ENVIRONMENTAL MIGRATION IN THE LOWER DETLA PLAIN OF WEST BENGAL, INDIA

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Submitted by

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CERTIFICATE FROM THE SUPERVISORS

This is to certify that the thesis entitled "**ENVIRONMENTAL MIGRATION IN THE LOWER DELTA PLAIN OF WEST BENGAL, INDIA**" submitted by Sri Shouvik Das who got his name registered on 13th December, 2016 for the award of Ph. D. (Science) degree of Jadavpur University, is absolutely based upon his own work under the supervision of Prof. (Dr.) Sugata Hazra and Dr. Ricardo Safra de Campos and that neither this thesis nor any part of it has been submitted for either any degree / diploma or any other academic award anywhere before.

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This work is dedicated to my parents Mrs. Debjani Das and Mr. Anandamoy Das and my wife Mrs. Swati Chaudhuri

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Working Paper:

- Samling, Clare Lizamit, **Shouvik Das**, and Sugata Hazra. *"Migration in the Indian Bengal Delta and the Mahanadi Delta: a review of the literature."* (2015).

Online Abstracts/ Presentations:

- **Das, Shouvik**, Sugata Hazra, Tuhin Ghosh. "*Paradox of Migration in Kolkata: A Megacity in GBM Delta"* at AGU Fall Meeting 2015 (14-18 December, San Francisco, California, USA), (GC43G-06)
- Bhadra, Tuhin, **Shouvik Das**, and Sugata Hazra (2015). *"Water for Agriculture in a Vulnerable Delta: A Case Study of Indian Sundarban."* Abstract: GC41F-1150. *AGU Fall Meeting 2015,* San Francisco.
- **Das, Shouvik**, Sugata Hazra, Tuhin Ghosh. *"Vulnerability and Poverty as Determinants of Labour Migration in Indian Sundarban"* at ULAB-International Conference on Sustainable Development (3-5th Feb'16, Dhaka, Bangladesh)
- **Das, Shouvik**, Sugata Hazra. *'Environmental Perceptions and Migration Decisions: A Study in Indian Bengal Delta'* at International Conference on Mathematical Analysis and Application in Modeling (9-11th January, 2018), Jadavpur University.

Abstract

Empirical research indicates that environmental changes including climate change have caused people to move for a safer place. Environmental changes brought about by rapid and slow onset events like floods, cyclones, droughts or sea level change have impacted the livelihoods of vulnerable communities and individuals across the globe. Migration is one form of response people have adopted either individually or as a community in the face of such changes. Rapid-onset events like cyclones or floods have the potential to cause considerable damage to infrastructure and property, as well as resulting in loss of life, and are therefore often associated with distress migration, known as environmentally forced migration. Slow-onset changes like sea level rise, erosion, salinization often stimulate permanent displacement as a first-order household adaptation. This may, however, initiate as temporary migration or short-term adaptation. Intergovernmental Panel on Climate Change suggests that the environmental degradation exacerbated by impacts of climate change can cause millions to migrate. Large numbers of people are moving as a result of environmental degradation that has increased dramatically in recent years. The scale and magnitude of such migration, though, may vary depending on local and regional vulnerabilities. As environmental changes increase, migration pressures related to these changes may also grow. However there is no single internationally agreed definition in identifying the flows of environmental migration as the migration, environment and climate change nexus is a complex one. The definitional issue is directly linked to the conceptualization and typologies of environmental migration, its estimates and forecasts, and the policy responses. There is also a serious debate whether environmental migration (migration induced by environmental degradation) can be recognized as a separate category of migrants at all, and if so, it can be distinguished from migration driven by economic or socio cultural reasons.

This study is aimed at the assessment of environmental migration in the lower delta plain of West Bengal with three objectives: (a) to develop a conceptual framework and identify the links between migration, the environment and climate change; (b) to understand migration behaviour in response to the impacts of climate change; (c) to estimate the number of people on the move because of environmental pressures today, and at points in the future.

Extensive surveys were conducted at household and community level with specific modules which include questions to identify migrants from the household, work activity of the migrant prior to migration, reasons for migration, work at the last destination and remittances, thresholds, environmental perception, etc. Binary logistic regression method was applied to understand the influence of various environmental and socio-economic variables on migration decision. To estimate the number of people on the move because of environmental pressures in the future, exposure mapping method was performed for this study.

The outcomes of this study are climate risk/impact and social vulnerability maps, migration map, conceptual model of environmental migration, sustainable livelihood options and policy recommendations.

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List of Abbreviations

AC:	Adaptive Capacity
AD:	Anno Domini
AR4:	Fourth Assessment Report
AR5:	Fifth Assessment Report
BC:	Before Christ
BLR:	Binary Logistic Regression
BMTPC:	Building Materials and Technology Promotion Council
BPL:	Below Poverty Line
CAPI:	Computer-Assisted Personal Interviewing
CCFVI:	Coastal City Flood Vulnerability Index
CD Block:	Community Development Block
CRS:	Catholic Relief Services
CSA:	Climate Smart Agriculture
CSE:	Centre for Science and Environment
DECCMA:	DEltas, vulnerability, Climate Change: Migration and Adaptation
EM:	Exposure Mapping
FGD:	Focus Group Discussion
GBM:	Ganga-Brahmaputra-Meghna
GDP:	Gross Domestic Product
GIS:	Geographic Information System
GoWB:	Government of West Bengal
GP:	Gram Panchayat
GPS:	Global Positioning System
GRID:	Global Report on Internal Displacement
HDI:	Human Development Index
IBD:	Indian Bengal Delta
IBTrACS:	International Best Track Archive for Climate Stewardship
IDMC:	Internal Displacement Monitoring Centre
IMD:	Indian Meteorological Department
INR:	Indian Rupee
IOM:	International Organization of Migration
IPCC:	Intergovernmental Panel on Climate Change
KMA:	Kolkata Metropolitan Area
KMC:	Kolkata Municipal Corporation
KMDA:	Kolkata Metropolitan Development Authority
KMO:	Kaiser-Meyer-Olkin
N 24 Parganas:	North 24 Parganas
NELM:	New Economics of Labour Migration
OBC:	Other Backward Class
OR:	Odds Ratio
PCA:	Principal Component Analysis

PI:	Potential Impact
QGIS:	Quantum Geographic Information System
RC:	Reference Category
RCP:	Representative Concentration Pathway
RI:	Risk Index
RMSL:	Relative Mean Sea Level
S 24 Parganas:	South 24 Parganas
SC:	Scheduled Caste
SHG:	Self Help Group
SLA:	Sustainable Livelihood Approach
SPSS:	Statistical Package for the Social Sciences
SSP:	Shared Socioeconomic Pathway
ST:	Scheduled Tribe
SVI:	Social Vulnerability Index
UNEP:	United Nations Environment Program
UNHCR:	United Nations Commissioner for Refugees
USD:	United States Dollar
VI:	Vulnerability Index
WBG CCKP:	World Bank Group Climate Change Knowledge Portal
WBSAPCC:	West Bengal State Action Plan on Climate Change
WRI:	World Resources Institute
WWF:	World Wide Fund for Nature
YBP:	Years Before Present

CHAPTER 1

Introduction

"The gravest effects of climate change may be those on human migration as millions are displaced by shoreline erosion, coastal flooding and severe drought." **- *IPCC, 1990, p. 20.***

1.1. Overview of the study:

Globally, deltas are important socio-ecological systems, which support more than 500 million people on just 1% of the total land area (Ericson et al., 2006; Foufoula-Georgiou et al., 2011; Renaud et al., 2014). The majority of these people are in the global south with significant development requirements (de Souza et al., 2015). For at least 30 years, deltas have been acknowledged as a highly vulnerable coastal system (Milliman et al., 1989; Tsyban et al., 1990) threatened by multiple factors of climate change and sea-level rise, upstream changes such as sediment starvation due to dams, and changes within the delta such as subsidence (Milliman et al., 1989; Ericson et al., 2006; Nicholls et al., 2020). At the same time, deltas are widely developing and experiencing significant demographic and economic change, which also impact delta areas in terms of intensified agriculture, expansion of aquaculture, and urbanisation (Woodroffe et al., 2006; Beondizio et al., 2016; Renaud et al., 2016; Szabo et al., 2016; Nicholls et al., 2020). As such, there is a strong nexus between the development of delta areas and managing these growing risks to ensure the well-being of delta residents.

Extreme environmental events (Helbing et al., 2011), both climatic and non-climatic, with the potential to adversely affect the community and their surrounding environment are perceived as 'hazards' by the community. While hazards like cyclones and surges are rapid onset type in nature, drought, sea level rise, salinization, coastal erosion in the deltas are of slow onset nature (Das et al., 2021). Be it slow onset or rapid, environmental hazards pose tremendous pressures on human life and livelihoods, such as losses in crop yields, food insecurity, damaged homes, and loss of sense of place (Olsson et al., 2014). Environmental hazards disproportionately affect the rural, poor, child, female, elderly, and marginalised communities (Kasperson and Kasperson, 2001; Vincent, 2004; Dasgupta et al., 2014).This situation contributes to poverty, hunger, inequality, and displacement of

inhabitants that create social destabilisation and affect the local economy in deltaic regions (Addo, 2015; Adger et al., 2014; Ayeb-Karlsson et al., 2016).

Photo 1. The people of Indian part of GBM delta are trying to build flood defense to protect their habitation in the face of increasing extreme weather events and sea level rise

Photo 2. The children on the eroding land brings a feeling of living on the edge

One sort of response to these changes that people have taken, either individually or collectively, is migration (Adger et al., 2014; McLeman, 2018). Rapid-onset is closely associated with distress migration, also known as environmentally forced migration, because it has the ability to seriously damage infrastructure and property as well as cause casualties. Permanent migration is often triggered by slow-onset changes as a first-order household adaptation. However, this may start as a temporary migration or short-term adaptation (Das et al., 2016). Recent empirical research studies highlight how environmental change-affected groups or individuals diversify their livelihoods to avoid moving at all or engage in long-established cyclic migration patterns (Adams, 2016; Farbotko and Lazrus, 2012; Klepp, 2017; Wiegel et al., 2019).

Intergovernmental Panel on Climate Change (IPCC) predicted that climate change would cause millions to migrate (IPCC, 1990). People are moving in large numbers as a result of environmental change, which has increased significantly in recent years (Laczko and Aghazarm, 2009). Environmental change-related migration, including disaster displacement, mainly happens within national borders. The most recent Global Report on Internal Displacement (GRID) (2021) from the Internal Displacement Monitoring Centre (IDMC) states that out of the 38 million internal displacements recorded in 2021, 23.7 million (62%) were displaced by disasters. By 2050, more than 1 billion people might be exposed to coastal hazards, which could force 10 to 100 million people to leave their homes, according to the IPCC.

The scale and magnitude of such migration vary depending on local and regional vulnerabilities. Migration pressures related to these changes may rise as environmental changes intensify (Campbell, 2014). However there is no single internationally agreed definition in identifying the flows of environmental migration as the migration, environment and climate change nexus is a complex one (Kniveton et al., 2008). The definitional issue is closely related to how environmental migration is conceptualised, its types, projections, and policy responses (Zhongming et al., 2012). There is also a serious debate whether environmental migration (migration induced by environmental degradation) can be recognized as a separate category of migrants at all, and if so, it can be distinguished from migration driven by economic or socio cultural reasons.

The present study was undertaken in the lower delta plain of West Bengal around three districts of Kolkata, North and South 24 Parganas which are under constant threat of climate change related impacts. This research attempts to identify the link and thresholds of environment related migration in order to distinguish it from other drivers of migration by tracking migrants from the sending areas to the receiving areas through household surveys. The study combines with secondary data analysis along with application of geo-informatics and modeling to develop appropriate criteria to resolve the issue of environmental migration.

1.2. Concept of migration

Migration is the process by which people, either as individuals or as entire households, move from their usual place of residence to another location. As a result of a change in the relative attractiveness, actual or perceived, of the usual place of residence with respect to the destination, this often includes crossing an administrative or national boundary and residing for at least six months (Samling et al., 2015). Economic factors, such as employment or education, and family are the principal reasons for migration (Mortreux and Adams, 2015). Environmental change and climate variability also influence migration and can affect migration decisions directly, such as through impacts on livelihoods and health, and indirectly through wider economic and political processes (Abu et al., 2014; Adger et al., 2021).

Migration is the "movement of persons away from their place of usual residence, either across an international border or within a State" – ***IOM, 2019.***

While migrants may stay in the destination location permanently, migration is usually more complex and migrants may return after a period of time; move between locations according to seasonal or other cycles (including between their original place of residence and another); or keep moving in an itinerant manner when permanent settlement is desired but impracticable (Mortreux and Adams, 2015). Migrants are part of a connected sending-receiving system. The impacts of migration on the wellbeing of the migrant and the household and community from which he or she originates, can be positive or negative (Szaboova et al., 2022).

1.3. Defining environmental migration

Migration related to environmental change was not until 1985 with El-Hinnawi's United Nations Environment Program (UNEP) Report titled 'Environmental Refugees' that environmental factors came to be a focus in the migration literature (El-Hinnawi, 1985; Westing, 1992; Lonergan, 1998). Since then, alarmist debates on climate change have seen environmentally induced migration framed as a serious cause for concern, with tens of millions of 'environmental refugees' projected (Myers, 1993; Jacobson, 1988; Westing, 1992). Alarmist claims like these have flourished despite a lack of empirical evidence to support them, often estimating 'environmental refugees' on the basis of the number of people at risk of being displaced by environmental change with apparent disregard of evidence showing that displaced populations tend to migrate short distances and return when possible (Tacoli, 2009; Gemenne, 2011).

Environmental migration is the "movement of persons or groups of persons who, predominantly for reasons of sudden or progressive changes in the environment that adversely affect their lives or living conditions, are forced to leave their places of habitual residence, or choose to do so, either temporarily or permanently, and who move within or outside their country of origin or habitual residence" ***- IOM, 2019.***

Environmental change will increase pressure on communities such that displacement, resettlement and forced migration will be likely to increase, but the extent of impact is not understood. The nature of the environmental change, such as the speed of onset and the impact on livelihoods, makes a big difference in people's ability to adapt (i.e. managed relocation vs. emergency response) however there are a range of other aspects that must be addressed to develop a nuanced understanding of migration drivers (Mortreux and Adams, 2015). Environmental change and climate variability are one of many structural and personal influences on migration and can affect the migration decision both directly, through impacts on, for example, livelihoods and health and indirectly through wider economic and political processes. It is important to remember that climate change, whilst having its unique challenges, is not in a vacuum (Doevenspeck, 2011; Black et al., 2011). Failing to ground debates in broader understandings of migration can lead to inappropriate policies that may undermine the rights of those vulnerable to climate change (Tacoli, 2009).

Environmental migrants are defined as "persons or groups of persons who, predominantly for reasons of sudden or progressive changes in the environment that adversely affect their lives or living conditions, are obliged to leave their habitual homes, or choose to do so, either temporarily or permanently, and who move within their country or abroad" ***- IOM, 2014****.*

1.4. Aims and Objectives

The study is aimed at the assessment of environmental migration in the lower delta plain of West Bengal with the following objectives:

- To assess vulnerability and risk following IPCC AR 4 and AR 5 approaches.
- To identify the connection between climate change, the environment, and migration.
- To understand migration behaviour in response to the impacts of climate change.
- To examine the drivers and the extent to which the environment acts as an underlying factor or main reason for movement of people.
- To estimate the number of people on the move because of environmental pressures today, and at points in the future.

1.5. Development of the research questions

A research question is an exploration concerning a point by point study of the subject. It is the introductory step of any research project. Existing concepts and definitions of "environmental migration" in selected literature were explored to develop related research questions. Following are the framed Research Questions:

1. ***Where are current hotspots?***
2. ***What are the patterns of migration?***
3. ***Who are migrating?***
4. ***What are the drivers of migration?***
5. ***What are the issues and consequences of migration?***
6. ***Is there any link between climate change, the environment, and migration?***
7. ***To what extent is climate change a driver of migration?***
8. ***How many people will move under future climate scenarios?***

1.6. Research structure and design

The current research comprises of twelve chapters. **Chapter one** produces an overview of the study, concept of migration, defining environmental migration, aims and objectives. It discusses the theoretical framework of the study as well as shows the way to achieve pre-set objectives. In **chapter two**, the literature of the same line has been reviewed thoroughly to understand research variables and research gaps. The study area has been covered in **chapter three**. It provides the detailed administrative, socio-economic characteristics and bio-physical characteristics of the study area. **Chapter four** describes the data and methods. **Chapter five** assesses the vulnerability (AR 4) and risk (AR5) at the local level (sub-district) to identify climate change impact hotspots. **Chapter six** constructs a social vulnerability index at the sub-district level taking secondary data. **Chapter seven** provides a further high-resolution analysis at the sub-district level using indirect net migration method, and identifies migration hotspots where out-migration dominates over in-migration. **Chapter eight** examines municipal ward and district levels net-migration and explores the reasons behind the current trend of de-population in Kolkata city. **Chapter nine** provides the correct understanding of the patterns of migration in the study area by linking sending and receiving areas. **Chapter ten** examines whether and how household perceptions of different types of environmental risks affect migration intention to migrate or to stay. **Chapter eleven** examines where, when, and how much climate migration may increase. **Chapter twelve** presents summary, recommendations, and conclusion of the study.

Chapters five and six present substantial, self-contained, complementary research in the format of scientific publications and are based on accepted submissions to academic journals. The description below establishes the candidate's contribution to the published papers:

- **Das, Shouvik**, Amit Ghosh, Sugata Hazra, Tuhin Ghosh, Ricardo Safra de Campos, and Sourav Samanta. *"Linking IPCC AR4 & AR5 frameworks for assessing vulnerability and risk to climate change in the Indian Bengal Delta."* Progress in Disaster Science 7 (2020): 100110.
- **Das, Shouvik**, Sugata Hazra, Anisul Haque, Munsur Rahman, Robert J. Nicholls, Amit Ghosh, Tuhin Ghosh, Mashfiqus Salehin, and Ricardo Safra De Campos. *"Social vulnerability to environmental hazards in the Ganges-Brahmaputra*

Meghna delta, India and Bangladesh." International Journal of Disaster Risk Reduction 53 (2021): 101983.

CHAPTER 2

Literature Review

"The literature on climate change and migration is generally very pessimistic about mobility arising from climate change. This creates a starting point bias in thinking about policy responses, eschewing the development of policies that seek to harness migration as a strategy to promote adaptation to climate change" - ***Barnett and Webber, 2009, p.19.***

2.1. Introduction

Deltas are complex systems where significant migration is occurring and yet migration from these places is poorly understood. Resource-dependent communities living in deltas are particularly vulnerable to environmental, economic, political and social changes (Seto, 2011). As such, the IPCC has identified deltas as a climate change 'hotspot' and projections suggest that high levels of migration from deltas in response to climate change impacts are likely (Seto, 2011). However, the relationship between vulnerability to changes in delta communities and existing migration patterns is not clear. It is important to first have an understanding of current migration patterns before analysing the impact of environmental change on migration. With this in mind, there are three objectives of the literature review on migration:

1) review the literature on migration to understand broad migration patterns;
2) review theories relevant to understanding migration, and
3) identify existing gaps in the migration literature.

2.2. Debate in Terminology and Classification of 'Environmental Refugees'

The United Nations Commissioner for Refugees (UNHCR) defines 'Refugees' as *"persons forced to flee across an international border because of a well-founded fear of persecution based on race, religion, nationality, political opinion or membership of the particular social group".* UNHCR in its 2004 Report has provided a figure of 10 million people displaced due to environmental reasons but they do not consider them as 'Refugees'. Three criticisms have been levelled on the definition of refugees provided by UNHCR – 1) it ignores the role of environmental disasters and degradation, 2) only addresses international migrants, and 3) does not address the

situation of those people if the whole country becomes inhabitable (Boon and Tra, 2007).

The term 'Environmental Refugees' was initially suggested by Lester Brown of the Worldwatch Institute in the 1970s. The studies on 'Environmental Refugees' mostly use the concept popularized by **El Hinnawi (1985)** who in the report for the UNEP has defined them as people "*who have been forced to leave their traditional habitat, temporarily or permanently, because of a marked environmental disruption (natural and/or triggered by people) that jeopardized their existence and/or seriously affected the quality of their life. By 'environmental disruption' is meant any physical, chemical and/or biological changes in the ecosystem (or the resources base) that render it temporarily or permanently, unsuitable to support human life*".

This definition and classification of El-Hinnawi have been criticized by **Bates (2002)** because it has given no clear criteria for distinguishing one type of refugee from the other or any specification of the differences between refugees. Further three criticisms have been cited by the author (Peroutt, 1995) on the past works on "Environmental Refugees". Firstly, the studies showcase a strong regional bias, where the focus is more on some parts of the world like Africa and Asia than on others. Secondly, comprehensive case studies of circumstances that result in environmental refugees are uncommon. Thirdly, the use of the term 'refugee' is usually avoided by scholars who are more inclined towards international law, security concerns, and broader questions of migration. The definition which is used to define 'Environmental Refugees', in past works/studies does not emphasize more on two of the important features of environmental refugees: *"the transformation of the environment to one less suitable for human occupation and the acknowledgement that this causes migration."*

Stojanov (2004) has categorised the environmental disruptions into five groups based on the classification of El-Hinnawi (1985): natural disasters, cumulative (slow onset) changes, involuntarily caused accidents and industrial accidents, development projects, conflicts and warfare. While generally agreeing with El-definition Hinnawi of "Environmental Refugees", Boon et al. (2007) added some depth, particularly to the second category. Three categories of environmental refugees have been identified, starting with those who are "temporarily displaced due to environmental stress", such as storms, earthquakes, and other natural disasters. Second, "permanently displaced

owing to Man-made difficulties", that is, individuals who have been moved because of the building of dams, roads, etc. Boon et al. (2007) correctly pointed out that people displaced due to the declaration of Protected Areas (PA) should also be included in this category. Thirdly, "permanently displaced due to environmental degradation", those that are displaced by events such as desertification etc.

The desertification theory was however criticized by **Black (2001)** and pointed out studies (Helldén, 1991; Thomas and Middleton, 1994; Swift, 1996; Cordell et al., 1996; Rain, 1999) which showed that Desertification is a 'myth' and that migration could be a result of agricultural decline and grazing lands during drought periods. Migration from the Sahel and other semi-arid regions was seen as more of a social and economic response and a direct link between drought and migration cannot be determined. According to Black (2001), it is inappropriate to refer to such migrants as "environmental refugees" because the movement of people according to the climate variations is not a new phenomenon. This can be contested from the point of the increasing threat of desertification for which the UN Conference on Environment and Development in 1992 had to pay special attention to the demand for a Convention on Combating Desertification, especially focusing on Africa. **Boon et al. (2007)** has further mentioned that once the devastated area is again restored to its original state, the migrants can return to the area. Case studies/examples of such restoration are however, very little known. A question can be raised here, what if the place remains inhabitable for very long stretch of time, like for e.g., destruction of a Nuclear Power Plant, then would the migrants be still termed as temporary migrants or would they be included as permanent migrants?

Bates (2002) has attempted to classify the migrants on the basis of environmental disruption, its origin, its duration, and whether migration was a planned outcome of the disruption. The first classification is the 'Environmental Refugees due to Disasters', which can be either natural for e.g., hurricane, floods etc. or anthropogenic/technological or a combination of both, resulting in either unplanned short-term movement or permanent refugees. The second classification is the 'Environmental Refugees due to Expropriation of Environment', which results from anthropogenic disruptions in the environment that purposefully displace populations, usually permanently, e.g., when people are relocated for the construction of dams.

This has been sub-classified into two categories based on two different situations, economic development and warfare. The second sub-category, warfare, produces a distinct type of refugees, largely due to ecocide, which involves the intentional destruction of the environment leading to forced migration of the people. The third classification is the 'Environmental Refugees due to Deterioration of Environment', resulting from gradual, anthropogenic alterations in their environment, either pollution or depletion of natural resources. As such, this involves an unplanned migration. Not much difference can be seen between the classification of Bates (2002) and Boon et al. (2007), except that the former author has elaborated each of the types.

Black (2001) examined the relationship between environmental degradation and conflict that results in refugee movement, which is currently the subject of the new 'conflict studies'. After reviewing 11 major conflicts that caused large scale forced migration (since 1990), the author opines that they are more for control over the natural resources rather than its degradation. The causes that create such conflict and migration can be looked in a much broader context, than simply as the cause of environmental degradation. As such, it is difficult to isolate the causes.

The link between environmental degradation and conflict has also been studied by others. **Myers (2001)** writes about the problems that are faced by the receiving areas, such as perceived threat to social cohesiveness and national identity posed by potential outbreaks of ethnic tension and civil disturbance, as well as political upheaval. Analyzing the link between forced migration and conflict, Castles (2002) didn't find any convincing answer from the past studies on the issue. Factors such as political divisions, ethnic rivalries and economic interests seemed more determining, leading to violent conflicts and not environmental degradation. He has tried to explain whether there exists a linkage between environmental change, forced migration and conflict, taking the case study of Indonesia's '*Transmigrasi*' programme. Environment in this example was not the direct causative factor for conflict and migration, as the programme was undertaken to have a more planned distribution. The conflict in this case largely originated from the opposing cultural practices, followed by the original inhabitants in agriculture (shifting cultivation), in contrast to the practice of settled cultivation followed by the newly introduced settlers.

A review of past literature (Myers and Kent, 1995; Black, 1998; Wood, 2001; Lee, 2001) has been done by **Castles (2002)**, where he concludes that the concept of 'environmental refugees' as illustrated in the studies is misleading. Migration is not directly triggered by environmental change, but rather by natural and environmental causes that are strongly related to economic and social problems that would result in poverty, conflict, and displacement. Later it seems that he is contradicting his observation by saying that not giving these refugees international protection and a definite terminology, would give advantage to those who want to restrict or refrain from the responsibilities of those refugees.

TERI (2009) in its report on the "Climate Change Induced Migration and its Security Implications for India's Neighbourhood", on the other hand opines that climate change could exacerbate conflict and would accentuate competition for land and water, distrust or adding to existing socio-economic disparities, cause strain on the receiving areas as well and would lead to environmental degradation especially in areas with high population density, like India.

Johnson (2009) has opined that environmental refugees are a cause of concern for both environment and security. This has been explained taking the example of the Sardar Sarovar Project in India, which resulted in displacement of people causing large scale civil unrest and perhaps security threat for the society as well as for the state. The relationship between environmental refugees and human security has also been illustrated by the case of Vanuatu, one of the Pacific Islands, where the people of the island faced life threatening situations due to climatic changes.

Barnett and Weber (2010) has typified seven types of migration that maybe stimulated by climate change viz., internal labour migrants, international labour migrants, internal displacement, international displacement, internal permanent migrants, international permanent migrants and relocation of communities. The last three groups face greater risk to their livelihood and human rights because these groups would involve a similar process of permanent migration. Further, they have observed that the pattern of migration is not random and is dependent on various factors like, financial and information barriers and are determined by social network, concentrating on those places where past migrants have demonstrated that it is habitable. Authors believe that it would continue in the same trend rather than

creating new flows, largely leading to 'internal migration' in developing countries. It was also observed that it is usually the lower middle classes who migrate. While it was earlier mentioned that the poor people usually do not migrate and even when they do, they migrate only short distances, the paper later made a contradictory statement that a large proportion of international migrants will be the rural poor, who due to financial constraints will move to the neigbouring developing countries.

A whole new viewpoint on the connection between environmental change and migration emerged in the latter part of the 2000s. Migration was increasingly acknowledged as having always played a significant role in how people adjust to changes in their environment, whether they be natural, political, or economic (McLeman and Smit, 2006; Black et al., 2011). Moving out from risky places and using remittances from emigrant relatives to create in situ resilience are crucial strategies from this perspective (McLeman & Smit, 2006; Sakdapolrak et al., 2016; Wiegel et al., 2019). According to key international institutions, including the International Organisation of Migration (IOM) and the Asian Development Bank (ADB) proactive environmental migration is becoming increasingly significant as an important adaptation strategy for reducing the vulnerability (IOM, 2018).

2.3. Environmental Migration - Global and Indian context

Studies in environmental change and migration have all talked about the works of Norman Myers, an Oxford Scholar. Using the IPCC's baseline (1990) as a starting point, **Myers (1993)** made an estimate for the year 2050 in his study. By 2050, there are expected to be 150 million environmental refugees worldwide, including 30 million in China, 30 million in India, 15 million in Bangladesh, 14 million in Egypt, 10 million in other delta regions and coastal zones, 1 million in island states, and 50 million in agriculturally dislocated areas. This is 1.5% of the projected 10 billion people in 2050.

Myers has projected only a population of 1 million people at risk in West Bengal and Odisha, when other studies have predicted this to be much higher (vide Delta Vision 2050: Indian Sundarbans, 2011, WWF-I). Coastal communities would largely move inland which would further cause strain on the existing population. Some of the other environmental problems foreseen, include, coastal flooding, water shortage, tropical

deforestation, land degradation, soil erosion and desertification. All of these will cause greater impact, leading to problems such as loss in agricultural crop production, shortage of food, spread of diseases, exerting pressure on countries harbouring refugees in terms of space and resources etc. The problem of refugees would result in social, economic, ethic, cultural and political consequences and the costs to be incurred by the developed countries in accommodating the refugees will be around $ 8 billion a year. In order to combat sea level rise, it will cost between $17.5 trillion and $20 trillion over the period of 50 years, including $2.5 trillion to $5.0 trillion for coastal protection expenses worldwide and $15 trillion for coastal land loss. There is no available estimation of the costs of disrupted agriculture in drought afflicted regions, but the refugee crisis would involve resettlement, maintenance and support costs, opportunity costs, cost for internal and external security, social disintegration. A question also arises here as to who would be responsible for these costs?

According to **Black (2001)**, although numerous studies have projected the expected number of migrants, the actual number of migrants in prior situations has never been defined. This is a criticism of the estimates of migration as a result of sea level rise. He points out that the past studies lack in strength due to lack of concrete and actual data and are repetitive in nature.

A study was undertaken by **Mortreux and Barnett (2009)** to understand climate change and the current migration trends of the citizens of Funafuti, Tuvalu, one of the South-Pacific Islands, which is more vulnerable to climate change. Three key factors were seen to influence peoples' perception to climate change viz., religion, no personal experience of climate change and attitude towards 'home'. The perception of the people was largely dependent on their understanding of the problem, its cost-benefit analysis and contextualized by the larger social milieu. Migration was seen as something that would violate their core social values and largely their human rights. The authors opine that migration from Tuvalu islands may be an outcome of policy responses of anticipated climate change impacts, rather than actual changes in the environment. Migration could be regarded as a form of 'Adaptation' at an individual level. It appears that the study would have been more fruitful, if the sample size had been larger. Inclusion of male respondents in this study would have added another dimension, as the authors have said that the males are the ones who are mostly

migrating, largely because of economic reasons. While it has been mentioned that the respondents selected in individual capacity were all female, but they have failed to mention whether the respondents in professional were all female or also included the male. The question remains as to what the people would do if there is threat of the entire islands submerging?

According to **TERI (2009)**, hotspots for climate change across India's borders include low-lying deltaic regions (Bangladesh), areas at risk of flash floods (Bangladesh, Nepal, Bhutan, China), areas with a risk of glacial lake outbursts (Nepal, Bhutan, China), areas where livelihoods are lost due to changing precipitation patterns (Nepal, Myanmar), and areas susceptible to sea level rise (Sri Lanka, Myanmar, Bangladesh). Potential long-term or short-term climate change-related migration in the Indian neighbourhood might include a huge influx of migrants or a slow, steady process. The North-East and Himalayan areas of India, as well as the flood plains of the main river basins, are the most prone to see rapid movements of people.

Barnett and Weber (2010) are however critical of the projections of migrants due to climate change. The reasons that have been pointed out are difficulty in constructing evidenced based future projections of climate change induced migrants because of the dearth of baseline data of such migrants on which future projections can be made.

Bera (2013) followed an ethnographic approach to see the demographic changes in the two locations viz., Patharpratima (G-Plot GP) and Sagar Blocks (Ghoramara GP and Dhablat GP) from Kakdwip subdivision of West Bengal, because these areas were severely affected by breaching of embankments and because of their high ranking of Vulnerability Index in the Human Development Report (2009). In this study the author has linked migration with that of the availability of livelihood opportunities. Social bonding was also another factor. The displaced people are resettled in "Colonies", where very often it is seen that the people shift from their traditional to alternative livelihood. Like for example, a fisherman becomes a rickshaw puller or daily wage labourers due to lack of access to fishing. Government provided areas for resettlement are usually declined by the affected population Migration decision was also dependent on social status and land holding status. But what would the migrants (forced) do if they do not have any choice? The author has not taken into account the poverty levels of the respondents. No quantified data on the

number of migrants has been provided. In this study, the cause (push factor) of migration seems to be rooted to economic deprivation resulting from gradual environmental degradation.

A similar study was carried out by **Ghosh et al. (2014)** to analyze land erosion and its impact on migration, in Ghoramara and Sagar Islands. The analysis showed that the entire area of Ghoramara was 8.51 sq. km in 1975 but only 4.43 square sq. km in 2012, clearly demonstrating the severity of erosion. The Lohachara, Suparibhanga, and Bedford Islands, as well as the Ghoramara settlements of Lakshmi Narayanpur, Khasimara, Khasimara Char, Bagpara, and Baishnabpara, have all been drowned during the period of severe erosion between 1975 and 1990. Of these four islands, Ghoramara and Lohachara were highly populated. The major event of migration took place between 1975 and 1990, due to the severe erosion within that island cluster. Due to the submergence of Lohachara and Bedford Islands, the people migrated to the neighbouring islands of Ghoramara and Sagar. As a result, the population annual growth rate of Ghoramara Island remain at 0.55%, but the growth rate in the Sagar block is much higher at 2.1%. Due to the significant number of immigrants who sought refuge on Sagar Island as a result of the submergence of Lohachara and five villages of Ghoramara, Sagar island's total population increased over the decade of 1981-1991, exceeding the predicted population (with the average 2.1% growth rate). Using the population growth rate and population statistics, the estimation of total migration has been analyzed from the difference between the expected and estimated population. In compared to other stable islands nearby, Ghoramara's growth rate during 1971, 1981, 1991, and 2001 is very slow, according to the Census of India (2001). The majority of the locals believe that 4000 individuals left the island of Ghoramara.

According to the World Bank's Groundswell report (2021), by 2050, climate change could force up to 216 million people to move within their countries in six different parts of the world - Sub-Saharan Africa, North Africa, Latin America, South Asia, East Asia and the Pacific, Eastern Europe and Central Asia (Clement et al., 2021).

The growing body of empirical research on environmental migration demonstrates that responses to migration pressures brought on by environmental change on the

ground are highly variable. It highlights how environmental change-affected groups or individuals diversify their livelihoods to avoid moving at all or engage in long-established cyclic migration patterns (Farbotko and Lazrus, 2012; Adams, 2016; Klepp, 2017; Wiegel et al., 2019).

Table 1. Empirical evidence of relationship between hazards and human migration

Articles	Study area	Hazards	Migration destination	Temporary or permanent migration
Bernzen et al. (2019)	Bangladesh	Coastal/riverine flooding; erosion; salinization	Unspecified	Unspecified
Bohra-Mishra et al. (2014)	Indonesia	Coastal/riverine flooding	Internal	Permanent
Boon (2014)	Australia	Riverine flooding	Unspecified	Unspecified
Buchanan et al. (2019)	USA (New York)	Coastal flooding	Unspecified	Permanent
Call et al. (2017)	Bangladesh	Riverine flooding	Unspecified	Temporary
Chen and Mueller (2018)	Bangladesh	Coastal/riverine flooding; salinization	Internal; International	Permanent
Chen and Mueller (2019)	Bangladesh	Coastal/riverine flooding; salinization	International	Unspecified
Codjoe et al. (2017)	Ghana	Coastal flooding	Unspecified	Unspecified
Goldbach (2017)	Ghana and Indonesia	Coastal flooding; erosion	Short-distance internal; long-distance; combined	Unspecified
Haney (2019)	Canada	Riverine flooding	Unspecified	Unspecified
Gray and Mueller (2012)	Bangladesh	Coastal/riverine flooding	Short-distance internal; long-distance; combined	Permanent
Mueller et al. (2014)	Pakistan	Coastal/riverine flooding	Short-distance internal; long-distance; combined	Permanent
Bera (2013)	India	Coastal flooding	Internal	Permanent
Ghosh et al. (2014)	India	Coastal flooding; SLR generally	Internal	Permanent
Song and Peng (2017)	USA (Florida)	Coastal flooding; SLR generally	Unspecified	Unspecified
Schwaller et al. (2020)	USA (North Carolina)	Coastal flooding	Unspecified	Unspecified

2.4. Migration in the Indian Bengal Delta

The Indian Bengal Delta is inhabited by about 4.5 million people, in 54 islands out of a total of 102 islands. Early human settlement in the Indian Bengal Delta is very vague. Some historical findings have shown that the area had been populated even during 273-232 BC. **Jalais (2010)** in her book "Forests of Tigers" starts the historical account from AD 1200, when Sufi holy men cleared the forests in northern and eastern parts of the delta and introduced agriculture. The area was thriving with small wealthy kingdoms before the 13th century, with naval trade to South-East Asia and Middle East. The Portuguese traders were followed by the invasion of the area by the "Arakan" pirates in the 16th-18th century. The 17th-18th century, witnessed inhabitation of the area in semi-permanent ways by woodcutters, pirates, fishermen, farmers and salt makers who lived in boats. However, large scale migration started after the middle of the 19th century, when British East India Company took over the administration of Bengal and converted the marshy/swampy lands of Sundarbans, especially the southern part of the region, into agricultural land, bringing in workers from places such as Hazaribagh, Chotanagpur, Manbhum now in Jharkhand, Balasore in Odisha, Arakan Coast in Myanmar, districts of Bankura, Midnapur, Birbhum, Nadia, Jessore in Bengal and also people from North 24 Parganas. The islands of Satjelia, Gosaba and Rangabelia were leased by Scottish businessman, Sir Daniel Hamilton in 1903, with the plan of starting a cooperative sector, where he brought in labourers to settle here.

Danda (2007) has mentioned "how infrastructure was built and public services provisioned and paid for in the estate, through a consumer cooperative, the oldest of its kind in India." The recent in-migration in the region was after the partition of Bengal which led to huge influx of refugees from East Pakistan (East Bengal), between 1951 to 1971 (GoWB, 2009). The next influx of refugees to West Bengal originated with the formation of Bangladesh in 1971, as an independent nation (Nandy, 2005; Ramachandran, 2005; Shamshad, 2008; Kumar, 2009).

Datta (2004) conducted a qualitative survey in Kolkata and North & South 24 Parganas, taking a total of 50 respondents from different backgrounds like political leaders, administrators, economists, demographers, journalists, sociologists etc. to get their account of migration from Bangladesh to West Bengal, starting from the time of

Partition in 1947 to the year 2002. Besides political, ethnic and religious reasons and even construction of Farakka barrage in the past which led to massive migration from East Bengal (Swain, 1996; Banerjee, 1999; Lamballe A, 2000; Opstal, 2006; Mukherjee, 2011). The new "Push" factors of migration, according to the respondents were, economic instability and depression, poverty, lack of employment opportunities, livelihood, loss of land and lack of industrialization. About 50% of the respondents also blame the high density of population in Bangladesh leading to migration. Amongst other "Pull" factors in the receiving areas (West Bengal) like economic opportunities, political stability etc., it was also noted that the regions (West Bengal and Bangladesh) share geographical proximity and similar cultural and linguistic similarities. These immigrants in the receiving area, working in low skilled jobs, face numerous problems of poor nutrition, improper medical facilities, poverty and so on. The author based her study more so on the opinion of a "second party" rather than the actual migrants. However, such migration is very hard to document and one cannot be sure of the actual figures of such migrants.

Catholic Relief Services (CRS, 2010) noted that migration during last many decades from IBD had happened for improved livelihood prospects and earning better money, getting higher education or skills. Such migration can be seen as seasonal in nature. However, research in the Indian Bengal Delta have increasingly focused on migration brought on by environmental hazards such as cyclones, storm surges, land degradation, breaching of embankments, or submersion of islands (Hazra et al., 2002; CRS, 2010; Ghosh, 2012; Bera, 2013; Ghosh, 2014; Ghosh et al., 2014; Mukherjee, 2014).

The Human Development Report of South 24 Parganas (GoWB, 2009), analyzing the Rural Household Survey (RHS of 2007) observed that there is an increasing flow of out-migration of youth from the islands into different parts of India. The report however mentions that there is also a trend of "large scale" in-migration from the districts of Medinipur to the blocks of Sagar and Namkhana which has had a positive impact on the education of people.

The Human Development Report of North 24 Parganas (2010) believes migration to be one of the coping mechanism resorted by people to escape the vulnerability with which the district is associated with- poverty, food insecurity, natural calamities such

as flooding, cyclones, storm surges, erosion as evidenced in the post 2009 Cyclone Aila period- and insecurity in border areas, livelihood insecurity. The same report has analyzed the study of Rural Household Survey (2007) carried out by Department of Panchayat and Rural Development, Government of West Bengal, where it was seen that the Block of Sandeshkhali II had the highest percentage of temporal (31.32%) and seasonal migrants (29.77%). But the study did not provide clear details of the migrants.

The Human Development Report also analyzed another study by **ORG-MARG (2008)** in North 24 Parganas, where it was seen that 76.75% cases of out migration were reported to be seasonal in nature, usually involving male migrants and the number of family migration was small. The migrants mostly belong to the age group of 18-34 and are illiterate or have attained only primary schooling. The percentage of female migrants was relatively small and only limited to the domestic sector in the city of Kolkata. The study also reveals that people mostly migrate outside the district but remain within the state of West Bengal (GoWB, 2010). But the report does not provide details in what work are the migrants employed in the receiving areas. However, in later studies it can be observed that the migrants are moving to other states of India (CRS, 2010; Taralekar et al., 2012; Ghosh, 2012; Bera, 2013; Ghosh, 2014). Analysis of census data (2001) by **Taralekar et al., (2012)** have taken West Bengal and Odisha also as the states which contributed more than 10,000 emigrants to Mumbai for ‘work’ and ‘education’.

