to July) and in the sowing season in Namkhana (July and August). In many instances, residents were not available in their homes as they had to work in their fields. In those cases, names of the residents were taken from neighbors and the residents had to be tracked down in their agricultural fields for surveys.

Participant selection

After selecting a household for the survey, the head of the household was requested to participate in the survey. The Census of India (2001) defines 'head of the household' as "one who is recognized to be so by the household." In case of absence of the head the next adult over 18 years of age was requested for the interview. Sixty-one percent of the time, the head of the household could be interviewed. Females were recognized as the household heads in only 14% of the households, and for the rest, males constituted the heads. Upon selecting the participant for the survey, the broad scope of the survey was explained and written documents about the scope of the survey were provided to each respondent. Signatures of the respondents were taken on the required papers from the Institutional Review Board of Kansas State University (Appendix D). No resident refused to participate in the survey.

Every field survey was accompanied by a local person chosen from the public transport depot outside the villages or appointed by the local Panchayat office. They were mostly (9 of 10 times) the drivers of the vehicles that were rented for transport within the villages. While renting the vehicle, it was made sure that the driver was acquainted with the residents of the respective villages. The insiders mostly helped with introducing me to the households. This helped establish rapport with the members of households for easier communication. Furthermore, after each day of survey, a general summary of findings was discussed with the insiders to ensure the interviewers' proper understanding of the responses.

Main household survey

A semi-structured questionnaire (Appendix A) was used for the survey. Its semi-structured design kept the interview more open ended to collect the maximum information about residents' perspectives on environmental problems, risks, and adaptation strategies (Sovacool et al., 2018).

The questionnaire was written in Bengali, the vernacular of the place. The unit of study was individual households. The Census of India (2011) defines a household as a group of people sharing the same kitchen. The head of the household was asked to respond to the questionnaire. In the absence of the head member, the next adult member was asked to respond. The conversation was recorded using a voice recorder machine. Each survey took approximately 15–20 minutes. The questionnaire was divided into 6 parts based on the objectives of the research. They are as follows.

Demographic and economic information: General information about respondents' age, household size, years of residence in the respective villages, sources of income, actual income, whether the household owned farmlands, types and amounts of crops grown, whether the households had ponds or fisheries for consumption or commercial purpose.

Identification of environmental problems: Respondents were asked about the environmental problems they faced in the last 10 years in the Sundarbans, whether she/he perceived changes in the intensities or frequencies of the environmental problems and rise in the level of water in the rives and the ocean over the years.

Environmental risk perception: A scale of 'no risk' to 'extreme risk' (0–4) was used to understand the level of environmental risk perception of each respondent. Following, they were asked if environmental risk increased or decreased over the years in the Sundarbans and if they were aware of global warming induced climate change. If they failed to understand the term "*Jolobayu Poriborton*"—the Bengali for climate change—the surveyor elaborated, it in layman's words: "Have you heard about increasing ice melt in the mountains and poles due to warming of the earth." If they replied yes, they were requested to explain what they knew.

Adaptation responses: The respondents were asked about the various ways they coped or adapted to environmental changes or problems. If they had not already mentioned they were asked if they had a membership with a micro-finance organization, had a kitchen garden, whether they received any monetary or non-monetary help from any non-governmental organization or from the local government in the last 10 years, and whether these strategies contributed towards mitigation of household economic risks.

Migration/non-migration: Respondents were asked if anyone migrated from their household in the last 10 years, length of stay in the destination, demographic information about the migrants, presence of acquaintances in the possible destinations, availability of information regarding migration destinations, and costs of migration. These were followed by open ended questions on reasons behind migrating and whether migration boosted the household economies (most of the time, I did not need to ask this question as respondents already talked about circular migration and its use when asked about their sources of income or use of adaptation).

Permanent relocation: Respondents were asked whether they wanted to relocate soon or in the future to reduce household environmental vulnerabilities, whether they had purchased land or homes outside the Sundarbans, and about their preparations in case they are forced to migrate due to island inundation in future.

Post field investigation

Transcription and coding

After the field visit, the voice recordings were transcribed in Bengali (an attempt to translate the recordings in English was made but it resulted in loss of information). It was then coded in Microsoft Excel. Two types of codes were used: 1) Numeric coding 2) Thematic coding.

Numeric coding: The variables (age, years of education, number of family members, and number of income sources) were coded with their respective numeric values, whereas the variables like sources of income, loss of livelihood due to erosion, salinization, storms and monsoonal variability, awareness about climate change, and perception of sea level rise, were coded with the value of 1 for Yes and value of 0 for No. The variable 'perception of environmental risk' was coded 0 to 4, 0 as No Risk and 4 as at an Extreme Risk. The variable Change in Risk was coded 0 to 3, where 0 is No Risk, 1 is Increase in Risk, 2 is Decrease in Risk, 3 is No Change in Risk.

Thematic coding- The questions about how the migrant households used migration to cope up with environmental loss and reasons behind their decision regarding permanent relocation were coded thematically. First, common words and phrases were identified, and then households were assigned to different categories (Marying, 2010; Elo and Kyngäs, 2008; Krippendorff, 1980.

Table 3-2 Variables used in the study and their distribution in the Namkhana and Gosaba Blocks.

Variables	Numeric Coding	Households in Namkhana Block	Households in Gosaba Block
Average Age of respondent	Numerical Data	43	44
Female: Male respondents	Numerical Data	29:100	29:100
Average Education of respondents	Numerical Data	6 years	8 years
Average Size of Households	Numerical data	4.94	4.75
Productive Crop Land (ha/capita)	Numerical data	0.06 ha	0.1 ha
Agricultural daily labor	1=Yes, 0=No	57%	53%
Non-agricultural business holders	1=Yes, 0=No	18%	27%
Salaried employees and quacks	1=Yes, 0=No	6%	8%
Commercial fishermen	1=Yes, 0=No	23%	3%
Income Loss Erosion	1=Yes, 0=No mention	27%	8%
Income loss Salinization	1=Yes, 0=No mention	53%	58%
Environmental Risk Perception	0-4 (no to extreme)	2.6	2.8
Change in Environmental risk	1=Increase; 2=Decrease, 3=No Change, 0=No Risk	1.5	1.9
Sea Level Rise Perception	1=Yes, 0=No	83%	87%
Climate Change Awareness	1=Yes, 0=No	13%	42%
Availability of information on labor migration	1=Yes, 0=No	100%	100%

Data for “amount of land holding” was collected in local unit of measurement called “bigha”, where 1 bigha = 0.13 hecta

Analysis of data

Both quantitative and qualitative methods of data analysis were used in this study. This study was divided into three parts: In the first part (Chapter 5) we evaluated residents' perceptions of environmental change and problems and their impacts on the household economies using simple descriptive statistics. In the second part (Chapter 6), we examined the nature of adaptive responses practiced by the households. For this the in-situ adaptations were analyzed using simple descriptive statistics. Following, we used qualitative content analysis to understand the different ways households practiced migration. Next, the differences in demographic, socio-economic characteristics of these categories of households, loss of livelihood due to environmental hazards and disasters, and their perception of environmental risk were analyzed using Mann-Whitney U test or Wilcoxon Rank Sum Test (MWW test) (for continuous variables) and Fisher's Exact test (for the categorical variables). These were used to compare the groups of migrant households to find whether there were any socio-economic and demographic differences, or differences in environmental risk perception among these households that might have influenced their ways of migration. MWW test is a non-parametric test, used to decide whether the two samples are derived from the same population and compare the differences between two independent groups in a sample with continuous or ordinal data (Nacher, 2008). Therefore, variables such as age, years of education, size of households, and number of productive lands were tested using the MWW test. A Fisher's exact test, on the other hand, is used to compare two variables with non-random categorical values generally using 2 by 2 contingency tables (Hess and Hess, 2017). The variables that have 0/1 (yes/no) values (Table 3.2) were tested using the Fischer's exact test. Next, qualitative content analysis was again conducted to understand respondents' willingness to permanently relocate from the Sundarbans in future.

In the third part of the study, we wanted to understand why some households pursued migration as a livelihood strategy and others did not. We used descriptive statistics to analyze the reasons stated by the respondents about migration and non-migration. We then used two logistic regression models in our analysis. A logistic regression model uses a binary dependent variable and a set of independent variables to predict the values of the dependent variable from a set of known values of the independent variables and explore the functional relationship between the dependent and the independent variable and analyze the causes of variations in the dependent variable. (Jha et al., 2018; Abu, 2014). We used logistic regression because our dependent variable was binary (migration/non-migration). The first model was used to analyze the relative importance of the socio-economic and environmental variables in migration. Some of the past studies revealed that households that depend on subsistence economies are most vulnerable to climate change, yet other studies revealed that relatively rich households pursue migration while the poorest do not (Morton, 2007; Bernzen et al., 2020). In this study we wanted to examine whether reliance on subsistence agriculture as the only source of household income (in-situ) had any impact on migration and used another logistic regression model for the analysis. These models are discussed in detail in Chapter 7. Prior to developing the logistic regression models, correlation coefficient analysis was done on the dataset to detect multi-collinearity. (Johnson and Wicheren, 2008).

Researcher's positionality statement

Researcher's positionality is crucial during face-to-face interviews. Factors like interviewer's age, gender, experience in the field, religion, socio-economic status may have an influence on the quality of data collected (Bourke, 2014). I had previous experience working in rural India and was well acquainted with the rural culture and economy. Throughout the survey, I therefore tried to be careful and clear myself off assumptions so that my pre-conceived notions

and any bias about rural India do not affect the interviews in the Sundarbans. The Indian Sundarbans is one of the most impoverished regions of the country with people constantly battling poverty. I, on the other hand, belong to the economically affluent group of Indians and was far away from the problems that the people of the Sundarbans battled. Initially, in the field I used to be worried, thinking it may be insensitive on my part to ask them about their socio-economic situations and what if the residents refuse to talk about their problems to someone from a completely different socio-economic background. I was wrong. Despite the differences, I think that the same Bengali linguistic culture helped to build a connection with the people, and none of the selected residents refused to participate in the survey. It seemed that the residents considered these interviews as means of communicating their problems with the world. In this context, I think that my affiliation with a university outside India might have influenced the interviews. There is a possibility that the residents overstated their problems to convince me of their severities, their everyday hardships and with a hope of receiving some aid if their problems reached the international community. Here I should mention that before every interview it was made clear that no incentive will be paid for participation.

In almost all cases, the household's residents enquired about my native place in India. That seemed to be a part of their culture. I noticed that their acceptance towards me increased as they came to know that I grew up in a very small town away from the metropolitan city of Kolkata. It is possible that if I grew up in a city, they would not have communicated their distrust in urban life, urban people and urban culture when talking about possibilities of permanent migration to the cities. In a few households however, older women were initially reluctant to participate and wanted the male members to respond. As per my understanding, due to prevailing patriarchy and lack of education, older women might not have considered themselves knowledgeable enough to respond

to interviews. Some of these women later responded after I explained the scope of the survey. Throughout the research process I was reflective about my positionality as a researcher. While I may have certain preconceived notions, if I discussed and evaluated the results of this research being reflective about my positionality as a researcher, I could provide a meaningful interpretation of data to address the research questions.

Chapter 4 - Environmental Problems in the Indian Sundarbans

Introduction

The Indian Sundarbans is one of the world's largest coastal wetlands and constitutes more than 100 small islands, out of which 56 are inhabited by 4.37 million people (Sil, 2016; De Souza et al., 2015; Dasgupta and Shaw, 2014; Dutta et al., 2013; Chand et al., 2012). This region experiences a wide range of environmental problems such as erosion, salinity, monsoonal variability, and frequent tropical storms. Erosion is a natural phenomenon in the Sundarbans which is formed by the deposition of major rivers—the Ganges, Meghna and Brahmaputra— draining into the Bay of Bengal. However, the rate of erosion in some parts of the Indian Sundarbans has been observed to be much faster than the rate of deposition (Hazra et al., 2010, 2002) which led to obliteration of some islands in its southern parts. Salinity of river water in the eastern parts of Indian Sundarbans is much higher than that in the western parts. Most rivers in the western region are distributaries of the Hooghly River, which is still fed by Himalayan snowmelt, whereas in the eastern region, rivers like the Matla, Bidyarthi and other rivers do not receive much freshwater supply and are primarily fed by baseflow (flow of water in between two precipitation events), precipitation and intruded saline water from the Bay of Bengal leading to increased levels of salinity in these rivers (Maitra et al., 2009). Haldar and Debnath (2014) showed that rivers in the eastern parts of Indian Sundarbans (Gosaba Block) have salinity ranging from 16 to 20 parts per thousand (ppt), as compared to average freshwater river salinity of 0.5 ppt and sea water salinity of 35 ppt. It was also shown that river water salinity in the eastern parts has gradually increased in the last 30 years from 13 ppt in 1980 to >20 ppt at present (Mitra et al., 2009). In contrast, in the western parts of the Indian Sundarbans, river water salinity has been decreasing since 1980, from 15 ppt to 11 ppt at present.

Many studies have shown that global climate change has influenced the local environment in the Indian Sundarbans. For instance, increase in sea surface temperature by 0.5ºC/decade has led to delayed and drier monsoons. A sea level rise of 5.22 mm/year, which is higher than the global average of 1.88 mm/year, has led to accelerated erosion and subsidence of islands in parts of the Indian Sundarbans. A very high population density of 957 persons/km^2, residents dependent on natural resources for survival, and extreme poverty of the population have resulted in extreme vulnerability of these people to climate change (Dasgupta and Shaw, 2015). In addition to these ongoing environmental problems, sudden onset climatic events like tropical storms were also reported to severely compromise the lives and livelihoods of the residents of the Sundarbans (Paul and Chatterjee, 2019). In 2009, the Sundarbans of Bangladesh and India was hit by a Tropical Cyclone Aila that caused a loss of 137 lives in India, mostly in the Sundarban delta. The cyclone resulted in storm surges followed by thousands of kilometers of embankment failures (Paul and Chatterjee, 2019). This storm brought large amounts of saline water causing a rapid increase in salinity in river water as well as surface soils particularly in the eastern parts that were on the trajectory of the storm (Mitra et al., 2009). More than 100,000 hectares of land were inundated by saline water intrusion causing long-term infertility of agricultural lands (Mukhopadhyay, 2009).

While meteorological and field measurements have confirmed the severity of environmental problems in the Indian Sundarbans, residents' perception of these problems may be variable. Prior studies conducted elsewhere have established that human perceptions of the environment, environmental processes and problems are shaped by the socio-cultural system they belong to (Cortés and Chavero, 2011), prior experiences and awareness (Ejembi and Alfa, 2012; Slegers, 2008), and the effects of environmental problems on residents cannot be examined through meteorological observations alone (Bomuhangi et al., 2016). Slegers (2008) described

perception as a range of beliefs, judgements and attitudes that become important while evaluating the localized effects of global climate change in the affected areas. Levels of personal and community knowledge or awareness about climate change also influences a resident's perception about local environmental problems. It has been seen that the residents perceive the effects of global climate change in the context of problems at the local scale that they face day-to-day, and resident responses to these local environmental problems are often based on their personal and community perceptions of the problems (Berkes et al., 2001). For example, in an area where meteorological measurements have confirmed an increase in sea level rise, the residents living close to the seashore may perceive SLR as a problem, whereas for residents residing further inland, SLR may not be a major issue. The response to the environmental problems may be through variety of adaptation strategies including in-situ changes in their ways of life, or through temporary or permanent migration from the place.

Minimizing the effects of climate change related environmental problems at the local level is largely done by developing adaptation strategies among the residents of the affected area. Knowledge gained from perception studies help in developing community-specific adaptation strategies which address the most relevant effects of climate change (Slegers, 2008). The residents adapt to the environmental problem as they perceive it rather than its physical or meteorological measurements. Hence, both physical measurements of the problem and resident perception of the problem needs to be studied to minimize the impacts of climate change related environmental problems. To date, very few studies have systematically studied the residents' perception of environmental problems in Indian Sundarbans. The present study specifically focuses on understanding how the residents perceive problems like erosion, salinity, monsoonal variability,

tropical storms, sea level rise, and whether they are economically impacted by these environmental problems.

Methods

A household level questionnaire survey was conducted in Gosaba (eastern) and Namkhana (western) community development (CD) blocks in the Indian Sundarbans during May–August 2017, and January 2018. Close ended questions were asked about whether residents perceived changes in the intensities of environmental hazards, whether they perceived sea level rise, and whether they suffered economic losses due to these hazards in the last 10 years (see questionnaire in Appendix A). This data was coded numerically, and simple descriptive statistics was used to address the objectives of this research. A 10-year period was adopted to capture the impacts of slow onset hazards like sea level rise and disasters like Tropical Storm Aila that struck the Sundarbans in 2009, eight years prior to the survey.

Perception of environmental problems by the residents

Excessive riverbank and coastal erosion, salinization of soil, monsoonal variability and tropical storms were identified as major environmental problems in the Indian Sundarbans. The residents perceived changes over the years mostly in excessive erosion and salinization of land, time of monsoon arrival and intensities of tropical storms over the Bay of Bengal. These environmental hazards and disasters also compromised their livelihoods. These environmental problems were previously reported by physical and meteorological measurements in the study area (Kitoh et al., 2013; Saxena et al., 2014; Hazra et al., 2002; Goswami et al., 2000).

Erosion and salinity

Table 4-1 shows the results of resident perceptions of changes in riverbank and coastal erosion and salinity intrusion in the last 10 years in their respective villages. In the Namkhana CD

Block, an increase in coastal erosion was mentioned by all the surveyed households in the coastal village of Lakshmipur. Similarly, an increase in the erosion of the banks of the Muriganga River (Figure 10-8) in Bagdanga and the Hatania-Doania River (Figure 10-8) in Narayanganj was mentioned by 100% and 92% of the surveyed households in the respective villages. These respondents also mentioned an increase in the rates of salinity intrusion in the land in the last decade during high tides and storm surges as embankments are heavily damaged due to increased rates of erosion. Resident perceptions of changes in the rates of erosion are consistent with studies that measured actual rates of erosion in some of these places. For example, in the Mousini Island (where the village of Bagdanga is located), Chatterjee et al. (2015); Ghosh (2017) reported a 40% loss of land in the last 32 years due to increased storm surge, tidal heights and strong tidal currents.

On the other hand, no major episodes of erosion of the banks of the rivers Saptamukhi and Hatania-Doania in the villages of Dakshin Chandanpiri and Madanganj, respectively was mentioned, and very few households identified salinity-intrusion as a major environmental hazard in these villages. The residents from Dakshin Chandanpiri and Madanganj villages reported that strong embankments in their localities were especially effective in controlling riverbank erosion and saline water intrusion over the years. In addition, the geomorphological measurements in the village of Dakshin Chandanpiri (Namkhana Block) showed that the banks of the Saptamukhi estuary have experienced substantial sediment deposition and bank progression (Ghosh, 2017). It is therefore implied that the responses of the residents in these villages could be a result of construction of strong embankments as well as natural deposition of sediments on the riverbank.

In the Gosaba Block, except for the village of Rangabelia, the residents of the other four villages reported embankment breaching to be one of the major environmental problems and not extreme riverbank erosion. In Rangabelia, on the other hand 19% residents reported an increase in

extreme riverbank erosion leading to loss of lands. In these villages, a mixed response about changes in the rates of salinity intrusion was obtained as well. While majority households and Bagbagan mentioned an increase in salinity intrusion, most of the households in Rangabelia, Hetalbari and Sudhangshupur mentioned a decrease in salinity intrusion or did not mention salinity intrusion as a major problem except the Aila related soil salinization.

Therefore, in the villages of the Gosaba Block, the residents shared a mixed response towards changes in the salinization of land. While 26% of the residents perceived an increase in soil salinity, 32% perceived a decrease in soil salinity and 11% perceived no change in soil salinity in the last 10 years which suggests that some parts of these villages experienced salinity intrusion while others did not. Physical measurements revealed that vast areas of the eastern Indian Sundarbans are affected by salinization as the eastern rivers are cut-off from the freshwater source and the extended periods of saline water inundation after Aila in 2009. This suggests that the residents of the Gosaba CD Block perceived changes in salinity differently when compared to physical measurements.

This might be because the salinization of land mostly occurs due to embankment failures either during storm surges or due to local bank erosion (Halder and Debnath, 2015; Dhara and Paul, 2016). While salinization due to embankment failures during storm surges may affect vast parts of land, at other times embankment failures can be local (as some embankments can be stronger than the others) causing local intrusion of saline water. The residents may have formed their opinions based on the local situation rather than considering the situations in other parts of their villages or nearby. The other possible reason why residents perceived changes in salinity differently might be that some residents considered rapid salinity increase during Aila and

underestimated the present day increase in salinity, whereas residents who did not compare the present-day salinity with Aila-related salinity may have overestimated the increase in salinity.

Monsoonal variability and tropical storms

Survey results showed that 100% of the respondents mentioned that they perceived an increase in monsoonal variability and tropical storms. Residents believed that monsoons were being delayed almost every year causing severe economic losses to the agricultural community. Even though the households relying on agriculture for a living suffered the most due to monsoonal delays (Table 4-3), the non-agricultural households also perceived increased monsoonal variations over the years highlighting how community's vulnerabilities from an event shapes individual perception. However, this observation needs cautious interpretation because of the timing of the survey which coincided with a delayed monsoon season and might have captured reactionary responses of the residents. Residents also emphasized their experience of storm surges during Aila in 2009 claiming that they witnessed large waves during the storm which they "had never seen before" and believed that storm intensities have increased perceptibly over the years.

Table 4-1 Household perception of changes in environmental challenges (land loss due to erosion and salinity intrusion) in the studied villages in the Indian Sundarbans.

Environmental Challenge	Response	Households (%)											
		Namkhana Block						Gosaba Block					
		V1	V2	V3	V4	V5	Mean± Std. Dev. (Min–max)	V6	V7	V8	V9	V10	Mean ± Std. Dev. (Min–max)
Riverbank / Coastal erosion Or Embankment breaching	Increased	100	100	0	92	0	73±49 (0- 100)	19	20	29	39	24	26±8 (19-39)
	Decreased	0	0	0	8	0	2±3 (0-8)	26	53	25	26	28	31±12 (25-53)
	Unchanged	0	0	0	0	0	0	26	13	7	0	7	11±10 (0-7)
	No Applicable*	0	0	0	0	100	40±55 (0-100)	29	13	39	34	48	33±13 (13-48)
Soil salinity	Increased	40	80	0	92	7	40 ±48 (0-100)	23	20	46	29	14	26±12 (20-46)
	Decreased	0	0	100	8	93	40±52 (0-100)	26	40	32	24	38	32±7 (32-40)
	Unchanged	20	20	0	0	0	8±11 (0-20)	10	20	14	3	14	11±5 (3-20)
	Varies with rain	10	00	00	00	00	2 (0-10)	00	00	00	00	00	00
	Not Applicable*	30	00	00	00	00	8 (0-30)	19	20	07	45	34	25±14 (7-45)

V1-Lakshmipur; V2-Bagdanga; V3-Dakshin Chandanpiri; V4-Naraynganj; V5-Madanganj V6-Rangabelia; V7-Hetalbari; V8-Banbagan; V9-Dakshin Radhanagar; V10-Sudhangshupur. (P) value represents statistical difference between the means of changes in environmental issues between the two CD Blocks of Gosaba and Namkhana. *Not applicable- The households either did not mention the environmental problem or mentioned that the problem did not exist in their village in the last 10 years.

Sea level rise

Table 4-2 shows the results of respondent perceptions about the rise in the levels of high tides and storm surges over the years. A total of 248 respondents (83% of the total respondents) perceived such rise. Survey results also indicated that this perception was partly shaped by the tidal surges during TS Aila in 2009, which according to the respondents were unusually high and unprecedented. In the village of Rangabelia, out of 22 respondents who were aware of climate change, four respondents were particularly aware of global warming and added that the Sundarbans will be at an extreme risk of inundation in the next few years. On the other hand, 10 survey participants from the village of Hetalbari, Dakshin Radhanagar and Bagbagan said that the estuaries in the Sundarbans are increasingly being choked due to rapid sedimentation of the rivers leading to rising levels of water in these estuaries and embankment failures. One of the survey participants, a quack (an accepted term in Indian rural medicine referring to untrained people practicing medicine) physician from the village of Dakshin Radhanagar said that he believed that the rise in water level was due to excessive extraction of ground water from the Bengal basin leading to submergence of the delta. The other respondents said that while they could perceive an increase in the level of water over the years, they were not sure about the reason behind such rise.

The opinions of residents about the reasons behind rise in the level of water over the years is consistent with scientific research in this area. Geomorphological studies from the eastern part of the Sundarbans reveal that excessive siltation of the rivers like the Bidyarthi is leading to a rise in high tides and storm surges (Trivedi et al., 2016; Mitra et al.,2009). Besides, land subsidence of 10–12 mm/year in the Bengal Delta has resulted in an increased rate of relative rise in sea-level in the Sundarbans. This subsidence is primarily a result of extraction of groundwater by the dense population of the nearby metro cities, sediment compaction, and to an influx of huge amounts of

sediments in the early Holocene due to strengthened monsoons. This sediment influx has since contributed to the subsidence of the Bengal Delta and is predicted to cause subsidence in the next thousands of years even if sedimentation stops (Karpytchev et al., 2018; Higgins et al., 2014).

Table 4-2 Respondent household perception of sea level rise

Development Blocks	Villages	Sea Level Rise Perception (%)
Namkhana	Lakshmipur	100
	Bagdanga	100
	Dakshin Chandanpiri	69
	Madanganj	60
	Narayanganj	86
Gosaba	Rangabelia	84
	Bagbagan	89
	Hetalbari	92
	Dakshin Radhanagar	84
	Sudhangshupur	85

Economic impacts of the environmental hazards

Residents suffered economic losses due to excessive riverbank and coastal erosion and related salinization, salinity intrusion due to occasional breaching of embankments, rainfall variability, loss of livelihoods from tropical storms (Table 4-3 and Figure Appendix 10-4). Economic losses occurred primarily due to damage to agriculture, and by obstructing employment of agricultural daily wage laborers. More than a quarter of the surveyed households (28.15%) in the Namkhana Block and 6.97% of the households in the Gosaba Block reported major loss of livelihood due to excessive riverbank erosion, and 45% and 70% of the households in these two blocks reported economic losses due to salinization of lands, respectively. The communities that did not rely on agriculture for survival, suffered less economic loss from these hazards compared

to the others. For example, only 20% of the households in the village of Lakshmipur reported loss of livelihood from erosion and related salinization of land (Figure Appendix 10-4). This was because the major economy of 70% of the respondent households was deep sea fishing (Figure Appendix 10- 3) and none of them owned agricultural lands within the villages. They mentioned that their incomes from sea-fishing were partially compromised during tropical storms and not due to riverbank erosion or salinization of land indicating that loss of livelihood in environmentally vulnerable places could be minimized if pursued livelihoods are less sensitive to the specific environmental hazards of a place. On the other hand, excessive riverbank erosion leading to loss of lands and related salinization of lands heavily affected the livelihoods of the residents of Bagdanga and Narayanganj villages in the Namkhana CD Block. In the Gosaba CD Block, most of the households in every village suffered economic losses from salinization of lands in the last 10 years. It should be noted that the villages that reported increased erosion and salinization (Table 4-1) also reported more cases of economic loss from the same (except Lakshmipur). This was because the residents were primarily farmers who either owned lands or worked as agricultural laborers in other's lands and experienced loss of income either due to land loss or salinization (Fig Appendix 10-3 and 10-4).

The TS Aila also caused an immense loss of life and property in the Sundarbans (Bhunia and Ghosh, 2011, Chakraborty, 2015; Kar and Bandyopadhyay, 2015; Paul and Chatterjee, 2019). Most of the respondent households in all surveyed villages faced economic losses (damages to crops, fisheries and property) during TS Aila in 2009 (Table 4-1), and the agricultural households particularly in the villages of Rangabelia, Dakshin Chandanpiri, Hetalbari, Dakshin Radhanagar, Madanganj, Bagbagan and Sudhanshupur, lost their livelihoods due to monsoonal delays. The main crop grown in these villages is rice, which is extremely sensitive to rainfall variations (Table

Appendix 10-4**)**. Rice requires rainwater during the nursery season. A delayed monsoon slows down germination of seeds. Additionally, if there is heavy rain in the pre-maturing season, rice plants rot (Halder and Debnath, 2015). Given that most of the residents in the studied villages of the Indian Sundarbans earned their living through farming, low rice yields heavily compromised household annual income. This in turn reduced agricultural labor employment within the villages, impacting the overall economy of the community. The households that did not have lands like the fisher households of Lakshmipur or the households that permanently lost their arable lands due to erosion and salinization, did not face a major economic loss due to monsoonal delays. However, due to very small sample size in Lakshmipur (10), this observation needs more research.

Table 4-3 Environmental hazards and disasters that resulted in economic loss in the study villages.

Community Development (CD) Blocks	**Villages**	**Households (%) who reported loss of livelihood due to**			
		Bank Erosion	**Breaching**	**Rainfall Variability**	**Major Storms (Aila in 2009)**
Namkhana	Lakshmipur	20	30	10	90
	Bagdanga	66	97	12	97
	Dakshin Chandanpiri	0	13	58	89
	Narayanganj	46	77	23	57
	Madanganj	0	7	33	100
Gosaba	Rangabelia	10	74	52	97
	Bagbagan	7	69	48	93
	Hetalbari	6	51	40	74
	Sudhangshupur	5	77	80	97
	Dakshin Radhanagar	8	79	66	100

Conclusion

The objective of this study was to examine resident perceptions of environmental changes and problems and their economic impacts in the Indian Sundarbans. Our results suggest that residents perceived changes in the rate of erosion and salinization mostly in the western part of the

Sundarbans, and their perceptions are consistent with the physical measurements of these hazards in these places. The respondents in the eastern part of the Indian Sundarbans however, had a mixed opinion about changes in salinity showcasing how local environmental events shape the perceptions of people towards larger scale issues. Residents also perceived more monsoonal delays over the years and believed that the intensities of tropical storms over the Bay of Bengal have increased. This perception was shaped by their experiences during Cyclone Aila in 2009 that caused unprecedented damage to their lives and livelihoods. Residents also largely perceived an increase in the level of high tides and storm surges over the years for which climate change, excessive sedimentation in the eastern rivers, and subsidence of the Bengal delta due to over extraction of ground water were considered the major contributing factors. The respondents also reported loss of livelihoods and an overall loss of economy due to these environmental hazards. It was noted that economic impacts due to environmental changes and problems largely depend on the nature of the household economy and not just by the intensities of the natural hazards in the vulnerable areas.

Chapter 5 - Adaptation to environmental changes and problems in the Indian Sundarbans

Introduction

Adaptation is defined as "an adjustment in the ecological, social or economic systems in response to observed or expected changes in climatic stimuli and their effects and impacts in order to alleviate adverse impacts of change or take advantage of new opportunities" by the IPCC in its Third Assessment Report (IPCC, 2011). Residents of vulnerable environments adapt to or cope with environmental problems and changes to mitigate environmental vulnerabilities by in-situ adaptation strategies at the existing places, or by temporarily migrating for work, or permanently migrating to less environmentally vulnerable places (Mallik and Vogt, 2014; Below et al., 2012; Scheffran et al., 2012; Bardsley and Hugo, 2010; Tol et al., 2008). This study identifies resident use of adaptations and coping strategies in the Indian Sundarban delta, a hotspot of global climate change which harbors 4.3 million people, the majority of whom are resource poor subsistence farmers and wage labors.

Past studies have identified different in-situ adaptive responses from various parts of the world (Silvesti et al., 2012; Apata et al., 2009; Asrat and Simane et al., 2018; Li et al., 2017; Alam et al., 2012, 2017; Rashid et al., 2014). However, their models and recommendations may not be applicable to other vulnerable communities as use of adaptations largely vary with the varying levels of environmental perceptions, household socio-economic conditions, institutional responses to environmental change, and types and intensities of climatic hazards and their impacts on household' economies. There is also a lack of primary level study that analyzes the role of migration as an adaptation. Some of the past studies investigated the role of migration as an

adaptation using conceptual ideas of vulnerabilities, exposure, adaptive capacity, and household resilience (Adger and Adams, 2013; Mc Leman and Smit, 2006; Gemenne and Blocher, 2017; Scheffran et al., 2012; Tacoli, 2009). Others evaluated the response in the context of political ecology (Radel et al., 2018; Wrathall et al., 2014). Some studies identified migration as a common post-disaster response (Mistri, 2013; Kartiki, 2011; Alscher, 2011) and Paul et al. (2005) challenged the inevitability of such response. Others examined if vulnerable residents would consider permanent relocation to environmentally safer places (Paul et al., 2020; Mortreux et al., 2009; Allgood and McNamara, 2017). At present temporary migration for livelihood diversification has been one of the most common adaptation strategies (Alam et al., 2017; Wrathall et al., 2014), and permanent relocation has received mixed responses from the victims of climate change. While vulnerable households at the Pacific Island of Kiribati have shown positive attitudes towards relocation, in places like coastal Bangladesh, the Pacific Island of Tuvalu, and islands of the Republic of Maldives in the Indian ocean residents shared their unwillingness to relocate from their birthplaces despite extreme environmental risks (Paul et al., 2020; Mortreux et al., 2009; Kelman et al., 2019).

