Climate Change and Socioeconomic Vulnerability:
Experiences and Lessons from South-western Coastal Bangladesh

MSc. Thesis

Md. Nasif Ahsan

MSc. International Development Studies
Registration No. 801229-007-150

WAGENINGEN UNIVERSITY
WAGENINGEN UR

Climate Change and Socioeconomic Vulnerability:
Experiences and Lessons from South-western Coastal Bangladesh

August 2010

MSc. Thesis
DEC 80433

Development Economics Group
&
Chair Disaster Studies

Wageningen University and Research Centre, The Netherlands

Md. Nasif Ahsan

Registration No. 801229-007-150
MSc. International Development Studies
Wageningen University & Research Centre
The Netherlands

Supervisor: Professor Dr Ir. Erwin Bulte (DEC)
Co-Supervisor: Dr Jeroen Warner (Disaster Studies)

Acknowledgement

My profound gratitude goes to the Almighty Allah for showering His blessings on me throughout the whole period of my study and research in the premises of Social Science at Wageningen University and Research Centre (WUR) in the Netherlands. In this regard, I am highly indebted to the Executive Board of WUR for providing me the WU Fellowship to pursue my MSc study in such a world-reputed university.

I am sincerely indebted, grateful and thankful to my esteemed supervisor Dr Ir. Erwin Bulte, Professor, Development Economics Group of Wageningen University; and co-supervisor Dr Jeroen Warner, Assistant Professor, Disaster Studies Chair Group of Wageningen University, the Netherlands for their cordial guidance, constructive and critical comments, suggestions and patience. Both of them inspired me immensely from the very beginning of writing the proposal for the thesis. I have learnt a lot from their guidance and suggestions.

I wish to extend my thanks and gratitude to Mr. Abu Bakar Siddique, the Chairman of Koyra upazila and Mr. Hasan Javed, the public relation officer of Koyra upazila office for their cordial cooperation during the data collection period. I would also like to the personnel in various Union Parishad offices in the study area for their support to arrange 'Focus Group Discussion' in different unions. My special thanks to Dr Md. Mujibor Rahman, Assistant Professor of Environmental Discipline and Mr. Subroto Kumar Dey, former student of the same Discipline of Khulna University, Bangladesh for their support during my research. I am also grateful to Mr. S. M. Reazul Ahsan (University of South Australia), Ms. Sonia Akter (Australian National University), Mr. Asif Iqbal (AIT, Thailand) and Dr Mohammed Ziaul Haider, Associate Professor of Economics Discipline of Khulna University, Bangladesh for their little but effective suggestions and observations during various phases of my research.

I am also indebted to the senior Masters and Bachelor students of Khulna University who put their utmost efforts with me during the data collection from the remotest as well as risky places. My special thanks to Mr. Firoz Ahmed ('04 Batch) and Mr. Rezwanul Haque ('05 Batch).

I belong to the MID-08 family which in a truest sense was a multi-cultural and trans-national in nature. I have enriched myself substantially from this group. MID-08 provided enormous support for me during my whole study period in Wageningen. It was a privilege for me to be part of the MID family. I would like to express my special thanks to Mutware S Joseph, Bjorn Lous, Andre Cortes, Shyam Basnet, Francisco Checchi, Marieke Lenders and all other MID-08 friends for their continuous support and inspiration for me.

I would also like to extend my thanks and gratefulness to Mr. Mohammad Ohid Ullah (PhD student of NMG Group, WUR) for his selfless help in numerous occasions of my data analysis. I thank to Arif bhai, Wasiul bhai, Parvez bhai, Deen bhai, Moshiur bhai, Shopon bhai, Nahid apa, Rasel bhai, Basu dada and my bosom friend Reza who all make my Wageningen life worthy as well as memorable.

I am also indebted to my job provider Khulna University, Bangladesh for providing me the study leave and other necessary supports for pursuing higher study. I express my heartiest gratefulness to my dear family and last of all but not the least to my loving and caring wife Tamanna for her encouragement and great sacrifice for my study in abroad.

Md. Nasif Ahsan
Wageningen
August 2010

Abstract

Statistical data reveals that increase in natural catastrophes over the last two decades has been taken place due to climate change in most part of the world (Birkmann and von Teichman, 2010). Bangladesh, a South Asian LDC, has recently been reported as in the worst position of long-term climate risk (Germanwatch, 2010). Most of the devastating disasters, especially cyclones which are very likely to be the effects of climate change, hit the coastal belt of Bangladesh each year. As a consequence, socioeconomic vulnerability is emerged among the coastal communities.

This study attempts a synergistic interdisciplinary approach to investigate vulnerability, poverty, capacity and adaptation-options for households in *Koyra* upazila of southwestern coastal Bangladesh. Using an index, adopted from *Community-based Disaster Risk Index* (Bollin and Hidajat, 2006), vulnerability of coastal community is quantified. This vulnerability index consists of five domains showing specific vulnerability (such as- physical, economic etc.) in union (community) level. This index provides numerical values for each union in *Koyra* where a higher value indicates higher level of vulnerability.

The nature and extent of relationship between vulnerability and important socioeconomic parameters of *Koyra* is investigated in this study. Hence, we examined how vulnerability and poverty are related to each other. We furthermore testified the relationship of poverty with domain-wise vulnerabilities in different unions of *Koyra*. Later we used ‘land ownership of households’ instead of poverty to address the capacity of households and investigated its relation with vulnerability. We also investigated relationships of social capital, literacy, household-size and vulnerability (both domain-wise and aggregate) with poverty, and with land ownership.

Finally we proposed a number of adaptation options, which can also be treated as mitigation. We drew these options as recommendation based on empirical data analysis and FGD (Focus Group Discussion) findings. We emphasized on capacity of households in *Koyra* while recommending for these adaptation strategies. We concluded this study by mentioning the areas where further research might be possible to accomplish a more integrated study in the realm of climate change, vulnerability, adaptation and mitigation. The findings of this study will be helpful for the local and national level policy-makers of Bangladesh in formulating upcoming adaptation planning for coastal areas.

Table of Contents

List of Tables

List of Charts

List of Figures

List of Flow-diagrams

List of Maps

Abbreviation

^0C	Degree Celsius
ADPC	Asian Disaster Preparedness Center
AR4	Fourth Assessment Report of IPCC
BBC	British Broadcasting Corporation
BMD	Bangladesh Meteorological Department
CERP	Coastal Embankment Rehabilitation Project
cm	Centimeter
COP15	Conference of Parties
CRI	Climate Risk Index
EM-DAT	The International Disaster Database
FAO	Food and Agricultural Organization
FGD	Focus Group Discussion
Fig	Figure
GDP	Gross Domestic Product
GHG	Green House Gas
GoB	Government of Bangladesh
ha	Hectare
IIED	International Institute for Environment and Development
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
IWM	Institute of Water Modeling
Km	Kilometers
Km^2	Square Kilometer
Km/h	Kilometers per hour
LDC	Least Developed Country
m	Meter (s)
mm	Millimeter
NAPA	National Adaptation Program of Action
NGO	Non Government Organization
OLS	Ordinary Least Square (Regression)
PAR	Pressure and Release (model)
PDO-ICZM	Project Director Office of Integrated Coastal Zone Management
RVCC	Reducing Vulnerability to Climate Change
SAARC	South Asian Association of Regional Cooperation
SAR	Second Assessment Report of IPCC
SIM	Subscriber's Identification Module
SST	Sea Surface Temperature
TAR	Third Assessment Report of IPCC
Tk.	Bangladeshi Taka (1€ = 90 Taka)
UN	United Nations
UNEP	United Nations Environment Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
VGF	Vulnerability Group Feeding
WMO	World Metrological Organization

Glossary

Adaptation
Adjustment in natural or *human systems* in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2007c).

Adaptive capacity
The ability of a system to adjust to *climate change* (including *climate variability* and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (IPCC, 2007c).

Climate change
Climate change refers to any change in *climate* over time, whether due to natural variability or as a result of human activity. This usage differs from that in the *United Nations Framework Convention on Climate Change (UNFCCC)*, which defines 'climate change' as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global *atmosphere* and which is in addition to natural climate variability observed over comparable time periods' (IPCC, 2007c).

Greenhouse gas (GHGs)
Greenhouse gases are those gaseous constituents of the *atmosphere*, both natural and *anthropogenic*, those absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere, and clouds. This property causes the *greenhouse effect*. Water vapor (H_2O), *carbon dioxide* (CO_2), nitrous oxide (N_2O), methane (CH_4) and *ozone* (O3) are the primary greenhouse gases in the Earth's atmosphere. As well as CO_2, N_2O, and CH_4, the *Kyoto Protocol* deals with the greenhouse gases sulphur hexafluoride (SF6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) (IPCC, 2007c).

Household
Usually a family, where all members share daily food from the same pot.

Mitigation
An *anthropogenic* intervention to reduce the anthropogenic forcing of the *climate system*; it includes strategies to reduce *greenhousegas sources* and emissions and enhancing *greenhouse gas sinks* (IPCC, 2007c).

Mouza
It is the smallest cluster of administratitive hierarchy of Bangladesh. It consists of a number of communities in a small area.

Union
It is the lowest tier in the local level government. Usually it consists of a number of villages.

Upazila
It is a kind of sub-district. It consists of a number of unions.

Dedicated to….

The marginal people of coastal communities in Bangladesh,

Who are not Climate Refugees but rather Climate Warriors……

Who are never hopeless while fighting with climatic catastrophes

Chapter ONE
Introduction

1.1 Background

The world is undergoing a broad set of global changes, like changes in population density, climate, resource use, land use, biodiversity, and urbanization and globalization processes. Climate change is one of the drivers of global change, which has over the years been received strong focus by scientists, policy-makers and leaders of the world (Vitousek, 1994). At present climate change is considered as emerging global threat that not only induces physical environmental impacts but also affects the social structures, economic factors and the overall development process (Birkmann and von Teichman, 2010). This emerging threat has introduced a new social community named *'Climate Refugee'* especially for the affected developing nations. The UN currently states that more refugees are displaced by environmental catastrophes than wars, and the number of the climate refugee is more than 25 million which is likely to become 50 million in coming decades (Myers, 2002). Out of those 25 million people about 10 million are from Africa who are directly affected by the climate change via droughts. The second largest group is from coastal areas of Asian countries, who are affected by natural disasters like cyclones, storm surges, floods, salinity and droughts (Anon, 2010).

The cumulative effects of climate change exacerbate food and water insecurity, loss of biodiversity and ecosystem, environmental degradation and human insecurity through social conflict, political conflict and violence in the affected developing countries (Adger and Kelly, 1999). Hence, the socioeconomic structures are undermined in these countries where the affected people are compelled to switch over occupations for livelihood. These are the people who can no longer ensure a secure livelihood in their origin of dwelling (Myers, 2002). Together with climate change effects, population pressure problem and hardcore poverty have induced a notable change in the whole economic structure of these countries. As a result, these countries are suffered from chronic socio-economic inequality and social instability (Barnett and Adger, 2007).

Bangladesh often makes top news all over the world. However, unlike most other countries, it is not because of politics but for devastating natural catastrophes causing huge death tolls and massive destruction. This South Asian LDC, since her independence in 1971, has been struggling with a number of socioeconomic and socio-political problems such as- rapid population growth, poverty, illiteracy, gender disparity, slow economic growth, institutional inertia, political instability, violence and so on. But from last two decades she started struggling with a new problem- the adverse effects of climate change in the form of natural disasters (Miliband and Alexandar, 2009). Over the last two decades these disasters have become regular phenomena contributed miserable suffering to millions of inhabitants who are vulnerable to the climatic shocks (GoB, 2005a). In other words, climate risk for Bangladesh is relatively higher than most other countries of the world. The *Global Climate Risk Index* prepared by Germanwatch shows that Bangladesh is at top of the ranking of most affected countries by climatic extreme events over the last two decades. Table 1.1 shows the overall ranking made by Germanwatch.

Table 1.1 Long term Climate Risk Index (CRI) for most affected countries for period 1990-2008

CRI 1990-2008	Country	CRI Score	Death toll*	Deaths/thousand*	Total looses in million US$ PPP*	Losses per GDP in %*
1	Bangladesh	8.00	8,241	6.27	2,189	1.81
2	Myanmar	8.25	4,522	9.60	707	2.55
3	Honduras	12.00	340	5.56	660	3.37
4	Vietnam	18.83	466	0.64	1,525	1.31
5	Nicaragua	21.00	164	3.37	211	2.03
6	Haiti	22.83	335	4.58	95	1.08
7	India	25.83	3,255	0.33	6,132	0.38
8	Dominican Republic	27.58	222	2.93	191	0.45
9	Philippines	27.67	799	1.11	544	0.30
10	China	28.58	2,023	0.17	25,961	0.78

* Annual
Source: Germanwatch, 2010

On basis of above-mentioned table, it is easy to apprehend why Bangladesh was cited numerous occasions in COP15 held in Copenhagen in 2009. At present this country is more likely to be exposed towards climatic extreme events than most of the countries in the world (UNFCCC, 2009a). These events, in form of natural disasters range from ravaging cyclones to devastating floods (Muhammad, 2007). Following Table 1.2 provides an overall idea on most devastating disasters occurred in Bangladesh since early twentieth century. This table shows that the most common disasters are flood and cyclone. Recent IPCC assessment reports (TAR, 2001 and AR4, 2007) also reveal that over the last two decades both of the above-mentioned disaster-events have become more frequent and devastating for Bangladesh. It is learnt from IPCC reports that 5-10% increase in wind speed is very likely during the cyclone-season in Bangladesh that would eventually enhance storm surge and coastal flooding, while 10-20% increases of wind intensity can cause floods both in coast and inlands as the cyclone makes land fall (Agrawala et al., 2003). It has been assessed that an increase of 2º C temperature and a 0.3 m sea level rise would cause a cyclone in the costal

Table 1.2 Disaster-log in Bangladesh since early 1900s

Disasters	Time		Disasters	Time
Epidemic	1918		Cyclone	24-5-1985
Drought	1943		Flood	22-7-1987
Cyclone	October 1942		Flood	August 1987
Cyclone	28-5-1963		Flood	June 1988
Cyclone	May 1965		Cyclone	29-4-1991
Cyclone	June 1965		Cyclone	15-5-1995
Flood	July 1968		Flood	5-7-1998
Cyclone	12-11-1970		Flood	September 2000
Flood	July 1974		Flood	20-6-2004
Drought	July 1983		Cyclone	15-11-2007
Flood	May 1984		Cyclone	27-05-2009

Source: EM-DAT, 2010

belt of Bangladesh as strong as cyclone of 1991; furthermore, such a cyclone is likely to result in a 1.5 m higher storm surge that may inundate 20% more land than 1991 cyclone (Ali, 1996). The most recent example of costal cyclone as possible effect of climate change is SIDR which battered the coastal belt in Bangladesh on 15th November 2007. The wind speed was about 220 to 240 km/hour and at least 3,113 people were reported as dead and more than 10,000 were missing; the damage due to this disaster had been around US$ 2.3 million (EM-DAT, 2009). The intensity of SIDR was not less than the 1991 cyclone in some part of the coastal areas and the impact was even more than that. Furthermore, on 27th May 2009, another devastating cyclone named AILA hit the South-western part of Bangladesh and West Bengal of India, which exacerbated the suffering for the affected people in Bangladesh; although an early warning system enabled the evacuation of an estimated 2.7 million people to higher ground and cyclone shelter-houses (BBC, 2009). It is predicted that a single meter rise of sea level would inundate more than 18% of the coastal belt and will affect 11% of the total country's population. Two-third of the whole country is only 10 m above the sea level; therefore, about 13 million of the total population may likely to be homeless and become environmental refugees as the victim of climate changing process (Huq et al., 1999). Khulna and Barisal, the costal divisions of Bangladesh are relatively disaster-prone, where about 3.2 million people are at risk and about one-eighth of the country's agricultural lands and more than 8,000 communication networks are likely to be affected due to climate change effects (Parvin et al., 2010).

1.2 Statement of the problem

About one third of the territory of Bangladesh is delimited as coastal areas which are combined of distinctive opportunities, diversified threats and vulnerabilities (Harun-or-Rashid et al., 2009). It is because coastal areas possess different geo-physical and environmental characteristics that distinguish the coastal zone from rest of the country. These distinctive characteristics are an interplay of tidal regime, salinity in soil and water, cyclone and storm surge; with economic and social implications on the population (PDO-ICZMP, 2003). Hence, such identical geo-physical pattern has introduced a completely different livelihood pattern, where people are involved with selected coastal economic activities like fishing, salt production, fry collection from the sea and resource collection from the adjacent mangrove forest (Ahmed, 2003, Islam, 2004).

Although the coastal areas are much more fertile land for agricultural production, these areas are relatively income-poor compared to the rest of the country. Average per capita GDP (at current market price) in the coastal zone was US$ 402 in 2008, compared to US$ 621 for the whole country on average (CDP, 2009, GoB, 2009a). There are ten different ethnic communities living in the coastal zones and they have complete different cultures and livelihood patterns. Along with the non-tribal people, those ethnic communities completely depend on the coastal natural resources for their livelihood (Kamal, 2001). Their despair and dream, plight and struggle, vulnerability and resilience are uniquely revolved round in an intricate ecological and social setting which make their livelihoods distinctive from other parts of the country to a considerable extent.

The Government of Bangladesh has already recognized coastal zone as areas of enormous potentials. In contrast, these areas are lagging behind in socio-economic development and vulnerable to different natural disasters and environmental degradation (Selvaraju et al., 2006). For a LDC like Bangladesh where the climate change takes a shape of natural disaster not only affects the socio-economic condition of coastal communities but also hinders obtaining an optimal GDP growth (ADPC, 2007). Climate change poses a significant threat for Bangladesh, particularly the projected climate change effects include sea level rise, higher temperature, enhanced monsoon precipitation and run-off, potentially reduced dry season precipitation and increase in cyclone intensity in this region (Agrawala et al., 2003). Those threats would induce serious impediments to the socioeconomic development of Bangladesh including coastal areas. A subjective ranking of key climate change effects for coastal Bangladesh identifies cyclone and sea level rise as being of the highest priority in terms of severity, certainty and urgency of impact (Parvin et al., 2009).

The National Adaptation Program of Action (NAPA) and other scholars have identified the coastal areas of Bangladesh as one of the most affected areas in the world due to the threats of climate change effects (GoB, 2005a). In the southwestern part of Bangladesh the physical isolation of coastal communities makes them highly resource-dependent available around the coast and adjacent mangrove forest (the *Sundarbans)*, which reduces their opportunities to access to alternative livelihoods indeed. These hindrances make the coastal communities vulnerable to any disruption, especially to natural catastrophes. As a result, households in coastal communities suffer from an imbalance of social and economic powers, lack of participation in decision-making, limited or zero asset ownership, and laws and regulations influencing people's ability to use assets or access to resources (Pomeroy et al., 2006).

1.3 Justification of the study

So far only a few studies have been conducted on coastal Bangladesh. These studies are mainly conducted on hazard warning and evacuation system (Paul and Dutt, 2010), health security due to disaster (Ray-Bennett et al., 2010), physical injuries during cyclones (Paul, 2009), and coastal hazards and community-coping method (Parvin et al., 2009). So, most of these studies focused on the coping and adaptation mechanisms in coastal areas. However, we hardly find any study that addressed the socioeconomic vulnerability in local level of coastal zone, especially in the southwestern part of Bangladesh. Hence, without identifying local-level vulnerability patterns the suggested coping or adaptation mechanism is likely to be least effective in reality. In this study we attempt to fill up the knowledge gap by identifying quantitative local-level vulnerability at first; then we try to look for optimal adaptation options based on empirical relationship between vulnerability and important socioeconomic parameters. Therefore, this study is an interdisciplinary one where we select *Koyra* upazila as our study area, which one of the most disaster-prone areas in southwestern coastal zone of Bangladesh.

1.4 Research questions and objectives of the study

Considering all the above-mentioned facts, we proceed with the discovery of logical answers of following research questions;

- What is the symptom of climate change in the study area?
- Which major climatic factors constitute for climate change here?
- Which factors exacerbate such vulnerability? Is there any single factor or multiple factors?
- What is the nature and magnitude of relationship between this vulnerability and socioeconomic factors in the study area?
- What are the possible adaptation options in terms of capacity for the vulnerable households in study area?

The above-mentioned research questions are addressed by the study objectives. Hence, the main study objectives are;

1. To understand and figure out the manifestation of climate change in the study area,
2. To quantify socioeconomic vulnerability and assess the nature and magnitude of the relationship between vulnerability and major socioeconomic parameters of the study area, and
3. To identify and recommend the optimal adaptation options in terms of capacity of households in the study area while addressing socioeconomic vulnerability.

1.5 Outline of this study

This study consists of nine chapters. Let us have a glimpse at the brief contents of all the chapters chronologically.

Chapter one is the introduction. It provides an overall picture on Bangladesh's status in relations with climate change effects. We briefly discuss about the problem statement and then we identify the possible knowledge gap of socioeconomic vulnerability in the study area. We conclude this chapter by mentioning a number of research questions, which are addressed by three main objectives of this study.

In Chapter two we focus on the theoretical background and theoretical framework for this study. Under theoretical background we mention and briefly discuss relevant literatures in accordance with our study objectives. Then we depict the theoretical framework for this study, which is used for quantifying socioeconomic vulnerability of the study area.

We mention about the methodology of this study in Chapter three. In this chapter we focus on types of research that we have adopted in this study. Then in accordance with study objectives we mention associated data type, collection techniques and data sources. We also mention the sampling method and sampling size. The construction of vulnerability index is discussed in this chapter. Finally we conclude by mentioning the impediments those we faced while accomplishing this study.

Chapter four deals with the description of study area *Koyra*. We mention important information about geographical location, administration, topographic, physiographic and socioeconomic condition. We include a 'Disaster Calendar' for our study area that we made by collecting information from households.

Chapter five deals with the identification of climate change effects and quantification of socioeconomic vulnerability at local level of study area. In this we show possible climate change effects in the study area based on empirical data and Focus Group Discussion (FGD) findings. Later we quantify vulnerability for each union by applying the Vulnerability Index. We show union-wise vulnerability with the help of maps.

Once we have quantified vulnerability, we conduct a number of econometric analyses in Chapter six in order to show relationship between vulnerability and important socioeconomic parameters of study area. We mention the major findings from analyses in two different tables. We also put brief explanation of models and variables used in this study.

In Chapter seven we discuss the major findings obtained from model analyses in elaborated way. Here we also mention the possible reasons behind the nature and extent of relationship between vulnerability and socioeconomic parameters of study area. At the end of this chapter we check the consistency of the vulnerability index by applying an alternative approach. Subsequent regression coefficients of alternative approach are also tested and compared with the old model results.

Based on the results of the relationship mentioned in chapter six and seven; we recommend the optimal adaptation options for the affected people through brief description in Chapter eight. We also draw few of our recommendations on basis of correlation between different variables. The existing adaptation options in study area are also mentioned in Chapter eight.

We conclude this study in Chapter nine. We summarize major findings from this study in a nut shell. Besides, we focus on shortcomings of the approach we used to quantify vulnerability. In fine we mention the issues that we did not address in this study where further research can be conducted.

Chapter TWO
Theoretical Background and Framework

2.1 Preamble

The term 'Climate change' refers to, in general, the variation in behavioral pattern of earth's climate-attributes over time (Adger, 1999). As a result of mounting concern on this issue, it has drawn the attention of researchers from different domains to study this phenomenon, and vulnerability for human created by it (Agrawala and van Aalst, 2008). Besides, means of humans' coping capacity in adapting to effects of climate change is emphasized by researchers. There exist an increasing number of literatures on this issue. In this chapter we construct both theoretical background and theoretical framework for this study. In this context, first we have divided the available relevant literatures into three groups in accordance with study objectives; then we go for a framework for this study. For theoretical background the first group of literatures deals with the manifestation of climate change in general; the second group deals with vulnerability concepts and dimensions; and the third group focuses on adaptation concepts in terms of capacity.

The notion of climate change sometimes possess bewildering array of terms with diversified meanings as used in different contexts by different authors. However, in this study we use the most relevant terms consistent with our research context. Therefore, the frequently used key terms for this study are 'climate change', 'vulnerability', 'adaptation' and 'adaptive capacity.'

2.2 Theoretical background for the study

2.2.1 Key concepts and literatures for first objective

There are two terms- 'climate change' and 'climate variability' used interchangeably in most cases. However, there exists a sharp distinction between them considering respective sources- the former is taken place due to various anthropogenic actions whereas the latter is due to solely natural actions. In this study we use the term 'climate change' assuming that it is the resultant of both anthropogenic and non-anthropogenic activities.

Quite interestingly, the most two notable definitions on climate change by IPCC and UNFCCC differ from each other. IPCC defines climate change as 'any change in climate over time, whether due to natural variability or as a result of human activity' (IPCC, 2007c). On the other hand, climate change is defined by the UNFCCC as 'a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods' (IPCC, 2007c). To begin with, a brief description of IPCC is presented along with observed and predicted results related to climate change.

The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 by the World Metrological Organization (WMO) and the United Nations Environment Program (UNEP) when they notified the problem of changing trends of global climate. Their function is to assess scientific, technical and socioeconomic information relevant for the understanding of climate change. Furthermore, IPCC also deals with potential impacts of climate and options for adaptation and mitigation based on the peer reviewed and published scientific/technical literature (IPCC, 2008). Therefore, IPCC does not conduct original research; rather it releases assessment reports prepared by contributing authors that summarizes the latest findings on climate change. So far IPCC has published four assessment reports revealing the scientific information on climate change, scientific-technical-environmental-economic and social aspects of the vulnerability and mitigation to climate change. These reports discloses new findings from the previous years' research. The *First Assessment Report* (FAR) was released in August 1990, *Second Assessment Report* (SAR) in December 1995, *Third Assessment Report* (TAR) in 2001 and most recently *Fourth Assessment Report* (AR4) in 2007 (Mohamed, 2008). The following subsections are mainly based on the observed evidence and projected scenarios for climate change by IPCC.

Greenhouse gas (GHG) emission

These gases present in atmosphere are responsible for reducing heat-loss into space and consequently contribute in raising global temperature. High concentration of GHGs in atmosphere is supposed to absorb more solar energy re-radiated from the earth making more energy available to existing climate system. The major global anthropogenic GHGs contributing in climate change are- carbon dioxide (CO_2), methane, ozone (O_3) and nitrous oxide (N_2O). assessment of IPCC indicate that anthropogenic GHGs are main culprits to observed climate change since industrial revolution era.