Cyclone Aila in 2009, apart from the devastation that it brought about, majorly impacted the livelihood of the people especially those who were dependent on agriculture- the primary occupation of the people in the region. Increase in salinity of the soil and ingression of salt water into the ponds made cultivation as well as fishing extremely difficult. A reference can be made here of a study on the impact of cyclone Aila on public health, on arable land, the effectiveness of rescue operation, the rate of morbidity and mortality and other socio-economic problems by **Mistry (2013).** About 891471 people were affected in just one district of IBD- South 24 Parganas. It is however not clear as to what were the parameters that the author used in calculating the number of people who were affected.

Post-Aila scenario witnessed large scale migration of people in search of alternative livelihoods. Collaborative research by Association of Bengal Collaborators for Development, Regional Forum-West Bengal, Catholic Relief Services, WWF-I and Palli Unnayan Samiti, Baruipur demonstrated that 50% of migrant households, from a sample of 501 households in three Gram Panchayats- Bali I & Bali II (Gosaba block) and Nafarganj (Basanti Block) migrated to places like the states of, Assam, Andhra Pradesh, Chhattisgarh, Chennai, Gujarat, Jharkhand (Ranchi), Karnataka (Bangalore), Kerala, Maharashtra (Mumbai), Madhya Pradesh, Orissa, Tamil Nadu (Kanyakumari), Rajasthan, Uttar Pradesh, Uttaranchal (Nainital), West Bengal (Burdwan, and Kolkata) and Delhi and Andaman. The male migrants, within the age group of 20-40, mostly belong to the 'Below Poverty Line' (BPL) category (usually belonging to Scheduled Tribes & Scheduled Castes), are semi-skilled or unskilled or uneducated. Family and female migration would take place within the state- to nearby peri-urban areas of Kolkata- while men migrated outside the state (CRS, 2010). The trapped population included, women, children and the elderly, who survived on the remittances sent by the migrant member of the family or through loans or alternative options.

Similarly, a study undertaken by civil society organization, **Centre for Science and Environment (CSE, 2012)** witnessed migration of especially able bodied male from Mousuni (Namkhana Block), Rangabelia, Satjelia and Lahiripur (Gosaba Block), Rajaballavpur (Patharpratima block) to other states within the country and even international destinations like Singapore and Saudi Arabia. But such choice of destination was dependent on the nature of work and the resources available at the household level. The CSE study (2012) found that women and family migrated only within the state. However such migration was taken as an autonomous form of adaptation. **Sarkar (2012)** also revealed nearly 50% male from 4371 families, residing in four villages from just only one Gram Panchayat- Lahiripur in Gosaba block migrated to other states of India from, after Aila.

Another factor that has led to migration of people from this region is the decline of natural resources, as has been shown by **Mistri (2013)** in his study in Satjelia island, where 74% of the respondents (out of 200) reported migration, 89% male and 11% female. Migrants being usually unskilled or semi-skilled were forced to work in sectors such as construction, manufacturing, service sector, agriculture and female

migrants as maid servants, starkly different from their earlier occupation. Inter-state migration was predominant- to states such as Gujarat, Andaman, Karnataka, Maharashtra and Tamil Nadu- rather than inter-district or intra-district. Within the state the migrants were restricted to Hooghly, Howrah, Burdwan, West Medinipur, Nadia and even North 24 Parganas. Thus, in-migration within the delta district can also be witnessed.

Such in-migration in Titagarh Municipality of North 24 Parganas of Bihari migrants was witnessed in the study of **Neogi and Dutta (2013)**. Existence of jute and paper mills in this area attracts migrants, who are usually within the age group of 20-50 and from low socio-economic households of the rural districts of Bihar, Uttar Pradesh and Andhra Pradesh and Odisha. This study on female migrants observed that marriage was the primary reason for them followed by lack of livelihood, while men migrated for employment and loss of land in the sending area. Their decision to migrate, however, rests with the husband and also household expenses. In this receiving area the women often turn into "camouflaged migrants" and made to work as casual labourers. However, the migrants are now re-migrating to other states like Kerala and Karnataka where the wage structure is reportedly higher. This has led to male migrating to far away states while the women are being left behind in Titagarh.

Land erosion and breaching of embankments also have proven to be one of the factors for migration in this deltaic region. **Bera (2013)** in his study of G-Plot of Patharpratima and Ghoramara GP and Dhablat GP of Sagar block observed that the impact of adverse effect of breaching of embankments, in a community, whether due to natural or anthropogenic factors, depends on the resources and livelihood of the families. Migration-decision was also dependent on social status and land holding status. Landless people bought land which is cheaply available at the flooded villages while the landowners tend to move towards the interior parts of the islands but to places which are closer to their earlier source of livelihood or their community. Cases of men asking for land in a safer location, as dowry have been observed. The construction of ring bunds which occupied more land space along the river side led to displacement of people where they were resettled in 'Colony (ies)', resulting in people adopting alternative sources of livelihood like for example, a fisherman has turned into a rickshaw puller because of the lack of source to catch fishes. However, the study does not give any empirical data on the migrants from the sending area or

their status in the receiving area. The author has not taken into account the poverty levels of the respondents and no quantified data on the number of migrants has been provided. In this study, the cause (push factor) of migration seems to be rooted to economic deprivation resulting from gradual environmental degradation.

In "Sea level rise and associated changes in the Sundarbans", **Hazra et al. (2002)** have shown that the sea level rise in Sundarbans (3.14 mm per year) is higher than the mean global sea level rise and that is has significant impact on erosion-accretion process and subsequent land use changes. This "rapid onset of environmental disaster" has over the last two decades have led to submergence of islands and its villages, have damaged crop and forest property worth 950 million rupees, affected 0.4 million people and forced to move 600 households. **Hazra and Bakshi (2003)** witnessed the forced migration in IBD from the vanishing islands of Ghoramara and Lohachara. People have been forced to change their traditional livelihood and opt for available alternative. However environmental migrants are yet to be recognised even as a separate class of migrants in India, leaving aside the need to maintain a record, to regulate migration or to formulate appropriate adaptation or rehabilitation policies for them (Hazra and Bakshi, 2003).

Research conducted by **Ghosh et al. (2014)** of how the submergence of the villages of Lakshmi Narayanpur, Khasimara, Khasimara Char, Bagpara and Baishnabpara of Ghoramara island, has led to people migrating to neighbouring Sagar island. The estimation of total migration has been analysed from the difference between the slow growth rate of population of Ghoramara island and the higher actual growth rate of Sagar island that the expected population based on census data. A questionnaire survey was also conducted to ascertain the finding, where majority of the local people perceive that around 4000 people migrated from Ghoramara island.

Mukherjee (2014) in her study evaluated the rehabilitation programme of such "migrants" to "Jibantala" Colony in Sagar (an island which is vulnerable and unstable) and shows how improper planning led to the programme being disastrous rather than beneficial. 1.5 bigha land (21,600 sq. ft.) was supposed to be given to each of the family, which was divided into three portions, for construction of house (built by the government), pond and the remaining area being kept for cultivation. Migration of people to these Colonies led to change in their occupation. Flood inundation,

salinization of land, waterlogging, poor transportation, lack of proper medical facilities and education, poor sanitary conditions, lack of electricity and drinking water and lack of adequate living space are some of the problems the people face in the rehabilitated areas. Constraint in resources led to conflict between the early settlers and the new migrants. Analysis has also been made on the type of hazard alleviating measures taken up by the government. Afforestation shows a high ranking, followed by construction of earthen embankments, brick and paved embankments, storm shelters, flood water control by sluices, relief distribution, but it was pointed out that there was hardly any effort to provide access to drinking water.

Pakrashi (2014) undertook a quantitative and a qualitative study of five villages namely Rangabelia, Gosaba and Pakhiralaya (Gosaba block), Beguakhali (Sagar block), and Masjidbari (Basanti block) of South 24 Parganas of the Indian Bengal Delta, in order to understand the problems of development and planning in the Indian Bengal Delta and analyzed the phenomenon of outmigration from the said villages. The study found that in search of better opportunities in the city, the youth are migrating from the islands and this trend has increased after Aila. The volume of such migration from the interviewed households (158 in total) was found to be highest in Rangabelia, followed by Beguakhali, Pakhiralay, Gosaba and Masjidbari. But apart from 'climate change' the study has also attributed the reason for outmigration also to lack of industrialization and development. However, it was seen that the savings of such migrants lasts only for a short term and do not build capital.

Studies on Migration in Indian Bengal Delta which have focused on women (CRS, 2010; CSE, 2012; Prakashi, 2014) have been divided into two categories, women migrants who migrate within the state to work as domestic maids or helpers and as non-migrants who are left-behind, taking on the additional role of looking after the household as well as the farm. These women run the household depending on the remittances sent by the men who have migrated. But such remittances are either meagre or untimely and as a result these women are further burdened with loans taken from the moneylenders.

2.5. Theoretical framework of migration

The task of theory building and model development is not always easy because human phenomena are highly dynamic and which change in their spatial and temporal dimensions with unusual rapidness. Moreover, it may be difficult to subject the individual human behaviour to a well-defined set of laws.

There are four broad migration theories which are relevant to understanding migration from resource-dependent communities within deltas. These approaches are: neoclassicism with its principally economic focus, structuralism with its focus on broader political systems, livelihoods approaches with a focus on development and household risk spreading strategies (including the New Economics of Labour Migration), and decision-making theories with a focus on social psychology. Each of these migration theories has their strengths and weaknesses.

After a detailed review of literatures and theories on migration, the conceptual theoretical framework which provides basic concepts of human movement in the IBD has been identified. Most of the migrants of IBD short distance and with increasing distance the number of migrants decreases **(**Ravenstein's laws of migration, 1875-89; Zipf's inverse distance law, 1949). Intra-state migration is common whereas inter-state migration is mostly found for labour migrants. Male migrants are more dominating than female migrants. In the absence of male members in the family, women take on the additional responsibility of looking after the household and the farms (CRS, 2010; Ghosh, 2012; Prakashi, 2014). Early migration theories paid relatively little attention to female movement; instead, they viewed women as either residuals or dependent migrants. Female migrants, who moved along with their partners or family, were regarded as 'associational migrants' (Thadani and Todaro, 1984; Neetha, 2004). **Ravenstien in one of his 'Laws of Migration'** draws the conclusion that women migrate more frequently than males, but only over shorter distances in order to work in fields like as manufacturing, household work, and workshops. In the Indian Bengal Delta, a similar tendency is seen, where women exclusively move to the peri-urban parts of Kolkata to work as domestic help (CRS, 2010; Ghosh, 2012; Prakashi, 2014). Thadani and Todaro (1979), in developing a framework on analysing female migration in the developing nations, claims that migration of women is subjected to economic as well as social factors but constrained

by socio-cultural evaluation. Marriage as an important reason for migration of women, has been given prime focus in this framework, as evident in India (Singh, 1984; Lusome and Bhagat, 2006).

A 'Push-Pull Model' of Migration distinguishing between 'origin' and 'destination' areas and 'intervening obstacles' in between these two areas was proposed by **Lee (1966)**. The decision of whether to migrate or not to migrate is influenced by both positive and negative aspects at both the origin and destination, which are estimated on the basis of intervening obstacles such distance, immigration restrictions, transportation costs, etc. Increase in the salinity of the soil due to climate change impacts, erosion of land, lack of alternative sources of livelihood, poor access to education and infrastructural facilities have led to people migrating to other parts of the state and too far away places, for refuge and sources of alternative livelihoods. The receiving areas include states of Kerala, Maharashtra, Delhi, Gujarat, Chhattisgarh, Karnataka, Andaman etc., and even to international destinations such as Dubai, where they get employed in construction sectors, brick kilns, factories etc. Intra-state migration was also prevalent where the migrants migrated to urban areas like Kolkata, Sonarpur (South 24 Parganas), Dum Dum (North 24 Parganas) etc. (CRS, 2010; Ghosh, 2012; Bera, 2013; Prakashi, 2014; Mukherjee, 2014).

According to Lee (1966), migration process is selective because differentials such as gender, age, and social class affect how people response to push-pull factors, and these conditions also shape their capacity to overcome intervening obstacles. Male migrants varied in age from 15 to 40, while female migrants ranged from 26 to 40. The majority of the migrants fall into the 'Below Poverty Line (BPL)' category, have lowest literacy rate, are marginal landowners and are usually unskilled. Rural residents are most likely to be migrants. The migration trend in the concerned deltas is from rural to rural and rural to urban areas, within the state or to other states and even to other countries (CRS, 2010; Ghosh, 2012; Bera, 2013; Mistri, 2013; Prakashi, 2014).

Seasonal migration was a common activity, mostly because there weren't many possibilities in the delta during the dry seasons (particularly as farming was dependent on monsoon rain), but in the case of IBD, the rate of migration increased after Cyclone Aila in 2009 (CRS, 2010; Ghosh, 2012; Sarkar, 2012). In IBD, forced

migration has been seen, such as moves from the disappearing islands of Ghoramara and Lohachara, in which an element of external impact predominate, including threats to life and livelihood stemming from natural or man-made causes (Hazra and Bakshi, 2003). People have been forced to change their traditional livelihood and opt for available alternative. However environmental migrants are yet to be recognised even as a separate class of migrants in India, leaving aside the need to maintain a record, to regulate migration or to formulate appropriate adaptation or rehabilitation policies for them (Hazra and Bakshi, 2003).

Gender studies on migration emphasise that men and women respond to migration issues differently and that sex discrimination in the workplace has an important impact (Zlotnik, 2003). The number of female migrants is rising but they are yet to be considered as equal actors worthy of being accounted for. The problem is further compounded because of exploitative practises of moneylenders and recruiting agents leading to accentuation of vulnerability of female migrants and also obstructs social security, health, education, and welfare benefits.

In the **Basic Livelihood Framework formulated by Ellis (2003)**, migration is viewed as a central feature in the livelihood of poor people in low income countries and that the decision to migrate is not solely economic but also social. Migration here is seen to contribute to secure livelihoods or 'activities', through the utilization of the 'assets' or 'resources' distinguishable as human capital, social capital, physical capital, financial capital and natural capital, which would help in the minimization of 'risks' or 'vulnerabilities' and ultimately help in the reduction of poverty, but the potentiality is often curtailed by the 'Policy environment' (McDowell et al., 1997; Scoones, 1998; Waddigton, 2003).

International Organization of Migration (IOM, 2008) suggested a framework, which combines the Sustainable Livelihood Approach (SLA) and New Economics of Labour Migration (NELM) models.

2.6. Existing gaps in the migration literature

The studies reviewed so far on migration in/from India are largely based on the secondary information from the Census data, which fails to capture adequately, factors like seasonal migration or migration due to natural disasters. Female Migration

figures are higher in the census data of India, with marriage stated as the primary reason, but the reviewed literature on Migration point towards largely male migrants. The concept of "Planned Migration" like that from the island of Ghoramara to Sagar island due to submergence of the island, is unique in the case of IBD. On the other hand, the Cyclone Aila of 2009 can be seen as a point that instigated large scale migration of people from the Indian Bengal Delta due to salinization of farm land, large scale death of livestock, collapse of mud houses and thereby leading to loss of livelihood and heavy debt burden. Migration in India is largely attributed to economic reasons but in the Indian Bengal Delta apart from this, the submergence of islands due to erosion and high intensity cyclones and storm surges also act as drivers of migration.

As the changing climate is viewed as one of the factors that are either directly or indirectly contributing to the movement of people, there is also a need for incorporating new causes or determinants of migration into the theoretical views of migration.

2.7. Chapter Summary

Seasonal migration was a common activity, mostly because there weren't many possibilities in the delta during the dry seasons (particularly as farming was dependent on monsoon rain), but in the case of IBD, the rate of migration increased after Cyclone Aila in 2009. Increase in the salinity of the soil, erosion of land and lack of alternative sources of livelihood, has led to people migrating to other parts of the state and to faraway places, for refuge and sources of alternative livelihoods. Male migration was the trend but now the number of female migrants have also increased but to shorter distances like the peri-urban areas of Kolkata where they are employed as maid or domestic helpers. Trafficking and child labour has also increased. The migrants belong to the age group of 15-45. The receiving areas include states of Kerala, Maharashtra, Delhi, Gujarat, Chhattisgarh, Karnataka, Andaman etc., and even to international destinations such as Dubai, where they get employed in construction sectors, brick kilns, factories etc. People have been forced to change their traditional livelihood and opt for available alternative, for example, fisherman turning into a rickshaw puller in the receiving area. The migrants mostly belong to BPL category, have low level of literacy, are marginal landowners and unskilled. It has

been observed that the remittances received by the migrants have improved their standard of living than before. Family migration could be observed in the case of submergence of islands in IBD. Trend of government-planned migration in the case of submergence of island was also observed but with poor rehabilitation measures in the islands where the migrants have been settled.

CHAPTER 3

The Study Area

"Coastal systems and low-lying areas will increasingly experience adverse impacts such as submergence, coastal flooding, and coastal erosion due to relative sea level rise" - ***IPCC 2014, p. 36.***

3.1. Introduction

One of the most significant and dynamic deltas in the world is the Ganga-Brahmaputra-Meghna (GBM) (Nicholls et al., 2020). It is the world's most populated delta and the second largest in terms of area (Woodroffe et al., 2006; Ericson et al., 2006). Depending on how the delta extent is defined, it covers most of Bangladesh and a portion of West Bengal in India, with a total population that exceeds 100 million (Woodroffe et al., 2006; Ericson et al., 2006). The delta front is about 380 km long (Allison, 1998). Tidal influence extends up to 100 km inland, with general land elevation here less than 3 m above mean sea level forming one of the largest coastal lowlands, globally (Kausher et al., 1996). The delta extends up to 450 km inland and reaches elevations of more than 20 m above sea level (Woodroffe et al., 2006).

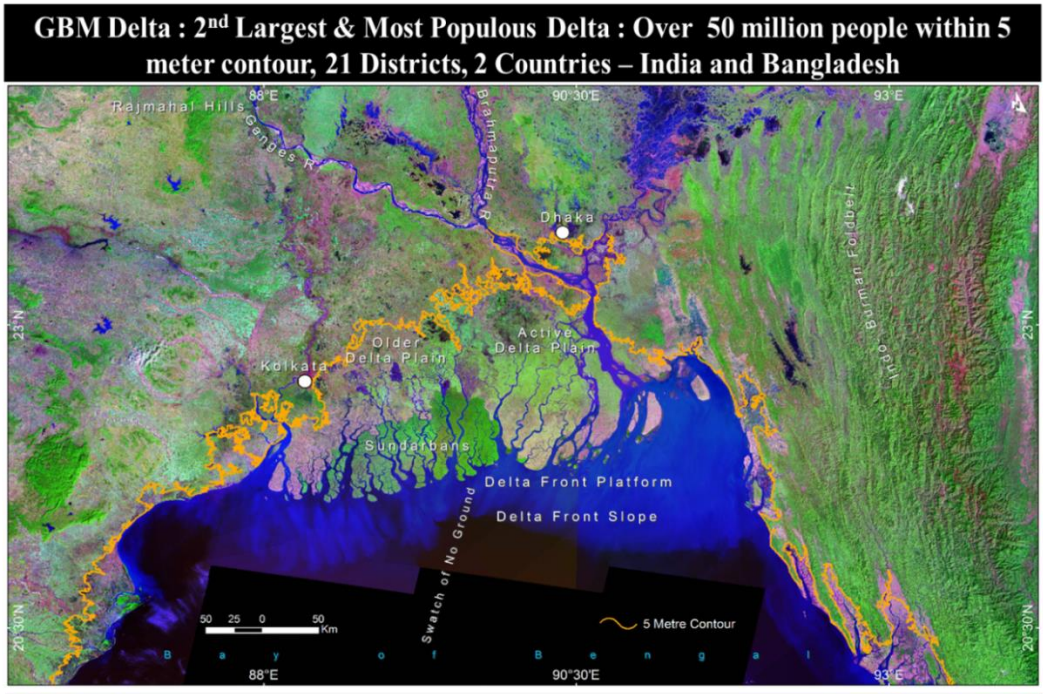


Figure 1. Ganga-Brahmaputra-Meghna Delta

The Indian part of the Ganges-Brahmaputra-Meghna delta is referred to as the Indian Bengal Delta (IBD)[1] (Lazar et al., 2015; Nicholls et al., 2020). The IBD, a natural habitat of the Royal Bengal Tiger, presents a complex ecosystem developed by an intricate system of tidal rivers, mudflats, and salt-tolerant mangrove forests (Nicholls et al., 2020).

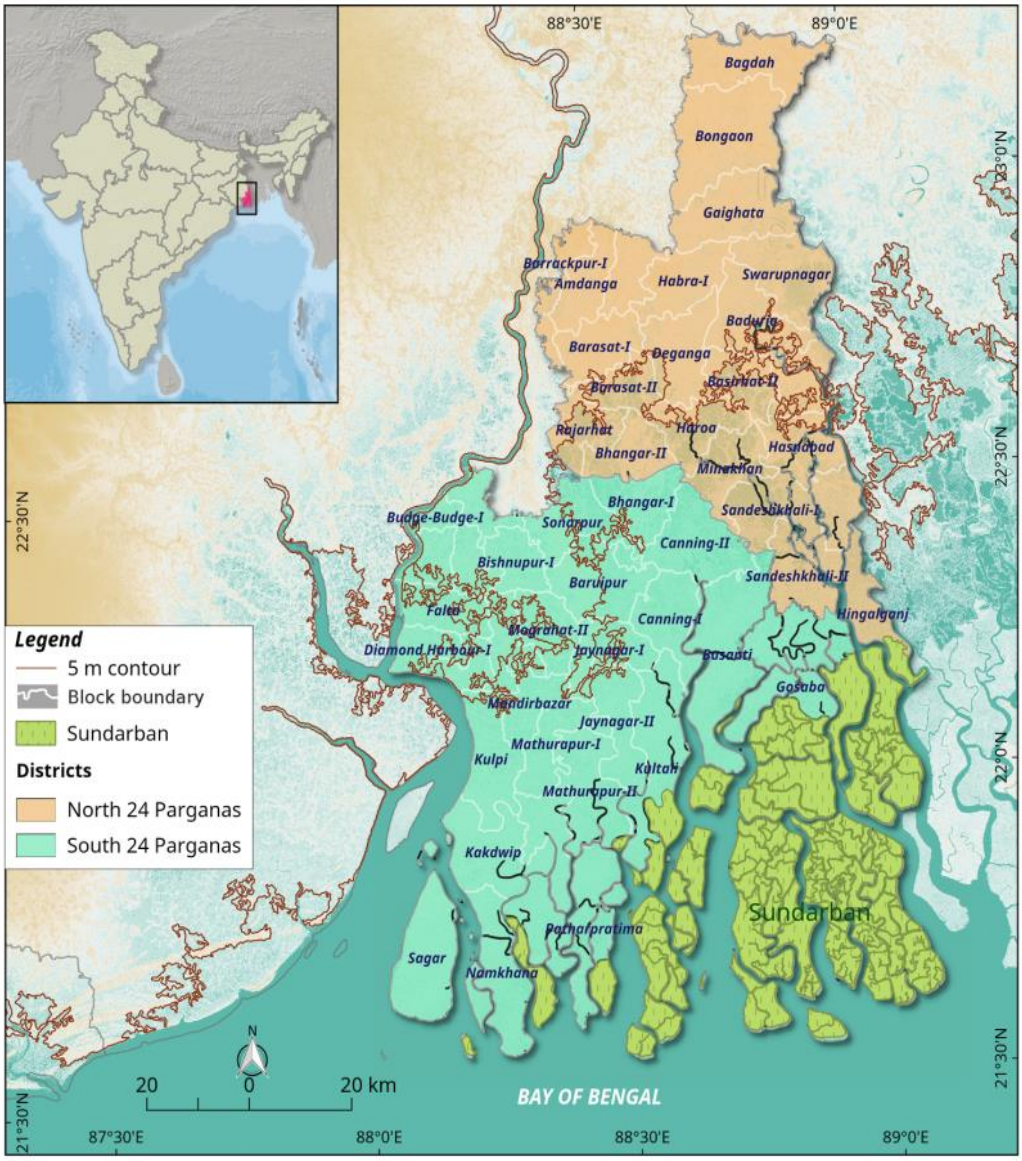


Figure 2. The Study Area – Indian Bengal Delta

3.2. Socio-economic and demographic characteristics

The socio-economic profile of the IBD is non-uniform due to its geographical settings and population composition, access to different sets of resources, and unavailability of

[1] The study area is delineated based on 5m contour and administrative boundaries under the DEltas, vulnerability, Climate Change: Migration and Adaptation (DECCMA) project.

sufficient fresh water (Das et al., 2020). The study area is 14,054 sq. km. and comprises of 51 sub-districts (Community Development Blocks in India) within two large districts - North 24 Parganas and South 24 Parganas. Many sub-districts are closer and better connected to Kolkata city and fall within Kolkata Metropolitan Area (KMA) get greater advantages in terms of livelihood opportunities and access to services such as grid electricity, tap water. On the other hand, the people in southern part of the delta are chronically poor and facing multiple climatic hazards and challenges of under development.

Table 2. Demographic characteristics of Indian Bengal Delta (2011)

Characteristics	Indian Bengal Delta	India
Total population (million)	18.2	1210.9
Population density (persons per km^2)	1293	382
Proportion of population less than 15 years (%)	27.6	33.0
Proportion of population aged 15-64 years (%)	66.5	61.5
Proportion of population aged 65 years and above	6.0	5.5
Age dependency ratio	51	63
Sex ratio	955	943
Crude birth rate (per 1,000 population)	11.1	21.4
Total fertility rate	1.5	2.3
Crude death rate (per 1,000 population)	2.5	7.0
Infant mortality rate (per 1,000 live births)	31	40
Under five mortality rate (per 1,000 live births)	35	49
Proportion urban (%)	43.0	31.2
Annual population growth rate (%)	1.5	1.8
Project population for 2040 (million)	23.5	1538.7
Project population for 2060 (million)	24.2	1602.9
Source: Civil Registration System (CRS), 2011, Census of India; Sample Registration System (SRS), 2013; Tables on Number of Women, Children Ever Born and Child Surviving, F-Series, Census of India, 2011 (for Indirect Measures); Primary Census Abstract (PCA), 2011, Census of India - North 24 Parganas & South 24 Parganas		

3.2.1. Population distribution and change

The line graph shows the decadal variation in population since 1901 in the districts of Indian Bengal Delta (IBD). The total population of North 24 Parganas and South 24 Parganas has increased throughout the century. According to 2011 census, the total population of IBD is 18.17 million, out of which male and female are 9.29 million (51%) and 8.88 million (49%) respectively. The population density in 2011 and the decadal growth rate during the period of 2001 and 2011 are 1293 persons per sq. km. and 15% respectively. North 24 Parganas is the most populated district with the population of 10 million and the population density of 2445 persons per sq. km. South 24 Parganas has an estimated 8.16 million people and is growing at a rate of 1.8% per year, making it far more populous than West Bengal and India between 2001 and 2011.

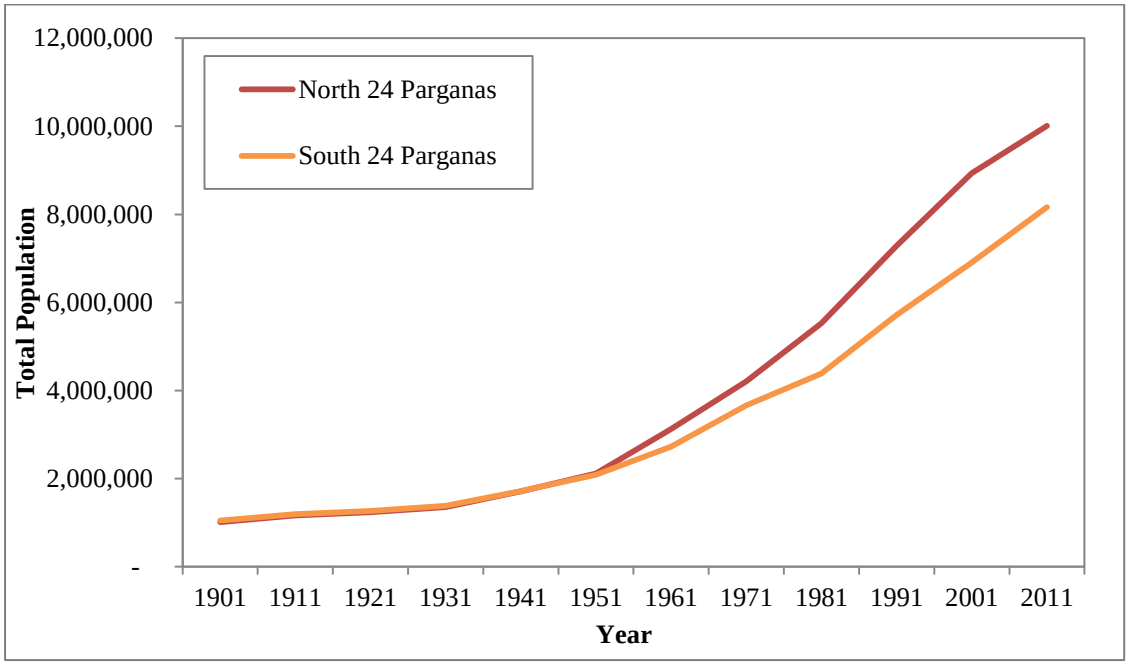


Figure 3. Decadal population growth for the districts within the Indian Bengal delta (1901-2011)

3.2.2. Population pyramid

One of the important demographic variables is age-sex structure or population pyramid. It is calculated as a percentage of the entire population or as a raw figure.

District wise age-sex pyramid was designed for IBD. Both the districts North and South 24 Parganas show wide base and narrow apex, indicating high birth and death rates (expansive pyramid) in the year of 2011. It illustrates the stage of demographic

transition model wherein both N & S 24 Parganas belong to the second phase of stage-II.

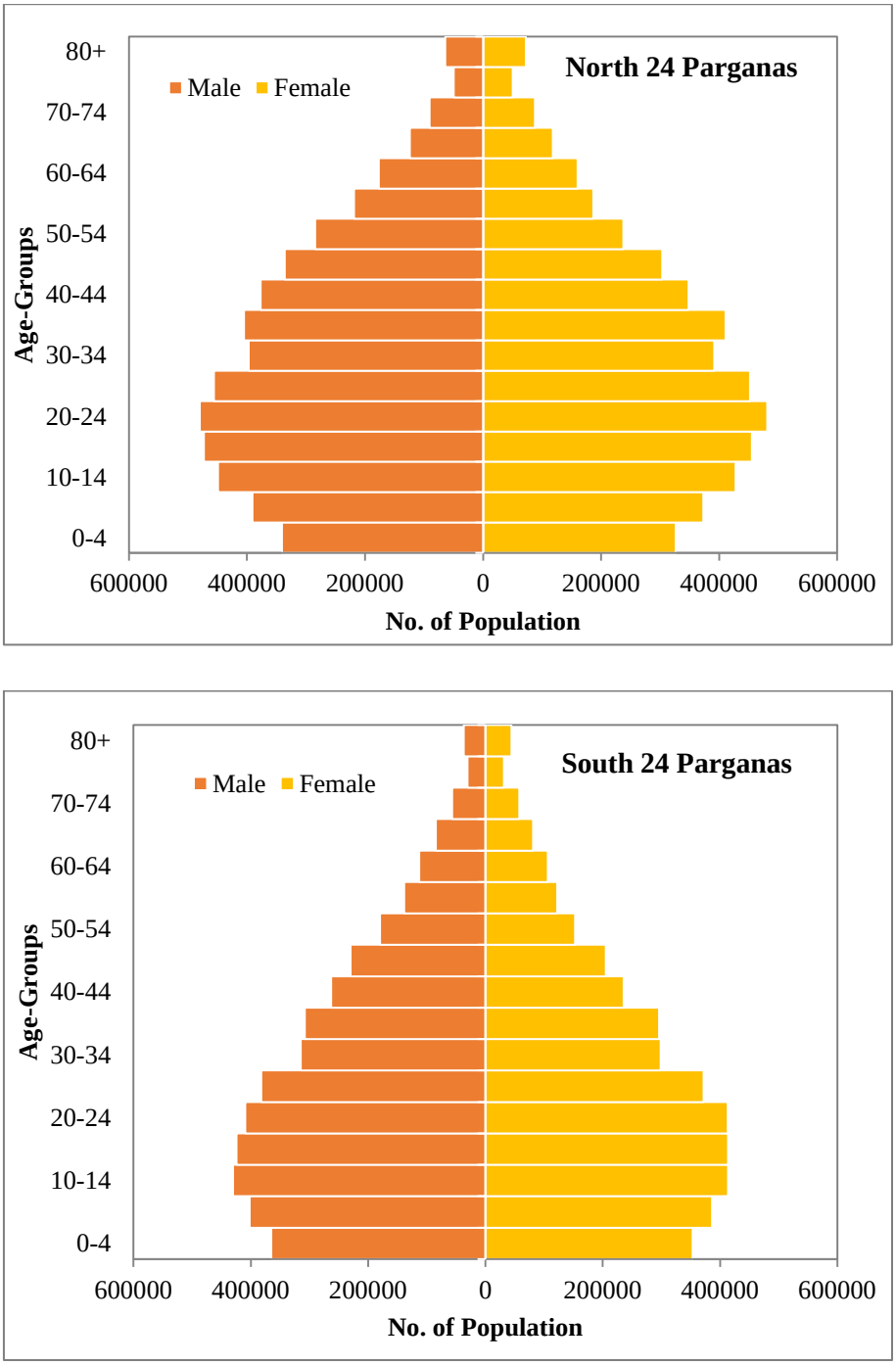


Figure 4. Population pyramids for the districts within the Indian Bengal delta (2011)

IBD has the highest proportion (66.5%) of population aged 15-64 years which is reflected in the age dependency ratio i.e. 0.51, which indicates the working-age population face a moderate burden in supporting the non-working age population.

3.2.3. Sex Ratio and Literacy Rate

The sex ratio in IBD is 955 females per 1000 of males whereas the sex ratio in West Bengal is 950 and India is 943. The crude literacy rate is 72.31%, and the male literacy rate (76.39%) is higher than the female literacy (68.04%).

3.2.4. Distribution of Scheduled Castes & Scheduled Tribes

The percentage of scheduled caste (SC) and scheduled tribe (ST) population to total population is 27.49. This percentage is more than 50% in several sub-districts like Hingalganj, Basanti, Sandeshkhali-I & II.

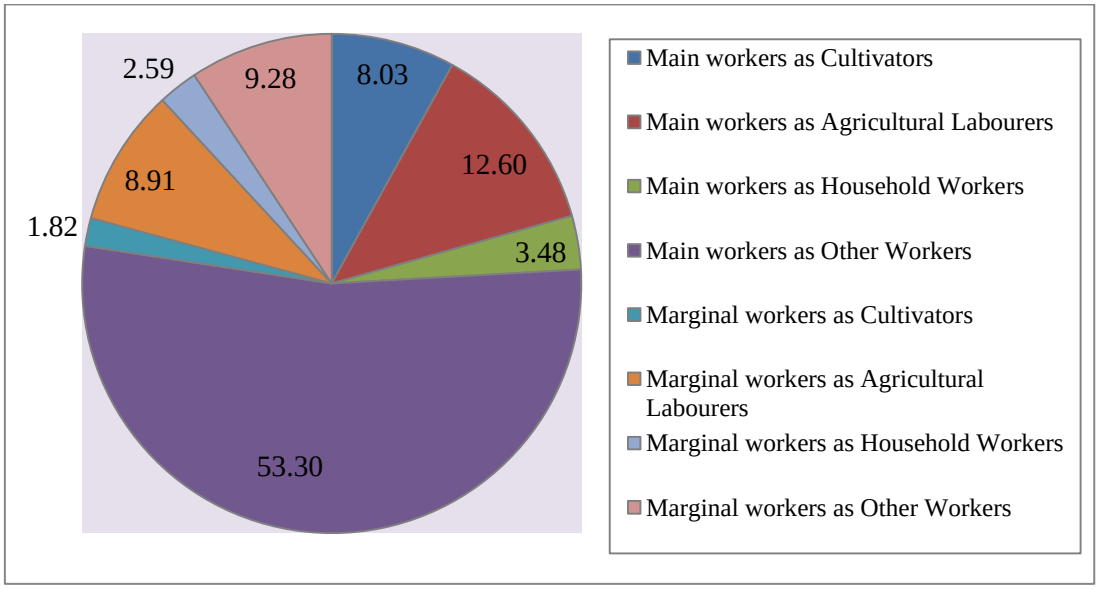


Figure 5. Distribution of workers (%) in the Indian Bengal delta (2011)

3.2.5. Distribution of workers

Total worker in IBD is 6.54 million, and the male work participation rate is 57%, whereas the female participation is only 14%. In both rural and urban areas, the larger proportion of female workers is engaging themselves in household industries. In IBD, 57% of the total population are rural population. They are mainly working as cultivators and agricultural labourers (main or marginal). Total cropped area during 2010-11 is 0.59 million hectare (42% of total area). The average size of land holdings is 0.61 hectare. The soil is very favourable for cultivation, but the saline soil of South 24 Parganas district is considered uneconomical. The presence of good number of rivers, creeks, canals etc. also favours the cropping pattern of this delta. The percentages of irrigated area to cultivated area in North 24 Parganas and South 24

Parganas are 73.07 and 34. Rice is the main crop in the delta. In North 24 Parganas, the yield rate for rice is 2698 kg per hectare, whereas in South 24 Parganas, it is 2322 kg per hectare. Varieties of rice viz. Aus, Aman and Boro and oil seeds, potato, chili and cash crops like jute are grown in the delta. Along with agriculture, rural people practice secondary livelihood activities related to sea and forest e.g. fishing, aquaculture, honey collection, boat maintenance, net making etc. Around 32% of people are extremely poor in this delta.

3.2.6. Net migration

Data from the last two population censuses of IBD (2001 & 2011) is used to estimate net migration. Total net migration rates of North 24 Parganas and South 24 Parganas are 3.07% and 2.08% respectively. This migration pattern as observed for the IBD changes our perception that negative net migration will be observed in North and South 24 Parganas as sending areas and also as bio-physically vulnerable districts. Kolkata, the adjoining city of IBD is densely populated. Nowadays, old migrants are leaving. Migration is gender selective, with a higher proportion of male migrants. People are moving out of the city to peri-urban areas; especially to adjoining districts like North 24 Parganas (Barrackpur-I & II, Barasat, Rajarhat) and South 24 Parganas (Sonarpur, Baruipur, Garia). That is why the population density has been reduced to 24,252 km^2 (2011) from 24,718 km^2 (2001).

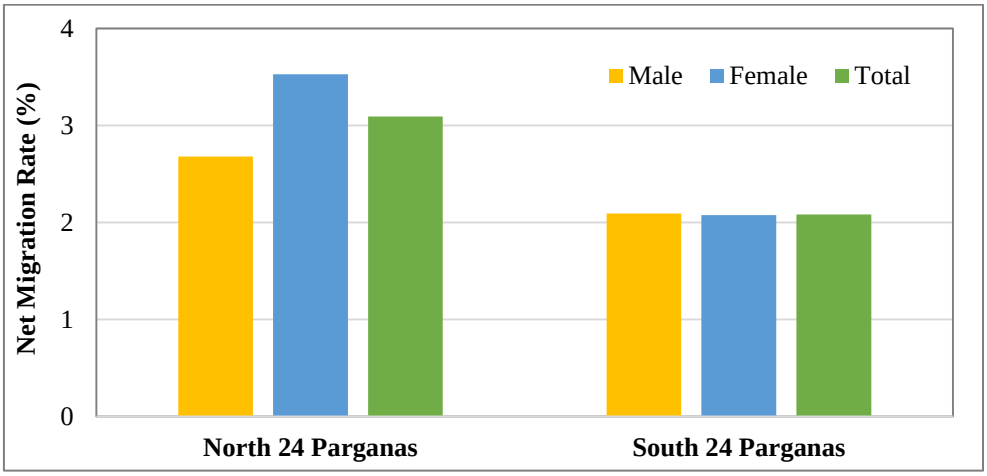


Figure 6. Net migration rates for the districts of Indian Bengal delta (2001-11)

Results also show that people between the age-group of 20 to 40 moves to other cities for better education and job opportunities. On the other hand, people between the age

groups 60 to 70 relocate to adjacent or less congested areas; especially rural areas after their retirement.

3.2.7. Population Projection

Population projection is a scientific method for estimating future population scenarios. Figure 7 and 8 show the projected population (in million) in all the districts of IBD. It reveals that there is an increasing trend in populations up to 2050, and thereafter a declining trend has been observed. The projection for 2100 could not be obtained using the software. A coarse inference may be drawn from this declining trend that the population in 2100 may be similar to that of 2011.