This study uses primary level data from the Indian Sundarbans to i) identify the in-situ adaptation strategies, iii) the different ways these households pursue labor migration, that is, whether as a livelihood diversification strategy or an alternative livelihood strategy, iv) the environmental and non-environmental controls of such dependence, and v) their views on future permanent relocation from the Sundarbans.

Methods

Primary data was collected from 300 households using a semi-structured questionnaire survey and the interviews were recorded and then transcribed (See Chapter 3- Research Methodology). The

questions were both open- and close-ended about resident use of in-situ adaptation and coping strategies, whether any member from the household migrated in the last 10 years, whether the migration was temporary or permanent, migration destinations, the frequency of migration, the circumstances under which migration took place, increase in average household income from remittances, use of remittances, and willingness to permanently relocate from the Sundarbans in the future. Information was also collected about a household's socio-economic and demographic conditions, environmental risk perceptions, and economic impacts of the environmental problems in the past 10 years.

The responses to the close-ended questions were quantitatively coded (see Table 3-1), and the open-ended responses were coded thematically based on themes pertaining to migration as a response to climate change. Based on the responses, surveys of household economic sources were divided into four different groups. The first group comprised daily agricultural laborers. This is an extremely unreliable source of income (Molinari, 2017). The second group comprised households with businesses within the Sundarbans. The third group comprised households with a fixed or stable income source such as government officials, schoolteachers, and quack physicians. The fourth group comprised commercial fishermen. These households either had large shrimp or fish farms in their villages that were used for commercial purposes or practiced deep sea fishing in the Bay of Bengal as their major economic activity.

Simple descriptive statistics were used to analyze household use of in-situ adaptation and migration. Content analysis (Hay, 2000) was used to analyze household responses regarding the different ways and the different circumstances under which they migrated and their willingness to permanently relocate from the Sundarbans in the future. For this the recorded interviews were transcribed, common words and phrases were identified, and the respondents were categorized

into groups. Statistical tests were done to analyze the difference among the groups of migrant households based on the different ways they migrated. For determining differences pertaining to the continuous variables, the MWW test was conducted, and for the categorical variables Fischer's exact test was used. The MWW test is a non-parametric test used to decide whether the two samples are derived from the same population and used to compare the differences between two independent groups in a sample with continuous or ordinal data (Nacher, 2008). A Fischer's exact test on the other hand, is used to compare two variables with non-random categorical values generally using 2 by 2 contingency tables (Hess and Hess, 2017).

Adaptation strategies and coping mechanisms to environmental changes and problems in the Indian Sundarbans

In -situ structural and non-structural measures

All 300 surveyed households of the Indian Sundarbans acknowledged the role of strong embankments in mitigating the impacts of environmental degradation. They wanted the government to invest in strong concrete embankments along the major estuaries like the Bidyarthi River, and stronger earthen embankments along the smaller estuaries. Their struggles with weak earthen embankments were revealed during the survey as many respondents shared how they were often required to fix breached embankments even in the middle of the night without any support from the local government. However, jobs were created in the construction sector when there were major requirements for reconstruction of embankments benefiting the villagers. The respondents also recognized the need for more storm shelters in their villages. In the erosion-affected village of Bagdanga, raised platforms were identified as a structural adaptation used by 12% of the surveyed households. These platforms were used during inundation following a high tide or storm surge. Building raised homes was also identified as a structural adaptation measure by six

households. Several other adaptive strategies after a loss of livelihood due to both sudden onset and slow onset environmental change were identified (Table 4.3). These results from the Indian Sundarbans were comparable to in-situ structural and non-structural adaptation measures used in other parts of the world such as rural Bangladesh, Nepal, and Uganda (Haque, 2017, 2006; Gentle and Maraseni, 2012; Hisali et al., 2011; Datta et al., 2011).

Table 5-1 In situ non-structural adaptation measures and coping strategies used by the residents.

Adaptive Measures	**Households (%)**
Government Aid*	72
Keeping mortgage	35
Micro-Credit Organizations	38
Kitchen Garden for consumption	39
Borrowing money from neighbors	14
Selling assets	0.3
Consumption reduction	0.6
Family members working together	0.3

*This reflects the percentage of houses that consider government aid as a significant coping or adaptation strategy and not the percentage of houses that received government aid in the last 10 years

Results showed that most of the residents from the study area, at least partially, relied on government aid. Government aid included a one-time sum of INR 10,000 ($200) per household and 10 kg rice per household per month which residents continued to receive during the survey duration, and additional food grains at a subsidized price under the governmental public food distribution schemes. Although such food distribution schemes were largely appreciated by the respondents and considered effective coping strategy, according to the FAO (2008), climate change may create a crunch on public resources leading to reduced support from these food distribution schemes, which may in turn increase food insecurities, hunger, and even starvation-related deaths in the future. Additionally, even though these food distribution schemes in India are meant to reduce food insecurities, they are fraught with corruption and the grain intended for the poor often fails to reach them or are misused (Lal, 2015). The subsistence farmers may benefit in

the long term with planned conversion of the salinized agricultural lands into saline fish farms, and with the distribution of saline-tolerant varieties of rice seeds which surprisingly none of the households reported to have received, even for experimentation purposes. Other in-situ adaptation and coping measures identified were borrowing money against mortgage, growing consumable food products in kitchen gardens, borrowing money from cooperative banks and non-institutionalized sources (neighbors and acquaintances), a very few residents sold their assets or reduced their consumption to cope with natural hazards mainly TS *Aila*., and some joined micro-credit organizations. These are "revolving funds" organizations where members are required to deposit INR 20–50 every month. In times of need, they can borrow money from these organizations and pay them back every month with an interest rate fixed by the respective organizations (Datta et al. 2011; Philcox et al. 2010). Apart from these strategies, the respondents from the agricultural households mentioned that they stored enough crops to survive on for a period of at least three to six months in case natural hazards compromised their produce, and recognized subsistence agriculture as one of the ways to combat environmental stress. During TS Aila, however, these stored grains were washed away and therefore many residents have been careful about storing their produce in safer places, such as raised areas inside their homes, to protect crops from sudden onset disasters. Although respondents considered storage of grains as one of the essential ways of coping with the impacts of environmental problems, dependence on subsistence economies cannot be considered an adaptation as climate impacts may severely compromise production thus creating food insecurities leading to a reduction in consumption among the members of households and allocating food preferentially to the earning members to keep them healthy (FAO, 2008).

Ex-situ measure

Temporary (labor) migration

Survey results indicated that labor migration was practiced by 58% of the surveyed households in the study area. For all of them migration was a household decision made after careful consideration of the cost-benefits of migration with all adult members of the family. In the western block of Namkhana, 20% of the households from Lakshmipur Village, 72% from Bagbagan, 49% from Madanganj, and 38% from Narayanganj in the Namkhana Block were labor migrants. In the Gosaba Block, 48% of the households from Rangabelia, 46% from Hetalbari, 72% from Bagbagan, 76% from Dakshin Radhanagar, and 74% from Sudhangshupur were labor migrants. At least one member from these households, usually males, temporarily migrated to different parts of India—and internationally—for employment in the last 10 years (for demographic information on the migrants see Table 5-2). This result was consistent with previous studies on labor migration from the Sundarbans (Maharajan, 2020). Remittances increased their annual income by an average of INR 50,000 (~$600). This money was used by 100% of the migrant households primarily for consumption that included daily food consumption and home renovation (n=2 households) and setting up and reconstruction of businesses in-situ (n=6 households). All the migrant households acknowledged the role of remittances as a survival mechanism either during times of needs, such as after a natural disaster, or simply to meet a household's financial requirements.

Table 5-2 Demographic characteristics of the migrant households

Block	Village	Number	Age	Male	Female	Single	Married
Namkhana Block	Lakshmipur	2	28	2	0	1	1
	Bagdanga	32	39	31	1	2	30
	Dakshin Chandanpiri	29	36	29	0	6	23
	Madanganj	10	33	10	0	1	9
	Narayanganj	5	35	5	0	0	5
Gosaba Block	Rangabelia	20	36	20	0	5	15
	Bagbagan	30	34	30	0	7	23
	Hetalbari	20	34	18	2	5	15
	Dakshin Radhanagar	43	38	38	5	1	42
	Sudhangshupur	45	32	45	0	18	27

The different groups of labor migrants

Migrants may be divided into three groups based on their motivation to migrate. The first group uses migration to cope with any economic losses. The second group considers migration as an additional income strategy, for the third group, migration is either the main livelihood option or serves as the alternative livelihood for the households which lost their in-situ livelihoods.

Labor migration as an immediate response to a sudden economic loss (Group 1)

This group of people migrated only after their households suffered an economic loss or if they suddenly required a large amount of money that is difficult to earn from the Sundarbans at that time. This could be due to destruction of property or assets during a tropical storm, salinization of farmland due to sudden embankment failures, low crop yields due to monsoonal delays or any economic loss due to non-environmental reasons or if they required money for the construction of homes, funding family member marriages, etc.

Remittances from these migrants served as the main income source after a hazard or a disaster until these households could generate income from their respective villages again. Remittances were used to cope with the aftermath of a disaster or a hazard, for household

consumption, and to prepare for future hazards. However, during other times of the year, these households survived by working in their respective villages and did not migrate for work.

One commonality among the migrants from this group was their migratory response after TS Aila in 2009. A migrant from Bagbagan mentioned:

"*After Aila I migrated. I brought 20,000 Rupees from Lakshadweep. Now I work in the village. If we suffer a loss anytime, we migrate and bring money back."*

The impacts of individual storms like Cyclone Aila are much more intense and devastating than that of slow and gradual processes associated with climate change like erosion or salinization. It is predicted that the frequency of tropical storms may increase in the future based on climate change modeling. Therefore, resident responses to migrate after Aila underline that such post-disaster temporary (labor) or circular migration may be used more frequently as a reactive response in future. A migrant from the village of Dakshin Chandanpiri mentioned:

> *"We normally do not have environmental problems in our village. However, if we do not get timely rain, or if there is inundation during the rainy season, we suffer an entire loss. We must go outside at that time. We had to migrate after Aila."*

Similar post-disaster labor migration was reported in Bangladesh during *Aila* as well as other disastrous events (Rahaman et al.,2015; Penning-Rowsell et al., 2013; Kartiki, 2011). By comparison, Paul (2005, 1998) did not find any evidence of migration in Bangladesh after a catastrophic storm in 2004 and flood in 1998. According to Paul (2005), adequate and prolonged supply of relief and disaster aid provided to the villages affected by the storms was the major reason why residents did not migrate. After Aila, the households in the Indian Sundarbans also received relief that helped them cope with the aftermaths of the disaster (Chakraborty, 2015;

Mukhopadhyay, 2009) which coincided with the survey results in this study where one of the residents mentioned:

> *"Aila was the most devastating event I have seen. We stayed on the embankments. We would not have survived without government help. The government provided tents, blankets, dry food, and medicines for a long time."*

However, in our study area, the relief might be insufficient to compensate the economic losses that followed the disaster. Agricultural fields were heavily salinized for years due to prolonged saline water stagnation consequential to storm surge during Aila (Halder and Debnath, 2014). The resulting loss of livelihood was compensated by working outside in the urban industrialized sector. Several residents in this group lived and worked in the destination for a stretch of three years and returned only after the agricultural lands in their respective villages became productive again. Others migrated multiple times during this period. Remittances reduced household economic vulnerability that resulted from Aila by providing an economic support during the recovery phase (approximately three years after Aila). While most of the migrants migrated several times until agriculture revived in their villages, two migrant households stayed at the destination with their families for three long years; during this time, all adult members of these households worked for a living.

Livelihood diversification: Partial dependence on remittance (Group 2)

Group 2 migrants diversified their livelihoods by migrating for a few months of the year while working the rest of the time in their native villages. Apart from subsistence agriculture, 66% of these households actively participated in both off-farm and non-farm wage labor in their respective villages, and 20% owned non-farm businesses in-situ. Such migration for livelihood diversification was conducted irrespective of any economic losses they did or did not suffer, unlike

for Group 1 migrants. However, a livelihood from outside was required in addition to farm, off-farm and non-farm livelihoods generated from the Sundarbans, making these households partially dependent on remittances for survival. According to a migrant's wife in Dakshin Radhanagar village:

> *"Our income comes from a van (public transport); my husband can earn 400 Rupees ($5) a day. Then we have our land, we grow crops… he goes outside to Kolkata (the nearest metropolitan city). He works in the building line (construction worker). That way we earn 1 lakh Rupees ($1300) a year."*

Diversifying livelihoods by pursuing non-farm activities has been one of the adaptation options among small-holder communities in different parts of the developing world. "It creates opportunities for accumulation as well as cushioning smallholders from losses due to climatic variability" (Weldegebriel and Prowse, 2017) as non-farm activities can provide substantial incomes during the lean seasons and are relatively less impacted by climate variabilities. Diversification to non-farm activities therefore provides a more secure livelihood to the smallholder communities, promotes additional income generation that can be further invested in less climate sensitive livelihoods, and supports optimal use of household labor and skills. These in turn reduce household economic vulnerabilities and promote effective adaptation to environmental change (Weldegebriel and Prowse, 2017; Debela et al., 2014; Bryan et al., 2009).

Among the surveyed households a total of 73 (42% of all migrant households) belonged to this category of migrant households. Among these households 71% mentioned that unreliable income from the Sundarbans due to major storms, sudden embankment failures, monsoonal variability, erosion, and salinity intrusion were the major reasons they were required to migrate for work for livelihood diversification. This could provide economic security in case they suffered hazard induced economic losses in future, indicating the practice of circular migration as an

anticipatory strategy. According to Smit et al. (2000), such anticipatory strategies are practiced with the intention to avert future impacts of climate change, or benefit from any opportunities that follows. Among these migrant households, 22% were business owners, 70% owned arable land or engaged in agriculture as their primary source of income, 53% suffered economic losses due to salinization and monsoonal variabilities (60%), by tropical storms (96%), and 36% of respondents believed that there has been a considerable increase in environmental risk in the last decade in the Indian Sundarbans.

Additionally, 67% of these households practiced migration because they failed to earn enough income from subsistence farming and had fewer options for in-situ livelihood diversification; there was lack of jobs at the Sundarbans that paid enough to sustain large families, and a limited scope for earning a substantial amount of money outside, especially by working in the construction sector. Therefore, Group 2 households practiced circular migration for livelihood diversification both as an anticipatory strategy and for present economic security. One of the respondents (a migrant's wife) from Bagbagan mentioned:

> *"The money that we can earn from here is always not enough, we have a big family, and, in the Sundarbans, we never know when there will be another Aila or the next embankment breaching. We may suffer economic loss anytime. That is why we try to go outside for an extra, solid income whenever we can."*

Among this category of migrant households, while most of them actively worked both at the Sundarbans and outside, three households had one member each who pursued labor migration full time, while other members worked in the Sundarbans.

This type of migration for livelihood diversification can be explained by the theory of New Economics of Labor Migration (NELM), that households often deploy at least one member to work elsewhere to reduce economic risks, ensure economic security at the source and reduce household

poverty (Ezra and Kiros, 2001; Stark and Bloom, 1985). Interestingly, no household in the villages of Lakshmipur practiced labor migration as a livelihood diversification strategy. The main source of income for the residents (for 70% of households) of Lakshmipur was deep ocean fishing, which remained unaffected by environmental factors such as erosion, salinity intrusion and embankment failure, and was the least affected by major tropical storms. As a result, residents relying on deep ocean fishing as the main source of income did not suffer major economic loss and therefore did not require an additional source of income.

Livelihood diversification & alternative livelihood with complete dependence on remittances (Group 3)

This group of households could be further divided into two sub-groups. For subgroup A migration was a livelihood diversification strategy with complete dependence on remittances besides subsistence farming. Within this subgroup, 33% households were landless and 61% of these landless households did not participate in off-farm or non-farm wage work but were completely dependent on remittances for survival. The other households in this sub-group owned lands but these households diversified livelihoods with a complete dependence on remittances in addition to subsistence farming. Of these households 68% were engaged in off-farm or non-farm wage labor at least once in the last 10 years, but during the survey period they mentioned that they did not actively participate in in-situ wage labor because wages were lower when compared to what they could earn from outside, and that any in-situ income had a negligible contribution to their household economies. These migrants worked outside the Sundarbans for more than nine months every year. One of these migrants mentioned: "*I work outside 5–6 months at a stretch. I come home for 15–20 days and then go again."*

Two of the Group 3 households, however, owned in-situ businesses. One of them managed to buy a public transport vehicle and was ready to diversify his income in his native village of

Rangabelia during the time of the survey. This migrant mentioned that previously labor migration was the only livelihood for his household for the last 12 years. During the time of the survey, his son was a full-time migrant, and the household purchased a vehicle with remittances. This finding highlights the importance of remittances in developing non-field and less climate sensitive income sources in vulnerable environments (Gemenne and Blochar, 2017). The other business-holding household in this group owned a power tiller that he previously rented to other farmers. However, due to extreme climatic vulnerability he failed to earn profit from renting the power-tiller and so pursued labor migration full time as an adaptation. A migrant in Rangabelia mentioned that:

> "*In the Sundarbans there is almost no income. I used to migrate even before Aila. This is my only income. Or else how will we survive here? Here if we work, we do not earn every day. We do not always get the money we deserve. But outside we do. I have constructed this house with remittances."*

The subgroup B households belonged to the erosion-affected village of Bagdanga. These households suffered irrevocable loss of in-situ livelihoods due to erosion and continuous salinity intrusion. These households were completely dependent on remittances for survival. For these households, circular migration was an alternative livelihood that replaced their in-situ farm livelihoods. A migrant from Bagdanga said:

> *"We have lost all our lands. All the lands in this part of Bagdanga are saline. No one can earn a living from lands anymore. Our only income comes from outside. We will not survive if we do not migrate. It is a lot of hard work but that is how we survive."*

Apart from migration, the people of Bagdanga pursued extremely unreliable and temporary forms of economies, and when asked about their income sources, some respondents mentioned the ways they try to acquire daily food and considered them as sources of income. For example, when

asked about source of income, one respondent mentioned: “My son tries to catch some shrimps for daily consumption.” Another respondent mentioned:

“I try to grow some vegetables for consumption if salinity is low after the monsoons, but it is becoming increasingly difficult.”

One of the migrants said:

“I go to Kerala regularly and when I am here, I try to see if there is any labor requirement in the village for digging a pond or digging soil for embankment repair or in someone’s backyard.”

The primary reasons for choosing labor migration as the main household income source by these households were: provision of continuous income from outside; higher wages outside compared to what they could earn in the Sundarbans (78%); very low income from the villages that is further reduced due to random environmental hazards (56%); low or no farm landholding (70%); and complete collapse of in-situ livelihoods due to environmental reasons. While previous research suggested that circular migration from the vulnerable environments is primarily pursued as a livelihood diversification strategy to spread economic risk, our results reveal that temporary migration may also be an alternative livelihood that may substitute the in-situ original livelihoods. The complete dependence on remittance is either due to rural—urban wage differences, inequalities in land access, or irrevocable loss of livelihoods due to environmental factors such as extreme erosion (Carr, 2008; Harris and Todaro, 1970).

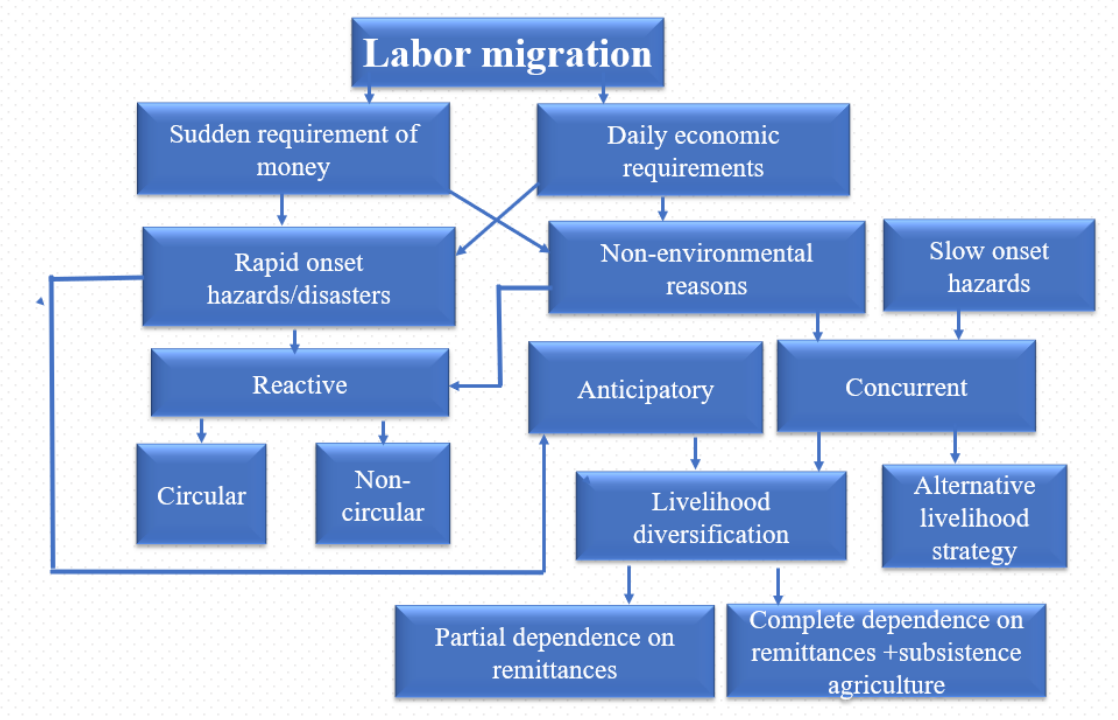

Figure 5-1 Different forms of labor migration and their motivations

A transition among migrants was also observed where 20 surveyed households reported that they first adopted labor migration in response to a major disaster (Group 1 type), then they continued to migrate to earn additional income (Group 2 type). Therefore, while labor migration for Group 1 households is only a reactive adaptation strategy, for the households of Bagdanga, migration was an alternative livelihood option that might have started as a reactive strategy to cope with erosion related losses, but later undertaken as a concurrent adaptation. For the others, labor migration is an attempt towards livelihood diversification with partial or complete dependence on remittances in addition to subsistence farming, pursued as a survival strategy and anticipatory adaptation. Broadly these are distress diversification strategies "to reduce vulnerability to unpredictable crises such as floods, droughts and illness as well as the seasonal fluctuations of natural resources" (Martin and Lorenzen, 2016).

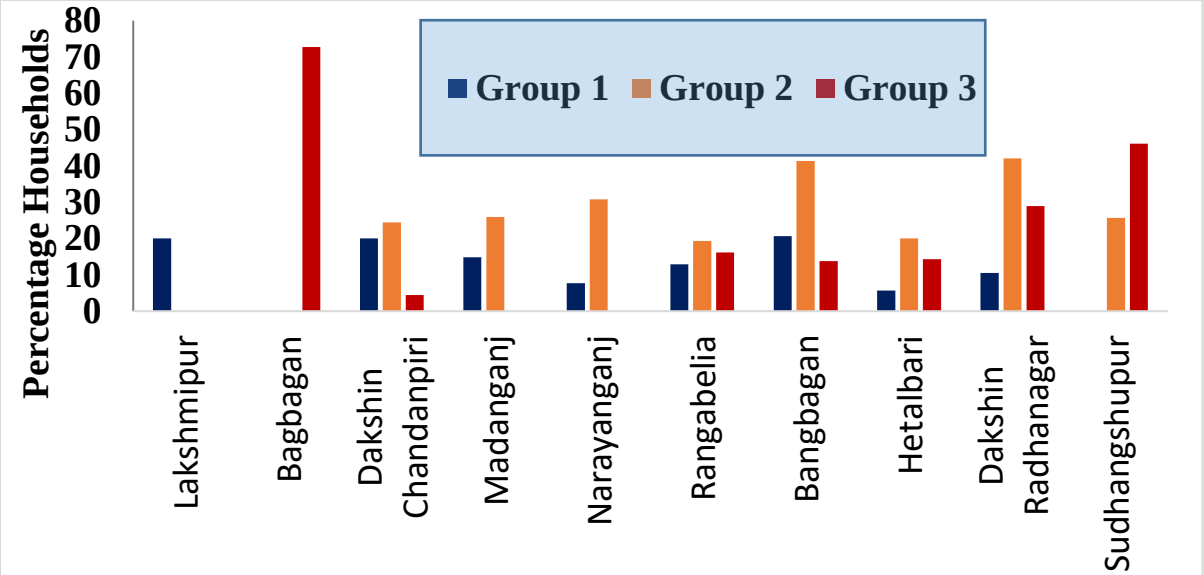

Figure 5-2 Percentage of households that belonged to the three different migrant groups in each study village. (See Appendix B for data tables)

Comparison of the three groups of labor migrants

The three groups exhibited significant differences in some of the socio-economic and demographic characteristics as well as in their perception about the environmental problems (Table 5-2). Migrants from Group 3 had significantly less landholding, a smaller number of income sources, and a negligible number of households from Group 3 earned their income from non-farm small businesses (3%) and did not actively take part in the off-farm wage economies. In comparison, migrants from Group 1 and 2 had more landholding, more income sources in their villages. More households (10–60%) from these groups earned their income from small businesses, commercial fisheries, and daily labor work. A significantly higher number of households from Group 3 suffered economic loss due to erosion compared to the migrants of Groups 1 and 2. Many of the Group 3 migrants belonged to village of Bagdanga (Table Appendix 10-2) who lost their lands permanently due to erosion, or their lands became infertile due to continuous saline water intrusion. The migrant households in Group 1 and 2, especially from the Gosaba CD Block, also experienced salinization, but this was occasional, mostly during tropical

storms, and their lands could be re-cropped after a few years of salinity intrusion. Group 3 migrants also perceived environmental risk much more profoundly than other two groups. These socio-economic variations among three groups indicate that the residents with lower landholding (hence lower agriculture-based income) due to erosion, a lower number of income sources (no or less non-agricultural income), and greater perception of environmental risk were more dependent on remittances compared to the others. Further, it appears that residents who suffered irrevocable and long-term losses due to erosion, salinity intrusion or due to storms like Aila were among the Group 3 migrants who completely shifted to labor migration for survival. In a study in Bangladesh, Joardar and Miller (2013) suggested that households that suffer a permanent loss of properties and assets due to environmental degradation are more likely to relocate. Our study shows that even after permanently losing productive agricultural lands, these residents continued their stays in Bagdanga and supported their households with remittances from outside. In contrast, Group 1 and 2 migrants were able to manage a part of their income through other small businesses, commercial fisheries, and daily labor work, and hence remittances were only a part of their income. The Indian Sundarbans is a very densely populated area with limited resources; migration is pursued in different ways by different households to reduce their overall vulnerabilities (Mistri, 2019; Dasgupta and Shaw, 2014). Whether practiced as a reactive, anticipatory, or concurrent response, the decision to migrate for work is influenced by a complex interplay of factors such as inequalities in land access, access to dwindling resources that are further compromised by environmental problems, and extreme governmental negligence towards providing feasible in-situ adaptation options. In such situations as Wrathall et al (2014) mention, migration becomes “the most viable adaptation alternative”.

Table 5-3 Descriptive statistics of the three groups of migrants. p statistics of MWW and Fisher's exact test Differences among the three groups of migrants

Variables	Mean (MIN-MAX)			p value (MWW Test)			p value (Fisher's Exact Test)		
	G1	G2	G3	G2 vs. G3	G1 vs. G2	G1 vs. G3	G2 vs. G3	G1 vs. G2	G1 vs. G3
People per household	5	5	5	*0.015	*0.009	0.28	n/a	n/a	n/a
Landholding per head (bigha)	0.7	0.8	0.4	*0.001	0.198	*0.0002	n/a	n/a	n/a
Income sources per household	1.8	1.8	1.3	*0.000	0.5	*0.001	n/a	n/a	n/a
Households (%) earning their income from									
Small businesses	25	21	2.8	n/a	n/a	n/a	*0.0143	1.00	*0.016
Commercial fishery	13	10	n/a	n/a	n/a	n/a	n/a	0.75	n/a
Daily labor	69	67	59	n/a	n/a	n/a	*0.34	0.08	0.6
Households (%) that suffered income loss due to									
Erosion	6.2	10	30	n/a	n/a	n/a	*0.009	0.47	*0.003
Salinity intrusion and soil salinization	59	53	63	n/a	n/a	n/a	0.49	0.55	1.00
Rain variability	66	60	41	n/a	n/a	n/a	*0.0022	1.00	0
Severe storms (Aila in 2009)	100	96	90	n/a	n/a	n/a	0.55	0.65	0.27
Environmental risk perception (0-4)	2.3	2.5	3.0	*0.004	0.292	*0.002	n/a	n/a	n/a
Change in environmental risk (0-3)	2.0	2	1.5	*0.020	0.06	*0.002	n/a	n/a	n/a
Sea Level Rise Perception (%)	78	84	84	n/a	n/a	n/a	1.00	1.00	1.00

Shaded cells indicate statistically significant difference with ($p < 0.05$). G1, G2 and G3 represent the three groups of labor migrants identified in the study.

Permanent Migration

Results show that 274 of the 300 surveyed households (92%) did not want to relocate from the Sundarbans in their lifetime. This comprises all the households in Lakshmipur, Dakshin Chandanpiri, Madanganj, Narayanganj, Hetalbari and Sudhangshupur, 45% of the households in Bagdanga, 84% of the households in Rangabelia, 97% households in Bagbagan, and 92% of the households in Dakshin Chandanpiri. These respondents mentioned economic and socio-psychological factors as reasons for their decision to stay in the Sundarbans. On the other hand, 8% of the surveyed households (n=25) wanted to relocate from the Indian Sundarbans. This comprises 55% of the households from Bagdanga, 16% of the households from Rangabelia, 7% of the households from Dakshin Radhanagar, and one household from Bagbagan Village. For these residents, environmental degradation, related loss of livelihood and better amenities in the cities were mentioned as reasons for their willingness to relocate from the Sundarbans.

Residents' unwillingness to relocate

Environmental risk perception and resistance to relocation

Survey results revealed that the level of environmental risk perception (extreme, high, medium, low and no environmental risk) varied among the 274 households who did not want to permanently migrate from their villages in Indian Sundarbans. Only 5% of the households perceived no environmental risk, whereas 30% of the households perceived extreme environmental risk. High, medium, and low environmental risk was perceived by 27%, 17% and 21% of the households, respectively. Therefore, 95% of households perceived at least some level of environmental risk but the risk was not translated to a decision to relocate from their ancestral places; residents believed that the situation is not risky enough for them to relocate to unknown destinations. The interviewed resident of Rangabelia said:

"Why will we go somewhere else? …. Relocation of people does not make any sense. If anyone relocated, I do not know why they did it."

The risk image of a place has been one of the dominant factors in resident willingness to stay (Dynes and Quarantalli, 1976). In this context Fordham (1992) suggested that residents from environmentally vulnerable places might be aware of hazards but do not always expect a disaster, and Lein (2000) suggested that residents who do not migrate even from extremely risky places do not perceive the risk of living in such places. However, our study suggests that after Cyclone Aila in 2009, people were aware of the possibilities and risks associated with future disasters and anticipated losses, but their perceptions of risk did not translate into a decision to relocate. One resident from Bagbagan said:

"It is extremely risky here but that doesn't mean we will take all the household members, abandon whatever we have and go somewhere else."

Instead, they wanted the government to invest in more storm shelters and said they would rely on remittances from circular migration in case of future disasters. Many residents also said that they have lived through environmental challenges and have adapted to such challenges. A few of them even said that they were so accustomed to environmental and economic hardships that they were not even afraid of death anymore. Some of the households—mostly from the villages of the Gosaba Block—said that even though the Cyclone Aila was the most devastating cyclone they had ever experienced, it made them stronger, strong enough to combat any future environmental problems. These respondents shared their hardships during and after the storm, how they lived on the embankments post-Aila, were crammed into the school buildings (used as storm shelters) without any basic amenities, but at the same time they were thankful for the aid and relief provided by the government and by non-governmental organizations. When asked about why they did not

want to relocate even after identifying such risks and hardships, they mentioned economic and socio-psychological factors as reasons to stay. The resistance to permanent migration despite perceiving environmental risks was therefore due to economic and socio-psychological factors. The survey results identify these various factors and highlight their relative importance in building resident opinions regarding permanent migration.

Economic Factors

One of the common responses by residents who were not willing to permanently migrate (75 of 274 households) was that they believed that household relocation was not an option for them because of poverty and the lack of resources to afford a life elsewhere. Another 57 of 274 households mentioned that they were reluctant to permanently migrate because they possessed property (land, home, pond, or livestock) in their villages which they did not want to lose; at the same time, they could not afford purchasing similar properties if they migrated elsewhere. They stated that they would never consider migrating for these reasons. These residents were aware of the high cost of land in cities as compared to that in their villages in the Sundarbans, and they were able to gauge the economic loss in case they had to sell their property, migrate to cities, and purchase new property. This supports the resource theory that lack of household resources discourages permanent migration (Paul et al., 2020; Penning-Rowsell, 2013; Chen et al., 2017; Afsar 2003). A resident of Dakshin Chandanpiri Village expressed these concerns during the interview:

"I do not have any land outside the Sundarbans. If someone has enough money, he might buy land outside but that is rare."