> *The balance of evidence suggests that there is a discernible human influence on the global climate change.*
>
> *(Second Assessment Report of IPCC, 1995)*

More strongly,

> *There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities.*
>
> *(Third Assessment Report of IPCC, 2001)*

And most recently,

> *Several of the major greenhouse gases occur naturally but increases in their atmospheric concentrations over the last 250 years are due largely to human activities.*
>
> *(Fourth Assessment Report of IPCC, 2007)*

In the latest assessment report IPCC discloses that the global atmospheric concentrations of carbon dioxide and nitrous oxide have gone up remarkably due to human activities since 1975 and that fossil fuel combustion (accounting for 2/3rds of carbon dioxide) and land use change (1/3rd of carbon dioxide) are the major sources of anthropogenic carbon dioxide emission (IPCC, 2001, IPCC, 2007a).

Temperature

IPCC assessment report results in 2001 indicate an increase in the global average temperature, which gears up turbulence in the climatic system resulting more frequent and intense storm activity (IPCC, 2001). This report also discloses that the global average air temperature has increased by 0.6° Celsius over the 20th century. The cause of such warming has been identified as mainly increasing atmospheric emission of GHGs. TAR (2001) concludes that the 'most of the warming over the last 50 years is *likely* to have been due to the increase in GHGs concentrations' and most recently IPCC AR4 (2007) reveals that it is not *likely* but ***very likely*** that the most of the observed increase in global average temperature since the mid of 20th century is due to increase in anthropogenic GHGs concentrations. For the Bay of Bengal, which is a part of Indian Ocean region (The Indian ocean region in IPCC refers to the area between 35°S to 17.5°N and 50°E to 100°E), temperature is expected to increase by 2.1° Celsius for the 2050s and 3.2° Celsius for the 2080s (Nurse and Sem, 2001). The estimated projection for the low scenario is 1.8° Celsius and for the high scenario is 4.0° Celsius (IPCC, 2007b).

Sea level rise

One of the most notable projected impacts of climate change is sea level rise which may induce inundation of coastal areas and low-lying islands, shoreline erosion, and destruction of important ecosystems such as wetlands and mangroves. With the increase in global temperature, sea level rise already underway is expected to accelerate due to a thermal expansion of upper layers of the ocean and melting of glaciers. Out of the many factors contributing to sea level rise, according to IPCC the most significant two causes are thermal expansion of the oceans (water expands as it warms) and the loss of land-based ice due to increased melting (the exchange of water between oceans and other reservoirs) (IPCC, 2007d). The IPCC has developed different future scenarios on the possible sea level rise up to year 2100. The following figure 2.1 shows the global mean sea level in the past and as projected for the 21st century.

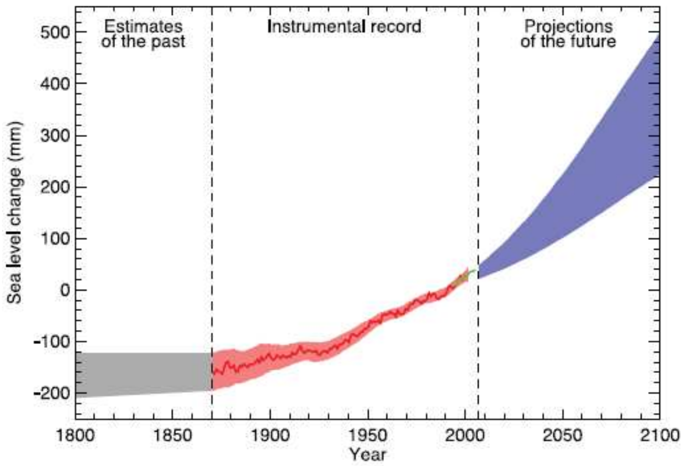


Fig 2.1 Estimated and projected sea-level rise
Source: IPCC, 2007d

In 1990 IPCC estimated scenario for the year 2100 was a global sea level raise of 66cm with high and low estimation of 110 cm and 31 cm respectively (IPCC, 1990). In 2001, IPCC predicted a global sea level rise between 9 and 85 centimeters by 2100 and the IPCC AR4 firmly reported that global mean sea level has been rising. It reported that from observation since 1961, the average temperature of the global ocean has increased to depths of at least 3000 m and that the ocean has been absorbing more than 80% of the heat added to the climate system causing sea water to expand contributing to sea level rise. From 1961 to 2003 the average rate of sea level rise was 1.8 ± 0.5 mm per year and the average rate of 1.7 ± 0.5 mm per year for the 20th century (IPCC, 2007b). Thus, IPCC concluded that the rate of sea level rise has increased between the mid-19th and the mid-20th centuries and that global sea level is projected to rise during 21st century at greater rate than during 1961 to 2003.

Extreme weather events

Climate change is being increasingly discussed in terms of extreme events and associated impacts from where a number of potential climate change effects have been identified such as-rising sea levels, changing rainfall patterns and temperature rise as mentioned above.) It is pointed that these wide range of potential impacts are likely to experienced by individuals and countries in two main ways- either as a change in average climate conditions (which is often referred to as slow onset change), or as an increase in sudden, extreme events (Tompkins and Neil Adger, 2005). Examples of slow onset changes and sudden, extreme events along with its socio-economic impacts are shown in figure 2.2. The IPCC assessment reports made it clear that climate change, indeed, is happening and the observed evidence on the major causes of the change in climate, namely- GHGs emission through different anthropogenic activities has increased (IPCC, 2001, IPCC, 2007a). As reported by IPCC AR4 that it is very likely that hot extremes, heat waves and heavy precipitation events will continue to become frequent; and moreover, the future tropical cyclones will likely be more intense having larger peak wind speeds and more heavy precipitation associated with ongoing increased of tropical sea surface temperature (IPCC, 2007d).

Extreme weather events play an important role not only in climate change issue but also in public forums regarding the impacts of global warming. The extreme climate events can be pointed out as extreme daily temperatures, extreme daily rainfall amounts, large areas experiencing unusual warm monthly temperature, or even storm events such as hurricanes (Easterling et al., 2000). Along with changes in average temperature, increase GHG concentrations in

Table 2.1 Observed and projected change in extreme weather and climate events by AR4 of IPCC

Phenomenon and direction of trend	Likelihood that trend occurred in late 20th century (typically post 1960)	Likelihood of future trends based on projections for 21st century
Warmer and fewer cold days and nights over most land areas	Very likely	Virtually certain
Warmer and more frequent hot days and nights over most land areas	Very likely	Virtually certain
Warm spells/heat waves. Frequency increase over most land areas	Likely	Very likely
Heavy precipitation events (or proportion of total rainfall from heavy rainfalls) increase over most areas	Likely	Very likely
Areas affected by droughts increases	Likely in many regions since 1970s	Likely
Intense tropical cyclone activity increase	Likely in many regions since 1970s	Likely
Increased incidence of extreme high sea levels (excluding Tsunami)	Likely	Likely

Source: IPCC, 2007b

the atmosphere are likely to bring changes in climate variability and extreme events. Projected changes in extreme weather and climate events in the 21st century include more frequent heat waves, less frequent cold spells, greater intensity of heavy rainfall and greater intensity of tropical cyclones (IPCC, 2001). Tropical cyclones are predicted to be enhanced in intensity by 10 to 20% (Nurse and Sem, 2001). The IPCC AR4 has referred clearly what are expected from climate change in terms of weather events, where the possibility of heavy precipitation events is *very likely* and increase in the intensity of tropical cyclone is *likely* for the current century. Table 2.1 gives a clear scenario regarding various weather and climate events.

2.2.2 Key concept and literatures for second objective

The second objective of this study deals with quantitative features of vulnerability and inter-relationship between vulnerability and various socioeconomic parameters. There are a number of dimensions such as- environmental, physical, political, social etc. to define peoples' vulnerability. In this study we mainly focus on socioeconomic dimension of vulnerability of the study area.

According to the IPCC SAR-1995, *Vulnerability* is defined as 'the extent to which climate change may damage or harm a system; it depends not only on a system's sensitivity but also on its ability to adapt to new climatic conditions.' Sensitivity, in this case, is 'the degree to which a system will respond to a change in climatic conditions' (IPCC, 1995). From this point of view, the definition of vulnerability must be contingent on estimates of the potential climate change and adaptive responses (Adger and Kelly, 1999). However, in the mid-1990s the concept of vulnerability to climate change was constructed by Neil Adger in terms of the physical aspect, such as- land area lost or agricultural production damaged due to extreme climate events (Adger, 1996). He differentiated two types of vulnerability- individual and collective on basis of key dimension in construction of vulnerability. He then defined *'Social Vulnerability'* as exposure of individuals or groups to stresses from exogenous risks, especially from climatic shocks which paves the way for social marginalization.

Neil Adger again reviewed the concept of *'Vulnerability'* and drew the attributes revolve round it. To him vulnerability is usually portrayed in negative notion as susceptibility of being harmed. Generally this term is applied together with environmental variation, more specifically, when climate change issues are taken into consideration (Adger, 2006). The concept *'Vulnerability'* is considered as a powerful analytical tool for disclosing states of susceptibility to harm, power discrimination and marginality of both physical and social systems. However, the pattern of vulnerability may change over time and thus, challenges for vulnerability are also changed.

Figure 2.2 shows how various sudden and slow events, originated from climate change, affect various factors in the society and therefore, create vulnerability.

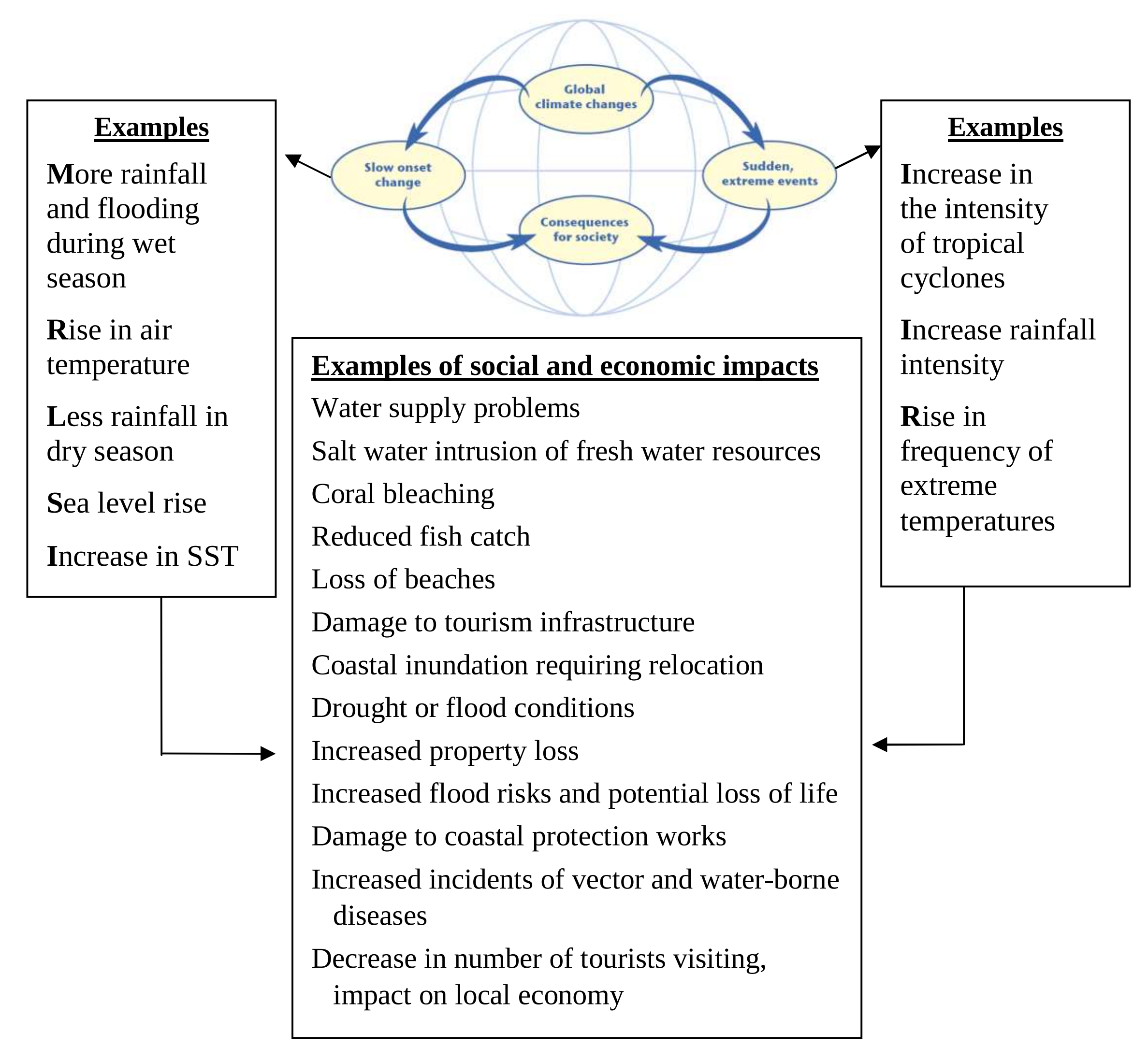


Fig 2.2 Relationship among climate change impacts, human experience and social consequences
Source: Tompkins et.al., 2005

Yamin et .al. defined vulnerability as a consequence of climate change and indeed, an impediment for development process in any country (Yamin et al., 2005b). The effects of climate variability manifest themselves floods, droughts, irregular rainfall, extreme events etc., which make the poor communities vulnerable in developing countries. Hence, these communities experience disproportionately higher levels of mortality, social discrimination and economic interruptions (Yamin et al., 2005a).

Again *Vulnerability* is defined by Neil Adger as an exposure of individual or collective groups to livelihood stress as a consequence of environmental variability (Adger, 1999). He argued that vulnerability is often the resultant from social norms, political institutions, resource endowment, technologies and discriminations during and after a climatic shock. Therefore, the extent of vulnerability is governed by the efficiency of institutional arrangement in the concerned disaster-affected areas. From this perspective institutional context of vulnerability to climatic shocks is a pivotal element. Hence, vulnerability can be explained through a combination of social institutional factors and environmental risks. Adger also argues that vulnerability is closely associated with the notion of development, which is actually a proxy for adjustments to livelihood condition. He kept arguing that institutional inertia might affect the socio-political harmony and thus, high level of rent-seeking may jeopardize the welfare maximization; which in turn escalates the vulnerability (Adger, 1999).

A study by Ibarraran et al. shows that climate change induced vulnerability affects different localities in different ways. They emphasize *'Resilience'* to face the vulnerability while developing a *Vulnerability-Resilience Indicator Model* for Mexican states and picked the important resilience factors that might be useful to face the challenges of vulnerability (Ibarrarãn et al., 2009).

A new dimension of vulnerability is introduced by Barnett in terms of the human security problem. He explains that increasing climate change trends undermines human security by reducing peoples' access to, and quality of natural resources that are essential for sustaining livelihood. At the same time climatic catastrophes hamper the capacity of the states in providing opportunities and services to people to secure their livelihood. In many a cases there is high risk of violent conflict within the communities that eventually hampers the peace in the society (Barnett and Adger, 2007).

An alternative dimension of vulnerability is introduced by Adger and Kelly on basis of capacity. They underpin vulnerability in terms of capacity of individual and social groups to respond to *i.e.* coping with, recovering from and adapting to any external shocks that may affect their livelihood or well-being. In this context, resource accessibility for the groups is considered as a key determinant for vulnerability. They focus on the land ownership pattern as a capacity indicator, which finally indicates the extent of resource accessibility (Adger and Kelly, 1999).

The association between climate change and vulnerability in terms of poverty is analyzed and explained in a study using a 30-years time series data, by applying GTAP (Global Trade Analysis Project) model simulation. This study shows that with the increase in climatic extreme events the agricultural productivity is hampered and as a result the prices for staple foods also go up, which in deed, enhances poverty. Therefore, the poor communities become the sufferers due to such climatic shocks. Their study results on seven socioeconomic groups in 16 developing countries showed that in short run extreme climate variations might affect the factors related with livelihood pattern of the poor people that exacerbates the vulnerability of marginal people in the communities (Ahmed et al., 2009).

A remarkable study is conducted in Bangladesh by Brouwer *et. al.* where they show that households with lower income and less access to productive resources are more vulnerable in terms of climatic risk exposure. Besides, both income and asset disparity induce the households to be more exposed to various risks and thus, become more vulnerable. They also show that under the climatic shock, and with presence of income and asset disparity, individual households become more vulnerable at collective or community level since the collective level is least capable to face a common shock like cyclone or flood (Brouwer et al., 2007).

2.2.3 Key concept and literatures for third objective

The third and last objective of this study deals with adaptation options in terms of capacity. Depending on the pattern of vulnerability, adaptation options also differs and hence, there are diversified concepts of adaptation. However, we only consider the adaptation concepts consistent with our study. According to UNFCC adaptation is a process through which societies make themselves better able to cope with an uncertain future. Thus, adapting to climate change involve taking the right measures to reduce the negative effects of climate change by appropriate adjustments and change which includes national, local and individual level measures (UNFCCC, 2009b).

Considering the climate change phenomenon, the issue of response capacity is mentioned by Tompkins. As a part of risk and resource management, adaptation and mitigation actions are usually taken. By contrasting Tompkins portrayed a set of responses in national level as a trade off between development investment and new technology diffusion, and investment in enabling society to change its behavior towards new technology adoption (Tompkins and Neil Adger, 2005).

Agrawala focused on adaptation for climate change induced vulnerability. He dealt with the potential barriers in mainstreaming adaptation. From a cross-country analysis he tried to figure out synergies and trade offs involved with integration of adaptations to climate change from the perspective of development cooperation activities, and in this way major barriers were indentified. He showed that countries more dependent on climate-sensitive natural resources are more likely to be vulnerable to climate shock. This study suggests that through better and efficient integration of climate risk management it is possible to development efforts for effective adaptation in disaster-prone areas (Agrawala, 2004).

Targeting the climate change vulnerability, a community-based adaptation model is suggested by IIED (International Institute for Environment and Development). In a report IIED mention several incapability of the poor which lead them to be more vulnerable to the climate shock. Considering all these factors IIED suggest a new approach for community-based adaptation, which is a bottom-up one. The bottom-up approach is quite able to adopt the proper action/strategy required for a successful adaptation. The major international contributor like World Bank still formulates a top-down approach in this case and thus, in many regions or countries the adopted actions fail to reach the objectives (IIED, 2009).

Hubner mentions that communities respond to disasters by the strategies of- reducing consumption, drawing from savings, selling productive assets, migration, and borrowing money. But the lower income population has neither savings to utilize nor the resources to migrate. Hence, their remaining options force them to abate in both current and future consumptions. He concludes that-

> *There is a disconnection between large-scale surveys reporting aggregate recovery and micro-level research implying long-term reductions in consumption. If an economy recovers evenly across all income levels, then we should see no long term changes in income distribution or consumption. However, if assets are flowing from lower to higher income deciles, then we should see increased income inequality and lower consumption marked by increased volatility at lower income deciles.* (Hubner, 2008)

A remarkable work on strengthening local capacity to cope with disaster (flood) is done by R. Few where he chalks out the growing tendency for interventions to prioritize strategy at the local level. Few recommended adaptation policy to challenge vulnerability, where strengthening the capacity of local people is emphasized (Few, 2003).

A theoretical perspective on institutional adaptation to social vulnerability to environmental shocks is mention by Neil Adger where institutional role in resource allocation is taken into consideration. In this work the adaptation of institutions to mediate vulnerability to climate change is observed through assessing the resource allocation and decision-making process by the institutions. In the context of economic and political transitions how effectively the coping and adaptation strategies work is examined in this study. Besides, how institutional inertia may affect coping capacity of the distressed communities is also explained (Adger, 2000).

Huq and Reid have worked on the classification of adaptation strategies. Side by side, they also focused on mitigation process considering on-going climate change process in the world. In the words of Huq, adaptation classifications are-

> *1. Anticipatory adaptation vs. reactive adaptation: Anticipatory adaptations are ones which are taken in anticipation of expected climate change impacts. Reactive adaptation occurs after the impacts have taken place.*
>
> *2. Adaptation to climate change vs. adaptation to climate variability: The former refers to adaptation to anticipate human induced climate change, whereas the latter refers to adaptation to naturally occurring climate variability.*
>
> *In practice, there is little difference between actions that would enhance adaptation to climate change and actions that would enhance adaptation to climate variability, but the distinction is significant in the context of funding for adaptation under the UNFCCC (which is supposed to fund the former but not the latter).* (Huq and Reid, 2004)

While dealing with 'Adaptive Capacity' Huq defines it as the ability of a community or a country to adapt climate change impacts. This capacity is again decomposed into two types- generic and specific; where the former refers to inherent or existing capacity of a community as a whole to cope with climate impacts assessed through levels of income, education, development etc. of the community or country; and the latter indicates the capacity of community or country coping with climate change impacts on basis of reckoning anticipated impacts of human-induced climate change (Huq and Reid, 2004).

On the ground of mainstreaming adaptation to climate change, Huq et al. mention the status of LDCs (group of poorest 49 countries). In this case they cited particularly Bangladesh and Mali since both of the countries made progress, although not at significant level, in introducing potential adaptation options. Nonetheless, there would remain much to be done in addressing adaptation in national level policy in terms of- relevant information on climatic risk for various stakeholders involved and policy-makers, role of civil society institutions, sharing the results of

NAPA with other countries, developing international negotiation capacities and playing more active role in funding issues (Huq et al., 2004).

Social capital and collective action are also suggested by Neil Adger as effective tools for addressing adaptation to climate change. In this case the unique feature of social capital, of possessing both public and quasi-public elements, is characterized in their role in developing bonding and networks in the society. By the dint of these social networks, communities are able to find strategies to manage climate change risks. The innate features of social capital, namely- trust, reputation, reciprocity etc. do have significant effect on social network formation through which resource accessibility in terms of property rights is ensured. Therefore, effective adaptation to climate change becomes robust once the role of social capital among communities is positive (Adger, 2003).

2.3 Theoretical framework

A major portion of this study revolves round a Vulnerability Index. Hence, the theoretical framework is about this index and its construction. As we have already mentioned in this study we will only deal with socioeconomic vulnerability, so the vulnerability for this study will only address the socioeconomic aspects of the study area.

We start with the idea of Pressure and Release (PAR) Model (Blaikie et al., 1994) for building a concept for vulnerability index. This PAR model is applicable for disaster-led vulnerability. The core theme of this model is that a disaster is the intersection of two opposing forces: the process generating vulnerability from one side, and the physical exposure to hazard from the other side. Increasing pressure can come from either side, however, vulnerability has to be reduced to relieve the pressure (Anon, 2008). Vulnerability is considered in three levels- root causes, dynamic pressures and unsafe conditions. The pros of this model are that it provides a possible complete view of vulnerability, it emphasizes the natural hazards and it gives a framework for inspecting vulnerability and livelihood. However, this model can not measure vulnerability without collecting and analyzing a great of data (Anon, 2008).

2.3.1 Model framework for this study

In this study we have adopted a Composite Indicator Framework Method, which is originally developed as *Community-based Risk Index* (Bollin and Hidajat, 2006). This method is used to assess vulnerability at local/community level and it resembles ‘vulnerability’ side of PAR model.

As we have already mentioned that vulnerability is considered in three levels in PAR model through a number of variables those show the levels of vulnerability. However, in this study we consider five Domains of vulnerability, where we also select a number of variables those address domains indeed. On the whole, in both the above-mentioned cases vulnerability is focused finally, but through slightly different approaches. We adopt this *Composite Indicator Framework Method* from a UNU (United Nations University) book edited by Joern Birkmann in 2006 (Bollin and Hidajat, 2006).

The *Community-based Risk Index* basically aims to identify and quantify the main risk factors like- exposure, vulnerability, management capacity etc. within a community (Birkmann, 2007). With the help of this index it is possible to compare risk-exposure levels between communities. At the same time it is also possible to figure out if this risk-exposure is an outcome of any hazard or natural disaster or vulnerability or capacity component (Bollin and Hidajat, 2006). Hence, this index consists of four basic components- hazards, exposure, vulnerability and capacity measure. There are a total of 47 indicators in this index which are further divided into factor-components/variables (Birkmann, 2007). The approaches used in this index can serve as important tool to identify and highlight the areas where both risk and vulnerability reduction are needed. Hence, this index provides comparative information on many aspects of disaster risk and vulnerability (Birkmann, 2007). However, there are some questions regarding the aggregation and choices for indicators under this index, which seem to be redundant to some extent and therefore, vulnerability and risk identification might not be accurate in all instances (Birkmann, 2007).

Since our main concern in this study is with vulnerability, we have adopted only the 'Vulnerability' component from this *Community-based Risk Index.* In original index, the vulnerability component is decomposed into four different thematic premises- physical, social, economic and environmental (Bollin and Hidajat, 2006). However, in this study we have modified the 'environmental' theme into 'disaster-exposure' and we have included 'demographic' as a new thematic area. We modify the original index in order to maintain relevance and applicability with the features/characteristics of our study area. Therefore, the modified approach in this study to identify vulnerability in numerical values consists of five thematic premises. We will define these premises as 'Vulnerability Domains,' and the new index as 'Vulnerability Index' in the following chapters. For each domain we select a number of relevant variables (see detail in Appendix I).

2.4 Summary

The literatures under theoretical background have chalked out the likelihood of climate change and its associated consequences on coastal areas and low-lying islands. Several authors have mentioned the vulnerability of Bangladesh to climate change. Due to unfavorable socioeconomic conditions the coastal people of Bangladesh are challenged with predicted sea-level rise, cyclone with storm surge and other consequences of climate change. From this perspective, vulnerability of these coastal people, in both household and community levels, and their coping capacity are important issues requiring urgent attention. Literatures also indicate the importance of adaptation and adaptive capacity in the coastal areas. In the next chapters we will see how our empirical findings comply with the issues addressed in the theoretical background. We are also interested to see the same in case of the theoretical framework for this study.

Chapter THREE
Methodology

3.1 Type of research

Research differs from field to field, approach to approach and nature of work. This study revolves round both descriptive and quantitative as it inclines for insights into the climate change induced vulnerability and its relationship with important socioeconomic factors in the study area. Hence, in this study we attempted to figure out the vulnerability magnitude in micro (union) level of study area. We further identified the nature and extent of influence of vulnerability on existing important socioeconomic factors; and finally we recommended possible adaptation options based on quantitative findings and outcomes of FGDs.

3.1.1 Descriptive research

Through this approach, we focused on features of study area such as location, area, proximity to the mangrove forest *Sundarbans* and sea along with other geophysical settings those make it vulnerable to climatic catastrophes. A list of disaster events and climatic trends was prepared from where the most frequent disasters, due to possible effects of climate change, were identified. We also tried to identify households' capacities in response towards such vulnerability in terms of adaptive options.

3.1.2 Quantitative research

Through this approach, we quantified vulnerability on basis of an index. Later we attempted in determining the relationship between vulnerability and important socioeconomic variables in terms of numerical values. Furthermore, we used these numerical values in drawing possible recommendation for study area.

