Livelihood Vulnerability Assessment and Local Adaptations against Climate Change in South West Coastal Belt of Bangladesh

By

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This is to certify that the thesis work entitled *"Livelihood Vulnerability Assessment and Local Adaptations against Climate Change in South West Coastal Belt of Bangladesh"* has been carried out by *Md. Bellal Hossen* in the *Department of Civil Engineering,* Khulna University of Engineering and Technology, Khulna, Bangladesh. The above thesis work or any part of this work has not been submitted anywhere for the award of any degree or diploma.

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ABSTRACT

Bangladesh is widely recognized as one of the most climate vulnerable countries in the world. It experiences frequent natural disasters that cause loss of life, damage to infrastructures and economic assets, and adversely impact on lives and livelihoods, especially of poor and marginal households. Addressing the most vulnerable coastal communities in Bangladesh, this thesis determines the Livelihood Vulnerability Index (LVI) using three methods named as SLVI (Composite index by Sullivan), LVI-IPCC (IPCC approach) and YLVI (Yates approach) to estimate climate change vulnerability in the coastal belt of Bangladesh. Nine villages were considered for this study; they are Laksmikhali village of Morrelganj upazila, Golbunia village of Mongla upazila, and Uttar Rajapur village of Sarankhola upazila, Dash Ani of Bagerhat Sadar upazila, Nalian villalge of Dacope upazila, Bhagba village of Koira upazila, Rajapur village of Rupsa upazila, Baintala village of Assasunni upazila and Herinnagor village of Sayamnagor upazila. The vulnerability of water resource from a gender perspective based on matrix framework is calculated in three villages; Uttar Rajapur village of Sarankhola upazil, Dash Ani of Bagerhat Sadar upazilas and Herinnagor village of Sayamnagor upazila. It also explores people' perception regarding their vulnerabilities to coastal hazards and investigates the methods that communities apply to cope with different coastal hazards. For LVI determination and investigation of people's perception regarding hazards, about 100 households were surveyed in each of nine village. Focus Group Discussion (FGD) conducted in three villages to assess vulnerability of water resources.

The major components indices of Livelihood Vulnerability Index (LVI) such as Socio-demographic profile, Livelihood strategies, Social network, Health, Food, Water, Natural disaster and climate variability were calculated based on survey data. The calculated results showed that Morrelganj may be more vulnerable in terms of social networks, Mongla may be more vulnerable in terms of food security, Sarankhola may be more vulnerable in terms of water resources, and Dacope may be more vulnerable in terms of health facility and Assasunni may be more vulnerable in terms of livelihood strategies while Sayamnagor may be more vulnerable in terms of two major vulnerability components; socio demographic profile and natural disaster and climate variability. The overall Livelihood Vulnerability Index (LVI) based on three methods is found higher for Sayamnagor compared to others district. The obtained scores of SLVI, LVI-IPCC and YLVI are, Morrelganj: 0.348, -0.020 and 0.340, Mongla: 0.345, -0.18 and 0.351, Sarankhola: 0.367, 0.001 and 0.406, Dacope: 0.396, 0.009 and 0.473, Koira: 0.365,-0.017 and 0.361, Assasunni: 0.383, 0.008 and 0.444, Sayamnagor: 0.401, 0.04 and 0.544, Bagerhat Sadar: 0.306, -0.016 and 0.253, Rupsa: 0.322 -0.015 and 0.274, respectively. It can be noted that the vulnerability score for SLVI ranges from 0 to 1. That of LVI-IPCC and YLVI ranged from -1 to +1 and 0 to 1, respectively.

In this study, it is observed that for the LVI-IPCC approach, although the contributing factors (exposure, sensitivity and adaptive capacity) individually show variations in their indices from one village to another, no major variation is observed for total livelihood index. However, the designed SLVI and YLVI shows variation among the studied nine villages. Therefore, it can be concluded that SLVI and YLVI

approaches are suitable for community or district level whereas the LVI-IPCC is suitable for regional level evaluation.