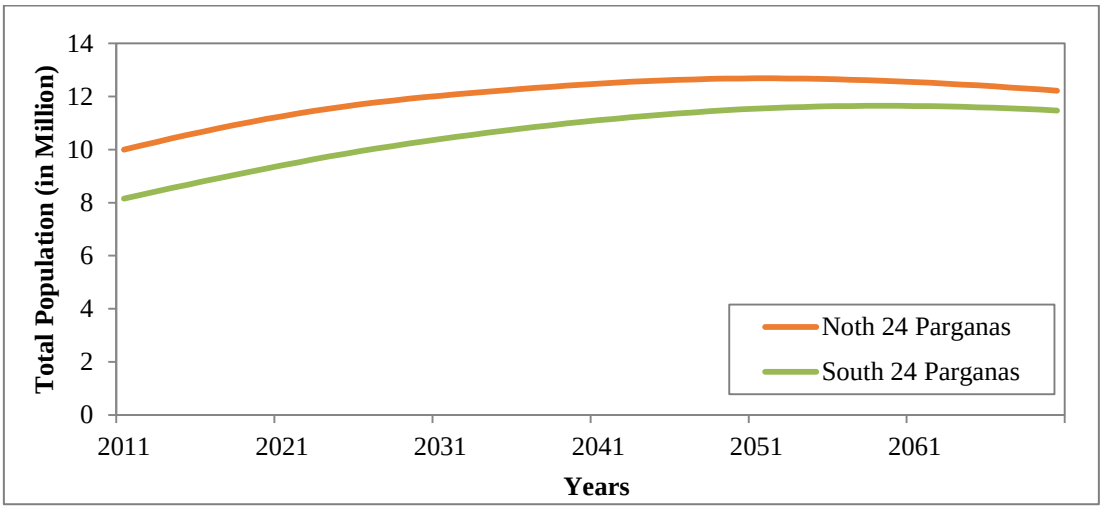


Figure 7. Population projections of Indian Bengal Delta from 2011 to 2070 using Component method

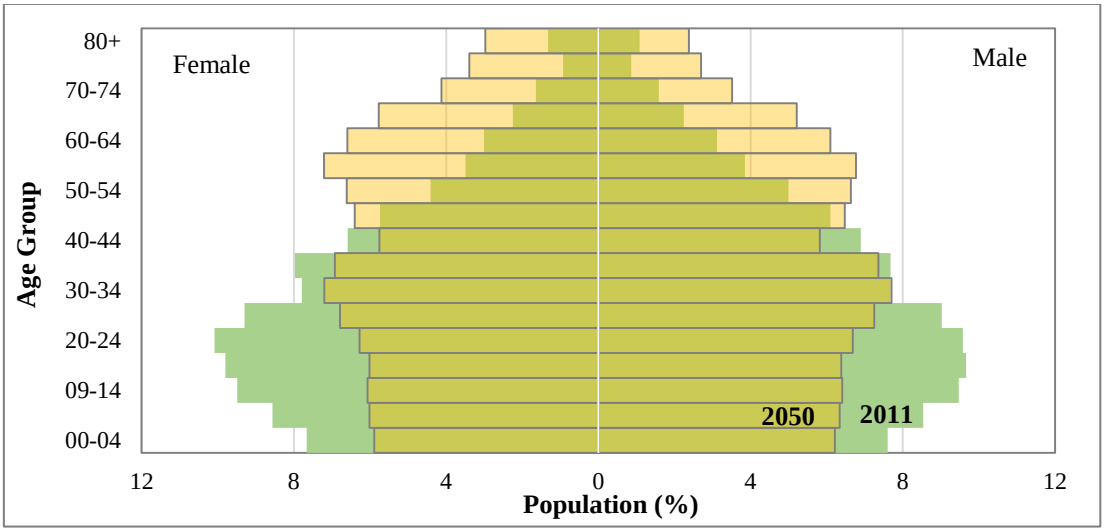


Figure 8. Population pyramids of Indian Bengal Delta for 2011 and 2050

Figure 8 illustrates that in the year of 2050, IBD will belong to the stage-III or IV of demographic transition model. This happens when there is a steady population overall due to low birth and death rates.

3.3. Bio-physical characteristics

The Ganges Brahmaputra Delta came into existence around 11000 YBP (Goodbred and Kuehl, 2000; Allison et al., 2003) earlier than the other Holocene deltas because of the large amount of sediment supply from the rising Himalayas in the north. The active delta, developed in a macro tidal (> 4m) regime has acquired a typical shape of tide-dominated deltas with 104 islands oriented along the strong tidal flow perpendicular to the shoreline in the Indian part (Goodbred and Saito, 2012). The Sundarban mangroves forest on the 'Sundarban surface' came into existence since 6000-3000 YB with the colonization of these islands by the salt tolerant halophytic Mangroves plants (Vaidyanadhan & Ghosh, 1993).

The study area is situated in the GBM delta. A large every area in the southern part is covered with the dense jungle of Sundarban with numerous rivers and its tributaries in between. Numerous islands are thus found in this area. Some of these islands remain totally sub-merged under water. Here the process of land making process is still going on.

3.3.1. Land use patterns

Agriculture is the dominant land use in the delta, representing about 48% of the land holdings, whereas about 30 percent land area is occupied by forest including natural vegetation and mangrove forest. The terrestrial forest and water-based ecosystem services play a major role in the rural livelihood, and its gradual degradation impacts the traditional farm-based economy. In IBD, the first land change occurred when mangroves were replaced by farmland and human settlement in the late 19th and early 20th centuries. This was followed by the decrease of agriculture, the conversion to aquaculture, and the development of brickfields. Other than fresh water fish farming, brackish water aquaculture is increasingly becoming popular because of the comparative profit (Chopra et al., 2009). Because of the lack of leaching activities and continuous increase of salinity, the aquaculture productivity generally decrease and land becomes unsuitable for aquaculture. Finally, the land is converted to brickfields.

This is one of the visible impacts of unplanned land conversion in the Indian part of the GBM delta. The other notable anthropogenic changes in the land use are progressive urbanization, growth of urban and rural settlements at the expense of agriculture land to accommodate the ever increasing population in the delta.

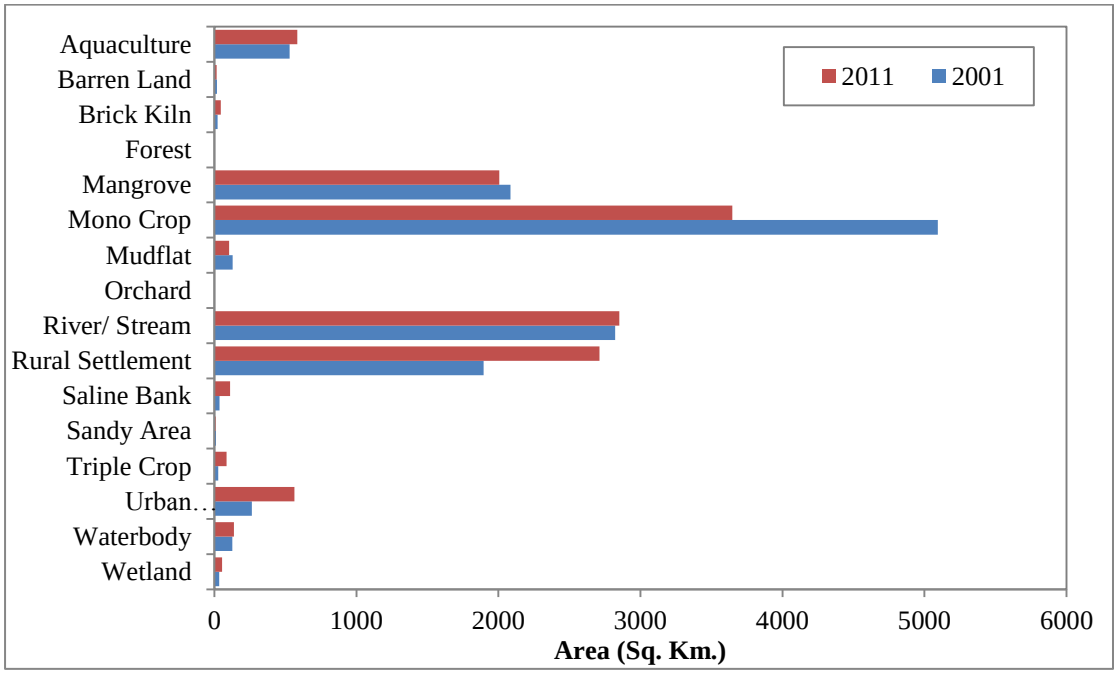


Figure 9. Decadal land use change dynamics in the Indian Bengal Delta (2001-11) (Source: Ghosh et al., 2018)

3.3.2. Mangrove Forest

The mangrove ecosystem is a highly productive system. High levels of habitat heterogeneity in mangrove ecosystems ensure an equally varied biodiversity with complex trophic relationships due to the large spatial and temporal variability in hydrological regimes (both freshwater inflows and the tides), topography and texture of the substratum, the salinity, and their interactions.

From the Indian portion of Sundarban, Sanyal et al. (2008) found 25 species of real mangroves, 9 semi-mangroves (grasses), 37 mangrove associates, and 22 mangrove commensals. The mangrove species which are commonly found in Sundarbans are *Avicennia* sp., *Bruguiera* sp., *Ceriops* sp., *Sonneratia* sp., *Xylocarpus* sp., *Excoecaria agallocha*, *Phoenix paludosa*. Fresh water loving mangroves *Heritiera fomes* or *Sundari* (from which the name Sundarban might have been derived) or *Nypa fruticans* are now rare in the Indian Sundarbans. A total of 1586 animal species have been reported so far from the Indian part of Sundarban from terrestrial, intertidal and

aquatic environs (Das, 1999). These animals comprise 1104 species of invertebrates, one species of hemichordate and 481 species of vertebrates including *Panthera Tigris*, the Royal Bengal Tiger

3.3.3. River networks

The delta was mainly formed by the Ganges and Brahmaputra in a neo-tectonically active basin affected by block faulting and rifting. This led to frequent changes in the meandering course and sediment supply to the delta. Due to the easterly tilt of the basin caused by block faulting, the main flow of the Ganges shifted eastward during the early 16th century, merging with the flow of the Brahmaputra and later with the Meghna (Morgan and McIntire, 1959), leaving the southerly-flowing distributaries like Bhagirathi-Hugly and Ichamati dry in most seasons except the monsoon. While the delta progradation, both in sub aerial and subaqueous domain continues currently on the east in Bangladesh part, the Ganga Delta on the west stands now as 'abandoned' (Allison, 2003) by the river Ganges and suffer delta destruction.

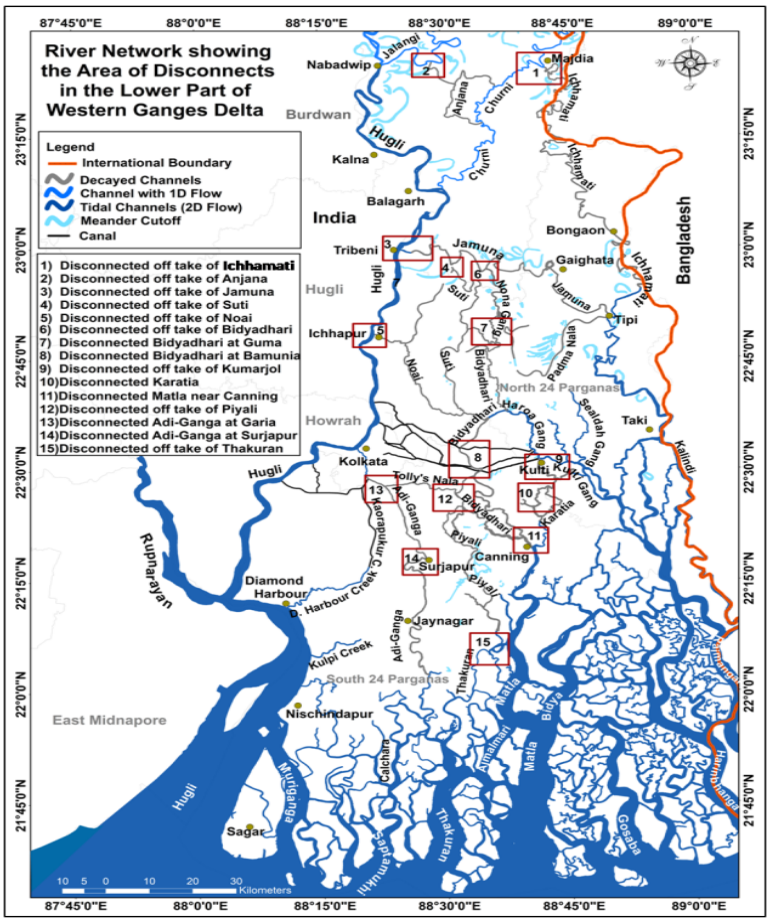


Figure 10. Catchment and distributaries with identified disconnects from the Ganges (Source: Bhadra et al., 2019)

The majority of the distributaries of the Ganges, like Jamuna, Saraswati, Vidya, Matla, Ichamati, etc., lost their upstream freshwater supplies and were gradually silted up (Rudra, 2014).The fourth largest sediment dispersal system in the world is the cumulative river water discharge through the GBM delta (Kuehl et al., 1989). Bhagirathi-Hugli has an insignificant contribution for the lower delta plain as very little water from the river now enters the lower delta and Sundarban via the river Muriganga and the Hataniya Doaniya channel. The river Bhagirathi-Hugli and its three distributaries, the Saraswati, the Jamuna-Bidyadhri, and the Adi-Ganga, started to decay as the Ganges flow shifted eastward (Bhadra et al., 2019).

The anthropogenic restriction imposed upon the flow and sediment dynamics in the delta are the earthen embankments which are now considered as life line of the delta community. The earthen dykes or artificial levees, erected in phases since 1770 to protect the habitation and agricultural land in the delta now stands mostly worn out, and the river beds have been raised by siltation (Dept. of Irrigation and Waterways, Govt. of West Bengal).

Photo 3. The fierceness of the sea waves in IBD

3.3.4. Climatic variability and change

The study area has a humid, tropical, maritime climate. In the central and northern areas, annual rainfall ranges from 1,650 to 1,800 mm, while it may reach 2,790 mm on the outer coast. The mean maximum temperature is 29°C (during June-July), whereas mean minimum temperature is 20°C. The relative humidity is comparatively high, between 70% and 80% (Chaudhuri and Choudhury, 1992). Recent studies indicate that the air temperature over the Sundarban and adjacent parts of the Bay of Bengal are progressively increasing (Huq et al., 1999; Agrawala et al., 2003). The summer monsoon (southwest monsoon), which receives 70 to 80 percent of the annual rainfall, causes considerable river discharge (between 2,952 and 11,897 m3 s-1), which is seen to gradually decrease during non-monsoonal months (varying from 900 to 1500 m3 s-1) (Mukhopadhyay et al., 2006). The present trend of climatic variability and change not only delayed the monsoon arrival time by 15 days or more (WBSAPCC) but also resulted in reduction post monsoon and pre monsoon rainfall affecting the Rabi (winter) and pre Kharif (summer) crop production in the delta. Thunderstorms are common in the summer afternoon, locally known as "Kalbaisakhi". Vigorous cyclonic storms are frequent during pre-monsoon period of April-May, and again in post monsoon during October- November, often accompanied by surge wave 2 to up to 7.5 m high (Seidensticker and Hai, 1983).

3.3.5. Climatic hazards

The Indian Bengal Delta is highly sensitive to the impacts of climate change, including sea level rise, coastal erosion, salinization, frequent cyclones, and floods (Das et al., 2020). In the past three decades, the Relative Mean Sea Level (RMSL) has risen to the order of 8 mm (Pethick and Orford, 2013) to 12 mm (Hazra et al., 2016) per year in the Bay of Bengal. The rate is significantly higher than earlier observations and also considerably higher than the global mean (3.2 mm per year). With accelerated sea level rise and subsequent changes in the hydrodynamic regime, the IBD faces severe land loss. Among 102 islands, 3 islands, viz. Lohachora and Suparibhanga and New Moore (Purbasha) (Hazra et al., 2001, 2016) are already submerged in the western region of the delta. Severe coastal erosion is being observed in several other islands- Ghoramara, Sagar, Mousuni, Jambudwip, Namkhana, Dhanchi, G-Plot, Dulibhasani, Bulcheri, Dalhousie, Bhangduni islands and coastal

villages (Hazra et al., 2009, 2010; Ghosh et al., 2014; Samanta et al., 2017).The entire populations of the villages of Lakshmi Narayanpur, Khasimara, Baisbanpara, Khasimara Char and Baghpara of Ghoramara island had to leave its usual place of residence and seek refuge in nearby islands such as Sagar (Hazra et al., 2002; Hazra and Bakshi, 2003; Ghosh et al., 2014). Recent studies suggest that in Mousuni island 224 families are likely to be displaced within the next 5 years due to the impacts of coastal erosion (Samanta et al., 2017).

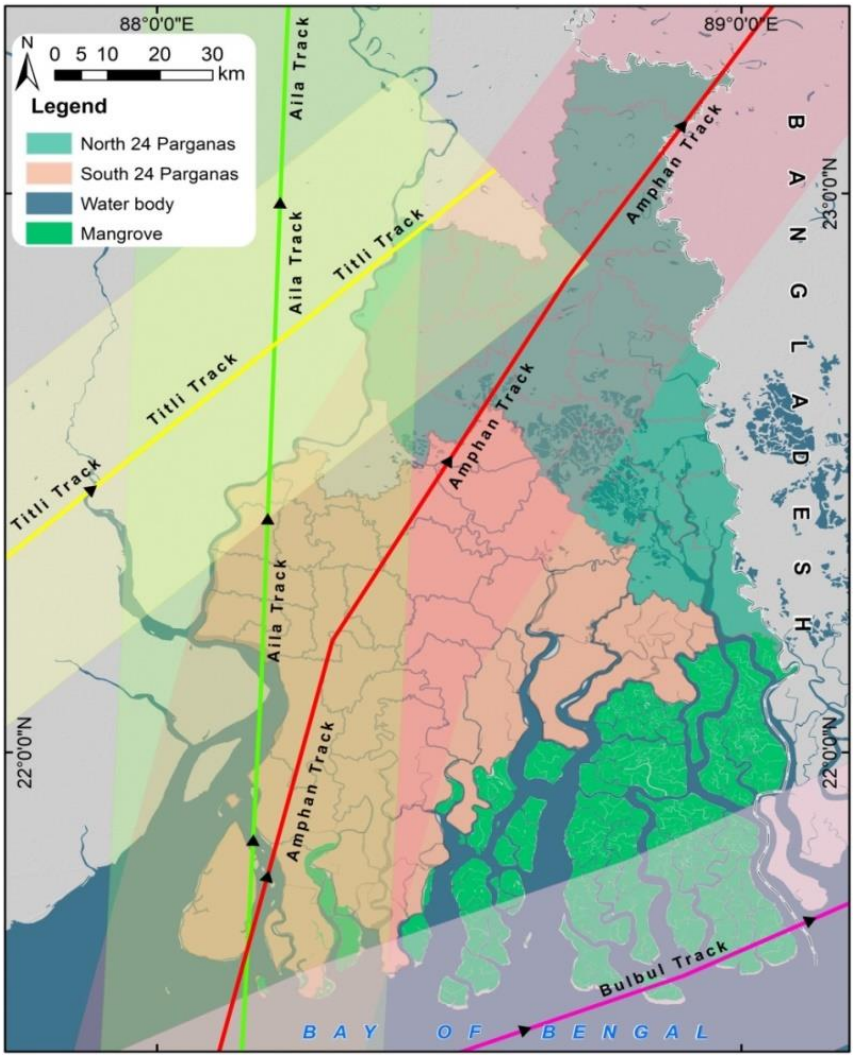


Figure 11. Cyclone tracks in Indian Bengal Delta in last 10-15 years

The Bay of Bengal normally registers 7% of the major cyclones of the world (Dube et al., 1997) and the frequency of high to very high intensity cyclones has increased between 20% to 26% in the last 120 years (Singh et al., 2002; Singh, 2007). For example, in May 2009, cyclone Aila hit as many as 34 sub-districts, 16 urban local bodies, and 3704 villages in the IBD damaging 380 thousand houses and impacting

almost 2.45 million people and 0.12 million hectares of agricultural area (GoWB, 2009). Cyclone Amphan, which made landfall on 20th May of 2020, has barrelled through the IBD at wind speeds of up to 190 kmph and heavy rains destroyed the river embankment across the Sundarbans which has led to salt water entering the land. Home dwellings and infrastructure rebuilt after cyclone Aila have been lost due to the most recent cyclone. The areas worst hit by Amphan are Ghoramara, Kakdwip, Namkhana, Sagar and Patharpratima. In the aftermath of the cyclone, it is estimated that more than two million farmers could be severely affected, potentially triggering a wave of human migration from the IBD (Das et al., 2020).

3.4. Chapter Summary

The socio-economic profile of the IBD is non-uniform due to its geographical settings and population composition, access to different sets of resources, and unavailability of sufficient fresh water. The IBD is very susceptible to the impacts of climate change, including sea level rise, coastal erosion, salinization, frequent cyclones, and floods. People in southern part of the IBD are chronically poor and facing multiple climatic hazards and challenges of under development.

CHAPTER 4

Data and Methodology

"Combination of environmental data with data on individuals' characteristics and their perceptions of environmental change can help shape understanding of potential future climatic impacts on migration decisions" – ***Koubi et al., 2016***.

4.1. Introduction

Climate variability and related hazards pose a serious threat to people's lives through the impact on livelihoods and economic security due to decreased crop yield, crop damage and loss of livestock. The impact on economic security has serious consequences as it can lead to poverty and increased indebtedness, thereby affecting food security, education and health. Absence of alternative sources of livelihood aggravates the problem. This is forcing individuals/households to migrate to other parts of the country.

The key indirect and direct impacts of climate change are illustrated in Figure 12.

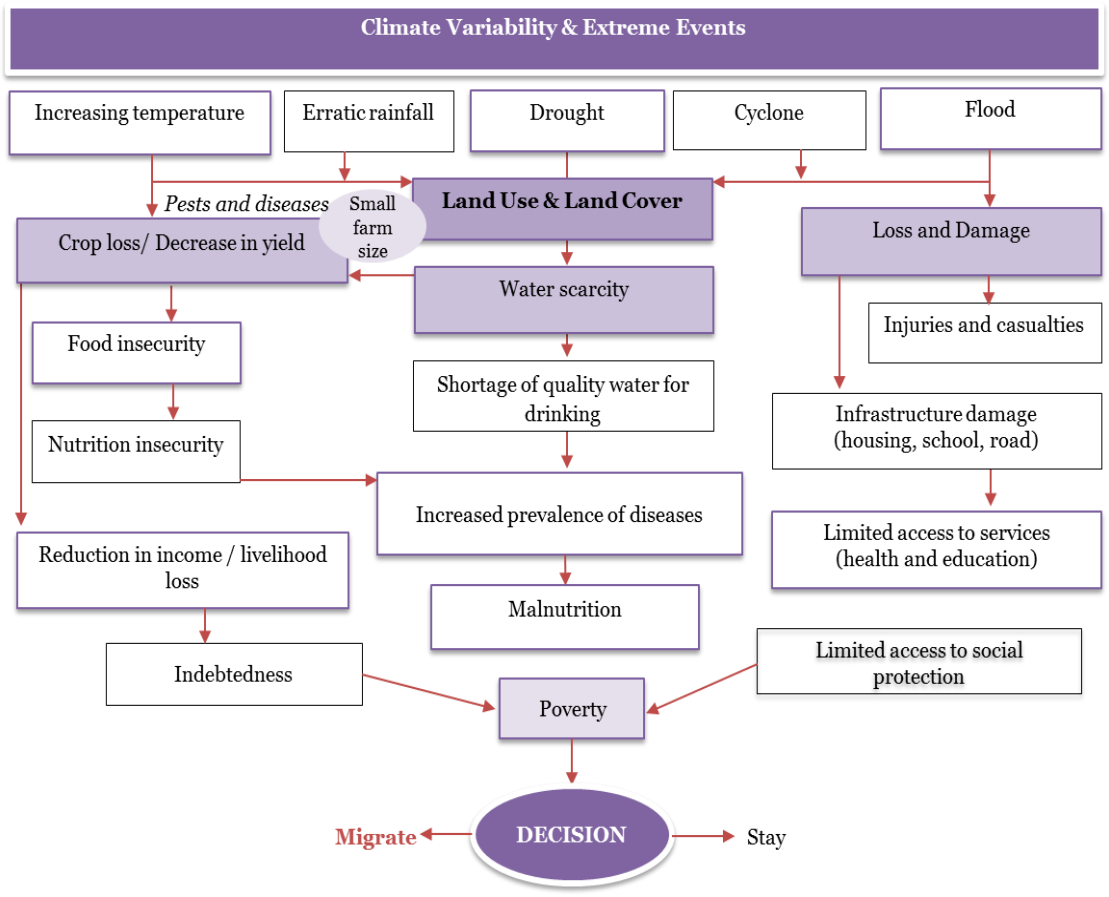
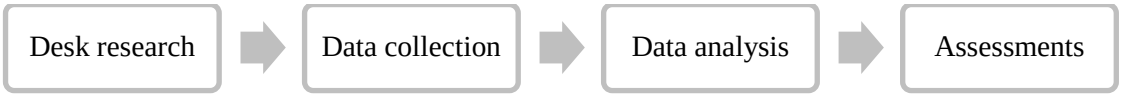


Figure 12. Causal linkages between climate change and migration decision

4.2. Overall approach

The approach for identifying the links between migration, the environment and climate change is based on four key pillars as illustrated below:



- **Desk research:** A comprehensive review of existing studies/reports was conducted to gain a broad understanding of the field. This exercise helps to identify the desired information.
- **Data collection:** The collection of all the required data/information from various sources was undertaken with the required official letters and contact with focal person(s). This process helps to capture and store the internal and external data - both qualitative and quantitative data that are needed for this study.
- **Data analysis:** This was done based on collected primary data to discover useful information for decision-making. In other words, this process helps to summarize the data and interpret their meaning in a way that provides clear answers to questions that initiated the study.
- **Assessments:** Based on the inputs obtained through desk research and consultations, risk assessment and migration hotspot mapping were carried out to achieve the goals of the study.

Figure 13 shows the conceptual framework of migration in the context of climate change.

4.3. Detailed methodology

4.3.1. Literature review

A systematic review of the literature was carried out to compile the most recent information on the impacts of environmental change on migration. Environmental change, risks, vulnerability, migration, and empirical research methodologies were all included in the search phrase. Following a three-step process that included title analysis, abstract and keyword analysis, and lastly a complete full text analysis, research articles were then reviewed and filtered for eligibility.

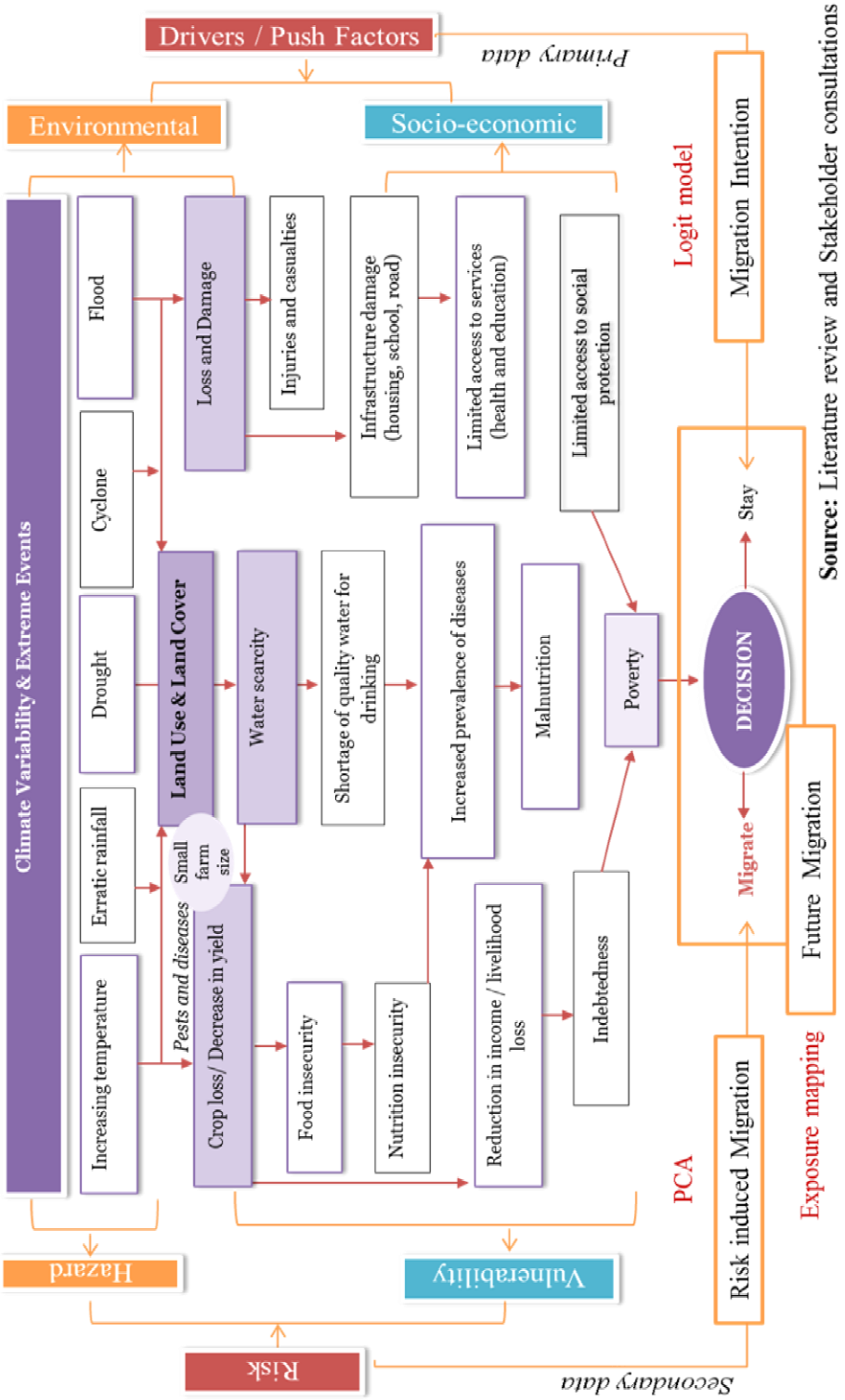


Figure 13. Conceptual framework of migration in the context of climate change

Photo 3. Breaching of embankments in the western part of the IBD

Photo 4. Fishing in agriculture land in IBD

4.3.2. Development of Impact Chain

The impact chain was developed to better understand the factors that drive vulnerability in the system and their cause-and-effect relationship. This activity involves the following steps:

- **Identification of hazards –** The climate hazards (climate variability as well as extreme events) was identified for IBD.
- **Identification of potential impacts –** Based on the understanding on hazards, direct and indirect impacts were also identified.
- **Determining exposure, sensitivity, and adaptive capacity –** For the finalized impacts, the following points were defined:
    - Who are more exposed to climate change?
    - What characteristics make the system susceptible to changing climate conditions?
    - Which adaptive capacities (knowledge, technology, institutions and economy allow the system to handle adverse climate change impacts)?

4.3.3. Identifying and selecting indicators

The list of indicators was prepared for hazards, exposure, sensitivity, and adaptive capacity components. This was validated by a multipronged process that includes literature review, and stakeholder consultations.

- **Hazard** – indicators related to climate-related physical trends such as changes in temperature or precipitation or their physical impacts manifesting in events such as floods, cyclone etc. were selected. This mostly consists of directly measured or modelled climate parameters.

- **Exposure** – indicators related to inventory of elements in the system of concern in which hazard events may occur were identified. Examples include population, agricultural land, livestock, etc.

- **Vulnerability**– indicators that reflect social, economic, bio-physical and institutional characteristics of the system defining:

    - The extent to which the system is susceptible to an external stress or hazard such as flood. Examples include agriculture dependence of the communities, poor households, change in land use pattern, ground water level etc.

    - The ability of systems, institutions and infrastructure to adjust to possible harm or change due to external stresses or hazards, including

climate. Examples include literacy rate, healthcare facilities, market linkages, social safety net, etc.

4.3.4. Identification of data sources

4.3.4.1. Secondary data

The collection of all the required data/information for the selected indicators was undertaken from various publicly available sources (Table 3).

Table 3. List of data sources

Data Type	Data Source
Socio-economic data	• District Census Handbook • District Statistical Handbook • Agriculture census • Livestock census • India State of Forest Report • India Water Portal • Statistical Abstract • Economic Survey Report • District Human Development Reports • National Family Health Survey • Socio Economic and Caste Census
Climate data	• Climate data from Indian Meteorological Department (IMD) • Climate projections from World Bank Group Climate Change Knowledge Portal (WBG CCKP)
Extreme events	• Disasters related data from State/ District Disaster Management Authority • Aqueduct Water Risk Atlas, World Resources Institute • IBTrACS, National Climatic Data Center, National Oceanic and Atmospheric Administration • Bhuvan - National Flood Vulnerability Assessment System • Vulnerability Atlas of India – BMTPC
Satellite images/ GIS layers	• United States Geological Survey - Earth Explorer • Bhuvan Portal • DIVA-GIS

4.3.4.2. Primary data

Applying the two-stage cluster sampling approach, total 50 locations in the Indian Bengal Delta were identified for the **sending area survey** under the DECCMA project (2014-19). The study area was divided into five multi-hazard zones (very low, low, medium, high, and very high) in the first stage using a village-level multi-hazard map (flood, cyclone, erosion). In the second round of sampling, each cluster of households in the study area was assigned one of five hazard categories. A number of locations were selected proportional to the total number of clusters (probability proportional to size) in each multi-hazard zone. Based on demographic and migration characteristics, a total 10,000 households (200 households in each location) were listed and from that, 1500 households (30 households in each location) were chosen proportional to the number of migrant households and non-migrant households.

A total of 512 delta migrants were interviewed during the **receiving area survey** in Sonarpur (South 24 Parganas) and Dum Dum (North 24 Parganas). The migrants from most vulnerable places of IBD are mostly found in Sonarpur. DECCMA receiving area survey gathered data on length of residence, subjective and material wellbeing, aspiration, future intention of the migrants in destination areas. Migrants were also asked to draw comparisons between place of origin and current location.

4.3.5. Models

4.3.5.1. Principal Component Analysis

The most common statistical method used to extract a smaller and more coherent set of uncorrelated components from a large number of variables is Principal Component Analysis (PCA) (Dunteman, 1989). First component accounts for the largest amount of variation in the input variables, and each following component accounts for as much of the remaining variability as possible (Dunteman, 1989; Field, 2009; Krishnan, 2010). As the variables are not standardised, the correlation matrix was employed as an input to PCA to extract the factors or components (Krishnan, 2010). Only those factors or components with an eigenvalue (the variances extracted by the factors) greater than 1 were selected using the "eigenvalue-greater-than-one" criteria provided by Kaiser (1960). The varimax (orthogonal) rotation was opted to improve the interpretability of factors (Field, 2009). Factor score coefficients, often referred to

as component scores, were determined for the purpose of calculating a composite index. Factor scores are the scores of each case, on each factor.

This method was applied in Social vulnerability analysis **(Chapter 6)**, and Vulnerability (AR4) and Risk (AR5) indices **(Chapter 5)**.

4.3.5.2. Binary Logistic Regression

Based on the behaviour of one or more independent variables, which can be either continuous or categorical, Binary Logistic Regression (BLR) (also known as the logit model), predicts the probability that an observation falls into one of two categories of a dichotomous dependent variable.

This method was applied to understand the influence of various environmental and socio-economic variables on migration decision **(Chapter 9)**. Based on the existing literature and available primary data sets, one dependent variable and 21 independent variables were selected. The present study has two types of independent variables, environment related parameters and the household's socio-economic characteristics. It is understood that the relationship between environment-related events and migration intention is complex. It is quite difficult to differentiate individuals for whom environmental factors are the main reason for migration. Economic and socio-political factors also drive migration. That's why, it is important to consider socio-economic factors when investigating whether people will migrate as a result of environment-related events.

4.3.5.3. Exposure Mapping

Exposure Mapping (EM) is the simplest method for predicting climate migration. In this method, a population distribution map is typically overlaid with a climate-related hazard. This method helps to estimate the number of people who will be relocated if that hazard happens. There is a large and growing body of literature on hazards that have been mapped in this way (Rigaud et al., 2018), such as sea level rise (McGranahan and Anderson, 2007; Mondal and Tatem, 2012; CIESIN, 2013; Neumann et al., 2015); floods (Hirabiyashi et al., 2013; Ghosh et al., 2019); multiple climate hazards (Christensen et al., 2014); and multiple climatic and non-climatic hazards (Dilley et al., 2005; Peduzzi et al., 2009). By doing so, it will be easier to

identify potential risks to human populations and make some very basic predictions about who will stay and who will go.

This method was applied to estimate the number of people on the move because of environmental pressures in the future **(Chapter 10)**.

Microsoft Excel (2010), Statistical Package for Social Sciences (SPSS) (version 22), R (version 3.3.3), ArcGIS (version 10.5) software were used for data analysis and modeling.

4.4. Chapter Summary

Literature review was conducted to compile current the most recent information on the on the impacts of environmental change on migration. To assess the vulnerability and risk, impact chain was developed and the list of indicators was prepared for hazards, exposure, sensitivity, and adaptive capacity components. IPCC AR4's vulnerability and AR5's risk assessment frameworks were followed for this study. All the required data for the selected indicators was collected from various publicly available sources. PCA method was applied in Social vulnerability analysis, and Vulnerability and Risk indices. To understand the migration patterns, primary survey was conducted in sending and receiving areas. BLR method was applied to understand the influence of various environmental and socio-economic variables on migration decision. EM method was applied to estimate the number of people on the move because of environmental pressures in the future.

CHAPTER 5

Climate Change Impact Hotspots

"Climate hotspots is a geographical area where a strong climate signal is combined with a large concentration of vulnerable, poor or marginalized people" – ***Tucker et al., 2015.***

5.1. Introduction

Vulnerability in particular is a key concept for climate and social sciences (Fussel and Klein, 2006; Adger, 2006). There are many various definitions of vulnerability in the literature, but they all focus around three fundamental ideas: exposure, sensitivity, and adaptive capacity (Kelly and Adger, 2000; Brooks, 2003; Adger et al., 2004; Brooks et al., 2005; Cutter et al., 2012). Previous research (Hahn et al., 2009; Nguyen, 2015) have used the IPCC working definition of vulnerability (2007), which combines exposure, sensitivity, and adaptive capacity, to measure multi-dimensional issues using variables as proxies. The concept of risk is first introduced in the IPCC's Fifth Assessment Report (AR5). This approach is different from the concept of vulnerability as mentioned in the IPCC AR4 (Fritzsche et al., 2014). Hence, there is limited understanding and empirical work on risk assessment following the IPCC AR 5 approach. This chapter is to link the new concept of risk (AR5) with the existing concept of vulnerability (AR4) using the basic underlying assumptions present in both IPCC frameworks. This chapter also assesses the vulnerability (AR4) and risk (AR5) at the local level (sub-district) to identify climate change impact hotspots to provide input for successful adaptation options.

5.2. Vulnerability and Risk

The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability in the Fourth Assessment Report (AR4) as 'the degree to which geophysical, biological and socio-economic systems are susceptible to, and unable to cope with, adverse impacts of climate change, including climate variability and extremes' (IPCC 2007, p.783). The term 'vulnerability' in AR4 is used to refer to the vulnerable system itself, e.g., low-lying islands or coastal cities; the impact to this system, e.g., flooding of coastal cities and agricultural lands etc. (Schneider et al., 2007). According to IPCC AR4, vulnerability is a function of three factors which are exposure (E), sensitivity (S), and adaptive capacity (AC) (Schneider et al., 2007; Hahn et al., 2009). Exposure in AR4

is the magnitude and duration of the climate-related stress such as a drought or change in precipitation, whereas sensitivity is the degree to which the system is affected by the climate related stress or extreme events. Adaptive capacity in AR4 refers to the system's ability to withstand or recover from the extreme events/damage (Ebi et al., 2006; Schneider et al., 2007; Hahn et al., 2009; Fritzsche et al., 2014).

$$\boldsymbol{V = f\ (E, S, AC)}$$

It has to be noted that the adaptive capacity of a system determines the vulnerability by modulating exposure and sensitivity (Adger et al., 2007).

The Fifth Assessment Report of the IPCC (AR5) introduces a new approach and terminology. This approach is similar to the concept of disaster risk, which differs from the current understanding of vulnerability as mentioned in the IPCC AR4 (Fritzsche et al., 2014). According to IPCC AR5, risk is 'the potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. It is often represented as the probability of occurrence of hazardous events or trends multiplied by the impacts' (IPCC 2014, p. 1048). The term 'risk' is used primarily to refer to the risks of climate-change impacts (Oppenheimer et al., 2014). Risk is the function of three factors which are hazard (H), exposure (E) and vulnerability (V).

$$\boldsymbol{R = f\ (H, E, V)}$$

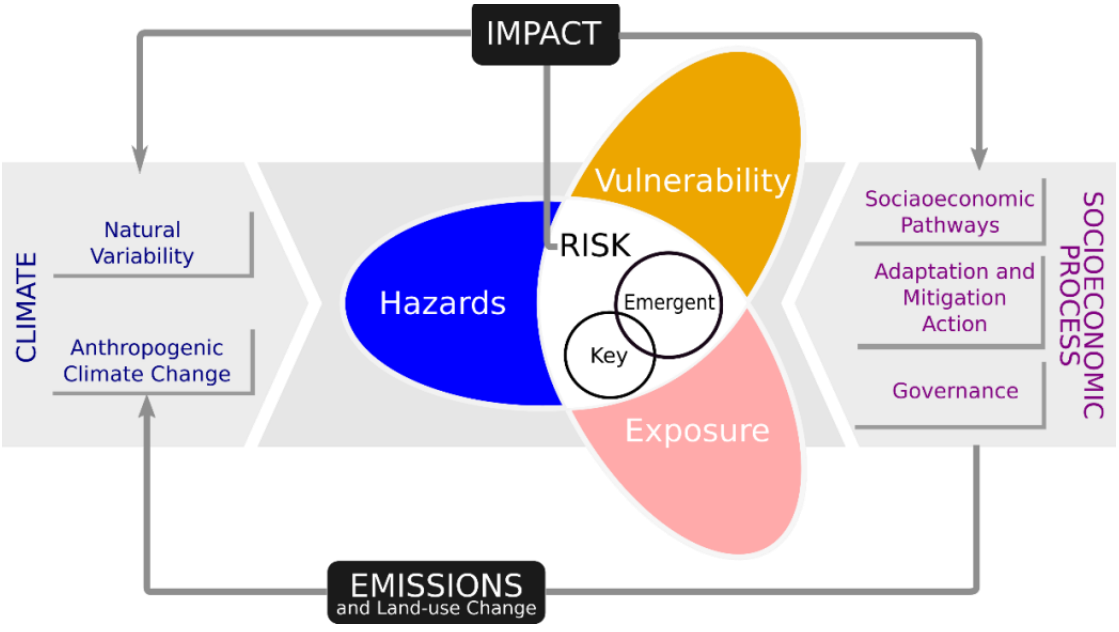


Figure 14. The contributing factors of Risk (adapted from IPCC AR5, 2014, P.1046)

5.3. Linking New Concepts

The terms 'exposure' and 'vulnerability' are common but used differently in IPCC AR4 and AR5. According to IPCC AR5, exposure is 'the presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected' (IPCC 2014, p. 1048) and vulnerability is 'the propensity or predisposition to be adversely affected' (IPCC 2014, p. 1048).Vulnerability in AR5 includes the concepts of sensitivity (susceptibility to harm) and adaptive capacity. Hazard is a new term in AR5, defined as 'the potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources'(IPCC 2014, p. 1048).