3.2 Selection of the study area and criteria

Discrete selection of the study area is very much momentous for conducting any study. It is remarkable that the success of any research work in social science premises depends much on the proper selection of the study area (de Vaus, 2001). Throughout the coastal belt of Bangladesh, some particular areas are most affected by climate change induced disasters since most of these catastrophes usually pass over these areas. Therefore, we selected *Koyra* upazila which is a significant disaster-prone coastal area due to possible effects of climate change in Bangladesh. The other important reasons for choosing this upazila as study area were-

- It was one of the most frequently cyclone and storm-surge affected areas in Bangladesh

- There was hardly any previous research/study regarding vulnerability and its relation with socioeconomic parameters on this coastal area
- *Koyra* was one of the most affected areas because of super cyclones AILA and SIDR within the span of last three years.

3.3 Research objectives and methodology

The array of questions addressed in this study required systematic methodology in order to capture the existing facts. Hence, we followed a number of sequential steps to realize the objectives of this study. In this context, our aim was to figure out the existing vulnerability of the study area first, and then to relate vulnerability with a number of economic determinants with a view to explaining the nature and extent of this relationship. The detailed methodology to accomplish this study is mentioned in the following part.

The objectives of this study mentioned in chapter one include three broad areas: understanding the local climate change in contrast with global climate change issues, quantifying vulnerability and its effect on socioeconomic parameters, and adaptation options in terms of households' capacity to cope with climatic shock. We used different methods to understand and explain these areas which are shown in the following figure 3.1 using different stages and output of the research.

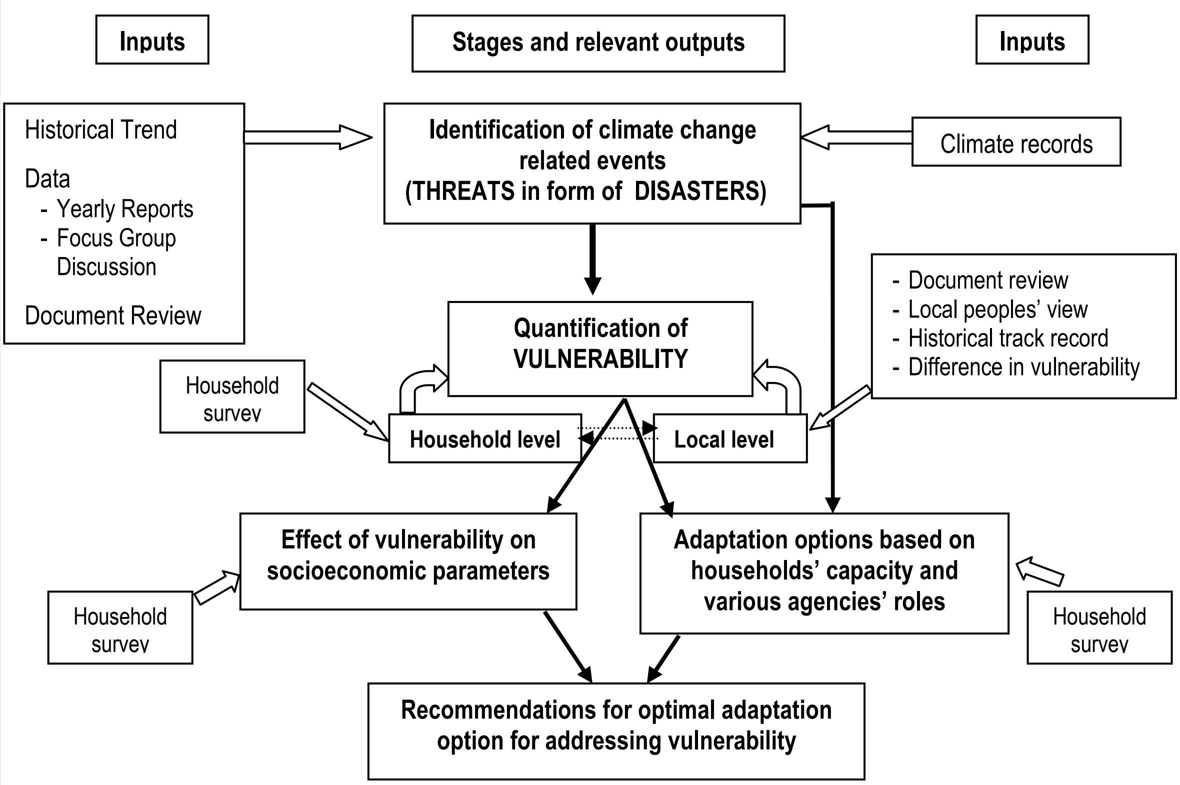


Fig 3.1 Methodological framework of this study

The methods applied in realizing the study objectives are detailed out below. With a view to realizing the objectives various types of data, data collection techniques and data sources were used. These different data-sets, concerned collection techniques and sources applied for each objective are explained in detail.

Objective 1: **To understand and figure out the manifestation of climate change in the study area.**

In order to understand the exposure of climate change, we selected the parameters associated with location, geological feature, climatic characteristics and disaster trends of the study area. Based on these parameters we aimed to understand if there is/are event(s) that are likely to be effects of climate change in this area.

Types of data: For understanding the effects of climate change, we collected historical disaster data. This particular dataset includes all the major disaster events occurred in our study area, which enabled us to understand and figure out the climate change related events. Moreover, we took the experiences of old-aged people through FGDs.

Data collection technique: Most data required for realizing this objective were collected by reviewing the concerned reports on climate trends. This required going through all the daily reports from local weather office, reports by Bangladesh Meteorological Department (BMD) and relevant literature on southwestern part of Bangladesh. Collected datasets included recorded temperature, rainfall, usual and unusual disaster events etc. of the study area. Besides, data on sea-level, an important indicator of climate change was collected from available online data bases. Side by side, interviews with the old aged people along with FGDs were conducted in order to have in depth understanding of effects of climate change.

Source of data: The local climate data were collected from BMD. Sea level, temperature and rainfall related data were obtained from online database of Dayton and Colorado University of USA. All the historical data were obtained through reviewing the available reports by BMD first, and then crosschecked with the outcomes from FGDs, where a larger percentage of participants were old-aged local people. Newspaper articles, NGO reports covering our study area were also examined. Some of the distinguished disasters of Bangladesh were reviewed from documents of UNFCCC and International Disaster Database (EM-DAT). We also consulted a number of IPCC assessment reports in order to check our study findings on effects of climate change with their assessment report findings and predictions.

***Objective 2:* To quantify socioeconomic vulnerability and identify the relationship pattern between vulnerability and major socioeconomic parameters of the study area.**

This research objective deals with numerical determination of climate change induced consequences in terms of vulnerability. Hence, we attempted to quantify the socioeconomic vulnerability applying an index in first phase; then we figured out relationship between vulnerability and socioeconomic parameters in our study area with the help of econometric models.

Types of data: In order to realize this objective, we mainly relied on primary data collected from households and outcomes from FGDs. Besides, some secondary data were also used along with primary data for developing the vulnerability index. Therefore, both primary and secondary data were used for vulnerability index. While assessing the relationship between vulnerability and various socioeconomic parameters we used primary data and numerical values determined from vulnerability index.

Data collection technique: In this case we considered mostly the variables which represent direct and indirect effects of climate change. It should be noted that we were only interested in socioeconomic context and thus, determining vulnerability we only took those variables representing socioeconomic aspects, not the environmental aspect. So, in order to quantify vulnerability we conducted questionnaire survey and FGDs. Besides, we collected required information from various published documents.

Source of data: Field level questionnaire survey with households along with group discussions with local people was the main source of primary data for this study. Moreover, for quantifying vulnerability we needed some secondary data that we had collected from population census, statistical bureau, local government reports and various post-disaster reports by NGOs.

***Objective 3:* To recommend the optimal adaptation options considering capacity of households.**

This research objective mainly focuses on figuring out available and possible adaptation options in study area. These options reflect the capacity of the climate-change affected households. In order to identify the adaptation options we first looked for the household-level consequences of climate change, then we triggered for optimal options that reflected the capacity of households.

Types of data: Considering climate change effects-led vulnerability in the study area, how the households had taken adaptive actions as per respective capacity was focused under this objective. Side by side, what measures had been adopted by government and NGOs while experiencing various climatic shocks were also investigated. The immediate actions taken in post disaster period by various public and private agencies were considered to get an overall idea regarding the responsiveness as well as consciousness of concerned agencies.

Data collection technique: To have a glimpse at adaptation options in terms of households' capacity, we collected primary data through questionnaire survey. Besides, we reviewed available relevant reports prepared by government and various NGOs focusing adaptation options in disaster-prone areas. We also interviewed a number of responsible personnel who were in charge of on-going adaptation programs in study area. However, the required information for this purpose was not well organized and systematic. Hence, we mainly depended on primary-data based analysis.

Source of data: Collection and compilation of primary data were accomplished through household questionnaire survey and a number of FGDs. Data indicating reported incidents and associated actions taken by various agencies were collected from reviewing available reports. Besides, newspapers reports and data presented in disaster-related seminars during our pre and post survey period were also taken as secondary data.

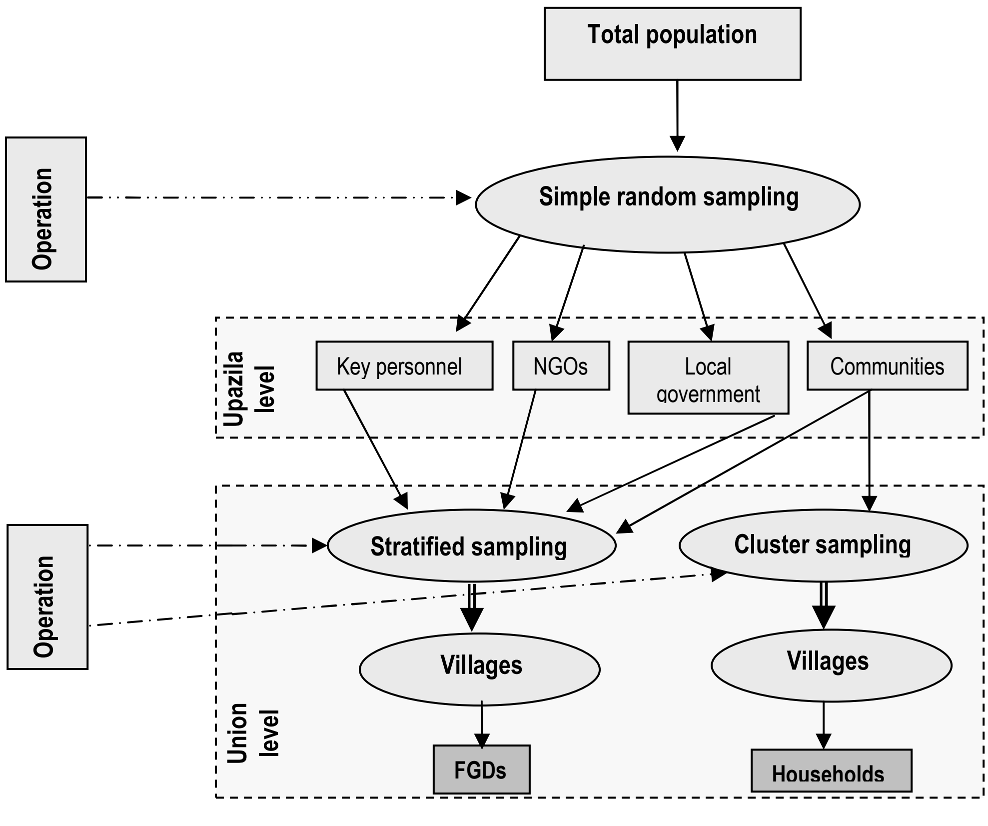
A summery of all types of data collected, respective techniques and sources are shown in flow diagram 3.1 in the following page.

Research objectives	Types of data	Collection technique	Data sources
To understand and figure out the manifestation of climate change in the study area	- Historical data on climatic disasters - Older peoples’ experience - Various published data - Events that affected households	- Daily reports from local weather office - Documents on climate trends (BMD and online data) - Interviews with old people	- Daily reports from local weather office - Recorded data on climate trends from USA university - Interviews with old people
To quantify socioeconomic vulnerability and identify the relationship pattern between vulnerability and major socioeconomic parameters of study area	- Demographic data - Social data - Economic data - Environmental data - Data showing households’ exposure to disasters	- Structured questionnaire - Reviewing government database	- Randomly selected households - FGDs - Government database - population census
To recommend the optimal adaptation options considering capacity of households	- Actions performed by households in post disaster period - Government’s actions - Private agencies’ actions	- Structured questionnaire - Reviewing government’s policy papers on adaptation - Interacting with various private agencies in study area	- Randomly selected households - FGDs - Government database - NGOs reports

Flow-diagram 3.1 Data collection framework

3.4 Sampling method

Since it was impossible to take into account the whole population of the study area, representative subsets from whole population were taken as samples. We maintained the following stages of sampling for conducting field survey and FGDs;



Flow-diagram 3.2 Sampling techniques

As we see from the above diagram that in the upazila level simple random sampling was applied. In union level stratified and cluster samplings were used. The former was adopted to conduct FGDs where participants from various levels attended; the latter was adopted for questionnaire survey from households. Hence, we conducted a 'Multi-stage random sampling' for this study.

3.5 Sample size

In this study we did not follow any established formula for sample size determination. Since the study area consists of 7 unions, we collected data from all of these unions. We randomly picked 60 households from each union. Hence, a total of 420 households were randomly chosen from the whole study area. During data collection once we picked a household for questionnaire survey, the very next one was chosen after ten households. We assumed that the number of households chosen from each union would reflect the real status of the concerned union. We conducted one FGD in each union and thus, total 7 FGDs were conducted. We ensured participation of people from all walks of life in each FGD so that we could grab the actual facts.

3.6 Data analysis techniques and tools

Once the collection and compilation of data were finished, we undertook the analyses using different tools. In this study we adopted both qualitative and quantitative approaches for analyzing and interpreting data. Qualitative approach was applied to chalk out specific features associated with different socioeconomic groups such as how the respondents acquired knowledge on coping with climatic shock (disasters), in present context which capacity of households might be developed in dealing with disasters and so on. We applied this approach mostly for summarizing the result from FGDs.

We applied quantitative approach in quantifying vulnerability and determining relationship between vulnerability and various socioeconomic parameters. In order to quantify vulnerability we used an index. Later we explained relationship between vulnerability and local socioeconomic aspects with the help of econometric model results.

3.6.1 Development of vulnerability index

This index was prepared by using a Composite Indicator Framework method, which was originally developed as *Community-based Risk Index* (Bollin and Hidajat, 2006). This risk index has some similarities with 'Disaster Pressure and Release Model' developed by Piers Blaikie (Blaikie et al., 1994). We adopted a part of *Community-based Risk Index* and modified it in accordance with relevant variables for our study area.

This Vulnerability Index consists of five domains- demographic, social, economic, physical, and exposure to natural disaster. Under each domain there are a number of relevant criterions, which are again divided in indicators (variables). These indicators/variables altogether possess certain characteristics of a specific domain in relation to climate variability and extremes (representing the household's sensitivity in relation to these components). Five domains, under this vulnerability index, comprise of 22 indicators/variables. A detailed list of domains, criterions and indicator/variables is given in table 3.1. We use the following formula, adopted from a study on water poverty index (Lawrence et al., 2003), to obtain an index value for each indicator;

$$\text{Indicator Index} = \frac{x_i - x_{min}}{x_{max} - x_{min}}$$

Where, x_i = original value of indicator for the household/community

x_{max} = the highest value of indicator for the household/community

x_{min} = the lowest value of indicator for the household/community

The indices therefore, produce numerical values showing concerned community's (obtained from aggregated response of households) relative position and for any one indicator this value lies between 0 and 1. The maximum and minimum values are usually adjusted so as to avoid values of more than 1. Any remaining values above 1 or below zero are fixed at 1 and 0, respectively.

Table 3.1 Domains, criterion and variables used in Vulnerability Index

Domain	Criteria	Variable / Indicator
Demographic	1. Density 2. Demographic pressure 3. Migration	1. People per km^2 2. % of old and children in the area 3. Male-female ratio 4. Population growth rate 5. % of households migrated to this area in last 5 years
Social	1. Literacy 2. Poverty level 3. Community participation 4. Attitude	6. % of illiterate households 7. % of households below poverty line 8. % households participated in the last local-election 9. % of households contributed free-labor to embankment construction or similar activity
Economic	1. Income source and employment 2. Housing condition 3. Land 4. Capital goods	10. % of households depend on natural source for their income (fisheries, agriculture etc.) 11. % of unemployed people (10+ years of age) 12. % of households not having brick-built house 13. % of households lost land (homestead and/or other) in last 5 years due to disasters 14. % of households suffered the damage or lost their capital goods (e.g. fishing boats, nets etc.) due to disasters
Physical	1. Social utility services 2. Infrastructural utility	15. % of households not getting electricity 16. % of households not having sanitary latrine 17. % of households use pond, river and well water for drinking 18. % of not-paved road in the area
Exposure to cyclone and storm surge	1. Population covered by cyclone shelter	19. % of households not willing to go to cyclone shelter 20. Provision of local early warning system 21. % households do not understand National Warning System 22. % households not having shelter in cyclone shelter or with neighbors

Source: Adopted from Bollin and Hidajat (2006) and modified

A number of outcomes from FGDs were used while developing the vulnerability index. Other than our own judgment, the local communities' perspectives are also taken into account in developing this index. Using the same set of indicators developed (and modified) by us, 7 separate FGDs are conducted in 7 unions in the *Koyra* upazila where participants are asked to provide their own weights for each indicator. Consensus was sought from the participants during the FGDs on specific weights that they should assign for each component indicators at various domain levels. Then the indicator weight is multiplied with the indicator index. In a row after getting all value by summation a domain wise vulnerability is calculated. In this way we obtain domain-wise vulnerability and total vulnerability for each union.

3.6.2 Data analysis tools

For data analysis and presentation we used different packages of software. We used MS Excel in developing vulnerability index, and then for showing the different vulnerabilities (union-wise) inside our study area we produced a number of maps using GIS. We developed these maps by using ArcGIS 9.1. For all econometric analyses in this study, we used a statistical package called STATA (version 10).

3.7 Limitations of the study

While conducting the study, especially the field survey, we had to experience a number of obstacles. Although these obstacles were not of high scale, however, we can consider those as limitations of this study. These are briefly mentioned in following part;

- During the survey some household-respondents thought that some kind of aid was coming for them and we were conducting the pre-assessment. We could realize that perhaps due to above-mentioned reason these respondents attempted to provide us such information that represented their worse condition. So we had to make some adjustment while compiling such data, although it happened in very few cases.
- We invited people from all walks of life to participate in FGDs. However, we found that several participants, who were actually nominated by the locally elected public representative, tried to influence our discussion. So for technical reason we had to exclude their opinions that seemed to be biased and in favor of that local public representative.
- In few cases we had requests from local political leaders from ruling party to conduct our surveys to the areas as they suggested. This was supposed to be an implied pressure from them. We had to conduct surveys to their suggested areas but finally we did not include any data from these surveys into our main database.
- We did not have sufficient budget to stay longer span and collect more data. Furthermore, during survey the temperature dropped down to less than 10^0C which was abnormal in winter season in Bangladesh. Such weather condition interrupted our survey.
- Time constraint had been a great challenge for us during the whole field survey.

Chapter FOUR
Study Area

4.1 Area and geographical location

Koyra Upazila is situated to the south west part of Khulna district. This upazila occupies an area of 1775.41 sq km. It is located in between 21°45' and 22°32' north latitudes and between 89°14' and 89°31' east longitudes. This upazila is bounded by *Paikgachha* upazila on the north, the Bay of Bengal and the *Sundarbans* on the south, *Dacope* upazila on the east, *Assasuni* and *Shyamnagar* upazila on the west.

4.2 Administrative units

Administration of Koyra upazila was established as *Thana* (kind of sub district) in 1980 and was turned into an upazila in 1983. This upazila consists of 7 union parishads, 72 mouzas[1] and 131 villages (BBS, 2007). The union named *Dakshin Bedakashi* is the last union to the south and *Amadi* union to the north.

4.3 Socioeconomic features of the study area

According to Bangladesh Population Census 2001 and as adjusted in 2007, total population of the study area is 165,473 where male is 49.68%, female is 50.32%. Density of population of the study area is 861 per sq. km, the growth rate is 1.7% per annum. The religious composition is- Muslim 74.29%, Hindu 25.35%, others 0.36% (BBS, 2007);

Table 4.1 Literacy conditions of 7 unions of the study area

Name of Unions	Literacy Rate		
	Male	Female	Total
Amadi	55.53	36.61	46.00
Bagali	53.41	36.95	44.87
Dakshin Bedakashi	46.23	30.53	38.35
Koyra	55.42	37.41	43.66
Maharajpur	54.42	35.95	45.13
Maheshwaripur	56.74	37.08	47.06
Uttar Bedakashi	51.94	34.01	42.96

Source: BBS, 2007

The average literacy rate in the study area is 44% where male and female occupy 53.4% and 35.51% respectively. There are a number of academic institutions comprising of 3 colleges, 22 secondary schools, 10 junior schools, 54 government primary schools, 57 non-government primary schools, 22 Madrasa[2], 11 community schools and 9 satellite schools (Banglapedia, 2006). Most noted educational institutions are Kobadak High School, Kamaruddin High School. The religious education is revolved round with 132 mosques and 135 temples in the study area. Two major occupations in *Koyra* upazila are *Sundarbans* based agriculture and

[1] Clusters
[2] Islamic education center

fishery. The percentages of different occupations include agriculture 43.39%, forestry 3.21%, fishing 4.98%, agricultural labourer 20.42%, non agricultural labor 4.59%, commerce 9.46%, service 2.9%, others 11.05% (BBS, 2007). The market price of the first grade agricultural land is on average Tk. 400,000 per ha (hectare). However, this price differs from union to union. In the study area the most common unit of land is decimal (1 ha = 246.9135 decimal); and the price of each decimal land is Tk. 1,619 only (Banglapedia, 2006).

4.4 Development organizations working in study area

We found a number of development organizations, especially NGOs have been working in this area for a long time. These are BRAC, Proshika, Grameen Bank, Prodipan, Ahsania Mission, World Vision, Grameen Swanirvar, Setu and JSS. Besides, Water Development Board of Bangladesh in collaboration with the Dutch Government also works in some unions of *Koyra* on dike maintenance.

4.5 Health service institutions

We also found that several private health institutions are working in the study area along with the public institutions. The public institutions include one Upazila Health Complex and two Family Planning Centers. Among the private/non-government institutions, the charitable hospitals conducted by Christian Missionaries are notable.

4.6 Topography

The spatial growth of *Koyra* upazila is explained by its topography. Height of *Koyra*, in the northern edge is about 2.0 meters and in the south is about 1.0 meter high from mean sea level (Banglapedia, 2006). As mentioned above that the study area lies in the southwestern part of Bangladesh, which is indeed, the downstream of the well known *Ganges* Deltaic Belt (Brammer, 1993). This area comprises of flat land with natural ground slope surrounded by the *Sundarbans* (world's largest mangrove forest) and Bay of Bengal from south-east and south directions respectively. We figured out from various secondary sources that in *Koyra* relatively elevated lands are found along the bank of rivers in the north whereas low lands are found in the southwestern part of the study area.

4.7 Physiographic conditions

Physiographically Bangladesh can be divided into three sub regions with 23 units (Brammer, 1993). The study area belongs to immature deltaic slope where the long belt of land is hardly above the sea level. The physiographic condition of *Koyra* upazila is broadly characterized by tidal flood plains having lower relief and crisscrossed by a number of river and cannel channels (Banglapedia, 2006).

4.8 General geology of the study area

The study area is located in the south-west part of the Bengal Basin, a long area of subsidence and deposition containing an almost complete sequence from the cretaceous to recent alluvium. The Bengal Basin is essentially a flat deposition center, formed by the deltas of the *Ganges*, *Brahmaputra* and *Meghna* rivers, and covers an area of some 60,000 km^2. The surface topography of the quaternary deposits is very gentle. The whole of the south-west region of Bangladesh is below elevation 17 m, and 75% of it is below 5 m (Brammer, 1993). The surface geology consists mainly of Quaternary sediments, although there are some tertiary deposits in the eastern flood belt. Clay soils are prevalent in the low laying areas, and medium textured soils at the higher grounds (Takagi et al., 2005). The purity of crystal size of minerals, the rock texture and porosity, the regional structure, the degree of fissuring and a good number of other factors might influence the composition of water passing over and through the rock (Hem, 1970). From experts of Water Development Board we came to know that the study area has been floated up by the Quaternary sediment deposited mainly by the *Ganges* River and its tributaries, lies south- western part of Bangladesh.

4.9 Major water bodies in study area

The river *Koyra* is the main flow stream in the *Koyra* upazila. As the study area is in the coastal rivers so rivers are found here as tidal rivers which include *Shibsa*, A*ura*, *Sakbari*, *Kobadak*, *Taldup*, *Pasur*, *Dharla*, *Malancha*, *Boll* and *Arpangachhia* (Banglapedia, 2006). Because of tidal in nature the rivers *Shibsa*, *Pasur* and *Dharla* have a significant influence on both surface and ground water quality (PDO-ICZMP, 2003). A canal named *Ghoshkhali* flows through the study area from north to south touching most of the unions.

4.10 Seasonal characteristics

Taking the seasonal variability in consideration, we categorize four main seasons in the study area namely dry, rainy, mild and winter seasons. The following table shows the seasons as per the duration in months.

Table 4.2 Seasonal variability in study area

Dry season	Rainy season	Mild season	Winter season
March to May	April to September	September to November	December to February

Source: Field Survey, 2010

4.11 Disaster events

Having situated in the coastal belt, the study area frequently faces different types of disasters. These include cyclone and tidal surge, flood, heavy rainfall, river erosion, soil salinity and water logging. Recently the area was hit by two consecutive devastating cyclones- SIDR in 2007 and AILA in 2009.

4.11.1 Disaster calendar

Throughout the year people of study area face different types of natural catastrophes. Based on the opinions of the old people of the study area, we prepare the following calendar to figure out the times (months) in a year when most natural disasters usually take place.