According to most of the interviewed residents, possession of property in their villages gave them a perception of financial security, whereas the high cost of property and associated uncertainties at destination cities created a perception of insecurity. Some residents (40 of 274

households) also reported they were used to working in the primary sector rural and subsistence economies, whereas if they migrated to cities, they would need salaried employments to survive with their families which they believed required additional skills that they lacked. One resident of Madanganj village stated that:

"I have my own house, my farmland, income sources. I have livestock here. Why would we abandon these and move to other places where we do not have anything of our own?"

This response reflected the resident's perception about the potential uncertainties at the destination, which appeared to be a major concern among many residents. According to Poncelet et al., 2010, sometimes uncertainties associated with moving to new places may seem riskier than environmental problems at the source. Another decisive factor identified by 17 of the 274 residents was that they were subsistence farmers and produced their own food for the family even when they did not have a continuous source of income such as a salaried job. Their concern was that if they moved to cities, they would have to purchase food from the stores and that would require stable salaried employment. These residents appeared to be either reluctant to pursue stable salaried employment or were unsure about getting a stable job in a completely new destination with much more competition than in their own villages. One of the residents stated:

> *"We are poor people. Sometimes we cannot earn enough to feed our families. During such times of distress, we completely rely on whatever vegetables and rice we produce in our farmlands. Even if we manage to find a place in the cities, we will not have enough income to buy food. We have never done that. We somehow survive here on whatever we can produce."*

Moreover, a response by one of the residents revealed that there was a cultural connotation to buying food from a store as compared to growing their own food. The resident shared their experience:

> *"I have relatives in Sonarpur (a nearby city). I used to go there sometimes. However, I did not like the place nor liked the lifestyle. I have nine mango trees here, grow rice, vegetables, have my own poultry, have cows for fresh milk and fish from my own pond. In the cities, you must buy everything except water. I do not find peace in the lifestyle. We have our own struggles with environmental problems in the Sundarbans. That is true. However, there is peace and freedom here. Why would someone move to a place where people must pay for foodstuffs and everything else except water?"*

Such responses infer that most of these residents were familiar with or adapted to fulfill the basic needs of their families through subsistence farming which is a part of their culture. On the other hand, they understood that after migrating to cities, subsistence farming to support family needs might not be a viable option and they would need to pursue other ways of earning income, which they never did before and found it culturally unacceptable. This thought process resulted in reluctance or resistance to permanent migration among the residents. This behavior of adhering to ones' culture even in the wake of extreme environmental risk is one of key elements considered during disaster risk reduction. It has been observed that people in the environmentally vulnerable places often adhere to unsustainable economies even after economic losses due to natural disasters because of their cultural preferences (Paul et al., 2020; Kulatunga, 2010; Cahn, 2000).

Socio-psychological reasons

Survey results revealed that, in addition to economic reasons, social obligations and psychological factors also played a very important role in creating resistance among the residents to permanently migrate from the Sundarbans despite perceiving environmental risks and associated economic hardship. Many (65 of 274 residents) insisted that they had a strong emotional

attachment to the Sundarbans, their village and community, and therefore were not willing to permanently migrate. Respondents further added that they would not abandon their birthplace for any reason except for extreme scenarios such as complete collapse or inundation of their island. Two of the respondents even indicated that they were willing to formulate in-situ adaptation policies to "save the Sundarbans" rather than migrate. The comments made by the residents highlight their emotional attachment to their birthplaces and how sense of place translates into a reluctance to relocate.

> *"Nobody wants to abandon his or her birthplace;" "Sundarbans is my birthplace and I love my birthplace;" "We share a parental affection with the Sundarbans." "The Sundarbans is our mother and we do not leave our mothers alone;" "Normally people do not relocate from their birthplaces. We are born here and will die here."*

An emotional attachment to a place comes from sense of belonging, enhanced community resilience, sense of efficacy and security (Adams, 2016; Fresque-Baxter and Armitage, 2012). A close relationship and strong emotional bond with neighbors (community) was reflected in a response by one of the labor migrants:

> *"When we go outside (to the cities) for work, we do not have to worry about our families here. We know that the neighbors will take care of them. The neighbors will be there in case of any emergency;" or "In case we do not have food, or anyone in the community does not have food, we do not starve. Our neighborhood takes care of us."*

According to Paul et al. (2020), when such strong bonds are created between places, people, and their communities, "*leaving can be next to impossible*" suggesting the importance of in-situ social capital in migration studies.

The survey results also highlighted that the differences between rural and urban lifestyles were of major concern to many (42 of 274) of the residents from the Sundarbans where the

residents believed that they were accustomed to living a rural life. According to these residents, they experienced freedom in the rural and natural environment, and they might not experience it in an urban lifestyle. Additionally, some residents mentioned that they were acclimatized to the weather conditions in the Sundarbans, and urban areas would be difficult as they must adjust to a different weather in cities. A few residents (13 of 274) also noted that urban living is more exposed to air and water pollution compared to their villages in the Sundarbans which was why they did not want to migrate from there. Some residents also voiced their concerns about increasing crime rates, women safety, and traffic accidents in the urban areas compared to that in their villages. To them, these risks were much worse than environmental risks in the Sundarbans, possibly because they knew how to deal with environmental risk, but not with urban or manmade risk. According to one resident:

> *"What environmental risk are you talking about? When you walk in the streets of Kolkata (the nearest metropolitan city) you might be run over by a bus anytime. Do people leave Kolkata and go somewhere else? There is risk everywhere."*

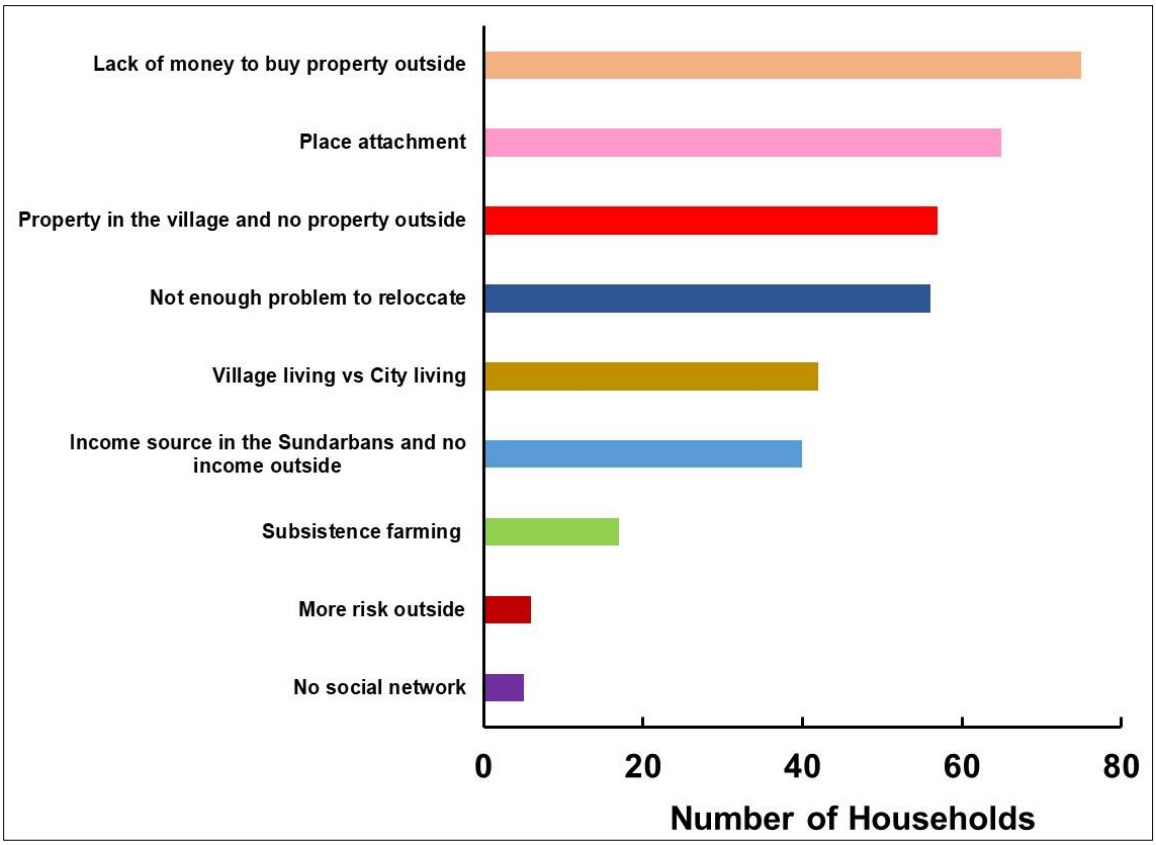

Figure 5-3 Reasons to stay in the Sundarbans.

The importance of place attachment in migration has been observed widely such as the residents of the Kiribati and Tuvalu islands who did not want to leave their islands and communities despite extreme vulnerability (Allgood and McNamara, 2017; Adams, 2016; Amundsen, 2015; Morteaux and Barnett, 2009). Results of this study reveal that in addition to place attachment, the residents of the Indian Sundarbans find themselves "safer and happier" within the Sundarbans when compared to lifestyles in potential migration destinations. The residents listed numerous environmental problems and associated economic hardships. However, when they were asked if they would consider migrating permanently, their responses reversed, and they listed the brighter side of continuing to live in the Sundarbans. This interesting finding highlighted that emotional attachment to place and community, a sense of security, dignity and

freedom are decisive socio-psychological factors that discouraged residents from migrating from the Sundarbans. These results from a primary household level survey provide evidence that these socio-psychological factors must be incorporated into models for predicting climate change induced mass migrations from places with environmental vulnerability.

Environmental risk perception and residents' willingness to relocate.

Twenty-six of the 300 surveyed residents indicated that they were willing to permanently relocate outside of the Sundarbans. Most of these residents are from the village of Bagdanga. They perceived the extreme environmental risk, especially because of erosion and salinization of land in this village. One of the residents from Bagdanga stated:

> *"I wish I could move to a better place. I just do not have money to move right now. All my farmlands are encroached by the river. Hundreds of people have lost lands in this village. We have no income within Bagdanga. Whenever we have enough resources, we will move out of Bagdanga."*

The island of Mousini where Bagdanga Village is located experiences extreme risk by rapid erosion (Mukherjee and Siddique, 2018; Hazra et al, 2018; Chatterjee et al., 2015) which has caused a reduction of agricultural yield and opportunity for agriculture related labor work. In addition, residents of one household in Rangabelia have already made plans to move to a nearby city after retirement. The respondent from this household said they had to migrate four times due to erosion and inundation of land in the past and were staying in a make-shift home at the time of the interview. This household was relatively rich compared to the others as two members had salaried employment. Such findings support previous findings that migration is pursued by the ones who can afford its costs (Penning-Rowsell et al., 2013; Bernzen et al., 2020). Resident

willingness to relocate from environmentally vulnerable islands were also reported in previous studies.

Allgood and McNamara (2017), in their study in the Kiribati islands reported that respondents wanted to migrate from Kiribati due to sudden or gradual impacts of climate change. Results from this study included the following expressions: “Who willingly wishes to die by drowning?” “We are being forced to die as we have no money to go anywhere;” “Even the groundwater is saline.” These expressions reflect extreme vulnerability towards environmental problems, and the lack of proper adaptation measures and government support (Morteaux et.al., 2018). Furthermore, fear and anticipation of future environmental risk due to flooding was also mentioned by one resident in Rangabelia as reasons he wanted to relocate in the future.

Apart from environmental risks, better economic and educational opportunities elsewhere were mentioned by residents of Dakshin Radhanagar, Bagbagan and Rangabelia as reasons they wanted to relocate from the Sundarbans in the future. Similar findings were also reported from the Pacific islands of Kiribati and Tuvalu where a portion of respondents wanted to migrate elsewhere due to better opportunities (Allgood and McNamara, 2017; Arnall and Kothari, 2015; Mortreux and Barnett, 2009).

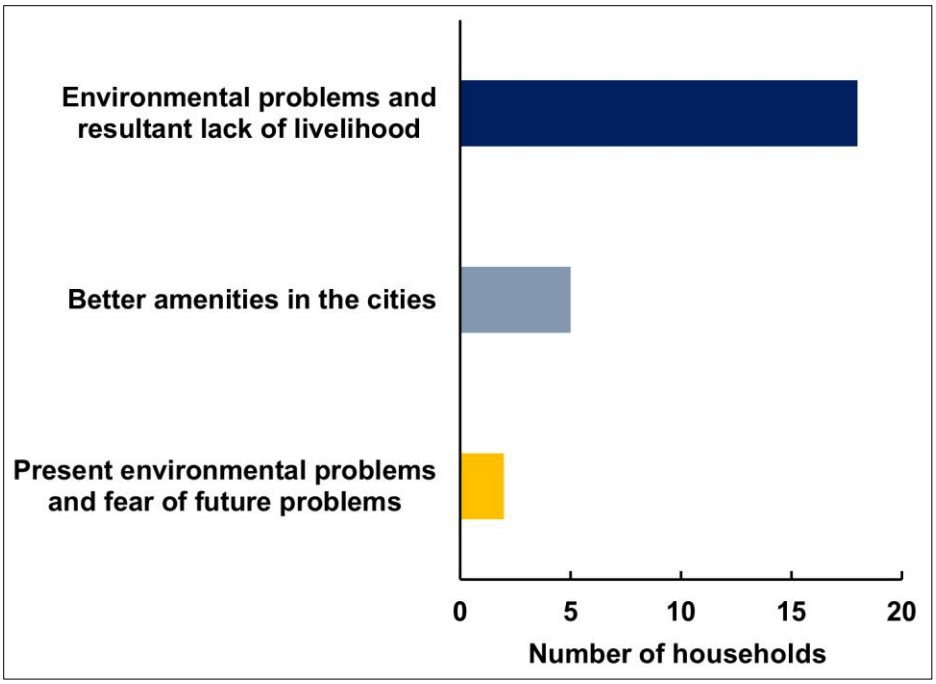

Figure 5-4 Reasons to relocate from the Sundarbans.

In case of forced migration

The question of forced migration in case of inundation and extreme erosion seemed relevant to the residents in Bagdanga, Narayanganj, parts of Rangabelia and parts of Dakshin Radhanagar where the residents experienced erosion. To the others this question of forced migration sounded hypothetical, and a majority had no answer for it. The residents of the villages of Dakshin Chandanpiri and Madanganj said that there was no such chance of island inundation in the future as erosion was not perceived as a major environmental problem. Even though several households had identified riverbank erosion in their localities, in Dakshin Radhanagar village, all 38 surveyed households mentioned that they believed there was no risk of either island inundation or losing their homes to erosion in the future. Six percent of households in Bagbagan and 9% households in Rangabelia and Hetalbari also had similar opinions regarding forced migration. On the other hand, 30% of households from Lakshmipur, 45% from Bagdanga, 12% from Hetalbari and 14% from Bagbagan mentioned that in the event they lost their lands to bank erosion, they

would follow their neighbors. Three percent of the households in Bagdanga, 8% in Narayanganj, 13% in Rangabelia and 10% in Bagbagan mentioned that they would try to move somewhere within their village. Temporary relocation to flood shelters or schools, on embankments and roads were also mentioned by 9% of households in Hetalbari, 14% in Bagbagan and 6% in Bagdanga. A few residents said that they would follow the instructions of the local government or would move somewhere to cities (10% of the households). However, three residents from Rangabelia, two residents from Hetalbari and one resident from Dakshin Radhanagar had purchased properties in the nearby cities; in case of island inundation, they were prepared to relocate to their city homes. The rest of the residents mentioned that they did not know where they would go in such a situation or simply mentioned that they never thought about such an issue. They said:

"…in that case we must go somewhere" or "I do not know where I will go, I will think about it if such a condition ever arises."

Therefore, even though the residents were aware of environmental risk, they did not prioritize it in their daily lives and had no concrete plans to relocate in case of inundation. While they perceived future risks from cyclones after their experience with Aila in 2009, many households perceived risk from erosion but did not anticipate extreme loss except for the households in Bagdanga. This behavior of the residents indicates that they expected extreme loss once they experienced such loss as in the case of Aila or in the erosion-affected village of Bagdanga.

Residents who had properties in cities

Six residents had purchased properties in the nearby cities of Canning, Piyali and Champahati. Among them, two households from Rangabelia wanted to migrate from the

Sundarbans in the future due to environmental problems and future threats. One resident mentioned:

> *"I know we have to relocate in the future. It requires preparation. That is why I bought land and built a home. Even scientists are sounding an alarm. I know that there will be a huge disaster in 10- or 20-years' time. I never thought about it before renovating this house (the house in the Sundarbans) or else I would not have wasted money on this."*

Another household from Rangabelia had built a home in the city to take shelter in times of disasters. The respondent specifically mentioned: "I built a home in Champahati in case there are sudden environmental hazards, and the Sundarbans is no longer fit for survival, but we are not going to stay there forever."

For others, better education for children and better medical facilities in the cities were reasons they had invested in properties outside the Sundarbans. Apart from Rangabelia, one resident belonged to the village of Hetalbari, and one resident belonged to Dakshin Radhanagar village. Among these residents, two households had businesses within the Sundarbans, and one was a commercial farmer with 50 bighas (1 hectare = 6 bigha) of agricultural land, three households had a salaried income source, and one household was a small-scale subsistence farmer whose major income source was remittances.

Differences between the Group 1 residents not willing to permanently migrate and the Group 2 residents willing to migrate.

Crop production, percentage of agricultural labor, business holders, households who lost income due to salinization and erosion, and the percentage of respondents who perceived rise in the level of water during high tides and storm surges and who were aware of climate change, were statistically different between the two groups of respondents. For the residents in Group 1, per

head productive agricultural land was 0.43 bigha/head (1 hectare =6 bigha). On the other hand, it was only 0.13 bigha/head from the residents of Group 2. This was because only 33% of the respondents of this group have productive agricultural land, and 67% of the respondents' lands were either saline or lost due to erosion. This was the reason why more respondents from Group 2 also reported loss of livelihood due to erosion and salinization compared to the respondents of Group 1.

Our results are consistent with the studies that explored rate of erosion on the island of Mousini where Bagdanga is located (Hazra et.al, 2018; Chatterjee et.al., 2015). This island is affected by erosion and salinization of land and residents have lost farmlands over the years. Moreover, two out of five households from Rangabelia in Group 2 also reported loss due to erosion and salinization of land. This could also explain why there is a higher percentage of respondents from Group 2 who perceived a rise in the level of water during storm surge. For the variable, 'climate change awareness', 55% of the respondents in Group 2 were aware of climate change versus 29% in Group 1. Even though the sample size of Group 2 was small (n=26), three out of five respondents from Rangabelia village were aware of climate change. This was mostly due to the efforts of a Non-Governmental Organization called The Tagore Society for Rural Development in the village of Rangabelia. This organization has been working to spread climate change awareness among the villagers, mostly in Rangabelia.

Even for the households in Group 1, 77% of the respondents from Rangabelia were aware of climate change as opposed to 20% of the households in Lakshmipur and Bagdanga, 22% of the households in Madanganj, 11% of the households in Dakshin Chandanpiri, 44% of the households in Bagbagan, 51% of the households in Hetalbari, 33% of the households in Dakshin Radhanagar,

and only 8% of the residents in Sudhangshupur. No residents in the village of Narayanganj were aware of climate change.

Table 5-4 Demographic, socio-economic characteristics, and environmental perception of respondents from Groups 1 and 2

Variables	Coding Criteria	Residents		p value
		Willing to relocate	Not willing to relocate	
Household Size	People / household	5.9	4.4	>0.05[1]
Landholding	Hectares / person	0.06	0.02	<0.05[1]
Age	Years	44.1	44.4	>0.05[1]
Gender Ratio	Female: Male	18:82	24:76	>0.05[2]
Education	Years	7.2	6.6	>0.05[1]
Households (%) earning their income from				
Agricultural daily labor	1= Yes, 0= No	68%	52%	<0.05[2]
Non-agricultural business holders	1= Yes, 0= No	22%	13%	<0.05[2]
Salaried employees and quacks	1= Yes, 0= No	9%	11%	>0.05[2]
Commercial fisheries	1= Yes, 0= No	13%	0%	>0.05[2]
Households (%) that suffered income loss due to				
Income Loss Erosion	= Yes, 0= No mention	16%	28%	<0.05[2]
Income loss Salinization	1= Yes, 0= No mention	56%	76%	<0.05[2]
Households (%) that perceived				
Environmental Risk	0-4 (no to extreme)	2.7	3.1	>0.05[1]
Change in Environmental risk	1= Increase; 2= Decrease, 3=No Change, 0 = No Risk	1.7	1.2	>0.05[1]
Effects of sea level rise	1= Yes, 0= No	85%	95%	<0.05[2]
climate change	1= Yes, 0= No	29%	55%	<0.05[2]

[1]p-value of statistical significance was calculated with Mann-Whitney-Wilcoxon (MWW) Test.
[2]p-value of statistical significance was calculated with Fischer's exact test.

Conclusion

This study aimed to identify adaptation strategies used by the residents of the Indian Sundarbans in response to the impacts of environmental problems and changes. The residents of the Indian Sundarbans used in-situ structural and non-structural adaptation to reduce overall

vulnerabilities at the source. Temporary labor migration was one of the most important ways residents adapted to or coped with both slow onset and rapid onset hazards. Labor migration was pursued as a reactive response after a hazard induced economic loss, as well as a concurrent adaptation and alternative livelihood strategy by families affected by erosion that suffered irrecoverable economic losses in-situ. Labor migration was also pursued as a livelihood diversification strategy to secure the present needs of households and to prepare them for future hazard related economic losses. As an attempt to diversify livelihoods, either one family member pursued labor migration full time while the others worked in-situ, or members worked part time as labor migrants for a few months of a year and spent the rest of the year working in-situ.

It was noted that the households which permanently lost assets and property due to erosion did not relocate from the Sundarbans as was suggested in some of the previous studies from Bangladesh (Joardar and Miller, 2013). They instead adopted labor migration full time and supported their families in the existing places with remittances from outside. Remittances were primarily used in household food consumptions, building more resilient homes, and for small investments in less climate sensitive local businesses.

While temporary migration was widely practiced, most of the residents did not prefer permanent household relocation as an effective adaptation strategy and were not willing to relocate despite environmental risks. This was because of poverty and lack of resources to migrate with their families, lack of proper wages to sustain families in the cities, place attachments, community obligations, and cultural differences between the Sundarbans and the possible destinations. However, households that faced extreme erosion and feared island inundation conveyed their wish to relocate if the government provided them with places to stay and jobs. These households,

however, had no plans in case they faced island inundation in the future other than to simply follow their neighbors and relying on the government's decision to provide them land.

Residents' reluctance to relocation does not however imply that there is no chance of future mass migration from the Indian Sundarbans. There are already instances of population displacement from the island of Lohachara and in the next 50 to 100 years as the impacts of climate change intensify there will be no other option than population relocation from these islands. Our findings rather call for more research to identify the islands which are at an imminent risk of inundation and the communities that need immediate relocation rather than generalizing the 'mass migration' scenario for the entire Sundarbans. Such generalizations about extreme situations might create public awareness and draw media attention towards this issue but will be detrimental towards the risk mitigation efforts for the concerned population. Our results also suggest that while planning for population relocation, the government must consider the socio-cultural and psychological factors of the residents, create more awareness about the future impacts of climate change, shift them to the places where they may safely practice their present livelihoods or arrange alternative livelihoods for the communities in the destinations and also provide assistance to help them shift their livelihoods. In the places that are not at an imminent risk of inundation, in-situ adaptation practices must be explored.

The findings also call for the government of India to provide attention to its labor migrants. India at present has faulty labor laws that fail to provide protection to the huge number of internal migrants who cross state borders (Gupta et al., 2021). A huge number of the interstate migrant workers are unregistered, engage in unauthorized sectors, and are regularly exploited by the employers (Tiwari et al., 2012). With the intensified effects of climate change, frequent disasters, the rate of labor migration from these poverty-stricken vulnerable environments is likely to

increase. India must therefore devise comprehensive action plans for labor migrants that addresses their working conditions, the prevention of exploitations at the destination, and provisions for social protections that are currently lacking.

Chapter 6 - Reasons and determinants of circular (labor) migration in the Indian Sundarbans

Introduction

Circular migration for work is a commonly practiced adaptation strategy against environmental change especially among the smallholder communities in the developing parts of the world (Wrathall et al., 2014; Foresight, 2011). Such migration generates remittances that reduce household economic vulnerability and increases adaptation capacity against environmental change (McLeman and Smit, 2006). This may be pursued as a reactive response to economic losses after a sudden onset disaster or as a livelihood diversification strategy for household economic security and to cope with the economic impacts of diminishing natural resources due to slow onset hazards such as sea level rise or drought (Afifi, 2011; Penning Rowsell et al., 2013). However, the environment may not be the sole determinant of such migration. Human migration involves a complex relationship among various socio-economic, demographic, and political factors and environmental problems may catalyze the process of migration by worsening the pre-existing economic conditions. For instance, labor migration following a rapid onset hazard may be determined by factors such as prevailing poverty, poor infrastructure, government negligence towards effective adaptation practices, while the disaster may serve as the immediate cause (Wrathall, 2012). Similarly, sustained circular migration from places challenged by slow onset environmental change, may also be determined by factors such as poverty, differences in wage between the source and the destination areas, the nature of household economy, possession of land, households' demographic factors such as size of households, and age of the members, social connections at the destinations, perception of relative deprivation and economic and environmental risk perception at the source (Bernzen et al., 2019; Massey et al., 1993; Van Wey, 2005; Clark,

2020; Mahinchai, 2010; Garip, 2008; Deshingkar, 2008). Environmental change and extreme events may trigger migration by negatively influencing some of these factors while the other factors might independently influence the decisions to migrate for work.

While past studies have generalized the factors of labor migration from environmentally challenged places, the extent to which each of these factors play a role in inducing labor migration from vulnerable environments is still poorly understood (Bernzen et al., 2019; Black, 2011; Foresight, 2011; McLeman and Smit, 2006). Our study was conducted in the Indian Sundarban delta where labor migration has been documented as an adaptation to environmental changes and problems (Maharajan, 2020). The objective of our study is to understand the reasons why vulnerable residents pursue labor migration as an adaptive response and evaluate the socio-economic and environmental variables to analyze their relative importance as determinants of such migration. In this study, we consider circular labor migration as a dependent variable whose value depends on several independent variables including environmental, economic, social, and perceptional parameters, and calculate statistically significant determinants of labor migration from the Indian Sundarbans.

Methods

A questionnaire survey was conducted in the Indian Sundarbans among 300 households (See methodology, chapter 3). The respondents were asked if any member(s) from the respective household migrated for work in the last 10 years. Information was then collected about the size of the household, the household's source(s) of income, if the household suffered economic losses in the last 10 years due to erosion, salinization of land, monsoonal delays, and tropical storms, and whether the respondent was aware of climate change and perceived sea level rise, environmental risks, and any changes in the environmental risks in the last 10 years. The respondents from the

households with migrants were then asked about the motivations and reasons behind pursuing labor migration. The respondents from the non-migrant households were asked why they did not pursue labor migration when so many other households from the Sundarbans did.

First, content analysis was done to group the residents based on their motivations to migrate or not migrate as mentioned by them during the survey. Second, summary statistics on the socio-economic and environmental variables of the migrants and the non-migrant households were conducted and the differences of these variables between the migrant and non-migrant households were determined using statistical non-parametric tests as the distribution of these variables were not found to be linear (Table 6-1). For determining differences pertaining to the continuous variables, the Mann Whitney Wilcoxon (MWW) test was conducted, and for the categorical variables Fisher's exact test was used (See coding Table 6-1). The MWW test is a non-parametric test used to decide whether the two samples are derived from the same population and compare the differences between two independent groups in a sample with continuous or ordinal data (Nacher, 2008). A Fisher's exact test, on the other hand, is used to compare two variables with non-random categorical values generally using 2 by 2 contingency tables (Hess and Hess, 2017).

Third, logistic regression models were used to identify the determinants of migration based on a household's economic and environmental variables. Before conducting the logistic regression model, the variables were tested for multi-collinearity using correlation coefficient analysis. No strong collinearity was found among the variables (Table Appendix C-5). In this study, migration was considered a household decision (Massey et al., 1993). Therefore, the variables pertaining only to the households (not individuals) were considered for the analysis.

Two logistic regression models were used in the analysis. The objective of the first model (Table 6-3) was to determine the relative importance of the socio-economic and environmental

factors of labor migration. The predictor variables used in the first model are as follows. 1) Size of household. 2) Per-head ownership of productive agricultural land (per head ownership was considered because 100% of the farmers practiced sustainable farming and primarily grew crops for household consumption; excess crops, if any were sold in the market. 3) Households that practiced daily agricultural labor work. 4) Non-agricultural business owners. 5) Households with salaried incomes and quacks. 5) Commercial fishermen. 6) Number of income sources per household. 7) Loss of livelihood due to erosion. 8) Loss of livelihood due to salinization of land. 9) Loss of livelihood due to rainfall variability. 10) Loss of livelihood due to tropical storms. 11) Availability of migration information. 12) Environmental risk perception. 13) Perception of change in environmental risk. 14) Perception of sea level rise.

Past studies highlighted that migration may be more common among people dependent on subsistence economies in smallholder communities in these environmentally fragile areas (Radel et al., 2019). In the Indian Sundarbans, most households depend on subsistence rice cultivation. Therefore, we used a second logistic regression model (Table 6-4) to understand whether reliance on small scale subsistence farming has a significant impact on labor migration from the Indian Sundarbans. For this model, the households that did not pursue any economy other than agriculture were coded 1 (Table 6-1). The agricultural households constituted the ones that owned or had taken cultivable agricultural lands on lease during the time of the survey and the households that pursued daily labor.

It should be mentioned here that in the Indian Sundarbans, the households that pursued daily labor work did not restrict themselves to agricultural labor alone (off-farm). They also engaged in small scale, temporary, non-agricultural daily labor work like digging ponds, and embankment repairs whenever such works were available (non-farm). However, given the

structure of the economy, all the households largely participated in agricultural labor work in other household fields within the Sundarbans. This is the most unstable form of economy as their daily income depends on whether any such work is available. During the survey, these households mentioned rarely getting paid as promised, occasionally even being unpaid for days. For the logistic regression model 2 (Table 6-3), if a household pursued any other economic activity other than agriculture or daily labor, such as business, government service or fishing, they were coded 0. The other predictor variables were the same as those used in model 1.

This study considered only the temporary circular migrants who migrated for work and returned to the Sundarbans after completion of work. In the study area, 18 households reported migration that required someone from the household to stay in their workplace. They were mostly teachers in government and government sponsored schools (15) and those serving in the Indian Army (3 households). These were neither considered circular migrant households nor non-migrant households. Therefore, 282 out of the 300 households were considered for this analysis.

Dependent variables

Migration and Non-Migration: Any household that had at least one adult circular migrant member was considered a migrant household. The households with no such migrant members were considered non-migrant households. As migration was considered a household decision in this study, households with more than one migrant were not separately analyzed. A total number of 173 households (58%) had at least one member who temporarily migrated for work outside the Sundarbans in the last 10 years. Out of these households, 64% were in the Gosaba CD Block and 36% belonged to the Namkhana CD Block. In the Gosaba CD Block, the village of Dakshin Radhanagar had the greatest proportion of migrant households to total households (79%), and Rangabelia had the least proportion of such migrant households (54%). In the Namkhana CD

block, the village of Bagdanga (76%) and Lakshmipur (20%) had the most and the least proportion of migrants to the total number of households. On the other hand, a total number of 109 households earned their living by working within the Sundarbans and never had any member who migrated in the last 10 years. (Figure 6.1). Of these households, 45% and 54% belonged to the Gosaba and Namkhana CD Blocks, respectively. In the Gosaba CD Block, the village of Hetalbari (43%) and Sudhangshupur (21%), and in Namkhana CD Block, the villages of Lakshmipur (80%) and Bagdanga (21%), had the greatest and the least proportion of non-migrant households to the total number of households in these villages, respectively.