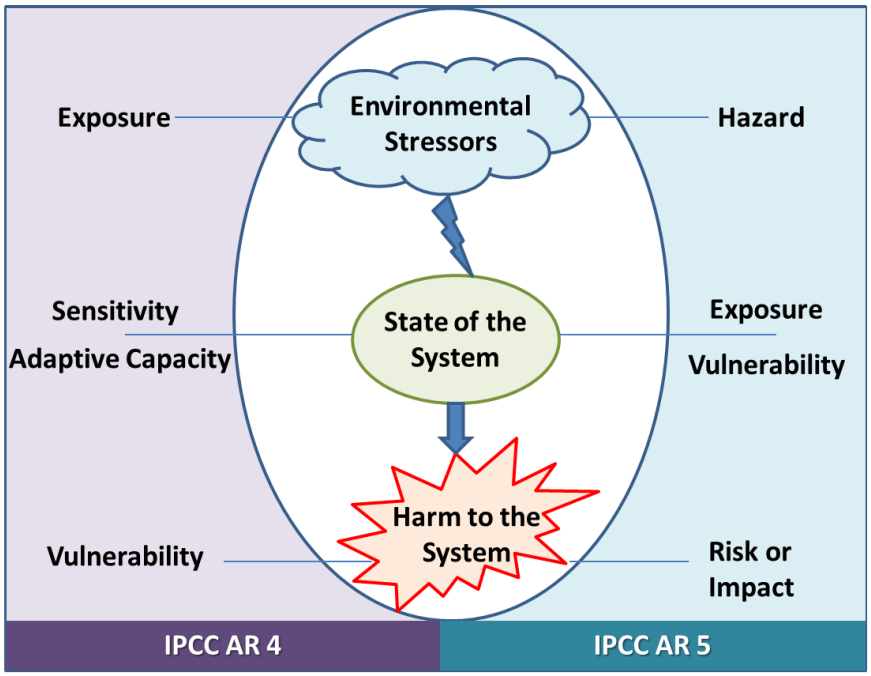


Figure 15. General logic of two different approaches (IPCC AR4 & AR5)

In both IPCC's AR4 and AR5 working definitions it is clear that vulnerability and risk include an external element, which is climate-related stress (e.g. extremes weather events) represented by the "exposure" according to AR4 and "hazard" in AR5, as well as an internal element, which comprises "sensitivity" and "adaptive capacity" in AR4 and "exposure" and "vulnerability" in AR5. The internal element describes the moderating attributes (socio-economic, physical or environmental) of

the system. It can be said that the terminology employed in both the IPCC assessment reports is different but the basic underlying assumptions follow a similar logic**.**

5.4. Data and Methodology

In quantitative methods for assessing vulnerability, the construction of an index based on certain sets of variables is frequently used (Adger et al., 2004, Adger, 2006). In the past, several methods were used to quantitatively assess vulnerability at various scales based on the IPCC contributing factors of exposure, sensitivity, and adaptive capacity (Sullivan, 2002; O'Brien et al., 2004; Vincent, 2004; Ebi et al., 2006; Polsky et al., 2007; Hahn et al., 2009; Fritzsche et al., 2014: Nguyen, 2015; Žurovec et al., 2017).

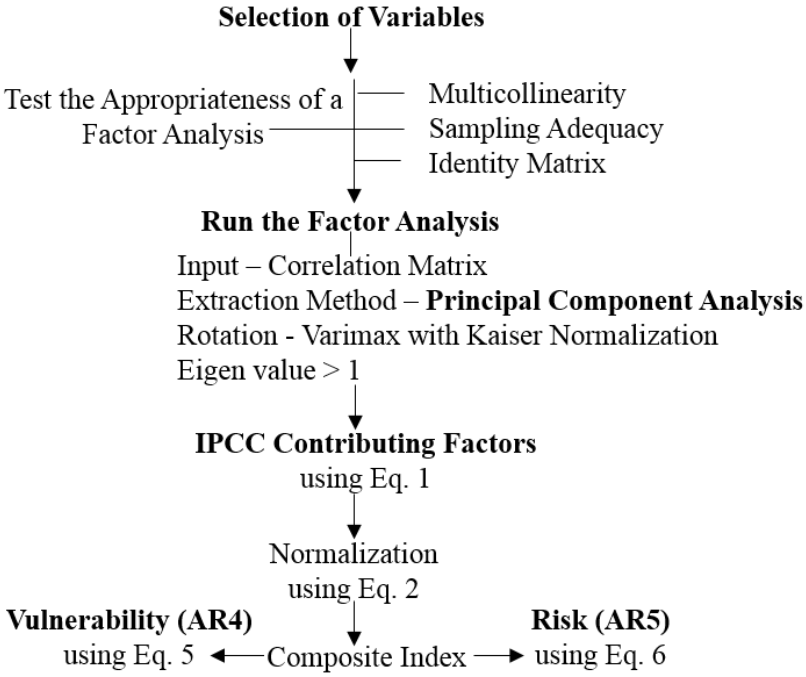


Figure 16. Methodological framework of Vulnerability (AR4) and Risk (AR5) assessments

Using the data reduction technique – 'Principal Components Analysis' (PCA) and the Statistical Package for the Social Sciences (SPSS) software, vulnerability and risk indexes were constructed at the sub-district level for this study. A similar approach was used in previous studies on vulnerability assessment (Cutter et al., 2003; Fotso and Kuate-defo, 2005; Antony and Rao, 2007; Fekete, 2009; Krishnan, 2010; Holand et al., 2011; Tate, 2012; Dunning and Durden, 2011, 2013; Opiyo et al., 2014; Armas and Gavris, 2013, 2016; Žurovec et al., 2017). The most common statistical method used to extract a smaller and more coherent set of uncorrelated components from a

large number of variables is Principal Component Analysis (PCA) (Dunteman, 1989). First component accounts for the largest amount of variation in the input variables, and each following component accounts for as much of the remaining variability as possible (Dunteman, 1989; Field, 2009; Krishnan, 2010).

Based on the IPCC AR4 and AR5 working definitions, the methodological frameworks of vulnerability and risk were designed for this study. The term 'vulnerability' in AR5 was divided into 'sensitivity' and 'adaptive capacity' for the simplification of the methodological framework of risk. In other words, risk is the function of four factors which are hazard (H), exposure (E), sensitivity (S) and adaptive capacity (AC).

5.4.1 Selection of variables

Based on a comprehensive review of the literature and available secondary data sets, 33 theoretically significant and policy-relevant bio-physical and socio-economic variables were chosen under ten major components (concepts) - climate variability, natural hazards, demographic profile, socio-economic status, livelihood activity, human resource capacity, economic security, infrastructure, basic facilities and agricultural livelihood strategies. The first two major components are related to the external dimension which in the AR4 is categorized as exposure, and as 'hazard' in the AR5. The average standard deviation of monthly maximum and minimum temperatures and precipitation for the past 30 years was used to quantify climate variability. Frequent cyclones, floods, coastal erosion are the major environmental stressors in IBD therefore these were used to measure the second major component namely natural hazards. The data sources of climate-related stress or extremes events are National Remote Sensing Centre (2003-2014), Indian Meteorological Department (1951-2014), United States Geological Survey (2001 & 2011).

Table 4. A detailed description of the selected variables for vulnerability and risk assessments

Sl. No.	Concepts	Variables	Explanation of Variables	IPCC Contributing Factors	References
1	Climate Variability	*Maximum Temperature*	Standard deviation of the average daily maximum temperature by month last 30 year is averaged	E1	Hahn et al., 2009; Heltberg and Bonch-Osmolovskiy, 2011

2		*Minimum Temperature*	Standard deviation of the average daily minimum temperature by month last 30 year is averaged	E2	Hahn et al., 2009; Heltberg and Bonch-Osmolovskiy, 2011
3		*Average Precipitation*	Standard deviation of the average monthly precipitation last 30 year is averaged	E3	Hahn et al., 2009; Heltberg and Bonch-Osmolovskiy, 2011; Shah et al., 2013
4	Natural Hazards	*Flood*	Percentage of area inundated with high return period flood during last 10 years	E4, H1	Clark et al., 1998; Cutter et al., 2000; Rygel et al., 2006, Boruff and Cutter, 2007; Hahn et al., 2009; Giupponi et al., 2012; Shah et al., 2013; Nguyen, 2015
5		*Cyclone*	Interpolated (kernel density estimation) wind speed (m/s) of tropical cyclone over last six decades	E5, H2	Hahn et al., 2009; Balica et al., 2012
6		*Coastal Erosion*	Rate of coastal erosion (sq.km./year)	E6, H3	FitzGerald et al., 2008; Balica et al., 2012
7	Demographic Profile	*Population Density*	Number of people per square kilometre	S1, EX1	Armas and Gavris, 2013; Wu et al., 2016
8		*Average Household Size*	Average number of people per household	S2, SS1	Adger, 1999; Cutter et al., 2003
9		*Female Population*	Percentage of female population to total population	S3, SS2	Cutter et al., 2003; Armas and Gavris, 2013; Nguyen, 2015
10		*Child Population*	Percentage of population under 7 years age (0-6 age group) to total population	S4, SS3	Cutter et al., 2003; Nguyen, 2015
11	Socio-Economic Status	*Socially Disadvantaged People*	Percentage of scheduled caste and scheduled tribe population to total population	S5, SS4	Samanta et al., 2017
12		*Food Insecurity*	Percentage of households that can manage less than one or one square meal a day for the major part of the year	S6, SS5	Heltberg and Bonch-Osmolovskiy, 2011; Nguyen, 2015
13		*Land holding*	Percentage of households without land holding	S7, SS6	Samanta et al., 2017
14		*Poverty*	Percentage of population living below the poverty line (BPL)	S8, SS7	Adger and Kelly, 1999; Cutter et al., 2003, Vincent, 2004 ; Siagian et al., 2014
15		*Rural Population*	Percentage of rural population to total population	S9, EX2	Cutter et al., 2003; Vincent, 2004; Fekete, 2009
16	Livelihood Activity	*Agricultural Dependency*	Percentage of cultivators and agricultural labours (dependent on agriculture) to total working population	S10, EX3	Cutter et al., 2003; Heltberg and Bonch-Osmolovskiy, 2011
17		*Marginal Workers*	Percentage of marginal workers (not work for the major part of the reference period i.e. less than 6 months) to total working population	S11, SS8	Kapur, 2010

18		*Non-workers (dependents)*	Percentage of total non-workers (not work at all in any economically productive activity - students, persons engaged in household duties, dependents) to total population	S12, SS9	Myers, 2008; Armas and Gavris 2013; Su et al., 2015
19	Human Resource Capacity	*Literacy Rate*	Percentage of literates to the total population age 7 years and above	A1, AC1	McCarthy et al., 2001; Brenkert and Malone, 2005
20		*Work Participation Rate*	Percentage of total workers (main and marginal) to total population	A2, AC2	Dhar, 2014
21	Economic Security	*Salaried Job*	Percentage of population working in organised/formal sector (regular salaried employed)	A3, AC3	Mannila, 2015
22		*Home Ownership*	Percentage of households have their own home	A4, AC4	Cutter et al., 2003; Tate, 2012
23		*Household Assets*	Percentage of households have household assets	A5, AC5	Vincent, 2004, 2007; Boruff and Cutter, 2007; Samanta et al., 2017
24	Infrastructure	*Pucca Houses*	Percentage of households living in Pucca houses (permanent structure)	A6, AC6	Samanta et al., 2017
25		*Health Care Centres*	Number of health care centres	A7, AC7	Yoo et al., 2011
26		*Educational Institutes*	Number of educational institutes	A8, AC8	Bryant et al., 2000
27		*Road Density*	Length of roads (in km.) per sq. km.	A9, AC9	Brooks and Adger, 2005
28	Basic Facilities	*Sanitation*	Percentage of households have sanitation facility within premises	A10, AC10	Cannon et al., 2003
29		*Electricity*	Percentage of households have electricity connection	A11, AC11	Boruff and Cutter, 2007; Cannon et al., 2003
30		*Safe Drinking Water*	Percentage of households reported tap water from treated source as main source of drinking water	A12, AC12	Spence and Walters, 2012
31	Agro Livelihood Strategies	*Crops*	Number of crops grown in a year	A13, AC13	Hahn et al., 2009
32		*Irrigation*	Percentage of irrigated area to total cultivated area	A14, AC14	Thapa et al., 2016
33		*Fertilizer*	Number of fertilizer depots	A15, AC15	Bryan et al., 2015
IPCC AR4 : E - Exposure, S - Sensitivity, A - Adaptive Capacity; IPCC AR5: H - Hazard, EX - Exposure, SS - Sensitivity; AC - Adaptive Capacity					
All the variables are showing the positive (+) functional relationship with IPCC contributing factors which mean the higher the value, higher the hazard/ exposure / sensitivity/adaptive capacity.					

In addition, eight major components show an internal dimension, which includes AR4's sensitivity and adaptive capacity and AR5's exposure and vulnerability. In terms of socio-economic resources (e.g., low-income groups, rural population,

illiterates and females) and physical mobility (e.g., children, aged, and disabled persons) people who are disadvantaged are often considered to be the most vulnerable to climate change impacts. Compared to males, females face more difficulties recovering from the disasters because of their roles as carers for their families (Cutter et al., 2003). Rural populations are especially susceptible since they depend more heavily on natural resources and have lower incomes (Vincent, 2004). Climate change and natural hazards have a significant negative impact on those whose primary source of income is agriculture (Cutter et al., 2003). It is noted that a few variables like population density, rural population and agricultural dependents were considered as exposure in AR5 and as sensitivity in AR4. Marginal workers have work for less than 6 months in a year, are economically disadvantaged people (Kapur, 2010). Poverty is a variable that captures lack of access to resources and income opportunities (Siagian et al., 2014). On the other hand, literate people who are working in the formal sector have access to early-warning information and can plan in advance how to respond to climate related stress or extreme events (Cutter et al., 2003, 2008; Brenkert and Malone, 2005). Access to sanitation, safe drinking water, electricity, and infrastructures such as road density, health and educational institutes determine the ability of the system to respond to and recover from the impacts of extreme events (Cannon et al., 2003). The socio-economic data sets used in this study are available in Census of India (2001 & 2011), Bureau of Applied Economics & Statistics (2011), United Nations Development Programme -India (2009 & 2010).

Table 5. Descriptive statistics of the selected variables for vulnerability and risk assessments

	Variables	Range	Mean	Std. Deviation
1	*Maximum Temperature*	0.14	0.43	0.02
2	*Minimum Temperature*	0.08	0.41	0.02
3	*Average Precipitation*	129.17	301.60	22.68
4	*Flood*	1.00	0.13	0.20
5	*Cyclone*	1.00	0.59	0.32
6	*Coastal Erosion*	1.00	0.07	0.18
7	*Population Density*	4837.34	1682.21	864.01
8	*Average Household Size*	1.29	4.50	0.29
9	*Female Population*	1.29	48.78	0.24
10	*Child Population*	8.52	12.29	1.84
11	*Socially Disadvantaged People*	62.05	33.43	15.56
12	*Food Insecurity*	16.11	4.54	2.86
13	*Without Land holding*	63.01	60.67	13.46

14	*Poverty*	58.45	31.76	13.30
15	*Rural Population*	76.11	85.00	19.00
16	*Agricultural Dependency*	70.10	44.47	18.62
17	*Marginal Workers*	44.98	28.29	12.33
18	*Non-workers*	20.25	63.69	3.09
19	*Literacy Rate*	19.20	77.10	4.76
20	*Work Participation Rate*	16.42	36.23	2.82
21	*Salaried Job*	24.14	13.23	5.26
22	*Home Ownership*	17.40	94.86	3.48
23	*Household Assets*	3.50	0.61	0.78
24	*Pucca Houses*	74.60	47.76	21.63
25	*Health Care Centres*	13.00	6.00	3.50
26	*Educational Institutes*	560.00	516.69	135.03
27	*Road Density*	10.21	1.54	1.70
28	*Sanitation*	65.40	67.17	17.48
29	*Electricity*	88.80	43.86	23.39
30	*Safe Drinking Water*	84.00	14.21	18.67
31	*Crops*	85.71	49.58	23.58
32	*Irrigation*	93.50	40.11	23.51
33	*Fertilizer*	371.00	95.27	82.33
Valid cases (*N*) = 51				

5.4.2 Testing the appropriateness of Factor Analysis

All variables are measured at the interval-level. The initial analysis revealed that some of the socio-economic variables are highly correlated with each other. For example, 'agricultural dependency' is highly correlated with 'landholding', 'Pucca houses' is correlated with 'electricity' and 'household assets'. It is very difficult to determine the unique contribution to a factor (or component) of the highly correlated variables. To address this limitation, the list of variables was reduced to 29 variables in AR4 framework by removing redundant variables ($r > \pm 0.8$) to avoid multi-collinearity (highly correlated) and singularity (perfectly correlated). In the case of AR5 framework, 28 variables were considered by excluding the correlated and not relevant variables. The issue of multi-collinearity can also be identified by looking at the determinant of the R-matrix (|R|), which should be greater than 0.00001 (Field, 2009).

In the present study, the Kaiser-Meyer-Olkin (KMO) test (Kaiser, 1970) was used to measure the sampling adequacy and to detect multi-collinearity in the data, so that the appropriateness of carrying out the analysis can be identified. Multi-collinearity can also be detected by looking at the determinant of the R-matrix (|R|), which should be greater than 0.00001 (Field, 2009). Using the Bartlett's (1954) Test of Sphericity,

another test of the strength of the association between variables was conducted. This test determines if the correlation matrix differs considerably from an identity matrix (Krishnan, 2010). Principal component analysis is suitable for the data, according to all tests.

5.4.3 Factor analysis and Final calculation

As the variables are not standardised, the correlation matrix was employed as an input to PCA to extract the factors or components (Krishnan, 2010). Only those factors or components with an eigenvalue (the variances extracted by the factors) greater than 1 were selected using the "eigenvalue-greater-than-one" criteria provided by Kaiser (1960). The varimax (orthogonal) rotation was opted to improve the interpretability of factors (Field, 2009). Factor score coefficients were determined for the purpose of calculating a composite index. Factor scores are the scores of each case, on each factor.

To calculate the value of the contributing factors indicated in the IPCC for all the sub-districts, factor score coefficients are multiplied by the proportion of the corresponding factor's variance and summed these products in SPSS software (Krishnan, 2010). The value of contributing factors has been calculated using the formula:

$$\boldsymbol{CF = \sum(Fi/TV) * FSi} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\mathbf{1})$$

Where, CF is an contributing factor (hazard, exposure, sensitivity and adaptive capacity), F_i is the percentage of variance explained by each factor (i), TV is the total variance explained by all the retained factors, FSi is the factor score coefficients on each factor (i).

The value of the CF can be positive or negative, making difficult to use it for final calculation. It is necessary to *normalize* all the CFs to ensure that they are comparable. This has been carried out using the methodology developed for the calculation of the Human Development Index (UNDP, 2006). The equation is expressed as:

$$\boldsymbol{Xij = \frac{(Xi - Min\ Xj)}{(Max\ Xj - Min\ Xj)}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\mathbf{2})$$

Where Xij is the normalized value of CF (j) with respect to sub-district (i), Xi is the actual value with respect to sub-district (i), and Min Xj and Max Xj are the minimum and maximum values, respectively, of CF (j) among all the sub-districts.

The normalized value ranges from 0 to 1.The next step after normalization is to *combine* all the normalized CFs into single *composite index*.

According to the framework proposed by Füssel and Klein (2006), exposure (E) and sensitivity (S) together compose the *potential impact* (PI), while adaptive capacity (AC) is the potential of a system to cope with these impacts.

$$\boldsymbol{PI = E \times S} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\mathbf{3})$$

It can be said that people who live in exposed areas and are also sensitive to climate change impacts are likely to become a 'potential vulnerable group'. This potential vulnerable group can be divided into two - with and without adaptive capacity. The latter part will be an *immediately vulnerable group*, as they cannot cope with climate change impacts (Nguyen, 2015). In other words, a system is more vulnerable if it is exposed and sensitive to the impacts of climate change and has only limited/no capacity to adapt.

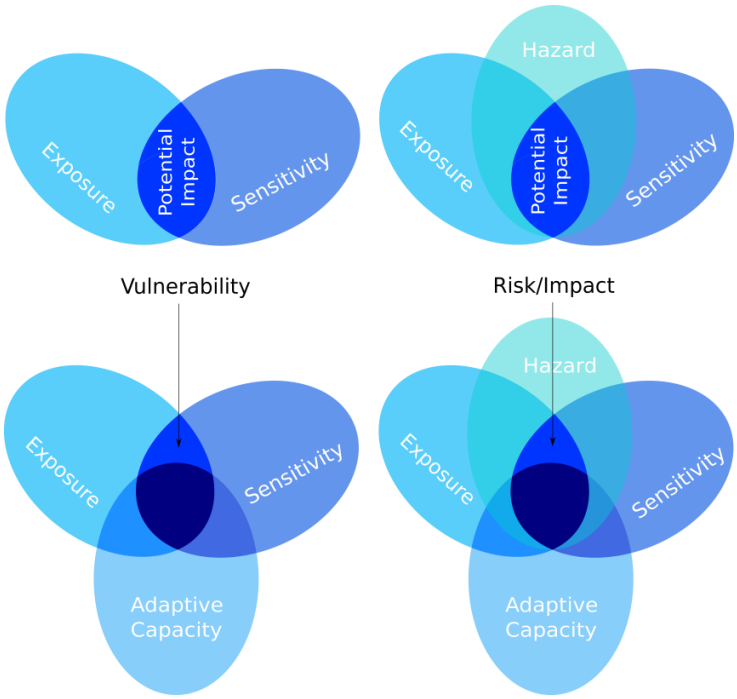


Figure 17. IPCC contributing factors for final calculation of Vulnerability (AR4) and Risk (AR5)

Vulnerability therefore can be expressed with the following mathematical equations:

$$\boldsymbol{V = PI - PI \times AC} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (\mathbf{4})$$

Or, $\boldsymbol{V = PI(1 - AC)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\mathbf{5})$

Equation 5 has also been employed in the final calculation of risk, where 'potential impact' is the combination of hazard, exposure, and sensitivity (Fig. 17).

$$\boldsymbol{R = H \times E \times S\ (1 - AC)} \ldots\ldots\ldots\ldots\ldots\ldots (\mathbf{6})$$

The final value represents current vulnerability and risk of IBD in changing climate conditions. The value for vulnerability and risk indexes ranges from 0 to 1, with higher values reflecting higher degree of vulnerability and risk. Finally, the entire range has been equally divided into five categories and each is assigned a qualitative indicator of vulnerability and risk (from very low to very high). In order to visualize and analyze the results in a geographic context, two separate maps have been prepared using ArcGIS software.

5.5. Results and Discussion:

People in IBD are facing multiple challenges associated with climatic hazards and under-development. Cyclone, coastal erosion/embankment breaching and flooding are the hazards that affect the delta region quite frequently. The low intensity cyclonic disturbances originated in the Bay of Bengal occur almost every year and severe cyclonic storms like Sidr-2007, Aila-2009 also make landfall in the delta from time to time. In most cases, saline floods are the result of embankment breaching and storm surges. Results derived from the analysis of multi-hazard data (flood, cyclone, and coastal erosion) of IBD suggest that coastal sub-districts such as Gosaba, Basanti, Patharpratima, Kultali, Hingalganj, and Sandeshkhali-II sub-districts are at very high risk. Another issue which magnifies the risk in the region is economic vulnerability of its inhabitants. The continuous degradation of natural resources and unsustainable pattern of economic activity combine to increase local poverty, which further exacerbates the existing vulnerability of this delta. Monsoon dependent mono cropping economy prevails in most of the physically vulnerable areas of IBD, with exception of multiple crop practices in few places. Basanti, Sandeshkhali II, Sandeshkhali I, Kulpi, Canning II, Patharpratima, Namkhana and Kultali sub-districts

have 45% of their population in conditions of chronic poverty. This poverty is associated with food insecurity, malnutrition, illiteracy, lack of primary health services and access to drinking water and sanitation facilities.

The spatial assessment of vulnerability/risk in the delta is a crucial element to consider, as it varies from place to place. Based on the results of PCA, vulnerability and risk have been estimated and mapped for all the sub-districts of IBD. In the vulnerability analysis (AR4), two components have accounted for 75.37 percent of the total variance in the data of exposure, whereas three components of sensitivity and four components of adaptive capacity have accounted for 73.96 percent and 73.80 percent of the total variance respectively. It is significant to notice that the first component has successfully accounted the majority of the data variation. The orthogonal rotation's factor loadings, which are the correlation coefficients between each variable and the factor or component, have a range of -1 to +1.

Photo 5. Breaching of embankments in the western part of the IBD

Table 6. PCA results for the Indian Bengal Delta: Varimax rotation factor matrix

Variables		Component (AR 4)				Component (AR 5)			
		1	2	3	4	1	2	3	4
1	*Maximum Temperature*	0.755	-0.474			N.A.			
2	*Minimum Temperature*	0.816							
3	*Average Precipitation*	0.800							
4	*Flood*		0.768			0.843			
5	*Cyclone*		0.881			0.762			
6	*Coastal Erosion*	0.885				0.761			
7	*Population Density*	N.C.				-0.959			
8	*Rural Population*	N.C.				0.947			
9	*Average Household Size*		0.904			0.921			
10	*Female Population*			0.866				0.693	
11	*Child Population*		0.850			0.921			
12	*Socially Disadvantaged People*	0.476	-0.408				-0.689		
13	*Food Insecurity*			0.567				0.793	
14	*Without Land holding*	-0.925				-0.509	0.737		
15	*Poverty*	0.690		0.480		0.576	-0.415	0.541	
16	*Agricultural Dependency*	0.911				0.940			
17	*Marginal Workers*	0.708		0.417		0.643	-0.553		
18	*Non-workers*	-0.506	0.679				0.810		
19	*Literacy Rate*	0.767				Same			
20	*Work Participation Rate*				0.767				
21	*Salaried Job*	N.C.							
22	*Home Ownership*	-0.876							
23	*Household Assets*	0.866							
24	*Pucca Houses*	N.C.							
25	*Health Care Centres*		-0.520						
26	*Educational Institutes*				0.777				
27	*Road Density*			0.768					
28	*Sanitation*	0.762	0.455						
29	*Electricity*	0.659		0.544					
30	*Safe Drinking Water*			0.831					
31	*Crops*		0.857						
32	*Irrigation*		0.822		0.407				
33	*Fertilizer*	0.514							
Percent of Variance	Exposure	45.217	30.167			Hazard	62.312		
	Sensitivity	33.969	23.785	16.207		Exposure	90.076		
	Adaptive Capacity	27.020	16.650	15.099	15.035	Sensitivity	31.978	24.720	17.349

Extraction Method: Principal Component Analysis; **Rotation Method:** Varimax with Kaiser Normalization

a. Adaptive Capacity is same for AR 4 and AR 5

b. Only one component was extracted. The solution cannot be rotated.

N.C. = Not Considered (to avoid multi-collinearity issue); N.A. = Not Applicable (as per definition of hazard in IPCC AR 5)

Suppress small coefficients (absolute value below .40)

Statistical Tests: Kaiser-Meyer-Olkin Measure of Sampling Adequacy = > 0.700; Determinant of Correlation Matrix = > 0.00001; Bartlett's Test of Sphericity = 0.00 (Significant); Communalities (Average) = > 0.750

For the first component in AR4, maximum and minimum temperature, average precipitation, coastal erosion, agricultural dependency, literacy rate, household assets, sanitation have shown markedly higher positive loadings, while variables like landholding and home ownership have shown strong negative factor loadings. The second component explains the variations in flood, cyclone, average household size, child population, crop diversity, irrigation. The third component explains female population, road density and safe drinking water. The fourth component which is related to adaptive capacity explains work participation rate and educational institutes. The results based on risk analysis (AR5) approach reveal a slight different scenario. One component has explained 62.31 percent of the variance in the data of hazard and 90.08 percent in case of exposure. For sensitivity, three components have explained 74.05 percent of the variance. Adaptive capacity is same as in vulnerability analysis (AR4). Flood, coastal erosion, average household size, child population, rural population, agricultural dependency have shown higher positive loadings and population density has shown negative loadings. The second component explains the variations in landholding, non-workers and third component explains food insecurity, female population. It is understood that eight variables largely determine the contributing factors of vulnerability and risk are flood, coastal erosion, agricultural dependency, average household size, landholding, household assets, sanitation, and rural population.

The climate change impact hotspots (vulnerability and risk) have been identified at the sub-district level considering both the IPCC working definitions of AR4 and AR5. Figures 18 and 19 show the influence of the contributing factors indicated by IPCC on top 10 most vulnerable sub-districts (AR4), and top 10 highest risk sub-districts (AR5). Coastal sub-districts like Gosaba, Basanti, Sandeshkhali-II, Kultali, and Patharpratima are at greatest risk/vulnerability due to both higher sensitivity and lower adaptive capacity.

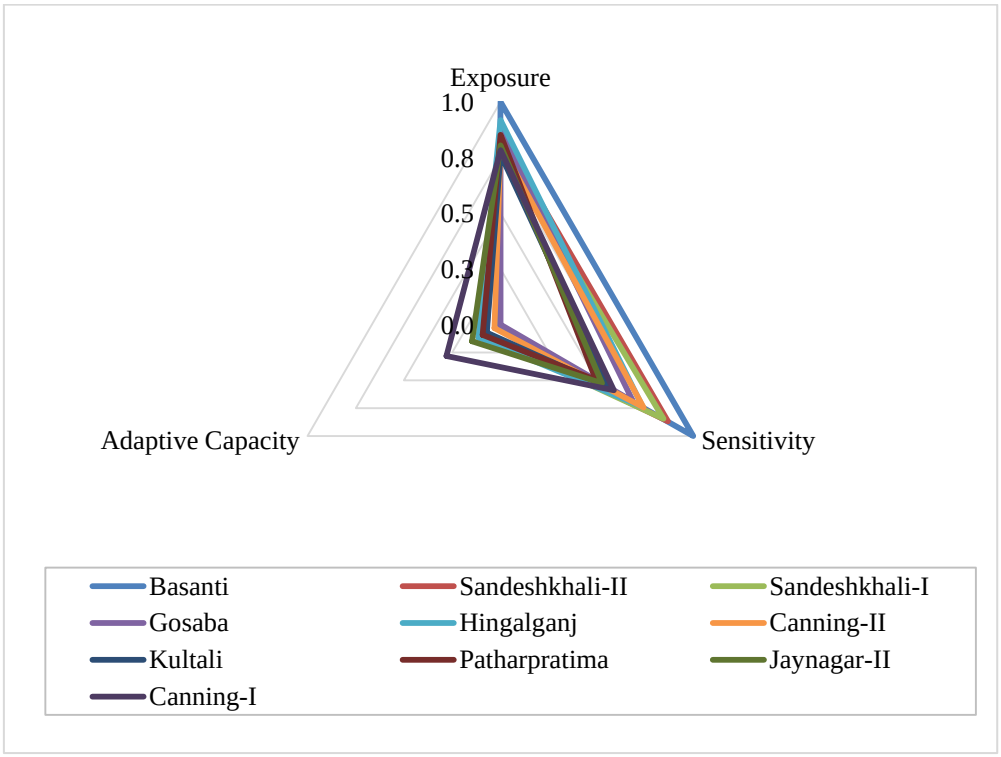


Figure 18. Top 10 most vulnerable sub-districts in the Indian Bengal Delta

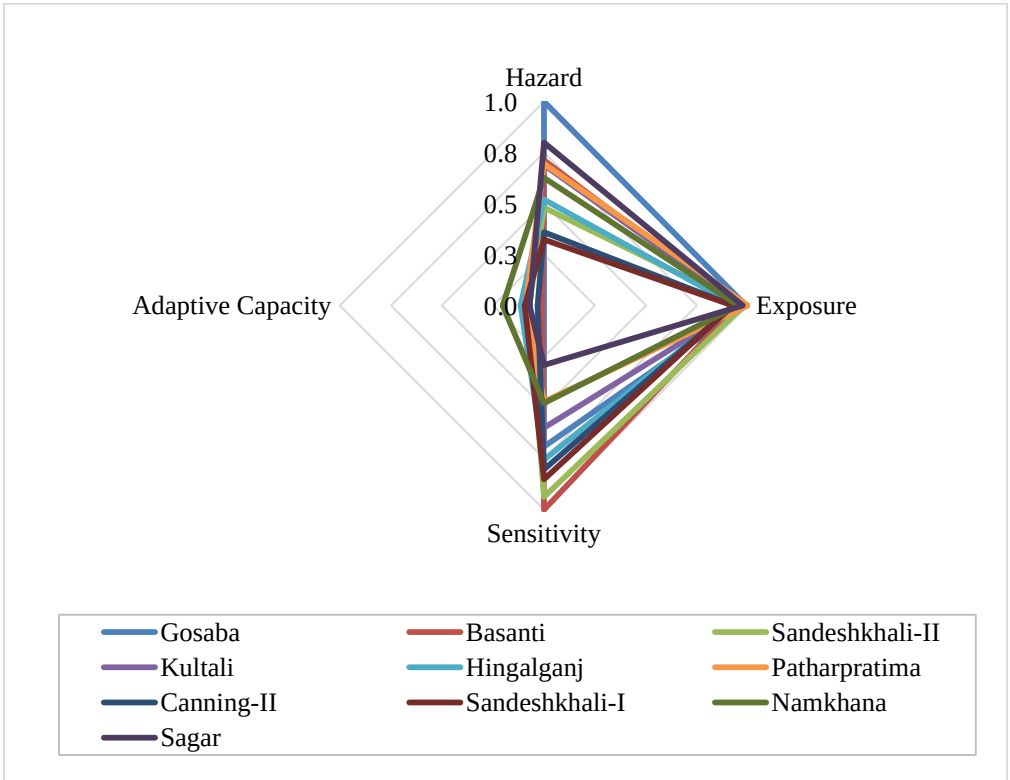


Figure 19. Top 10 highest risk sub-districts in the Indian Bengal Delta

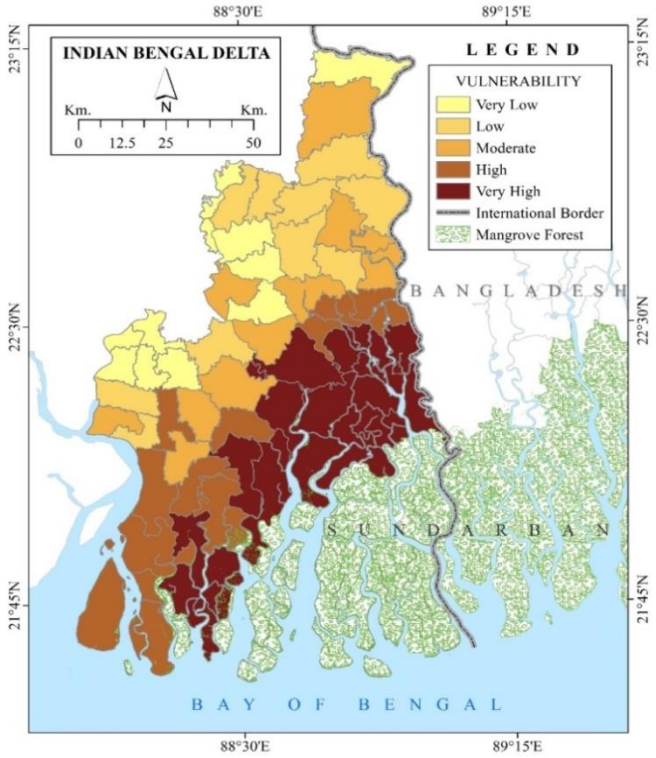


Figure 20. Vulnerability map of Indian Bengal Delta (following the IPCC AR4 approach, 2007)

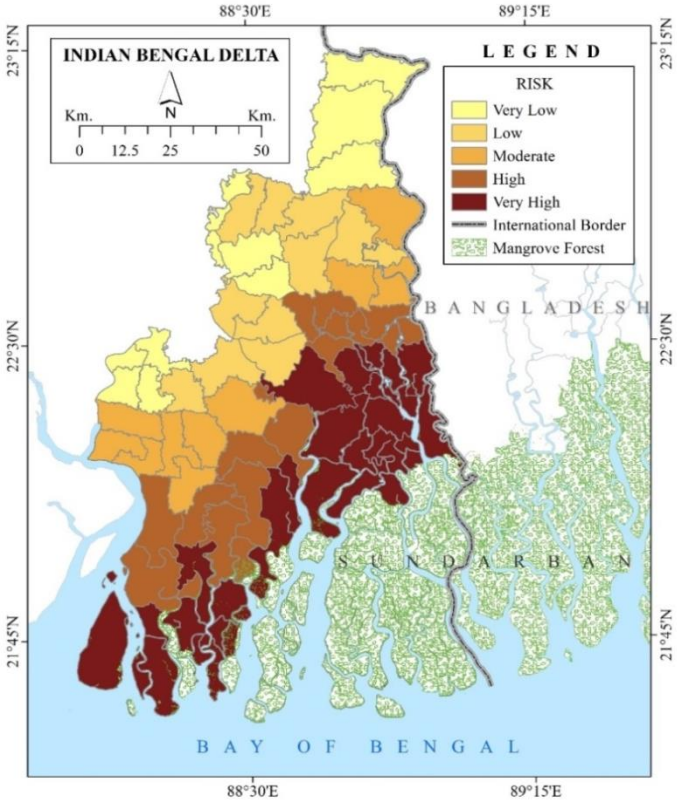


Figure 21. Risk map of Indian Bengal Delta (following the IPCC AR5 approach, 2014)

The results indicate that the majority of the vulnerable communities are living in the marginal areas of the delta. According to the AR4 approach, Basanti is assessed as the most vulnerable sub-district, however the AR5 approach determines that Gosaba is at highest risk. Both are spatially contiguous and geographically similar. Basanti is bordered by vulnerable sub-districts Canning-II, Sandeshkhali-II and Gosaba and Sundarban forests. Gosaba is the last settlement at the margin of the deep forests of the Indian Sundarban. Limited livelihood opportunities, poor socio-economic and institutional resilience, and increasing bio-physical vulnerabilities combine to make these two sub-districts the most vulnerable and exposed to highest risk in the IBD. Other vulnerable (AR4)/ highest risk (AR5) sub-districts are Sandeshkhali-I & II, Hingalganj, Canning-II, Kultali, Patharpratima. These sub-districts have maximum vulnerability/risk, and have the potential to be adversely affected by climate change, where focused adaptation measures are immediately needed. The least vulnerable sub-districts (AR4) are Barrackpur-I & II, Barasat-II, Budge-Budge-I, Bishnupur-II and lowest risk sub-districts (AR5) are Barrackpur-I & II, Budge-Budge-I, Thakurpukur-Maheshtala, Bagdah. All sub-districts are closer and connected to Kolkata city and fall within the Kolkata Metropolitan Area (KMA) which results in greater advantages in terms of livelihood opportunities and access to frontline services.

The most significant difference between the results of the AR4 and AR5 approaches is the change in sub-district level relative ranking. The overall level of vulnerability/risk (very low to very high) is almost the identical for all the sub-districts. This result suggests a link between the new concept of risk (AR5) and the existing concept of vulnerability (AR4). It is also noted that the concept of exposure (people, livelihoods, etc.) in AR5 is more adequate to identify the vulnerable communities in any areas. This is considered as an advantage of AR5 over the AR4 framework.

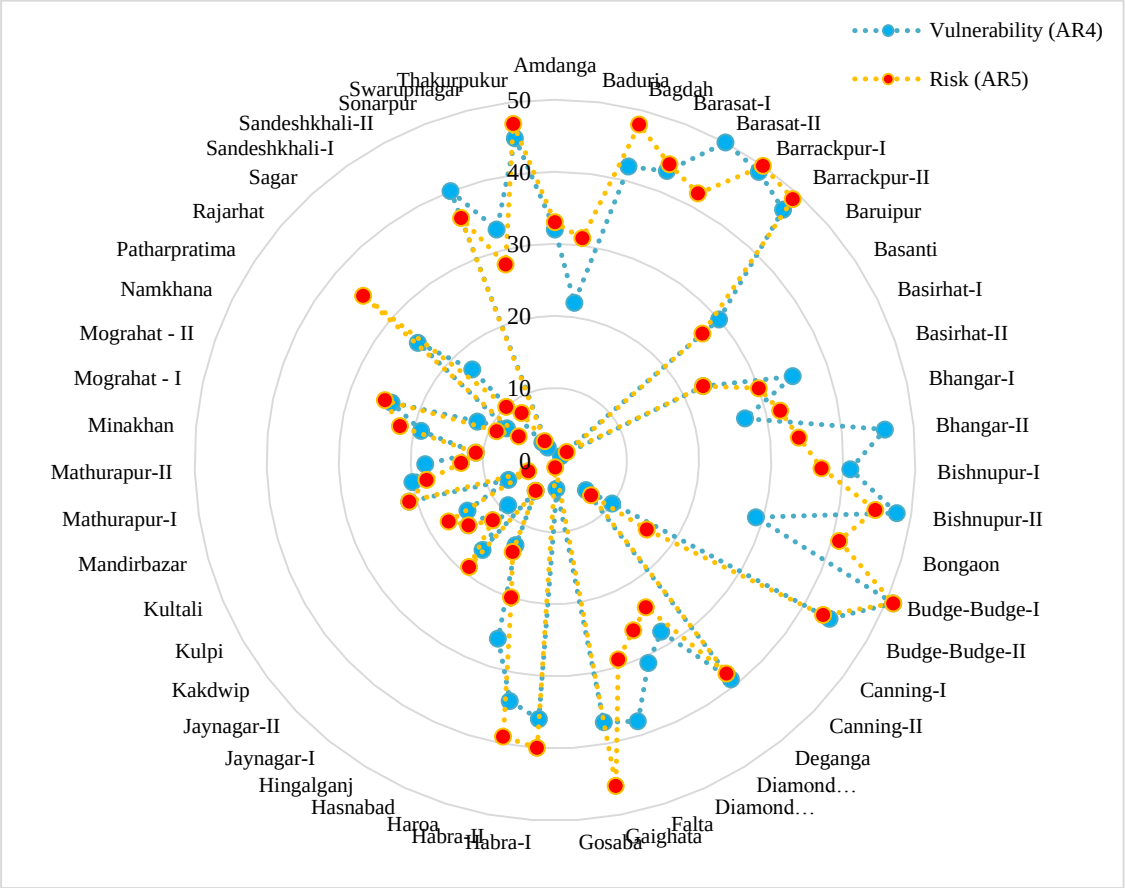


Figure 22. Sub-district level relative ranking of Indian Bengal Delta

5.6. Chapter Summary

Coastal sub-districts like Gosaba, Basanti, Sandeshkhali-II, Kultali, and Patharpratima are at greatest risk/vulnerability due to both higher sensitivity and lower adaptive capacity. This study provides a first representation of the risk of a coastal region following the IPCC AR5 approach. Applying the IPCC AR4 and AR5 frameworks to the same data set, two different sub-districts located in the IBD delta have been identified to be the most vulnerable or exposed to highest risk. Interestingly, the two sub-districts are spatially contiguous and geographically similar. This is also similar for other sub-districts of IBD. The difference between the results of the AR4 and AR5 approaches is the change in sub-district level relative ranking. This suggests a link between the new concept of risk (AR5) and the existing concept of vulnerability (AR4). The concept of exposure (people, livelihoods, etc.) in AR5 is more adequate to identify the vulnerable communities in any areas. This is considered as an advantage of AR5 over the AR4 framework.