Table 4.3 Disaster calendar of study area

Types of Disaster	Months											
	Jan-Feb (Magh)*	Feb-Mar (Falgun)*	Mar-Apr (Choitra)*	Apr-May (Boishakh)*	May-Jun (Joistho)*	Jun-Jul (Ashar)*	Jul-Aug (Shrabon)*	Aug-Sep (Bhadro)*	Sep-Oct (Ashwin)*	Oct-Nov (Kartik)*	Nov-Dec (Ogrohayon)*	Dec-Jan (Poush)*
Cyclone and tidal surge												
Flood due to high tide and dam collapse												
Water logging												
Heavy rainfall												

* Name of the Bengali months

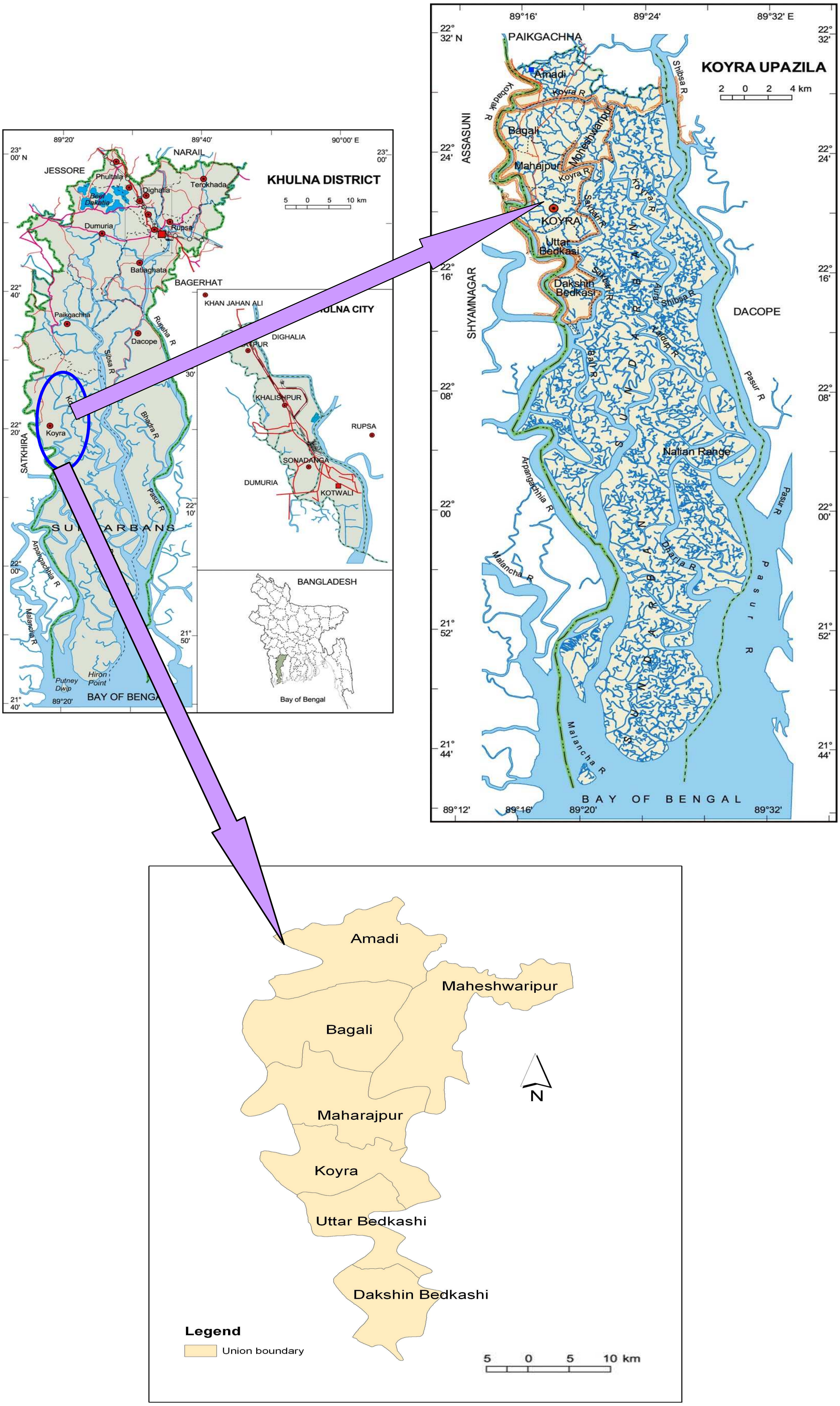
Disaster prone period **Anytime can take place**

Sources: Field Survey, 2010

As we have already mentioned that the latest two disasters (cyclones) hit this area in 15th November 2007 and 29th May 2009 respectively, which are consistent with the above disaster calendar for the study area.

4.12 Location map of the study area

Koyra is one of the upazilas of Khulna district in Bangladesh. Top two figures under map 4.1 show the location of the study area with respect to Bangladesh as well as with respect to Khulna district; and the bottom one shows the administrative units of the study area known as union.



Map 4.1 Location map (top two) and union level digitized map (bottom one) of study area

Chapter FIVE

Identification of Climate Change Effects and Quantification of Vulnerability

5.1 Background

Climate change manifests itself through its effects causing death and physical injury of people, death of livestock, destruction and damage of physical infrastructure and damage of asset. A developing country like Bangladesh possessing weak economy, population pressure, low level of physical and non-physical infrastructure, institutional inertia and political instability is eventually vulnerable. Furthermore, future climate change effects may exacerbate this vulnerability more. Hence, in this study we have dealt with *'Koyra,'* one of the most disaster prone coastal areas of Bangladesh. In this chapter we try to figure out the existing possible effects of climate change in *Koyra* based on secondary sources and field-survey findings. Later we quantify the vulnerability in various unions of *Koyra* by using the Vulnerability Index.

5.2 Identification of climate change effects in *Koyra*

5.2.1 Extreme climatic events

Being a coastal zone, *Koyra* is likely to experience extreme weather events. Nonetheless, it is important to figure out whether these extreme events are the effects of climate change *i.e.* if there is any anomaly in the trend of climatic catastrophes. Therefore, we start with a 'Ranking of extreme climatic events' in the study area which is obtained from result of FGDs from different unions in *Koyra*. During the FGDs the participants were asked to rank the most frequent extreme climatic events or natural disasters in their respective areas. The raking is shown in the table 5.1;

Table 5.1 Raking of most common disasters in the study area

Disaster events	Rank	Average % of respondents supported during FGDs
Cyclone and storm surge	1	83
Flood	2	74
Temperature rising	3	71
Change in rainfall pattern	4	68
Water logging	5	61
Salinity intrusion	6	56
Erosion	7	41
Drought	8	12

Source: FGD, 2010

The raking is constructed by taking the average percentages of respondents who ranked disasters within the FGDs and among the FGDs. The table shows that the most common disaster is cyclone and storm surge followed by flood, temperature rising and so on. We assume that there is a close association between the top two disasters since the former usually causes the latter.

Now let us have a glimpse at the historical trend of cyclones those hit the coastal Bangladesh. Within the span of last 40 years (1970 to 2010), five major cyclone and storm surge hit Bangladesh. This seems to be an indication that Bangladesh gradually becomes prone to frequent tropical cyclones associated with storm surge. From table 5.2 it can be observed that the returning period of these devastating cyclones is declining over the years. Since the late 90's this declination took a sharp change in return cycle which reached at 2 years at the beginning of 21st century. Such time frame indicates the changes in the climatic characteristics in coastal Bangladesh that is likely to bring cyclones as most common disaster with huge losses. Not only cyclone but also storm surge, flood, drought and water logging become a regular climatic catastrophes for this area.

Table 5.2 Cyclone trend in Bangladesh

Name of the cyclone	Year and date	Return year
Greater *Bhola* cyclone	12 November, 1970	50
Tropical cyclone	29 April, 1991	21
Orissa cyclone	29 October, 1999	8
Cyclone SIDR	15 November, 2007	8
Cyclone AILA	29 May, 2009	2

Source: Hossain et al., 2009, BMD, 2009

5.2.2 Temperature

Temperature is an important parameter for evaluating the climatic condition of any area. Therefore, yearly average temperature trend depicts a clear picture of gradual warmer or cooler condition of any country. *Koyra* upazila is located in South-western climatic sub-zone of Bangladesh. Temperature trend of the above-mentioned area for last 61 years shows that since 1990s the yearly average temperature is gradually escalating. It is shown in chart 5.1 where the yellow line indicates the trend of yearly average temperature (in ^{0}C). This average has gone up to more than 31^{0}C which indicates possible anomaly in climatic condition.

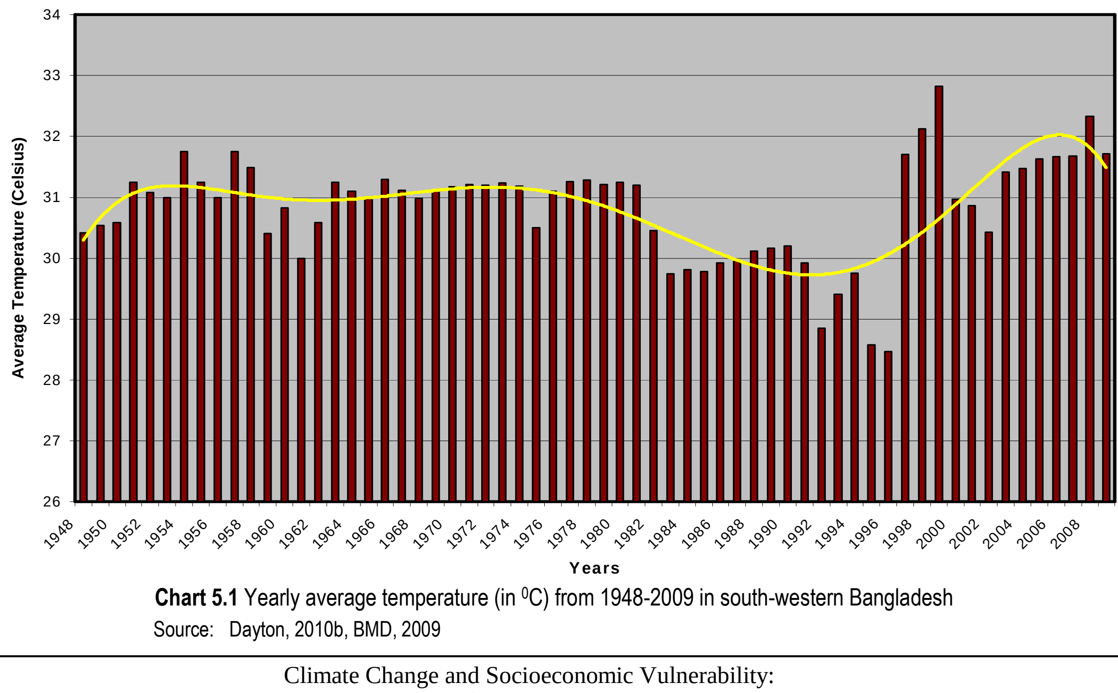


Chart 5.1 Yearly average temperature (in ^{0}C) from 1948-2009 in south-western Bangladesh

Source: Dayton, 2010b, BMD, 2009

5.2.3 Rainfall pattern

The rainfall pattern is quite similar with the other locations of the southwest coastal belt. This pattern raises up to 320 mm in the rainy season and in the dry season it falls below 50 mm. However, heavy rainfall is common in the study area and it occurs two or three times in a year. Like the previous parameter, a trend of yearly average rainfall (in mm) for same time period is conducted and the result shows a slight upward trend of annual rainfall in the southwestern coastal zone of Bangladesh. This trend shows that since late 1990s the annual average rainfall goes up to more than 150 mm. Chart 5.2 gives an overall idea on this rainfall trend.

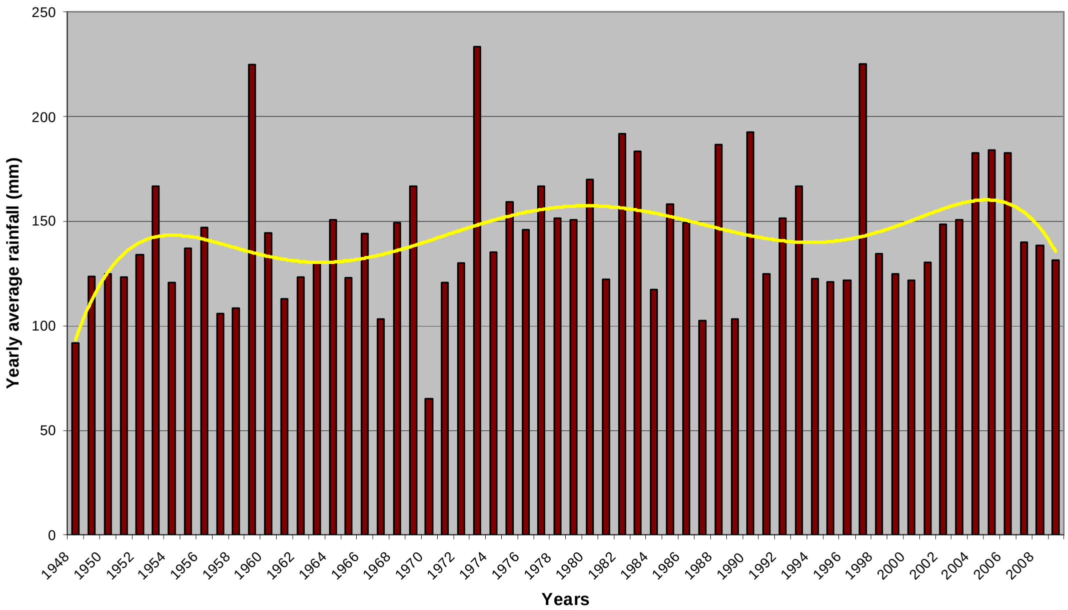


Chart 5.2 Annual average rainfall (in mm) from 1948-2009 in south-western Bangladesh
Source: Dayton, 2010a, BMD, 2009

5.2.4 Change in sea level

Based on the available data on sea level, it is figured out that over the span of last eighteen years the mean sea level of the Bay of Bengal is rising. Particularly from the year 2000 it started rising at a significant rate. Among the important climatic factors, rise in mean sea level shows relatively strong indication of possible change in climatic characteristics in the coastal zone of Bangladesh.

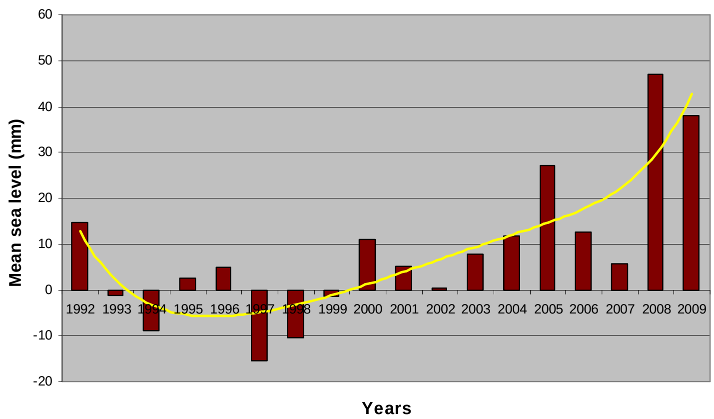


Chart 5.3 Change in sea level from 1992-2009
Source: Boulder, 2010

By considering respective trends of temperature, rainfall and sea-level change altogether, we get the overall climatic trend of the southwestern coastal zone of Bangladesh. By comparing these trends with the world trends it will be possible for us to conclude if climate change is likely to take place in our study area.

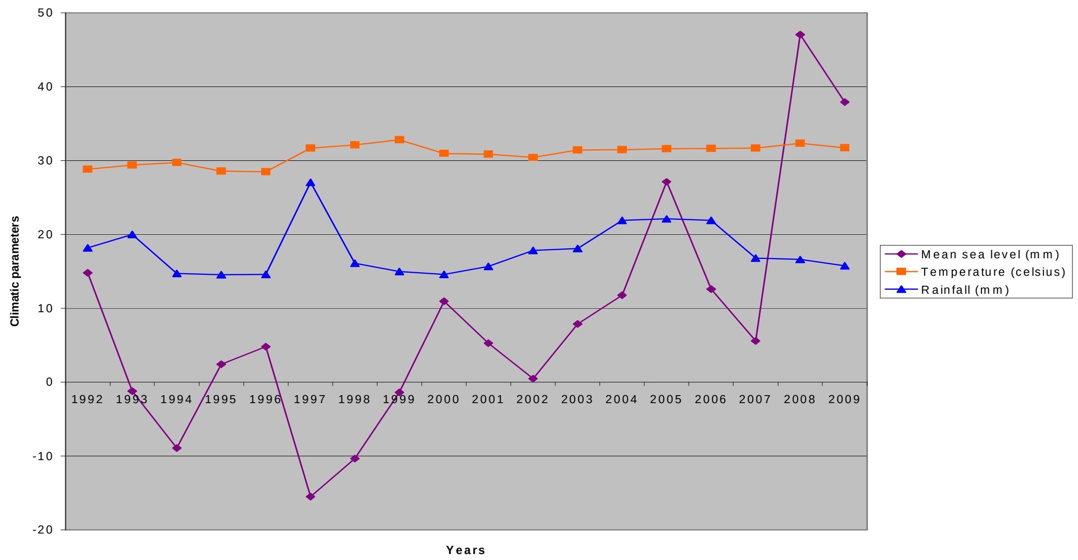


Chart 5.4 Trends of important climatic parameters during 1992-2009 in study area

Chart 5.4 shows that all the three climatic parameters namely temperature, rainfall and mean sea-level are relatively in increasing trend during the last eighteen years. From this time frame we observe a significant trend change only for mean sea-level. However, as we take the long-term trends (1948-2009) for the mentioned climatic factors, we find that average yearly deviations in temperature and sea-level rise are 0.6^0C and 48 mm respectively, which is consistent with IPCC's synthesis report in 2007 (IPCC, 2007d). We then compare the rainfall trend for the same period with 'precipitation assessment' by Working Group I of IPCC (IPCC, 2007e) and find that yearly average rainfall for coastal Bangladesh complies, although not completely, with IPCC's precipitation assessment report.

We can conclude that the important climatic parameters in the study area show relatively anomalous trends, which affect all living species. Besides, frequency of climatic catastrophes is increased and cyclone return-year is declined over the last two decades. Compared with findings and projections of AR4 of IPCC, and the testimonies of the old-aged people of the study area, these empirical findings of local climatic factors indicate that climate is very likely to change in southwestern coastal zone of Bangladesh.

5.3 Quantification of vulnerability in the study area

As mentioned in the 'Methodology' chapter, vulnerability is quantified with the help of a *Vulnerability Index*. This index considers five main Domains namely- demographic, social, economic, physical, and disaster-exposure. Under these Domains, fourteen criterions are selected and finally for addressing Domains and Criterions, twenty two variables (indicators) are chosen as per relevance for our study area (for detail see *Methodology* chapter). This index provides a single value or score for each union (both for domain-wise and total). The higher the score, the higher is vulnerability for concerned union. While explaining domain-wise vulnerability we have mentioned variables with higher percentages in that domain.

5.4 Domain-wise vulnerability

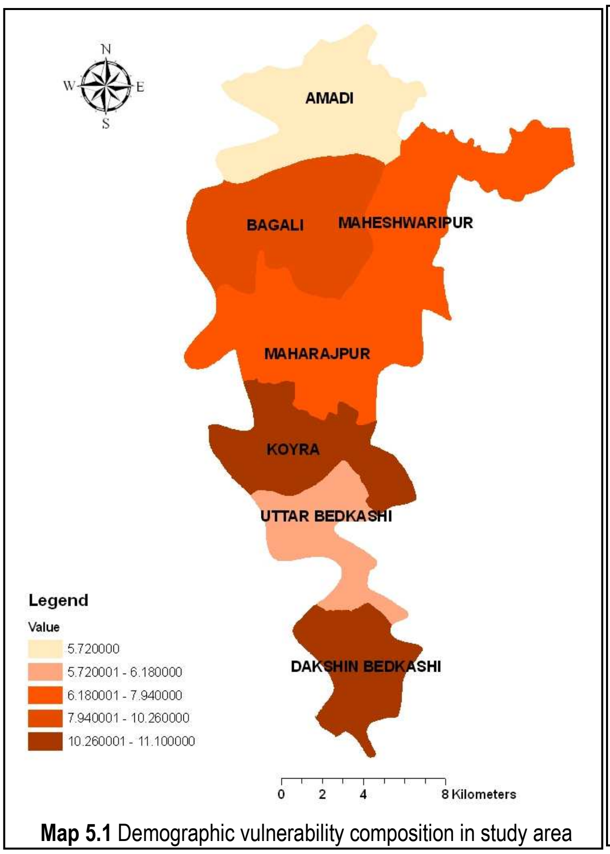
5.4.1 Demographic vulnerability

Demographic vulnerability is determined on basis of information obtained from five different variables under three criterions. Table 5.3 shows that in our study area *Koyra* is demographically most vulnerable union, followed by *Dakshin Bedkashi* and *Bagali union*. On the other hand *Amadi, Uttar Bedkashi, Maheshwarpur* and *Maharajpur* unions are Demographically less vulnerable compared to the other unions. *Bagali* is the most densely populated and *Uttar Bedkashi* is the least densely populated union. The former occupies the highest percentage (49.44) of old and children and the latter occupies the lowest percentage (45.82). *Koyra* and *Bagali* possess highest male-female ratio of 1.05 whereas *Maheswarpur* possesses the lowest ratio of 0.95. *Dakshin Bedkashi* is having highest population growth rate of 2.10% and

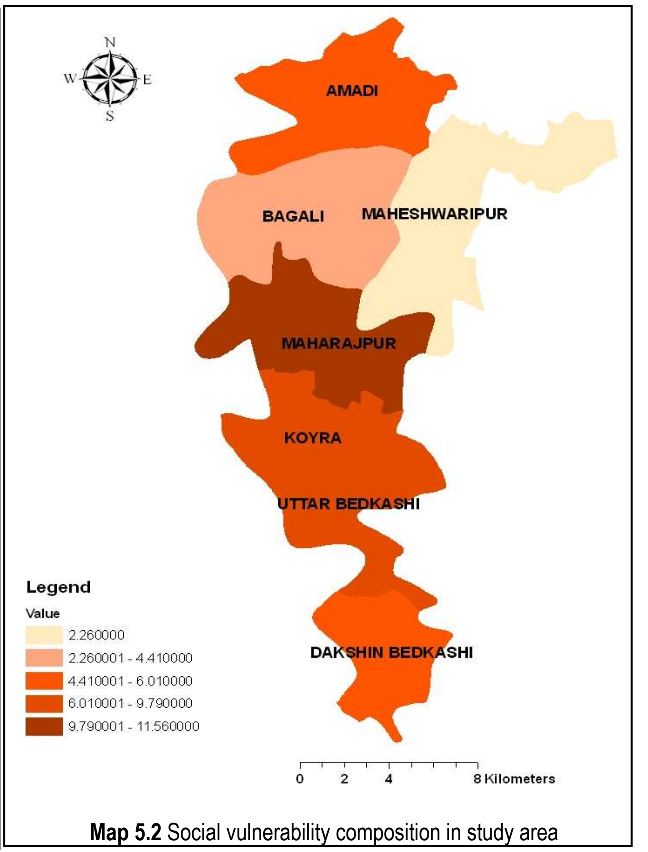
Table 5.3 Demographic vulnerability of study area

Sl. No.	Name of Union	Demographic Vulnerability Index
1	Amadi	5.72
2	Bagali	10.26
3	Dakshin Bedkashi	10.98
4	Koyra	11.10
5	Maharajpur	7.94
6	Maheshwarpur	7.16
7	Uttar Bedkashi	6.18

Source: Appendix I



Map 5.1 Demographic vulnerability composition in study area



Map 5.2 Social vulnerability composition in study area

Maharajpur occupies the lowest growth rate of 1.17% (BBS, 2007). In *Uttar Bedkashi* there is highest percentage of migrant households (16.70) and in *Maheshwarpur* this percentage is the lowest (1.00). Map 5.1 shows the pictorial presentation of demographic vulnerability.

5.4.2 Social vulnerability

In this Domain four different variables are selected under four criterions. Table 5.4 shows the status of social vulnerability among different unions in the study area. It is observed from the social vulnerability index that *Maharajpur* is the most socially vulnerable union, followed by *Koyra*, *Uttar Bedkashi* and *Dakshin Bedkashi*. However, *Maheshwarpur* is the least socially vulnerable union in the study area. Variables under this domain show that highest percentage (93) of illiterate households is in *Koyra* and *Maharajpur*; and the lowest percentage (20) is found in *Maheshwarpur* union. In case of poverty[3] the highest percentage (84.50) of households living under this line is found in *Uttar Bedkashi* Union and the lowest is in *Amadi* (15%). We found exceptionally positive response in case of participating in national level election by the households which shows that 88-100% households in all the unions voted in the last election. But we found a poor response with greater deviation in case of free labor contribution by the households, which is supposed to be a good proxy for the social responsibility. We found that in *Amadi* 96.70% households contribute free labor in case of common issue like embankment construction, whereas only 43.30% households make their contribution for the same job in *Bagali*. Map 5.2 shows the overall composition of social vulnerability in the study area.

Table 5.4 Social vulnerability of study area

Sl. No.	Name of Union	Social Vulnerability Index
1	Amadi	5.83
2	Bagali	4.41
3	Dakshin Bedkashi	6.01
4	Koyra	9.79
5	Maharajpur	11.56
6	Maheshwarpur	2.26
7	Uttar Bedkashi	8.76

Source: Appendix I

5.4.3 Economic vulnerability

For this Domain, five variables are selected under four criterions. Union-wise economic vulnerabilities in the study area are shown in Table 4.6. Therefore, it is observed that the most economically vulnerable union is *Maheshwarpur*, follwed by *Maharajpur*, *Bagali* and *Koyra*. The least vulnerable union is *Amadi*, followed by *Uttar Bedkashi* and *Dakshin Bedkashi*. However, variables under this domain show that in *Maharajpur* highest percentage (66.70) of households depend on natural sources for their income, and this is lowest in *Uttar Bedkashi* (23.3%).