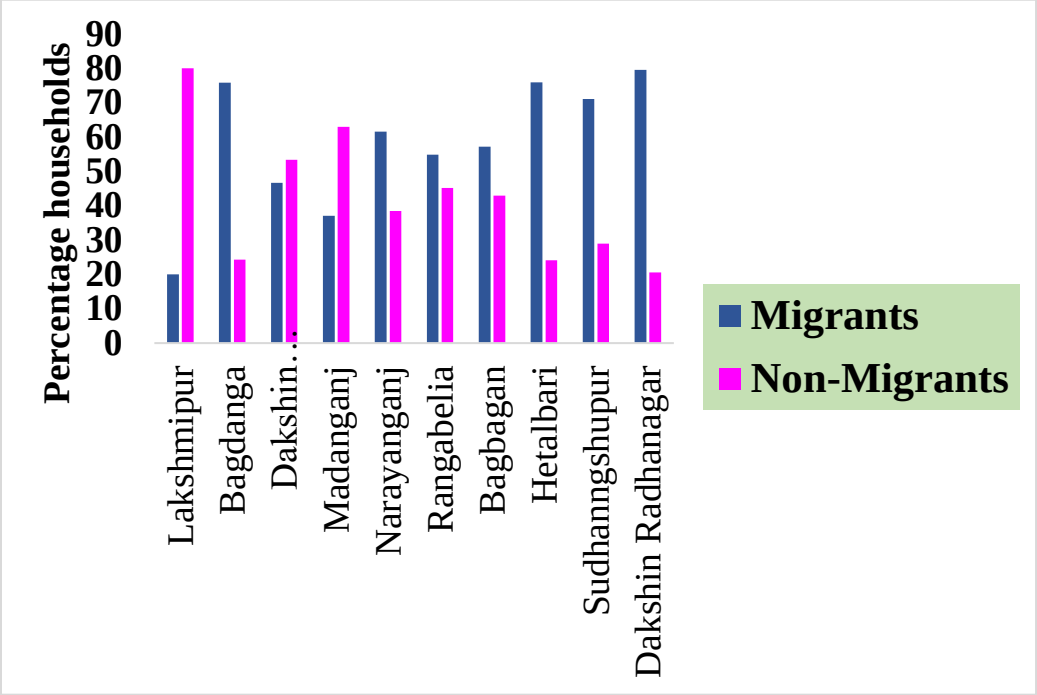

Figure 6-1 Percentage of migrants and non-migrant households to the total number households in each village

Predictor Variables

Size of the households: The average size of a migrant household in the study area was six persons per household, with a minimum of two persons per household in Dakshin Chandanpiri and maximum of 12 persons per household in Lakshmipur. The average size of a non-migrant

household was four persons with a minimum size of three in Rangabelia and the maximum size of six persons in Bagbagan. The difference in the mean of the household size was found statistically significant between the migrant and the non-migrant households in the study area.

Amount of cultivable landholding: As the households in the Indian Sundarbans grow food crops primarily for household consumption, the size of productive landholdings for each land owing household (per bigha) was divided by the number of family members in the households. The resultant size of landholdings per head per household was 0.07 and 0.09 hectare/household on average among the migrants and the non-migrant households, respectively. This difference was however not statistically significant ($p > 0.05$). Among the migrants, the households of Dakshin Radhanagar (1.4 bigha/head) and Lakshmipur (0.13 bigha/head) had the maximum and minimum amount of per head productive land. Among the non-migrants, the households of Rangabelia (1.35 bigha/head) and Lakshmipur (0.16 bigha/head) had the maximum and minimum amounts of per head productive agricultural land, respectively. For both the migrants and the non-migrant categories, the households in Gosaba Block (migrants 1.5 bigha/head, non-migrants 0.79 bigha/head) had more per head productive agricultural land compared to the households in Namkhana block (0.44 bigha/head, non-migrants 0.56 bigha/head).

Agriculture as the only source of in-situ income: In the entire study area, 64% (n=183) of the households relied only on agriculture or daily agricultural labor work. Among them 72% were migrant households. In the Namkhana CD Block no migrant household belonged to this category in Lakshmipur, but in the erosion-affected village of Bagdanga, 64% of the households that relied on agriculture for survival were households with migrants. Among the villages of the Gosaba CD Block, migration took place from all such agricultural households in Sudhangshupur. In the Gosaba CD block all the households that relied on agriculture or agricultural labor for survival

were households with migrants. In this block, the village of Hetalbari had the minimum number of migrants belonging to this economic category. A statistical difference of mean between the migrants and non-migrant households were found for this variable for the entire study area. This variable is used in Model 2 as one of the economic variables to test whether having agriculture as the only source of income in places like the Sundarbans influences migration.

Other sources of income: The sources of incomes were further categorized into four different groups. The first group was 'daily unskilled laborers.' The second group was 'commercial fisheries.' The households that owned an inland fish or shrimp farm for commercial use and the ones that pursued deep sea fishing were included in this group. The third group was 'local businesses' consisting of households with small businesses in-situ including those who owned local public transport vehicles (engine vans). The fourth group was the 'salaried households and quacks.' These were the schoolteachers, government workers and nurses who had a secure source of income. The quacks were also included in this group because during the survey they mentioned that they had income stability, and like the salaried households their incomes were not impacted by environmental problems.

Daily laborers: Households with migrants pursued in-situ daily labor activities more frequently than non-migrant households. While 73% of the migrant households had at least one person who worked as a daily laborer in the Sundarbans, only 42% of the non-migrant households pursued this economic activity. In the Namkhana CD Block, among the families with migrants, Dakshin Chandanpiri had the maximum proportion of such households (82%), and Madanganj had the least proportion (42%) among the non-migrant households. However, Bagdanga, Narayanganj (88%) and Dakshin Chandanpiri, Madanganj (33%) had the greatest and the least proportion of such households. In the Gosaba CD Block, Sudhanshupur (79%) and Bagbagan (47%) had the

largest and the least proportion of households that pursued daily labor work, and among the non-migrant households, 63% and 18% of households from Dakshin Radhanagar and Rangabelia pursued this economy.

In-situ small businesses: Small local businesses were owned by 22% of the migrant households and 27% of the non-migrant households, and there was a statistical difference of mean between the migrants and non-migrant households for this variable. In the Namkhana CD block the village of Narayanganj (40%) had the maximum number of business households and Madanganj had so such households. In Gosaba the maximum and minimum proportion of migrant households with businesses were Rangabelia (40%) and Hetalbari (18%). Among the non-migrant households, the maximum and minimum from Namkhana CD Block were Bagdanga (38%) and Narayanganj (13%), respectively, and from Gosaba Block, Bagbagan (54%) and Dakshin Radhanagar (21%), respectively.

Commercial Fisheries: Inland commercial fisheries were owned by 18% of the migrant households, including 41% of the households in Madanganj. No migrant household from Bagdanga, Narayanganj, Rangabelia and Dakshin Radhanagar owned fisheries. For the non-migrant households, 13% either had inland commercial fisheries or practiced deep sea fishing. In Lakshmipur, 63% households practiced deep sea fishing. Households from Bagbagan, Rangabelia, Sudhangshupur, and Dakshin Radhanagar villages neither owned a commercial fishery nor pursued deep sea fishing.

Salaried sources and quacks: For the salaried households and quacks, 13% of the households from non-migrant group and only one household from the migrant group had a salaried employment.

Households with more than 1 income source: Several households had more than one income source. Among the migrant group, 28% of the households had more than one income source, and 4% of the households had no income source within their respective villages. Among the non-migrant group, 57.79% of the households had more than one income sources.

Loss of livelihood due to erosion, salinization of land, rainfall variability and storms: Seventeen percent of the migrant households reported a loss of livelihood due to riverbank or coastal erosion, with the maximum of 75% households from Bagdanga Village. For the non-migrant group, only 13% households reported major economic loss due to riverbank or coastal erosion. Among them, 38% of the households belonged to Narayanganj and Bagdanga. No households from Dakshin Chandanpiri, Madanganj, Bagbagan, Hetalbari and Sudhangshupur reported a major loss of livelihood due to bank erosion in the last 10 years. Loss of livelihood due to salinization of agricultural lands was more universal in the study area. For the migrant households, 59% reported loss of livelihood due to salinization of land with 100% households from Bagdanga and Narayanganj and a minimum of 30% in Dakshin Chandanpiri, Madanganj, Hetalbari and Dakshin Radhanagar. For the non-migrant households, 58% reported loss of livelihood due to salinization with a maximum of 88% from Hetalbari and minimum of 28% from Lakshmipur.

For loss of livelihood due to monsoonal variability, 50% of migrant households suffered a loss, with a minimum of 4% in Bagdanga and a maximum of 82% in Sudhangshupur. For the non-migrants, 86% of the households suffered loss of livelihood due to monsoonal variability with a maximum of 86% in Bagbagan. No households in Lakshmipur mentioned loss of livelihood due to monsoonal variability. On the other hand, 94% of the migrants and non-migrant households mentioned loss of livelihood due to tropical storms in the last 10 years. Among these variables

only the differences of economic losses suffered due to erosion between the migrant and non-migrant households were found statistically significant.

Perception of environmental risk within the Sundarbans: Environmental risk perception varied geographically. Among the migrant group, environmental risk perception was 2.73 on a Likert scale of 0 to 4 (where 0 indicated no risk and 4 indicated extreme risk) indicating an overall high risk. While 100% of the households (both migrants and non-migrants) in Bagdanga perceived an extreme environmental risk due to erosion and related salinization, both migrant and non-migrant households of Dakshin Chandanpiri and Madanganj perceived a low environmental risk in their villages and nearby environs. It was observed that resident perception of environmental risk largely depended on tropical cyclones, salinization, and erosion. Residents also perceived a change in environmental risk in the last 10 years. Among the migrant households, 49% perceived an increase in environmental risk, 23% perceived a decrease in environmental risk and 28% perceived no change in environmental risk over the years. Among the non-migrant households 45%, 28% and 23% (locations?) perceived an increase, decrease and no change in environmental in the last decade.

For sea level rise perception, the residents were asked if they perceived a rise in the level of water during storm and tidal surges over time. To this, all the migrant households in Lakshmipur, Bagdanga and 70% households in Madanganj mentioned that they perceived an increase in the level of water during meteorological events. Among the non-migrant households, 100% from Bagdanga and Lakshmipur, and 53% from Madanganj perceived sea level rise.

Availability of migration information: 100% of the respondent households had access to information regarding labor migration, such as possible destination, wages and required period of

stay; this information was provided by middlemen who frequently visited their villages is search of possible laborers.

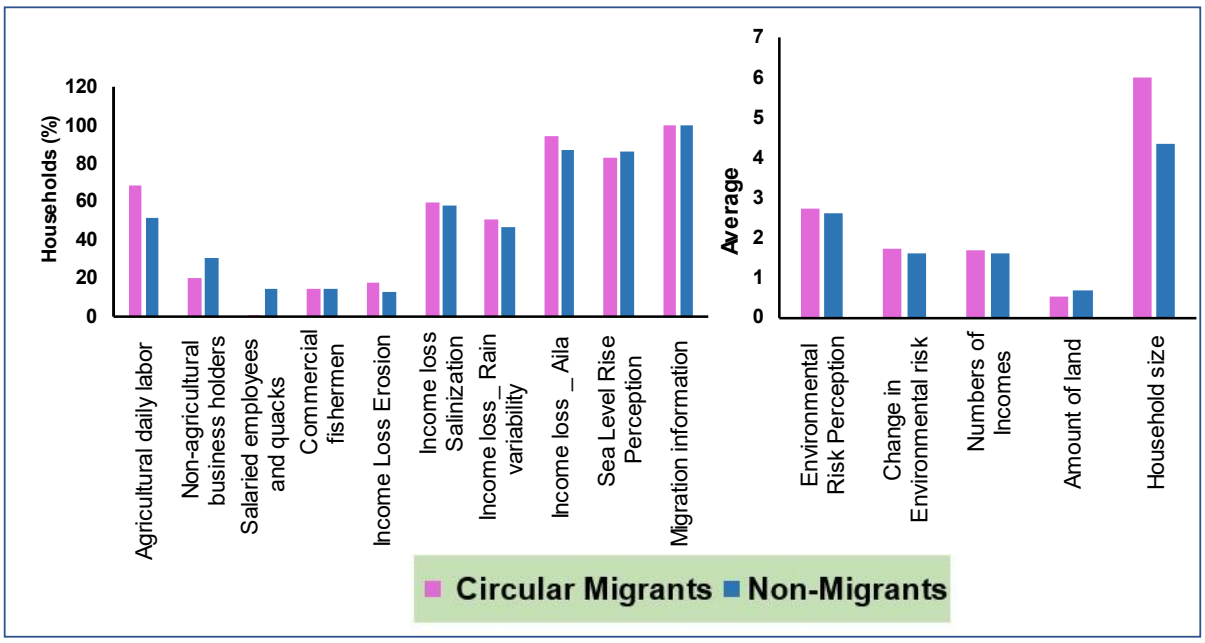

Figure 6-2 Distribution of the predictor variables

Table 6-1 Coding and distribution of predictor variables

Variables	Coding Criteria	Migrant	Non-Migrant	p value
Dependent variable				
Migration	At least 1 migrant (=1) No migrants (=0)	173	109	NA
Independent variables				
Family size	People per household	5	4	<0.05[1]
Landholding	bigha / person	0.5	0.07	>0.05[1]
Environmental Risk Perception	0-4 (no to extreme)	2.7	2.3	>0.05[1]
Change in Environmental risk	1= Increase; 2= Decrease, 3=No Change, 0 = No Risk	1.8	1.8	>0.05[1]
Daily labor	1= Yes, 0= No % Households	73	46	<0.05[2]
Non-agricultural business holders	1= Yes, 0= No % Households	22	27	>0.05[2]
Salaried employees and quacks	1= Yes, 0= No % Households	-	13	NA
Commercial fishermen	1= Yes, 0= No % Households	18	13	>0.05[2]
Only agriculture	1= Yes, 0= No % Households	72	28	<0.05[1]
Income Loss Erosion	1 = Yes, 0= No mention % Households	17	13	<0.05[2]
Income loss Salinization	1= Yes, 0= No mention % Households	59	58	>0.05[2]
Sea Level Rise Perception	1= Yes, 0= No % Households	83	89	<0.05[2]
Availability of migration information	1= Yes, 0= No % Households	100	100	-

[1]p-value of statistical significance was calculated with Mann-Whitney-Wilcoxon (MWW) Test.
[2]p-value of statistical significance was calculated with Fischer's exact test.

Reasons and determinants of temporary labor migration

Table 6-2 provides the reasons for migration and non-migration as mentioned by the migrant and the non-migrant households. In general, circular migration was practiced avoiding poverty and starvation that resulted from an overall lack of economic development, lack of work within the Sundarbans and surrounding places, lower wages in the Sundarbans, surplus labor compared to the available work in the Sundarbans and loss of livelihoods due to natural hazards

and disasters. Ineffective social welfare and rural employment schemes, dependence on dwindling natural resources, contraction of secure forms of employment and expansion of marginal and less secure work has also contributed to unemployment and poverty among the households in the Indian Sundarbans (Molinari, 2017). This resulted in a growing economic vulnerability that is further exacerbated by environmental changes and problems as these compromised the vital natural resources required for survival.

Availability of employment in the cities, on the other hand, ensured a flow of money and helped reduce household poverty (Methmann & Oels, 2015; Black, 2011; Foresight, 2011; Deshingkar, et al., 2008; Tacoli, 2009; McLeman and Smit 2006). During the survey, residents also indicated that after the Cyclone Aila in 2009, when many people started going outside for work, networking developed with the employers at the destination that later promoted more moves. Employers could now contact them via mobile phones or with the help of middlemen who are aware of the huge number of potential migrants in the Indian Sundarbans. These middlemen often visited the villages with employment related information. Moreover, young men, seeing their friends and acquaintances from their communities migrating, were motivated to follow their example. During the survey, several participants indicated that friends and neighbors migrated together to same destinations and stayed together to avoid travel related risks and to reduce the cost of staying in the cities. Past research on labor migration identified the role of social networks as facilitating factors (Haug, 2008; Gurak and Caces, 1992; Massey et al., 1987). In the Indian Sundarbans, both informal networking among friends and neighbors and formal networking with the middlemen and employers served as facilitating factors of migration.

Among the non-migrant households, 23% had a secure income source and said that they did not need to migrate elsewhere for work, but respondents from 36% of the non-migrant

households said that even though they faced difficult economic conditions, the income generated from the Sundarbans served their survival requirements. One of the respondents from a non-migrant household mentioned:

> "*The people of the Sundarbans do not require a lot of money to survive. Each household with agricultural land has a store of a minimum of six months of rice. We grow vegetables for consumption in our backyards and can earn enough by working here and there. People migrate because they want to improve their economic conditions but not for survival. We have enough to survive."*

However, 13 respondents mentioned that they could not migrate due to family compulsions; they will need to migrate in the future to cope with household poverty. During the interview with both the migrant and the non-migrant households, the phrase "we somehow survive with the money we can earn" was mentioned by many respondents when talking about their economic struggles.

Table 6-2 Reasons behind circular labor migration and non-migration

Reasons of labor migration as mentioned by the residents	**Number of Households**
Random economic loss (agricultural) due to rapid onset disasters, salinization, and variability of monsoon/less profit due to random environmental hazards	75
General lack of work in the Sundarbans/less income in-situation/more income outside/growing labor force in the Sundarbans/no work after each harvest/no land/avoid poverty/starvation/growing families and needs	109
Reasons for not migrating for labor work as mentioned by the residents	**Number of Households**
Secured employment in the Sundarbans	26
Still able to manage households with the incomes generated from the Sundarbans	70
Family compulsions and need to migrate for work in future	13

Table 6-3 Logistic Regression Model 1

Coefficients	**Estimate**	**Standard Error**	**z value**	**Pr (>|z|)**
Intercept	-2.052	0.960	-2.136	0.032*
Household Size	0.241	0.085	2.824	0.004**
Landholding per head	-0.029	0.095	-0.312	0.755
Income sources per household	0.293	0.252	1.162	0.245
Households (%) earning their income from				
Agricultural daily labor	-0.094	0.315	-0.299	0.765
Non-agricultural business holders	-0.968	0.361	-2.676	0.007**
Salaried employees and quacks	-4.229	1.110	-3.81	0.000****
Commercial fisheries	-1.315	0.494	-2.661	0.007**
Households (%) that suffered income loss due to				
Erosion	1.039	0.488	2.128	0.033*
Salinity intrusion and soil salinization	-0.373	0.332	-1.121	0.262
Rainfall variability	0.404	0.305	1.325	0.185
Severe storms (Aila in 2009)	0.745	0.540	1.379	0.167
Households (%) that perceived				
Environmental risk	0.147	0.138	1.066	0.286
Change in environmental risk	0.213	0.185	1.152	0.240
Effects of sea level rise	-0.024	0.396	-0.062	0.950

* Indicates $p < 0.05$; ** indicates $p < 0.01$; **** indicates $p < 0.0001$.

Table 6-4 Logistic Regression table with 'agricultural population' as control variable Model 2

Coefficients	Estimate	Standard Error	z value	Pr(>|z|)
Intercept	1.920	0.898	-2.145	0.0319
Household Size	0.212	0.076	2.776	0.005**
Landholding per head	0.022	0.094	-0.233	0.815
Numbers of Incomes	0.163	0.225	0.725	0.468
Households (%) earning their income from				
Only agriculture	1.510	0.298	-5.061	0.000****
Non-agriculture	N/A	N/A	N/A	N/A
Households (%) that suffered income loss due to				
Erosion	0.801	0.457	1.754	0.079
Salinity intrusion and soil salinization	0.110	0.314	-0.352	0.724
Rainfall variability	0.301	0.291	1.034	0.301
Severe storms (Aila in 2009)	0.789	0.513	1.538	0.124
Households (%) that perceived				
Environmental risk	0.172	0.131	1.314	0.188
Change in environmental risk	0.259	0.180	1.44	0.149
Effects of sea level rise	0.156	0.387	-0.403	0.686

* Indicates $p < 0.05$; ** indicates $p < 0.01$; **** indicates $p < 0.0001$.

The results of logistic regression model 1 revealed that the variables ‘in-situ non-farm income sources’, ‘household size’, and ‘economic losses due to erosion’ were important determinants of labor migration among the households in the Indian Sundarbans. Model 1 (Table 6-3) results suggested that with every unit increase in the number of households with salaried employment, non-farm businesses and commercial fisheries, the log odds of labor migration decreased by 4.2, 1.3 and 0.96, respectively. In contrast, with increase in the number of households with solely agricultural-based income including the daily laborers, the log odds of labor migration increased by 1.5 (Model 2, Table 6-4).

This suggests that the revenue generated from agriculture or by working as in-situ daily laborers within the Sundarbans was not enough to run these households and it was necessary to diversify their livelihoods by pursuing non-farm and stable economies to survive. Such practices of livelihood diversifications are meant for creating a ‘diverse portfolio of activities’ for economic

benefits (Ellis, 1988). In case residents failed to find viable livelihood diversification options in place, they migrated.

Agriculture in the Sundarbans is primarily practiced for household consumption and any surplus is sold. With limited cropping area, huge population density and fragmented croplands, yield is low (Ghosh et al., 2019; Das et al., 2015). Yield is further reduced due to environmental problems like erosion, salinization of lands, rainfall delays and cyclones (Hazra et al., 2018). In the villages of Gosaba Block, 84 households pursued agriculture as their only income source. All these households reported economic losses due to environmental problems of which 92% migrated for work. Even in the villages of Dakshin Chandanpiri and Madanganj where erosion and salinization were not reported as major environmental problems, 72% of the respondents who migrated had agriculture as their only income source.

On the other hand, non-farm income sources like government jobs and businesses generated more money compared to subsistence agriculture, and these economies are less climate sensitive. Therefore, the households with non-farm income sources had a lesser probability of migration. This probability was least among the households that had a fixed monthly income, e.g., schoolteachers, government officials or the quack physicians who were well established in their practices. Only one household that had a government job belonged to the 'migrant category,' but this migration took place before the migrant's son got a job in the local government office.

Businesses also provided a more secure income compared to subsistence agriculture. The business owners mentioned that they too faced economic losses, mostly after cyclones or crop failures due to salinity intrusion or monsoonal delays; at such times, the economies of the entire village community are affected. Sixty-eight percent of the business-owning households also owned agricultural lands and all of them reported economic losses due to environmental problems.

Among these households, 52% belonged to the migrant category and migrated for an additional income that was required for their survival. The others who did not migrate mentioned that they could generate enough income from their businesses and agricultural lands (if any) to sustain them in the Sundarbans. During times of economic stress, they survived on savings till their businesses revived.

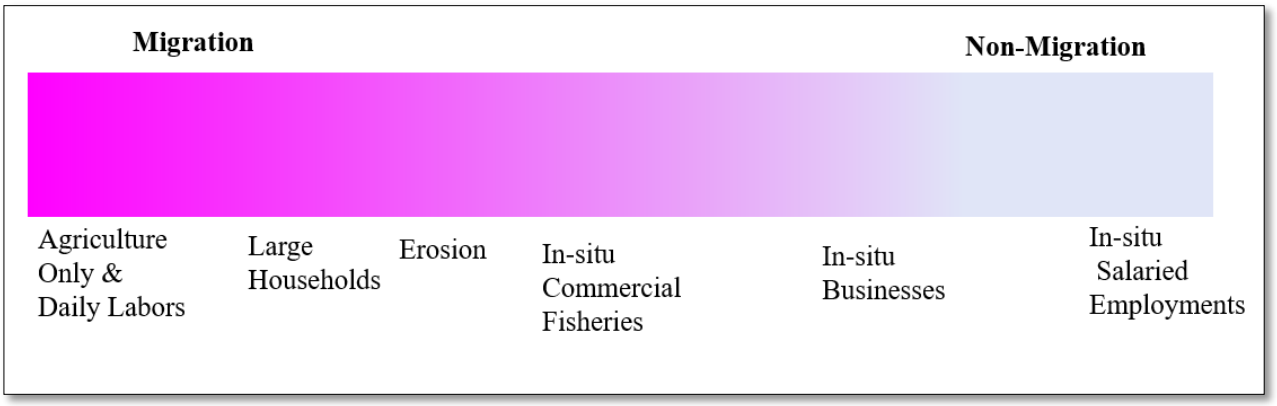

Figure 6-3 The determinants of circular labor migration in the Indian Sundarbans

Commercial fishing lowers the odds of migration; 70% of households that practice deep sea fishing did not migrate for labor work anywhere outside the Sundarbans as income generated from fishing was enough for their survival. However, the households with inland fish farms reported economic losses due to environmental problems and five of these households pursued temporary labor migration as a reactive adaptation after they suffered huge economic losses during the Cyclone Aila in 2009.

Among the variables pertaining to environmental risk perceptions, i.e., perception of sea level rise, environmental risk perception, and perception of changes in environmental risk, were also not found to be statistically significant determinants of migration. Economic loss due to erosion was the only environmental variable that was classified as a determinant of migration as one unit increase in erosion increased log odds of labor migration by 1.04 (Model 1) (but economic

losses due to erosion was not found a statistically significant determinant of migration as per Model 2).

This determinant was particularly relevant in the erosion-affected village of Bagdanga where 73% of the households pursued labor migration and survived on remittances as their lands were permanently lost due to erosion or suffered a permanent loss of productivity due to continuous salinity intrusion. Erosion was also found to be one of the propelling factors of migration in a study in the coastal areas of Bangladesh (Bernzen et al., 2019). By comparison, in the village of Lakshmipur, while 80% of its residents reported an increase in coastal erosion, only 20% of them reported economic losses due to these hazards. This is because some of them pursued deep sea fishing, an activity not impacted by erosion in the village. Additionally, they did not own any agricultural land during the time of the survey.

It should be noted here that even though 56% of the households reported major economic loss due to salinization of land, this variable was not characterized as a determinant of migration according to the results of the logistic regression models 1 and 2. Chen and Muller (2019) reported an increase in the rates of internal migration during periods of salinity in Bangladesh, but according to our study, while a considerable number of people migrated to cope with salinization related economic losses, 36% households in the study area did not migrate even after being affected by major salinization, and there was no statistical difference of mean between the number of migrant and non-migrant households who suffered due to salinization.

While erosion resulted in permanent loss of lands and destruction of assets, leaving no option other than migration, salinization due to embankment breaching or during cyclones resulted in a temporary loss of productivity of the agricultural lands (Joardar and Miller, 2013). After Cyclone Aila, vast parts of the study area were inundated with saline water. But according to the

respondents, these lands regained productivity approximately three years following the storm. The non-migrant households that suffered salinization of lands mentioned that during times of such economic loss, they managed to find some work within their villages or in the nearby villages until their lands regained productivity or the overall economy of their communities improved. Others however, migrated.

Similar explanations can be provided for the variables such as 'economic loss due to monsoonal delays' and 'economic loss due to tropical storms.' These environmental hazards affected large parts of the Sundarbans but did not result in the permanent destruction of assets. Some of the households that suffered economic loss due to these problems managed to find work within the villages despite environmental stress. Others could not, indicating the influence of unequal access to resources on the decisions to migrate (Carr et al., 2008, Wrathall et al., 2014).

The Sundarbans has limited resources that are unequally distributed among a population of 4.5 million. These resources are frequently affected by different environmental problems. These environmental problems reduce agricultural yield and restrict access to natural resources (Radel et al., 2019). Moreover, the Indian Sundarbans do not have an established secondary or tertiary sector economy that may sustain the growing population (Molinari, 2017). Therefore, while some people managed to find work that paid them enough to survive even during times of temporary environmental distress, others migrated to places with better wages, and remittances formed a part of their household income.

However, when extensive parts of the villages or islands suffered permanent loss of agricultural lands due to erosion and related salinization, the chances of finding work in their villages declined and the proportion of migrant households increased. Both the logistic regression models (Table 6.3 and 6.4) indicate that the odds of migration increased with increased size of

households. While the relationship might seem straightforward in the sense that larger households require more resources to survive, without adequate information about household compositions any conclusion will be premature.

Conclusion

This study identified and quantified the determinants of labor migration among households in Indian Sundarbans using household-level primary survey data, qualitative analysis, and a logistic regression modeling approach. The results revealed that residents migrated for work to avert poverty and starvation that largely results from dependence on subsistence farming and the lack of economic development in the area. Migration was facilitated by networking that eventually developed between the migrants and their employers and by middlemen who regularly visited these villages with work related information. Results also suggested that shifting from solely agricultural-based livelihoods to non-agricultural livelihoods significantly reduced the probability of labor migration among households of Indian Sundarbans. Among non-agricultural livelihoods, salaried employment was found to be the most effective determinant that acted against labor migration, followed by non-agricultural businesses, and commercial fisheries, respectively. We also investigated the role of erosion, salinity intrusion, rainfall variability and severe storms like cyclone Aila on labor migration and found that erosion was the only environmental factor that significantly determined a household's probability of migrating for work; other environmental hazards may have motivated such moves. Erosion leads to a permanent loss of lands and assets among households with agricultural-based income, restricts other income opportunities in place by gradually affecting the overall economy of the community, thus leaving little or no option other than to migrate for a living.

Labor migration may seem one of the most viable adaptation options in the Sundarbans at present. Whether it should be promoted as an adaptation to climate change, however, should be reconsidered as it may leave behind vulnerable seniors and children, and will not be beneficial to the families that do not have a member fit enough to migrate. Labor migration also entails extreme hard work, and migrants may be subjected to exploitation at the destination. While migration is being pursued as one of the economic strategies to maintain the needs of families amid environmental risk, in the long term the residents of the Indian Sundarbans can benefit from robust in-situ adaptation options such as planned conversion of the permanently saline agricultural lands to commercial saline water fisheries, use of salinity tolerant rice varieties, and establishing non-farm income sources. One additional option would be to develop vocational training for youth with a focus on skill sets used in the secondary and tertiary sectors of the local economies.

Chapter 7 - Conclusions

This study investigates the adaptation strategies and coping mechanisms used by the residents of the Indian Sundarbans to respond to the impacts of environmental changes and problems. It specifically focuses on the role of migration as an adaptation and uses resident perceptions of environmental problems to understand their types, intensities and impacts on household economies.

A household-level primary survey was conducted in ten villages from western and eastern areas of the Indian Sundarbans. Survey results showed that the residents perceived riverbank erosion, salinity intrusion, monsoonal delays, and tropical cyclones as the major environmental problems that adversely affected their livelihood, and acknowledged the effects of sea level rise, rapid sedimentation in the rivers, global warming, and subsidence of the delta. To cope with the impacts of such environmental challenges, residents preferred several in-situ structural adaptation measures which included the strengthening of embankments, construction of storm shelters and raised platforms as a shelter during flooding. Households also used in-situ non-structural adaptation strategies and coping mechanisms such as borrowing money, taking out mortgages, acquiring government aid, using subsidized grains, and growing produce in small kitchen gardens.

Circular labor migration was pursued by 58% of the surveyed households in the study area as an adaptation strategy mainly to reduce economic vulnerability. These households sent at least one member to work outside the Sundarbans to cities and used remittances for household consumption, rebuilding houses after a disaster, building stronger houses to survive future hazards, and setting up small in-situ non-farm businesses. Such migration was pursued as an adaptation strategy in different ways by different households depending on their socio-economic characteristics and the types and intensities of the environmental problems they faced.

It was found that circular migration could be used as a reactive response when pursued after a sudden onset hazard, as a livelihood diversification strategy, and as an alternative livelihood strategy mostly in the erosion affected areas where people have suffered permanent loss of livelihoods. When used for livelihood diversification, households could either rely partially on remittances while simultaneously actively working in the source area or rely completely on remittances besides subsistence farming at the source. Livelihood diversification through temporary migration could be practiced as a present survival mechanism or as an anticipatory adaptation measure to reduce household vulnerability from future natural hazards. Landless households could also rely completely on remittances for survival. These migrants spent considerably more time away from their villages compared to the others. Lower wages in the Sundarbans, provision of continuous income from outside, a high chance of being economically affected by environmental problems, and permanent loss of livelihoods (agricultural lands) due to erosion were some of the reasons these households relied completely on remittances for survival.

This study also evaluated the socio-economic and environmental determinants of circular migration. Households that solely relied on agriculture for survival had the greatest probability of such migration. This probability decreased as they shifted to non-agricultural income sources such as small businesses, salaried employments, or deep-sea fishing. Among the environmental factors, erosion was the only significant factor that determined a household's probability of migration.

These findings together highlight that circular labor migration was driven by several factors: reliance on subsistence economy; prevailing poverty and lack of secondary or tertiary sector activities at the source. Such migration was facilitated by the networking between migrants and employers that developed over time.

Environmental factors such as salinity, monsoonal delays or cyclones might have acted as catalysts of migration but their effects were not statistically significant as determinants of migration. These hazards mostly caused temporary disruptions to agriculture. While some people migrated after such disruptions, others survived by working odd jobs at the source until their land could be re-cropped. Erosion however, resulted in permanent loss of land and was a dominant factor in migration from the places that experienced this natural hazard.

While circular labor migration was used as an adaptation strategy and coping mechanism to reduce economic vulnerability caused by both environmental and non-environmental factors, permanent migration from the Sundarbans to less environmentally vulnerable places was not a preferred adaptation strategy. Even though residents perceived an environmental risk, it was not enough to initiate relocation and abandonment of their ancestral homes and communities. Poverty, lack of resources required to settle somewhere else, strong community and place attachments, cultural gaps with the possible destinations, and lack of income opportunities to sustain families at the destinations were the major reasons why people wanted to stay in the Sundarbans despite environmental risks.

Moreover, the people of the Sundarbans have lived through environmental challenges and are adapted to extreme situations. For them poor infrastructure in the Sundarbans and lack of in-situ employments were more pressing issues. They considered traffic congestion and frequent road accidents in the destination cities riskier than environmental challenges in the Sundarbans that they were used to. However, the households that had lost their homes and assets due to erosion conveyed their wish to relocate if the government provided them with places to stay and jobs. These households however, had no plans for potential island inundation in the future other than to simply follow their neighbors and rely on the government's decision to provide them lands.

To my knowledge this is the first systematic study of its kind in the Indian Sundarbans. Previous studies in other places revealed that migration could be used as an adaptation to reduce economic vulnerabilities in environmentally challenged places. This study contributed to the environmental migration and adaptation literature by highlighting the different ways migration could be used as an adaptation, how such adaptive responses varied with types of environmental problems such as salinization, tropical cyclones, erosion, and the relative importance of the economic and environmental factors in migration from the Indian Sundarbans.