Vulnerability of water resources based on matrix framework from a gender view point shows that Sayamnagor is more vulnerable to climate change induced disaster events whereas in Bagerhat Sadar and Sarankhola is more vulnerable to climate associated gradual changes. In Sayamnagor, the total vulnerability is greater than the specific vulnerability due to average seasonal change and smaller than disaster induced vulnerability. On the contrary, Sarankhola and Bagerhat Sadar show that the specific vulnerability due to average seasonal change is greater than total vulnerability and the specific vulnerability due to average change in induced disaster events is smaller than total vulnerability. However, the overall water resource vulnerability is higher in Sayamnagor (2.21) than Sarankhola (2.03) and Bagerhat Sadar (1.04).

The people' perception regarding their vulnerabilities to coastal hazards and their coping strategies show that people perceived an increase in both the intensity of hazards and their vulnerabilities. In spite of having a number of socio-economic and location factors enhancing their vulnerabilities, the community is creating their ways to cope with these hazards. For different aspects of life like food and shelter, water supply, sanitation, and health, communities are found to apply different coping methods that vary with the types of hazards. According to the people' perceptions, the most prevalent coastal hazards in the study areas are cyclone, flood, and tidal surge. In case of shelter system, there are more kacha houses in Dacope upazila than Morrelganj, Mongla, Sarankhola, Koira, Assasunni, Bagerhat Sadar and Rupsa. Therefore Dacope is more vulnerable in case of existing housing pattern. In case of water supply system during natural hazard, Sayamnagor, Dacope and Assasunni is found more vulnerable compared to other areas as more than 70% of water sources were found to be unusable due to the hazard. In case of sanitation system, people from Sayamnagor use more unhygienic latrine (about 58%) than Morrelganj, Mongla, Sarankhola, Dacope, Koira, Assasunni, Bagerhat Sadar and Rupsa. In this case, the sanitation system of Sayamnagor became more unusable than Morrelganj, Mongla, Sarankhola, Dacope, Koira, Assasunni, Bagerhat Sadar and Rupsa. In case of health impact, people are suffered from various kinds of diseases due to the impact of natural hazards. Diarrhea, dysentery and Skin diseases are the most prevalent disease during disaster. Before starting hazards, taking preventive measure for health problem is not common in the study areas. It is observed that more than 80% people do not stock emergency medicine before hazards starting. On the other hand, generally in every locality of the surveyed area, as a preparation for natural hazards, the households store dry food such as chira-muri, gur (molasses) and chal (rice), dal (pulse), tel (oil), nun (salt) etc.

Knowledge and understanding of households' vulnerability acquired from such study may provide government and other relevant agencies with critical information for proper distribution of relief materials. Households' local adaptation strategies for resilience help them in implementing non-structural mitigation measures, which also benefit overall development through capacity building. Furthermore, households with low levels of human, financial, social and physical capital are found to have less capacity to meet the challenges of a disaster. Moreover, this study will help the

development organizations, policymakers and public health practitioners with a practical tool to understand demographic, social and health factors contributing to climate vulnerability at the district or community level.

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NOMENCLATURE

LVI	Livelihood Vulnerability Index
BBS	Bangladesh Bureau of Statistics
CZP	Coastal Zone Policy
EEZ	Exclusive Economic Zone
EPZ	Export Processing Zones
FAO	Food and Agricultural Organization
GBM	Ganges-Brahamputra-Meghna
ICZM	Integrated Coastal Zone Management
IMD	India Meteorological Department
IPCC	Intergovernmental Panel on Climate Change
JTWC	Joint Typhoon Warning Center
MoEF	Ministry of Environment and Forest
MoLGRDC	Ministry of Local Government, Rural Development and Cooperatives
MoWR	Ministry of Water Resource
NAPA	National Adaptation Program of Action
UNISDR	United Nations International Strategy for Disaster Reduction
WARPO	Water Resources Planning Organization
NGO	Non-Governmental Organization
PRSP	Poverty Reduction Strategy Paper
UNISDR	United Nations International Strategy for Disaster Reduction

CHAPTER I

Introduction

1.1 General

Bangladesh is widely recognized as one of the most climate vulnerable countries in the world (Harmeling 2010). It experiences frequent natural disasters that cause loss of life, damage to infrastructures and economic assets, and adversely impact on lives and livelihoods, especially of poor and marginal households. The interface or transition areas between land and the sea including the large inland lakes are commonly known as coastal areas. In Bangladesh, coastal areas are diverse in function and form. They are dynamic in nature and difficult to define by strict spatial boundaries (FAO, 1998). As per the recent delineation, the coastal zone of Bangladesh consists of 19 districts comprising 147 sub-districts covering an area of 47,201 km^2 (Islam, 2004). The coastal districts of Bangladesh have been demarcated into three adjoining regions, as south-west constituting Satkhira, Khulna and Bagerhat; south-central comprising Jessore, Patuakhali, Noakhali and Barisal, and south-east consisting of Chittagong and Cox's Bazar. Figure 1.1 shows the coastal areas of Bangladesh.