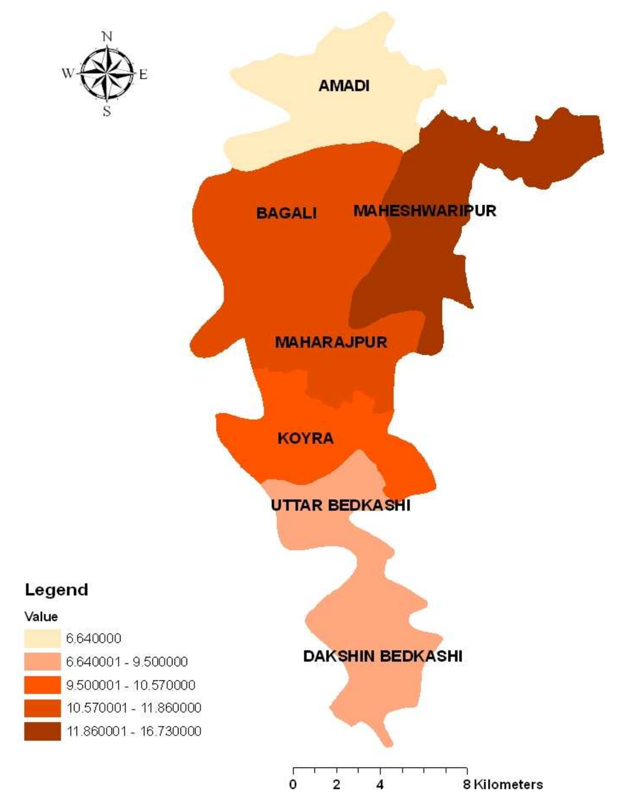
Table 5.5 Economic vulnerability of study area

Sl. No.	Name of Union	Economic Vulnerability Index
1	Amadi	5.06
2	Bagali	11.26
3	Dakshin Bedkashi	9.50
4	Koyra	10.57
5	Maharajpur	11.86
6	Maheshwarpur	16.73
7	Uttar Bedkashi	9.07

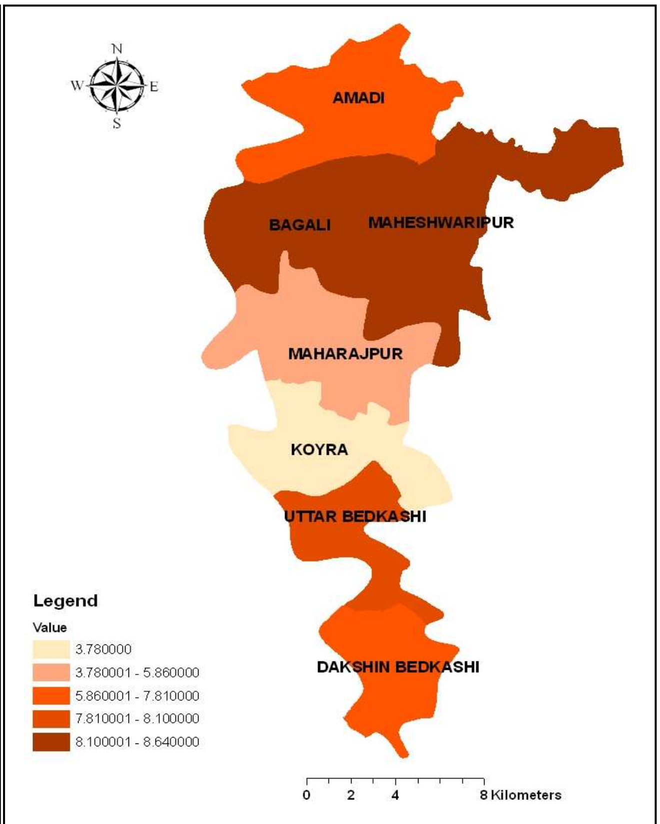
Source: Appendix I

[3] 1 US$ per capita/day

highest percentage (66.70) of households depend on natural sources for their income, and this is lowest in *Uttar Bedkashi* (23.3%). Highest number of unemployed households[4] (32.86%) live in *Amadi* and least number live in *Uttar Bedkashi* (27.95%). As dwelling place 96.7% households in *Bagali* do not have any brick-built houses which is the maximum; on the other hand, 90% households in *Amadi* do not have such houses, which is the lowest percentage. Hence, on this particular issue it is found that in different unions in the study area majority of households do not have brick-built dwelling places. In *Maheshwarpur* highest number of households (51.7%) has lost their land due to natural disaster in last five years whereas the lowest number in this case is in *Bagali* (10.3%). From the perspective of disaster damage in terms of economic cost, highest number of households (96.7%) has suffered in *Maheshwarpur* whereas in this case the lowest number of households (25%) is in *Amadi*. Map 5.3 shows the composition of economic vulnerability in different unions in the study area.



Map 5.3 Composition of economic vulnerability in study area



Map 5.4 Composition of physical vulnerability in study area

5.4.4 Physical vulnerability

Four variables are chosen under two criterions in this Domain of physical vulnerability. Results from domain show that physically most vulnerable union is *Maheshwarpur*, followed by *Bagali* and *Uttar Bedkashi*. Variables under this domain show that

Table 5.6 Physical vulnerability of study area

Sl. No.	Name of Union	Physical Vulnerability Index
1	Amadi	7.81
2	Bagali	8.43
3	Dakshin Bedkashi	7.62
4	Koyra	3.78
5	Maharajpur	5.86
6	Maheshwarpur	8.64
7	Uttar Bedkashi	8.10

Source: Appendix I

[4] Unemployed household refers to the ones where the household head does not have a paid or wage job

highest percentage (98.4) of households not getting electricity is in *Uttar Bedkashi* and the lowest is in *Maheshwarpur* (76.7%). Quite surprisingly almost all households in *Maheshwarpur* do not have any sanitary latrine; however, the lowest percentage (11.0) of households in this case is in *Amadi*. Almost all households in *Amadi* and *Bagali* use ponds and wells as sources of drinking water, however, the least number of households (8.3%) do so in *Koyra*. Considering the paved road network in the whole study area, *Maharajpur* possesses the lowest percentage (11.71) of paved road out of its total road network, and *Koyra* is having the highest percentage (39.22) in this case. Map 5.4 shows union-wise composition of physical vulnerability.

5.4.5 Exposure to cyclone and storm surge vulnerability

Vulnerability of this domain is determined with the help of four variables under only one criterion. Results from this domain show that *Dakshin Bedkashi* is the most vulnerable union towards natural disasters, followed by *Maheshwarpur* and *Bagali*. The least vulnerable union is *Amadi*, followed by *Koyra* and *Uttar Bedkashi*. Variables under this Domain show that highest number of households (73.3%) not willing to shift to cyclone during any natural disaster is in *Dakshin Bedkashi*, whereas the lowest (6.7%) is in *Koyra*. None of the unions does have any provision of early warning system in case of any upcoming natural disaster. The highest number of households (48.3%) do not understand the *National Warning System* live in *Bagali* union, whereas in *Amadi* almost all the households know and understand the above-mentioned warning system. During any crisis period (usually in natural disasters) the highest number (63.3%) of households do not get shelter in either cyclone shelter or neighbors' place is found in *Maheshwarpur* union, whereas this number is minimum (6.7%) in *Amadi*. Map 5.5 shows the composition of exposure to cyclone and storm surge vulnerability in various unions of the study area.

Table 5.7 Exposure to cyclone and storm surge vulnerability of study area

Sl. No.	Name of Union	Exposure to cyclone and storm surge Vulnerability Index
1	Amadi	4.08
2	Bagali	10.34
3	Dakshin Bedkashi	11.89
4	Koyra	5.80
5	Maharajpur	7.03
6	Maheshwarpur	10.46
7	Uttar Bedkashi	6.61

Source: Appendix I

5.5 Overall socioeconomic vulnerability composition in study area

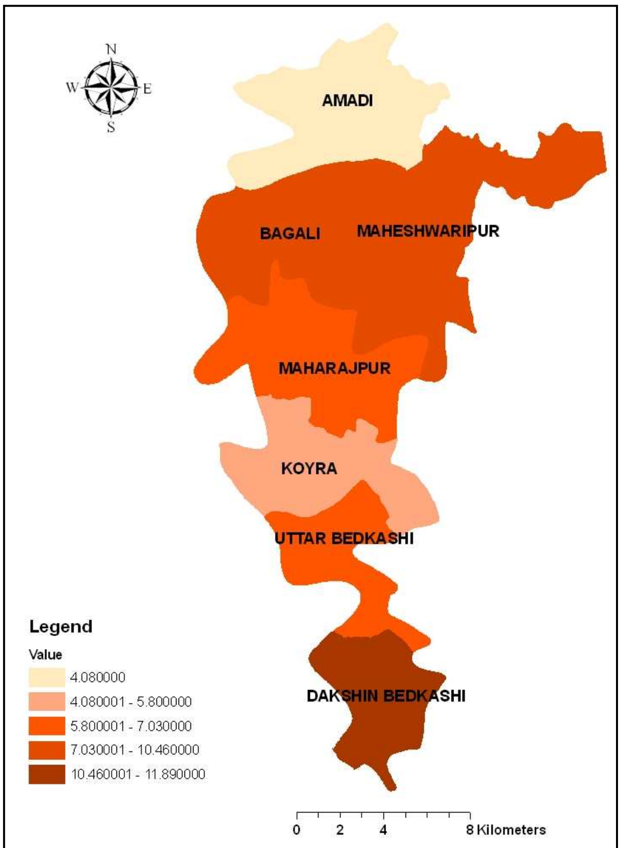
By summing up all the domain-wise vulnerabilities, total vulnerabilities in different unions in the study area are determined. Therefore, it is found that *Dakshin Bedkashi* is socioeconomically most vulnerable union, followed by *Maheshwarpur*, *Bagali* and *Maharajpur*. On the other extreme, socioeconomically the least vulnerable union is *Amadi*, followed by *Uttar Bedkashi* and *Koyra*. Map 5.6 shows the composition of total socioeconomic vulnerability in the study area.

Therefore, on basis of aggregate/total vulnerability-score it can be concluded that the most vulnerable union (*Dakshin Bedkashi*) is at the south of the study area and it is surrounded mostly by mangrove forest *Sundarbans* from south and south-eastern sides. The second and fourth most vulnerable unions are *Maheshwarpur* and *Maharajpur*; which are also surrounded by the *Sundarbans* from south-eastern sides but with different border-lengths. However, *Bagali* is the third most vulnerable union, which is not surrounded by the *Sundarabans*.

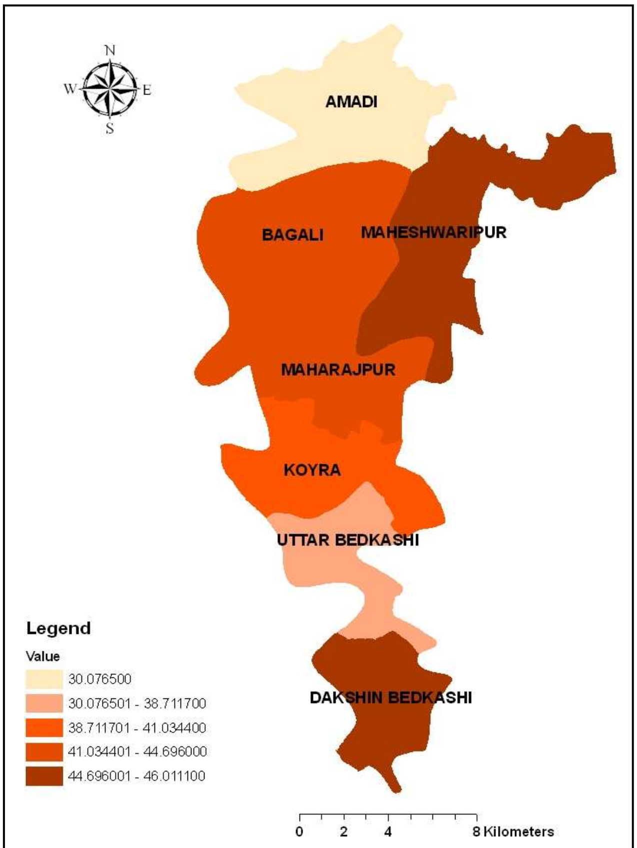
Table 5.8 Total vulnerability composition in study area

Sl. No.	Name of Union	Total Vulnerability Index
1	Amadi	30.07651661
2	Bagali	44.69602584
3	Dakshin Bedkashi	46.01110174
4	Koyra	41.03444662
5	Maharajpur	44.25480193
6	Maheshwarpur	45.24802694
7	Uttar Bedkashi	38.71174523

Source: Appendix I



Map 5.5 Exposure to cyclone and storm surge vulnerability composition in study area



Map 5.6 Total vulnerability composition in study area

Chapter SIX
Econometric Analysis

6.1 Background

We have quantified socioeconomic vulnerability both domain-wise and total, by applying Vulnerability Index in the previous chapter. Now we would like to continue with figuring out the nature and extent of relationship between vulnerability and important socioeconomic parameters of *Koyra*. Hence, in this chapter we conduct econometric analysis with the help of a number of models. In the following part we deal with these models and results obtain from these models.

6.2 Variables used in econometric models

With a view to identifying the relationship pattern between vulnerability and major socioeconomic parameters, we ran a number of econometric models. But before we proceed to the operation with econometric models, let us have a look at the variables used in these models.

6.2.1 Dependent variables

The main dependent variable is expenditures by household for a basket of basic needs, which is considered as a measurement of 'poverty.' This expenditure measurement actually represents a poverty threshold value, which is derived from HIES (Household Income-Expenditure Survey 2008) by BBS and is equivalent to US$ 202/capita/year (BBS, 2008). It is referred as 'Basic Need Cost' in the model. Besides, in order to address capacity we also used a variable- 'Land in 2009' as a proxy for wealth of the households. This variable indicates how much land was owned by the household in 2009. Both of these variables were taken in log.

6.2.2 Independent variables

Below we have mentioned the independent variables, with short explanation, that we used in models.

Variable 'household size' refers to the total number of members in a household.

'Education' refers to household's average aggregate academic schooling year. It is the number obtained by summing up of formal schooling years of all members in a household and then diving it with the number of total household members. This variable is considered as a proxy for *capacity* of households.

The variable 'Duration with community' refers to the number of years the respondent household living with the current community. This variable is used as a proxy for *Social Capital* and hence, we mention this variable as social capital in explaining results.

Total vulnerability is defined as the sum of *Domain* vulnerabilities from demographic, social economic, physical and disaster-exposure. While running the models we took domain vulnerabilities and total vulnerability separately along with other independent variables in different models. In econometric models we take logarithm value of total vulnerability.

Along with the above-mentioned dependent and independent variables, we used the following two independent variables for constructing correlation and regression. We used these results while recommending optimal adaptation options.

We used 'access to *Sundarbans*' as a *Likert Scale* showing the frequency of access-opportunity into *Sundarbans* for the households. Five levels under this variable are: (1) very frequent, (2) frequent, (3) rare, (4) very rare and (5) never.

'Membership of any NGO or cooperative' is binary variables where '1' indicates household's affiliation with any NGO or cooperative and '0' for no affiliation.

6.3 Explanation of models

Results from various OLS regression models are shown in Table 6.1 and 6.2. The former shows results when models are run with domain-wise vulnerabilities while the latter shows results when total vulnerability is incorporated with other independent variables. Despite similar t-values and p-values, values of normal coefficient and beta coefficient differ for the independent variables in the result table. In this study we showed the beta coefficients along with normal coefficients from OLS regression in order to figure out relatively influential independent variables. For each coefficient associated standard errors are mentioned in the parentheses.

We used a Heckman Two Step Model for dependent variable 'land in 2009' in order to find out if there is any sample selection bias in the model. This model consists of two processes that are addressed by two different equations: a selection equation and a conditional equation. The first probit equation is a selection process for the households having land-ownership or not. In the second equation the effects of independent variables on *land in 2009* are examined. These processes are related to each other through their error terms which contain the unobservable. If there is no correlation between the error terms of the two equations, there is no need to perform a Heckman two step approach as there is no sample selection bias and an OLS regression provides the unbiased result (Dow and Norton, 2003). For such a model, the bottom line in STATA output gives a value for ρ (rho) with associated p-value (detailed in Appendix II). This ρ is a likelihood ratio indicating the correlation between the error terms of the equations in Heckman model.

6.4 Model results

Using consumption-expenditure (*i.e.* our measure of poverty) as a dependent variable in OLS regression, we found all the explanatory variables are significant (Table 6.1). We also found significant positive relationship for education and social capital with expenditure whereas it is significantly negative for household size. For the vulnerability domains, the result shows that demographic, social, economic and physical vulnerabilities have significant inverse relationship with expenditure. However, disaster-exposure vulnerability does have a significant positive relationship with expenditure. In the next chapter discussion we will try to chalk out the possible explanations for such interesting relationship. Considering the absolute values of the beta coefficients (model I in table 6.1), the result shows that physical vulnerability is the most influential among independent variables followed by demographic, social and disaster-exposure vulnerability (detailed in Appendix II).

Table 6.1 Summery for model I and model III

	Model I		Model III		
	lnbcn (Expenditure)		lnlnduse2009 (Land in 2009)		
	OLS		Heckman 2nd stage	OLS	
	Normal coefficient	Beta coefficient		Normal coefficient	Beta coefficient
Household size	-.0357074* (.016348)	-.1011274*	.4361334 (.290438)	.0348126 (.046386)	.0375936
Education	.0635488* (.010055)	.3229734*	.1487238 (.128006)	.1512468* (.030824)	.2857759*
Duration with current community	.004812* (.001943)	.1107967*	.0230931 (.0176353)	.0179585* (.005924)	.1462854*
Demographic	-.162317* (.029606)	-.5432913*		-.149929 (.085697)	-.1892319
Social	-.1060497* (.021808)	-.5052605*		-.240586* (.065379)	-.4205176*
Economic	-.059757* (.015423)	-.3076161*		-.315331* (.044408)	-.6323797*
Physical	-.253997* (.0533219)	-.6537877*	-1.271344 (1.380046)	-.339000* (.157358)	-.3171287*
Disaster-exposure	.111715* (.0251089)	.4869792*	.085866 (.1750879)	.2033898* (.074873)	.3393168*

* Significant at 5% level

On the other hand, household size is the least influential variable followed by social capital and education variables. The notable feature in this result is that all the vulnerability domains have relatively greater influence on expenditure (poverty) than those of rest of the variables.

When we took total vulnerability, instead of different vulnerability-domains, along with same other independent variables; again we had had all significant independent variables with expected relationship with expenditure (model II in Table 6.2). However, in this case beta coefficients show that the most influential independent variable is education followed by social capital. Total vulnerability in this case is inversely associated with expenditure but not as influential as education and social capital.

We used the Heckman two step model while taking *land in 2009* as a dependent variable (model III in Table 6.1). In the conditional equation of this model, along with other independent variables, we only considered two vulnerability domains: disaster-exposure and physical vulnerabilities. Because, we found from FGDs and our own observation that the physical infrastructure of study area had been massively suffered due to disasters. Result in model III shows that no independent variable is significant under this conditional equation. The likelihood ratio (ρ = 0 with p-value 0.7967) shows that there is no correlation between the error terms of the two equations in Heckman model (detailed in Appendix II) and hence, we conducted OLS. Result of OLS (coefficients in model III) in this case shows that education and social capital are significant; and among the vulnerability-domains social, economic and physical vulnerabilities are significant with expected relationship with dependent variable (model III in Table 6.1). However, like OLS regression in model I, here disaster-exposure vulnerability also shows a positive relationship with land ownership (dependent variable).

Table 6.2 Summery for model II and model IV

	Model II		Model IV		
	lnbcn (Expenditure)		lnlnduse2009 (Land ownership in 2009)		
	OLS		Heckman 2nd stage	OLS	
	Normal coefficient	Beta coefficient		Normal coefficient	Beta coefficient
Household size	-.0315999** (.0167065)	-.0894944	.4036895 (.2498939)	.0338232 (.0488095)	.0365251
Education	.0863462* (.0089959)	.4388366	.11488 (.1326608)	.1456066* (.0271656)	.2751189
Duration with community	.0050105* (.0019944)	.1153569	.0231359 (.0173128)	.0168861* (.0062677)	.1375498
lnvul	-.413301* (.1705904)	-.1075266	-.0642915 (2.198003)	-2.864805* (.483134)	-.294567

* Significant at 5% level
** Significant at 10% level

Taking the *total vulnerability* as one of independent variables in Heckman model, we found none of the variables significant in conditional equation (model IV in Table 6.2). The likelihood ratio (ρ = 0 with p-value 0.8093) in this case also indicates no correlation between error terms of equations. Therefore, we have conducted an OLS (model IV) and found all independent variables, expect household size, are significant. For the significant variables, the expected relationships with dependent variable are also same as model II in Table 6.2. The absolute values of significant beta coefficients (model IV) indicate that total vulnerability is the most influential independent variable followed by education and social capital. Detailed STATA results of the above-mentioned 4 models are shown in Appendix II.

Chapter SEVEN
Discussion

7.1 Preamble

In the last two chapters, we showed the likeliness of climate change in *Koyra* and then we figured out sub-sequent socioeconomic vulnerability in different unions of *Koyra*. Furthermore, we showed the nature and extent of relationship between vulnerability and important socioeconomic parameters in study area. In this chapter we are going to discuss the major findings that we obtained from econometric models. At the end of this chapter we will reflect on the robustness of the vulnerability index by crosschecking with another index developed by an alternative approach. We will also check the econometric model results from the new vulnerability index.

7.2 Brief overview on socioeconomic features in *Koyra*

We start with the following Table 7.1, which shows major demographic and socioeconomic characteristics of the surveyed respondent households in the study area. This table reveals that majority of the households live under poverty and dependent on various natural sources for their livelihood and hence, their respective income sources are not secured enough. Most of them have

Table 7.1 Summery statistics of socioeconomic characteristics of surveyed households in *Koyra*

Respondent (Household) characteristic		Value	
Percentage male respondents in sample		83.3	
Respondent average age (median value)		41	(40)
Percentage of respondents' religion	Muslim	88.3	
	Hindu	11.7	
Percentage of literate households*		38.3	
Respondent occupation (%)	Self-employed farmer	20.7	
	Self-employed fisherman	14.5	
	Daily labor	21.7	
	Others	16.0	
	Unemployed	12.9	
Average number of family members (min-max)		4.85	(4-16)
Average household expenditure for basic needs [US$/year] (st. dev.)		771	(763)
Average per capita expenditure for basic needs [US$/year] (st. dev.)		155.2	(106.5)
Percentage of households dependent on NRDI**		73.7	
Percentage of households under poverty threshold***		78.6	
Squared poverty gap		0.0542	
Income inequality [Gini coefficient) (min-max)		0.29	(0.21 - 0.36)
Percentage of households owing agricultural land		78.7	
Average size (ha) land owned by households		0.33	
Percentage of households having sanitary latrine		57.4	
Percentage of households having tube-well (for drinking water)		56.9	
Percentage of households having electricity connection		19.3	
Average annual disaster damage (US$)		177	

Source: Field survey, 2010

* A household is considered as literate if its average aggregate academic schooling is at least 5 years
** Natural Resource Dependent Income (NRDI) is considered as income obtaining from agriculture (crop cultivation), fishery and forest resource collection
*** The Bangladesh Bureau of Statistics calculates Basic Need Cost as a poverty threshold value, which was US$ 202/capita/year in 2008-09

either minimal or nil asset (such as, land or capital goods). At the same time a good number of households suffer from lack of basic housing utilities like sanitary latrine, pure drinking water and electricity. Although both squared poverty gap and gini coefficient show a mediocre income inequality in the study area as a whole, there exists relatively higher income inequality in some of the unions adjacent to the *Sundarbans* forest area.

7.3 Major findings and discussion

Over the last decade the people of *Koyra* upazila had suffered most of the devastating effects of climate change. As a consequence, households in the community level are likely to become socioeconomically vulnerable. But this vulnerability differs from union to union within the same upazila, indicating different domain-vulnerability among the unions. Based on the scores of domain-vulnerabilities, we found that *Maheshwarpur* is the most vulnerable union from the perspective of 'economic' and 'physical' vulnerability; *Dakshin Bedkashi* scored the highest for 'disaster-exposure' vulnerability; *Maharajpur* obtained the highest score for 'social' vulnerability and *Koyra* union got the highest score for 'demographic' vulnerability (for detail see Appendix I). Total vulnerability score (sum of all domain scores) shows that relatively more vulnerable unions are situated to the southern and south-eastern sides of *Koyra* upazila, and these vulnerable unions have greater proximity with the mangrove forest *Sundarbans*. Besides, these unions belong to 'severe tidal surge' zone in Bangladesh (Mapbangla, 2009). We will discuss the findings of this study with the help of results from model I, model III in table 6.1, and model II, model IV in table 6.2 in previous chapter. Therefore, we first discuss relationship between vulnerability (with domains) and poverty as a measure of consumption-expenditure; then we focus on vulnerability (with domains) and land ownership of households.

In the study area large portion of households (73.7%) depend on natural sources for their livelihood. These natural sources mainly cover the resource collections from adjacent forest *Sundarbans*. We figured out from household-survey and FGDs that these households possessed very weak construction of their homesteads and also poorer level of infrastructural support by the local government. As a result, in case of any climatic shock these households were more likely to be vulnerable through deepening their poverty level because such shock contributed massive destruction in both *Sundarbans* and its adjacent localities. Our empirical result complies with this scenario since all vulnerability-domains, except disaster-exposure, indicate relatively greater negative effects on the household poverty level. The result (model II) shows that 1%

increase in the total vulnerability would contribute in 41% significant increase in poverty for the households.

Key findings from FGDs in different unions indicate that during post disaster period the households in most cases suffered from lack of employment opportunity, well-constructed homestead and capital assets. We came to know from the local government that due to heavy damage in the *Sundarbans* in the last two cyclones in year 2007 and 2009, the central government imposed embargo on accessing into this forest for an unlimited time. Hence, this had induced a serious impact on the local household communities which led to a serious economic vulnerability for the local households. As we deal with domain-wise vulnerabilities our empirical result (model I) reflects the same scenario, which indicates about 6% significant increase in the poverty level due to just 1 unit increase in the economic vulnerability.

We also had the same result for physical vulnerability. Our survey findings indicated that due to the effect of powerful cyclones over this area most of the physical infrastructure were either heavily damaged or destroyed. Therefore, households suffered from lack of pure drinking water, sanitation, electricity and road network. These altogether contributed the physical vulnerability for the households. Our empirical result (model I) indicates that 1 unit increase in physical vulnerability significantly exacerbates 25.4% poverty for the households in the study area.

Similarly there would be demographic vulnerability if households suffered from the death or severe injury of the main earning member in the family due to any natural disaster. In some cases households were supposed to migrate towards urban area or relatively cheaper rural areas during post disaster periods. These features altogether constituted demographic vulnerability which ultimately affected household poverty. Our empirical result (model I) shows that 1 unit increase in this vulnerability results 16.2% significant increase in the household poverty level. In the same way, in the post disaster period there might be social vulnerability due to less involvement of households in local decision-making process and common activities. Result (model I) shows that 1 unit increase in social vulnerability significantly exacerbates 43% poverty for the households.

However, for the disaster-exposure vulnerability our empirical result provides a complete opposite scenario whereas the expected relationship between this vulnerability and poverty is supposed to be inverse. Quite surprisingly our empirical result (model I) shows that 1 unit increase in disaster-exposure vulnerability would significantly lessen 11.2% household poverty. We tried to discover the reason behind such peculiar relationship and we focused towards key findings of FGDs and informal discussions conducted in different unions of the study area. Finally we were able to discover that during the post disaster period lots of reliefs were usually sent to the affected unions which ultimately pushed the consumption-expenditure level of the affected households and hence, their poverty level was diminished. But in the end we also figured out that such a fall in poverty was perhaps a short-term phenomenon since we found quite a many households were migrating to urban areas for their livelihood, which indicated their struggling with poverty. Major reasons behind this vulnerability are absence of or least effective local early system, lack of knowledge on warning signals and indifferent attitude of households on disaster preparedness. We also figured out that in many occasions households were hardly willing to leave their capital assets such as cattle, plough, fishing nets etc. during disaster and shift to cyclone shelter. Finally we found a good number of households who ignored the forecasting of disaster and in the end suffered a lot. These households ignored the warning because in a number of occasions they shifted to cyclone shelter once they had heard the warning and later they had found nothing happened, which made them indifferent to early warning or forecasting.