This study also shows that even though there are numerous speculations about mass migration due to the economic impacts of environmental change and island inundation, the residents in the Indian Sundarbans did not consider such migratory response as a viable option towards reduction of environmental or economic risks except in the places that experienced extreme erosion. This does not imply that future mass migration from the Indian Sundarbans may not happen. At present environmental risk might not pose a challenge big enough to induce permanent migration, but as the impacts of climate change are predicted to intensify over the next 50 to 100 years, without planned in-situ adaptation measures, the environment might pose a bigger risk to these communities, and residents may respond differently. Our research calls for identification of the islands that are at an imminent risk of inundation and developing and implementing plans towards respectfully relocating the affected population.

The results of this research have important implications for the formulation of future policies regarding the reduction of climate change impacts in the Indian Sundarbans. One view is that circular migration from climate vulnerable places should be considered as an effective way to reduce climate vulnerabilities, but others have considered such migration as coercive and exploitative and doubted the “democratic and progressive” nature of policies facilitating such

migration. Bettini (2014) criticized the adaptive (climate) migration discourse on the grounds that it inadvertently implies that in order to be resilient to climate impacts, the poverty-stricken victims of climate change must be available to the needs of the neo-liberal market, must adapt to the policies of the market and are compelled to develop capacities as demanded by the market economy to be competitive enough to survive in the market. Similarly, Felli and Castree (2012), suggest that the effective responses to climate change should be a societal responsibility and not require individual households to change their livelihoods or migrate from their native places except under extreme situations like island inundation. However, effects of positive mitigation measures to reduce greenhouse gas emissions on a global level would take decades to be felt in vulnerable places such as the Indian Sundarbans and with the intensified effects of climate change, frequent disasters, the rate of labor migration from these poverty-stricken vulnerable environments is likely to increase. An effective policy to facilitate temporary migration is needed, but this cannot be viewed as a solution to climate impacts. Such policies must be directed towards wellbeing and development of the migrant workers, ensure social security, fair working hours, healthcare benefits and prevent exploitation at the regions of destination.

This study revealed that the probability of migration is highest among people who are solely dependent on agriculture and those who lost lands and assets due to erosion. To reduce the vulnerabilities faced by agricultural households in such environmentally challenged places, a shift towards in-situ less-climate sensitive non-farm livelihood should be prioritized. This may include community based alternative livelihood activities in the local food processing industries, household-scale textile industries, animal husbandry, and the expansion of commercial scale coconut plantations that is being pursued under the guidance of some non-governmental organizations such as *MUKTI* locally in small pockets of the Indian Sundarbans. In places

impacted by salinization, saline water fisheries can be lucrative. Extensive research on salinity tolerant rice varieties should be conducted and their use should be promoted among the farming communities. Micro-credit organizations should be strengthened so that households can use loans to set up in-situ businesses. Such ventures can however be feasible and profitable only if the government invests in infrastructure development such as the construction of roads and bridges connecting various blocks of the Sundarbans to the mainland. Ecosystem based protection efforts such as mangrove plantation along the coasts and riverbanks should also be undertaken after careful planning and research. The government and non-government bodies should also promote community-based climate awareness to educate the locals on the present and future environmental risks and formulate adaptation measures considering local knowledge and preferences.

The government should also expand vocational training programs in the Sundarbans. Such programs may impart trainings of advanced agriculture and commercial fishing, business management, marketing, tourism, engineering, health care, and small-scale household industries, among many others. Through vocational training, the youth of the Indian Sundarbans could effectively join the skilled labor market in the urban and mainland areas. These adaptation measures will address the present environmental vulnerability and can empower the residents to decide whether to voluntarily relocate in future to environmentally safer places.

In places that are at an imminent risk of inundation, the government must conduct planned relocation of the affected population to places where they could practice their present livelihoods without facing climate threats or practice alternative livelihoods. Relocation must be conducted considering the social and psychological aspects of such population relocation.

References

1) Adams, H. (2016). Why populations persist: mobility, place attachment and climate change. *Population and Environment*, *37*(4), 429-448.

2) Adger, N., & Adams, H. (2013). Migration as an adaptation strategy to environmental change. *World Science Report* (261-264)

3) Adger, W. N., Arnell, N. W., & Tompkins, E. L. (2005). Successful adaptation to climate change across scales. *Global environmental change*, 15(2), 77-86.

4) Adger, W. N., Dessai, S., Goulden, M., Hulme, M., Lorenzoni, I., Nelson, D. R., ... & Wreford, A. (2009). Are there social limits to adaptation to climate change? *Climatic change*, 93(3), 335-354.

5) Adger, W. N., Hughes, T. P., Folke, C., Carpenter, S. R., & Rockström, J. (2005). Social-ecological resilience to coastal disasters. *Science*, 309(5737), 1036-1039.

6) Adger, W. N., Huq, S., Brown, K., Conway, D., & Hulme, M. (2003). Adaptation to climate change in the developing world. *Progress in development studies*, 3(3), 179-195.

7) Afifi, T. (2011). Economic or environmental migration? The push factors in Niger. *International Migration*, *49*, e95-e124.

8) Afifi, T., & Warner, K. (2008). The impact of environmental degradation on migration flows across countries. *UN Institute of Environment and Human Society, Bonn.*

9) Afsar, R. (2003, June). Internal migration and the development nexus: the case of Bangladesh. In *Regional Conference on Migration, Development and Pro-Poor Policy Choices in Asia* (pp. 22-24).

10) Agesa, R. U., & Kim, S. (2001). Rural to urban migration as a household decision: Evidence from Kenya. *Review of Development Economics*, *5*(1), 60-75.

11) Agrawala, S., & Carraro, M. (2010). Assessing the role of microfinance in fostering adaptation to climate change. OECD, Environment Directorate, France

12) Akhand, A., Chanda, A., Dutta, S., Manna, S., Sanyal, P., Hazra, S. & Dadhwal, V. K. (2013). Dual character of Sundarban estuary as a source and sink of CO 2 during summer: an investigation of spatial dynamics. *Environmental monitoring and assessment*, *185*(8), 6505-6515.

13) Al, W., Orking, G., & Clima, O. (2008). Climate change and food security: a framework document. *FAO Rome*.

14) Alam, G. M., Alam, K., & Mushtaq, S. (2017). Climate change perceptions and local adaptation strategies of hazard-prone rural households in Bangladesh. *Climate Risk Management*, *17*, 52-63.

15) Allgood, L., & McNamara, K. E. (2017). Climate-induced migration: Exploring local perspectives in Kiribati. *Singapore Journal of Tropical Geography*, *38*(3), 370-385.

16) Alscher, S. (2011). Environmental degradation and migration on Hispaniola Island. *International Migration*, *49*, e164-e188.

17) Amundsen, H. (2015). Place attachment as a driver of adaptation in coastal communities in Northern Norway. *Local Environment*, *20*(3), 257-276.

18) Anik, S. I., & Khan, M. A. S. A. (2012). Climate change adaptation through local knowledge in the north eastern region of Bangladesh. *Mitigation and adaptation strategies for global change*, *17*(8), 879-896.

19) Anurag Danda, A., Ghosh, N., Bandyopadhyay, J., & Hazra, S. (2019). Managed retreat: adaptation to climate change in the Sundarbans ecoregion in the Bengal Delta. *Journal of the Indian Ocean Region*, *15*(3), 317-335.

20) Apata, T. G., Samuel, K. D., & Adeola, A. O. (2009). *Analysis of Climate Change Perception and Adaptation among Arable Food Crop Farmers in Southwestern Nigeria* (No. 1005-2016-79140).

21) Arnall, A., & Kothari, U. (2015). Challenging climate change and migration discourse: Different understandings of timescale and temporality in the Maldives. *Global Environmental Change*, *31*, 199-206.

22) Asrat, P., & Simane, B. (2018). Farmers' perception of climate change and adaptation strategies in the Dabus watershed, North-West Ethiopia. *Ecological processes*, *7*(1), 1-13.

23) Asrat, P., & Simane, B. (2018). Farmers' perception of climate change and adaptation strategies in the Dabus watershed, North-West Ethiopia. *Ecological processes*, *7*(1), 1-13.

24) Azevedo de Almeida, B., & Mostafavi, A. (2016). Resilience of infrastructure systems to sea-level rise in coastal areas: Impacts, adaptation measures, and implementation challenges. Sustainability, 8(11), 1115.

25) Bandyopadhyay, S, N S Kar, S Dasgupta, and D Mukherjee. (2018b) "Long-Term Island Area Alternations in the India and Bangladeshi Sundarban: An Assessment Using Cartographic and Remote Sending Sources." Paper prepared for the Sundarbans Targeted Environmental Studies, South Asia Water Initiative, *World Bank, Washington, DC*

26) Banerjee, S., Chowdhury, A. N., Schelling, E., & Weiss, M. G. (2013). Household survey of pesticide practice, deliberate self-harm, and suicide in the Sundarban region of West Bengal, India. *BioMed research international*, *2013*.

27) Bardsley, D. K., & Hugo, G. J. (2010). Migration and climate change: examining thresholds of change to guide effective adaptation decision-making. *Population and Environment*, *32*(2), 238-262.

28) Barik, J., Mukhopadhyay, A., Ghosh, T., Mukhopadhyay, S. K., Chowdhury, S. M., & Hazra, S. (2018). Mangrove species distribution and water salinity: an indicator species approach to Sundarban. *Journal of Coastal Conservation*, *22*(2), 361-368.

29) Barnett, J., & Webber, M. (2009). Accommodating migration to promote adaptation to climate change. *Commission on Climate Change and Development*.

30) Barnum, H. N., & Sabot, R. H. (1977). *Education, employment probabilities and rural-urban migration in Tanzania* (Vol. 39, No. 2). Publication Unit, World Bank.

31) Becker, G. S. (1975). Investment in human capital: effects on earnings. In *Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education, Second Edition* (pp. 13-44). NBER.

32) Below, T. B., Mutabazi, K. D., Kirschke, D., Franke, C., Sieber, S., Siebert, R., & Tscherning, K. (2012). Can farmers' adaptation to climate change be explained by socio-economic household-level variables? *Global Environmental Change*, *22*(1), 223-235.

33) Bera, M. K. (2013, September). Environmental refugee: A study of involuntary migrants of Sundarban islands. In *Proceedings of the 7th international conference on Asian and Pacific Coasts (APAC 2013) Bali, Indonesia* (pp. 916-925).

34) Bernzen, A., Jenkins, J. C., & Braun, B. (2019). Climate change-induced migration in coastal Bangladesh? A critical assessment of migration drivers in rural households under economic and environmental stress. *Geosciences*, *9*(1), 51.

35) Berringer, A. (2012). *Climate change displacement and global governance: a case study of three intergovernmental organizations and the conflict between the member states and bureaucracy*. (Doctoral Dissertation, Louisiana State University)

36) Berringer, A. C. (2012). Climate change and emigration: comparing" Sinking islands" and Jamaica. *Miradas en movimiento*, (1), 125-141.

37) Bettini, G. (2013). *Climatised Moves: Climate-induced Migration and the Politics of Environmental Discourse* (Doctoral dissertation, Lund University).

38) Bettini, G. (2014). Climate migration as an adaption strategy: de-securitizing climate-induced migration or making the unruly governable? *Critical Studies on Security*, *2*(2), 180-195.

39) Bhandari, P. (2004). Relative deprivation and migration in an agricultural setting of Nepal. *Population and Environment*, *25*(5), 475-499.

40) Bhattachan, A., Jurjonas, M. D., Moody, A. C., Morris, P. R., Sanchez, G. M., Smart, L. S., & Seekamp, E. L. (2018). Sea level rise impacts on rural coastal social-ecological systems and the implications for decision making. *Environmental Science & Policy*, *90*, 122-134.

41) Bhunia, R., & Ghosh, S. (2011). Waterborne cholera outbreak following cyclone Aila in Sundarban area of West Bengal, India, 2009. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, *105*(4), 214-219.

42) Biermann, F., & Boas, I. (2008). Protecting climate refugees: the case for a global protocol. *Environment: Science and Policy for Sustainable Development*, *50*(6), 8-17.

43) Bilsborrow, R. E., McDevitt, T. M., Kossoudji, S., & Fuller, R. (1987). The impact of origin community characteristics on rural-urban out-migration in a developing country. *Demography*, *24*(2), 191-210.

44) Black, R., Adger, N., Arnel, N., Dercon, S., Geddes, A., & Thomas, D. (2017). Foresight: Migration and global environmental change, final project report.

45) Black, R., Arnell, N. W., Adger, W. N., Thomas, D., & Geddes, A. (2013). Migration, immobility and displacement outcomes following extreme events. *Environmental Science & Policy*, *27*, S32-S43.

46) Black, R., Bennett, S. R., Thomas, S. M., & Beddington, J. R. (2011). Migration as adaptation. *Nature*, *478*(7370), 447-449.

47) Black, Richard (2001) Environmental refugees: myth or reality? United Nations High Commissioner for Refugees. New issues in refugee research, working paper 34.

48) Bomuhangi, A., Nabanoga, G., Namaalwa, J. J., Jacobson, M. G., & Abwoli, B. (2016). Local communities' perceptions of climate variability in the Mt. Elgon region, eastern Uganda. *Cogent Environmental Science*, *2*(1), 1168276.

49) Bourke, B. (2014). Positionality: Reflecting on the research process. *Qualitative Report*, *19*(33).

50) Brock, V. T., & Paul, B. K. (2003). Public response to a tornado disaster: the case of Hoisington, Kansas. In *Papers and Proceedings of Applied Geography Conferences* (Vol. 26, pp. 343-351). [np]; 1998.

51) Brooks, N. (2003). Vulnerability, risk and adaptation: A conceptual framework. *Tyndall Centre for Climate Change Research Working Paper*, *38*(38), 1-16.

52) Brooks, N., Adger, W. N., & Kelly, P. M. (2005). The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. *Global environmental change*, *15*(2), 151-163.

53) Brown, L. A., & Moore, E. G. (1970). The intra-urban migration process: a perspective. *Geografiska Annaler: Series B, Human Geography*, *52*(1), 1-13.

54) Bryan, E., Deressa, T. T., Gbetibouo, G. A., & Ringler, C. (2009). Adaptation to climate change in Ethiopia and South Africa: options and constraints. *Environmental science & policy*, *12*(4), 413-426.

55) Cai, R., & Oppenheimer, M. (2013). *An Agent-Based Model of Climate-Induced Agricultural Labor Migration* (No. 150972). Agricultural and Applied Economics Association.

56) Carr, E. R. (2005). Placing the environment in migration: environment, economy, and power in Ghana's Central Region. *Environment and Planning A*, *37*(5), 925-946.

57) Castles, S. (2002). Environmental change and forced migration: making sense of the debate. Geneva, UNHCR.

58) Cattaneo, C., Beine, M., Froehlich, C. J., Kniveton, D., Martinez-Zarzoso, I., Mastrorillo, M., & Schraven, B. (2019). Human migration in the era of climate change. Review of Environmental Economics and Policy, 13 (2), 189–206.

59) Census of India, 2011. South 24 Paragana District Population data

60) Chakraborty, S. (2015). Investigating the impact of severe cyclone Aila and the role of disaster management department-A study of Kultali block of Sundarban. *American Journal of Theoretical and Applied Business*, *1*(1), 6-13.

61) Chand, B. K., Trivedi, R. K., & Dubey, S. K. (2012). Climate change in Sundarban and adaptation strategy for resilient aquaculture. *CIFRI Compendium on Sundarban, Retrospect and Prospects. Central Inland Fisheries Research Institute, Kolkata, India*, 116-128.

62) Chen, J. J., Mueller, V., Jia, Y., & Tseng, S. K. H. (2017). Validating migration responses to flooding using satellite and vital registration data. *American Economic Review*, *107*(5), 441-45.

63) Chen, J., & Mueller, V. (2018). Coastal climate change, soil salinity and human migration in Bangladesh. *Nature Climate Change*, *8*(11), 981-985.

64) Chowdhury, A., Maiti, S. K., & Bhattacharyya, S. (2016). How to communicate climate change 'impact and solutions' to vulnerable population of Indian Sundarbans? From theory to practice. *SpringerPlus*, *5*(1), 1-17.

65) Christian, A. (2007). Human tide: The real migration crisis. London: Christian Aid.

66) Clark, W.A.V. (1986). Human Migration. Reprint. Edited by Grant Ian Thrall. WVU Research Repository, 2020.

67) Conisbee, M., & Simms, A. (2003). *Environmental refugees: The case for recognition* (pp. 17-18). London: New Economics Foundation.

68) Connelly, L. M. (2008). Pilot studies. *Medsurg Nursing*, *17*(6), 411.

69) Cross, J. A. (2001). Megacities and small towns: different perspectives on hazard vulnerability. *Global Environmental Change Part B: Environmental Hazards*, *3*(2), 63-80.

70) Das, S., Bhadra, T., & Hazra, S. (2015, December). Water for Agriculture in a Vulnerable Delta: A Case Study of Indian Sundarban. In *AGU Fall Meeting Abstracts* (Vol. 2015, pp. GC41F-1150).

71) DasGupta, R., & Shaw, R. (2015). An indicator based approach to assess coastal communities' resilience against climate related disasters in Indian Sundarbans. *Journal of coastal conservation*, *19*(1), 85-101.

72) Datta, D., Chattopadhyay, R. N., & Deb, S. (2011). Prospective livelihood opportunities from the mangroves of the Sunderbans, India. *Research Journal of Environmental Sciences*, *5*(6), 536.

73) Davis, Benjamin, Guy Stecklov, and Paul Winters. "Domestic and international migration from rural Mexico: Disaggregating the effects of network structure and composition." *Population Studies* 56.3 (2002): 291-309.

74) De Souza, K., Kituyi, E., Harvey, B., Leone, M., Murali, K. S., & Ford, J. D. (2015). Vulnerability to climate change in three hot spots in Africa and Asia: key issues for policy-relevant adaptation and resilience-building research.

75) Debela, N., Mohammed, C., Bridle, K., Corkrey, R., & McNeil, D. (2015). Perception of climate change and its impact by smallholders in pastoral/agropastoral systems of Borana, South Ethiopia. *SpringerPlus*, *4*(1), 1-12.

76) Debnath, A. (2018). Land Use and Land Cover Change Detection of Gosaba Island of the Indian Sundarban Region by Using Multitemporal Satellite Image. *Int. J. Hum. Soc. Sci*, *7*(1), 209-217.

77) Deressa, T. T., Hassan, R. M., & Ringler, C. (2011). Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia. *The Journal of Agricultural Science*, *149*(1), 23-31.

78) Deshingkar, P. (2008). Circular internal migration and development in India. *Migration and development within and across borders: research and policy perspectives on internal and international migration. Geneva: International Organization for Migration/Social Science Research Council*, 161-87.

79) Deshingkar, P., Sharma, P., Kumar, S., Akter, S., & Farrington, J. (2008). Circular migration in Madhya Pradesh: changing patterns and social protection needs. *The European Journal of Development Research*, *20*(4), 612-628.

80) Dey, T., Pala, N. A., Shukla, G., Pal, P. K., & Chakravarty, S. (2017). Perception on impact of climate change on forest ecosystem in protected area of West Bengal, India. *Journal of forest and environmental science*, *33*(1), 1-7.

81) Dhara, S., & Paul, A. K. (2016). Status of agriculture-a case study at Patharpratima Block of South 24 Parganas district. *International Journal of Innovative Science, Engineering & Technology*, *3*(2), 239-246.

82) Donner, S. D., & Webber, S. (2014). Obstacles to climate change adaptation decisions: a case study of sea-level rise and coastal protection measures in Kiribati. *Sustainability Science*, *9*(3), 331-345.

83) Dynes, R. R., & Quarantelli, E. L. (1976). *Organizational Communications and Decision Making in Crises*. Ohio State Univ Columbus Disaster Research Center.

84) Ejembi, E. P., & Alfa, G. B. (2012). Perceptions of climate change in Africa: regional agricultural perspectives. *Research on Humanities and Social Sciences*, *2*(5), 1-10.

85) Ellis, F. (1998). Household strategies and rural livelihood diversification. *The journal of development studies*, *35*(1), 1-38.

86) Ericson, J. P., Vörösmarty, C. J., Dingman, S. L., Ward, L. G., & Meybeck, M. (2006). Effective sea-level rise and deltas: Causes of change and human dimension implications. *Global and Planetary Change*, *50*(1-2), 63-82.

87) Ezra, M., & Kiros, G. E. (2001). Rural Out-migration in the Drought Prone Areas of Ethiopia: A Multilevel Analysis 1. International Migration Review, 35(3), 749-771.

88) Fankhauser, S., Smith, J. B., & Tol, R. S. (1999). Weathering climate change: some simple rules to guide adaptation decisions. *Ecological economics*, *30*(1), 67-78.

89) Felli, R., & Castree, N. (2012). Neoliberalising adaptation to environmental change: foresight or foreclosure?. *Environment and Planning A*, *44*(1), 1-4.

90) Findlay, A., & Geddes, A. (2011). Critical views on the relationship between climate change and migration: some insights from the experience of Bangladesh. In *Migration and climate change* (pp. 138-159). UNESCO/Cambridge University Press.

91) Fordham, M. H. (1992). *Choice and constraint in flood hazard mitigation: the environmental attitudes of floodplain residents and engineers* (Doctoral dissertation, Middlesex University).

92) Fresque-Baxter, J. A., & Armitage, D. (2012). Place identity and climate change adaptation: a synthesis and framework for understanding. *Wiley Interdisciplinary Reviews: Climate Change*, *3*(3), 251-266.

93) Frihy, O. E., & El-Sayed, M. K. (2013). Vulnerability risk assessment and adaptation to climate change induced sea level rise along the Mediterranean coast of Egypt. *Mitigation and adaptation strategies for global change*, *18*(8), 1215-1237.

94) Ganguly, D., Mukhopadhyay, A., Pandey, R. K., & Mitra, D. (2006). Geomorphological study of Sundarban deltaic estuary. *Journal of the Indian Society of Remote Sensing*, *34*(4), 431-435.

95) Garip, F. (2008). Social capital and migration: How do similar resources lead to divergent outcomes?. *Demography*, *45*(3), 591-617.

96) Gemenne, F. (2010). Migration, a possible adaptation strategy? institute of sustainable development and international relations, Paris, France

97) Gemenne, F., & Blocher, J. (2017). How can migration serve adaptation to climate change? Challenges to fleshing out a policy ideal. *The Geographical Journal*, *183*(4), 336-347.

98) Gentle, P., & Maraseni, T. N. (2012). Climate change, poverty and livelihoods: adaptation practices by rural mountain communities in Nepal. *Environmental science & policy*, *21*, 24-34.

99) Ghosh, A., & Mukhopadhyay, S. (2016). Quantitative study on shoreline changes and Erosion Hazard assessment: case study in Muriganga–Saptamukhi interfluve, Sundarban, India. *Modeling Earth Systems and Environment*, *2*(2), 75.

100) Ghosh, A., & Mukhopadhyay, S. (2017). Process Form Responses of Shoreline Erosion Using Geo-Spatial Techniques: Case Study in Muriganga-Saptamukhi Interfluve, Sundarban. *Earth Science India*, *10*.

101) Ghosh, A., Schmidt, S., Fickert, T., & Nüsser, M. (2015). The Indian Sundarban mangrove forests: history, utilization, conservation strategies and local perception. *Diversity*, *7*(2), 149-169.

102) Ghosh, M. K., Kumar, L., & Langat, P. K. (2018). Mapping tidal channel dynamics in the Sundarbans, Bangladesh, between 1974 and 2017, and implications for the sustainability of the Sundarbans mangrove forest. *Environmental monitoring and assessment*, *190*(10), 1-15.

103) Ghosh, T., Bhandari, G., & Hazra, S. (2003). Application of a 'bio-engineering'technique to protect Ghoramara Island (Bay of Bengal) from severe erosion. *Journal of Coastal Conservation*, *9*(2), 171-178.

104) Ghosh, T., Hajra, R., & Mukhopadhyay, A. (2014). Island erosion and afflicted population: Crisis and policies to handle climate change. In *International perspectives on climate change* (pp. 217-225). Springer, Cham.

105) Gibbs, M. T. (2016). Why is coastal retreat so hard to implement? Understanding the political risk of coastal adaptation pathways. Ocean & coastal management, 130, 107-114.

106) Gopal, B., & Chauhan, M. (2006). Biodiversity and its conservation in the Sundarban Mangrove Ecosystem. *Aquatic Sciences*, *68*(3), 338-354.

107) Goswami, A., Roy, N., Mazumdar, A. K., & Duttagupta, R. (2000). Behavioural study of the livestock owners to enhance the productivity in saline belt of Sundarban, West Bengal. *Indian Journal of Animal Health*, *39*(2), 42-46.

108) Gray, C. L. (2011). Soil quality and human migration in Kenya and Uganda. *Global Environmental Change*, *21*(2), 421-430.

109) Gupta K (2009) Cross-cultural analysis of responses to mass fatalities following the 2009 cyclone aila in Bangladesh and India. Quick response report 216, University of Colorado, The Natural Hazards Center, Boulder.

110) Habiba, U., Shaw, R., & Takeuchi, Y. (2012). Farmer's perception and adaptation practices to cope with drought: Perspectives from Northwestern Bangladesh. *International Journal of Disaster Risk Reduction*, *1*, 72-84.

111) Hajra, R., Ghosh, T., Chadwick, O., & Renaud, F. (2018). Agricultural productivity, household poverty and migration in the Indian Sundarban Delta. *Elementa: Science of the Anthropocene*, *6*.

112) Hajra, R., Szabo, S., Tessler, Z., Ghosh, T., Matthews, Z., & Foufoula-Georgiou, E. (2017). Unravelling the association between the impact of natural hazards and household poverty: evidence from the Indian Sundarban delta. *Sustainability Science*, *12*(3), 453-464.

113) Haldar, A., & Debnath, A. (2014). Assessment of climate induced soil salinity conditions of Gosaba Island, West Bengal and its influence on local livelihood. In *Climate Change and Biodiversity* (pp. 27-44). Springer, Tokyo.

114) Haque, M. (2017). Community–based Adaptation to Climate Change: Experience of the Coastline of Bangladesh. *CULTURE, ADAPTATION AND RESILIENCE*, 173.

115) Haque, S. A. (2006). Salinity problems and crop production in coastal regions of Bangladesh. *Pakistan Journal of Botany*, *38*(5), 1359-1365.

116) Harris, J. R., & Todaro, M. P. (1970). Migration, unemployment and development: a two-sector analysis. *The American economic review*, *60*(1), 126-142.

117) Hauer, M. E., Fussell, E., Mueller, V., Burkett, M., Call, M., Abel, K., ... & Wrathall, D. (2020). Sea-level rise and human migration. *Nature Reviews Earth & Environment*, *1*(1), 28-39.

118) Hay, Iain (ed.) (2000). _Qualitative Research Methods in Human Geography_. Oxford University Press.

119) Hazra, S., & Samanta, K. (2016). *Temporal Change Detection (2001-2008): Study of Sundarban*. eSocialSciences. Working Papers id:10526, eSocialSciences.

120) Hazra, S., Mukhopadhyay, A., Mukherjee, S., Akhand, A., Chanda, A., Mitra, D., & Ghosh, T. (2016). Disappearance of the New Moore Island from the Southernmost Coastal Fringe of the Sundarban delta-a case study. *Journal of the Indian Society of Remote Sensing*, *44*(3), 479-484.

121) Hess, A. S., & Hess, J. R. (2017). Understanding tests of the association of categorical variables: the Pearson chi-square test and Fisher's exact test. *Transfusion*, *57*(4), 877.

122) Higgins, S. A., Overeem, I., Steckler, M. S., Syvitski, J. P., Seeber, L., & Akhter, S. H. (2014). InSAR measurements of compaction and subsidence in the Ganges-Brahmaputra Delta, Bangladesh. *Journal of Geophysical Research: Earth Surface*, *119*(8), 1768-1781.

123) Hisali, E., Birungi, P., & Buyinza, F. (2011). Adaptation to climate change in Uganda: evidence from micro level data. *Global environmental change*, *21*(4), 1245-1261.

124) Houghton, J. T., Ding, Y. D. J. G., Griggs, D. J., Noguer, M., van der Linden, P. J., Dai, X., ... & Johnson, C. A. (2001). *Climate change 2001: the scientific basis*. The Press Syndicate of the University of Cambridge.

125) Hulme, M. (2008). Climate refugees: Cause for a new agreement commentary). *Environment*, *50*(6), 50-52.

126) Hunter, L. M. (2005). Migration and environmental hazards. *Population and environment*, *26*(4), 273-302.

127) Hunter, P. (2016). Margin of error and confidence levels made simple. [online] Available: https://www.isixsigma.com/tools-templates/sampling-data/margin-error-and-confidence-levels-made-simple/.

128) Huy, H. T., & Nonneman, W. (2016). Economic effects of labor migration on agricultural production of farm households in the Mekong River Delta region of Vietnam. *Asian and Pacific Migration Journal*, *25*(1), 3-21.

129) Ibrahim, F. (2003) 'Notes from the Field'. South Asia Newsletter. Spring. pp. 8 and 12

130) International Agencies (Action Aid, Concern World Wide, Dan Church Aid, Muslim Aid, Islamic Relief, Oxfam-GB and Save the Children-UK) (2009) In-depth recovery needs assessment of cyclone aila affected Areas, Dhaka

131) Ishtiaque, A., & Nazem, N. I. (2017). Household-level disaster-induced losses and rural–urban migration: Experience from world's one of the most disaster-affected countries. *Natural hazards*, *86*(1), 315-326.

132) Ishtiaque, A., & Ullah, M. S. (2013). The influence of factors of migration on the migration status of rural-urban migrants in Dhaka, Bangladesh. *Human Geographies*, *7*(2), 45.

133) Jamero, M. L., Onuki, M., Esteban, M., Chadwick, C., Tan, N., Valenzuela, V. P., ... & Avelino, J. E. (2019). In-situ adaptation against climate change can enable relocation of impoverished small islands. *Marine Policy*, *108*, 103614.

134) Joarder, M. A. M., & Miller, P. W. (2013). Factors affecting whether environmental migration is temporary or permanent: Evidence from Bangladesh. *Global Environmental Change*, *23*(6), 1511-1524.

135) Jodi Jacobson. (1988) Environmental Refugees: A Yardstick of Habitability Worldwatch Paper No. 86 (Washington, D.C.: Worldwatch Institute.

136) Joshi, H. G., & Ghose, M. (2014). Community structure, species diversity, and aboveground biomass of the Sundarbans mangrove swamps. *Tropical Ecology*, *55*(3), 283-303.

137) Junk, W. J., Brown, M., Campbell, I. C., Finlayson, M., Gopal, B., Ramberg, L., & Warner, B. G. (2006). The comparative biodiversity of seven globally important wetlands: a synthesis. *Aquatic Sciences*, *68*(3), 400-414.

138) Kar, N. S., & Bandyopadhyay, S. (2015). Tropical storm Aila in Gosaba block of Indian Sundarban: remote sensing based assessment of impact and recovery. *Geographical review of India*, *77*(1), 40-54.

139) Karpytchev, M., Ballu, V., Krien, Y., Becker, M., Goodbred, S., Spada, G., ... & Khan, Z. (2018). Contributions of a strengthened early Holocene monsoon and sediment loading to present-day subsidence of the Ganges-Brahmaputra delta. *Geophysical Research Letters*, *45*(3), 1433-1442.

140) Kartiki, K. (2011). Climate change and migration: a case study from rural Bangladesh. *Gender & Development*, *19*(1), 23-38.

141) Kay, S., Caesar, J., Wolf, J., Bricheno, L., Nicholls, R. J., Islam, A. S., ... & Lowe, J. A. (2015). Modelling the increased frequency of extreme sea levels in the Ganges–Brahmaputra–Meghna delta due to sea level rise and other effects of climate change. *Environmental Science: Processes & Impacts*, *17*(7), 1311-1322.

142) Kelman, I., Orlowska, J., Upadhyay, H., Stojanov, R., Webersik, C., Simonelli, A. C., ... & Němec, D. (2019). Does climate change influence people's migration decisions in Maldives?. *Climatic change*, *153*(1), 285-299.

143) Kemp, K. B., Blades, J. J., Klos, P. Z., Hall, T. E., Force, J. E., Morgan, P., & Tinkham, W. T. (2015). Managing for climate change on federal lands of the western United States: perceived usefulness of climate science, effectiveness of adaptation strategies, and barriers to implementation. *Ecology and Society*, *20*(2).

144) Kitoh, A., Endo, H., Krishna Kumar, K., Cavalcanti, I. F., Goswami, P., & Zhou, T. (2013). Monsoons in a changing world: A regional perspective in a global context. *Journal of Geophysical Research: Atmospheres*, *118*(8), 3053-3065.

145) Klein, R. J. (2011). Adaptation to climate change. In *Climate* (pp. 157-168). Springer, Dordrecht.

146) Klein, R. J., Nicholls, R. J., Ragoonaden, S., Capobianco, M., Aston, J., & Buckley, E. N. (2001). Technological options for adaptation to climate change in coastal zones. *Journal of Coastal Research*, 531-543.