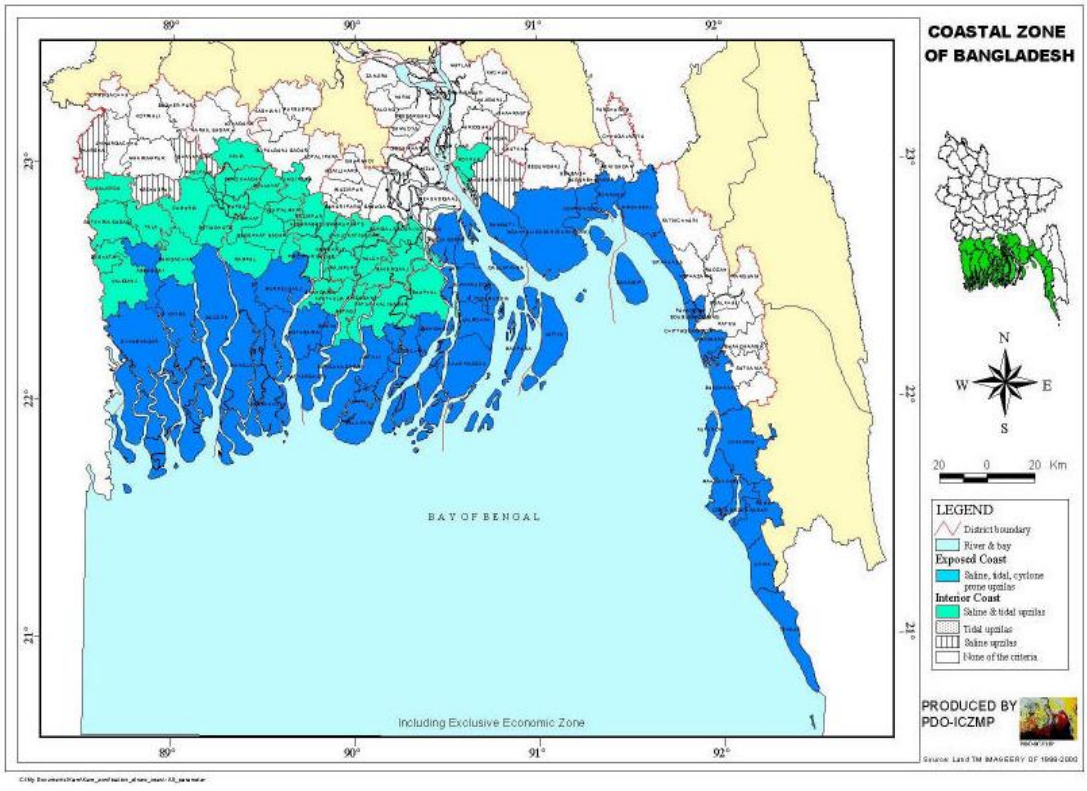


Figure 1.1: Coastal zone of Bangladesh (MoWR, 2006)

The coastal area, about 32 % of the country's total area, is aggravated by climate change and its impact. Climate change is now the major global concern. The climate is changing and weather patterns are becoming extreme and unpredictable (IPCC, 2007). Disruptions of the earth's atmosphere in terms of rise in temperature due to increase in the amount of greenhouse gases have resulted in increased frequency and

intensity of extreme weather events like cyclones, floods, heavy rainfall and droughts. Bangladesh is a tropical country and extremely vulnerable to various natural disasters such as floods, cyclones, tornadoes, tidal surges, storm surges, river bank and coastal erosion, and droughts. It is currently ranked as the most climatically vulnerable country in the world (IPCC, 2007). There are approximately 711 km of costal area in Bangladesh. Over a period of 100 years, 508 cyclones have affected the Bay of Bengal Region; of Which 17 per cent Caused serious land erosion. Though the majority of the population have experienced disasters in varying degrees and forms. It has affected Bangladesh by land erosion, salinity intrusion and loss in biodiversity. Sea level rise has different impacts on Bangladesh. A one-meter sea level rise (SLR) will affect the country's vast costal area and flood plain zone. Most vulnerable sectors to one-meter sea level rise are costal resources, water resources, agriculture and the ecosystem of Bangladesh.