When we considered the other independent variables (household size, education and staying duration with current community), in both models education (literacy) was found as most influential among these three followed by social capital and household size. Our empirical result shows that with one year additional education for a household, their poverty would be lessened by 6.4% (model I) and 8.6% (model II) respectively; one additional year staying with current community, indicating higher level of social capital, would diminish their poverty by 0.5% in both cases (model I and model II); whereas one additional member in household would escalate their poverty by 3.6% (model I) and 3.2% (model II). These results are consistent with our key findings from FGDs and informal discussion with people in study area. We found that households with greater number of literate members were well aware about the weather forecasts and they did have better jobs and hence, they were less vulnerable and less poor. At the same time, the longer period households stayed with the same community the larger social network (social capital) they had and by the dint of this network they were more likely to cope the disaster shocks and poverty as well. Finally, we found that households with more members were more likely to be vulnerable to disaster-effects and also poorer. Beta coefficients indicate that among domains physical vulnerability is the most influential followed by demographic, social and disaster-exposure (in model I). Whereas in case of total vulnerability the most influential variable is literacy (education) followed by social capital and total vulnerability (in model III).

So far we have dealt with poverty, in terms of expenditure for basic needs, in order to figure out empirical relationship between poverty and vulnerability. We again examine the same relationship, however, with a different proxy for poverty. In this case we adopt ‘land use in 2009’ as a proxy since this refers to land ownership (capacity) for respective households and in our sample about 79% households own their own land although quantities are very small. Above all, we mainly focus on relationship between poverty and vulnerability.

Result (normal coefficients) from model III shows that among the vulnerability-domains social economic and physical vulnerabilities have significant inverse relationship whereas disaster-exposure vulnerability has significant positive relationship with land ownership of households in the study area. Beta coefficients in this model indicate that economic vulnerability is the most influential among significant independent variable followed by social, disaster-exposure, physical vulnerability and education.

Key findings from FGDs and informal discussion indicate that during post disaster periods the affected households tried to survive by smoothing their consumption levels and hence, in most cases they sold their lands to local landlords at very nominal price. We also figured out that during such situation landlords took the advantage of taking over lands from affected households by creating psychological pressure on these households with the help of local pressure groups. Our empirical result is consistent with this fact, which shows that with 1 unit increase in economic, social and physical vulnerabilities the affected households lose 31.5%, 24% and 33.9% of their land respectively. However, we also have an opposite scenario for disaster-exposure vulnerability where we found relatively better off households, who played role of pressure group for landlord, in many cases purchased lands from severely affected households in the post disaster period. Our empirical result (OLS in model III) shows that 1 unit increase in disaster-exposure vulnerability enhances 20.3% increase in land ownership/quantity for households. This result suggests that in study area total land quantity remained the same; however, the ownership was gradually confined among a few people. We infer that this scenario is common in more vulnerable unions of our study area. FGDs and household informal discussion revealed that households with higher education and longer staying period with same community possessed relatively more land. Our empirical result complies with this finding by showing one additional year in both education and staying with current community would result 15.1% and 1.8% increase in land ownership/quantity for households.

Taking the total vulnerability (OLS in model IV) along with the same set of independent variables used in previous models, we found on basis of beta coefficients that vulnerability is the most influential significant independent variable followed by education and staying period with same community. Although the beta coefficient for ‘household size’ in this model provides quite opposite direction of expected relationship with ‘land’, this coefficient is not significant. The result of model IV (OLS) indicates that 1% increase in total vulnerability would significantly decrease 286% land ownership for households, which is too much indeed. For education and staying duration with same community, the result shows that one additional year in both education and staying with same community would give 14.5% and 1.7% rise in the land ownership for households. We infer that the underlying causal relationships of these significant variables with dependent variable are same as we mentioned in model II.

By reviewing the above-mentioned findings, we can conclude that vulnerability as a whole exacerbates poverty for households. We have also found that vulnerability affects the capacity (in terms of land ownership) of households and there is a significant inverse correlation between capacity and poverty; and between capacity and vulnerability (detailed in Appendix III).

7.4 Magnitude of the effects

For each of the model mentioned in table 6.1 and 6.2 in the previous chapter, we test the magnitude of effects for a certain variable. Therefore, we have chosen ‘Physical vulnerability’ for model I and III; and ‘Total vulnerability’ for model II and IV as the variable of our interest.

We have found that an increase of the value of physical vulnerability by one standard deviation taking all other independent variables at the mean, results a decrease of 65% in the expenditure of households, which indicates an exacerbation of poverty by 65% for the households (model I). We did the same for model III and found that the above-mentioned vulnerability reduces 85% land-ownership for the households (detailed in Appendix II).

When we take ‘Total vulnerability’ as our variable of interest, we have found that one standard deviation increase in the value of this vulnerability results 20% decrease in expenditure of households, which shows exacerbation of poverty indeed (model II). For model IV we have found that Total vulnerability reduces 34% land-ownership for the households (detailed in Appendix II).

7.5 Reflection on vulnerability index and econometric model results

We are interested to check the consistency of vulnerability index and hence, we adopt an alternative approach to obtain the vulnerability scores. However, we do not consider the scores of individual domain-vulnerabilities rather we only deal with the scores of total vulnerability for each union. Using relevant scores from the original index (Appendix I), we adopt the following formula to determine total vulnerability score for each union;

$$\text{New vulnerability score} = \frac{(\sqrt[5]{demographic \times social \times economic \times physical \times disaster\ \exp osure})}{110}$$

By applying this formula we have obtained a new vulnerability score for each union. We then make a ranking where rank '1' indicates least vulnerable and '7' indicates most vulnerable union. Furthermore, we compare the new ranking with those from first one in order to check consistency of the first vulnerability index. Table 7.2 shows these rankings where the left-hand panel shows the vulnerability-ranking (old ranking) of unions by taking scores from the first index; and the right-hand panel shows the old ranking with new scores.

We have found that in case of new scores, ranking for three unions (*Maheshwarpur*, *Uttar Bedkashi* and *Maharajpur*) is changed although in both panels the most vulnerable and the least vulnerable unions are the same. Hence, we can conclude that new vulnerability scores comply 58% with the first (old) vulnerability scores.

Table 7.2 Comparison of old and new vulnerability scores

Old Ranking	Unions	Old score		Old Ranking	Unions	Old score	New score
7	Amadi	30.077		7	Amadi	30.077	0.053494
6	Uttar Bedkashi	38.712		2	Maheshwarpur	45.248	0.068583
5	Koyra	41.034		5	Koyra	41.034	0.068979
4	Maharajpur	44.255		6	Uttar Bedkashi	38.712	0.069579
3	Bagali	44.696		3	Bagali	44.696	0.077277
2	Maheshwarpur	45.248		4	Maharajpur	44.255	0.077425
1	Dakshin Bedkashi	46.011		1	Dakshin Bedkashi	46.011	0.081206

Source: Appendix I for old scores; and formula in previous page for new scores

We have also tested the regression coefficients for old and new scores of total vulnerability. In both cases for model II, we find all the variables are significant and coefficient values for all variables, except vulnerability, are almost similar. In table 7.3 all these coefficients are shown.

We take the deviation between old and new coefficient and find very nominal deviation except for vulnerability. The average deviation for model II is 0.1, which is relatively very nominal.

Table 7.3 Regression coefficients for old and new vulnerability scores

	For model II				For model IV		
	old coefficient	new coefficient	Deviation		old coefficient	new coefficient	Deviation
Household size	-0.0315999	-0.0315993	-0.0000006		0.0338232	0.0338232	0
Education	0.0863462	0.0863453	0.0000009		0.1456066	0.1456066	0
Duration with community	-0.0089959	0.0050107	-0.0140066		-0.027166	0.0168861	-0.0440517
Invul	0.0050105	-0.412819	0.4178295		0.0168861	-2.864805	2.8816911
Average			**0.1009558**				**0.70940985**

Source: Appendix I for old scores; and formula in previous page for new scores

For model IV, except vulnerability we have obtained almost the same coefficient values for the other variables. In both cases except household-size, we find the other variables significant. We find mentionable deviation for 'vulnerability' variable and the average deviation for this model is 0.7, which is higher than that of model II.

Chapter EIGHT
Optimal Adaptation Options for the Study Area

8.1 Preamble

During the COP15 in Copenhagen in December 2009, a good number of recommendations were proposed focusing on *adaptation* strategies for the climate-change affected developing nations (BDNews, 2009). Adaptation, due to effect of climate change, is one of the two principal response strategies. The other strategy is mitigation. The basic difference between these two response strategies is that the former focuses on coping with the problems of climate effects when they take place while the latter attempts preventing the climate change problem from taking place at all (Huq and Reid, 2004). Based on the empirical results from data analysis and FGDs for this study, we would focus mostly on adaptation strategies addressing by adaptive capacity of the vulnerable coastal households. Between anticipatory and reactive adaptations (Huq and Reid, 2004), for this study we emphasize on the anticipatory ones since the reactive ones were carried out by various agencies in our study area in the immediate post-disaster period. But before we recommend for the optimal adaptation options, let us have a glimpse at the existing adaptation options and the associated pros and cons.

8.2 Existing adaptation strategies

Adaptation options for coping with natural disasters (effects of climate change) depend on a number of factors such as- geographical, economical, social and cultural settings (Dey and Rahman, 2009). As a disaster-prone area there are a good number of strategies adapted by the local inhabitants over the years in order to cope with the effects of natural disasters in the whole southwestern coastal zone of Bangladesh. People adapted these strategies in the forms of structural as well as non-structural measures with a view to diminishing their vulnerability to natural hazards. However, these adaptation strategies or options differ from area to area. Hence, in this study we consider only the adaptation options available in *Koyra* upazila and in the following part these are mentioned in a nut-shell.

8.2.1 Disaster early warning system

The Bangladesh Meteorological Department (BMD) is entrusted with all sorts of weather forecasting. BMD is situated in the capital and we find that it reconciles all the weather-data from sub-stations across the country. Weather warning system including cyclone, came into being historically through evolution in order to mitigate suffering of people. It is observed that relatively accurate and timely forecasting system and timely information dissemination, mobilization and action were more effective to reduce the loss of life and damage to properties during the cyclones since 1990s (GoB, 2009a). As proven under Cyclone Preparedness Program (CPP), the early warning with more innovative approach could be one of the most effective coastal defenses (IWM, 2007). For *Koyra* such warning is only available with radio-news.

8.2.2 Safe haven facilities

There are a number of raised earthen mounts known as *killas*, which are mostly naturally formed. These *killas* along with cyclone shelters have proved their effectiveness as safe haven during the cyclone induced storm surges (IWM, 2007). Our empirical findings from FGDs and household survey reveal that most of the people fail to get shelter in cyclone shelters during natural hazards avail the protection by *killas*.

8.2.3 Coastal embankments

With the assistance of the Dutch government in 1953 the the-then government constructed coastal embankment, known as polders, with a view to managing coastal crest levels (GoB, 2005b). However, the local Water Development Board did not the probable sea level rise in future. Hence, during the storm surge or any catastrophic events this coastal embankment does not resist the flooding inside *Koyra* upazila. A study found that with 27cm sea level rise 4 numbers of polders will be submerged, and this number will increase to 13 polders with 62 cm sea level rise (IWM, 2007). The embankment inundation can be avoided by raising the crest according to the influence of sea level rises. Nevertheless, this coastal embankment still plays the role of safe-guard for the coastal communities.

8.2.4 Afforestation

The Forest Department (FD) in Bangladesh has implemented a project named *Coastal Green Belt Project* (1995-2002) under which over 1300 km of embankment plantations, 7500 km of strip plantations, 665 ha of foreshore plantations were carried out (GoB, 2009b). Under Coastal Embankment Rehabilitation Project (CERP) huge plantation was done both on embankment slopes and foreshore. The intention of the foreshore plantation was to protect the embankment from direct wave action which is very detrimental to the sustainability of the polder (GoB, 2009b). However, the local people and experts opine that for *Koyra* upazila the mangrove forest *Sundarbans* always plays the key role to abate the devastating impact of natural disasters, particularly cyclone impacts. The CERP covered the borders of *Koyra* with the *Sundarbans* so that this forest not only protects coastal communities but also paves the way for securing livelihoods for those communities (Ramamasy and Baas, 2007).

8.2.5 Vulnerability group feeding

We have found that the local and central governments are currently conducting VGF (Vulnerability Group Feeding) scheme for the affected people in *Koyra* upazila. This scheme is adopted as an immediate adaptation measure in the post-disaster period. Under this scheme an affected household is given 20 kg rice per month. This scheme is taken in order to support the survival of affected households. Our finding indicates that this VGF scheme is most effective in *Dakshin Bedkashi*, the most vulnerable union of *Koyra* where people have too narrow a range of income opportunity.

8.3 Optimal adaptation options

In the following part we are going to recommend a number of adaptation options drawn on basis of discussions from FGDs, household survey, and finally our observation and discussion with concerned local-government representatives. While recommending these options we consider the behavior of the coastal people towards their livelihood earning. Hence, the following recommended options are mentioned in accordance with these peoples' behavior, attitude and capacity to earn livelihood. In this case we have prioritized the adaptation options considering the above-mentioned attributes of the coastal people. For the first two options we test if these comply with the results from the correlation matrix and regression result in Appendix III. For the rest of the recommended options, we rely on outcomes of FGDs household survey and observations as we have already mentioned.

8.3.1 Co-management of the *Sundarbans*

The role of mangrove forest *Sundarbans* is inseparable in case of coastal societies since it provides a good number of positive externalities to the coastal people (Iftekhar, 2008). Besides, this mangrove forest plays the crucial role of safeguard during natural catastrophes (Harun-or-Rashid et al., 2009). Our survey findings show that 73.7 % people from all the unions under *Koyra* upazila are dependent directly or indirectly for their livelihood on the mangrove forest *Sundarbans*. However, the existence of this forest is at a stake due to uncontrolled resource extraction from and absence of legal bindings for this forest. As a result, the environmental balance is likely to be hampered which further contributes into exacerbation of cyclone frequency in coastal zone (Iftekhar, 2008, Muhammed et al., 2008).

With the introduction of co-management in the *Sundarbans* forest, it is possible to carry out both adaptation and mitigation for climate change effects. Adaptation in the sense that co-management will ensure a secure income for the people who live in the borders and adjacent area of *Sundarbans* and who will be involved in this process. This can be done by providing a part of the revenue generated from *Sundarbans* among the people who will be contracted by the local Forest Office. As a consequence, these beneficiary groups along with local forest-force will resist any unauthorized access to and resource extraction from this forest. In this way, the forest-resources will be systematically depleted that will pave a sustainable conservation of *Sundarbans.* Moreover, by conducting this practice the environmental balance can be least harmed and thus, mitigation can be ensured. This kind of practice is in vogue in *Lawachara* forest in north-eastern part of Bangladesh where co-management provides financial security to the participants and sustainable conservation for the local forest (Islam, 2009). In addition, the protected forest zone, especially in Bangladesh, provides a good number of short-term and long-term benefits to both local and national GDP (Chowdhury and Koike, 2010).

Our data analysis shows that 'access to *Sundarbans*' has a significant positive correlation (0.104) with expenditure, which is a measure of poverty in this study; and a significant negative correlation (-0.385) with total vulnerability. With all the vulnerability-domains, except social vulnerability, 'access to *Sundarbans*' has significant negative correlation Our regression shows that for a household there is likely to significant lessen 17% of its poverty once it has the access to *Sundarbans* (for detailed correlation and regression, see Appendix III). Therefore, a well contracted 'co-management' and 'resource regimes' in terms of access into the *Sundarbans* may not only work as an adaptation option but also mitigation for the people of *Koyra* while facing effects of climate change.

8.3.2 Social capital

Adaptation for effects of climate change can be considered as a dynamic social process where collective action takes the lead role (Adger, 2003). This collective action depends on trust, reputation and reciprocity among members of the society, which indeed indicate social capital (Slangen et al., 2008). The Southeast Asian experience shows that by the dint of social capital the coastal communities are capable to cope with the climate-related extreme events (Adger, 2003).

This is also possible for Bangladesh as a South Asian country. We find from this study that in relatively more vulnerable unions in *Koyra,* the people often use their family and social network while coping with climatic shocks. We find more social integration in comparatively more vulnerable areas where people adapt available strategies to cope with effects of natural catastrophes. Our regression result shows that social capital abates poverty (0.3%) of the vulnerable community significantly (for detailed correlation and regression, see Appendix III).

Therefore, if the NGOs, which are currently working in *Koyra* take initiatives with the collaboration of local government to arrange some motivational programs then these coastal people will be able to possess better norms, values, reliability and responsibility among them. In this way a stronger social capital can be created among the communities that may work as glue for them by the dint of which these people can cope with effects of natural catastrophes.

8.3.3 Livelihood coping and adaptation

Adaptation options for coping with the natural disasters depend on geographical, social and cultural settings of the region (Dey and Rahman, 2009). So, in coastal communities people need to adopt different adaptation options to cope with existing effects of climate change that strike as natural disasters. In this context, along with the structural measures, non-structural measures can also be fruitful to reduce vulnerability of the coastal livelihoods. The adaptation options can be different for each livelihood groups. As an initiative of IUCN-Netherlands the RVCC (Reducing Vulnerability to Climate Change) Project 2005 has come up with several adaptive strategies such as: increase income by alternative livelihood, increase food and crop production, ensure health safety and access to pure drinking water, and increase income by using common property (CDP, 2009). These strategies can be taken into action to achieve household and community level adaptation to climate change. Examples of the RVCC Project identified adaptation options for agriculture are: vegetable farming on floating bed, integrated farming (crop, fish and livestock) and cage culture (Fig 8.1).

Since the inundated area has been increased due to storm surge and sea level rise, the crop cultivation system could be changed to cultivation on water instead of soil (Dey and Rahman, 2009). Therefore, fish culture could be more effective through cage culture in water logged areas. *Bagda* (shrimp) farming in brackish water is a well accepted and widely practiced option. Similarly, livestock and poultry farming in raised platform could be feasible options. For instance, duck rearing could be very realistic option in water logged areas (Figure 8.2a). Moreover, training and awareness of people about the possible future impacts of sea level rise and adaptation options is very important which can be done through street-dramas and folk songs (Figure 8.2b).

For our study area *Koyra* the above-mentioned livelihood coping and adaptation strategies may have been effective if all the necessary actions can be taken accordingly. According to our observation, these adaptation strategies are most suitable for *Dakshin Bedkashi* union in *Koyra* upazila since it has mostly been water logged since May 2009.


Integrated Farming (Rice, fish, poultry, vegetable

Vegetable garden on floating bed

Cage culture of fish

Fig 8.1 Different adaptation options for agriculture and fisheries

Fig 8.2a Duck rearing in water logged area

Fig 8.2b Awareness rising through folk cultural program

Source: IWM, 2007

8.3.4 Use of mobile phones

A report by *The Economist* suggests that mobile phone technology can be an effective tool to delimit peoples' sufferings from the natural disasters and 4 billion people of the world can be provided direct assistance through mobile in case of any upcoming disaster (Economist, 2009). A study in 32 tsunami affected villages in Srilanka shows that mobile phone technology functions the most effective early warning tool during any disaster (Samarajiva and Waidyanatha, 2009). Empirical result from this study shows that villages that adopted mobile phone as early warning experienced least affect than those who didn't adopt this technology in the natural disasters after tsunami. Among the developing countries Bangladesh is considered as one of the most prospecting markets for mobile phones in Asia and taking this into account a study was conducted to examine the risk and benefit of using mobile phone for providing health care services (Van Kleef et al., 2010). Findings from this study indicate that mobile phone can be very effective in Bangladesh while disseminating the early warning during any upcoming natural disaster.

At present the total number of mobile phone subscribers in Bangladesh is 58.36 million (GoB, 2010) and day by day this figure is increasing. It is because mobile phones are relatively very cheap in this country. For example, the total cost for a handset plus SIM card is less than US$ 20. Hence, it is not much burden for a lower-middle income family to afford a mobile connection. The existing mobile-operators have spread their networks over the remotest places in Bangladesh even in the coastal zones. Therefore, it is possible to use the existing mobile operators to disseminate information regarding any upcoming disaster among the grass-root level people. We find that at present the mobile operators provide hourly news update to their subscribers and one can listen to this update by dialing to a particular number at a nominal cost. We also find that during any important event, like national immunization day, these mobile operators send text-message to subscribers on behalf of the government to make them aware about that event. The same approach can be adopted to disseminate early warning to coastal areas. However, in this case a voice message is more effective than a text message since most of the coastal people are illiterate. Hence, these people may take urgent actions to evacuate and shift to cyclone shelters once they receive a voice message in their mobile phones. Such adoption of mobile phone technology in disseminating early disaster warning is certainly more certainly more effective than BMD forecasting. In this case government may rely on forecasting of SAARC Meteorological Research Center (SMRC) and ask mobile phone operators to send voice message in case of any upcoming climatic catastrophe.

8.3.5 Use of community radio

Over the last few years community radio has become a popular medium for news and recreation in Bangladesh and hence, international agencies like UNESCO avail the help of community radio for informing people about their activities and programs (UNESCO, 2006). The most distinctive feature of this radio is to inform people regarding the 'traffic congestion' in the city which is already proved worthy for the city dwellers. However, this community radio is available only in the Dhaka and Chittagong (Khan, 2007). Therefore, if any substation of community radio can be set up in the coastal zone and in case of any natural disaster if the message is broadcast beforehand, then it will be easy to make people aware since the frequency of such a radio is supported by both mobile phones and short-band radio. There are few areas where mobile network does not work but radio frequency does. For these areas if any emergency message can be broadcast through such radio then at least this message can be announced from the mic (a kind of loud speaker) so that people may aware about the event. This application of community radio can be as effective as mobile phones in coastal zones.

8.3.6 Community-based adaptation training

We find that a number of NGOs arrange small-scale training for local community to acquaint them with possible adaptation strategies during natural disasters (Cordaid, 2009). Under this training usually a female representative is selected from each small cluster of the whole community and they are trained by concerned NGO. Afterwards those representatives arrange informal gathering within the society where various adaptation strategies are explained to them. For instance, people are taught how to pack-up their life-supporting belongings while they shift to cyclone shelters, how to preserve their valuables in underground and so on. When a good number of people become familiar with such actions during emergency, they also start disseminating this knowledge to their families and relatives. Our FGDs indicate that this kind of trainings is proved effective for adaptation. However, this kind of training is conducted in too few places in *Koyra* upazila. Hence, if the local government pursues the existing NGOs to arrange such training in all the unions of *Koyra* then more and more people can be brought under such training and hence, effective adaptation knowledge will be available with community levels in coastal areas.

8.3.7 Institutional reformation

Institutions are the principal mediating factor for decision-making process (Adger, 2000). Therefore, inefficient institutions may indulge into institutional inertia and in case of adaptation for climate change effects such inertia constitutes multiple consequences like biasd decision-making, discrimination in resource allocation, rent seeking, corruption and nepotism (Agrawala and van Aalst, 2008). So in order to maintain proper synergy among various adaptation strategies institutional efficiency and transparency are essential.

During our study we figure out institutional inertia in local level government of *Koyra* followed by ruling party's influence. Out of a bunch of observations on consequences of institutional inertia in our study area, we depict here only three. The first one is about the repairing of the damaged embankment in *Dakshin Bedkahi* union, where due to rent-seeking intention of the public officials and mighty local political leaders the embankment-repairing was delayed till April 2010. The second one is about VGF-card distribution among the distressed people in various unions of *Koyra*, where the elected public representatives practice nepotism and hence, aid from central government does not reach to affected people who actually deserve this aid (VGF-card). The third and last one is about the activities of the 'local pressure groups' who are the representatives of the mighty landlords or political leaders; these pressure groups grab resources from the *Sundarbans* and shimp production plant forcefully, and hence, they create impediment in implementation of any adaptation-related development project in *Koyra* through extortion.

We figure out that it is necessary to reform every level of institution in this coastal area, especially public administration with a view to maintaining synergy among various adaptation-related projects. Once the public institutions become efficient, perhaps there will be no necessity to continue adaptation programs in these areas over the years rather the ongoing programs will be sufficient enough to lift the coastal people from vulnerability.

8.4 Remarks

As far as we observed, we have found that the existing climate change adaptation strategies in various unions of *Koyra* are 'top-down' in nature. However, we recommend optimal adaptation options that are mostly 'bottom-up' in process. Because we think that people from community level are well aware about the existing scenario of their vulnerability; and if any strategy is developed by considering these peoples' observations then the strategy is supposed to be more effective than top-down strategies. Hence, for formulating adaptation options it is supposed to be better focusing on community level of the vulnerable people. We have also emphasized community level while recommending the optimal adaptation strategies for coastal vulnerable people.

Chapter NINE
Conclusion

9.1 Background

Bangladesh, one of the 49 LDCs of the world, is contributing the least to the carbon and greenhouse gases (GHGs) emissions. However, this country is among the fewer most vulnerable countries due to effects of climate change (Huq et al., 2004). This study is set out to consider climate change induced socioeconomic vulnerability in *Koyra,* a southwestern coastal area of Bangladesh. Hence, we started with three general objectives for this study those were addressed by a number of research questions. We have tried to realize those objectives through descriptive and analytical approaches.

We have accomplished this interdisciplinary study through a number of segments. First we attempted to identify the possible effects of climate change those were manifested in form of powerful cyclones, storm surge and flood in our study area *Koyra*. Then we constructed a vulnerability index consists of five domains and we determined domain-wise and total vulnerability for each of the 7 unions in *Koyra* upazila. Afterwards we ran a number of econometric models to chalk out the nature and extent of relationship of vulnerability (domain-wise and total) with poverty and land ownership pattern of households. In these analyses we also considered a number of socioeconomic variables like household-size, literacy and social capital. Based on the outcomes from these analyses finally we recommended for some optimal adaptation options considering the existing options in the study area.

9.2 Summery of study findings

Due to growing debate on the issue of climate change, especially after climate scientists' rejection of projected sea-level rise calculated by IPCC (Adam, 2010), we started with the issue if there is really any symptom of climate change in our study area. We have found that the return-year of cyclones in the coastal area of Bangladesh has been declining since 1970 and during 2007-2009 periods it dropped down to only 2 years. We have also found for the study area that since 1948 the important climatic factors had gradual increasing trends- yearly average temperature by 0.02^0C, rainfall by 7.82 mm and sea-level by 0.65 mm. However, since 1990 a sharp increase is taken place with sea-level rise which is on average 1.4 mm per year. In the last 20 years this area is hit by powerful cyclones followed by storm surge and flood in almost every year. These findings altogether indicate some anomalies in the usual climatic behavior, which are complied with testimonies of old-aged local people on abnormal climatic behavior. In contrast with the world scenario of these climatic factors (IPCC, 2007d), we concluded that climate change is likely to take place in coastal Bangladesh and cyclones are the most frequent effect of it.