147) Knutson, T. R., McBride, J. L., Chan, J., Emanuel, K., Holland, G., Landsea, C., ... & Sugi, M. (2010). Tropical cyclones and climate change. *Nature geoscience*, *3*(3), 157-163.

148) Koubi, V., Bernauer, T., Kalbhenn, A., & Spilker, G. (2012). Climate variability, economic growth, and civil conflict. *Journal of peace research*, *49*(1), 113-127.

149) Kuenzer, C., & Renaud, F. G. (2012). Climate and environmental change in river deltas globally: expected impacts, resilience, and adaptation. In *The Mekong Delta System* (pp. 7-46). Springer, Dordrecht.

150) Lal, Neeta. (1 July, 2015) "Poor Bear the Brunt of Corruption in India's Food Distribution System." Inter Press Service, Inter Press Service News Agency. www.ipsnews.net/2015/07/poor-bear-the-brunt-of-corruption-in-indias-food-distribution-system/accessed 3/28/2021

151) Lauria, V., Das, I., Hazra, S., Cazcarro, I., Arto, I., Kay, S., ... & Fernandes, J. A. (2018). Importance of fisheries for food security across three climate change vulnerable deltas. *Science of the Total Environment*, *640*, 1566-1577.

152) Leavy, J., & Greeley, M. (2011). Evaluation of Adaptation to Climate Change from a Development Perspective. *Evaluating Climate Change and Development*, *8*, 241.

153) Lein, H. (2000). Hazards and'forced'migration in Bangladesh. *Norsk Geografisk Tidsskrift*, *54*(3), 122-127.

154) Li, S., Juhász-Horváth, L., Harrison, P. A., Pintér, L., & Rounsevell, M. D. (2017). Relating farmer's perceptions of climate change risk to adaptation behaviour in Hungary. *Journal of environmental management*, *185*, 21-30.

155) Ma, A. T., Wong, G. K., Cheung, L. T., Lo, A. Y., & Jim, C. Y. (2021). Climate change perception and adaptation of residents in Hong Kong. *Journal of Cleaner Production*, *288*, 125123.

156) Mabogunje, A. (1970). Migration policy and regional development in Nigeria. *Nigerian Journal of Economic and Social Studies*, *12*(2), 243-262.

157) Mabogunje, A. L. (1970). Systems approach to a theory of rural-urban migration. *Geographical analysis*, *2*(1), 1-18.

158) Maharjan, A., Tuladhar, S., Hussain, A., Mishra, A., Bhadwal, S., Ishaq, S., ... & Hassan, S. T. (2021). Can labour migration help households adapt to climate change? Evidence from four river basins in South Asia. *Climate and Development*, 1-16.

159) Mahinchai, M. (2010). Determinants of migration: A case study of Nang Rong, Thailand. *Grad-uation thesis, Trinity College, Duke University, Durham, North Carolina, USA*.

160) Mallick, B., & Siddiqui, T. (2015). Disaster-induced migration and adaptation discourse in Bangladesh. In *Environmental change, adaptation and migration* (pp. 164-185). Palgrave Macmillan, London.

161) Mallick, B., & Vogt, J. (2014). Population displacement after cyclone and its consequences: Empirical evidence from coastal Bangladesh. *Natural hazards*, *73*(2), 191-212.

162) Mandal, A. K., & Nandi, N. C. (1989). *Fauna of Sundarban mangrove ecosystem, west Bengal, India* (Vol. 3). Zoological Survey of India.

163) Mann, H. B., & Whitney, D. R. (1947). On a test of whether one of two random variables is stochastically larger than the other. *The annals of mathematical statistics*, 50-60.

164) Marshall, N. A., Marshall, N. A., Marshall, P. A., Tamelander, J., Obura, D., Malleret-King, D., & Cinner, J. E. (2010). *A framework for social adaptation to climate change: sustaining tropical coastal communitites [sic] and industries*. IUCN.

165) Massey, D. S., Arango, J., Hugo, G., Kouaouci, A., Pellegrino, A., & Taylor, J. E. (1993). Theories of international migration: A review and appraisal. *Population and development review*, 431-466.

166) McCarthy, James J., et al., eds. *Climate change 2001: impacts, adaptation, and vulnerability: contribution of Working Group II to the third assessment report of the Intergovernmental Panel on Climate Change*. Vol. 2. Cambridge University Press, 2001.

167) McLeman, R., & Smit, B. (2006). Migration as an adaptation to climate change. *Climatic change*, *76*(1), 31-53.

168) Mcleman, R., & Smit, B. (2006). Vulnerability to climate change hazards and risks: crop and flood insurance. *Canadian Geographer/Le Géographe canadien*, *50*(2), 217-226.

169) McNamara, K. E., & Des Combes, H. J. (2015). Planning for community relocations due to climate change in Fiji. *International Journal of Disaster Risk Science*, *6*(3), 315-319.

170) Mendelsohn, R., Dinar, A., & Williams, L. (2006). The distributional impact of climate change on rich and poor countries. *Environment and development economics*, 159-178.

171) Methmann, C., & Oels, A. (2015). From 'fearing'to 'empowering'climate refugees: Governing climate-induced migration in the name of resilience. *Security Dialogue*, *46*(1), 51-68.

172) Mikhailov, V. N., & Dotsenko, M. A. (2007). Processes of delta formation in the mouth area of the Ganges and Brahmaputra Rivers. *Water Resources*, *34*(4), 385-400.

173) Mistri, A. (2013). Migration and sustainable livelihoods: a study from Sundarban biosphere reserve. *Asia Pacific Journal of Social Sciences*, *5*(2), 76-102.

174) Molinari, N. (2017). Intensifying Insecurities: The impact of climate change on vulnerability to human trafficking in the Indian Sundarbans. *Anti-Trafficking Review*, (8).

175) Mondal, I., Bandyopadhyay, J., Chakrabarti, P., & Santra, D. (2015). Morphodynamic Change of Fraserganj and Bakkhali Coastal Stretch of Indian Sundarban, South 24 Parganas, West Bengal, India. *Int J Remote Sens Appl*, *5*, 1-10.

176) Mortreux, C., & Barnett, J. (2009). Climate change, migration and adaptation in Funafuti, Tuvalu. *Global Environmental Change*, *19*(1), 105-112.

177) Mortreux, C., de Campos, R. S., Adger, W. N., Ghosh, T., Das, S., Adams, H., & Hazra, S. (2018). Political economy of planned relocation: A model of action and inaction in government responses. *Global Environmental Change*, *50*, 123-132.

178) Mukherji, S. (1985). The syndrome of poverty and wage labour circulation: the Indian scene. *Circulation in Third World Countries. Londres: Routledge & Kegan Paul*, 279-298.

179) Mukhopadhyay, A. (2009). *Cyclone Aila and the Sundarbans: an enquiry into the disaster and politics of aid and relief* (pp. 18-20). Kolkata: Mahanirban Calcutta Research Group.

180) Mullick, M. R. A., Tanim, A. H., & Islam, S. S. (2019). Coastal vulnerability analysis of Bangladesh coast using fuzzy logic based geospatial techniques. *Ocean & Coastal Management*, *174*, 154-169.

181) Myers, N. (1993). Environmental refugees in a globally warmed world. *Bioscience*, *43*(11), 752-761.

182) Myers, N. (2001). *Perverse subsidies: how tax dollars can undercut the environment and the economy*. Island Press.

183) Myers, N. (2002). Environmental refugees: a growing phenomenon of the 21st century. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, *357*(1420), 609-613.

184) Myers, N. (2002). Environmental refugees: a growing phenomenon of the 21st century. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, *357*(1420), 609-613.

185) Myers, N., & Kent, J. (1995). Environmental Exodus: an Emergent Crisis in the Global Arena (Washington DC: Climate Institute).

186) Nachar, N. (2008). The Mann-Whitney U: A test for assessing whether two independent samples come from the same distribution. *Tutorials in quantitative Methods for Psychology*, *4*(1), 13-20.

187) Nandy, S., & Kushwaha, S. P. S. (2011). Study on the utility of IRS 1D LISS-III data and the classification techniques for mapping of Sundarban mangroves. *Journal of Coastal Conservation*, *15*(1), 123-137.

188) Naskar, K. (2004). *Manual of Indian mangroves*. Daya Pub. House.

189) Negi, V. S., Maikhuri, R. K., Pharswan, D., Thakur, S., & Dhyani, P. P. (2017). Climate change impact in the Western Himalaya: people's perception and adaptive strategies. *Journal of Mountain Science*, *14*(2), 403-416.

190) Nicholls, R. J., Hoozemans, F. M., & Marchand, M. (1999). Increasing flood risk and wetland losses due to global sea-level rise: regional and global analyses. *Global Environmental Change*, *9*, S69-S87.

191) Niles, M. T., Lubell, M., & Haden, V. R. (2013). Perceptions and responses to climate policy risks among California farmers. *Global Environmental Change*, *23*(6), 1752-1760.

192) Nunn, P. D. (2013). The end of the Pacific? Effects of sea level rise on Pacific Island livelihoods. *Singapore Journal of Tropical Geography*, *34*(2), 143-171.

193) Oppenheimer, M., B.C. Glavovic , J. Hinkel, R. van de Wal, A.K. Magnan, A. Abd-Elgawad, R. Cai, M. Cifuentes-Jara, R.M. DeConto, T. Ghosh, J. Hay, F. Isla, B. Marzeion, B. Meyssignac, and Z. Sebesvari, 2019: Sea Level Rise and Implications for Low-Lying Islands, Coasts and Communities. In: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. In press

194) Paavola, J. (2008). Livelihoods, vulnerability and adaptation to climate change in Morogoro, Tanzania. *Environmental Science & Policy*, *11*(7), 642-654.

195) Pachauri, R. K., Allen, M. R., Barros, V. R., Broome, J., Cramer, W., Christ, R., ... & van Ypserle, J. P. (2014). *Climate change 2014: synthesis report. Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change* (p. 151). IPCC.

196) Patt, A. G., & Schröter, D. (2008). Perceptions of climate risk in Mozambique: implications for the success of adaptation strategies. *Global Environmental Change*, *18*(3), 458-467.

197) Paul, B. K. (2005). Evidence against disaster-induced migration: the 2004 tornado in north-central Bangladesh. *Disasters*, *29*(4), 370-385.

198) Paul, B. K., Rahman, M. K., Crawford, T., Curtis, S., Miah, M. G., Islam, M. R., & Islam, M. S. (2020). Explaining mobility using the Community Capital Framework and Place Attachment concepts: A case study of riverbank erosion in the Lower Meghna Estuary, Bangladesh. *Applied Geography*, *125*, 102199.

199) Peacock, W. G., Morrow, B. H., & Gladwin, H. (Eds.). (1997). *Hurricane Andrew: Ethnicity, gender, and the sociology of disasters*. Psychology Press.

200) Penning-Rowsell, E. C., Sultana, P., & Thompson, P. M. (2013). The 'last resort'? Population movement in response to climate-related hazards in Bangladesh. *Environmental science & policy*, *27*, S44-S59.

201) Perch-Nielsen, S. L., Bättig, M. B., & Imboden, D. (2008). Exploring the link between climate change and migration. *Climatic change*, *91*(3), 375-393.

202) Philcox, N., Knowler, D., & Haider, W. (2010). Eliciting stakeholder preferences: an application of qualitative and quantitative methods to shrimp aquaculture in the Indian Sundarbans. *Ocean & Coastal Management*, *53*(3), 123-134.

203) Piguet, E (2008), "Climate change and forced migration", Research Paper No 153, New Issues in Refugee Research Series UNHCR, Geneva

204) Piguet, E. (2011, October). The migration/climate change nexus: An assessment. In *International Conference: Rethinking Migration: Climate, Resource Conflicts, and Migration in Europe. Bremen, Germany, October* (pp. 13-14).

205) Piguet, E., Pécoud, A., & De Guchteneire, P. (2011). Migration and climate change: An overview. *Refugee Survey Quarterly*, *30*(3), 1-23.

206) Piguet, E., Pécoud, A., de Guchteneire, P., & Guchteneire, P. F. (Eds.). (2011). *Migration and climate change*. Cambridge University Press.

207) Piore, M. J. (1979). *Birds of passage: Migrant labor and industrial societies*.Cambridge University Press, Cambridge.

208) Poncelet, A., Gemenne, F., Martiniello, M., & Bousetta, H. (2010). A country made for disasters: environmental vulnerability and forced migration in Bangladesh. In *Environment, forced migration and social vulnerability* (pp. 211-222). Springer, Berlin, Heidelberg.

209) Prokopy, L. S., Arbuckle, J. G., Barnes, A. P., Haden, V. R., Hogan, A., Niles, M. T., & Tyndall, J. (2015). Farmers and climate change: A cross-national comparison of beliefs and risk perceptions in high-income countries. *Environmental management*, *56*(2), 492-504.

210) Raha, A. K. (2014). Sea level rise and submergence of Sundarban Islands: a time series study of estuarine dynamics. *Jour-nal of Ecology and Environmental Sciences*, *ISSN*, 0976-9900.

211) Rahman, A. F., Dragoni, D., & El-Masri, B. (2011). Response of the Sundarbans coastline to sea level rise and decreased sediment flow: A remote sensing assessment. *Remote Sensing of Environment*, *115*(12), 3121-3128.

212) RAHMAN, L. M. (2016). Development initiatives of the Sundarban of Bangladesh. *THE MALAYSIAN FORESTER*, *79*(1&2), 77-88.

213) Rahman, M. K., Paul, B. K., Curtis, A., & Schmidlin, T. W. (2015). Linking coastal disasters and migration: A case study of Kutubdia Island, Bangladesh. *The Professional Geographer*, *67*(2), 218-228.

214) Rangel-Buitrago, N., de Jonge, V. N., & Neal, W. (2018). How to make integrated coastal erosion management a reality. Ocean & Coastal Management, 156, 290-299.

215) Rashid, M. H., Afroz, S., Gaydon, D., Muttaleb, A., Poulton, P., Roth, C., & Abedin, Z. (2014). Climate change perception and adaptation options for agriculture in Southern Khulna of Bangladesh. *Applied Ecology and Environmental Sciences*, *2*(1), 25-31.

216) Rigaud, K. K., de Sherbinin, A., Jones, B., Bergmann, J., Clement, V., Ober, K., et al (2018). Groundswell: Preparing for internal climate migration. Washington D.C. Retrieved from https://openknowledge.worldbank.org/handle/10986/29461.

217) Rosén, B. (1997). On sampling with probability proportional to size. *Journal of statistical planning and inference*, *62*(2), 159-191.

218) Roy, A. (2010). Vulnerability of the Sundarbans ecosystem. *Journal of Coastal Environment*, *1*(2), 169-181.

219) Roy, C., & Guha, I. (2013). Climate change induced migration: A case study from Indian Sundarbanas. *ACUMEN-Marian Journal of Social Work*, *5*(1), 72-93.

220) Rudra, K. (2014). Changing river courses in the western part of the Ganga–Brahmaputra delta. *Geomorphology*, *227*, 87-100.

221) Saha, C. K. (2015). Dynamics of disaster-induced risk in southwestern coastal Bangladesh: an analysis on tropical Cyclone Aila 2009. *Natural Hazards*, *75*(1), 727-754.

222) Saha, S. K. (2017). Cyclone Aila, livelihood stress, and migration: empirical evidence from coastal Bangladesh. *Disasters*, *41*(3), 505-526.

223) Sahana, M., Hong, H., Ahmed, R., Patel, P. P., Bhakat, P., & Sajjad, H. (2019). Assessing coastal island vulnerability in the Sundarban Biosphere Reserve, India, using geospatial technology. *Environmental Earth Sciences*, *78*(10), 1-22.

224) Sánchez-Cortés, M. S., & Chavero, E. L. (2011). Indigenous perception of changes in climate variability and its relationship with agriculture in a Zoque community of Chiapas, Mexico. *Climatic change*, *107*(3), 363-389.

225) Sandefur, G. D., & Scott, W. J. (1981). A dynamic analysis of migration: an assessment of the effects of age, family and career variables. *Demography*, *18*(3), 355-368.

226) Sarkhel, P. (2015). Flood risk, land use and private participation in embankment maintenance in Indian Sundarbans. *Ecological Economics*, *118*, 272-284.

227) Sarthi, P. P., Ghosh, S., & Kumar, P. (2015). Possible future projection of Indian Summer Monsoon Rainfall (ISMR) with the evaluation of model performance in Coupled Model Inter-comparison Project Phase 5 (CMIP5). *Global and Planetary Change*, *129*, 92-106.

228) Saxena, R., & Kumar, S. N. (2014). Simulating the impact of projected climate change on rice (Oryza sativa L.) yield and adaptation strategies in major rice growing regions of India. *Journal of Agrometeorology*, *16*(1), 18.

229) Scheffran, J., & Battaglini, A. (2011). Climate and conflicts: the security risks of global warming. *Regional Environmental Change*, *11*(1), 27-39.

230) Scheffran, J., Marmer, E., & Sow, P. (2012). Migration as a contribution to resilience and innovation in climate adaptation: Social networks and co-development in Northwest Africa. *Applied geography*, *33*, 119-127.

231) Seddon, D., Adhikari, J., & Gurung, G. (2002). Foreign labor migration and the remittance economy of Nepal. *Critical Asian Studies*, *34*(1), 19-40.

232) Shankar, C. G., & Behera, M. R. (2019). Wave Boundary Layer Model based wind drag estimation for tropical storm surge modelling in the Bay of Bengal. *Ocean Engineering*, *191*, 106509.

233) Shrestha, S. S., & Bhandari, P. (2007). Environmental security and labor migration in Nepal. *Population and Environment*, *29*(1), 25-38.

234) Sil A. (2016). Reaching the unreached in Sunderbans. *Community eye health*, *29*(95), S10–S12.

235) Silvestri, S., Bryan, E., Ringler, C., Herrero, M., & Okoba, B. (2012). Climate change perception and adaptation of agro-pastoral communities in Kenya. *Regional Environmental Change*, *12*(4), 791-802.

236) Silvestri, S., Bryan, E., Ringler, C., Herrero, M., & Okoba, B. (2012). Climate change perception and adaptation of agro-pastoral communities in Kenya. *Regional Environmental Change*, *12*(4), 791-802.

237) Slegers, M. F. (2008). "If only it would rain": Farmers' perceptions of rainfall and drought in semi-arid central Tanzania. *Journal of Arid Environments*, *72*(11), 2106-2123.

238) Smit, B., & Pilifosova, O. (2003). From adaptation to adaptive capacity and vulnerability reduction. In *Climate change, adaptive capacity and development* (pp. 9-28).

239) Smit, B., & Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Global environmental change*, *16*(3), 282-292.

240) Smit, B., Burton, I., Klein, R. J., & Wandel, J. (2000). An anatomy of adaptation to climate change and variability. In *Societal adaptation to climate variability and change* (pp. 223-251). Springer, Dordrecht.

241) Speare, A. (1974). Residential satisfaction as an intervening variable in residential mobility. *Demography*, *11*(2), 173-188.

242) Spence, A., Poortinga, W., Butler, C., & Pidgeon, N. F. (2011). Perceptions of climate change and willingness to save energy related to flood experience. *Nature climate change*, *1*(1), 46-49.

243) Stanley, D. J., & Hait, A. K. (2000). Holocene depositional patterns, neotectonics and Sundarban mangroves in the western Ganges-Brahmaputra delta. *Journal of Coastal Research*, 26-39.

244) Stark, O., & Bloom, D. E. (1985). The new economics of labor migration. *The american Economic review*, *75*(2), 173-178.

245) Stark, O., & Levhari, D. (1982). On migration and risk in LDCs. *Economic development and cultural change*, *31*(1), 191-196.

246) Stark, O., & Taylor, J. E. (1989). Relative deprivation and international migration oded stark. *Demography*, *26*(1), 1-14.

247) Stern, N. H., Peters, S., Bakhshi, V., Bowen, A., Cameron, C., Catovsky, S., ... & Zenghelis, D. (2006). *Stern Review: The economics of climate change* (Vol. 30, p. 2006). Cambridge: Cambridge University Press.

248) Syvitski, J. P. M. (2008). Deltas at risk, Sustain. Sci., 3, 23–32.

249) Syvitski, J. P., Kettner, A. J., Overeem, I., Hutton, E. W., Hannon, M. T., Brakenridge, G. R., ... & Nicholls, R. J. (2009). Sinking deltas due to human activities. *Nature Geoscience*, *2*(10), 681-686.

250) Tacoli, C. (2009). Crisis or adaptation? Migration and climate change in a context of high mobility. *Environment and urbanization*, *21*(2), 513-525.

251) Tanaya DuttaGupta, Amrita Chakraborty, and Anamitra Anurag Danda, "Confronting Cascading Disasters, Building Resilience: Lessons from the Indian Sundarbans," *ORF Occasional Paper No. 297*, January 2021, Observer Research Foundation.

252) Tessler, Z. D., Vörösmarty, C. J., Grossberg, M., Gladkova, I., & Aizenman, H. (2016). A global empirical typology of anthropogenic drivers of environmental change in deltas. *Sustainability science*, *11*(4), 525-537.

253) Tiwary, G., Gangopadhyay, P. K., Biswas, S., Nayak, K., Chatterjee, M. K., Chakraborty, D., & Mukherjee, S. (2012). Socio-economic status of workers of building construction industry. *Indian journal of occupational and environmental medicine*, *16*(2), 66.

254) Todaro, M. P. (1969). A model of labor migration and urban unemployment in less developed countries. *The American economic review*, *59*(1), 138-148.

255) Todaro, M. P. (1976). Urban job expansion, induced migration and rising unemployment: a formulation and simplified empirical test for LDCs. *Journal of Development Economics*, *3*(3), 211-225.

256) Tol, R. S., Klein, R. J., & Nicholls, R. J. (2008). Towards successful adaptation to sea-level rise along Europe's coasts. *Journal of Coastal Research*, *24*(2 (242)), 432-442.

257) Trivedi, S., Zaman, S., Chaudhuri, T. R., Pramanick, P., Fazli, P., Amin, G., & Mitra, A. (2016). Inter-annual variation of salinity in Indian Sundarbans.

258) Tsegai, D. (2007). Migration as a household decision: What are the roles of income differences? Insights from the Volta basin of Ghana. *The European journal of development research*, *19*(2), 305-326.

259) Unnikrishnan, A. S., & Shankar, D. (2007). Are sea-level-rise trends along the coasts of the north Indian Ocean consistent with global estimates?. *Global and Planetary Change*, *57*(3-4), 301-307.

260) Unnikrishnan, A. S., Kumar, M. R., & Sindhu, B. (2011). Tropical cyclones in the Bay of Bengal and extreme sea-level projections along the east coast of India in a future climate scenario. *Current Science*, 327-331.

261) Vanwey, L. K. (2003). Land ownership as a determinant of temporary migration in Nang Rong, Thailand. *European Journal of Population/Revue européenne de Démographie*, *19*(2), 121-145.

262) VanWey, L. K. (2005). Land ownership as a determinant of international and internal migration in Mexico and internal migration in Thailand. *International Migration Review*, *39*(1), 141-172.

263) Von Storch, H., & Woth, K. (2008). Storm surges: perspectives and options. *Sustainability Science*, *3*(1), 33-43.

264) Vormoor, K. (2010). *Water engineering, agricultural development and socio-economic trends in the Mekong Delta, Vietnam* (No. 57). ZEF Working Paper Series.

265) Wamsler, C., Brink, E., & Rentala, O. (2012). Climate change, adaptation, and formal education: the role of schooling for increasing societies' adaptive capacities in El Salvador and Brazil. *Ecology and Society*, *17*(2).

266) Warner, K., Hamza, M., Oliver-Smith, A., Renaud, F., & Julca, A. (2010). Climate change, environmental degradation and migration. *Natural Hazards*, *55*(3), 689-715.

267) Webber, M., & Barnett, J. (2010). *Accommodating migration to promote adaptation to climate change*. The World Bank.

268) Weldegebriel, Z. B. (2016). Social protection and vulnerability to climate shocks: A panel data evidence from Rural Ethiopia. *Ethiopian Journal of the Social Sciences and Humanities*, *12*(2), 99-132.

269) Weldegebriel, Z. B., & Prowse, M. (2017). Climate variability and livelihood diversification in northern Ethiopia: a case study of Lasta and Beyeda districts. *The Geographical Journal*, *183*(1), 84-96.

270) Westing, A. H. (1994). The Almería Statement on Desertification and Migration. *Environmental Conservation*, *21*(2), 179-181.

271) Wilson, C. A., & Goodbred Jr, S. L. (2015). Construction and maintenance of the Ganges-Brahmaputra-Meghna delta: linking process, morphology, and stratigraphy. *Annual Review of Marine Science*, *7*, 67-88.

272) Winters, P., De Janvry, A., & Sadoulet, E. (2001). Family and community networks in Mexico-US migration. *Journal of human resources*, 159-184.

273) Wolpert, J. (1965, December). Behavioral aspects of the decision to migrate. In *Papers of the Regional Science Association* (Vol. 15, No. 1, pp. 159-169). Springer-Verlag.

274) Wrathall, D. J. (2012). Migration amidst social-ecological regime shift: The search for stability in Garifuna villages of northern Honduras. *Human Ecology*, *40*(4), 583-596.

275) Zimmermann, Klaus F. (2014) "Circular migration." IZA World of Labor.

Appendix A - **Survey Questionnaire**

1. What is your age?
2. How many years have you stayed in this village?
3. Size of household?
4. What is your source(s) of income?
5. What is your annual/monthly income?
6. Do you have agricultural land? If yes, how much?
7. Do you grow crops? if yes, what crops? How many harvests a year?
8. If no? Why not?
9. Did you previously grow crop? If yes, why did you stop growing crop?
10. Do you have a pond? Do you have a fishery? If yes, Commercial or for consumption?
11. Do you face any environmental problem in the Sundarbans at present? (Original question). However, most of the residents failed to understand the nature of the problems and talked about roads and infrastructure. Later, this question had to be reframed.
12. Reframed Question: Did you face environmental problems in the Sundarbans like erosion, salinity, flood etc.? what are the problems that you faced?
13. Did you notice any change (increase/decrease/no change) in environmental hazards in the last 10 years in this village? Which problems/hazards?
14. Did you face any economic loss due to the environment in the last 10 years? Did you face loss due to erosion, salinity, flood, storms? Did you face loss due to any other problem? How much? How often do you face loss?
15. [To this question, most of the residents only talked about the economic impacts of the last tropical storm Aila. Therefore, Question was asked: Did you face any economic loss in the last 10 years other than from Aila?
16. What are your preferred responses towards mitigation of the economic impacts of hazards and disaster?
17. If not already mentioned by the resident, are you a registered member of any micro-credit organization? Do you have a kitchen garden? Do you grow crops for consumption or commercially?
18. Did you receive any assistance from the local government or any working NGO in this context?
19. Did any of you migrate from this household in the last 10 years? If yes? How many residents?
20. What was the migration for?
21. How often do you migrate?
22. What is /are place(s) of destination?
23. What is the length of stay during each migration?
24. What is the age, education, gender, and marital status of the migrants?
25. Do you have any contacts at the destination? How do you decide whether to migrate and to where?
26. Is migration (for you) an individual decision or household decision?
27. What are the costs of migration?
28. Did migration help to increase your yearly income? If yes, how much?

For non-migrants

29. Why did you not choose to migrate when many other people in the Sundarbans did?
30. In this situation of environmental degradation, stress, economic loss (if the resident talked about the environmental problems) Have you considered permanent relocation from the Sundarbans in future to any place with better environmental conditions? If yes, why? If not, why not?
31. Do you think there is any environmental risk at present in the Sundarbans? If so, rate your risk – No risk Low Risk, Medium risk, High risk, Extreme risk.
32. What kind of risk?
33. Do you think there was environmental risk before? If yes, did the risk increase or decrease?
34. Are you aware of Climate Change? If yes, where did you get information from? What according to you is Climate Change?
35. Do you perceive, increase in the level of water in the rivers and in the ocean?
36. Rate your attachment to the Sundarbans on a scale of 0-4, 0= No attachment, 4- High attachment.
37. For the residents who mentioned erosion, - What would you do if you lose your home to erosion in future?