CHAPTER 6

Social Vulnerability Analysis

"Vulnerability of deltaic communities reflects the socio-economic condition of the community before the occurrence of such events" - ***Žurovec et al., 2017****.*

6.1. Introduction

The assessment of social vulnerability across deltas or other areas of interest improves understanding of how, where and which communities are exposed to slow onset environmental hazards like sea level rise and coastal erosion and fast onset hazards like cyclones and surges, as well as communities' ability to withstand and recover from the damages sustained (Das et al., 2021). The spatial assessment of social vulnerability at a higher resolution identifies possible impact hotspots where adaptation measures are urgently required. This is a prerequisite for any delta level intervention to reduce vulnerability to environmental hazards adhering to the principles of the Sendai framework of disaster risk reduction (2015-30). This chapter has an aim to construct a social vulnerability index consistent for the Indian part of GBM delta at the sub-district level (Community Development Block in India), taking secondary data from Census (2011).

6.2. Social vulnerability

Social vulnerability is the incapacity of individuals, groups, and societies to tolerate the negative effects of the many stresses to which they are exposed (Adger, 1999; Adger and Kelly, 1999; Vincent, 2004). It is an important concept, especially in the arena of sustainability science, and viewed as a system's innate quality resulting from its intrinsic properties (Cutter et al. 2003; Adger et al., 2005). Social vulnerability is determined by socio-economic factors, such as economic status - wealth, income, and poverty, education level, housing quality, tenure type, built environment, family structure, age, gender, marginalisation, food insecurity, and access to insurance (Adger and Kelly, 1999; Mileti, 1999; Buckle et al., 2000; Cross, 2001; Cutter et al., 2003, 2008; Brooks and Adger, 2003; Dwyer et al., 2004; Blaikie et al., 2005; Burton and Cutter, 2008). It is one of the key factors that determine vulnerability, and plays an equivalent role of sensitivity in the IPCC vulnerability framework where human systems are concerned (Brooks, 2003; Adger et al., 2005).

6.3. Data and Methodology

To assess social vulnerability at various scales, a range of different techniques and procedures were employed (Cutter et al., 2003; Vincent, 2004; Nguyen, 2015; Armas and Gavris, 2016). Using the data reduction technique – 'Principal Component Analysis' (PCA) and SPSS software (version 22), a social vulnerability index (SVI) was constructed at the sub-district level for this study. Several researchers used PCA in the field of vulnerability assessment (Cutter et al., 2008; Antony and Rao, 2007; Krishnan, 2010; Holand et al., 2011; Dunning and Durden, 2013; Armas and Gavris, 2016; Žurovec et al., 2017). The most common statistical method used to extract a smaller and more coherent set of uncorrelated components from a large number of variables is Principal Component Analysis (PCA) (Dunteman, 1989). First component accounts for the largest amount of variation in the input variables, and each following component accounts for as much of the remaining variability as possible (Dunteman, 1989; Field, 2009; Krishnan, 2010).

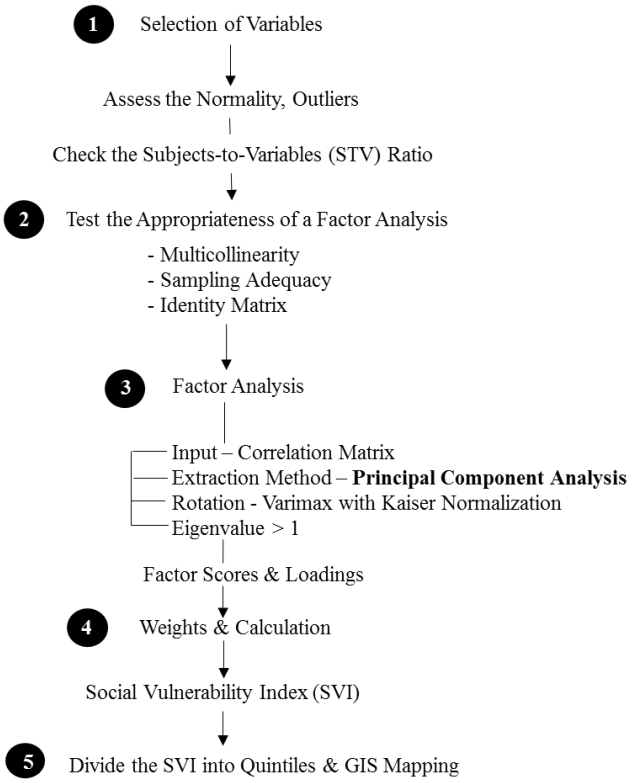


Figure 23. Methodological Steps of developing the Social Vulnerability Index

6.3.1. Selection of variables

A detailed review of the literature and the availability of secondary datasets from Census of India for the year 2011 were made. It was found that only 14 important socio-economic variables could be selected for the present analysis at the sub-district level. All the aspects for determining the social vulnerability – household structure, gender, education, occupation, socio-economic status, housing, access to basic services and rural/urban proportion were considered during this selection. The selected variables are important to identify the socio-economically vulnerable communities exposed to multiple hazards. All variables can be measured at the interval level. Table 7 provides the description of the variables used in the present study.

Table 7. Selected variables for Social Vulnerability Analysis

Variables	Description	References
Household Size	Average number of people per household	Cutter et al., 2003; Adger, 1999
Female Population	Percentage of female population to total population	Cutter et al. 2003; Hajat et al., 2003; Armas and Gavris, 2013
Rural Population	Percentage of rural population, defined as the difference between the total population and urban population	Vincent, 2004; Cutter et al., 2003; Fekete, 2009
Dependency Ratio	Ratio of the population under 15 and over 65 years of age to the population between 15 and 65 years of age (economically active)	Dwyer et al., 2004; Dunning et al., 2013
Widowed/Divorced/Separated	Percentage of widowed/divorced/separated population to total population	Dunning and Durden, 2011; Armas and Gavris, 2016
Disabled Persons	Percentage of disabled persons to total population	Kuhlicke et al., 2011, Reid et al., 2009, Cutter et al. 2003; Brodie et al., 2006, Dunning et al., 2013
Agricultural Dependency	Percentage of cultivators and agricultural labours (dependent on agriculture) to total population	Cutter et al., 2003
Poverty	Percentage of households who belong to Below Poverty Line (BPL) category	Cutter et al., 2003, Vincent,20004,
Kutcha House	Percentage of households live in temporary structure of houses	Schmidlin, 2009; Samanta et al., 2017
Illiteracy	Percentage of illiterate persons to total population	Schmidlin 2009; Cannon et al., 2003
Unemployed	Unemployed/ not working population to total population	Armas and Gavris, 2013, Myers, 2008; Holand et al., 2011
No Sanitation	Percentage of households reported that have no sanitation facility	Cannon et al., 2003
No Electricity	Percentage of households reported that have no electricity connection	Cannon et al., 2003; Samanta et al., 2017

Unsafe Drinking Water	Percentage of households reported others (ponds/canal/spring/river) as main source drinking water	Spence and Walters, 2012
All the variables are showing the positive (+) functional relationship with social vulnerability which means the higher the value, higher the social vulnerability		

6.3.2. Testing the appropriateness of Principal Component Analysis

The sample size (cases) is 51 sub-districts for this study (Table 8)**.** The subjects-to-variables (STV) ratio is not lower than 3 (3:1 ratio) (OCED, 2008). Histogram, normal Q-Q plot, box plot and descriptive statistics were used to identify the outliers in the SPSS platform. The Kolmogorov-Smirnov statistic was examined to test for normality, and the result (sig. = 0.00) indicates that the assumption of normality has not been violated.

Table 8. Descriptive Statistics of the Socio-Economic Variables

Variables	N	Range	Mean	Std. Deviation
Household Size	51	1.30	4.50	0.30
Female Population	51	1.29	48.78	0.24
Rural Population	51	76.11	83.02	15.41
Dependency Ratio	51	0.10	0.48	0.05
Widowed/Divorced/Separated	51	0.99	5.14	0.50
Disabled Persons	51	0.58	2.53	0.29
Agricultural Dependency	51	70.10	44.47	18.62
Poverty	51	58.45	31.76	13.30
Kutcha House	51	75.00	20.83	23.06
Illiteracy	51	23.78	32.29	5.37
Unemployed	51	20.25	63.69	3.09
No Sanitation	51	65.40	32.83	17.48
No Electricity	51	88.80	56.14	23.39
Unsafe Drinking Water	51	3.17	1.16	0.84

In the present study, the Kaiser-Meyer-Olkin (KMO) test (Kaiser, 1970) was used to measure the sampling adequacy and to detect multi-collinearity in the data, so that the appropriateness of carrying out the analysis can be identified. Multi-collinearity can also be detected by looking at the determinant of the R-matrix (|R|), which should be greater than 0.00001 (Field, 2009). Using the Bartlett's (1954) Test of Sphericity, another test of the strength of the association between variables was conducted. This test determines if the correlation matrix differs considerably from an identity matrix (Krishnan, 2010). Principal component analysis is suitable for the data, according to all tests.

6.3.3. Principal component analysis and final calculation

As the variables are not standardised, the correlation matrix was employed as an input to PCA to extract the factors or components (Krishnan, 2010). Only those factors or components with an eigenvalue (the variances extracted by the factors) greater than 1 were selected using the "eigenvalue-greater-than-one" criteria provided by Kaiser (1960). The varimax (orthogonal) rotation was opted to improve the interpretability of factors (Field, 2009).

To calculate the *Social Vulnerability Index (SVI)* for all the sub-districts of IBD, component scores are multiplied by the proportion of the variance (weights) and are summed up in SPSS platform (Krishnan 2010). This index can be expressed with the following mathematical equation:

$$\boldsymbol{SVI} = \sum \left(\frac{\boldsymbol{Fi}}{\boldsymbol{TV}}\right) * \boldsymbol{FSi}$$

Where, F_i is the percentage of variance explained by each component (i), TV is the total variance explained by all the retained components, and FSi is the component scores on each component (i).

The SVI value indicates that the higher the value, the higher is the social vulnerability, and the lower the value, the lower is the social vulnerability. Finally, the entire range has been divided into five equal categories, and each is assigned to a qualitative indicator of social vulnerability (from very low to very high). In order to visualise and analyse the results in a geographic context, choropleth maps has been prepared using QGIS software (3.4.4 "Madeira").

6.4. Results and Discussion

Based on the results of the PCA, the index value of social vulnerability has been estimated and mapped for all the sub-districts to examine the spatial dimension. The socio-economically most vulnerable sub-districts are Gosaba, Basanti, Canning-I & II, Sandeshkhali-I & II and Patharpratima. These are concentrated in the southern part of Indian Bengal Delta.

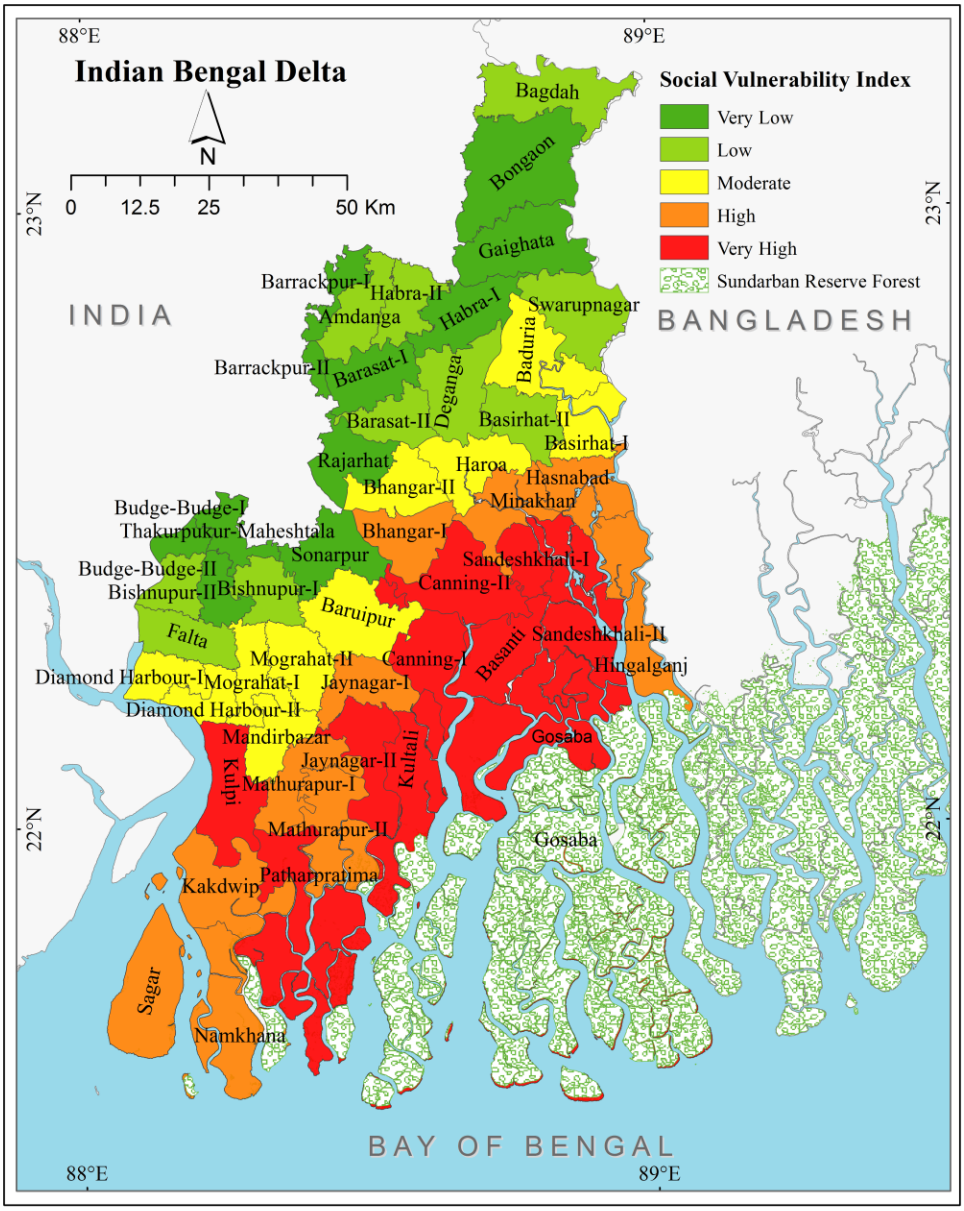


Figure 24. Sub-district level Social Vulnerability map of IBD

There is a consistent declining landward vulnerability gradient throughout the delta. Both on the eastern and western parts, the sub-districts along the coastal fringe like Gosaba, Patharpratima, Basanti, and Kultali have a very high social vulnerability, while the inland sub-districts close to the cities of Kolkata have a very low social vulnerability. People on the delta margin (Bay of Bengal) are more exposed to environmental hazards, have limited economic opportunities and less access to services such as grid electricity, tap water and road transport.

Photo 6. Kutcha house is more sensitive to climate change

Photo 7. Females are more vulnerable to climate change

Photo 8. Collecting drinking water is the most pressing challenge in IBD

The identification of socially vulnerable sub-districts and the components contributing to social vulnerability is an important element for the preparation of the location based hazard specific plans and development strategies for the vulnerable areas of IBD. This study reveals that the more socially marginalised and vulnerable communities are living on the delta margin in IBD, and that components such as strong dependency on agriculture and natural resources, high illiteracy, living in kutcha house, and no electricity, poor sanitation facility and other services make them more sensitive to hazard events and climate variability.

Apart from agriculture, marine fishing is the other important livelihood of delta margin communities. While the economic return from agriculture is becoming increasingly low from the delta margin, due mostly to higher price of labour, fertiliser and equipment costs, repeated salinity ingress, and market failures, the declining commercial marine fish catch in the northern Bay of Bengal appeared to be insufficient to alleviate the poverty of the delta population, particularly for those living in the delta margin. The profit of the capital intensive mechanised fishing is shared mostly by the trawler owners, businessmen, and exporters in the urban centres far away from the coast.

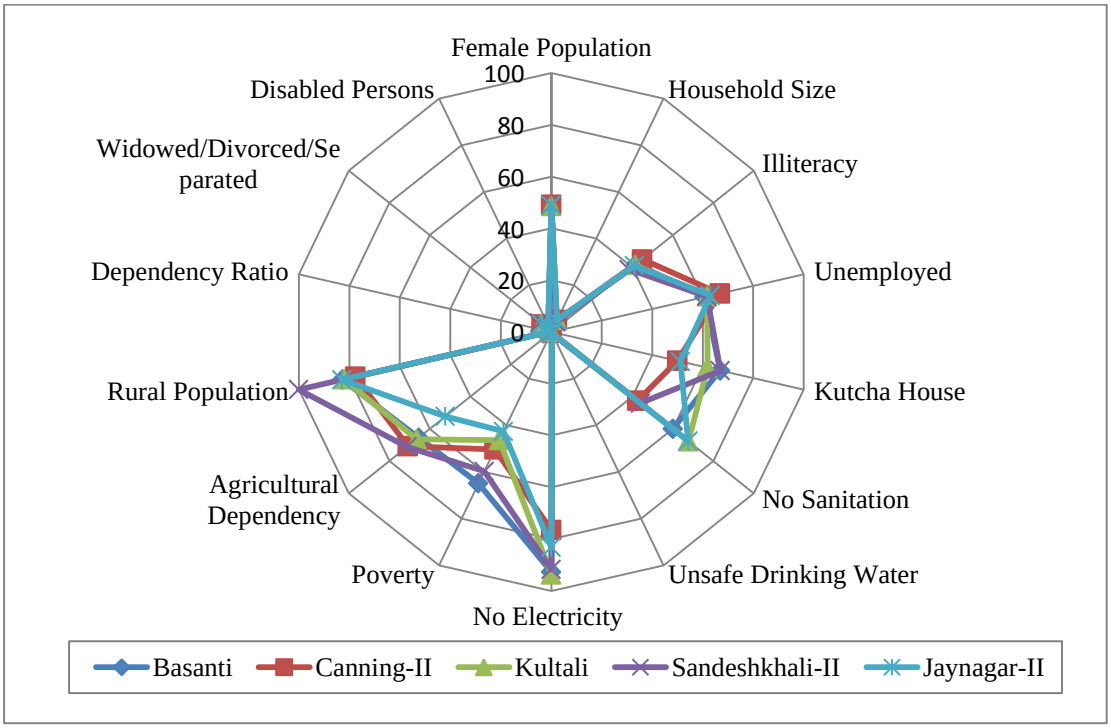


Figure 25. Variables contributing to social vulnerability in top five vulnerable sub-districts

Basanti has a large *rural population*, high incidence of *poverty*, and *non-workers* (Census 2011a; GoWB 2009). It was the last among all the 29 sub-districts (South 24 Parganas) in terms of standard of living, and the second most vulnerable sub-district in the composite vulnerability index (GoWB 2009). People in Basanti are living in chronic poverty with poor physical and socio-economic resilience and are exposed to repeated coastal flooding and storm surges (Dasgupta et al., 2016). Kultali, ranked 25th in standard of living, last in infrastructure development, and third most vulnerable sub-district in the composite vulnerability index in South 24 Parganas (GoWB, 2009). This sub-district was inundated by surge during Cyclone Aila, is exposed to frequent coastal flooding, and has an issue of arsenic contamination (Dasgupta et al., 2016). Patharpratima is also exposed to coastal flooding and erosion. G-plot and other marginal areas are highly inaccessible (Dasgupta et al., 2016). All of these factors have led to increasing poverty and inequality. These coastal sub-districts with maximum social vulnerability have the potential to be adversely affected by environmental hazards, where focussed adaptation measures are immediately required. The least vulnerable sub-districts in both the years are more urbanised ones, within Kolkata Metropolitan Area. These sub-districts that are closer and better

connected to the city and the district headquarters get greater advantages in terms of livelihood opportunities and access to services such as grid electricity and tap water.

6.5. Chapter Summary

Social vulnerability analysis indicates that socially marginalised and vulnerable communities are mainly concentrated along the seaward margin of the delta. Gosaba, Patharpratima, Basanti, and Kultali have a very high social vulnerability, while the inland sub-districts close to the cities of Kolkata have a very low social vulnerability. Variables such as strong dependency on agriculture and natural resources, high illiteracy, living in kutcha house, and no electricity, poor sanitation facility and other services make them more sensitive to hazard events and climate variability. A combination of these factors has led to increasing poverty and inequality. These coastal sub-districts with maximum social vulnerability have the potential to be adversely affected by environmental hazards, where focussed adaptation measures are immediately required. Concerted efforts for adaptation and development can systematically reduce social vulnerability, and improve the standard of living of residents in spite of climate shocks and changing climate conditions.

CHAPTER 7

Migration Hotspots

"By 2030, some countries could see the emergence of migration 'hotspots' that will experience a large outflux of migrants as a result of climate change impacts" – ***Clement et al., 2021****.*

7.1. Introduction

Migration hotspots are areas where population will decrease under scenarios that consider climate change impacts relative to a population projection that does not consider climate change impacts into account. The "fast" demographic variable, out-migration, is responsible for these declines. Understanding the relationship between climate, migration, and development requires looking at possible futures and seeing patterns of potential "hotspots" (Clement et al., 2021). This chapter provides a high-resolution analysis at the sub-district level using the indirect net migration method - vital statistics, and identifies migration hotspots where out-migration dominates over in-migration.

7.2. Net Migration

The difference between in-migration and out-migration for a certain location over time is known as net migration. A positive net migration rate (in-migration > out-migration) indicates that more people are migrating into an area than are leaving it. A negative net migration rate (in-migration < out-migration), on the other hand, indicates that more individuals are leaving an area than are entering in.

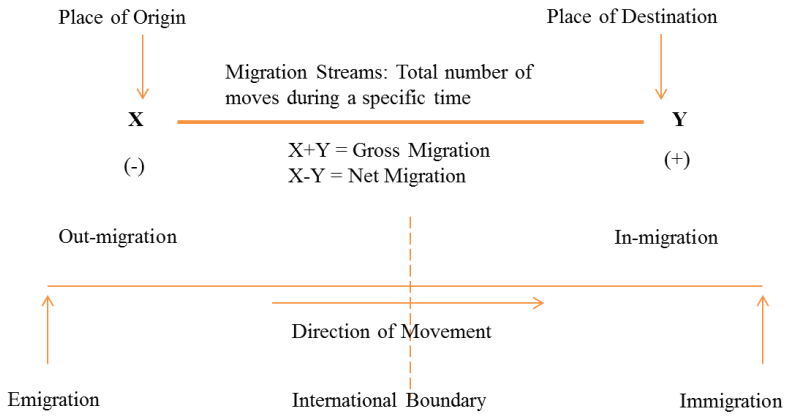


Figure 26. Framework for estimating net-migration

Two methods, namely direct and indirect methods can be used to estimate net migration. The direct method provides more reliable estimates. However, the indirect method is recommended where there is no data on place of birth and place of enumeration.

- *Estimating net migration using Direct Method:* Census questions about place of birth and place of enumeration are the basis for analyses of internal migration estimates. This provides a broad picture of the net effect of internal migration over the lifetime of the surviving population.
- *Estimating net migration using Indirect Method:* The population of component areas at two successive censuses, combined with certain other information that is often available from the censuses or from other sources, can be used to estimate net inter-censal migration whether or not direct questions on migration have been asked in the census. There are two different methods for predicting the expected population or expected change: (a) using vital data, or the Vital Statistics Method; and (b) using estimations of the chance of survival, or the Residual Method.

7.3. Data and Methodology

In absence of data on place of birth and place of enumeration at the sub-district level, the calculation of net migration was carried out using the vital statistics approach (indirect method). The Census of India, the District Statistical Handbook, and the Chief Medical Officer of Health for the North and South 24 Parganas are the sources of the data.

7.3.1. Vital Statistics Method

It is feasible to estimate the natural increase between two census dates or between any two dates for which the population is known when reliable records of births and deaths to residents of each component area of a nation are available. Once the natural growth has been subtracted from the overall population change, the estimate of net migration is derived. This equation can be expressed in the simple manner shown below:

$$\textbf{Net } M = (Pt+n)-Pt-(B-D)$$

Where for any given area

Net *M* = net migration,

Pt is the population at the earlier census,

Pt+n is the population at the later census,

B is the number of births that occurred to residents of the area during the inter-censal period,

D is the number of deaths that occurred to residents.

7.4. Results and Discussion

A sub-district level study was undertaken to understand the net migration dynamics in the delta. This brings out important spatial variation pointing out areas of out migration hotspots. In North 24 Parganas, all the sub-districts have positive net migration rates as they are closer and connected to Kolkata city and fall within the Kolkata Metropolitan Area (KMA) which results in greater advantages in terms of livelihood opportunities and access to frontline services.

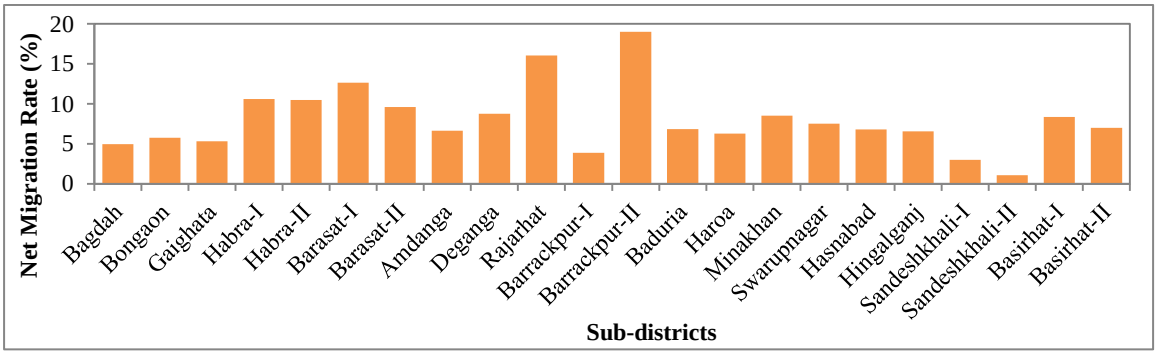


Figure 27. Net Migration Rate for sub-districts of North 24 Parganas

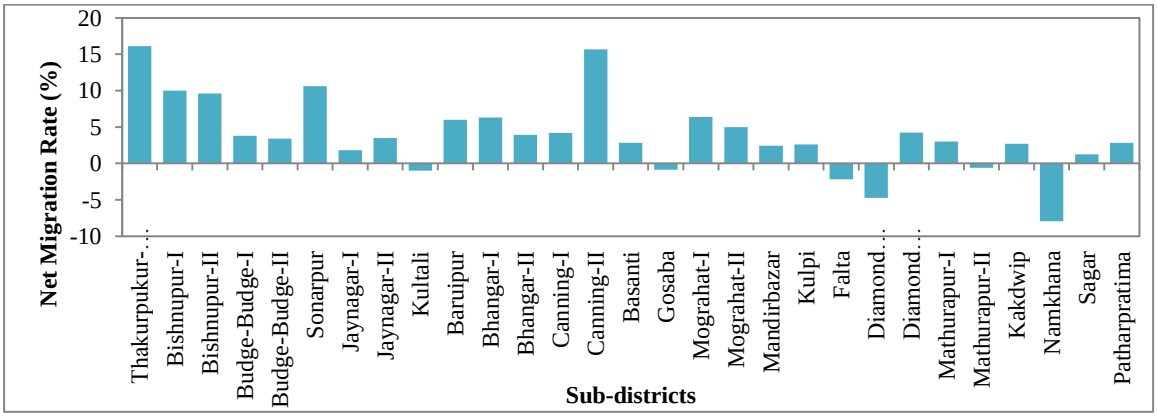


Figure 28. Net Migration Rate for sub-districts of South 24 Parganas

The coastal sub-districts Namkhana, Gosaba, Mathurapur-II and Kultali, show negative net-migration where out-migration dominates over in-migration. In few other places like Jaynagar, Patharpratima, Basanti and Sagar in the southern fringe, the in-migration marginally surpasses outmigration. On the other hand, in the sub-districts well connected with Kolkata by rail or bus routes like Canning II, Rajarhat, Thakurpur-Maheshtala, Barrackpur-II show positive net-migration (more in-migration).

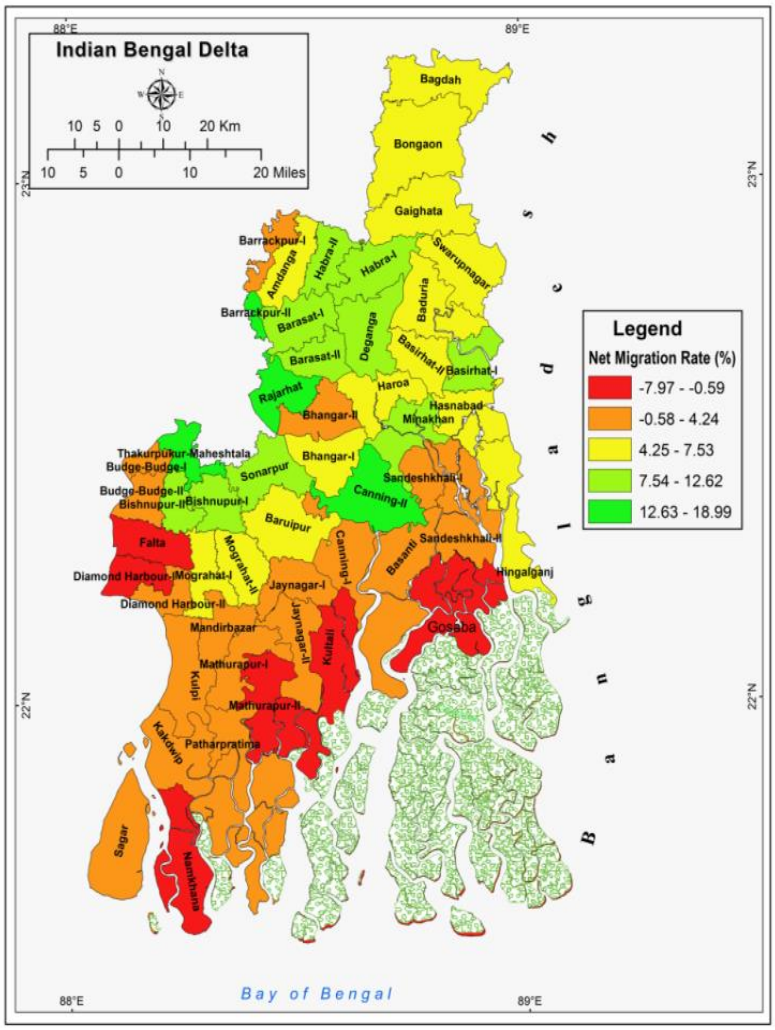


Figure 29. Net Migration Map of Indian Bengal Delta showing Migration Hotspots

According to the overlay analysis, there is a strong correlation between outmigration hotspots and places with high climatic risks and high social vulnerabilities, whereas the low hazard zones in the delta mostly show up as net receiving areas.

Table 9. Sub-districts with high risk and higher out-migration

Hotspots				
Risk/Impacts	**Vulnerability (Social)**	**Migration**	**Vulnerability & Migration**	**Risk & Migration**
Gosaba, Basanti, Sandeshkhali-II, Kultali, Patharpratima, Namkhana, Sagar	Basanti, Kultali, Canning-I & II, Sandeshkhali-I & II, Patharpratima, Gosaba	Namkhana, Gosaba, Mathurapur-II, Kultali, Sandeshkhali- II	Gosaba, Kultali, Sandeshkhali-II	Gosaba, Namkhana, Kultali, Sandeshkhali-II, Sagar, Patharpratima

Table 9 shows that the sub-districts with high risk and higher out-migration are Namkhana, Kultali, Gosaba, Sandeshkhali-II, Sagar, and Patharpratima. Similarly, sub-districts with high vulnerability and higher out-migration are Gosaba, Kultali, and Sandeshkhali- II.

Table 10. Details of sub-districts with high risk and higher out-migration

Sub-Districts	**Risk & Migration**	**Explanation**
Gosaba	Very High	Last habitation at the margin of deep forests of the Indian Sundarban; isolation and limited livelihood opportunities, poor socio-economic and institutional resilience (Dasgupta, 2016); rural population (90.36), agricultural dependency (73.6), poverty (38.03) (Census 2011a, GoWB, 2009); Gosaba had a rank of 21 amongst all the 29 sub-districts (GoWB, 2009)in terms of living standard; surrounded by earthen embankments – mostly damaged during the cyclone Aila, coastal flooding, erosion, salinization, ground water contamination are major problems, prevalence of man animal conflict (Dasgupta, 2016)
Sagar	Very High	According to Human Development Index (HDI), Sagar had a rank of 24 amongst all the 29 sub-districts whereas in Education Index, ranked 2 in South 24 Parganas (GoWB, 2009); agricultural dependency (68.18), kutcha house (37.80) (Census 2011a,b); exposed to severe coastal erosion, embankments were damaged during the cyclone Aila, Ghoramara is submerging island under Sagar, evidence of resettlement (Ghosh et al., 2014; Dasgupta, 2016)

Namkhana	Very High	According to HDI, Namkhana ranked 19 amongst all the 29 sub-districts (GoWB, 2009); agricultural dependency (57.33), kutcha house (35.80) (Census 2011a, b); Mousuni is most vulnerable island in Namkhana, exposed to severe cyclones and tidal flooding, extremely affected during cyclone Aila, area is further prone to erosion and rising salinity of the inland waters, several cases of internal displacement (Dasgupta, 2016; Samanta et al., 2017). No grid electricity connection.
Patharpratima	Very High	Agricultural dependency (73.17), without electricity (93.00), poverty (49.13) (Census 2011a,b; GoWB, 2009); Patharpratima had a rank of 26 amongst all the 29 sub-districts in standard of living and 25 in composite vulnerability index (GoWB, 2009), severely exposed to coastal flooding and erosion, G-plot and other extreme coastal areas are highly inaccessible (Dasgupta, 2016)
Kultali	Very High	Without electricity (93.60), illiteracy (41.45), non-sanitary (67.70) (Census 2011a, b); in standard of living Kultali had a rank of 25 amongst all the 29 sub-districts; it was last amongst all sub-districts in infrastructure development and 27th in composite vulnerability index (GoWB, 2009); decadal growth rate 23.33% -significantly high compared to the other coastal sub-districts, exposed to coastal flooding, southern tip of the sub-district was inundated during the cyclone Aila, reported arsenic contamination (Dasgupta, 2016)

Photo 9. Living in the disappearing island of Ghoramara (Namkhana), lost his land and house due to extreme events

This analysis brings out first line of evidence on how climatic risk compounded with high social vulnerabilities can become a major driver of permanent population movement in vulnerable deltas such as Indian Bengal delta. It also brings out important observation about rapid urban growth, supported by in- migration and land transformation, as an emerging pattern in the vulnerable deltas, in peri-urban areas of existing cities or megacities.

7.5. Chapter Summary

This analysis sheds light on important spatial variation pointing out areas of out migration hotspots. Migration hotspots are Namkhana, Gosaba, Mathurapur-II and Kultali. In few other places like Jaynagar, Patharpratima, Basanti or Sagar in the southern fringe, the in-migration marginally overshadows outmigration. Sub-districts well connected with Kolkata by rail or bus routes like Canning II, Rajarhat, Thakurpur-Maheshtala, and Barrackpur-II show positive net-migration (more in-migration).

CHAPTER 8

Paradox of Migration in Kolkata

"The fluctuating population figures of Kolkata city tell a story of several waves of historically contingent developments – partition, rural-urban distress migration due to environmental reasons like floods and famines, the administrative reshuffles of the territorial limits of the city, and the declining industrial landscape of the city" - ***Bagchi, 2015***.

8.1. Introduction

Kolkata Municipal Corporation (KMC or Kolkata city) has 4.5 million residents (Census, 2011a,b), and the urban agglomeration defined as Kolkata Metropolitan Area (KMA or Kolkata megacity) in the Vision 2025 document (KMPC, 2004), has a population of 14.1 million, placing the KMA among the 30 largest mega-cities of the world (UN, 2005; World Bank, 2011). Kolkata is the third-most populous metropolitan area and the most densely populated area in India (KMDA, 2011), and it is an important economic centre is due to the concentration of industrial complexes, financial services and commercial activities (Banerjee, 2014; Kundu, 2003). Similar to several other large cities of India, a significant proportion of the urban growth in Kolkata is associated with internal migration. In addition to internal migration, Kolkata has a rich history of international migration that dates back to 1971, when the city and its surrounding districts received a large influx of Bangladeshis as a result of the Bangladesh Liberation War (Mukherji, 2013). In spite of past large rural to urban migration flows, previous studies suggest that India is experiencing de-urbanization and suburbanization over the past four decades (Tumbe, 2016). This is reflected in Kolkata city's persistent trend of de-population over the last decade. The current decadal population growth rate is '-1.67 %' (Census, 2011c, 2001a). This rate is an all-time minimum in the history of census in India with persistent falling rates of population density (Mitra, 2015). The situation is more paradoxical when compared to Dhaka in Bangladesh, which is growing at about 4 percent per year, one of the highest rates amongst Asian cities (BBS, 2011; Chan et al., 2012; Rabbani et al., 2011).

Population and urbanization challenges in Kolkata city are compounded by vulnerability issues associated with environmental change. Kolkata, a coastal city in Ganga-Brahmaputra-Meghna (GBM) delta, is one of the world's most flood-prone coastal cities (Sachan, 2012). Previous studies on port cities with high exposure and

vulnerability to climate extremes indicate that Kolkata, along with Mumbai, Guangzhou, Shanghai, Miami, and Ho Chi Minh, are very susceptible to climatic events (Hanson et al., 2011; Nicholls et al., 2008). Several studies suggest that by 2070 Kolkata is expected to become the most vulnerable city with regard to exposed population (Basu, 2012; Nicholls et al., 2008; World Bank, 2011). Moreover, the vast majority of its economic assets are exposed to coastal flooding (Chan et al., 2012; Hanson et al., 2011; Nicholls et al., 2008; World Bank, 2011). According to Coastal City Flood Vulnerability Index (CCFVI), Kolkata ranks third out of nine most vulnerable cities in the world, largely because of the size of the cities, degree of exposure (for example, the occurrence of frequent floods) and relatively low resilience (Balica et al., 2012). The flat topography and low relief of the area intensify flooding events in Kolkata city and about 15% of the total population remain vulnerable to flooding from the Hooghly River (Ghosh, 2010). This chapter examines municipal ward and district levels net-migration and explores the reasons behind the current trend of de-population in Kolkata city.

8.2.Kolkata and migration

According to the 2011 census, Kolkata district [2] (hereafter referred to as 'Kolkata city' or 'city') has a population of 4,496,694 of which 2,356,766 (52.41%) are males and 2,139,928 (47.59%) are females. In the 2001 census, Kolkata had a population of 4,572,876 of which 2,500,040 were males and the remaining 2,072,836 were females. Population growth rate over the inter-censal period 2001-2011 is -1.67%, which is substantially lower than that of the state of West Bengal (13.84%) and the national average (17.72%) during the same period. In 2011, the population density of Kolkata city is 24,306 people per sq. km. whereas in 2001, it was 24,718 people per sq. km (Census, 2011a, b). The total population of Kolkata urban agglomeration[3] (hereafter referred to as 'Kolkata megacity' or 'megacity') is 14,112,536 (Census, 2011f). The population of Kolkata megacity was almost 50% higher than Kolkata city in 1901, but in 2011 census, it is almost 212% higher than the city (Sen, 2016). The total population of Kolkata megacity is rising considerably due to rapid efforts towards

[2, 3] Data sets are available in census with these terminologies only. Kolkata district and Kolkata urban agglomeration (KUA) have been representing Kolkata Municipal Corporation (KMC) or Kolkata city and Kolkata Metropolitan Area (KMA) or Kolkata megacity respectively.

development and urbanization. However, the city has been witnessing a sharp decline in the decadal population growth (KMDA, 2011).