We then tried to figure out the socioeconomic vulnerability in our study area *Koyra* due to effects of climate change. Hence, we adopted a vulnerability index constructed by Bollin and Hidajat in 2006, and modified in accordance with relevant variables for this study area. In this index, we decomposed total vulnerability into 5 domains as- demographic, social, economic, physical and disaster-exposure. Using a formula we obtained values (score) for each of the above-mentioned vulnerability domain for each union of *Koyra* upazila (detailed in Appendix-I). Summing up subsequent score of respective domains for a union we have obtained total vulnerability for that union. Total vulnerability scores indicate that socioeconomically the most and the least vulnerable unions are *Dakhin Bedkashi (46.01)* and *Amadi (30.08)* respectively. Our findings show that unions having longer boundary with mangrove forest *Sundarbans* as well as nearer to the Bay of Bengal are relatively more vulnerable.

Once we determined the vulnerability scores for the unions, we ran a model to identify the nature and extent of relationship between vulnerability and important socioeconomic factors like household-poverty, household-size, literacy, social capital and land ownership. In this context, first we figured out relationship between poverty and various vulnerability-domains including selected socioeconomic variables; then we repeated the same model but with total vulnerability instead of various domains. Lastly we ran the same model; however, this time we took households' land ownership pattern (quantity of land owned in 2009) instead of household poverty. In this study we measured poverty on basis of a threshold expenditure-value (consumption) of US$ 202/capita/year, and we also used a proxy variable (staying period with present community) for social capital.

We have found that all the vulnerability-domains except disaster-exposure have significant inverse relationship with poverty (model I). However, in this case disaster-exposure domain does have a significant positive relation with poverty. We have found that such positive relationship is a short-term phenomenon due to abundance of relief and aids during the post-disaster periods. Based on the absolute values (beta coefficients) from model I, we found that disaster-exposure, physical and economic domains are respectively more influential vulnerabilities. As we conducted the same analysis by replacing vulnerability-domains with total vulnerability, we found a significant inverse relationship between poverty and vulnerability (model II). For both of the above mentioned cases (model I and model II) we have found significant positive relationship for literacy and social capital while significant negative relationship for household-size with poverty. These model results are mostly complied with our findings from FGDs (Focus Group Discussions) and household survey.

Later we used households' land ownership pattern, instead of poverty in order to address capacity of households, to investigate relationship with the same independent variables used in model I and II. We have found that except disaster-exposure, all other vulnerability domains have negative relationship with land ownership; however, in this case only social and economic vulnerability domains are significant (model III). The disaster-exposure vulnerability is positively correlated with land ownership in the same model and this relationship is significant. Using total vulnerability we have obtained a significant negative relationship with land ownership (model IV). We found positive relationship (in model III and IV) for household size, literacy and social capital with land ownership; however, the relationship is significant only for literacy and social capital.

On the whole, our empirical data analysis shows that vulnerability, both in the form of domain-wise and aggregated (total), has mostly significant inverse relationship with poverty. Our study findings imply that relatively larger households suffer more from poverty, literate and better educated households are better off and less suffered by poverty, and households with better social capital are also less affected by poverty. These findings are significantly consistent with outcomes of our data analysis.

One of the significant results from this study shows positive correlation (0.237) between expenditure (measurement of poverty) and land ownership; while an inverse correlation (-0.279) between vulnerability and land ownership (detailed in Appendix III). Hence, land ownership might be a crucial factor for capacity of the households while facing challenges of both poverty and vulnerability. We have mentioned in the earlier chapter that the exacerbated social and economic vulnerabilities along with local pressure group force the disaster-affected households to transfer (sell) ownership of their lands at a nominal price to local landlords. We found during field survey that after transferring of land ownership some households migrate to nearby urban area while some stay in the same union. Hence, these households are self-selected to stay in the same union and even after selling their lands. We have identified two specific reasons for such behavior of households- the first one is about their poverty level, that is they are too poor to shift somewhere else even after they sell their lands during post-disaster period; and the second reason is that these households try to grab proportionately more relief and aids from various local agencies by staying in a less populated area during the post disaster period. We have found this scenario in relatively more vulnerable unions of our study area *Koyra.*

So our empirical study-findings conclude that possible effects of climate change exacerbate socioeconomic vulnerability in Southwestern coastal Bangladesh. Furthermore, depending on its domains such vulnerability differs from union to union; and significantly exacerbates poverty and incapability (such as, lack of land ownership) for the affected households.

9.3 Summery of recommended adaptation options

We have found that capacity of households becomes a pivotal factor to face the adverse consequence of socioeconomic vulnerability created from effects of climate change. Taking this into consideration we have recommended a number of optimal adaptation options along with the existing ones. We have emphasized co-management of mangrove forest *Sundarbans* so that affected people may have a secure income from this forest and at the same time its conservation is also ensured. We did so since our finding indicates that about 73.7% households are directly or indirectly dependent on the *Sundarbans* and this forest plays the key role for maintaining environmental balance in the south and southwestern parts of Bangladesh. Furthermore, as a capacity we recommend for usage of social capital in reducing vulnerability-led poverty as because we found that society with better integration is well capable of coping the effects of disasters and poverty. Our empirical result from data analysis also supports this recommendation for co-management (see correlation table in Appendix III).

As an adaptation option we also recommend for the use of mobile phones as early warning system in coastal area through sending voice message. It is because BMD (Bangladesh Meteorological Department) is not well equipped with modern system to forecast efficiently and effectively any upcoming disaster. Hence, mobile phones which are relatively cheap and with vast network in Bangladesh can be better effective under such circumstances. The usage of mobile phone as disaster early warning has already been succeeded in Srilanka (Samarajiva and Waidyanatha, 2009) and hence, this might also be fruitful for Bangladesh. Side by side we have also recommended for broadcasting of 'community radio,' which is available with all short-band frequency radios, in case of any emergency. In coastal area community radio may be as effective as mobile phones. We argued for mic (loud speaker) in mosques to make people aware about upcoming disaster where mobile network is unavailable but radio frequency is available.

We have also argued for livelihood coping as adaptation, where strategies for co-farming of fishery and poultry in an inundated area are suggested (for detail see last chapter). Such strategies are in practice under a project in Bangladesh (IWM, 2007), which have been successful in some water-logged areas. Hence, we think that these strategies may be also prospective for *Koyra* which is disaster-prone coastal areas. We also opine for community-based adaptation training that are already in vogue in some selected places of Bangladesh. Under such training some selected representatives (preferably women) are picked by a NGO and train them to disseminate necessary information within community regarding the actions to be taken prior to and during any disaster (for detail see last chapter).

Finally we have recommended for institutional reformation, particularly public administration in our study area *Koyra.* We found that almost all development projects/actions are hampered by a number of institutional inefficiency such as- biased decision-making, discrimination in aid distribution, rent seeking, political influence, corruption and nepotism. These altogether constitute a kind of institutional inertia and as a consequence both socioeconomic vulnerability and poverty are exacerbated in various unions of *Koyra.* Therefore, we argued for motivational development for both local people and responsible administrative personnel. This can be done through development of norms, values and rights of the general people along with proper implication of legal bindings for existing institutions. Since institutions are the main mediating factor for decision-making process (Adger, 2000), successful implication of adaptation options largely depends on institutional efficiency.

9.4 Shortcomings of vulnerability index and econometric models

Using an index, in this study we have determined vulnerability in the union (community) level; we did the same in case of subsequent vulnerability domains. While constructing and modifying the vulnerability index from the original index, we considered only the relevant and important variables in different domains. However, some variables are very context-specific and need to be handled carefully. Furthermore, there might be missing variables and unobservable that may have influence on the relationship among variables that we have already investigated. This might also be happened for variables at household-level. In other words, we used both primary and secondary sources while constructing this vulnerability index. The secondary data were used from population census which had been conducted in 2001 and adjusted in 2007. Therefore, in some unions we found a few deviated scenario, especially in case of population density and growth rate. For instance, we found population density per square km. as 803 in Dakshin Bedkashi union (BBS, 2007); however, during our survey we observed this density was much lower. Hence, in a few cases we had to proceed with a bit deviated data while constructing vulnerability index. Side by side, in this study we have investigated only one way casual relationship between vulnerability and poverty. However, there might be a reverse causality between these variables that we did not address in our study. When we tested the consistency of this index with another alternative approach, we got some changes in the ranking of vulnerable unions. In this case the new approach of vulnerability complied 58% with the old approach. Between regression coefficients from these two vulnerability indices, we found the little deviations.

In all of the 4 econometric models we have got almost all variables significant. However, these models are not sufficiently explained (R squares and adjusted R squares in Appendix II). Furthermore, correlation coefficients in Appendix III are not strong enough. Despite a sample size of 420 households, a possible reason may be underlying in the vulnerability scores. We have determined these vulnerability scores (both domain-wise and total) union-wise, not household wise. Hence, in this study a vulnerability score is used like a 'community variable.' We obtained individual value of poverty measurement for each household in our sample whereas we got and assigned only a single value for 60 households in a particular union. Therefore, for the whole sample we had only seven different values of vulnerability (both domain-wise and total) that we used repeatedly in our regression models. In other words, vulnerability scores are likely to be exogenous in the econometric models. Furthermore, while applying Heckman two stage model, for conditional equation we did not consider all of the variables, especially vulnerability-domains (model IV).

9.5 Concluding remarks

Through this study we have tried to outline several challenges and gaps that persists while effectively bridging vulnerability and adaptation options due to climate change effects. We have also tried to conclude regarding the manifestation of climate change in study area *Koyra.* While determining socioeconomic vulnerability, we have found that relatively more vulnerable areas are located along with the borders of mangrove forest *Sundarbans* and close proximity of the Bay of Bengal. Based on empirical results we have found that socioeconomic vulnerability exacerbates poverty for households. We have also found that all the domain-vulnerabilities, except disaster-exposure, have significant inverse relationship with poverty. Social capital, literacy status and household-size are also important socioeconomic parameters affecting vulnerability-induced poverty. The empirical findings of this study might be very helpful for local and national level policy-makers who are responsible for adaptation planning on behalf of the government. Furthermore, these study-findings can also help government to have a clear picture of specific vulnerabilities (like physical or economic etc.) in various unions of *Koyra* which are more likely to be similar in most other coastal areas.

In order to maintain a synergy between study findings and suitable adaptation options, we have proposed a number of strategies as recommendations those are likely to be both adaptation and mitigation. However, we think that there is ample scope for further research on this premise. Particularly, the vulnerability index can be further modified to apply in individual household level with a view to quantifying vulnerability. Besides, variables/indicators under different vulnerability-domains may be rearranged so that context-specificity of this index is minimized. In our recommendation we did not focus on the role of civil society and detail of social engineering in formulating adaptation options. Therefore, these can be an interesting issue for further research.

In fine, we suggest for more intensive study on both mitigation and adaptation in order to lessen vulnerability of coastal people in Bangladesh. It is because both of those strategies are applied for same purpose- to reduce the adverse effects of climate change. Both of them are linked with coastal climate system and hence, the more efficient mitigation is adopted now, the less necessity for adaptation in future.

Reference

ADAM, D. (2010) Climate scientists withdraw journal claims of rising sea levels. *Environment.* London, The Guardian.

ADGER, W. N. (1996) Approaches to vulnerability to climate change. *Working Paper - Centre for Social and Economic Research on the Global Environment*, GEC 96-05.

ADGER, W. N. (1999) Social vulnerability to climate change and extremes in coastal Vietnam. *World Development,* 27**,** 249-269.

ADGER, W. N. (2000) Institutional adaptation to environmental risk under the transition in Vietnam. *Annals of the Association of American Geographers,* 90**,** 738-758.

ADGER, W. N. (2003) Social capital, collective action, and adaptation to climate change. *Economic Geography,* 79**,** 387-404.

ADGER, W. N. (2006) Vulnerability. *Global Environmental Change,* 16**,** 268-281.

ADGER, W. N. & KELLY, P. M. (1999) Social vulnerability to climate change and the architecture of entitlements. *Mitigation and Adaptation Strategies for Global Change,* 4**,** 253-266.

ADPC (2007) Climate Forecast Application in Bangladesh. *Climate Risk Management.* Bangkok, Asian Disaster Prepardness Center.

AGRAWALA, S. (2004) Adaptation, development assistance and planning: Challenges and opportunities. *IDS Bulletin,* 35**,** 50-54.

AGRAWALA, S., OTA, T., AHMED, A. U., SMITH, J. & VAN AALST, M. (2003) Development and Climate Change in Bangladesh: Focus on Coastal Flooding and the Sundarbans. Paris, France, Organisation for Economic co-operation and Development, OECD.

AGRAWALA, S. & VAN AALST, M. (2008) Adapting development cooperation to adapt to climate change. *Climate Policy,* 8**,** 183-193.

AHMED, M. (2003) Coastal Livelihoods, situation and context. IN PLAN, W. P. I. C. Z. M. (Ed.). Governmnet of Bangladesh, 91-98.

AHMED, S. A., DIFFENBAUGH, N. S. & HERTEL, T. W. (2009) Climate volatility deepens poverty vulnerability in developing countries. *Environmental Research Letters,* 4.

ALI, A. (1996) Vulnerability of Bangladesh to climate change and sea level rise through tropical cyclones and storm surges. *Water, Air, and Soil Pollution,* 92**,** 175.

ANON (2008) Techniques used in disaster risk assessment. *UN-HABITAT: Disaster Assessment Portal.* Disaster Assessment Portal.

ANON (2010) Climate Refugees.

BANGLAPEDIA (2006) Koyra Upazila. *Banglapedia- The National Encyclopedia of Bangladesh.* Dhaka, Asiatic Soiety.

BARNETT, J. & ADGER, W. N. (2007) Climate change, human security and violent conflict. *Political Geography,* 26**,** 639-655.

BBC (2009) Cyclone Aila.

BBS (2007) Bangladesh Population Census 2001. IN PLANNING, M. O. (Ed.). Dhaka, Government of the People's Republic of Bangladesh.

BBS (2008) Monthly Statistical Bulletin. Dhaka, Ministry of Planning, Government of Peoples Republic of Bangladesh.

BDNEWS (2009) Bangladesh 'failed to highlight security'. *COP15.* Dhaka, BDNews24.com.

BIRKMANN, J. (2007) Risk and vulnerability indicators at different scales:. Applicability, usefulness and policy implications. *Environmental Hazards,* 7**,** 20-31.

BIRKMANN, J. & VON TEICHMAN, K. (2010) Integrating disaster risk reduction and climate change adaptation: Key challenges-scales, knowledge, and norms. *Sustainability Science,* 5**,** 171-184.
BLAIKIE, P., CANNON, T., DAVIS, I. & WISNER, B. (1994) Disaster Pressure and Release Model. *At Risk : Natural Hazards, People's Vulnerability and Disasters.* London [etc.], Routledge.
BMD (2009) Yearly Weather Report. Dhaka, Bangladesh Meteriological Department.
BOLLIN, C. & HIDAJAT, R. (2006) Community-based disaster risk index: Pilot implementation in Indonesia. IN BRIKMANN, J. (Ed.) *Measuring Vulnerability to Natural Hazards- Towards Disaster Resilient Societies.* Tokyo, New York, Paris, UNU-Press.
BOULDER, U. O. C. A. (2010) Sea level of the Bay of Bengal. *Sea level change.* Boulder.
BRAMMER, H. (1993) Geographical complexities of detailed impact assessment for the Ganges-Brahmaputra-Meghna delta of Bangladesh. *Climate and sea level change***,** 246-262.
BROUWER, R., AKTER, S., BRANDER, L. & HAQUE, E. (2007) Socioeconomic vulnerability and adaptation to environmental risk: A case study of climate change and flooding in Bangladesh. *Risk Analysis,* 27**,** 313-326.
CDP (2009) *Upokul Barta* (in English: Coasatal Bulletin). Khulna.
CHOWDHURY, M. S. H. & KOIKE, M. (2010) An overview on the protected area system for forest conservation in Bangladesh. *Journal of Forestry Research,* 21**,** 111-118.
CORDAID (2009) The Dove, The Duck and The Camel: Building Resilient Communities to Climate Change. The Netherlands.
DAYTON, U. O. (2010a) Rainfall database for Bangladesh. Ohio, Department of Mechanical and Aerospace Engineering.
DAYTON, U. O. (2010b) Temperature database of Bangladesh. *Global Temperature.* Ohio, Department of Mechanical and Aerospace Engineering.
DE VAUS, D. A. (2001) *Research design in social research,* London [etc.], SAGE.
DEY, S. K. & RAHMAN, D. M. (2009) Assessment of vulnerablity for climate change induced livelihood pattern using GIS approaches in south west coastal region of Bangladesh. *National seminar on climate change induced livelihood pattern.* Khulna University, Bangladesh, Khulna University.
DOW, W. H. & NORTON, E. C. (2003) Choosing between and interpreting the Heckit and two-part models for corner solutions. *Health Services and Outcomes Research Methodology,* 4**,** 5-18.
EASTERLING, D. R., KARL, T. R., GALLO, K. P., ROBINSON, D. A., TRENBERTH, K. E. & DAI, A. (2000) Observed climate variability and change of relevance to the biosphere. *Journal of Geophysical Research D: Atmospheres,* 105**,** 20101-20114.
ECONOMIST, T. (2009) Mobile Phones: Sensors and sensitivity. *Science and Technology.* London, The Economists.
EM-DAT (2009) Damage due to diasater in Bangladesh. *International Disaster Database.* Louvain, Université Catholique de Louvain.
EM-DAT (2010) Top 10 natural disasters in Bangladesh from 1900-2010. Luven, International database for disasters.
FEW, R. (2003) Flooding, vulnerability and coping strategies: local responses to a global threat. *Progress in Development Studies,* 3**,** 43-58.
GERMANWATCH (2010) Global Climate Risk Index 2010. IN HARMELING, S. (Ed.) *Briefing paper.* Bonn, Germanwatch.

GOB (2005a) National Adaptation Prgramme of Action (NAPA). Dhaka, Ministry of Environment and Forest; Peoples Republic of Bangladesh.
GOB (2005b) Polder information upto 2004. Dhaka, Bangladesh Water Development Board.
GOB (2009a) Economic Review of Bangladesh 2008. IN FINANCE, M. O. (Ed.). Dhaka, Government of Peoples Republic of Bangladesh.
GOB (2009b) The Rights-based Plaining & Motitoring: Disaster Preparedness. IN BUREAU, D. M. (Ed.). Dhaka, Ministry of food and disaster management.
GOB (2010) Mobile phone subscribers in Bangladesh. Dhaka, Bangladesh Telecommunication and Regulatory Commission.
HARUN-OR-RASHID, S., BISWAS, S. R., BÃ¶CKER, R. & KRUSE, M. (2009) Mangrove community recovery potential after catastrophic disturbances in Bangladesh. *Forest Ecology and Management,* 257**,** 923-930.
HEM, J. D. (1970) *Study and interpretation of the chemical characteristics of natural water : a review of chemical, geologic, and hydrologic principles and processes that control the composition of natural water, with methods for studying and interpreting chemical analysis,* Washington, United States Department of the Interior.
HOSSAIN, M. Z., ISLAM, M. T., SAKAI, T. & ISHIDA, M. (2009) Impact of Tropical Cyclones on Rural Infrastructures in Bangladesh. *Agricultural Engineering International; Vol. X.* The CIGR E-journal.
HUBNER, K. (2008) Natural Disasters: Sudden Impact, Permanent, Consequences on Income Inequality. *Pacific Development Conference.* San Francisco.
HUQ, S., KARIM, Z., ASADUZZAMAN, M. & MAHTAB, F. (1999) *Vulnerability and adaptation to climate change for Bangladesh*, University Press Limited (UPL), 59.
HUQ, S. & REID, H. (2004) Mainstreaming adaptation in development. *IDS Bulletin,* 35**,** 15-21.
HUQ, S., REID, H., KONATE, M., RAHMAN, A., SOKONA, Y. & CRICK, F. (2004) Mainstreaming adaptation to climate change in Least Developed Countries (LDCs). *Climate Policy,* 4**,** 25-43.
IBARRARÃN, M. E., MALONE, E. L. & BRENKERT, A. L. (2009) Climate change vulnerability and resilience: current status and trends for Mexico. *Environment, Development and Sustainability***,** 1-24.
IFTEKHAR, M. S. (2008) An overview of mangrove management strategies in three South Asian countries: Bangladesh, India and Sri Lanka. *International Forestry Review,* 10**,** 38-51.
IIED (2009) Community-based adaptation to climate change. *Participatory Learning and Action 60.* IIED (International Institute for Environment and Development).
IPCC (1990) First Assessment Report (FAR) 1990. *Impact Assessment of Climate Change.* Cambridge, United Kingdom and New York, USA.
IPCC (1995) Second Assessment Report (SAR) 1995. *Economic and Social Dimension of Climate Change.* Cambridge, United Kingdom and New York, Intergovernmental Panel on Climate Change.
IPCC (2001) Contribution of Working Group II to the Third Assessment Report of IPCC on Climate Change, 2001. *Impacts, Adaptations and Vulnerability.* Cambridge, United Kingdom and New York, USA.
IPCC (2007a) Contribution of Working Group II to the Fourth Assessment Report of IPCC on Climate Change, 2007. *Impacts, Adaptations and Vulnerability.* Cambridge, United Kingdom and New York, USA.
IPCC (2007b) Fourth Assessment Report. *November.* New York, United Nations Environment Program (UNEP), 368, 397.

IPCC (2007c) Glossary of Terms used in the IPCC Fourth Assessment Report (WG II). *Contribution of Working Group II to the Fourth Assessment Report of IPCC on Climate Change, 2007.* Cambridge, United Kingdom and New York, USA.
IPCC (2007d) Observed changes in climate and their effects. *The AR4 Synthesis Report: Contribution of Working Groups I, II and III to the Fouth Assessment Report of IPCC.* Geneva, IPCC.
IPCC (2007e) Working Group I: The Physical Science Basis. *Climate Change.* Geneva, IPCC.
IPCC (2008) IPCC: Organization and History. Geneva, Intergovernmental Panel on Climate Change.
ISLAM, M. R. (2004) *Where Land Meets the Sea: A Profile of the Coastal Zone of Bangladesh.,* Dhaka, Bangladesh, UPL (University Press Limited), 57.
IWM (2007) Investigating the impact of relativesea-level riseon coastal communities and their livelihoods in Bangladesh. Dhaka, UK Department for Environment, Food and Rural Affairs.
KAMAL, M., AVIJIT, R. Q., AND SANZIDA, A. (2001) Resource Use by Indigenous Communities in the Coastal Zone. *PDO-ICZMP*, July**,** 531-533.
KHAN, A. (2007) Community Radio. *Communication and Technology.* Dhaka, The Daily Star.
LAWRENCE, P., MEIGH, J. & SULLIVAN, C. (2003) The Water Poverty Index: an International Comparison. *Keele Economics Research Papers.*
MAPBANGLA (2009) Flood prone areas in Khulna. Khulna, Map Bangla.
MILIBAND, E. & ALEXANDAR, D. (2009) Urgency of tackling climate change. *Special Feature.* Dhaka, The Daily Star.
MOHAMED, M. (2008) Vulnerability to Maldives Islands to Climate Change and Extreme Weather Events: A Study on Perceptions, Impacts and Adaptations. *SERD.* Bangkok, Asian Institute of Technology Thailand.
MUHAMMAD, N. M. (2007) Bangladesh: A Land of Natural Disasters. *Online documentary resources.* Islam Online.
MUHAMMED, N., KOIKE, M. & HAQUE, F. (2008) Forest policy and sustainable forest management in Bangladesh: An analysis from national and international perspectives. *New Forests,* 36**,** 201-216.
MYERS, N. (2002) Environmental refugees: A growing phenomenon of the 21st century. *Philosophical Transactions of the Royal Society B: Biological Sciences,* 357**,** 609-613.
NURSE, L. A. & SEM, G. (2001) Chapter 17: Small Island States. *IPCC CLimate Change Report.* Cambridge, United Kingdom and New York, USA.
PARVIN, G. A., AHSAN, S. R. & SHAW, R. (Eds.) (2010) *Community-based coastal zone management in Bangladesh,* Singapore and Chennai, Research Publishing.
PARVIN, G. A., TAKAHASHI, F. & SHAW, R. (2009) Coastal hazards and community-coping methods in Bangladesh. *Journal of Coastal Conservation***,** 1-13.
PAUL, B. K. (2009) Human injuries caused by Bangladesh's cyclone sidr: an empirical study. *Natural Hazards***,** 1-13.
PAUL, B. K. & DUTT, S. (2010) Hazard warnings and responses to evacuation orders: The case of Bangladesh's cyclone Sidr. *Geographical Review*, 100**,** 336-355.
PDO-ICZMP (2003) Delineation of the Coastal Zone IN PAPER, W. (Ed.). Government of Bangladesh, 119-127.
POMEROY, R. S., RATNER, B. D., HALL, S. J., PIMOLJINDA, J. & VIVEKANANDAN, V. (2006) Coping with disaster: Rehabilitating coastal livelihoods and communities. *Marine Policy,* 30**,** 786-793.

RAMAMASY, S. & BAAS, S. (2007) *Climate variability and change: adaptation to drought in Bangladesh : a resource book and training guide,* Rome, Asian Disaster Preparedness Center (ADPC) [etc.].

RAY-BENNETT, N. S., COLLINS, A., BHUIYA, A., EDGEWORTH, R., NAHAR, P. & ALAMGIR, F. (2010) Exploring the meaning of health security for disaster resilience through people's perspectives in Bangladesh. *Health and Place,* 16**,** 581-589.

SAMARAJIVA, R. & WAIDYANATHA, N. (2009) Two complementary mobile technologies for disaster warning. *Info,* 11**,** 58-65.

SELVARAJU, R., SUBBIAH, A. R., BAAS, S. & JUERGENS, I. (2006) Livelihood Adaptation to Climate Variability and Change in Drought-prone Areas in Bangladesh. *Improved Adaptive Capacity to Climate Change for SustainableLivelihoods in the Agriculture Sector.* Rome, ADPC and FAO.

SLANGEN, L. H. G., LOUCKS, L. A. & SLANGEN, A. H. L. (2008) *Institutional economics and economic organisation theory : an integrated approach,* Wageningen, Wageningen Academic Publishers, 24-28, 47, 68, 83.

TAKAGI, T., OGUCHI, T., ZAIKI, M. & MATSUMOTO, J. (2005) Geomorphological and geological studies for Bangladesh: A review. *Chikei/Transactions, Japanese Geomorphological Union,* 26**,** 405-422.