Appendix B - **Supplementary Figures**

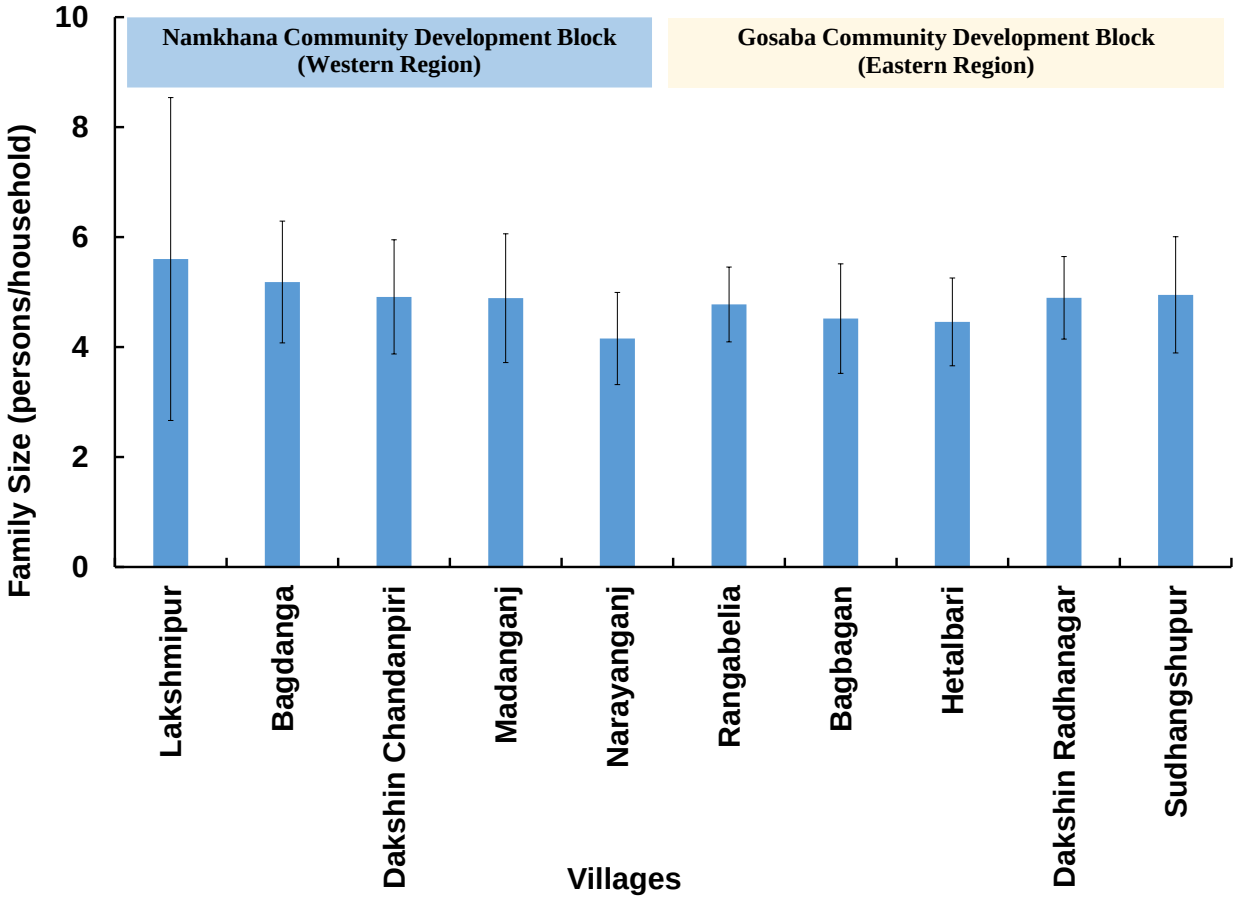

Figure B-1 Average size of households in the study area

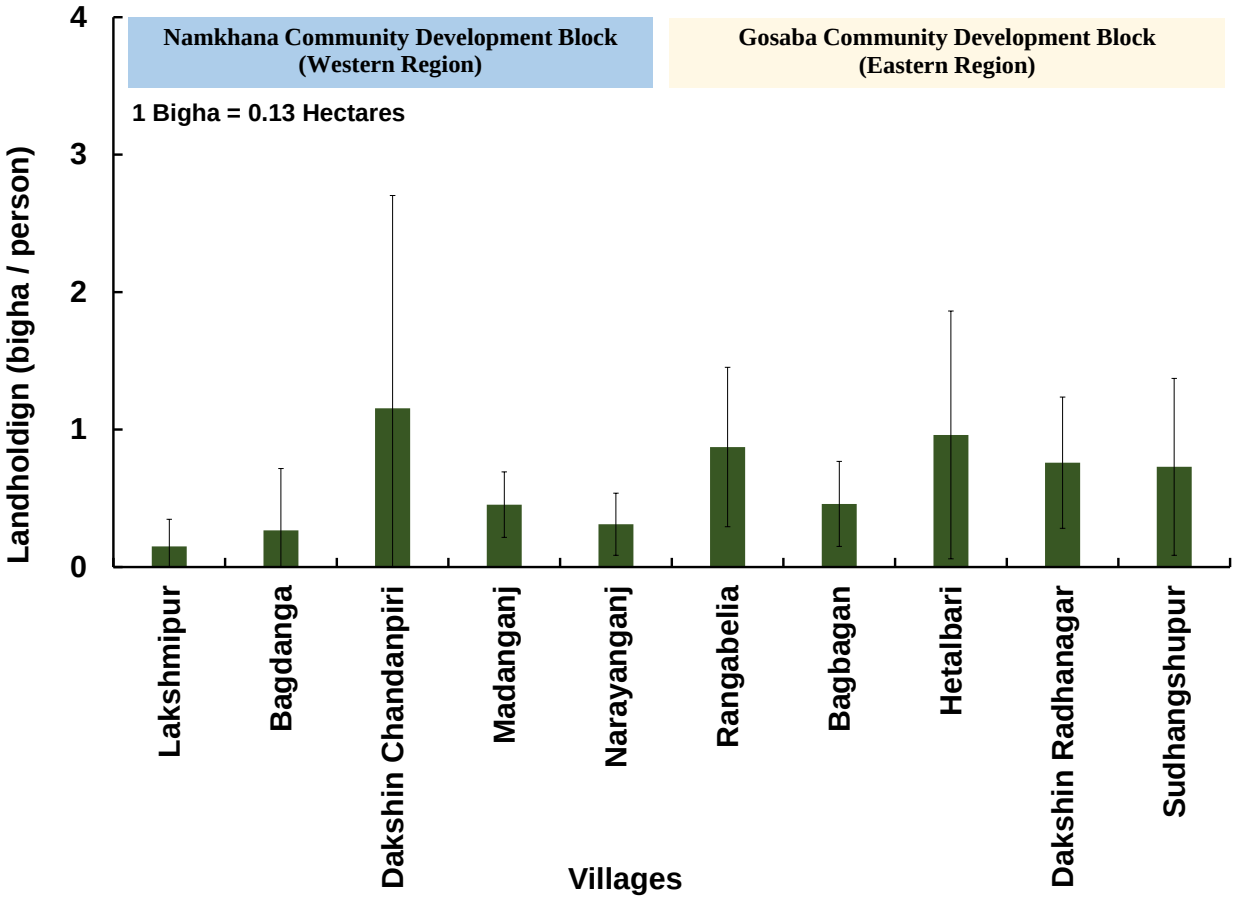

Figure B-2 Per capita productive agricultural landholding in the study area

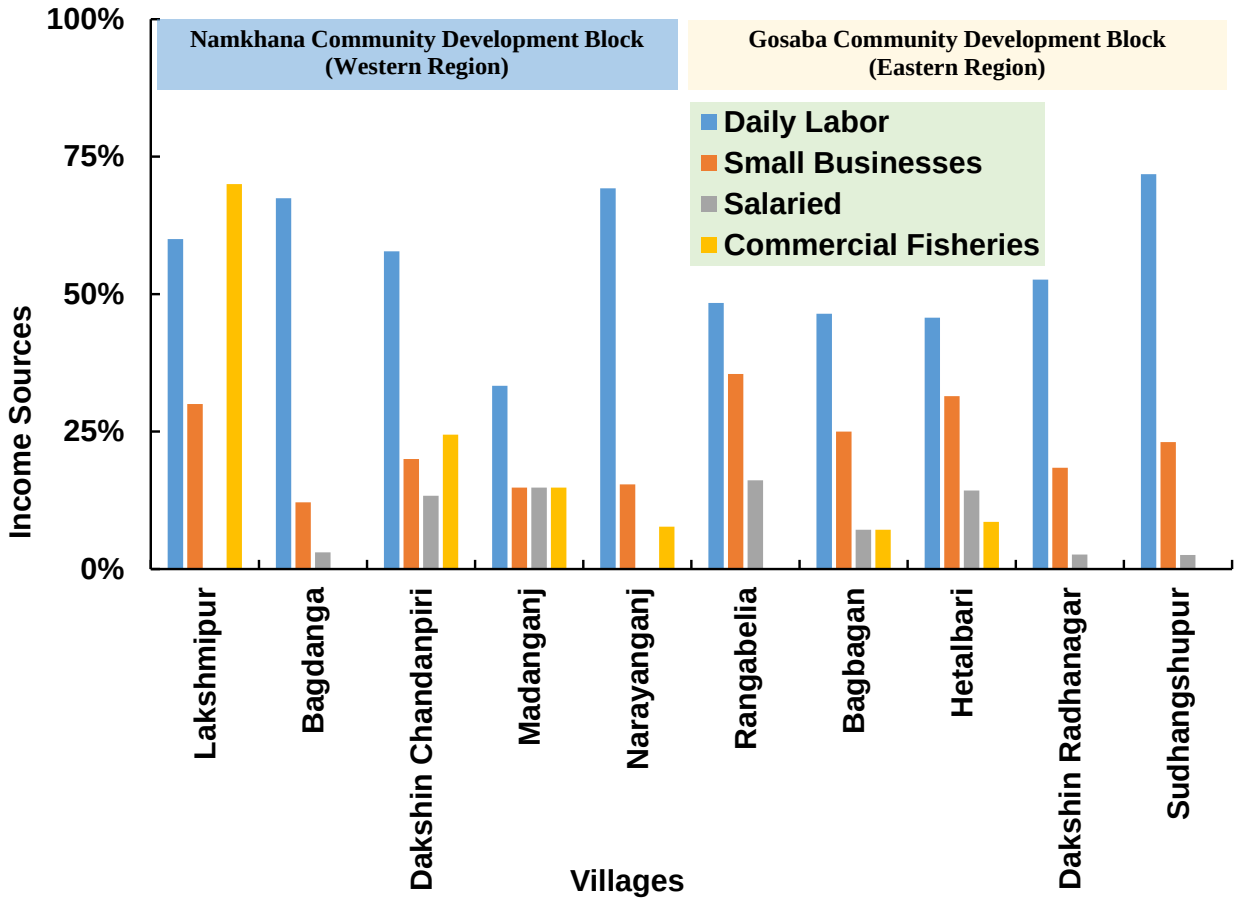

Figure B-3 Major sources of income in the study area

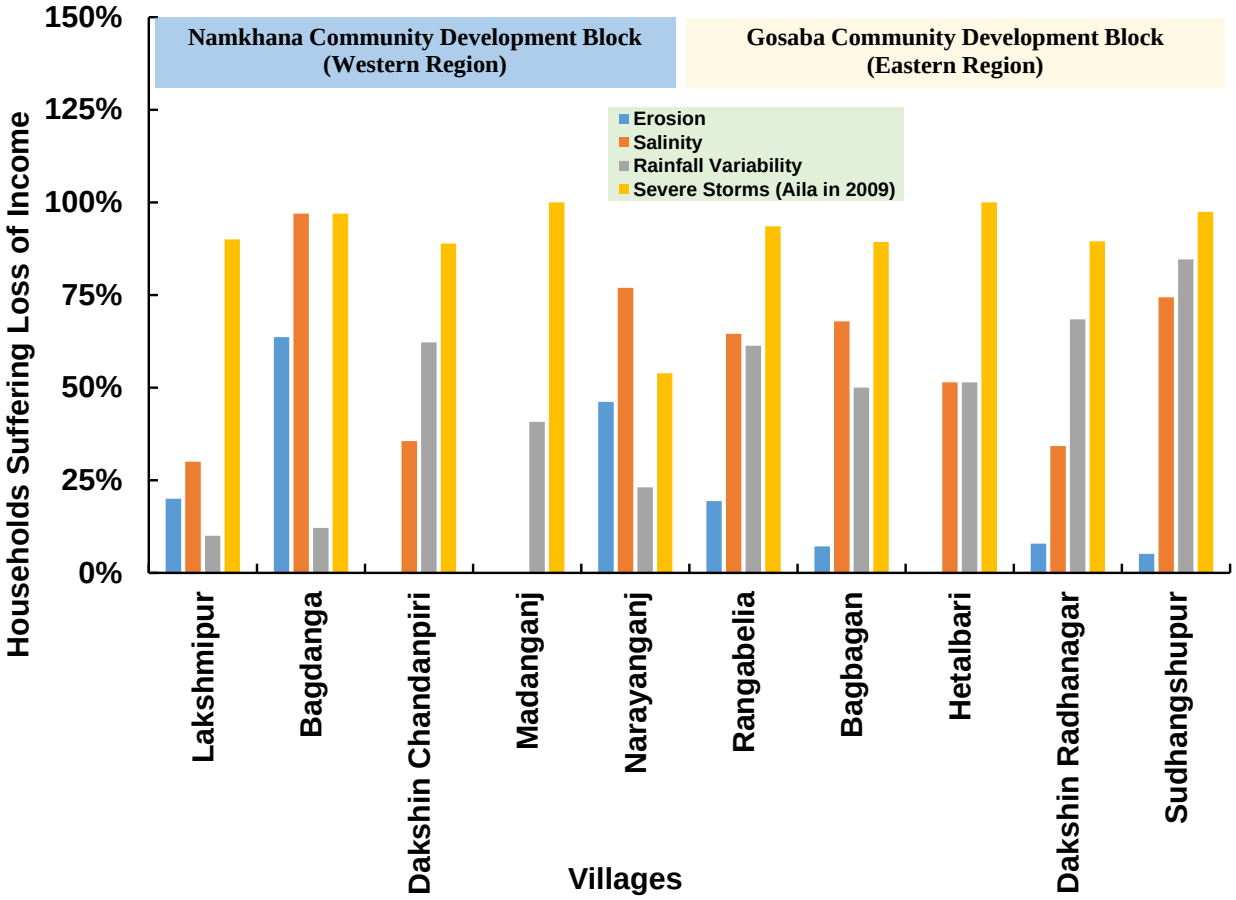

Figure B-4 Loss of livelihood suffered due to environmental hazards in the study area.

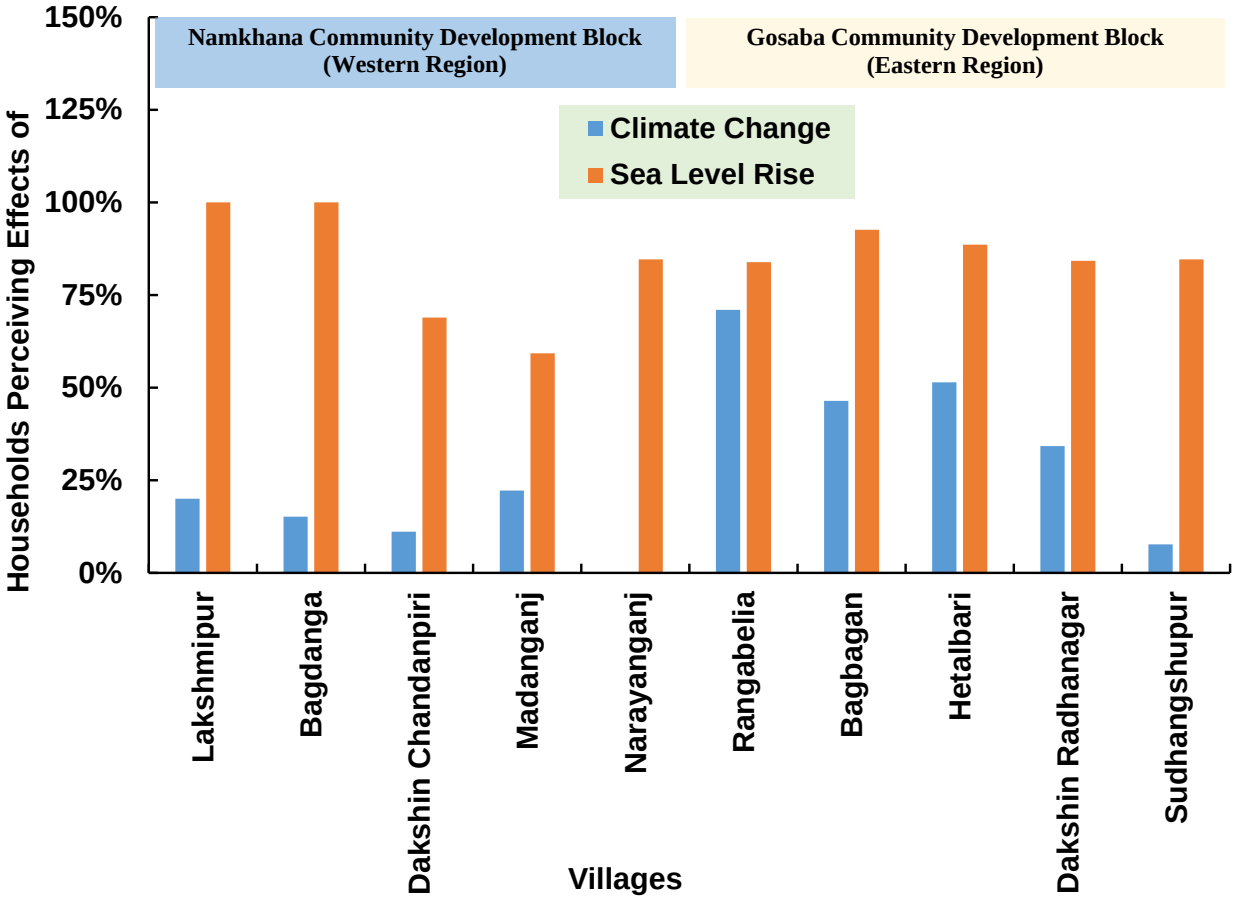

Figure B-5 Climate change awareness and sea level rise perception in the study area

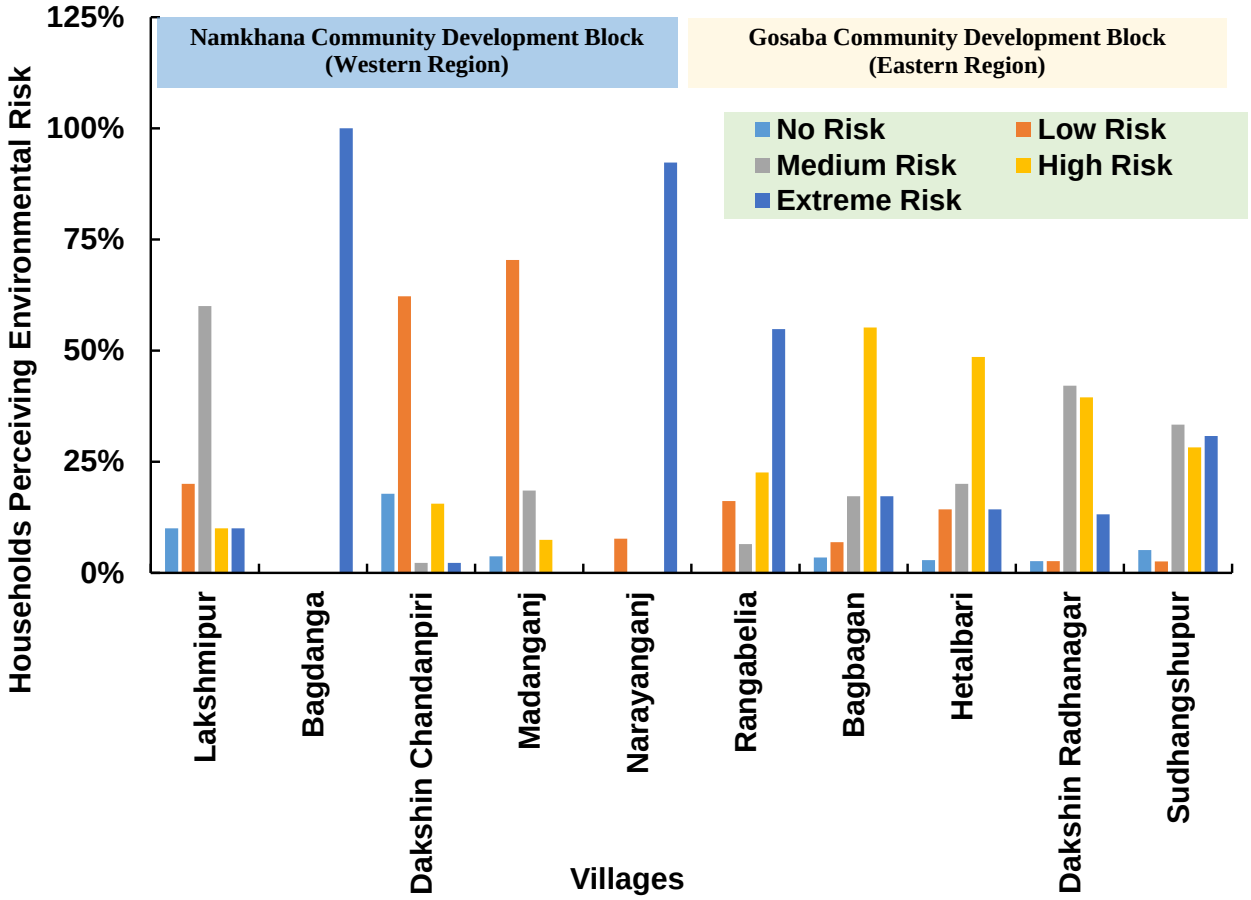

Figure B-6 Perception of environmental risk in the study area

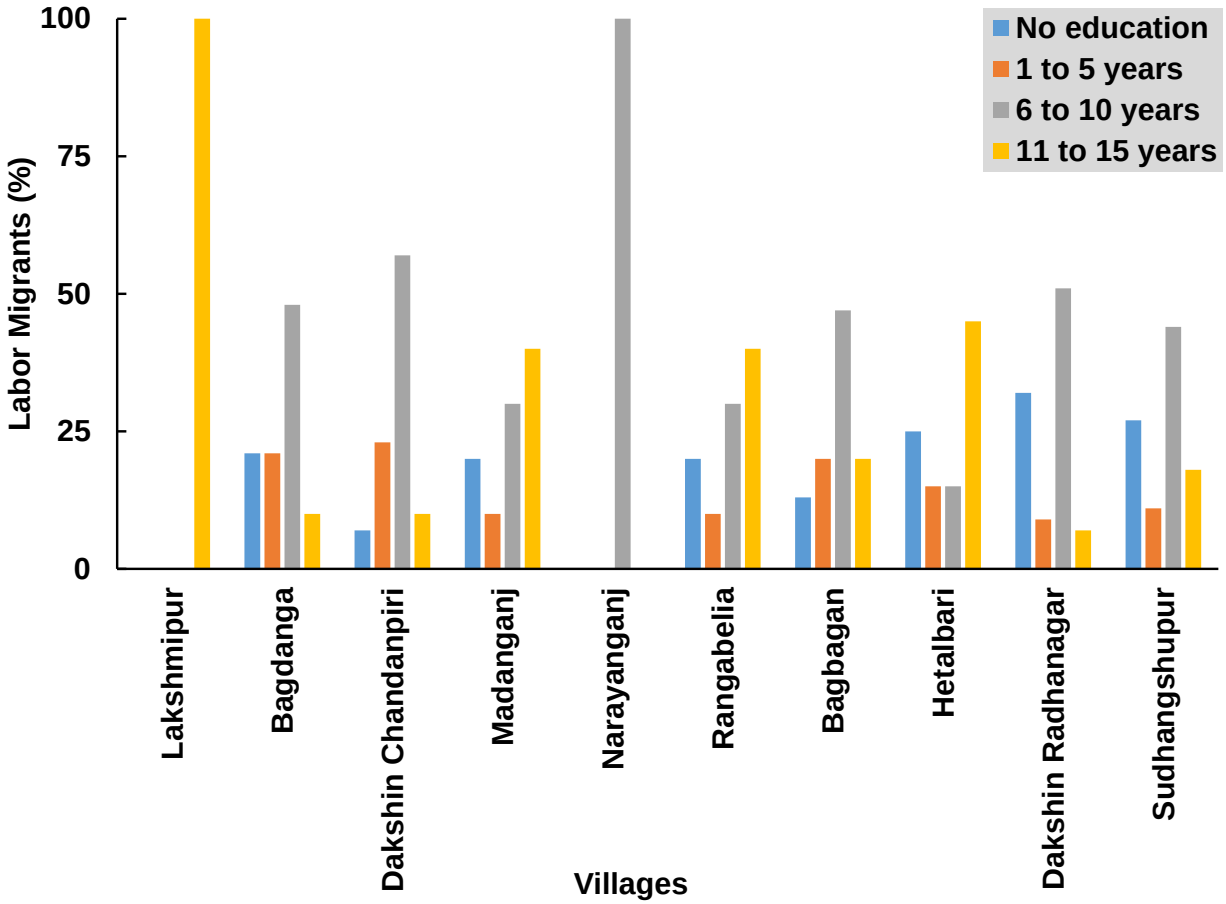

Figure B-7 Years of education for the migrants in the study area

Appendix C - **Supplementary Tables**

Table C-1 Household demographic, socio economic variables, environmental risk perception

Variables	**Namkhana Block**				**Gosaba Block**					
	V1	**V2**	**V3**	**V4**	**V5**	**V6**	**V7**	**V8**	**V9**	**V10**
Household size	5	5	5	5	4	5	5	4	5	5
Landholding	0.15	0.27	1.15	0.45	0.31	0.87	0.48	0.96	0.76	0.73
Households (%) earning their income from										
Agricultural daily labor	60	67	58	33	69	48	46	45	53	72
Small businesses	30	12	20	15	15	35	25	31	18	23
Government employment	0	3	13	15	0	16	7	14	3	3
Commercial fisheries	70	0	24	15	8	0	7	8	0	0
Households (%) that suffered income loss due to										
Erosion	20	64	0	0	46	19	7	0	7	5
Salinity intrusion and soil salinization	30	97	35		77	64	68	51	34	74
Rainfall variability	10	12	62	40	23	61	50	51	68	85
Severe storms (Aila in 2009)	90	97	89	100	54	94	89	100	89	97
Households (%) that perceived										
Effects of climate change	20	15	11	22	0	71	46	51	34	8
Effects of sea level rise	100	100	69	59	84	84	93	89	84	85

V1-Lakshmipur; V2-Bagdanga; V3-Dakshin Chandanpiri; V4-Madanganj; V5-Narayanganj V6-Rangabelia; V7-Bagbagan; V8-Hetalbari; V9-Dakshin Radhanagar; V10-Sudhangshupur.

Table C-2 Raw data for 300 households**.**

Household properties include Family Size (A) and Landholding (B); Income sources include, Daily Labor (C), Small Businesses (D), Salaried (E) and Commercial Fisheries (F); Income loss due to, Erosion (G), Salinity Intrusion (H), Rainfall Variability (I) and Severe storms like Aila in 2009 (J); Households perceiving Environmental Risk (K), Change in Environmental Risk (L), Effects of Climate Change (M) and Effects of Sea Level Rise (N).

Household No.	Block	Village	A	B	C	D	E	F	G	H	I	J	K	L	M	N
LA 2	Namkhana	Lakshmipur	22	0	1	0	0	1	0	0	0	1	3	1	1	1
LA 6	Namkhana	Lakshmipur	4	0.25	1	1	0	1	0	1	1	1	3	1	0	1
LA 1	Namkhana	Lakshmipur	6	0	0	0	0	1	0	0	0	1	3	3	0	1
LA 3	Namkhana	Lakshmipur	3	0	1	0	0	1	1	0	0	1	3	1	0	1
LA 4	Namkhana	Lakshmipur	4	1.25	0	0	0	1	1	1	0	1	3	1	0	1
LA 5	Namkhana	Lakshmipur	4	0	1	0	0	1	0	1	0	1	3	3	0	1
LA 7	Namkhana	Lakshmipur	3	0	1	0	0	0	0	0	0	1	2	1	0	1
LA 8	Namkhana	Lakshmipur	3	0	1	1	0	0	0	0	0	1	4	1	0	1
LA 9	Namkhana	Lakshmipur	5	0	0	0	0	1	0	0	0	1	2	1	0	1
LA 10	Namkhana	Lakshmipur	2	0	0	1	0	0	0	0	0	0	0	0	1	1
BG 2	Namkhana	Bagdanga	2	1.5	1	0	0	0	0	1	0	1	4	1	1	1
BG 3	Namkhana	Bagdanga	3	0	0	0	0	0	0	1	0	1	4	1	0	1
BG 4	Namkhana	Bagdanga	6	0	0	0	0	0	1	1	0	1	4	1	0	1
BG 8	Namkhana	Bagdanga	6	0	1	0	0	0	0	1	0	1	4	1	0	1
BG 9	Namkhana	Bagdanga	4	0	1	0	0	0	1	1	0	1	4	1	0	1
BG 10	Namkhana	Bagdanga	4	0	1	0	0	0	1	1	0	1	4	1	0	1
BG 11	Namkhana	Bagdanga	4	0	1	0	0	0	1	1	0	1	4	1	0	1
BG 15	Namkhana	Bagdanga	12	0	1	1	0	0	1	1	0	1	4	1	0	1
BG 17	Namkhana	Bagdanga	5	0	1	0	0	0	1	1	0	1	4	1	1	1
BG 18	Namkhana	Bagdanga	4	0	1	0	0	0	1	1	0	1	4	1	0	1
BG 24	Namkhana	Bagdanga	3	0	0	0	0	0	0	1	0	1	4	1	0	1
BG 25	Namkhana	Bagdanga	3	0	0	0	0	0	0	1	0	1	4	1	0	1
BG 26	Namkhana	Bagdanga	6	5	1.25	0	0	0	0	1	1	1	4	1	1	1

BG 29	Namkhana	Bagdanga	4	0	1	1	0	0	0	1	0	1	4	1	0	1
BG 1	Namkhana	Bagdanga	9	0	0	0	0	0	0	1	1	1	4	1	0	1
BG 5	Namkhana	Bagdanga	6	0	0	1	0	0	1	1	0	1	4	1	0	1
BG 6	Namkhana	Bagdanga	5	0	0	0	0	0	1	1	0	1	4	1	0	1
BG 7	Namkhana	Bagdanga	3	0	1	0	0	0	0	1	0	1	4	1	0	1
BG 12	Namkhana	Bagdanga	3	0	1	0	0	0	1	1	0	1	4	1	0	1
BG 13	Namkhana	Bagdanga	4	0	1	0	0	0	1	1	0	1	4	1	0	1
BG 14	Namkhana	Bagdanga	8	0	1	0	0	0	1	1	0	1	4	1	0	1
BG 16	Namkhana	Bagdanga	3	0.6	1	0	0	0	1	1	0	1	4	1	0	1
BG 19	Namkhana	Bagdanga	4	0	0	0	0	0	1	1	0	1	4	1	0	1
BG 20	Namkhana	Bagdanga	4	0.5	0	0	0	0	1	1	0	1	4	1	0	1
BG 21	Namkhana	Bagdanga	5	0.4	0	0	0	0	1	1	0	1	4	1	1	1
BG 22	Namkhana	Bagdanga	7	0.29	1	0	0	0	1	1	0	1	4	1	0	1
BG 23	Namkhana	Bagdanga	5	0	1	0	0	0	1	1	0	1	4	1	0	1
BG 27	Namkhana	Bagdanga	10	0.2	1	0	0	0	0	1	1	1	4	1	0	1
BG 28	Namkhana	Bagdanga	7	0	1	0	0	0	0	1	1	1	4	1	0	1
BG 30	Namkhana	Bagdanga	7	0	1	0	0	0	0	0	0	0	4	1	0	1
BG 31	Namkhana	Bagdanga	5	0	1	1	0	0	1	1	0	1	4	1	0	1
BG 33	Namkhana	Bagdanga	6	0.33	1	0	1	0	1	1	0	1	4	1	1	1
BG 32	Namkhana	Bagdanga	4	0	0	0	0	0	1	1	0	1	4	1	0	1
DC 19	Namkhana	Dakshin Chandanpiri	5	1	1	1	0	0	0	0	1	1	1	2	1	1
DC 12	Namkhana	Dakshin Chandanpiri	6	1	0	1	0	0	0	1	1	1	1	2	0	1
DC 16	Namkhana	Dakshin Chandanpiri	3	0.3	1	0	0	0	0	0	0	1	1	2	0	0
DC 27	Namkhana	Dakshin Chandanpiri	8	0.2	0	0	0	0	0	0	1	1	0	2	0	0
DC 4	Namkhana	Dakshin Chandanpiri	3	1	1	0	0	0	0	1	1	1	1	2	0	1
DC 5	Namkhana	Dakshin Chandanpiri	3	0	0	0	0	0	0	0	0	1	1	2	0	1
DC 9	Namkhana	Dakshin Chandanpiri	4	0.75	1	0	0	0	0	1	1	1	2	1	0	1
DC 14	Namkhana	Dakshin Chandanpiri	8	0.75	0	0	0	1	0	1	1	1	1	2	0	1
DC 22	Namkhana	Dakshin Chandanpiri	3	0.5	1	0	0	0	0	0	0	1	1	2	0	1
DC 25	Namkhana	Dakshin Chandanpiri	4	0.75	1	0	0	0	0	0	1	1	1	2	0	1

DC 29	Namkhana	Dakshin Chandanpiri	4	1.25	0	0	0	1	0	1	1	1	1	2	0	1
DC 30	Namkhana	Dakshin Chandanpiri	3	0	1	0	0	0	0	0	0	1	3	2	0	1
DC 31	Namkhana	Dakshin Chandanpiri	5	0	1	1	0	0	0	1	1	1	3	2	0	0
DC 1	Namkhana	Dakshin Chandanpiri	2	21	1	0	0	1	0	0	1	1	0	2	0	0
DC 15	Namkhana	Dakshin Chandanpiri	4	0	1	0	0	0	0	1	1	1	1	2	0	0
DC 17	Namkhana	Dakshin Chandanpiri	6	1.5	1	0	0	1	0	0	0	1	1	2	0	1
DC 20	Namkhana	Dakshin Chandanpiri	6	0.25	1	0	0	0	0	0	1	1	1	2	0	1
DC 21	Namkhana	Dakshin Chandanpiri	5	0.6	1	0	0	0	0	0	0	1	1	2	0	1
DC 23	Namkhana	Dakshin Chandanpiri	3	1	1	0	0	0	0	0	0	1	1	2	0	1
DC 26	Namkhana	Dakshin Chandanpiri	10	0.1	1	0	0	0	0	0	0	1	1	2	0	1
DC 32	Namkhana	Dakshin Chandanpiri	5	0.02	1	0	0	0	0	0	0	1	4	3	0	1
DC 37	Namkhana	Dakshin Chandanpiri	8	0.25	1	0	0	1	0	0	1	0	3	2	0	1
DC 40	Namkhana	Dakshin Chandanpiri	4	0	1	0	0	0	0	0	1	0	0	2	0	0
DC 42	Namkhana	Dakshin Chandanpiri	6	0.25	1	1	0	0	0	1	0	1	0	2	0	0
DC 2	Namkhana	Dakshin Chandanpiri	4	0.25	0	0	0	1	0	1	1	1	3	1	0	1
DC 3	Namkhana	Dakshin Chandanpiri	5	0.4	0	0	0	1	0	0	1	1	1	2	0	0
DC 6	Namkhana	Dakshin Chandanpiri	9	0.6	0	0	0	0	0	1	1	1	1	2	0	1
DC 7	Namkhana	Dakshin Chandanpiri	5	1	0	0	0	0	0	1	1	1	1	2	0	1
DC 8	Namkhana	Dakshin Chandanpiri	3	1.7	0	1	0	1	0	1	1	1	3	1	1	1
DC 10	Namkhana	Dakshin Chandanpiri	4	1.75	1	0	0	1	0	1	1	1	3	1	0	1
DC 11	Namkhana	Dakshin Chandanpiri	8	0.25	0	0	0	0	0	1	1	1	1	2	0	1
DC 13	Namkhana	Dakshin Chandanpiri	3	2	0	1	0	0	0	1	1	1	1	2	0	1
DC 18	Namkhana	Dakshin Chandanpiri	4	0.125	0	0	0	1	0	0	0	1	1	2	0	1
DC 24	Namkhana	Dakshin Chandanpiri	5	0.4	1	0	0	0	0	0	0	1	1	2	0	1
DC 28	Namkhana	Dakshin Chandanpiri	4	2.5	0	1	0	0	0	0	0	1	1	2	0	0
DC 33	Namkhana	Dakshin Chandanpiri	3	0.7	0	0	1	0	0	0	1	1	3	2	0	1
DC 34	Namkhana	Dakshin Chandanpiri	5	2.4	0	0	1	0	0	0	1	1	1	2	1	1
DC 35	Namkhana	Dakshin Chandanpiri	12	0.5	0	1	1	0	0	0	0	1	1	2	0	1
DC 36	Namkhana	Dakshin Chandanpiri	4	1.25	1	1	0	0	0	0	0	1	1	2	0	0
DC 38	Namkhana	Dakshin Chandanpiri	4	1	1	0	1	0	0	0	1	0	0	2	1	0