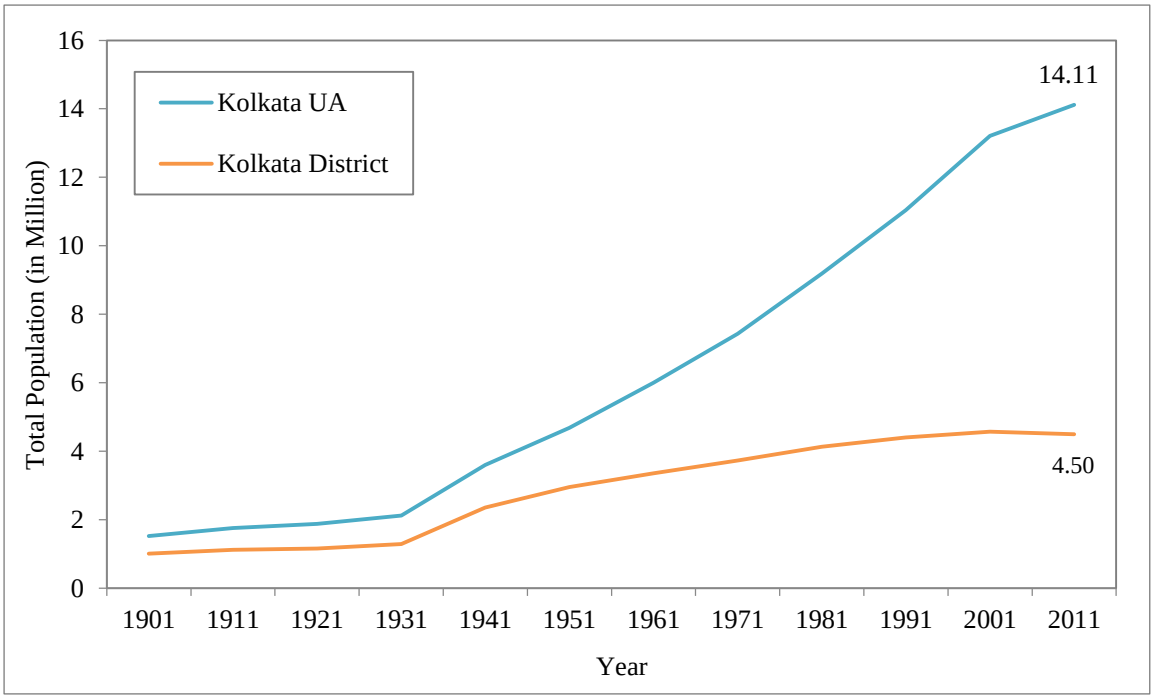


Figure 30. The decadal variation of population of Kolkata district and Kolkata urban agglomeration since 1901

Kolkata has long been a sought-after destination for migrants in Eastern India (Census 2001c; Mukherji, 2013). Such rich history of migration is associated with the political formation of India. The political status of Kolkata as the capital of the country until 1911 attracted thousands of migrants from adjoining districts of Bengal and from both neighboring states such as Bihar, Orissa, Assam and Uttar Pradesh and from distant states such as Punjab, Rajasthan and Tamil Nadu (Mukherji, 2013; UNICEF, 2014). A large influx of international migrants from Nepal and Bangladesh occurred after the partition of the state in 1947 when more than 0.25 million people arrived into the city (UNICEF, 2014). In 1948, the number increased to almost 0.6 million (ISS, 2007). According to the 2001 census, Kolkata received 0.69 million migrants which is more than 50 percent of total international migrants compared to cities of similar size during the period of 1921-2001. The refugees, coming from the eastern part of the former province of Bengal spread across West Bengal and in the greater Kolkata region (Sengupta, 2015). During 2001-11 inter-censal period, about 0.20 million people have migrated into Kolkata city, of which 49.8 percent are males and 50.2 percent females. Short distance migration (intra-district and inter-district) is more prevalent. The majority of them have come from rural areas.

Table 11. Kolkata: Internal and International Migration by the Place of Residence

Type of Migration	**Last residence**	**Duration of residence 0-9 years (2001-11)**					
		Total Migrants		Male Migrants		Female Migrants	
	Total / Rural / Urban	*City*	*Megacity*	*City*	*Megacity*	*City*	*Megacity*
Total	**Total**	**198,576**	**1,609,256**	**99,027**	**704,494**	**99,549**	**904,762**
Internal Migration	Total	189,046	1,549,353	94,237	676,199	94,809	873,154
Internal Migration	Rural	96,050	517,717	50,575	233,171	45,475	284,546
Internal Migration	Urban	76,712	950,737	35,555	407,908	41,157	542,829
Inter-district Migration	Total	88,617	685,632	38,588	296,604	50,029	389,028
Inter-district Migration	Rural	44,286	174,695	19,691	77,637	24,595	97,058
Inter-district Migration	Urban	37,072	484,965	15,705	208,062	21,367	276,903
Inter-state Migration	Total	100,429	311,817	55,649	161,924	44,780	149,893
Inter-state Migration	Rural	51,764	170,021	30,884	92,931	20,880	77,090
Inter-state Migration	Urban	39,640	119,952	19,850	57,769	19,790	62,183
International Migration – Last residence outside India	Total	9,382	59,424	4,709	28,031	4,673	31,393
International Migration – Countries in Asia beyond India	Total	8,248	54,382	4,141	25,788	4,107	28,594
International Migration – Other Countries	Total	1,134	5,042	568	2,243	566	2,799
‘All durations of residence’ includes ‘unspecified duration’.							
The place of last residence unclassifiable as ‘Rural’ or ‘Urban’ is included in ‘Total’.							

In the most recent decades, internal migration has played a crucial role in its population dynamics (Sen, 2016). The total number of migrant population steadily increased in the period 1921-1951, reaching 52% of the total population of Kolkata city in 1951. From the 1980s, a declining trend of in-migration has been observed in the city.

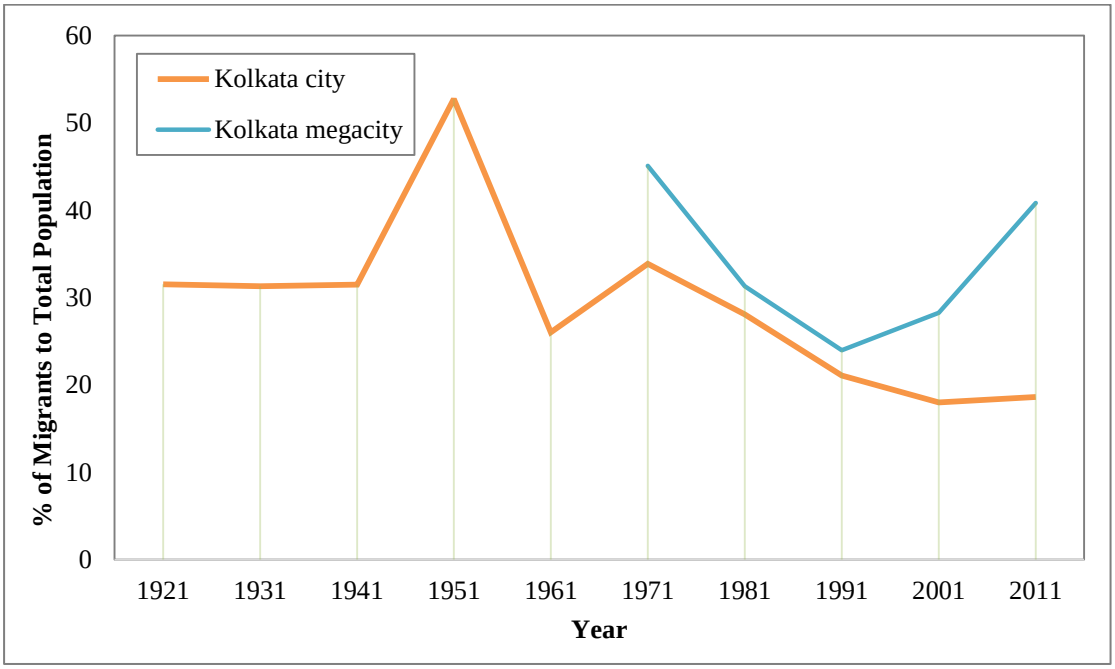


Figure 31. Percentage of migrants in Kolkata city (1921-2011) and Kolkata megacity (1971-2011)

Kolkata city has lower in-migrants than other surrounding districts compared to urban West Bengal and other parts of India due to the development of other urban centres like Asansol, Durgapur and Siliguri (Banerjee, 2016). Kolkata city has the negative net migration (more out-migration), whereas surrounding districts of Kolkata have positive net migration (more in-migration).Over the recent years, the industrial stagnation of Kolkata combined with the economic rise of other parts of the country produced an impact of migration flows. As a result Kolkata received less inter-state migrants in the recent decades (Banerjee, 2016; Kundu & Gupta, 2000; Mukherji, 2013; Roy, 1994; UNICEF, 2014).

Kolkata city experienced fast growth in peripheral areas due to the concentration of big, medium and small industrial units and employment opportunities for skilled, semi-skilled and unskilled workers in service, industrial and informal sectors (Sivaramakrishna et al., 2005; Sivaramakrishna and Maiti, 2009). The availability of infrastructure facilities especially health, education and other frontline services have also contributed to this population shift. During the period of 1991-2001, the population growth rate of Kolkata city was just 3.9%, whereas in the suburban areas it was over 30% which means that new areas have been urbanized and new urban and peri-urban interfaces emerged because of an improved transport network (Bagchi, 2015).

Table 12. Different dimensions of migration in Kolkata city

Dimensions	Impact	Description
Demography	High	High population pressure and density, urban slums
Education	Low	Major higher educational institutes at or near city.
Health	High	Poor living condition, diseases like dengue, malaria,
Economy	High	Increased cost of living, industrial stagnation
Environment	High	Air-water pollution, low green cover
Changing Climate	High	Heavy rainfall, frequent water logging, cyclone and storm surges
Development	High	Unplanned and unregulated urbanization, low capacity drainage, poor sewage facility
Social Issues	Mod	Marriage, moving with households
Policy	Low	No appropriate policy for migration
Source: Mukherji, 2013; World Bank, 2011; UNICEF, 2014; Bagchi, 2015; Banerjee, 2016; Dhar, 2014a,b; Sen, 2016		

8.3. Kolkata and vulnerability

Kolkata has a tropical wet-and-dry climate with a marked monsoon season. The annual mean temperature is 26.8 °C and the monthly mean temperatures in the range of 19-30°C (Dasgupta et al., 2012; World Bank, 2011). Kolkata normally gets most of its rainfall from the South-West Monsoon between June and September. The Annual Rainfall is about 1600 mm and the highest rainfall occurs usually in August (Dasgupta et al., 2012; Ghosh, 2010; World Bank, 2011). Almost every year, Kolkata experiences flooding events in the rainy season (Kundu, 2003). In addition to recurrent floods, Kolkata is also impacted by a various other natural hazards including cyclones, tidal upsurge, urban storms, and water-logging due to frequent and intense rainfall during the monsoon season (Dasgupta et al., 2012; Ghosh, 2010). The heavy precipitation that impacts Kolkata is a result of persistent low-pressure areas that are formed in the Bay of Bengal region. Over the last two decades, the precipitation pattern around Kolkata has been characterised by an uneven distribution of rainfall with sudden heavy precipitation events towards the end of the Monsoon period resulting in flooding in urban areas (Ghosh, 2010). High intensity rainfall events exceeding 100 mm/day have significantly increased in the last few decades exacerbating the flood risk in the various low lying areas in the city. Water logging in

the central parts of the city is a recurring hazard. A maximum water logging depth of 42 cm had been observed in the south-eastern part of the city to a minimum of 8 cm in the northern part (KMC, 2013).

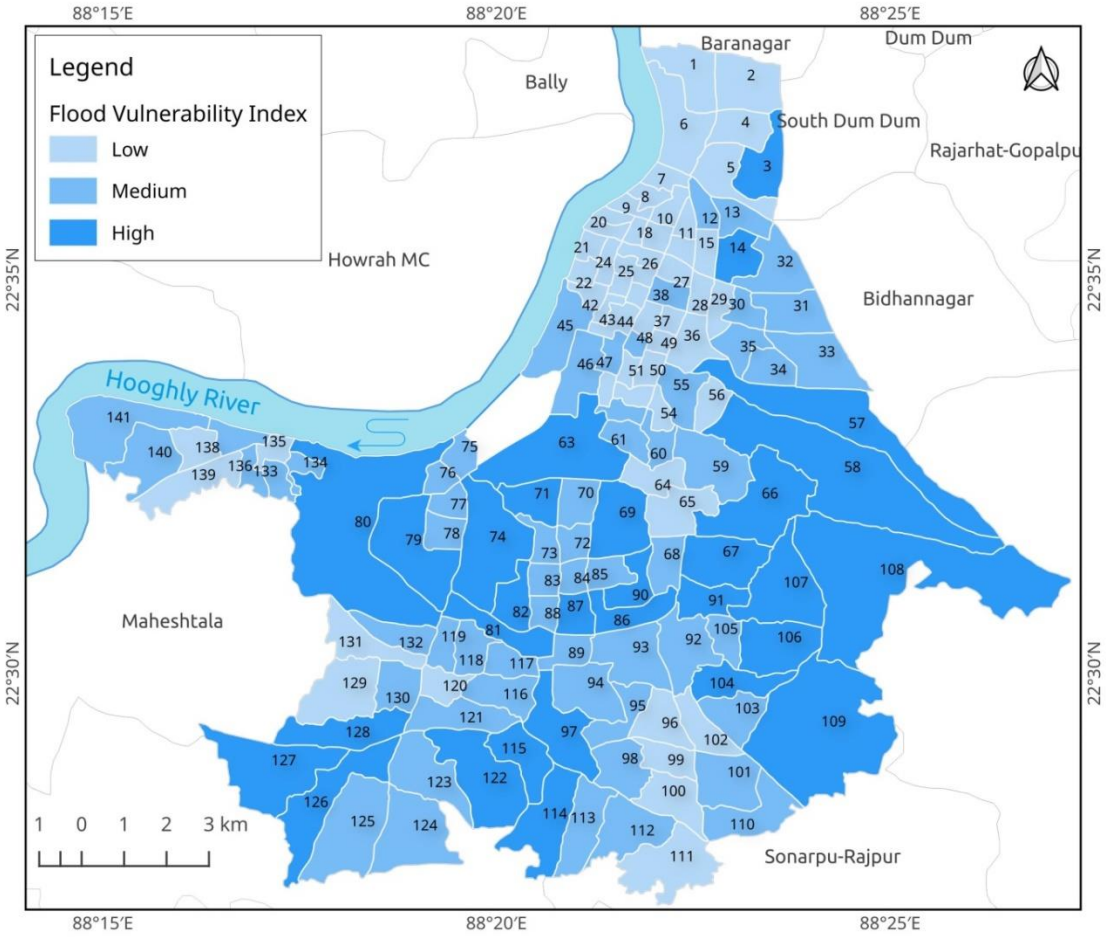


Figure 32. Flood Vulnerability map of Kolkata city (after World Bank, 2011)

The flood vulnerability study conducted by The World Bank (2011) also had similar observation. Some of the wards on the eastern portion of the city have very high vulnerability to flooding. Figure 32 divides the Kolkata city into three categories in order to build a vulnerability assessment. The most vulnerable wards based on that analysis are: 14, 57, 58, 67, 79, 80, 97, 106, 107, 108, 109, 115, 122, and 126. Vulnerability in those areas is associated with unplanned and unregulated urbanization, low drainage capacity and poor sewerage infrastructure (World Bank, 2011). Heavy and moderate storms produce high flows in Kolkata because large sections of natural channels are obstructed by pavement and other urban structures (Chakraborty, 2009). Certain areas of Kolkata (Ward 101-144) suffer from poorly planned sewerage systems and on an average 50% of sewers are silted up which results in water logging and flooding in the city (Ghosh, 2010). About 15% of the

total population of the city remains vulnerable to flooding from the Hooghly River (Ghosh, 2010). Residents living in single story houses, Kutcha houses (temporary structures made predominantly of mud), and houses in the vicinity of flyover/bridges are particularly vulnerable to flooding events (Sengupta, 2007) and are exposed to indirect health effects of such as malaria and dengue (Patz et al., 2005).

Kolkata city is often referred to as an example of urban pathology, where thousands of people are compelled to live in slums or on dirty pavements (Mukherji, 2013). The negative effects of poor housing situation are compounded by widespread unemployment and overall high levels of poverty increasing residents' vulnerability to natural disasters (Mukherji, 2013, World Bank, 2011). There are 2,011 registered, and 3,500 unregistered slums in Kolkata (Kundu, 2003). More than a third of the population of the city reside in slums (Kundu, 2003) with wards number - 58, 29, 137, 134, 65, and 135 have around 90 % of their residents living in slums (Census, 2011a,b; World Bank, 2011). High population pressure, congested urban slums and poor living conditions in most parts of the city are potential factors driving people away from the metro core (Kundu, 2003; Ghosh, 2010; World Bank, 2011; Mukherji, 2013). Another important factor which plays a vital role for the loss of population is associated with industrial pollution. The majority of factories in West Bengal are concentrated in Kolkata city (World Bank, 2011). Of the bout 40 lead factories in the city, 22 are located in the Picnic Garden area making this area lowest rated in environmental quality in the city (Ghosh, 2010).

8.4. Data and methodology

Both the direct and indirect methods have been employed to estimate net migration[4]. The two most common methods of indirect estimation are the *national growth rate method* and the *residual method*, comprising (a) vital statistics method and (b) survival ratio method (Shryock et al., 1971; Rahman, 1987). In this study, the survival ratio method has been used because of the errors in the births and deaths registers (vital statistics) in some places. This method involves the use of survivorship probabilities for the period between two censuses (UN, 1970). The basic assumptions of this method are that (i) there is no abnormal influence on mortality and (ii) the census information is accurate. Thus, estimated net migration is the difference

[4] Net migration is the difference of in-migration and out-migration of an area in a period of time.

between actual population at time "t" and the population at time "0" that survived to time "t". The information required for its computation is the following:

$P0_a$ = population in age-group "a" at time 0

Pt_{a+t} = Population in age-group "a+t" at time t

Based on Census Survival Ratio (CSR) method, net migration can be estimated in three ways:

1. Forward estimation – All migrants come at the end of the time interval (or, none of the migrants die during the period between time "0" and "t").

$$\mathbf{M1 = (Pt_{a+t} - CSR * P0_a) \ldots\ldots\ldots\ldots\ldots (1)}$$

2. Reverse estimation - All migrants come at the beginning of the time interval (or, all migrants are subjected to the pattern of mortality among the population for the entire period between time "0" and "t").

$$\mathbf{M2 = \{(Pt_{a+t} / CSR) - P0_a\} \ldots\ldots\ldots\ldots (2)}$$

3. Average estimation - All migrants come at the middle of the time interval (or, all migrants are subjected to the pattern of mortality among the population during half of the period between time "0" and "t")

$$\mathbf{M3 = \{(M1 + M2) /2\} \ldots\ldots\ldots\ldots\ldots\ldots (3)}$$

The average estimation method has been used in this paper. This method averages the estimates from both forward and reverse methods. This estimation has been done for Kolkata district (or city), Kolkata Urban Agglomeration (or megacity) and surrounding districts of Kolkata, as the required disaggregated data by age and sex is only available at district and upper levels.

For a ward level estimation of net migration, the national growth rate method has been employed as the requirement of data is minimal, viz. total population only (Rahman, 1987). It requires no vital statistics (Shryock et al., 1971).

Let P_o and P_T be the populations of a region at the beginning and the end of the inter-censal period respectively, and let P_o' and P_T' be the corresponding national populations. Then the estimated net migration rate, M_i for area i is given by

$$\mathbf{Mi = \{(P_T - P_o)/ P_o - (P_{T'} - P_{o'})/ P_{o'}\} \ldots\ldots\ldots\ldots\ldots\ldots (4)}$$

A rough indication of the extent of net migration may be obtained by comparing the rate of growth of this area with the rate of natural growth of the nation (DTRC, 1961). If the rate of regional growth greater than the national growth rate is interpreted as net

in- migration, and a regional rate less than the national rate as net out-migration (Rahman, 1987).

8.5. Results and discussion

Figure 33 shows the population growth rate in the period 1951-61. From 1961 onwards, a declining trend can be noted. According to the 2011 census, the decadal growth rate of the Kolkata city is recorded at '-1.67%' which means that it has now 76,182 lesser people than it had ten years ago. This however, does not reflect the growth of population in peri-urban areas of Kolkata city, which incidentally are included in the neighbouring districts (KMDA, 2011). Population of the neighboring districts of Kolkata city such as Howrah, North 24 Parganas and South 24 Parganas have expanded by 15% on average over the past decade, which suggests that people from the city might have moved to the suburbs as urban infrastructure expanded.

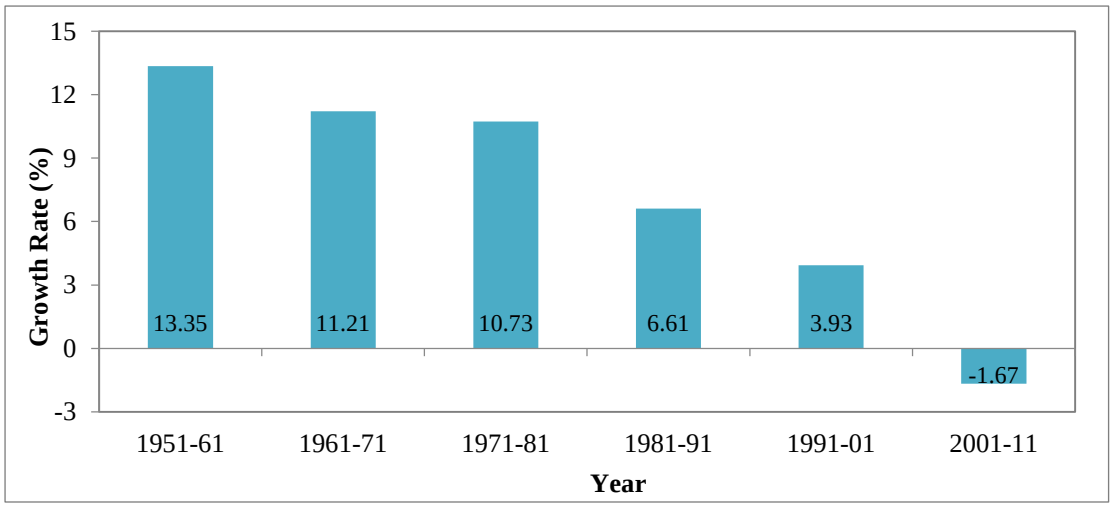


Figure 33. The population growth rate (%) of Kolkata city since 1951-61

In 2001, Kolkata city recorded a decadal growth rate of 3.93%, which suggests that the city has become super saturated (Census, 2011e, 2001a; Ghosh, 2010). During the period of 1991-2001, the percentage of municipal wards with negative growth rate was 45%, whereas for the period of 2001-2011 these figures increased to 57%. Municipal ward numbers – 12, 25, 43, 45, 46, 47, 52, 62, and 70 recorded a negative growth, whereas ward numbers - 66, 99, 106, 107, 108, 109,112, 114 and 141 displayed positive growth with the rate of more than 25%.

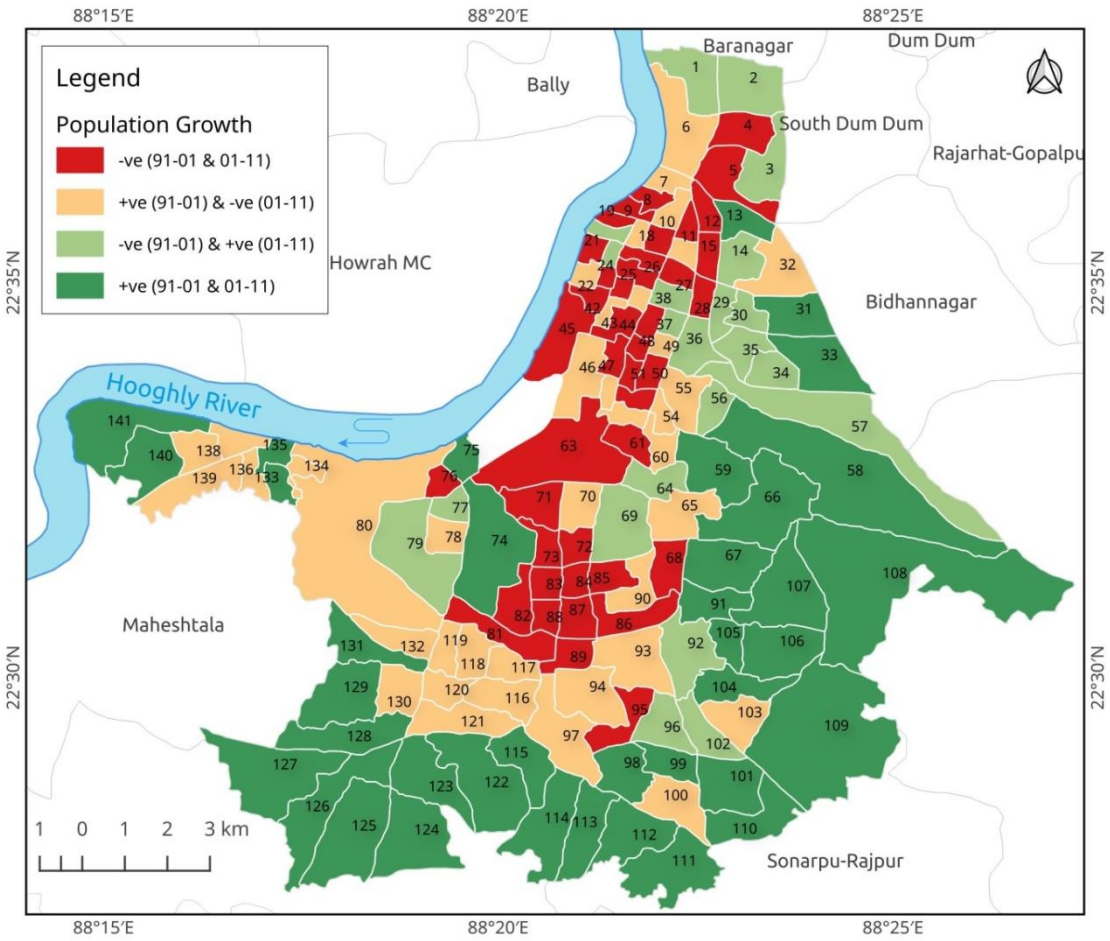
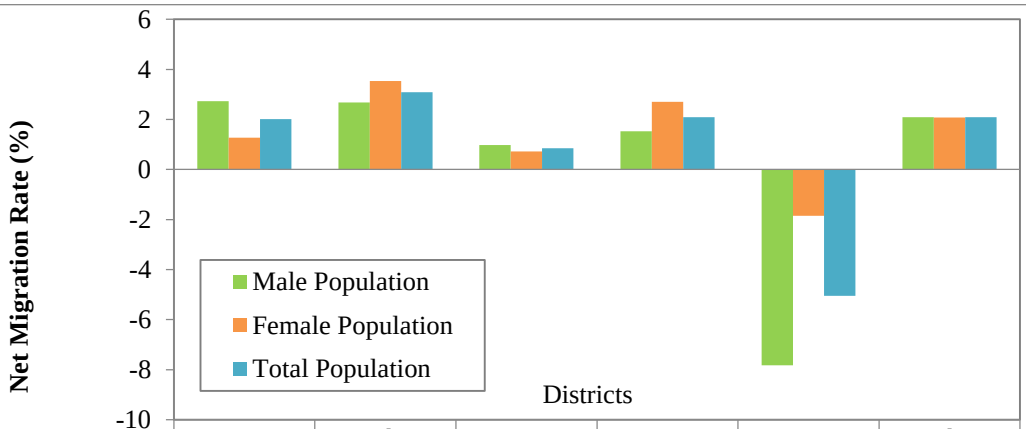


Figure 34. The population growth map of Kolkata city (1991- 2001 & 2001-2011)

Population growth across all wards for the inter-censal periods of 1991-2001 and 2001-2011 is shown in four categories in Figure 34. The 42 wards in dark black colour, which are close to Hooghly River, show a trend of de-population whereas several wards at the periphery of Kolkata city, close to North 24 Parganas and South 24 Parganas districts indicate persistent population growth over the last two decades. One of the potential explanations for this phenomenon is associated with movement of people from the central part of the city to peri-urban areas because of lower land prices and expanded public transport network.



	Nadia	North 24 Parganas	Hugli	Haora	Kolkata	South 24 Parganas
Male Population	2.73	2.68	0.97	1.52	-7.82	2.09
Female Population	1.26	3.53	0.72	2.70	-1.85	2.07
Total Population	2.02	3.09	0.85	2.09	-5.05	2.08

Figure 35. Net migration rate of Kolkata district/city and surrounding districts (2001-2011)

The estimation of net migration shows that Kolkata city is a net sender of migrants representing -5.05% of the mid-term of total population. The estimated total number of out-migrants is about -228,942 people including about -189,948 males and -38,995 females. In addition, all the surrounding districts of Kolkata city experienced positive net migration. The district of North 24 Parganas, a populated and highly urbanized district, recorded the highest (3.09%), whereas Hugli recorded the lowest net in-migration (0.85%). This result reveals that more people are leaving Kolkata city and moving to surrounding districts but within the boundary of KMA or Kolkata megacity. Negative net migration is prevalent between the age groups of 20-40 and 60-70 of the population. This is consistent with the literature that suggests that people between the age-group of 20 to 40 tend to migrate for better education and job opportunities (Bernard et al., 2014). While the young generation is migrating to other cities and abroad for employment, other adults are being pushed to the outskirts due to increasingly high real estate costs in the city. Moreover, elderly people (aged 60 to 70) are shifted to adjacent or less congested areas, especially rural parts of West Bengal after their retirement. These findings aligns with elements of micro theory of neoclassical economics which suggests that migration is associated with the decision made by individual actors to maximise their income according to their skills and qualifications (Massey et al., 1993).

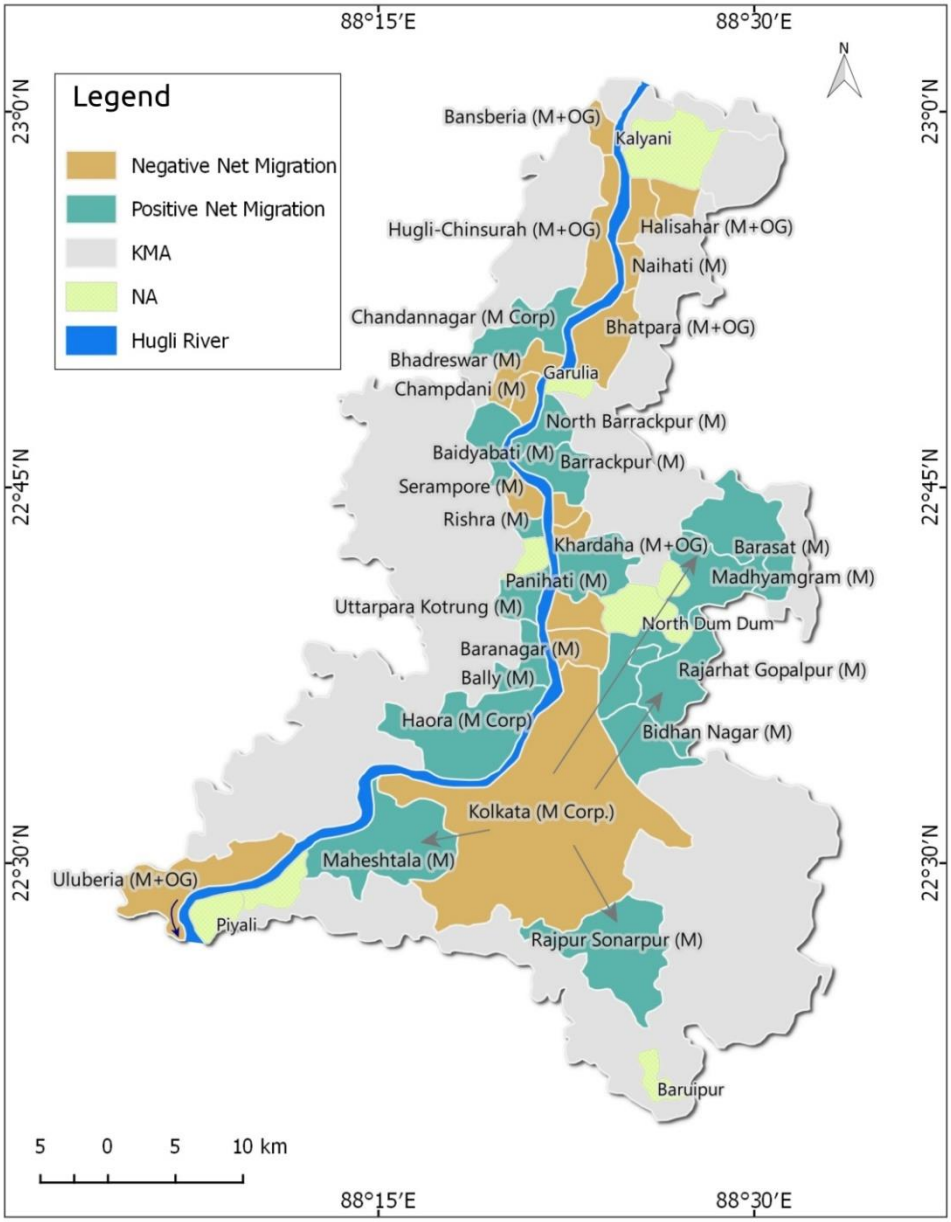


Figure 36. Net migration of Municipal areas of KMA/megacity using Survival Ratio Method (2001-11)

The net migration map of municipal areas of KMA shows a negative net migration in Kolkata city and a positive net migration in all the surrounding municipalities of KMA. It is clear that the immediately surrounding municipal areas of Kolkata city have been growing at higher rates. This observation supports the mobility transition model by Zelinsky (1971) where rural-urban migration is replaced by urban-urban moves, a characteristic of advanced societies characterized in the fourth stage of the mobility transition model.

The majority of the urban-urban moves are associated with people permanently relocating to different areas of the eastern part of KMA because the Hooghly River acts as a major barrier of migration flow in the western part. Similarly, movements of urban-urban nature are happening from the central parts of Kolkata city to adjoining districts of North 24 Parganas (specific areas of Barasat, Madhyamgram, and Rajarhat) and South 24 Parganas (specific areas of Sonarpur, Joka, Baruipur). An explanation of these movements is associated with the 'Push-Pull Hypothesis'(Lee, 1966) whereby exposure to environmental hazards, high population density and poor living conditions combine to act as push factors for the people reside in Kolkata city. Pull factors towards peri-urban areas are associated with lower land prices, availability of space and accommodation, lower costs of living, development of different modes of commuting and communication, availability of infrastructure facilities and better environmental quality.

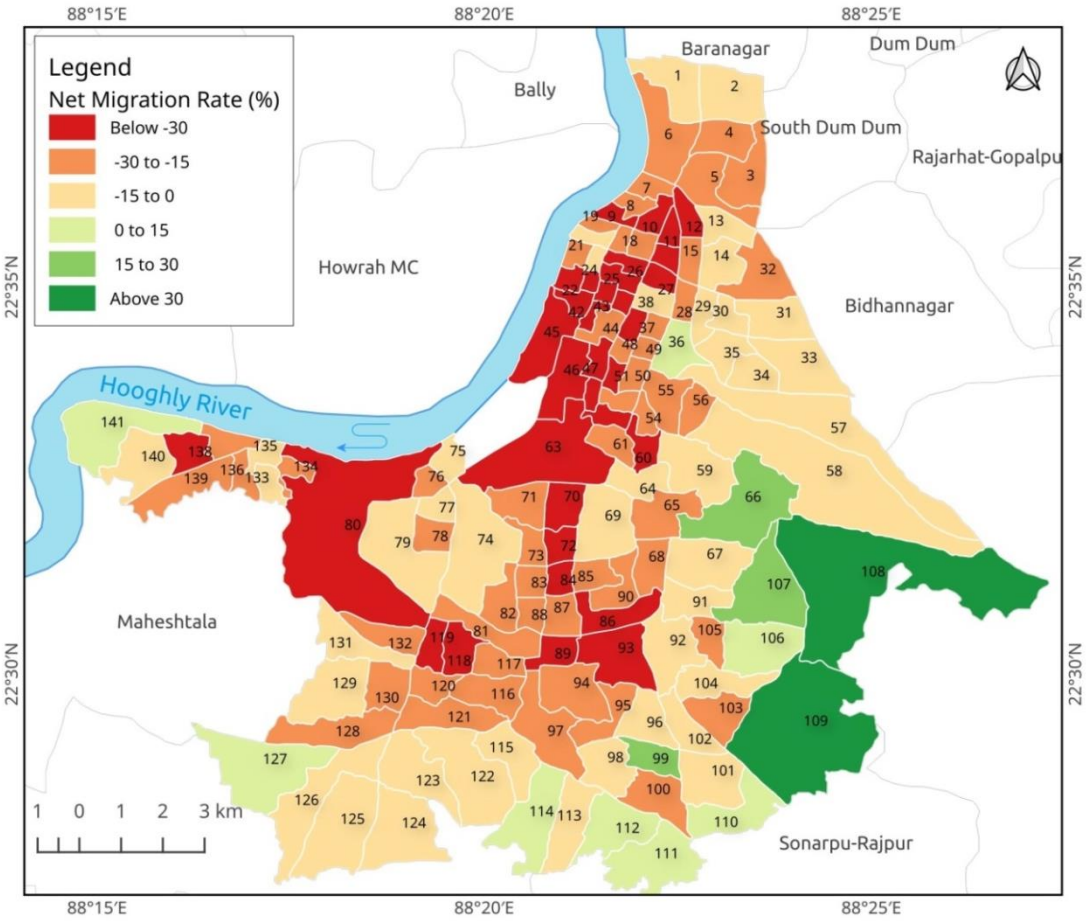


Figure 37. Net migration of Kolkata city applying National Growth Rate Method (2001-11)

Negative net migration has been observed in almost all wards of Kolkata city. Only 13 wards mostly towards the outskirts of the city have a positive net migration. This implies that the majority of the wards are net senders of migrants. This situation may probably explain the slight reduction in the population density with a falling rate from 24,718 per square kilometers in 2001 to 24,306 per square kilometers in 2011 (Census, 2011c, 2001a). People are moving from densely to sparsely populated areas within the KMA which have severe environmental constraints. It is important to note that in addition to all short distance movements identified in this study, there is also movement from Kolkata city to other states within India or to international destinations. These movements are predominantly driven by better employment opportunities and increased quality of life.

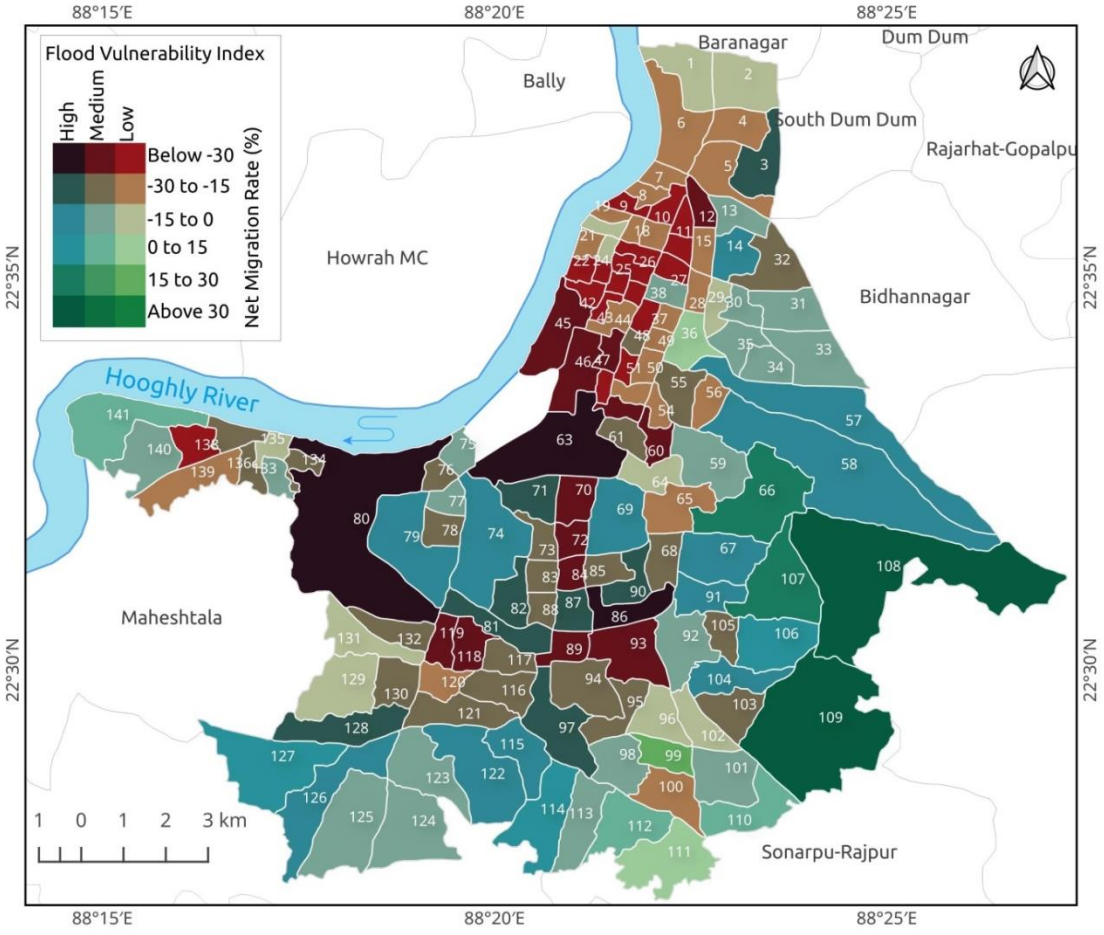


Figure 38. Migration status of vulnerable wards in Kolkata city

The nature of migration is changing significantly in Kolkata and our analysis suggests that exposure to environmental hazards is a significant contributing factor. Almost all the high vulnerable wards are showing out-migration with different magnitude. Wards - 63, 86, 80 have the highest net out migration rate i.e. more than -30% covering parts

of vulnerable locations adjacent to Hooghly River such as Park Street, Ballygunge and Kidderpore. Localities in the eastern and south-eastern parts of the city, in spite of being vulnerable to flooding and water-logging, indicate in-migration due to higher availability of land and accommodation and lower costs of living.

8.6. Chapter Summary

Migration is one of the main components of population dynamics of Kolkata. Based on available data and indirect methods of estimation of net migration, an overall in-migration pattern to Kolkata megacity has been analysed. On the other hand, out-migration from Kolkata city is a contemporary trend associated with infrastructure, economic and environmental factors. Consistent with observed patterns in other large urban centres in developing countries, the inflow of migrants has a direct relation with the size of cities because large urban areas tend to concentrate the majority of income opportunities, frontline services and infrastructure improvements. However, Kolkata city has been losing population to surrounding municipal areas due to a combination of economic progress and infrastructure developments implemented in the adjoining peri-urban areas of the city. Labour mobility in Kolkata is high but is mostly male-dominated, semi-permanent, and remittance-based in nature leading to masculine urbanization with important implications for urban growth and urbanization. Climatic events, however, such as increased frequency of heavy rainfall, floods, cyclones, and other forms of environmental degradation can bring about both direct and indirect impacts on Kolkata, with the potential to increase existing out-migration rates from the city. The paradox of migration in Kolkata, therefore, is reflected by a declining population of the city but a sharp increase in population of its megacity resulting in one of the major urban centres of the 21st century.