TOMPKINS, E. L. & NEIL ADGER, W. (2005) Defining response capacity to enhance climate change policy. *Environmental Science and Policy,* 8**,** 562-571.

UNESCO (2006) UNESCO supports creation of Bangladesh's first community radio station. *Communication and Information Service.* New Delhi, United Nations Educational, Scientific and Cultural Organization.

UNFCCC (2009a) A Climate Neutral COP15. *Energy efficiency project at brick factories in Bangladesh makes COP15 neutral.* Bonn, United Nations Framework Convention on CLimate Change.

UNFCCC (2009b) LDCs Work Programs and NAPAs. *Cooperation and Support.* UNFCC.

VAN KLEEF, E., FISCHER, A. R. H., KHAN, M. & FREWER, L. J. (2010) Risk and benefit perceptions of mobile phone and base station technology in Bangladesh. *Risk Analysis,* 30**,** 1002-1015.

VITOUSEK, P. M. (1994) Beyond global warming: Ecology and global change. *Ecology,* 75**,** 1861-1876.

YAMIN, F., MITCHELL, T. & TANNER, T. (2005a) Linking climate adaptation: A research agenda. *IDS Bulletin,* 36**,** 126-131.

YAMIN, F., RAHMAN, A. & HUQ, S. (2005b) Vulnerability, adaptation and climate disasters: A conceptual overview. *IDS Bulletin,* 36**,** 1-14.

Appendix I: Vulnerability Index Table

Domains	Variables/ Indicators	Amadi			Bagali			Dakshin Bedkashi			Koyra			Maharajpur			Maheshwarpur			Uttar Bedkashi		
		Indicator Index	Average weight	wt. vulnerability	Indicator Index	Average weight	wt. vulnerability	Indicator Index	Average weight	wt. vulnerability	Indicator Index	Average weight	wt. vulnerability	Indicator Index	Average weight	wt. vulnerability	Indicator Index	Average weight	wt. vulnerability	Indicator Index	Average weight	wt. vulnerability
Demographic	People/km²	0.94	3.5	3.31	1.00	3.5	3.50	0.27	3.5	0.93	0.96	3.5	3.38	0.86	3.5	3.00	0.86	3.5	2.99	0.00	3.5	0.00
	% of old and child in area	0.18	4	0.72	0.99	3	2.97	0.83	4.5	3.75	0.93	4	3.70	0.87	3.5	3.05	0.00	4	-.01	0.00	4	0.00
	Male-female ratio	0.29	2.5	0.74	0.32	2.5	0.80	0.29	2.5	0.72	0.32	2.5	0.80	0.30	2.5	0.74	0.27	2.5	0.68	0.29	2.5	0.71
	Population growth rate	0.11	3	0.32	0.41	4.5	1.84	1.00	4.5	4.50	0.46	4.5	2.08	0.00	4	0.00	1.00	3.5	3.50	0.55	4.5	2.47
	% of hh migrated in last 5 yrs	0.25	2.5	0.64	0.57	2	1.15	0.36	3	1.09	0.57	2	1.15	0.57	2	1.15	0.00	2	0.00	1.00	3	3.00
		Domain total		**5.72**	**Domain total**		**10.26**	**Domain total**		**10.98**	**Domain total**		**11.10**	**Domain total**		**7.94**	**Domain total**		**7.16**	**Domain total**		**6.18**
Social	% of illiterate hh	0.48	1.5	0.73	0.82	1.5	1.23	0.49	1.5	0.74	1.00	1.5	1.50	1.00	2.5	2.50	0.11	1.5	0.16	0.68	1.5	1.02
	% of hh under poverty line	0.10	3	0.31	0.48	3	1.44	0.79	3	2.36	0.65	3	1.94	0.91	3	2.72	0.35	3	1.06	1.00	3	3.00
	% of hh participated in election	0.37	3.5	1.29	0.28	3.5	0.99	0.15	3.5	0.51	1.00	3.5	3.50	1.00	3.5	3.50	0.00	3.5	0.00	0.57	3.5	2.00
	% of hh contribute free labor	1.00	3.5	3.50	0.25	3.5	0.75	0.69	3.5	2.41	0.81	3.5	2.84	0.81	3.5	2.84	0.29	3.5	1.03	0.78	3.5	2.73
		Domain total		**5.83**	**Domain total**		**4.41**	**Domain total**		**6.01**	**Domain total**		**9.79**	**Domain total**		**11.56**	**Domain total**		**2.26**	**Domain total**		**8.76**
Economic	% of hh income from nature	0.42	**2.5**	1.06	0.08	2.5	0.20	0.27	2.5	0.67	0.32	2.5	0.81	1.00	2.5	2.50	0.77	2.5	1.92	0.00	2.5	0.00
	% of unemployed people	1.00	4	4.00	0.66	4	2.63	0.08	4	0.31	0.11	4	0.43	0.55	3.5	1.93	0.54	4	2.17	0.00	4	0.00
	% of hh live in non-brick house	0.00	3.5	0.00	1.00	3	3.00	0.25	3.5	0.89	0.75	3.5	2.61	0.45	3	1.34	0.90	3.5	3.13	0.75	3.5	2.61
	% of hh lost land in last 5 yrs	0.28	3.5	0.99	0.56	5	2.78	0.72	4	2.87	0.64	5	3.19	0.64	4	2.55	1.00	5	5.00	0.58	5	2.91
	% of hh suffered disaster-dmg	0.17	3.5	0.59	0.88	3	2.65	0.95	5	4.76	0.88	4	3.53	0.88	4	3.53	1.00	4.5	4.50	0.89	4	3.54
		Domain total		**6.64**	**Domain total**		**11.26**	**Domain total**		**9.50**	**Domain total**		**10.57**	**Domain total**		**11.86**	**Domain total**		**16.73**	**Domain total**		**9.07**
Physical	% of hh without electricity	0.44	4	1.75	0.46	3.5	1.61	0.87	4	3.48	0.45	4	1.79	0.40	3.5	1.39	0.00	4	0.00	1.00	4	4.00
	% of hh without sanitary latrine	0.01	3	0.02	0.33	2.5	0.81	0.06	2.5	0.14	0.79	2.5	1.99	0.79	2.5	1.97	1.00	2.5	2.50	0.76	3	2.29
	% of hh drinking pond water	1.00	4.5	4.50	1.00	4	4.00	0.13	4.5	0.57	0.00	4.5	0.00	0.00	4.5	0.00	0.95	4.5	4.25	0.05	4.5	0.25
	% of not paved road in area	0.44	3.5	1.53	0.80	2.5	2.01	0.98	3.5	3.42	0.00	2.5	0.00	1.00	2.5	2.50	0.75	2.5	1.88	0.52	3	1.56
		Domain total		**7.81**	**Domain total**		**8.43**	**Domain total**		**7.62**	**Domain total**		**3.78**	**Domain total**		**5.86**	**Domain total**		**8.64**	**Domain total**		**8.10**
Exposure to cyclone and storm surge	% of hh not go to c. shelter	0.02	3.5	0.08	0.55	4	2.20	1.00	4.5	4.50	0.00	4.5	0.00	0.00	4.5	0.00	0.62	3.5	2.19	0.12	4.5	0.56
	Early warning system	1	4	4.00	1	3	3.00	**1**	4	4.00	1	3.5	3.50	1	3.5	3.50	1	5	5.00	1	4	4.00
	% of hh not realize w. system	0	4	0.00	1	3.5	3.5	0.45	3	1.35	0.28	3.5	0.96	0.49	3.5	1.71	0.07	4	0.27	0.38	4	1.52
	% of hh not having shelter	0	3.5	0.00	0.47	3.5	1.64	0.51	4	2.04	0.38	3.5	1.34	0.52	3.5	1.82	1	3	3	0.18	3	0.53
		Domain total		**4.08**	**Domain total**		**10.34**	**Domain total**		**11.89**	**Domain total**		**5.80**	**Domain total**		**7.03**	**Domain total**		**10.46**	**Domain total**		**6.61**
Total Vulnerability Index				**30.077**			**44.696**			**46.011**			**41.034**			**44.246**			**45.248**			**38.712**

Appendix II: STATA Outputs for Econometric Models & Outputs of Magnitude of Effects

1. STATA results for Model- I

```
. regress lnbcn totalhhmember edulevel duringwithcomty demographic social economic physical
disaster_e, beta

      Source |       SS       df       MS              Number of obs =     420
-------------+------------------------------           F(  8,   411) =   16.62
       Model |  40.8716902     8  5.10896128           Prob > F      =  0.0000
    Residual |  126.309802   411   .30732312           R-squared     =  0.2445
-------------+------------------------------           Adj R-squared =  0.2298
       Total |  167.181493   419  .399001176           Root MSE      =  .55437

------------------------------------------------------------------------------
       lnbcn |      Coef.   Std. Err.      t    P>|t|                     Beta
-------------+----------------------------------------------------------------
totalhhmem~r |  -.0357074   .0163486    -2.18   0.030                -.1011274
    edulevel |   .0635488   .0100553     6.32   0.000                 .3229734
duringwith~y |   .0048124    .001943     2.48   0.014                 .1107967
 demographic |  -.1623171   .0296055    -5.48   0.000                -.5432913
      social |  -.1060497   .0218081    -4.86   0.000                -.5052605
    economic |  -.0597572    .015423    -3.87   0.000                -.3076161
    physical |  -.2539967   .0533219    -4.76   0.000                -.6537877
disaster_e~e |   .1117154   .0251089     4.45   0.000                 .4869792
       _cons |   8.162582   .7132672    11.44   0.000                        .
------------------------------------------------------------------------------
```

2. STATA results for Model- II

```
. regress lnbcn totalhhmember edulevel duringwithcomty lnvul, beta

      Source |       SS       df       MS              Number of obs =     420
-------------+------------------------------           F(  4,   415) =   25.02
       Model |  32.4843758     4  8.12109394           Prob > F      =  0.0000
    Residual |  134.697117   415  .324571366           R-squared     =  0.1943
-------------+------------------------------           Adj R-squared =  0.1865
       Total |  167.181493   419  .399001176           Root MSE      =  .56971

------------------------------------------------------------------------------
       lnbcn |      Coef.   Std. Err.      t    P>|t|                     Beta
-------------+----------------------------------------------------------------
totalhhmem~r |  -.0315999   .0167065    -1.89   0.059                -.0894944
    edulevel |   .0863462   .0089959     9.60   0.000                 .4388366
duringwith~y |   .0050105   .0019944     2.51   0.012                 .1153569
       lnvul |   -.413301   .1705904    -2.42   0.016                -.1075266
       _cons |   5.951293   .6393881     9.31   0.000                        .
------------------------------------------------------------------------------
```

3. STATA results for Model- III

```
. heckprob lnlnduse2009 totalhhmember edulevel duringwithcomty physical disaster_exposure,
select(accesstosundarbans tota
> lhhmember edulevel duringwithcomty demographic social economic physical disaster_exposure)
nolog

Probit model with sample selection              Number of obs      =       420
                                                Censored obs       =        81
                                                Uncensored obs     =       339

                                                Wald chi2(5)       =      5.47
Log likelihood = -199.8342                      Prob > chi2        =    0.3612

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lnlnduse2009 |
totalhhmem~r |   .4361334   .2904375     1.50   0.133    -.1331136     1.00538
    edulevel |   .1487238   .1280059     1.16   0.245    -.1021631    .3996108
duringwith~y |   .0230931   .0176353     1.31   0.190    -.0114713    .0576576
    physical |  -1.271344   1.380046    -0.92   0.357    -3.976185    1.433497
disaster_e~e |    .085866   .1750879     0.49   0.624    -.2572999    .4290319
       _cons |   9.138779   10.29723     0.89   0.375    -11.04342    29.32098
-------------+----------------------------------------------------------------
select       |
accesstosu~s |   .1097615   .1083526     1.01   0.311    -.1026057    .3221286
totalhhmem~r |   .0066816   .0462696     0.14   0.885    -.0840052    .0973684
    edulevel |   .0003014   .0267822     0.01   0.991    -.0521906    .0527935
duringwith~y |   .0167242   .0053886     3.10   0.002     .0061627    .0272857
 demographic |  -.0287427   .0841991    -0.34   0.733    -.1937699    .1362845
      social |  -.1579714   .0608429    -2.60   0.009    -.2772213   -.0387214
    economic |  -.0891829   .0458078    -1.95   0.052    -.1789645    .0005986
    physical |  -.1074994   .1469793    -0.73   0.465    -.3955737    .1805748
disaster_e~e |   .0491415   .0664803     0.74   0.460    -.0811574    .1794405
       _cons |   2.424545    2.11347     1.15   0.251     -1.71778    6.566869
-------------+----------------------------------------------------------------
     /athrho |  -1.792569   65.95507    -0.03   0.978    -131.0621     127.477
-------------+----------------------------------------------------------------
         rho |  -.9460311   6.926947                            -1           1
------------------------------------------------------------------------------
LR test of indep. eqns. (rho = 0):   chi2(1) =     0.07   Prob > chi2 = 0.7967
------------------------------------------------------------------------------


. regress lnlnduse2009 totalhhmember edulevel duringwithcomty demographic social economic
physical disaster_exposure, bet
> a

      Source |       SS       df       MS              Number of obs =     339
-------------+------------------------------           F(  8,   330) =   15.96
       Model |  268.402872     8   33.550359           Prob > F      =  0.0000
    Residual |  693.775834   330  2.10235101           R-squared     =  0.2790
-------------+------------------------------           Adj R-squared =  0.2615
       Total |  962.178706   338  2.84668256           Root MSE      =  1.4499

------------------------------------------------------------------------------
lnlnduse2009 |      Coef.   Std. Err.      t    P>|t|                     Beta
-------------+----------------------------------------------------------------
totalhhmem~r |   .0348126   .0463864     0.75   0.453                 .0375936
    edulevel |   .1512468   .0308238     4.91   0.000                 .2857759
duringwith~y |   .0179585   .0059239     3.03   0.003                 .1462854
 demographic |  -.1499288   .0856971    -1.75   0.081                -.1892319
      social |  -.2405863    .065379    -3.68   0.000                -.4205176
    economic |  -.3153307   .0444079    -7.10   0.000                -.6323797
    physical |  -.3390004   .1573583    -2.15   0.032                -.3171287
disaster_e~e |   .2033898   .0748729     2.72   0.007                 .3393168
       _cons |   8.375566   2.069696     4.05   0.000                        .
------------------------------------------------------------------------------
```

4. STATA results for Model- IV

```
. heckprob lnlnduse2009 totalhhmember edulevel duringwithcomty lnvul, select(totalhhmember
edulevel duringwithcomty lnvul
>  disaster_exposure physical economic)nolog

Probit model with sample selection              Number of obs      =       420
                                                Censored obs       =        81
                                                Uncensored obs     =       339

                                                Wald chi2(4)       =      5.45
Log likelihood = -205.1947                      Prob > chi2        =    0.2444

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lnlnduse2009 |
totalhhmem~r |   .4036895   .2498939     1.62   0.106    -.0860936    .8934726
    edulevel |     .11488   .1326608     0.87   0.387    -.1451304    .3748903
duringwith~y |   .0231359   .0173128     1.34   0.181    -.0107966    .0570685
       lnvul |  -.0642915   2.198003    -0.03   0.977    -4.372299    4.243716
       _cons |   .0307324   8.502271     0.00   0.997    -16.63341    16.69488
-------------+----------------------------------------------------------------
select       |
totalhhmem~r |  -.0071596   .0448552    -0.16   0.873    -.0950743     .080755
    edulevel |  -.0137484   .0260713    -0.53   0.598    -.0648473    .0373505
duringwith~y |   .0161438   .0053057     3.04   0.002     .0057448    .0265427
       lnvul |  -5.024287   1.876301    -2.68   0.007    -8.701769   -1.346806
disaster_e~e |   .2119208   .0887753     2.39   0.017     .0379244    .3859171
    physical |  -.0302237   .0710878    -0.43   0.671    -.1695533    .1091059
    economic |   .0424387   .0406206     1.04   0.296    -.0371762    .1220537
       _cons |    17.0464   6.465695     2.64   0.008     4.373866    29.71893
-------------+----------------------------------------------------------------
     /athrho |  -1.677782   38.53334    -0.04   0.965    -77.20175    73.84618
-------------+----------------------------------------------------------------
         rho |  -.9325731   5.021178                            -1           1
------------------------------------------------------------------------------
LR test of indep. eqns. (rho = 0):   chi2(1) =     0.06   Prob > chi2 = 0.8093
------------------------------------------------------------------------------
```

```
. regress lnlnduse2009 totalhhmember edulevel duringwithcomty lnvul, beta

      Source |       SS       df       MS              Number of obs =     339
-------------+------------------------------           F(  4,   334) =   18.60
       Model |  175.321429     4  43.8303572           Prob > F      =  0.0000
    Residual |  786.857277   334  2.35586011           R-squared     =  0.1822
-------------+------------------------------           Adj R-squared =  0.1724
       Total |  962.178706   338  2.84668256           Root MSE      =  1.5349

------------------------------------------------------------------------------
lnlnduse2009 |      Coef.   Std. Err.      t    P>|t|                     Beta
-------------+----------------------------------------------------------------
totalhhmem~r |   .0338232   .0488095     0.69   0.489                 .0365251
    edulevel |   .1456066   .0271656     5.36   0.000                 .2751189
duringwith~y |   .0168861   .0062677     2.69   0.007                 .1375498
       lnvul |  -2.864805    .483134    -5.93   0.000                -.2945674
       _cons |   12.15352   1.820496     6.68   0.000                        .
------------------------------------------------------------------------------
```

5. Magnitude of effects of physical vulnerability

A. For model I

	Constant	HH size	Edu level	During with com'ty	Demographic vulnerability	Social vulnerability	Economic vulnerability	**Physical vulnerability**	Disaster-exposure	**Total**
Mean	8.163	4.889	4.526	39.029	8.490	6.945	10.578	**7.176**	8.520	
SD	0	1.811	3.210	14.543	2.115	3.009	3.252	**1.626**	2.753	
Regression coefficient	8.163	-0.036	0.064	0.005	-0.162	-0.106	-0.060	**-0.254**	0.112	
Expenditure1	66.635	-0.175	0.288	0.188	-1.378	-0.737	-0.632	**-1.823**	0.952	**63.320**
Expenditure2	66.635	-0.175	0.288	0.188	-1.378	-0.737	-0.632	**-2.236**	0.952	**62.905**
					% change					**-0.652**

B. For model III

	Constant	HH size	Edu level	During with com'ty	Demographic vulnerability	Social vulnerability	Economic vulnerability	**Physical vulnerability**	Disaster-exposure	**Total**
Mean	8.376	4.889	4.526	39.029	8.490	6.945	10.578	**7.176**	8.520	
SD	0	1.811	3.210	14.543	2.115	3.009	3.252	**1.626**	2.753	
Regression coefficient	8.376	0.035	0.151	0.018	-0.150	-0.241	-0.315	**-0.339**	0.203	
Land1	70.150	0.170	0.684	0.701	-1.273	-1.671	-3.336	**-2.433**	1.733	**64.727**
Land2	70.150	0.170	0.684	0.701	-1.273	-1.671	-3.336	**-2.984**	1.733	**64.176**
					% change					**-0.852**

C. For model II

	Constant	HH size	Edu level	During with com'ty	**Total vulnerability**	**Total**
Mean	5.951	4.889	4.526	39.029	**3.718**	
SD	0.000	1.811	3.210	14.543	**0.164**	
Regression coefficient	5.951	-0.032	0.086	0.005	**-0.413**	
Expenditure_1	35.418	-0.155	0.391	0.196	**-1.537**	34.31
Expenditure_2	35.418	-0.155	0.391	0.196	**-1.605**	34.25
			% change			**-0.20**

D. For model IV

	Constant	HH size	Edu level	During with com'ty	**Total vulnerability**	**Total**
Mean	12.154	4.889	4.526	39.029	3.718	
SD	0.000	1.811	3.210	14.543	0.164	
Regression coefficient	12.154	0.034	0.146	0.017	-2.865	
Land_1	147.708	0.165	0.659	0.659	-10.652	138.539
Land_2	147.708	0.165	0.659	0.659	-11.123	138.069
			% change			**-0.340**

6. STATA results for new vulnerability index (applied alternative method to get scores)

```
. regress lnbcn totalhhmember edulevel duringwithcomty lnvul_nw, beta

      Source |       SS       df       MS              Number of obs =     420
-------------+------------------------------           F(  4,   415) =   25.02
       Model |  32.4807433     4  8.12018582           Prob > F      =  0.0000
    Residual |  134.700749   415  .324580119           R-squared     =  0.1943
-------------+------------------------------           Adj R-squared =  0.1865
       Total |  167.181493   419  .399001176           Root MSE      =  .56972

------------------------------------------------------------------------------
       lnbcn |      Coef.   Std. Err.      t    P>|t|                     Beta
-------------+----------------------------------------------------------------
totalhhmem~r |  -.0315993   .0167067    -1.89   0.059                -.0894929
    edulevel |   .0863453   .0089961     9.60   0.000                 .4388321
duringwith~y |   .0050107   .0019944     2.51   0.012                 .1153635
    lnvul_nw |   -.412819   .1705564    -2.42   0.016                -.1074249
       _cons |   5.949489   .6392558     9.31   0.000                        .
------------------------------------------------------------------------------


. heckprob lnlnduse2009 totalhhmember edulevel duringwithcomty lnvul_nw, select(totalhhmember edulevel
duringwithcomty lnvul_nw disaster_exposure physical economic)nolog

Probit model with sample selection              Number of obs      =       420
                                                Censored obs       =        81
                                                Uncensored obs     =       339

                                                Wald chi2(4)       =      5.45
Log likelihood = -205.1947                      Prob > chi2        =    0.2444

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lnlnduse2009 |
totalhhmem~r |   .4036895   .2498939     1.62   0.106    -.0860936    .8934726
    edulevel |     .11488   .1326608     0.87   0.387    -.1451304    .3748903
duringwith~y |   .0231359   .0173128     1.34   0.181    -.0107966    .0570685
    lnvul_nw |  -.0642915   2.198003    -0.03   0.977    -4.372299    4.243716
       _cons |   .0307324   8.502271     0.00   0.997    -16.63341    16.69488
-------------+----------------------------------------------------------------
select       |
totalhhmem~r |  -.0071596   .0448552    -0.16   0.873    -.0950743     .080755
    edulevel |  -.0137484   .0260713    -0.53   0.598    -.0648473    .0373505
duringwith~y |   .0161438   .0053057     3.04   0.002     .0057448    .0265427
    lnvul_nw |  -5.024287   1.876301    -2.68   0.007    -8.701769   -1.346806
disaster_e~e |   .2119208   .0887753     2.39   0.017     .0379244    .3859171
    physical |  -.0302237   .0710878    -0.43   0.671    -.1695533    .1091059
    economic |   .0424387   .0406206     1.04   0.296    -.0371762    .1220537
       _cons |    17.0464   6.465695     2.64   0.008     4.373866    29.71893
-------------+----------------------------------------------------------------
     /athrho |  -1.677782   38.53334    -0.04   0.965    -77.20175    73.84618
-------------+----------------------------------------------------------------
         rho |  -.9325731   5.021178                            -1           1
------------------------------------------------------------------------------
LR test of indep. eqns. (rho = 0):   chi2(1) =     0.06   Prob > chi2 = 0.8093
------------------------------------------------------------------------------


. regress lnlnduse2009 totalhhmember edulevel duringwithcomty lnvul_nw, beta

      Source |       SS       df       MS              Number of obs =     339
-------------+------------------------------           F(  4,   334) =   18.60
       Model |  175.321429     4  43.8303572           Prob > F      =  0.0000
    Residual |  786.857277   334  2.35586011           R-squared     =  0.1822
-------------+------------------------------           Adj R-squared =  0.1724
       Total |  962.178706   338  2.84668256           Root MSE      =  1.5349

------------------------------------------------------------------------------
lnlnduse2009 |      Coef.   Std. Err.      t    P>|t|                     Beta
-------------+----------------------------------------------------------------
totalhhmem~r |   .0338232   .0488095     0.69   0.489                 .0365251
    edulevel |   .1456066   .0271656     5.36   0.000                 .2751189
duringwith~y |   .0168861   .0062677     2.69   0.007                 .1375498
    lnvul_nw |  -2.864805    .483134    -5.93   0.000                -.2945674
       _cons |   12.15352   1.820496     6.68   0.000                        .
------------------------------------------------------------------------------
```

Appendix III: Correlation Matrix

	Education	Duration with community	Access to sundarbans	Cooperative member	Indemog	Insoc	Inecon	Inphys	Inexposure	Inbcn	Invul	Lnlanduse 2009
Education	1.000											
Duration with community	0.023	1.000										
Access to sundarbans	-0.274*	0.068	1.000									
Cooperative member	-0.113*	-0.019	0.192*	1.000								
Indemog	-0.177*	-0.035	-0.122*	0.045	1.000							
Insoc	-.0.359*	0.000	0.257*	0.122*	0.106*	1.000						
Inecon	0.223*	-0.012	-0.380*	-0.296*	0.376*	-0.346*	1.000					
Inphys	0.259*	-0.027	-0.140*	-0.019	-0.450*	-0.632*	-0.042	1.000				
Inexposure	0.215*	-0.041	-0.436*	-0.173*	0.492*	-0.281*	0.751*	0.263*	1.000			
Inbcn	0.408*	0.105*	0.104*	0.026	-0.185*	-0.224*	0.013	0.164*	0.033	1.000		
Invul	0.12*	-0.036	-0.385*	-0.206*	0.621*	-0.059	0.866*	-0.089	0.916*	-0.068	1.000	
Inlanduse 2009	0.264*	0.163*	-0.079	0.13*	-0.158*	-0.118*	-0.308*	0.205*	-0.147*	0.237*	-0.279*	1.000

* Significant at 5% level

```
. regress lnbcn edulevel duringwithcomty accesstosundarbans ngomember lnvul, beta

      Source |       SS       df       MS              Number of obs =     420
-------------+------------------------------           F(  5,   414) =   24.00
       Model |  37.5702183     5  7.51404367           Prob > F      =  0.0000
    Residual |  129.611274   414  .313070711           R-squared     =  0.2247
-------------+------------------------------           Adj R-squared =  0.2154
       Total |  167.181493   419  .399001176           Root MSE      =  .55953

------------------------------------------------------------------------------
       lnbcn |      Coef.   Std. Err.      t    P>|t|                     Beta
-------------+----------------------------------------------------------------
    edulevel |   .0925593   .0088786    10.42   0.000                 .4704134
duringwith~y |   .0034496   .0018868     1.83   0.068                 .0794212
accesstosu~s |   .1688879   .0393904     4.29   0.000                 .2093963
   ngomember |   .0448029   .0567823     0.79   0.431                 .0352539
       lnvul |  -.1093854   .1821599    -0.60   0.549                -.0284583
       _cons |   3.944429   .7652527     5.15   0.000                        .
```