DC 39	Namkhana	Dakshin Chandanpiri	4	0.75	0	0	1	0	0	0	1	0	0	2	1	0
DC 41	Namkhana	Dakshin Chandanpiri	4	1.63	0	0	1	1	0	0	0	0	0	2	0	0
DC 43	Namkhana	Dakshin Chandanpiri	4	0.38	1	0	0	0	0	1	0	1	0	2	0	0
DC 44	Namkhana	Dakshin Chandanpiri	5	0	1	0	0	0	0	0	1	1	1	2	0	1
DC 45	Namkhana	Dakshin Chandanpiri	4	0	1	0	0	0	0	0	1	1	1	2	0	1
M13	Namkhana	Madanganj	3	0	1	0	1	0	0	0	1	1	0	2	0	0
M15	Namkhana	Madanganj	7	1	0	0	0	0	0	0	1	1	3	3	1	1
M2	Namkhana	Madanganj	5	0	1	0	0	0	0	1	1	1	1	3	0	0
M7	Namkhana	Madanganj	5	0.3	1	0	0	0	0	0	1	1	1	3	0	1
M12	Namkhana	Madanganj	3	0.5	0	0	0	0	0	0	1	1	1	2	0	1
M20	Namkhana	Madanganj	6	0.5	0	0	0	0	0	1	1	1	3	1	0	1
M4	Namkhana	Madanganj	6	0.7	1	0	0	0	0	0	0	1	2	3	1	0
M6	Namkhana	Madanganj	5	0.6	1	0	0	1	0	0	0	1	1	3	1	1
M11	Namkhana	Madanganj	4	0.25	0	0	0	0	0	0	1	1	1	2	0	1
M16	Namkhana	Madanganj	6	0.5	0	0	0	0	0	0	0	1	2	3	0	1
M24	Namkhana	Madanganj	10	0.2	0	0	0	0	0	0	1	1	1	1	0	0
M27	Namkhana	Madanganj	5	0.3	0	0	0	0	0	1	1	1	1	3	0	1
M 1	Namkhana	Madanganj	4	0	1	1	0	0	0	0	1	1	1	3	0	0
M3	Namkhana	Madanganj	2	0	0	0	0	0	0	1	0	1	1	3	0	0
M5	Namkhana	Madanganj	4	0	1	0	0	0	0	0	0	1	2	3	0	0
M8	Namkhana	Madanganj	4	0	1	0	0	0	0	0	0	1	2	3	0	1
M9	Namkhana	Madanganj	1	1.5	0	0	0	1	0	0	0	1	1	2	1	1
M10	Namkhana	Madanganj	2	1.5	0	0	1	0	0	0	0	1	1	2	0	0
M14	Namkhana	Madanganj	4	0	0	0	1	0	0	0	0	1	1	3	0	1
M17	Namkhana	Madanganj	4	0	0	1	0	1	0	0	0	1	1	3	1	1
M18	Namkhana	Madanganj	7	0.6	0	1	0	0	0	1	0	1	2	3	0	1
M19	Namkhana	Madanganj	4	1.125	0	1	0	0	0	1	1	1	1	3	0	0
M21	Namkhana	Madanganj	5	0.9	0	0	0	1	0	1	0	1	1	3	1	1
M22	Namkhana	Madanganj	3	0	1	0	0	0	0	0	0	1	1	3	0	1
M23	Namkhana	Madanganj	12	0.3	0	0	1	0	0	0	0	1	1	3	0	1

M25	Namkhana	Madanganj	7	0.3	0	0	0	0	0	0	0	1	1	3	0	0
M26	Namkhana	Madanganj	4	1.25	0	0	0	0	0	0	0	1	1	3	0	0
N 1	Namkhana	Narayanganj	4	0.5	1	0	0	0	0	1	0	1	4	1	0	0
N 3	Namkhana	Narayanganj	3	0	1	1	0	0	1	1	0	1	4	1	0	1
N 5	Namkhana	Narayanganj	6	0.3	1	0	0	0	1	1	0	0	4	1	0	1
N 9	Namkhana	Narayanganj	6	0	1	0	0	0	1	1	0	1	4	1	0	1
N 11	Namkhana	Narayanganj	6	0	1	0	0	0	0	1	1	1	4	1	0	1
N 2	Namkhana	Narayanganj	4	1.5	0	1	0	0	0	0	1	0	1	3	0	0
N 4	Namkhana	Narayanganj	2	0	1	0	0	0	1	1	0	0	4	1	0	1
N 6	Namkhana	Narayanganj	3	0.7	1	0	0	0	0	1	1	0	4	1	0	1
N 7	Namkhana	Narayanganj	5	0	1	0	0	0	1	1	0	0	4	1	0	1
N 8	Namkhana	Narayanganj	5	0.3	1	0	0	0	0	1	0	0	4	1	0	1
N 10	Namkhana	Narayanganj	3	0	0	0	0	1	1	1	0	1	4	1	0	1
N 12	Namkhana	Narayanganj	6	0.75	0	0	0	0	0	0	0	1	4	1	0	1
N13	Namkhana	Narayanganj	1	0	0	0	0	0	0	0	0	1	4	1	0	1
R 20	Gosaba	Rangabelia	6	1.7	1	0	0	0	0	1	1	1	1	3	1	1
R 19	Gosaba	Rangabelia	2	1	1	0	0	0	0	1	1	1	1	3	0	0
R 21	Gosaba	Rangabelia	6	1	0	1	0	0	0	0	1	1	4	1	1	1
R 26	Gosaba	Rangabelia	3	0	1	0	0	0	0	0	0	1	4	3	1	1
R 24	Gosaba	Rangabelia	5	0	0	0	1	0	1	0	0	0	4	1	1	1
R 5	Gosaba	Rangabelia	6	0.3	1	0	0	0	0	1	0	1	4	3	1	1
R 8	Gosaba	Rangabelia	6	0	1	0	0	0	0	1	1	1	2	2	1	1
R 11	Gosaba	Rangabelia	6	0	1	1	0	0	0	0	0	1	4	3	0	0
R 30	Gosaba	Rangabelia	6	0.3	1	0	0	0	0	1	1	1	4	3	1	1
R 25	Gosaba	Rangabelia	3	2.3	1	0	0	0	2	0	1	1	1	3	1	0
R 15	Gosaba	Rangabelia	5	0.4	1	0	0	0	0	1	0	1	4	1	1	1
R 18	Gosaba	Rangabelia	7	2.3	0	1	0	0	0	1	0	1	3	3	0	1
R 28	Gosaba	Rangabelia	5	0.4	0	1	0	0	0	0	1	1	1	2	1	1
R 1	Gosaba	Rangabelia	4	0.38	1	0	0	0	1	1	1	1	4	3	0	1
R 7	Gosaba	Rangabelia	7	0.2	1	1	0	0	0	1	1	1	3	1	1	1

R 9	Gosaba	Rangabelia	4	0	0	1	0	0	0	1	1	1	4	1	1	1
R 12	Gosaba	Rangabelia	4	0.25	0	1	0	0	0	1	1	1	3	3	0	1
R 16	Gosaba	Rangabelia	3	0	1	0	0	0	0	0	0	1	4	3	1	1
R 3	Gosaba	Rangabelia	5	1.2	0	0	1	0	0	1	0	1	1	1	1	1
R 4	Gosaba	Rangabelia	6	5.7	1	0	0	0	0	1	1	1	4	1	1	1
R 6	Gosaba	Rangabelia	4	1.25	0	0	0	0	0	1	1	1	3	3	1	1
R 10	Gosaba	Rangabelia	5	1.4	0	1	0	0	0	1	0	1	1	2	0	0
R 17	Gosaba	Rangabelia	4	1.5	0	0	0	0	0	1	1	1	4	1	1	1
R 22	Gosaba	Rangabelia	5	0	0	1	0	0	0	0	0	1	3	3	1	1
R 23	Gosaba	Rangabelia	4	0.25	0	0	1	0	0	0	1	1	4	1	0	1
R 31	Gosaba	Rangabelia	4	2.5	1	0	0	0	0	1	1	1	3	1	1	1
R 13	Gosaba	Rangabelia	5	0	0	0	1	0	1	0	0	0	4	1	1	1
R 29	Gosaba	Rangabelia	2	1	0	1	0	0	0	0	0	1	3	1	1	1
R 14	Gosaba	Rangabelia	7	0.6	1	0	0	0	0	1	1	1	4	1	0	0
R 2	Gosaba	Rangabelia	5	0.3	0	0	1	0	1	1	1	1	2	3	0	1
R 27	Gosaba	Rangabelia	4	0.75	0	1	0	0	0	1	1	1	4	3	1	1
BG 23	Gosaba	Bagbagan	7	2.6	1	0	0	0	0	1	1	1	2	1	1	1
BG 5	Gosaba	Bagbagan	5	0.4	0	0	0	0	0	1	1	1	3	1	1	1
BG 6	Gosaba	Bagbagan	4	0	0	0	0	1	0	1	0	1	3	3	1	1
BG 10	Gosaba	Bagbagan	10	0	1	0	0	0	1	1	0	1	3	3	1	
BG 12	Gosaba	Bagbagan	6	0.3	0	0	0	0	0	1	1	1	4	3	0	1
BG 13	Gosaba	Bagbagan	5	0.5	0	0	0	0	0	1	0	1	3	1	1	1
BG 20	Gosaba	Bagbagan	3	0	0	0	0	0	0	1	0	1	3	3	1	1
BG 24	Gosaba	Bagbagan	5	0.6	1	0	0	0	0	0	0	1	1	3	0	1
BG 25	Gosaba	Bagbagan	5	0.4	0	1	0	1	0	0	0	1	2	3	0	1
BG 11	Gosaba	Bagbagan	4	0	1	0	0	0	0	1	0	1	2	3	0	1
BG 14	Gosaba	Bagbagan	3	0.3	0	0	0	0	0	0	0	1	3	3	0	0
BG 17	Gosaba	Bagbagan	3	1.3	1	0	0	0	0	1	1	1	4	3	1	1
BG 21	Gosaba	Bagbagan	7	1.9	1	1	0	0	0	1	1	1	3	1	1	1
BG 26	Gosaba	Bagbagan	4	0.5	1	0	0	0	0	1	0	1	3	1	0	1

BG 3	Gosaba	Bagbagan	5	0	1	0	0	0	0	0	0	1	3	3	0	0
BG 4	Gosaba	Bagbagan	3	0.3	1	0	0	0	0	1	1	1	3	1	1	1
BG 7	Gosaba	Bagbagan	4	0.25	0	1	0	0	0	1	1	1	3	1	0	1
BG 9	Gosaba	Bagbagan	10	0.3	0	0	0	0	0	1	0	1	3	2	1	1
BG 15	Gosaba	Bagbagan	4	0	0	0	0	0	1	0	1	0	3	1	0	1
BG 19	Gosaba	Bagbagan	5	0	0	0	0	0	0	1	0	1	4	3	0	1
BG 28	Gosaba	Bagbagan	5	0.4	1	0	0	0	0	0	0	0	2	1	0	1
BG 1	Gosaba	Bagbagan	3	0	0	1	0	0	0	0	0	0	3	1	1	1
BG 2	Gosaba	Bagbagan	4	0.375	1	0	0	0	0	0	1	1	4	3	0	1
BG 8	Gosaba	Bagbagan	3	0	1	0	0	0	0	1	1	1	3	2	0	1
BG 18	Gosaba	Bagbagan	3	1.3	0	1	1	0	0	0	1	1	1	2	1	1
BG 22	Gosaba	Bagbagan	3	1	0	1	0	0	0	1	1	1	3	1	0	1
BG 27	Gosaba	Bagbagan	4	0.5	0	1	1	0	0	1	1	1	2	1	1	1
BG 29	Gosaba	Bagbagan	3	0	1	0	0	0	0	1	1	1	4	1	0	1
BG 19	Gosaba	Bagbagan	1	0	1	0	0	0	1	1	1	4	0	1	1	0
H	Gosaba	Hetalbari	7	1	0	1	1	0	0	1	1	1	2	1	1	1
H	Gosaba	Hetalbari	6	1	0	0	1	0	0	0	1	1	3	3	1	1
H	Gosaba	Hetalbari	7	1	0	0	1	0	0	1	1	1	3	2	0	1
H	Gosaba	Hetalbari	2	1	1	1	0	0	0	1	1	1	4	3	1	1
H 7	Gosaba	Hetalbari	4	1	0	0	0	1	0	1	1	1	3	1	1	1
H 8	Gosaba	Hetalbari	4	0	1	0	0	0	0	1	1	1	3	3	0	0
H 10	Gosaba	Hetalbari	4	1.5	0	0	0	0	0	0	0	1	3	2	0	0
h 11	Gosaba	Hetalbari	7	0.6	1	1	0	0	0	1	1	1	2	3	0	1
h 16	Gosaba	Hetalbari	5	0.3	1	1	0	0	0	1	1	1	3	3	0	1
h 20	Gosaba	Hetalbari	6	0.2	1	1	0	0	0	0	0	1	3	3	0	1
H 2	Gosaba	Hetalbari	5	1	1	0	0	0	0	1	1	1	3	1	0	1
H 4	Gosaba	Hetalbari	4	0	0	0	0	0	0	0	1	1	2	2	0	1
H 6	Gosaba	Hetalbari	6	0.3	1	0	0	0	0	1	0	1	3	1	1	1
H 11	Gosaba	Hetalbari	4	0.75	0	0	0	0	0	0	1	1	2	2	1	1
H 1	Gosaba	Hetalbari	4	0	1	0	0	0	0	0	1	1	3	3	0	1

H 5	Gosaba	Hetalbari	7	0	1	0	0	0	0	0	0	1	1	3	0	0
H 9	Gosaba	Hetalbari	2	1	0	0	0	0	0	0	0	1	4	1	0	0
H 3	Gosaba	Hetalbari	2	5	1	0	0	0	0	0	1	1	2	3	0	1
H 13	Gosaba	Hetalbari	3	0.3	0	0	0	0	0	0	0	1	3	1	1	1
H 14	Gosaba	Hetalbari	4	0.25	0	1	1	0	0	0	1	1	4	1	1	1
H 15	Gosaba	Hetalbari	5	10	1	0	0	1	0	1	1	1	4	1	1	1
h 1	Gosaba	Hetalbari	4	0.25	0	0	0	0	0	0	0	1	3	1	0	1
h 3	Gosaba	Hetalbari	5	0.4	0	1	0	1	0	1	0	1	3	1	1	1
h 4	Gosaba	Hetalbari	2	1.5	0	1	0	0	0	1	0	1	1	2	0	1
h 5	Gosaba	Hetalbari	4	0.75	1	0	0	0	0	1	1	1	3	1	1	1
h 6	Gosaba	Hetalbari	5	0.3	1	0	0	0	0	0	0	1	2	1	0	1
h 8	Gosaba	Hetalbari	4	0.875	0	1	0	0	0	1	0	1	1	3	1	1
h 9	Gosaba	Hetalbari	2	1	0	1	0	0	0	1	0	1	1	2	1	1
h 10	Gosaba	Hetalbari	2	1.5	0	1	0	0	0	1	0	1	3	3	1	1
h1 2	Gosaba	Hetalbari	5	0.3	1	0	0	0	0	1	1	1	1	2	1	1
h 13	Gosaba	Hetalbari	4	0.25	1	0	0	0	0	1	0	1	4	2	1	1
h 19	Gosaba	Hetalbari	6	0.2	1	0	1	0	0	0	1	1	3	1	1	1
h 2	Gosaba	Hetalbari	7	0.1	0	0	0	0	0	0	0	1	0	2	1	1
h 7	Gosaba	Hetalbari	5	0	0	0	0	0	0	0	0	1	2	3	0	1
h 15	Gosaba	Hetalbari	3	0	0	0	0	0	0	0	0	1	3	2	0	1
DR	Gosaba	Dakshin Radhanagar	4	1	1	0	0	0	0	0	1	1	2	3	1	1
Dr 17	Gosaba	Dakshin Radhanagar	5	0	0	0	0	0	0	0	1	1	4	3	0	1
Dr 24	Gosaba	Dakshin Radhanagar	3	0.7	1	0	0	0	0	0	1	1	3	3	0	1
Dr 26	Gosaba	Dakshin Radhanagar	5	0.6	1	0	0	0	0	0	1	1	1	2	0	1
Dr 35	Gosaba	Dakshin Radhanagar	5	0.9	1	0	0	0	0	0	1	1	3	2	1	1
Dr 36	Gosaba	Dakshin Radhanagar	4	0.25	0	1	0	0	0	0	0	1	2	3	1	1
Dr 29	Gosaba	Dakshin Radhanagar	2	1.5	0	1	0	0	0	0	1	1	2	1	1	1
Dr 4	Gosaba	Dakshin Radhanagar	5	0	1	0	0	0	0	0	1	1	2	2	0	0
Dr 12	Gosaba	Dakshin Radhanagar	8	0.625	1	0	0	0	0	1	1	1	2	3	1	1
Dr 15	Gosaba	Dakshin Radhanagar	6	0.7	0	0	0	0	0	1	1	1	4	1	1	1

Dr 16	Gosaba	Dakshin Radhanagar	5	1.2	0	1	0	0	0	0	0	1	2	2	0	1
Dr 18	Gosaba	Dakshin Radhanagar	2	2.5	0	0	1	0	0	1	1	1	4	1	1	1
Dr 32	Gosaba	Dakshin Radhanagar	7	0.6	0	1	0	0	0	1	1	1	4	1	0	1
Dr 38	Gosaba	Dakshin Radhanagar	7	0.4	0	1	0	0	1	1	1	1	2	1	0	1
DR1	Gosaba	Dakshin Radhanagar	7	0.7	1	0	0	0	0	1	1	1	3	1	0	1
Dr 2	Gosaba	Dakshin Radhanagar	6	1.7	1	0	0	0	0	0	1	0	0	2	0	1
Dr 3	Gosaba	Dakshin Radhanagar	5	0	1	0	0	0	0	0	0	1	4	1	0	0
Dr 9	Gosaba	Dakshin Radhanagar	5	0	1	0	0	0	0	0	0	1	2	1	0	1
Dr 10	Gosaba	Dakshin Radhanagar	7	0.3	1	0	0	0	0	0	0	0	3	3	0	1
Dr 11	Gosaba	Dakshin Radhanagar	4	0	0	0	0	0	0	0	0	0	2	3	1	1
Dr 13	Gosaba	Dakshin Radhanagar	7	0	1	0	0	0	0	0	0	0	2	3	0	1
Dr 14	Gosaba	Dakshin Radhanagar	5	2	1	0	0	0	0	1	1	1	3	1	0	1
Dr 20	Gosaba	Dakshin Radhanagar	5	0	0	0	0	0	0	0	1	1	3	1	1	1
Dr 21	Gosaba	Dakshin Radhanagar	4	0	0	0	0	0	0	0	0	1	2	3	1	1
Dr 25	Gosaba	Dakshin Radhanagar	5	0.4	1	0	0	0	1	1	1	1	3	1	0	1
Dr 31	Gosaba	Dakshin Radhanagar	4	0.5	0	0	0	0	0	0	1	1	3	3	0	0
Dr 22	Gosaba	Dakshin Radhanagar	3	2	0	0	0	0	0	0	1	1	2	3	0	1
Dr 6	Gosaba	Dakshin Radhanagar	5	1.2	0	1	0	0	0	0	1	1	3	2	0	0
Dr 7	Gosaba	Dakshin Radhanagar	4	0	1	0	0	0	0	1	1	1	3	3	0	0
Dr 8	Gosaba	Dakshin Radhanagar	5	0	1	0	0	0	0	0	0	1	2	1	1	1
Dr 23	Gosaba	Dakshin Radhanagar	4	0	1	0	0	0	0	1	0	1	3	3	0	1
Dr 27	Gosaba	Dakshin Radhanagar	5	0.6	1	0	0	0	0	0	1	1	2	3	0	1
Dr 28	Gosaba	Dakshin Radhanagar	4	0	1	0	0	0	0	1	1	1	2	1	0	1
Dr 34	Gosaba	Dakshin Radhanagar	8	3.38	0	0	0	0	1	1	1	1	3	1	1	1
Dr 5	Gosaba	Dakshin Radhanagar	4	4	1	0	0	0	0	0	1	1	3	1	0	0
Dr 37	Gosaba	Dakshin Radhanagar	2	0	0	1	0	0	0	0	0	1	2	3	0	1
Dr 33	Gosaba	Dakshin Radhanagar	5	0.6	0	0	0	0	0	1	1	1	3	1	1	1
Dr 30	Gosaba	Dakshin Radhanagar	5	0.6	0	0	0	0	0	0	0	1	3	1	0	1
S 10	Gosaba	Sudhanshupur	5	1	1	1	0	0	0	1	0	1	4	1	0	1
S 8	Gosaba	Sudhanshupur	4	0	1	1	0	0	0	1	1	1	3	2	0	1

S 1	Gosaba	Sudhanshupur	4	6.5	1	0	0	0	0	1	1	1	4	1	0	1
S2	Gosaba	Sudhanshupur	6	0	1	0	0	0	0	1	1	1	0	1	0	1
S 5	Gosaba	Sudhanshupur	7	0.9	1	0	0	0	0	0	1	1	2	1	0	1
S 4	Gosaba	Sudhanshupur	11	1.3	1	1	0	0	0	1	1	1	4	1	0	1
S 6	Gosaba	Sudhanshupur	8	0	1	1	0	0	0	0	1	1	4	1	0	1
S 3	Gosaba	Sudhanshupur	5	0	1	1	0	0	0	1	1	1	2	2	0	1
S 7	Gosaba	Sudhanshupur	4	0	1	1	0	0	0	1	1	1	4	2	0	1
S 9	Gosaba	Sudhanshupur	4	0.75	1	0	0	0	1	1	1	1	0	1	0	1
S 21	Gosaba	Sudhanshupur	4	0.25	0	0	0	0	0	1	1	1	3	1	0	1
S 28	Gosaba	Sudhanshupur	6	0.25	1	0	0	0	0	1	0	1	4	1	0	1
S 13	Gosaba	Sudhanshupur	5	0	0	0	0	0	0	0	0	0	2	3	0	0
S 14	Gosaba	Sudhanshupur	4	0	0	0	0	0	0	0	0	1	2	1	0	1
S 17	Gosaba	Sudhanshupur	7	0.4	1	0	0	0	0	1	1	1	3	1	0	1
S 22	Gosaba	Sudhanshupur	3	0.8	0	0	0	0	0	1	1	1	4	3	0	1
S 38	Gosaba	Sudhanshupur	4	0.05	1	0	0	0	0	1	1	1	2	3	0	0
S 27	Gosaba	Sudhanshupur	4	0.5	1	0	0	0	0	1	0	1	3	1	0	1
S 11	Gosaba	Sudhanshupur	4	0.25	1	0	0	0	0	0	1	1	3	2	0	1
S 18	Gosaba	Sudhanshupur	6	0.25	1	0	0	0	0	1	1	1	3	1	0	1
S 16	Gosaba	Sudhanshupur	4	0.375	0	0	0	0	0	0	1	1	2	2	0	1
S 39	Gosaba	Sudhanshupur	5	0.6	1	0	0	0	0	0	1	1	3	1	0	1
S 26	Gosaba	Sudhanshupur	4	0.125	0	0	0	0	0	0	1	1	2	1	0	0
S 19	Gosaba	Sudhanshupur	5	0.4	1	0	0	0	0	0	1	1	1	3	0	0
S 12	Gosaba	Sudhanshupur	4	1.25	1	0	0	0	1	1	1	1	2	1	0	1
S 24	Gosaba	Sudhanshupur	13	0.1	1	0	0	0	0	1	1	1	4	1	0	1
S 25	Gosaba	Sudhanshupur	3	0.3	1	0	0	0	0	1	1	1	2	2	0	0
S 32	Gosaba	Sudhanshupur	5	0.3	1	0	0	0	0	1	1	1	2	1	0	1
S 15	Gosaba	Sudhanshupur	5	5	1	0	0	0	0	1	1	1	3	3	0	1
S 31	Gosaba	Sudhanshupur	5	0.4	0	1	0	0	0	1	0	1	2	1	0	1
S 34	Gosaba	Sudhanshupur	2	1.5	0	0	0	0	0	1	1	1	3	2	1	1
S 33	Gosaba	Sudhanshupur	5	0.4	1	0	0	0	0	0	1	1	3	1	1	1

S 20	Gosaba	Sudhanshupur	2	2	1	0	0	0	0	1	1	1	3	2	0	1
S 29	Gosaba	Sudhanshupur	5	0	0	1	0	0	0	1	1	1	4	2	1	1
S 36	Gosaba	Sudhanshupur	6	0.8	1	0	0	0	0	1	1	1	4	1	0	1
S 23	Gosaba	Sudhanshupur	5	0.6	0	0	0	0	0	1	1	1	4	2	0	0
S 37	Gosaba	Sudhanshupur	4	1	0	0	1	0	0	1	1	1	2	2	0	1
S 38	Gosaba	Sudhanshupur	2	0	1	1	0	0	0	1	1	1	2	1	0	1
S 39	Gosaba	Sudhanshupur	4	0	1	0	0	0	0	1	1	1	4	1	0	1

Table C-3 Demographic information about the migrant population

Block	Village	Number	Age	Male	Female	Single	Married
Namkhana Block	Lakshmipur	2	28	2	0	1	1
	Bagdanga	32	39	31	1	2	30
	Dakshin Chandanpiri	29	36	29	0	6	23
	Madanganj	10	33	10	0	1	9
	Narayanganj	5	35	5	0	0	5
Gosaba Block	Rangabelia	20	36	20	0	5	15
	Bagbagan	30	34	30	0	7	23
	Hetalbari	20	34	18	2	5	15
	Dakshin Radhanagar	43	38	38	5	1	42
	Sudhangshupur	45	32	45	0	18	27

Table C-4 Distribution of socio-economic, demographic variables and environmental risk perception among the three groups of migrants (village wise)

Household properties include Family Size (A) and Landholding (B); Income sources include, Daily Labor (C), Small Businesses (D), Salaried (E) and Commercial Fisheries (F); Income loss due to, Erosion (G), Salinity Intrusion (H), Rainfall Variability (I) and Severe storms like Aila in 2009 (J); Households perceiving Environmental Risk (K), Change in Environmental Risk (L), Effects of Climate Change (M) and Effects of Sea Level Rise (N).

Groups	Villages	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Group 1	Lakshmipur	4.96	0.14	0.63	0.08	0.00	0.00	0.75	1.00	0.04	1.00	4.00	1.00	0.13	1.00
	Dakshin Chandanpiri	5.50	0.26	0.50	0.00	0.00	0.00	0.00	0.00	0.50	1.00	0.50	2.00	0.00	0.00
	Madanganj	4.40	0.17	0.60	0.60	0.00	0.00	0.20	0.80	0.80	1.00	3.60	2.20	0.60	1.00
	Narayanganj	5.14	0.18	0.43	0.14	0.00	0.00	0.14	0.57	0.43	0.71	3.00	1.71	0.29	0.86
	Rangabelia	4.67	0.19	0.33	0.00	0.00	0.00	0.00	0.00	0.17	1.00	2.17	2.33	0.17	0.67
	Bagbagan	5.07	0.83	0.64	0.00	0.00	0.00	0.07	0.21	0.57	0.71	2.50	1.93	0.21	0.79
	Hetalbari	5.00	0.60	0.68	0.00	0.00	0.00	0.05	0.63	0.79	0.95	2.63	1.68	0.00	0.74
	Dakshin Radhanagar	4.96	0.34	0.54	0.12	0.00	0.00	0.17	0.46	0.47	0.91	2.63	1.84	0.20	0.72
Group 2	Dakshin Chandanpiri	5.36	2.27	1.00	0.09	0.00	0.27	0.00	0.18	0.45	0.82	1.18	2.09	0.00	0.64
	Madanganj	6.00	0.41	0.33	0.00	0.00	0.17	0.00	0.17	0.50	1.00	1.33	2.50	0.33	0.67
	Narayanganj	5.25	0.08	1.00	0.25	0.00	0.00	0.75	1.00	0.25	0.75	4.00	1.00	0.00	1.00
	Rangabelia	6.17	0.50	1.00	0.17	0.00	0.00	0.00	0.83	0.67	1.00	3.17	2.50	0.67	0.67
	Bagbagan	5.38	0.28	0.25	0.13	0.00	0.25	0.13	0.75	0.25	1.00	2.75	2.50	0.63	1.00
	Hetalbari	4.75	0.52	0.50	0.00	0.00	0.00	0.00	0.50	0.75	1.00	2.50	1.50	0.50	1.00
	Dakshin Radhanagar	5.63	0.82	0.25	0.38	0.13	0.00	0.13	0.63	0.75	1.00	2.88	1.50	0.38	0.88
	Sudhanshupur	5.80	1.04	1.00	0.60	0.00	0.00	0.10	0.80	0.90	1.00	2.70	1.30	0.00	1.00
Group 3	Dakshin Chandanpiri	0.48	0.73	0.18	0.00	0.36	0.00	0.55	0.64	1.00	1.82	1.73	0.09	0.91	0.82
	Rangabelia	0.33	0.50	0.00	0.00	0.00	0.00	0.50	1.00	1.00	1.50	2.25	0.00	0.75	1.00
	Bagbagan	0.50	1.00	0.00	0.00	0.00	0.00	1.00	0.00	1.00	4.00	1.00	0.00	0.00	1.00
	Hetalbari	1.10	0.83	0.17	0.00	0.00	0.00	0.83	0.50	1.00	2.83	2.00	0.50	0.83	0.50
	Dakshin Radhanagar	0.59	0.67	0.50	0.00	0.17	0.00	0.67	0.67	1.00	2.83	2.50	0.17	0.67	0.67
	Sudhanshupur	0.65	0.43	0.29	0.00	0.00	0.00	0.14	0.86	1.00	2.57	2.14	0.57	1.00	0.71

Table C-5 Correlation matrix for variables between migrants and non-migrant households.

	Migration	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Migration	1.00															
A	0.17	1.00														
B	-0.06	-0.11	1.00													
C	0.16	0.08	0.05	1.00												
D	-0.15	-0.01	-0.04	-0.23	1.00											
E	-0.32	0.00	0.03	-0.24	-0.01	1.00										
F	-0.16	0.02	0.20	-0.13	-0.04	0.00	1.00									
G	0.10	0.01	-0.08	0.09	-0.07	0.00	-0.04	1.00								
H	0.05	0.05	0.02	0.10	0.08	-0.15	-0.03	0.25	1.00							
I	0.05	0.03	0.21	0.03	-0.02	0.05	-0.07	-0.21	0.15	1.00						
J	0.09	0.02	0.06	-0.01	0.06	-0.13	0.01	-0.07	0.20	0.09	1.00					
K	0.11	0.04	-0.10	0.15	-0.01	-0.14	-0.12	0.29	0.39	-0.08	0.08	1.00				
L	0.05	-0.06	-0.01	-0.08	0.04	-0.05	-0.07	-0.25	-0.25	-0.01	0.09	-0.34	1.00			
M	-0.10	-0.01	0.12	-0.14	0.05	0.16	0.05	0.01	0.05	0.05	0.00	0.01	0.00	1.00		
N	0.01	0.08	-0.10	-0.01	0.01	-0.02	0.06	0.13	0.23	-0.03	0.08	0.30	-0.22	0.15	1.00	
O	-0.08	0.11	0.22	0.08	0.22	0.19	0.25	-0.20	0.03	0.13	0.02	-0.18	0.02	0.06	-0.01	1

Household properties include Family Size (A) and Landholding (B); Income sources include, Daily Labor (C), Small Businesses (D), Salaried (E) and Commercial Fisheries (F); Income loss due to, Erosion (G), Salinity Intrusion (H), Rainfall Variability (I) and Severe storms like Aila in 2009 (J); Households perceiving Environmental Risk (K), Change in Environmental Risk (L), Effects of Climate Change (M) and Effects of Sea Level Rise (N), Number of in-situ income sources (O).

Appendix D - **Institutional Review Board (Kansas State University)**

Consent Form

KANSAS STATE UNIVERSITY | University Research Compliance Office

TO: Dr. Bimal Paul
Geography
121 Seaton Hall

Proposal Number: 8803

FROM: Rick Scheidt, Chair
Committee on Research Involving Human Subjects

DATE: 05/15/2017

RE: Approval of Proposal Entitled, "Reducing Climate Change Vulnerability through adaptation with Particular Importance to migration: A Study in the Indian Sundarbans."

The Committee on Research Involving Human Subjects has reviewed your proposal and has granted full approval. This proposal is **approved for one year from the date of this correspondence, pending "continuing review."**

APPROVAL DATE: 05/15/2017

EXPIRATION DATE: 05/15/2018

Several months prior to the expiration date listed, the IRB will solicit information from you for federally mandated **"continuing review" of the research**. Based on the review, the IRB may approve the activity for another year. **If continuing IRB approval is not granted, or the IRB fails to perform the continuing review before the expiration date noted above, the project will expire and the activity involving human subjects must be terminated on that date. Consequently, it is critical that you are responsive to the IRB request for information for continuing review if you want your project to continue.**

In giving its approval, the Committee has determined that:

☒ There is no more than minimal risk to the subjects.
☐ There is greater than minimal risk to the subjects.

This approval applies only to the proposal currently on file as written. Any change or modification affecting human subjects must be approved by the IRB prior to implementation. All approved proposals are subject to continuing review at least annually, which may include the examination of records connected with the project. Announced post-approval monitoring may be performed during the course of this approval period by URCO staff. Injuries, unanticipated problems or adverse events involving risk to subjects or to others must be reported immediately to the Chair of the IRB and / or the URCO.

203 Fairchild Hall, Lower Mezzanine, 1601 Vattier St., Manhattan, KS 66506-1103 | 785-532-3224 | fax 785-532-3278 | comply@ksu.edu | k-state.edu/research/comply