CHAPTER 9

Migration Patterns in the Study Area

"Due to declining agricultural incomes and rural households' inability to survive solely on farming, "Migrarian" livelihoods, which combine agriculture with migration, are essential to India's economy" - ***Sharma et al., 2014***.

9.1. Introduction

Migration is a significant livelihood strategy across rural India (Singh, 2019). Internal migrants contribute 10% to the country's GDP (UNESCO, 2019). According to the Economic Survey (2016–17), at least 9 million individuals moved within the country between 2011 and 2016, the majority of them in search of employment. Delhi is the most popular destination for migrants, followed by Mumbai; in recent years, the southern states have attracted an increasing number of migrants. The majority of them depart from Uttar Pradesh, Bihar, Madhya Pradesh, West Bengal, and Assam, frequently travelling more than 3,000 kilometers to Kerala, which is far away.

The estimation of future population redistribution would be made easier with a proper understanding of the patterns of migration (Rees et al., 2017). This chapter provides the proper understanding of the patterns of migration in the study area by linking sending and receiving areas.

9.2. Migration in India

Several studies show that interstate movement in India is not very common, but the fact that nearly one-third of the country's population is counted outside of their place of birth highlights the significance of migration as a key demographic phenomenon in India. According to 2011 census, the data on migration by place of last residence in India, indicates that there are 454 million migrants overall in India, accounting for all durations of residence. Of these, 141 million (31.06%) are male migrants, and 313 million (68.94%) are female migrants. This number was 314.5 million in 2001 census, increased by 44.36% during 2001 to 2011. About 161 million (or 35.6%) documented as migrants, had migrated over the past 10 years. Marriage is social reason for migration, cited as the pre-dominant reason among females. Over the past 10 years, about 58.68 million migrants (56.07%) out of total 104.66 million female migrants reported this reason. The most important reason for male migration is related to work.

More than 15 million out of 56.76 million male migrants (27.28%) moved for better employment opportunities in India during last decade. Education is also another important reason for both male and female migration in different parts of India. The data also shows that 15 million male migrants and 20 million female migrants moved with household in the last decade. The majority of this movement occurs from rural to urban areas as well as from smaller towns and cities to larger metropolitan areas in India.

Table 13. The patterns of migration in India

Migrants (in Million)		Total	Male	Female
All durations of residence		453.64	140.96	312.68
Duration of residence 0-9 years		161.42	56.76	104.66
Reasons	Work/Employment	18.69	15.48	3.21
	Business	1.31	0.96	0.36
	Education	5.15	3.00	2.15
	Marriage	60.18	1.49	58.68
	Moved after birth	20.93	10.99	9.95
	Moved with Household	35.54	15.25	20.29
	Others	19.62	9.59	10.03
Patterns	Rural - Rural	69.10	15.70	53.40
	Urban - Rural	11.46	4.71	6.74
	Rural - Urban	32.16	15.03	17.12
	Urban - Urban	32.95	15.05	17.90
Note: All durations of residence includes 'unspecified duration'.				
Data Source: D-5, Migrants by place of last residence, age, sex, reason for migration and duration of residence, Census of India, 2011				

Uttar Pradesh, Bihar, Rajasthan, Madhya Pradesh, Andhra Pradesh, Chhattisgarh, Jharkhand, Orissa, Uttarakhand, and Tamil Nadu are the top source states in India, whereas Delhi, Maharashtra, Gujarat, Haryana, Punjab, and Karnataka are the top destination states.

9.3 Data and Methodology:

While net migration analysis estimates permanent migration, to understand temporary or seasonal forms of migration, drivers and benefits, both quantitative and qualitative data were collected from sending and receiving areas in IBD. In order to gather primary data, a mixed-method approach was adopted, combining quantitative methods focusing on household surveys with qualitative methods such as focus group

discussions and key informant interviews with stakeholders. Supplementary information was based on a review of existing literature.

9.3.1. Sending Area Survey

Applying the two-stage cluster sampling approach, total 50 locations in the Indian Bengal Delta were identified for the sending area survey under the DECCMA project (2014-19). The study area was divided into five multi-hazard zones (very low, low, medium, high, and very high) in the first stage using a village-level multi-hazard map (flood, cyclone, erosion). In the second round of sampling, each cluster of households in the study area was assigned one of five hazard categories. A number of locations were selected proportional to the total number of clusters (probability proportional to size) in each multi-hazard zone. Based on demographic and migration characteristics, a total 10,000 households (200 households in each location) were listed and from that, 1500 households (30 households in each location) were chosen proportional to the number of migrant households and non-migrant households.

Photo 10. Field survey in IBD

9.3.2. Receiving Area Survey

A total of 512 delta migrants were interviewed during the receiving area survey in Sonarpur (South 24 Parganas) and Dum Dum (North 24 Parganas). The migrants from

most vulnerable places of IBD are mostly found in Sonarpur. DECCMA receiving area survey gathered data on length of residence, subjective and material wellbeing, aspiration, future intention of the migrants in destination areas. Migrants were also asked to draw comparisons between place of origin and current location.

A detailed questionnaire was prepared covering various aspects related to climate change, vulnerability and migration. The questionnaire was translated into local language to ensure that the respondents understand the questions and can provide accurate and appropriate responses. The questionnaire was implemented for the survey using computer-assisted personal interviewing (CAPI) tools. This helped in executing the survey using mobiles and tablets and made it possible to capture high quality data/information with GPS location of households which form individual survey units. The survey questionnaire was tested through pilot surveys in order to assess and validate key factors pertinent to the survey such as the adequacy of the questionnaire, suitability of the survey frame, operational procedures, and more.

After data collection, the detailed analysis was carried out to understand the deterministic factors of household livelihood vulnerabilities. Several tables like socio-economic characteristics of households, patterns and drivers of migration were generated using SPSS software.

9.4. Results and Discussion

A total 1315 households were interviewed during the DECCMA sending area survey. The participation rate was 88%. A brief profile of the households surveyed is presented in Table 14.

Table 14. Socio-economic characteristics of respondents in IBD

Characteristics		**Responses (%)**
Household Size	*1-3*	37.8
	4-6	54.8
	≥ 7	7.4
	Mean Household Size	4.1
Age (Years)	*≤ 40*	40.2
	41 - 60	45.0
	> 60	14.8
	Mean Age	45.8
Marital	*Never married*	1.9

Status	*Currently married*	88.2
	Widowed	8.9
	Divorced/ Abandoned / Separated	1.1
Caste	*General*	45.3
	Scheduled Caste (SC)	45.0
	Scheduled Tribe (ST)	1.8
	Other backward caste (OBC)	7.9
Formal Education	*No Education*	25.0
	Primary Education	38.7
	Secondary Education	29.8
	Higher Education	6.5
Main Livelihood	*Farmer & Fishermen*	19.7
	Daily Labour	17.1
	Regular Salaried Employee	7.4
	Small Business Owner	14.8
	Construction & Factory Workers	22.1
	Unpaid Home Carer	8.8
	Retired	7.0
	Others	3.1
Monthly Income (Indian Rupees)	*No Income*	13.6
	≤ 3000	22.5
	3001 - 6000	43.9
	> 6000	20.0
	Mean Monthly Income	4756.7
Farm Size (Hectares)	*0*	63.8
	0.01 - 1.00	35.3
	1.00+	0.8
Total Observations		**1315 (100.0)**

Most of the respondents were in the age group of 41 – 60 years. Almost 88% of the respondents were married, and 9% of the respondents were widowed. 45% of the total respondents belonged to the scheduled caste (SC) category in IBD. The percentage of STs was negligible (1.8%) in the study area. The education level of male respondents is much higher than the female. It is observed that respondents with primary education (38.7%) are more than those with no and secondary education. The mean monthly income of the household head is Rs. 4756.7 (1 Indian Rupees = 0.012 US Dollar). More than 13 percent of the heads have no income and 23 percent have less than Rs. 3000 per month, and this exacerbates the existing economic vulnerability in IBD. Respondents are mostly construction and factory workers (22.1%) and farmers and fishermen (19.7%), whereas female respondents are mainly unpaid home carers (8.8%). The study shows that majority of the respondents have small houses with less

than 50 square meters area, and almost 64 percent of total respondents have no farm land.

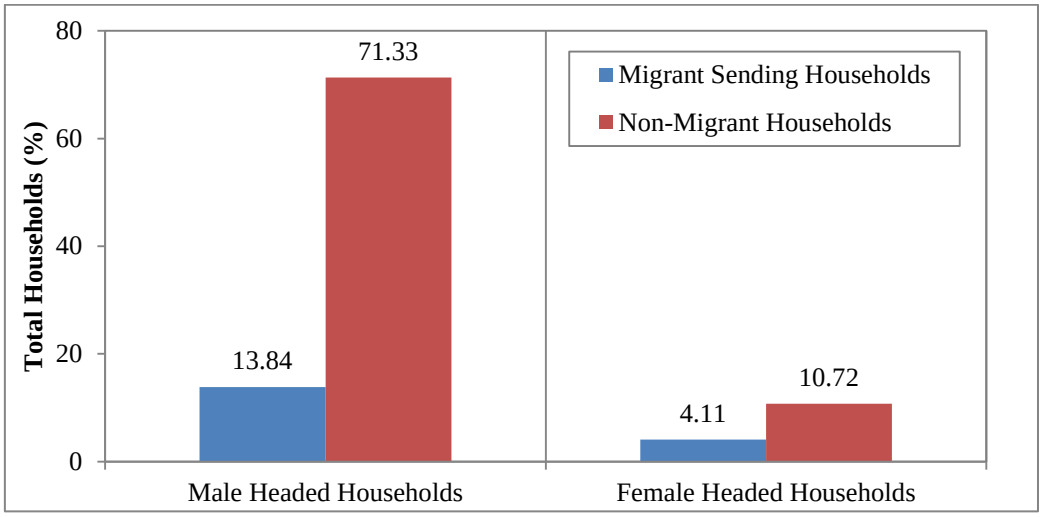


Figure 39. Migrant and Non-Migrant Households

9.4.1. What are the prevalent types of migration?

A total 1315 households were surveyed during sending area survey in IBD, of which 18% have sent migrants. The number of migrant in IBD is 423, of which 47% are returned migrants. Seasonal migration is most prevalent. Depending on the seasons, people migrate once or twice, from rural to urban areas. So the flow is mainly towards urban areas. The percentage of migrant sending households is high in case of female headed households. This indicates that there is a positive correlation between the migrant sending households and female headed households as mostly men migrate, leaving behind women, taking additional responsibilities of households as household head.

Table 15. Migration patterns in IBD

Responses			**%**
Type		Seasonal migration	56.83
Scale		Internal migration	96.02
Destinations	*State*	West Bengal, Maharashtra, Tamil Nadu, Kerala	76.26
	District	Kolkata, North 24 Parganas, South 24 Parganas	85.59
	City	Dum Dum (M), Madhyamgram (M), North Dum Dum (M)	41.46

Migrant's Characteristics	*Sex*	Male	83.04
	Age	21- 40	57.59
	Marital Status	Currently Married	55.36
	Education	Secondary	44.86
	Livelihood	Construction Worker, Factory Worker, Regular Salaried Employee	60.82
	Monthly Income	Rs. 5000 - 10000	59.38
Reasons	*Economic*	Seeking employment	61.67
	Social	Family obligations / problems	12.33
		Seeking education	10.33
	Environmental	Environmental degradation/ Extreme event	6.67
Remittances		Send remittances (money, goods)	66.08
	Type	Money	57.71
	Frequency	Monthly	44.00
	Amount	Rs. 5000 and Below	78.67
Uses of Remittances	*Rank-1*	Daily consumption (food, bills)	35.17
	Rank-2	Health care	24.48
	Rank-3	Education	14.14

9.4.2. Who are migrating?

Demographic factors are playing major role in migration decision making. Compared to other age groups, the male migration rate is higher in the 21–40 age group. The choice to move in the case of female migrants is influenced by the household. Typically, they move with their family. It can be said that male migration is the prevalent trend but recently the number of female migrants have also increased but to shorter distances like the peri-urban areas of Kolkata where they are employed as maid or domestic helpers or working in household industry.

From the survey data analysis, it is found that people who are falling in lower strata of the caste system (scheduled caste or SC) migrate most compared to other caste categories. Male migrants with primary and secondary education migrate more than those without education or with higher education, which supports our current understanding. Interestingly, female migrants with secondary and higher education mostly move with their family members.

9.4.3. Where are they migrating to?

Men and women both migrate seasonally, mainly to Kolkata (West Bengal), the nearest metropolitan area. The other Indian states attracting migrants from IBD include Gujarat, Tamil Nadu, Kerala, and Maharashtra.

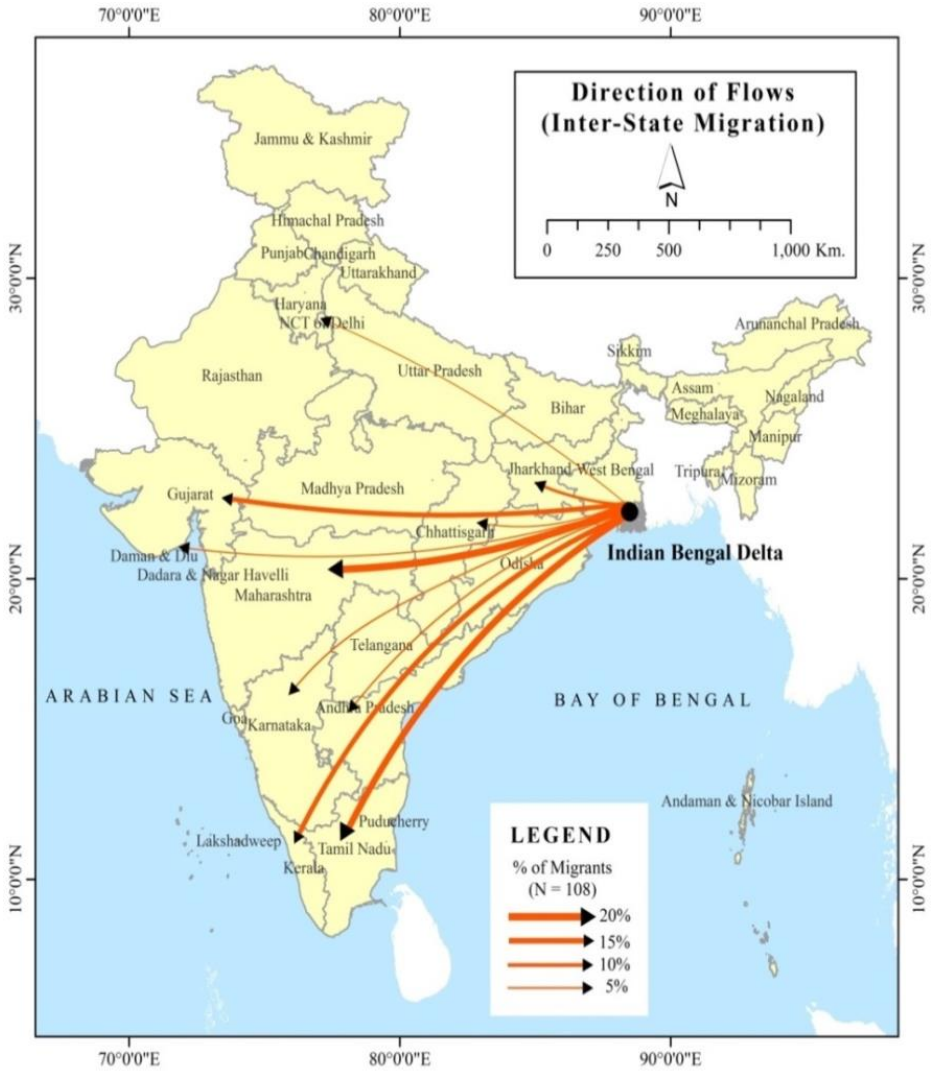


Figure 40. Inter-State Migration from IBD

9.4.4. Why are they migrating?

Nearly 62 percent of respondents stated that economic factors play a major role in migration, with the majority of migrant populations moving in search of better employment prospects. Family obligations (12.3%) are the second most often cited reason for IBD. Only 10% of those respondents said the migrant went to finish their education or acquire new skills. Females mostly migrate to join their partner or for marriage. It is found that employment opportunity is the main reason for preferring

the above mentioned destinations. A small percentage of the respondents (3.0%) in IBD cited directly that an environmental stressor was a major factor in their choice to move.

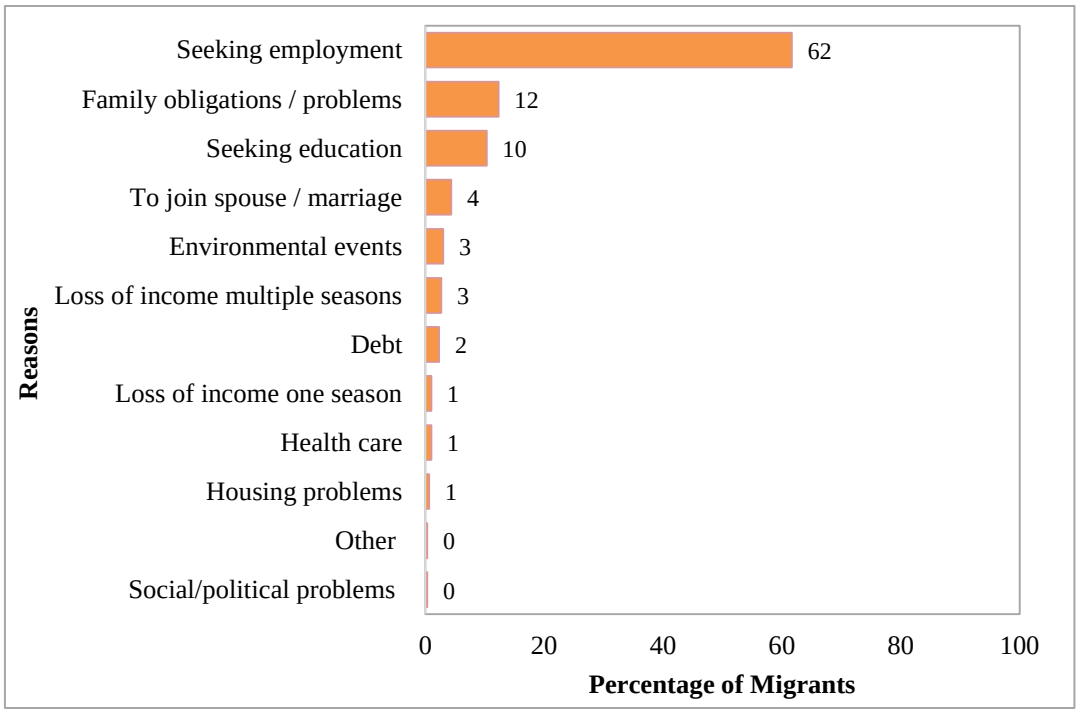


Figure 41. Reasons for migration in IBD

9.4.5. How are they migrating?

Friends who have already migrated temporarily to these areas encourage employment chances the most. The involvement of middlemen in arranging for employment and housing is less common, as internal migration is predominant in IBD.

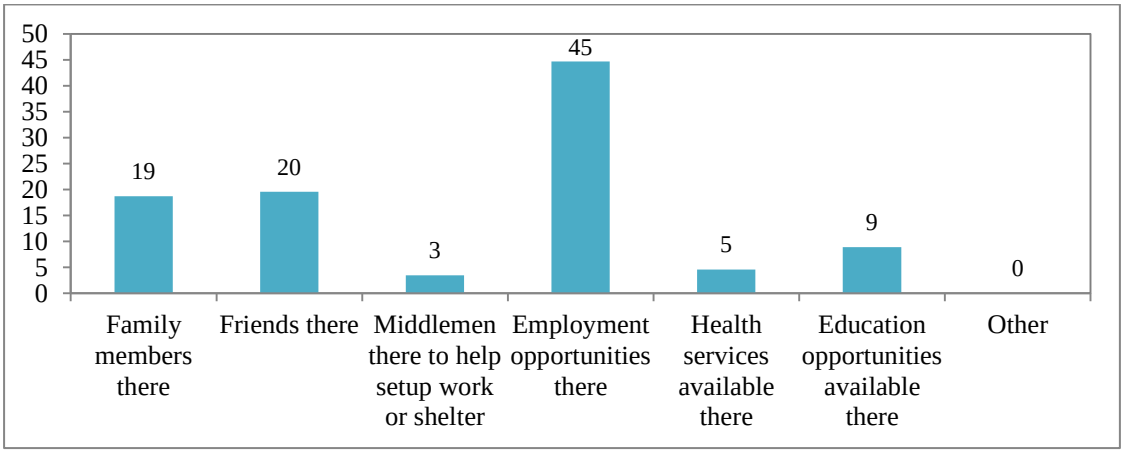


Figure 42. Reasons for preferring particular destination

"Most of the people who are migrating are doing so with the hope of seeing some economic improvement. The economic improvement is definitely taking place. So migration is bringing economic success. But the pitfalls of this migration include diseases (mostly fever and tuberculosis as reported by the males) contracted when they are going to Chennai or Andamans. At times the sole earning member of the family is getting affected and dying, as a result of which the entire family faces hardships. Also when the migrants are getting exploited at the hands of the middlemen, the migration is hardly as success." **- FGD, Satjelia, Gosaba, IBD.**

9.4.6. What are the outcomes of migration?

Migration increases the social and economic statuses of migrants and migrant sending households. It improves economic and food security in origin. It gives better work and education opportunities for children. It infuses the community with new concepts and methods. The adverse effect of migration is that the village does not have enough young people.

Table 16. Impacts of Migration on Migrants and Household and Village

Characteristics	Responses (%)
Dimensions at Individual Level (Impacts of Migration on Migrants)	
Social status (+)	61.44
Education and work opportunities (+)	83.27
Economic security (+)	73.00
Get sick or be in danger (-)	68.82
Respected in their destination (+)	41.44
Don't feel like they belong there (-)	52.24
Better opportunities for children (+)	74.75
Dimensions at Collective Level (Impacts of Migration on Household and Village)	
Social status (+)	59.54
Financially secure (+)	76.81
Difficult to maintain livelihood & responsibility (-)	75.74
Brings new ideas and practices (+)	76.96
Less young people in the village (-)	73.61

9.4.7. Is migration helpful /successful?

More than 60 percent of all respondents said that migration is beneficial for migrants and somewhat successful for family members outside household and friends. Every month or every two to three months, they get remittances. Remittances have raised

their level of living by enabling them to pay for necessities like food and utilities, as well as for their healthcare and children's education. When asked about the overall outcome of migration, the majority of survey respondents indicated that relocating elsewhere was helpful.

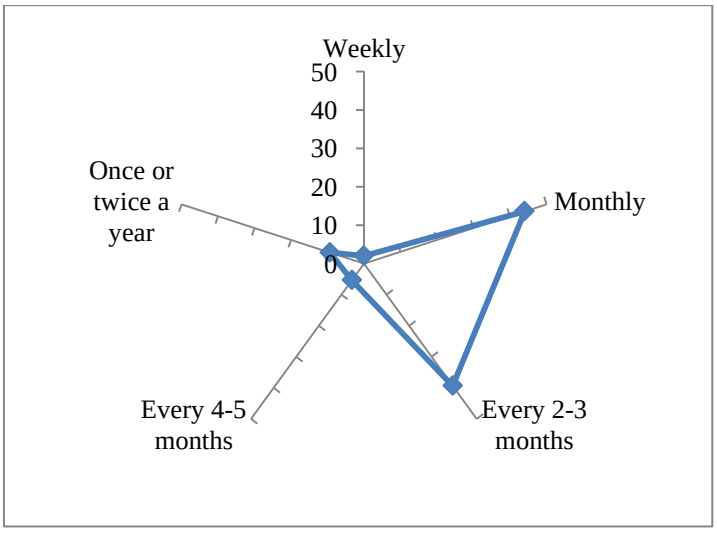


Figure 43. Frequency of remittances in IBD

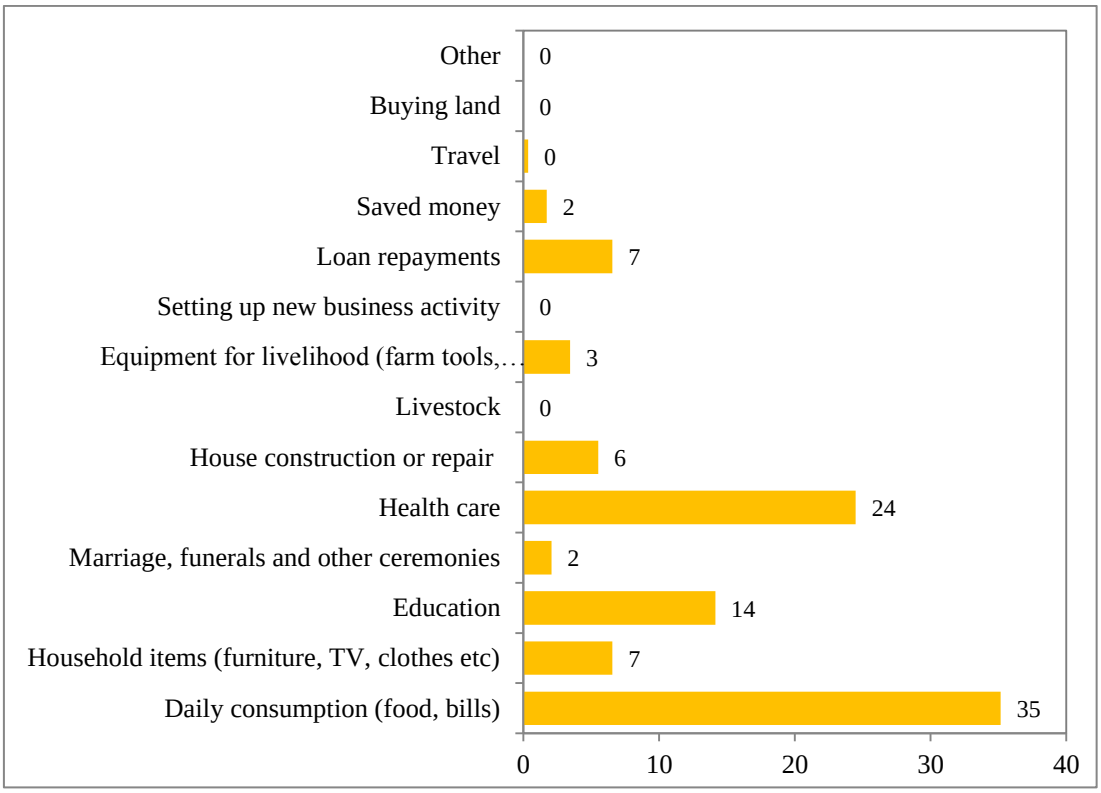


Figure 44. Use of remittances in IBD

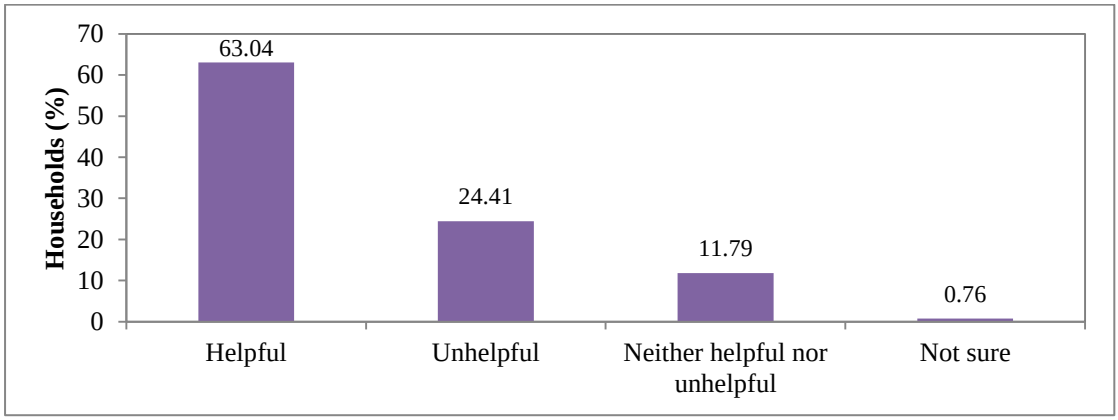


Figure 45. Migration is Helpful or Unhelpful

9.4.8. Are migrants happy in current place?

Receiving survey data shows that migrants' access to different utilities and public services such as tap water, electricity, heath services, school/higher education etc. are improved in current place compare to place of origin. It is also observed that migrants are happy in life in current location, whereas they were unhappy in place of origin. This may be due to limited economic opportunities and services and/or increasing vulnerabilities in place of origin.

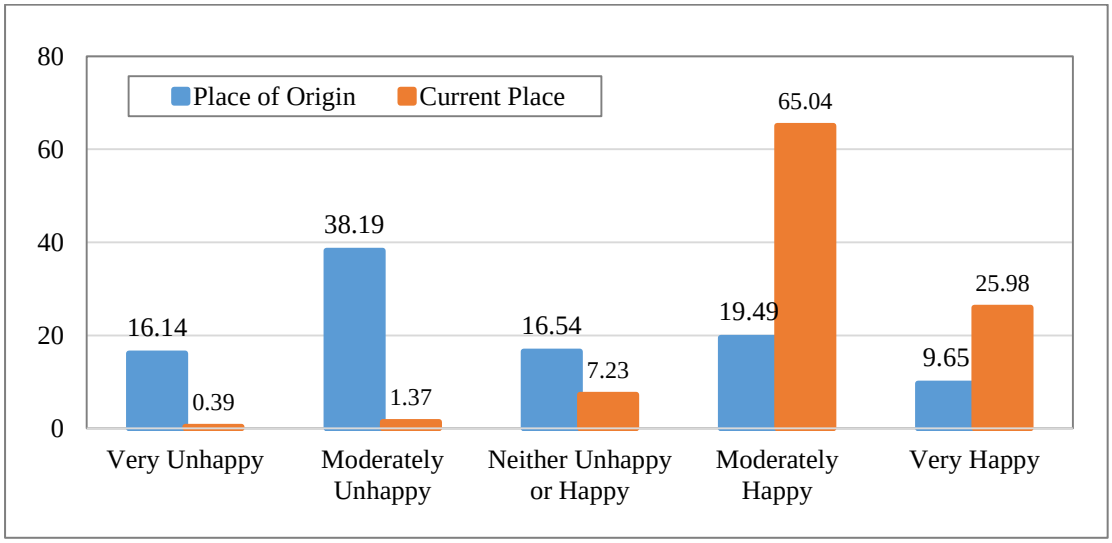


Figure 46. Subjective wellbeing in place of origin and current place

9.4.9. Have migrants met their aspirations in current place?

Most of the migrants before they moved to current location had the aspirations to improve their family's prospect, obtain stable living conditions and permanently settle in the city they currently reside. Only 16 percent of total migrants mentioned that they

had aspiration to make sufficient money to remit money or goods to household in the place of origin. It is clear from Figure 47 that more than 50 percent of total migrants have met their aspirations in current place. This percentage is more than 80 percent for the aspirations of move permanently and reunites with family, relatives and friends in current place.

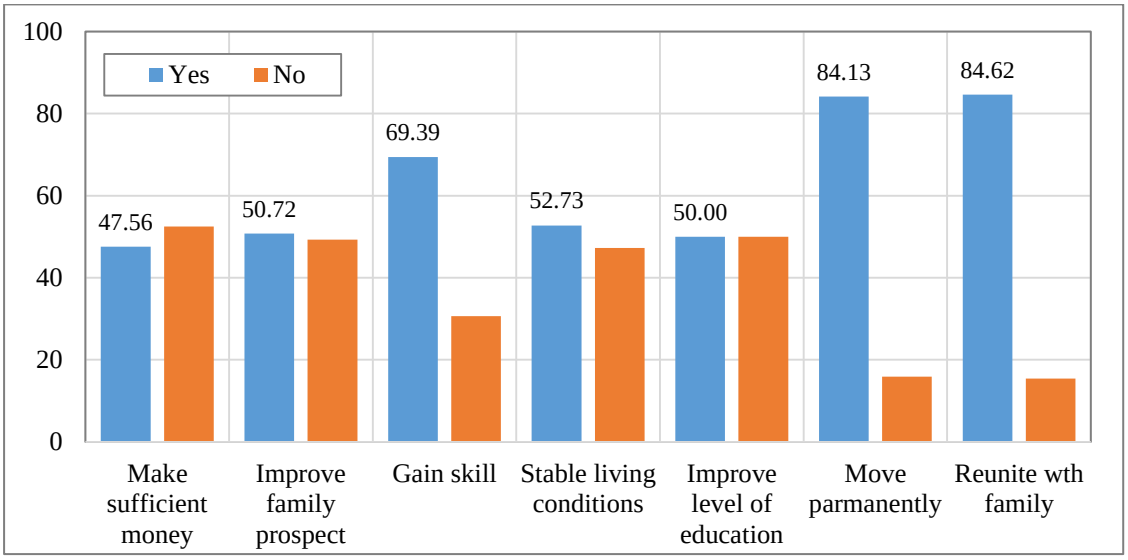


Figure 47. Migrants have met (yes) or haven't met (no) their aspirations

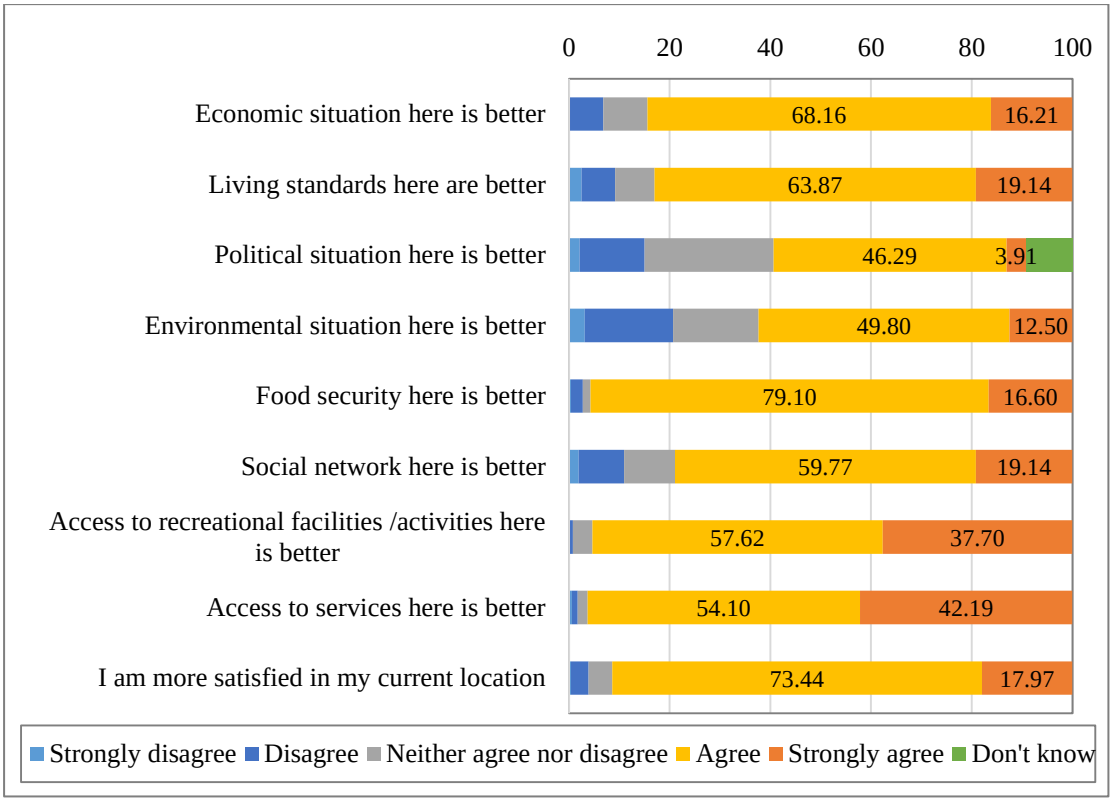


Figure 48. Migrants views in current place

9.4.10. What are the migrant views in current place?

Most of migrants who responded the survey mentioned that they are more satisfied with their life in current location considering almost all things - economic situation, living standards, food security, and access to different services. The higher percentage of disagreement has also been observed in case of environmental and political situations. Migrants in current place experienced many environmental issues like water-logging, pollution.

Only 5.5 percent of total migrants experienced the discrimination (social/economic/ political/ ethnic) since they have arrived at current location. Total 8.4 percent mentioned that local people were unwelcoming towards migrants at the time of arrival in the locality. Only 5.3 percent of total migrants are part of social groups, associations or cooperatives in current location. The informants of the job and shelter are relatives and friends who migrated permanently to these areas play a major role to speed up the migrant's adaptation in the destinations.

9.4.11. Will migrants return to their place of origin?

Only 16 percent of migrants are able and intend to go back to their place of origin. The choice to go back to place of origin was made for a variety of reasons, including family obligations in place of origin, always intended to return, unsuitable employment in current place. Migrants who had no plans to return to their place of origin mentioned that limited economic opportunity in sending area is the main barrier to migration.

Table 17. Linking between sending and receiving areas

Findings	Sending Area	Receiving Area
Vulnerability	Flood, Cyclone, Erosion, Salinization are major environmental problems	Water logging, Pollution, Population pressure are major issues
Economic and livelihood Opportunities	Agricultural dependency is high, and lack of alternative livelihood options	More economic and livelihood opportunities in hotel, factory, transport, construction sectors

Higher education	Very few higher educational institutions	More opportunities –training centres, colleges, universities
Social Networks	Family and friends	Family, relatives and friends
Female migration	Shorter distances, move with family	Move to reunite with family and relatives
Subjective wellbeing	Unhappy with economic and food securities	Moderately happy with economic security and access to utility and services
Future Intention	23 percent of non-migrant households intended to migrate in the future for better economic opportunities	16 percent of total migrants intended to migrate in place of origin for family obligations
Barrier to Migration	Fear of leaving family unprotected, lack of resources to leave and family commitments	limited economic and livelihood opportunities, increasing vulnerability in sending area

9.5. Chapter Summary

Seasonal migration is most prevalent. People migrate once or twice depending on the seasons, and the prevalent direction of movement is rural to urban. Almost 62 percent reported that the main reason driving their migration decision is economic, with the majority of migrants moving in search of improved employment prospects. Migrants rely mainly on in friends who have already moved temporarily to these areas to find employment. Migrant's access to different utilities and public services such as tap water, electricity, heath services, school/higher education etc. are improved in current place compare to place of origin. Only 16 percent migrants have the option and intention to go back to their place of origin. The reasons behind the decision to go back to place of origin are family obligations in place of origin, always intended to return, unsuitable employment in current place.

CHAPTER 10

Environmental Stress and Migration Intention

"Environmental risks affect population movements at various spatial and temporal scales" - ***Adger et al., 2015***.

10.1. Introduction

Koubi et al. (2016) examine perceptions of slow and rapid onset hazards on the likelihood of migration in households across five countries in Asia, East Africa and Central and South America, finding that those perceptions of greater risk decrease migration related to slow-onset change, but increase migration in relation to flood risk. Results of secondary data analysis discussed in Chapter 7 suggest higher out-migration from high hazard coastal zones in IBD. This chapter examines whether and how household perceptions of different types of environmental risks affect migration intention to migrate or to stay.

10.2. Data and Methodology

To investigate what type of environmental factors may trigger migration intent, a binary logistic regression was used in this study. Based on the behaviour of one or more independent variables, which can be either continuous or categorical, Binary Logistic Regression (BLR) (also known as the logit model), predicts the probability that an observation falls into one of two categories of a dichotomous dependent variable. Based on the existing literature and available primary data sets, one dependent variable and 21 independent variables were selected. The present study has two types of independent variables, environmental factors and the household's socio-economic characteristics. It is understood that the relationship between environmental factors and migration intention is complex. It is quite difficult to differentiate individuals for whom environmental factors are the main reason for migration. Economic and socio-political factors also drive migration. That's why, it is important to consider socio-economic factors when investigating whether people will migrate as a result of environmental factors.

In the present study, the environmental factors were derived from the sending area survey based on the perception of the household heads on if and how their livelihoods have been affected by the changing environment in the last 5-10 years. Household

heads play a key role in migration decision-making. They typically have the final say in major household decisions. Social vulnerability of households was measured using a mix of characteristics of household heads and general household data. These included the household head's age, educational level, as well as the household size, household income and present migration status of household. These factors can either increase overall climate change vulnerability or decrease it. Table 18 shows the details of the selected variables for binary logistic regression.

Table 18. Description of dependent and independent variables in this study

Variables	Definitions
Exposure to Environmental Stress	
Flood	= 1 if happened (last 10 years), = 0 otherwise
Drought	
Erosion	
Salinity	
Storm Surges	
Cyclone	
Perceptions of Environmental Change	
Rainy Season/ Monsoon Onset	= 1 if change (last 5 years), = 0 otherwise
Rainfall	
Temperature	
River Flooding	
Coastal Flooding	
Coastal / River Erosion	
Salinization	
Drought	
Impact on Household's Economic Security	
Impact on Household's Economic Security	= 1 if negative impact, = 0 otherwise
Socio-Economic Variables	
Household Size *	NA
*Age of Head of Household**	
No Education	= 1 no education, = 2 primary education, = 3 secondary education, = 4 higher education
Primary Education	
Secondary Education	
Higher Education	
Main Livelihood of Head of Household	= 1 if other than ecosystem based, = 0 otherwise
*Total Income of Household Members**	NA
Family Members or Friends Migrated (Network)	=1 if yes, = 0 otherwise
* Continuous variables	

10.2.1. Dependent variable

The likelihood of future migration from the study area was measured in this study using migration intention as a proxy. Migration intention is the dependent variable in this analysis. Household heads were asked, 'Do you or other household members intend to migrate in the future?' The question sought to identify household heads who intended to migrate from the study area. Households that indicated 'yes' were those who have migration intention in the future while those who said otherwise were classified as those who have no migration intention.

10.2.2. Independent variables

The independent variable used in the model was the environmental factors that household heads indicated affected them most in the last 5-10 years. Drought, flood, heat wave, and cyclone are the major climate related events in the selected states. The severity of each event as scored in the household was used in the regression model as the main independent variables.

Age and level of education of household head, household size and household income are known to influence migration intention. Age, household size and household monthly income are continuous variables. Education was categorized as those with no education and those with primary education. Few respondents have a secondary or higher education. Family members or friends who have already migrated are considered as migration network in this analysis.

10.3. Results and Discussion

The distribution of the dependent and independent variables included in the model is summarized in Table 19.

Table 19. Percentage distribution of dependent variable and independent variables

Variables	*N*	Percent
Dependent Variable		
Migrant Households	231	17.9
Non-Migrant Households	1061	82.2
Independent Variables		
Exposure to environmental stress		

Flood	819	63.4
Drought	127	9.8
Erosion	303	23.5
Salinity	300	23.2
Storm Surges	131	10.1
Cyclone	867	67.2
Perceptions of environmental change		
Rainy Season/ Monsoon Onset	918	71.1
Rainfall	1155	89.4
Temperature	1213	93.9
River Flooding	610	47.2
Coastal Flooding	367	28.4
Coastal / River Erosion	478	37
Salinization	414	32.1
Drought	328	25.4
Perceptions of impact on household's economic security		
Impact on Household's Economic Security	509	39.4
Socio-economic variables		
Mean Household Size	4.28	-
Mean Age of Head of Household (Years)	45.75	-
No Education	324	25.1
Primary Education	499	38.6
Secondary Education	385	29.8
Higher Education	84	6.5
Main Livelihood of Head of Household	1038	80.3
Mean Income of Household Members (Indian Rupees)	6595.8	-
Family Members or Friends Migrated (migrant network)	528	40.9
Total Observations	**1292**	**100.0**

Table 19 shows that more 18% of the respondents had intention to migrate. The average age of household heads in the study communities is 45.75 years, younger than the national average age for rural India. There are low levels of education in the study area. Almost 25% of the respondents had no education with the remaining having attained primary and lower education. This will make respondents less competitive in the formal sector of the economy, and so they may be limited to the informal sector,

which does not provide much security for households' well-being in times of climate-related hazards.

Additionally, households typically consist of four people, which is lower than the national average (4.4). Nearly half of the respondents in the communities had an annual income below the national minimum wage. In addition, the migration network of the household often determines how decisions regarding migration are made.

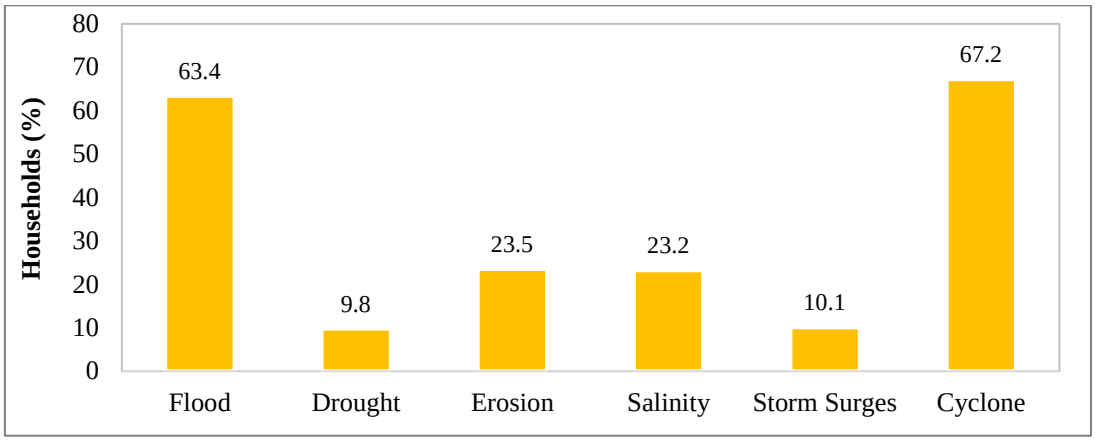


Figure 49. Exposure to Environmental Stress in IBD

Environment related events are among the major stressors mentioned by household heads. More than two thirds (63%) of the respondents indicated that flood and cyclone are major stressor in IBD. From the radar diagram, it can be understood that all hazards bring about negative impacts on economic security of households.

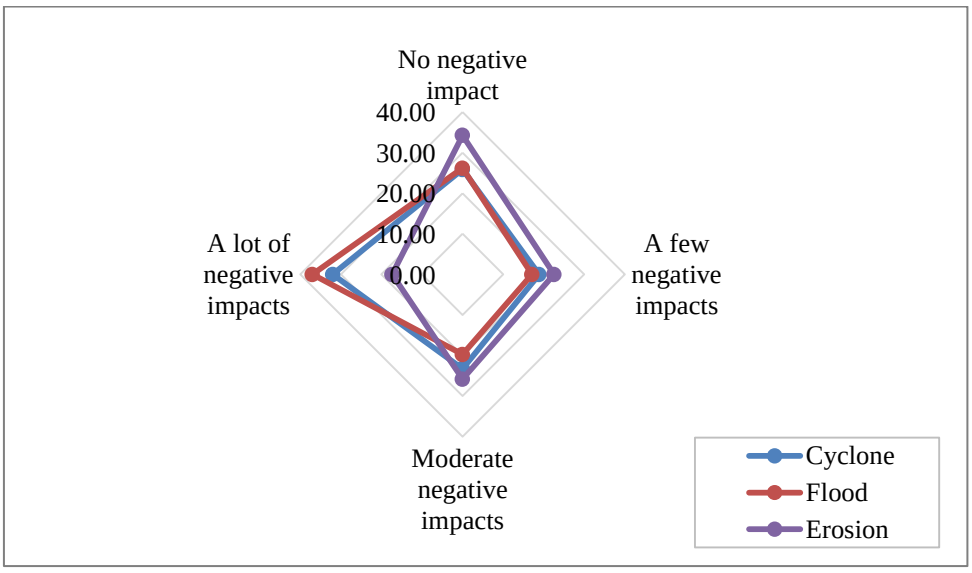


Figure 50. Impact on Economic Security in IBD

More than 70% of households experienced damages, financial losses. 6% of households lost more than 1 lakh rupees due to extreme events.

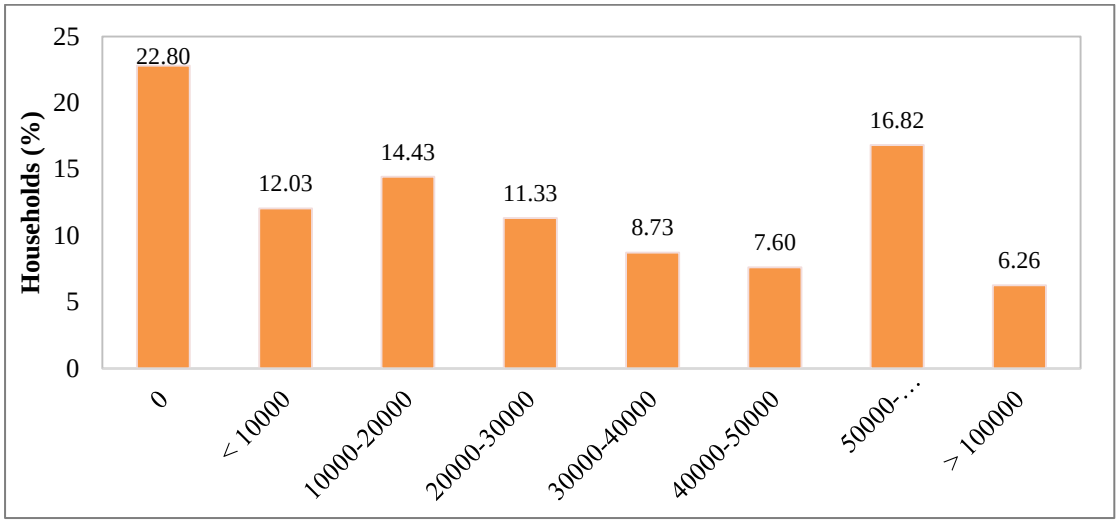


Figure 51. Total Damage (Rs.) due to Extreme events in IBD

Four models were run for the study. The first model (Model 1) examines the relationship between environmental hazard and migration intention. The second model (Model 2) investigates relationship between perceptions of environmental change and migration intention. The third model (Model 3) includes both environmental hazard and perceptions of impact on household's economic security. The final model (Model 4) includes socio-economic and all environment related variables. The regression results are presented in Tables 20 and 21.

The results show that all the models are fit for analysis. Models 1 and 2 show that climatic events like flood, salinity, storm surge, and cyclone act as ‘stressors’ and drive individuals or households to contemplate migration as a survival strategy. As per Model 4, household size, total income and migration network are significant variables that can trigger migration responses at household level. This is an indication of the strong role socio-demographic factors play in intentions to migrate.

Table 20. Results of binary logistic regression model for Indian Bengal Delta

Variables	Model 1			Model 2			Model 3			Model 4		
	S.E.	Sig.	Exp(B)	S.E.	Sig.	Exp(B)	S.E.	Sig.	Exp(B)	S.E.	Sig.	Exp(B)
Exposure to environmental stress												
Flood	0.208	0.057	1.487	0.209	0.048	1.512	0.222	0.019	1.681	0.229	0.036	1.617
Drought	0.254	0.093	0.653	0.267	0.065	0.611	0.269	0.088	0.632	0.283	0.068	0.596
Erosion	0.273	0.194	1.426	0.283	0.304	1.338	0.287	0.229	1.412	0.3	0.427	1.269
Salinity	0.277	0.035	1.793	0.292	0.036	1.844	0.295	0.026	1.926	0.31	0.064	1.776
Storm Surges	0.239	0.016	1.776	0.246	0.012	1.857	0.246	0.011	1.874	0.257	0.005	2.044
Cyclone	0.232	0	2.491	0.234	0	2.526	0.234	0	2.562	0.239	0.002	2.082
Perceptions of environmental change												
Rainy Season/ Monsoon Onset				0.178	0.127	1.312	0.178	0.115	1.324	0.183	0.115	1.333
Rainfall				0.264	0.635	0.882	0.265	0.6	0.87	0.276	0.814	0.937
Temperature				0.339	0.767	1.106	0.339	0.784	1.098	0.352	0.981	0.992
River Flooding				0.22	0.33	1.239	0.221	0.312	1.251	0.232	0.864	1.04
Coastal Flooding				0.229	0.585	0.882	0.229	0.552	0.872	0.237	0.732	0.922
Coastal / River Erosion				0.253	0.502	1.185	0.253	0.486	1.193	0.265	0.318	1.303
Salinization				0.236	0.281	0.775	0.237	0.273	0.771	0.246	0.225	0.742
Drought				0.195	0.466	1.153	0.196	0.435	1.165	0.204	0.45	1.166
Perceptions of impact on household's economic security												
Impact on Household's Economic Security							0.196	0.174	0.767	0.209	0.146	0.738
Socio-economic variables												
Household Size										0.049	0	1.288
Age of Head of Household										0.006	0.269	1.007
No Education										0.424	0.862	1.077
Primary Education										0.409	0.758	1.134
Secondary Education										0.415	0.731	0.867
Main Livelihood of Head of Household										0.198	0.885	1.029
Total Income of Household Members										0	0.001	1
Family Members or Friends Migrated (migrant network)										0.166	0	2.514
Constant	0.215	0	0.058	0.431	0	0.044	0.432	0	0.044	0.709	0	0.014

Table 21. Results of binary logistic regression model (Model 4)

Variables	Odd Ratio
Exposure to environmental hazard	
Flood	1.617** (.229)
Drought	.596* (.283)
Erosion	1.269 (.300)
Salinity	1.776* (.310)
Storm Surges	2.044*** (.257)
Cyclone	2.082*** (.239)
Perceptions of environmental change	
Rainy Season/ Monsoon Onset	1.333 (.183)
Rainfall	.937 (.276)
Temperature	.992 (.352)
River Flooding	1.040 (.232)
Coastal Flooding	.922 (.237)
Coastal / River Erosion	1.303 (.265)
Salinization	.742 (.246)
Drought	1.166 (.204)
Perceptions of impact on household's economic security	
Impact on Household's Economic Security	.738 (.209)
Socio-economic variables	
Household Size	1.288**** (.049)
Age of Head of Household	1.007 (.006)
No Education	1.077 (.424)
Primary Education	1.134 (.409)
Secondary Education	.867 (.415)
Main Livelihood of Head of Household	1.029 (.198)
Total Income of Household Members	1.000**** (.000)
Family Members or Friends Migrated (Network)	2.514**** (.166)
Constant	.014**** (.709)
**** $p < 0.001$, *** $p < 0.01$, **$p < 0.05$, * $p < 0.1$; Standard Error (S.E.) in parentheses	
An odds ratio (OR) is a measure of association between an exposure and an outcome. OR=1 Exposure does not affect odds of outcome, OR>1 Exposure associated with higher odds of outcome, OR<1 Exposure associated with lower odds of outcome.	

The discussion below examines the results of the binary logistic regression:

10.3.1. Socio-Economic Variables

Household size: The size of the household also determines how well it will be able to function during environment-related events. In comparison to smaller households, larger households may be more vulnerable in times of an extreme event. However, larger households can find it easier to diversify their income by sending one of their members elsewhere. The odd ratio of 1.288 suggests that household size increase the intentions to migrate by 1.288 times. It can be said that *increasing household size increases the intentions to migrate.*

Household income: Income plays a major role in the migration decision process (OR = 1.000). *Households that have the financial resources will be able to sponsor members to embark on migration* while those who do not have the financial resources may resort to other ways of coping with the situation.

Migration network: The current migration status of the household head determines how attached the household is to the community and the resources that the household could enjoy in the community. Results reveal that *migration network plays important role in migration decision-making* (OR = 2.514).

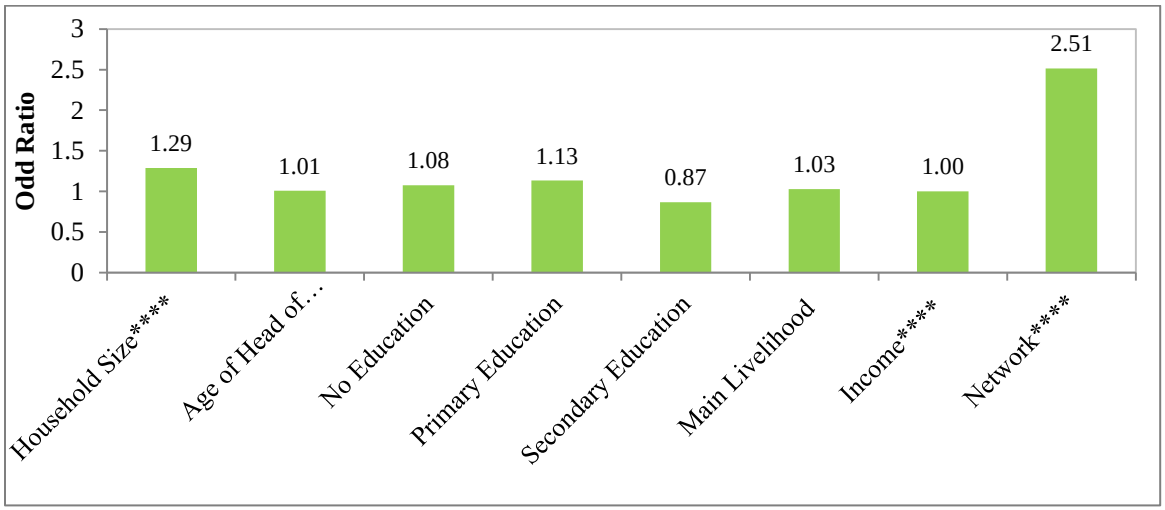


Figure 52. Socio-economic variables

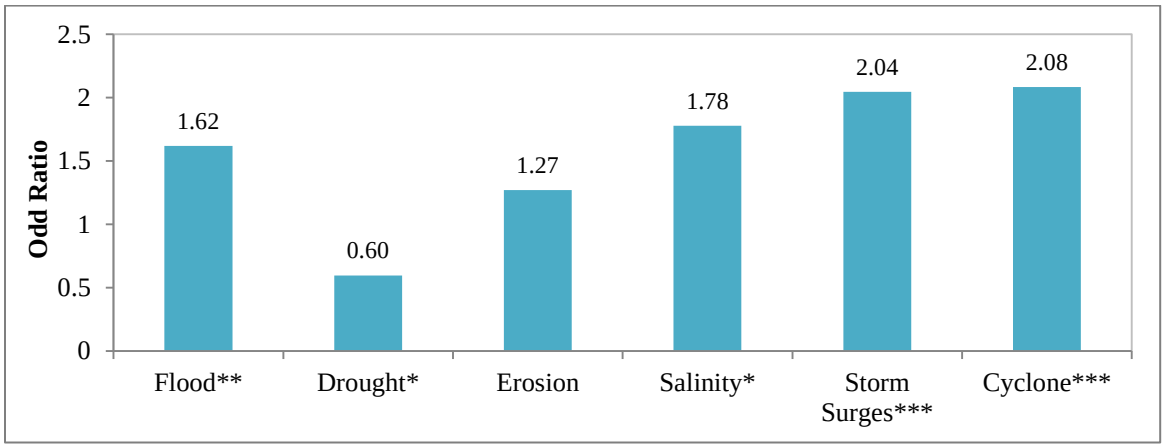


Figure 53. Environmental variables

10.3.2. Environment-related events

Flood: IBD had experienced significant flooding in the last 10-15 years. During monsoons, heavy rains regularly flood villages on the riverbanks. Households that are exposed to flood are 1.617 times as likely as those who are not exposed to have the intention to migrate.

Drought: Results indicate that households exposed to drought are 0.596 times as likely as those who are not exposed to have the intention to migrate.

Storm surge: Storm surge is another extreme event in IBD. Households that are exposed to storm surge are 2.044 times as likely as those who are not exposed to have the intention to migrate.

Cyclone: IBD had also experienced cyclonic events in the last 10-15 years. Households that are exposed to cyclone are 2.082 times as likely as those who are not exposed to have the intention to migrate.

"Breach of the embankment left households vulnerable to erosion and flooding. Land has become saline and no longer cultivable. You can see some work being carried out there on that side (back side). It will only be up to that area, I don't think there is going to be any work done here (front side), this year. Sir, we did not get any support from the government, not even a place to reside during this time of crisis. If we want to move in another location, the people there are objecting. Those who could afford to buy small bits of land, they have all moved to the interior part of the island. What should we do? Please help us" – **FGD, Dhablat, Sagar, IBD.**

Photo 11. Breach of the embankment left households vulnerable to erosion and flooding. Land has become saline and no longer cultivable

10.4. Chapter Summary

Household size, household monthly income, and migration network are the significant socio-economic variables that influence the migration decision-making. This analysis indicates that the majority of household heads perceive climate-related events as their most pressing stressor. This is so because agriculture, which is the main livelihood of the people, depends on rainfall. The model 4 reveals that exposure to flood (OR = 1.617), storm surge (OR = 2.044), and cyclone (OR = 2.082) have positive effect on intentions to migration in IBD. It can be said that climatic events like flood, salinity, storm surge, and cyclone are believed to function as ‘stressors’ and drive individuals or households to contemplate migration as a survival strategy.

CHAPTER 11

Climate Migration Modeling

"Internal climate migration will likely rise through 2050 and then accelerate unless there are significant cuts in greenhouse gas emissions and robust development action" - ***Rigaud et al., 2018****.*

11.1. Introduction

Climate migration is already occurring. The scale of climate migration is expected to increase as the impacts of climate change intensify in the coming decades (McLeman, 2018). Climate migration modeling is a pioneering approach to present the projections of climate change impact into a model of future population distribution. It focuses on critical elements that are particularly significant as potential migration drivers, including crop productivity, water availability, and sea level rise amplified by storm surge. This employs a scenario-based approach to determine the portion of future changes in population distribution that could be attributed to climate migration (Rigaud et al., 2018). This chapter examines how much climate migration may grow, over what time frame, and where.

11.2. Exposure mapping

A new but growing field is climate migration modeling (de Sherbinin and Bai, 2018; McLeman, 2013). There are different methods for climate migration modeling: Exposure Mapping, Agent based model, System dynamic, Gravity model. Exposure Mapping (EM) is the simplest method for predicting climate migration. In this method, a population distribution map is typically overlaid with a climate-related hazard. This method helps to estimate the number of people who will be relocated if that hazard happens. There is a large and growing body of literature on hazards that have been mapped in this way (Rigaud et al., 2018), such as sea level rise (McGranahan et al., 2007; Mondal and Tatem, 2012; CIESIN, 2013; Neumann et al., 2015); floods (Hirabiyashi et al., 2013; Ghosh et al., 2019); multiple climate hazards (Christensen et al., 2013); and multiple climatic and non-climatic hazards (Dilley et al., 2005; Peduzzi et al., 2009). By doing so, it will be

easier to identify potential risks to human populations and make some very basic predictions about who will stay and who will go.

11.3. Data and Methodology

11.3.1. Climate scenario

To predict future emissions and other human variables that influence climate, the IPCC advises employing a variety of scenarios with different assumptions about future economic, social, technological, and environmental conditions. A greenhouse gas concentration trajectory used by the IPCC is known as a **Representative Concentration Pathway (RCP)**. IPCC Fifth Assessment Report (2014) used four pathways for climate modeling and research. In the RCP 2.6 scenario, the temperature rise from pre-industrial levels is kept to less than 2°C. There are two medium-stability pathways, RCP 4.5 and RCP 6.0, with various degrees of mitigation. RCP 8.5 is a scenario that takes no additional mitigation into account.

Shared Socioeconomic Pathways (SSPs) take into account a variety of underlying variables, such as demographic, technological, and economic growth, which, even in the absence of climate policy, might result in drastically different future emissions and warming consequences. They were used in the preparation of the IPCC's Sixth Assessment Report on Climate Change, which was released in 2021. The RCP 4.5 is closely related to the SSP 2.

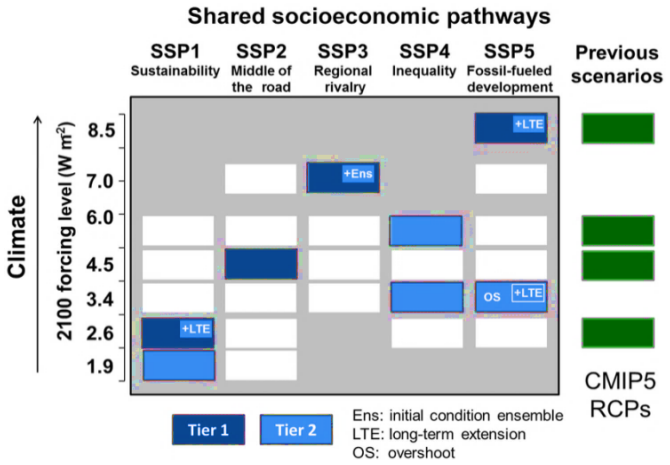


Figure 54: RCPs & SSPs (*Source: IPCC AR6, 2021*)

11.3.2. Methodological steps

Three steps were followed for exposure mapping in IBD:

Step 1: Coastal flood indictor was selected. Coastal flooding map (2050) under the Optimistic Scenario (RCP 4.5, SSP 2) was prepared based on the World Resources Institute (WRI) Aqueduct Floods data for 5 yr. and 100 yr. return period.

Step 2: Population distribution map was prepared using the trend extrapolation method. This method generally applied for projections of total population, is solely based on the continuation of readily observable historical trends (Siegel and Swanson, 2004). Average value of all the trend extrapolation method s was used to prepare the sub-district level population distribution map.

Step 3: Finally, the coastal flood map was overlaid on a population distribution map to estimate the number of people will be displaced by 2050.

11.4. Results and Discussion

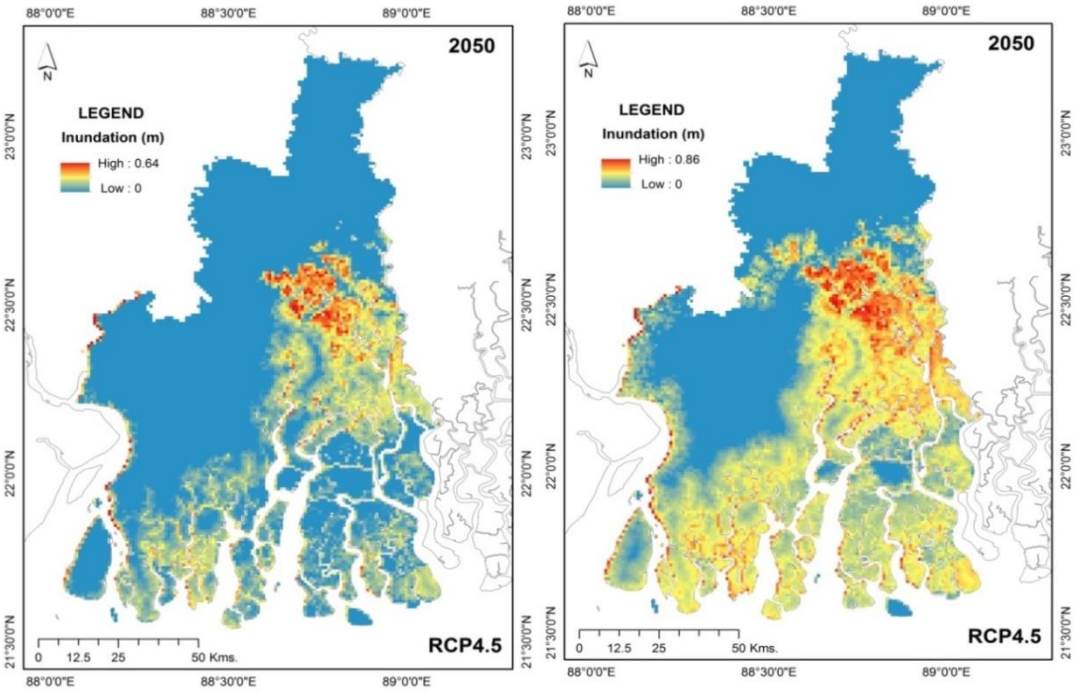


Figure 55. Coastal flooding (2050) under the Optimistic Scenario (RCP 4.5, SSP 2) – (a) 5 yr. return period (20% probability of occurrence per year), (b) 100 yr. return period (1% probability of occurrence per year)

Coastal sub-districts such as Gosaba, Basanti, Patharpratima, Kultali, Hingalganj, and Sandeshkhali-II will be at very high risk due to coastal flooding by 2050 under the Optimistic Scenario (RCP 4.5, SSP 2).

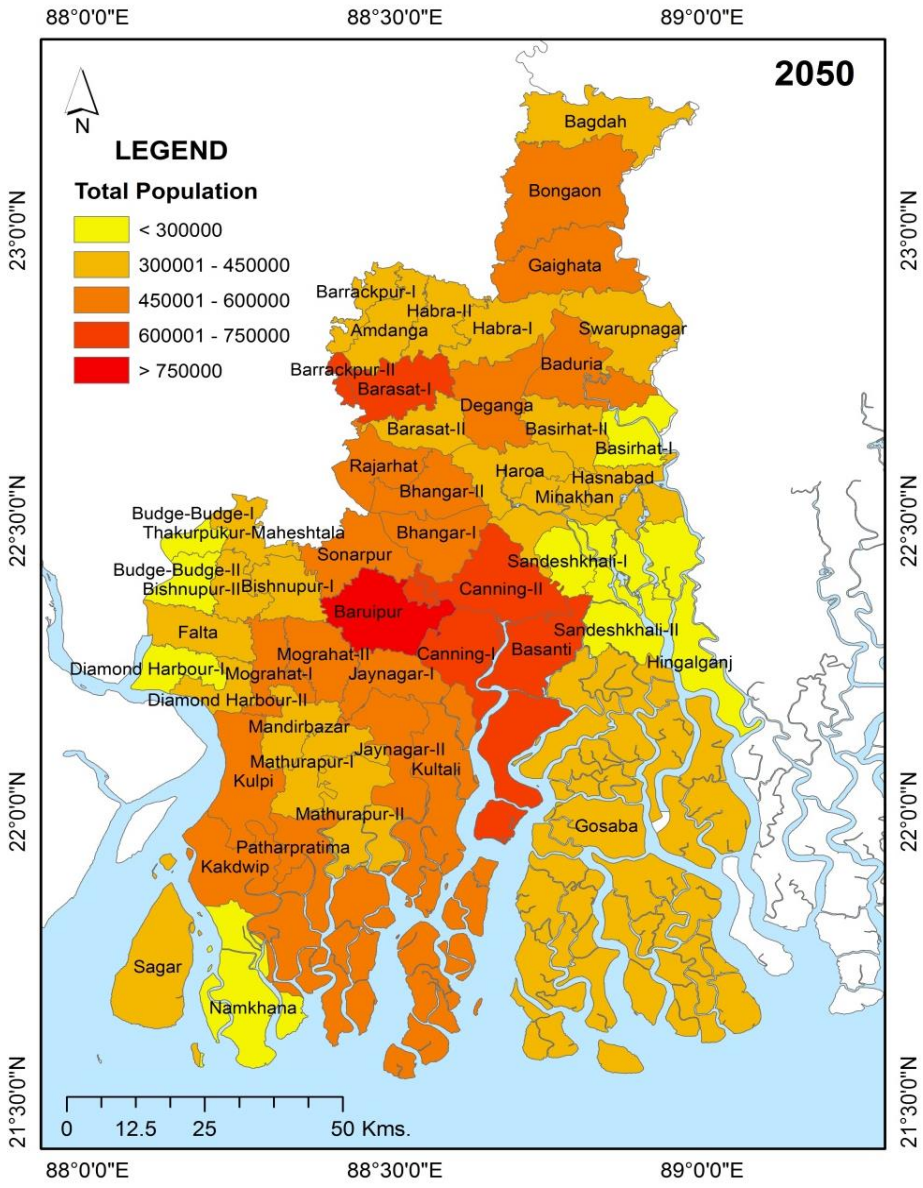


Figure 56. Population distribution (2050)

In 2050, the total population would be highest in Baruipur (902733), followed by Canning-I (655393), Basanti (656235), Barasat-I (633611), and Canning-II (606799). A declining or static trend has also been observed in Namkhana, Sagar, Kakdwip and Mathurapur-II.

To estimate the number of people will be displaced by 2050, the coastal flood map was overlaid on a population distribution map of IBD. Results indicate that under the Optimistic Scenario (RCP 4.5, SSP 2), more than 5 million persons will be displaced by coastal flooding by 2050. This will happen mainly from Basanti, Canning –I &II, Patharpratima and Kakdwip sub-districts of IBD. People who were unable to migrate will migrate in future. It can be said that climate migration is likely to increase in future in IBD.

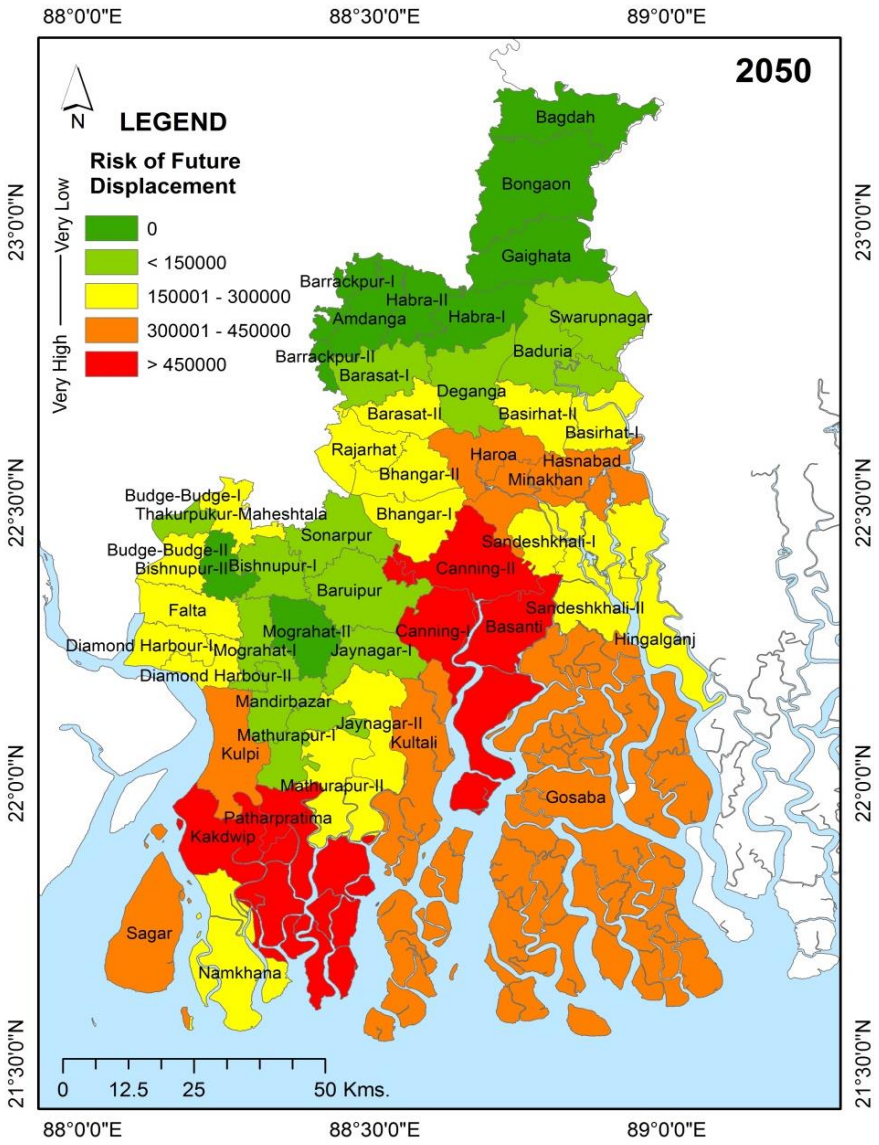


Figure 57. Climate Migrants (2050) by Coastal Flooding (100 yr. return period) under the Optimistic Scenario (RCP 4.5, SSP 2)

Photo 12. People have lost their lands and houses due to extreme events and climate migration is likely to increase in future

11.5. Chapter Summary

Each modeling approach is different and has a separate set of requirements. Exposure mapping is the simplest approach for modeling climate migration. By 2050, more than 5 million persons will be displaced by coastal flooding, mainly from Basanti, Canning –I &II, Patharpratima and Kakdwip sub-districts under the Optimistic Scenario (RCP 4.5, SSP 2).

CHAPTER 12

Summary and Conclusions

"Large numbers of people are moving as a result of environmental degradation that has increased dramatically in recent years. The number of such migrants could rise substantially as larger areas of the earth become uninhabitable as a result of climate change." ***- IOM, 1992.***

12.1. Summary

An intensive dependence on agriculture and agricultural products, low economic and high population growth, illiteracy, lack of access to safe drinking water, sanitation and other services all contribute to make the IBD more vulnerable to climatic hazards. Coastal sub-districts like Gosaba, Basanti, Sandeshkhali-II, Kultali, and Patharpratima are at greatest risk/vulnerability due to both lower adaptive capacity and higher sensitivity. Socially marginalised and vulnerable communities are found on the delta margin (Gosaba, Basanti, Canning-I & II, Sandeshkhali-I & II and Patharpratima) and are away from the urban center of Kolkata. Vulnerable population of the identified sub-districts are less likely to respond to, cope with, and recover from the impacts of climatic hazards.

According to the GIS overlay study, outmigration hotspots are closely associated with locations with high climatic hazards, whereas the low hazard zones in the delta mostly appear as net receiving areas. Sub-districts with high risk and higher out-migration are Namkhana, Kultali, Gosaba, Mathurapur-II, Sandeshkhali-II, Sagar and Patharpratima. This analysis brings out first line of evidence how climatic risk compounded with high social vulnerabilities can become a major driver of permanent population movement in vulnerable deltas.

To understand the patterns of migration, primary survey was conducted in IBD. It indicates male migration is the trend, but now the number of female migrants have also increased but to shorter distances like the peri-urban areas of Kolkata. Due to lack of alternative livelihood options, seasonal migration is a common practice in IBD. Almost 62 percent reported that the main reason driving their migration decision is economic, with the majority of migrants moving in search of improved employment opportunities. In order to get work, migrants mostly rely on their friends who have already moved

temporarily to these places. Migrant's access to different utilities and public services such as tap water, electricity, heath services, school/higher education etc. are improved in current place compare to place of origin.

The population structure of migrant sending areas is changing as the working age population tends to leave. Migration has an impact on gender roles, with women in sending areas frequently becoming overburdened as males migrate. In terms of infrastructure, the migrant-receiving areas are generally not ready to accommodate them. As a result, migrants frequently live in unhealthy environments and get sick. Interstate migrants experience significant difficulties assimilating and accessing state-sponsored social security programmes in India.

12.3. Contribution to body of knowledge

Many individuals and families migrate from rural areas because they have no viable option for moving out of poverty within their own communities. Nowadays, migration is an important component of household livelihood strategies. The communities that depend on forests, smallholder family farmers, and small-scale fishermen are hardest hit by weather-related disasters, which are occurring more frequently and with greater intensity. Floods, droughts, and the associated instability in food prices all contribute to an increase in poverty and hunger, as well as the need to look for viable options. Land degradation and desertification affect about one-third of agricultural land, as well as farmer productivity and resilience. These issues are aggravated further by the effects of climate change and improper farming practices. Over 60% of people do not have adequate access to social protection. The majority of people reside in rural regions, where they struggle to manage social, economic, and environmental risks.

This research helps to shape the understanding of potential future environmental impacts on migration intensions and decisions. Higher perceptions of environmental risks by the migrant members compared to the non-migrant members indicate environmental events as one of the major drivers for out-migration in the delta. This is so because agriculture, which is the main livelihood of the people, depends on rainfall. The model 4 reveals that exposure to flood, storm surge, and cyclone have positive effect on intentions to

migration in IBD. It can be said that climatic events like flood, salinity, storm surge, and cyclone act as 'stressors' and drive individuals/households to consider migration as a survival strategy. Under the RCP4.5 scenario, more than 5 million persons will be displaced by coastal flooding by 2050. People who didn't migrate now want to migrate in future. Migration is likely to increase in the future.

This study also helps to prepare location specific emergency plans to combat hazards associated with climate change and variability and also to reduce the distress migration. Addressing the underlying reasons for distressed migration requires a focus on agriculture and rural development. Extensive participatory demonstrations of location-specific agricultural practises are used in capacity building for climate smart agriculture to develop farmers' knowledge and confidence in dealing with unfavourable weather conditions. Capacity building of farmers on alternative livelihood options include skills and knowledge development on animal husbandry (poultry, goat and duck farming, etc.) and value addition of produce (value-added food products, handicrafts, etc.). There is also a need to establish or strengthen water management structures in order to address the existing challenges related to water and the future risks to its availability due to climate change.

Other responses could take the form of implementation of a forecasting system for extreme weather events in combination with grass root dissemination of these forecasts. Additionally, the construction of multipurpose cyclone and flood shelters would help improve the resilience of impacted communities. Other response strategies such as retreat and realignment of embankments, mangrove plantations, introduce sluicing of smaller creeks could be also implemented at the local level. In situ responses such as safe drinking water, sanitation facilities, primary health services, multiple livelihood options through skill development projects, eco-tourism development may help improve the standard of living of residents and reduce the overall vulnerability. Sharing information with communities, strengthen community-led participatory research, and implement pilot adaptation strategies etc. are important strategies which can be taken for vulnerable communities in IBD.

All the above-mentioned measures can increase the adaptive capacity of local communities to extreme events and climate variability and promote their sustainable development. These measures can contribute to the achievement of SDG 1 (No Poverty), SDG 2 (No Hunger), SDG 3 (Good Health and Well-being), and SDG 10 (Reduced Inequality) and SDG 13 (Climate Action).

12.4. Contribution to methods

IPCC AR5 risk assessment framework was followed for this study. At the sub-district level, vulnerability and risk indices were constructed for IBD using the PCA method. The most common statistical method used to extract a smaller and more coherent set of uncorrelated components from a large number of variables is PCA. First component accounts for the largest amount of variation in the input variables, and each following component accounts for as much of the remaining variability as possible.

Binary logistic regression method helps to understand the influence of various environmental and socio-economic variables on migration decision. The present study has two types of independent variables, environment related parameters and the household's socio-economic characteristics. It is understood that the relationship between environment-related events and migration intention is complex. It is quite difficult to differentiate individuals for whom environmental factors are the main reason for migration. Economic and socio-political factors also drive migration. It is important to consider socio-economic factors when investigating whether people will migrate as a result of environment-related events.

Another approach is exposure mapping. In this method, a population distribution map is typically overlaid with a climate-related hazard. This method helps to estimate the number of people who will be relocated if that hazard happens. By doing so, it will be easier to identify potential risks to human populations and make some very basic predictions about who will stay and who will go. This method was applied to estimate the number of people on the move because of environmental pressures in the future.

12.5. Contribution to policy

Migration needs to be managed to reduce the difficulties and improve the benefits. A national and/or state-level strategy, policy or action plan on climate and environmental-induced migration, as well as rehabilitation and relocation of vulnerable migrants, would provide the necessary policy framework for this to be supported. In particular such a policy/action plan should recognise that:

- In order to support farmers and create alternative and sustainable livelihood options in rural areas, with a particular focus on women and youth, it may also be essential to scale up existing government programmes (promoting the adaptation of sustainable agricultural practices, diversification to off-farm activities, seasonal employment schemes in agriculture). By doing so, it will also address the very root cause of distress migration (no livelihood options to survive).
- Government programmes and departments offer initiatives related to agriculture and rural development. All of these must be brought together under one mission as part of the recovery plans.
- Migrants are mainly unskilled, and they lose monetary benefits in the destination areas. Attention should be paid to skill development opportunities so that more women start benefiting from them. Skill development programmes can boost the chances of successful migration.
- Gender issues should be addressed to help migrants (mainly male) and those left behind (mainly female) to develop their adaptive capacity.
- Thriving peri-urban areas require appropriate infrastructure and planning to manage the influx of migrants.
- Resettlement plans should consider livelihood assistance in addition to home and land.
- Migrants should be made part of social groups, associations or cooperatives. This could increase their attachment with the place and also make them feel more welcome.
- In the destination areas, migrant workers are primarily engaged in the informal sector. They typically work in manual, unskilled, or semi-skilled jobs and struggle

to get suitable positions when they first start out. They generally receive low-paying, high-risk jobs that have either been passed over by local employees or haven't been given to them.

- After they leave their hometown, there is no tracking policy or specific office for them. Migrants themselves describe their motivation for moving as being economic (such as looking for job) rather than climate-related, perpetuates this lack of awareness. Additionally, migrants do not register their movements to any authorities. There must be a proper procedure in place to record these moves.

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Chapter 1

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