The southern part of Bangladesh falls under coastal zone that receives discharge of numerous rivers, including Ganges-Brahmautra-Meghna (GBM) river system, creating one of the most productive ecosystems of the world. Unfortunately, these areas are highly vulnerable to both natural and man-made hazards and disasters like coastal cyclone, tidal surge, flooding, river bank erosion and drought, etc. The month of April-May and September-November is known as 'Cyclone season', these natural and climate-related disasters have a significant and lasting impact on their lives and livelihoods of extreme poor particularly in 12 districts including Khulna, Bagerhat and Satkhira. Cyclone Aila struck the South-West coast on the 25th of May 2009 with 13 ft. height of tidal surge. It causes breaking of river embankments, dyke and polders in several places, washing away the lives and livelihoods of people of Khulna, Bagerhat and Satkhira, in the South-West costal belt. Before Aila, cyclone Sidr hit the coastal areas of Bangladesh on November 15, 2007 with a surge height of 16 ft.

As stated above, the SW Coastal belt is consisted of three districts Khulna, Bagerhat and Satkhira, which includes 30 upazilas (PDO-ICZMP, 2003). The people in these areas are vulnerable to cyclone, tidal surges and river erosion, along with salinized water and soil. Among all, the extreme poor people are suffering the most because of their deep dependence on nature for their lives and livelihood. The vulnerable livelihood parameters are different for different regions. Moreover, the impact of the same hazard are not same for all the areas. However, for the preparedness and protection against hazard as well as for the mitigation of post-hazard emergency needs, it is necessary to understand the demographic, socio-economic, public health and natural resources factors including regional vulnerable communities with spatial variations.

1.2 Statement of the study

This study is aimed to find out the Livelihood Vulnerability Index (LVI) to quantifying the strength of current livelihood, health, water, social network and climate change and variability based on composite LVI named as SLVI, Yates approach named as YLVI and IPCC vulnerability definition named as LVI-IPCC. Applying matrix framework, this study also evaluate the vulnerability of water resources. The study is also highlight the type of occurrence of coastal hazards, the

impact on the various livelihood parameters of people and their local coping methods against these impacts.

1.2 Objectives

The main objective of this study is to assess the livelihood vulnerability and local adaptations against climate change in south west coastal belt of Bangladesh.

The specific objectives of this study are outlined as below:

- To determine the Livelihood Vulnerability Index using three methods: developed by Sullivan *et al.* (2002) named as SLVI, by IPCC (2001) named as LVI-IPCC and by Yates (2010) named as YLVI.
- To investigate the spatial variation of vulnerability indices in the south-west costal belt of Bangladesh.
- To determine the vulnerable livelihood parameters based on the calculated index.
- To determine vulnerability of water resource from gender perspective using vulnerability assessment matrixes.
- To examine the coastal community's perception to the hazards and their vulnerabilities and local coping methods against the effect of various coastal hazards.

1.4 Scope of the Study

Bangladesh is a tropical country and extremely vulnerable to various natural disasters. The extreme poor people are most vulnerable in the coastal area. Adaptation and mitigation are two choices for Bangladesh. This study is carried out to evaluate the most vulnerable livelihood parameters based on composite index approach named as SLVI, Yates approach named as YLVI and IPCC approach named as ILVI- IPCC. In case of climate change induced vulnerability, women becoming the most sufferers due to their gender differentiated role and lack of access and control over resources. Considering these, this study evaluate the vulnerability of water resources using a matrix framework based on perceived response of women from community. This study is also highlight the type of occurrence of coastal hazards and the local coping methods against these hazards. This study will help the development organizations, policymakers and public health practitioners with a practical tool to understand demographic, social and health factors contributing to climate vulnerability at the district or community level.

1.5 Organization of Report

The study comprises of seven chapters including Introduction. A review of related previous studies is presented in **Chapter Two**. Methodology of composite LVI approach, IPCC framework approach and Yates framework approach are explained in **Chapter Three**. Vulnerability of water resource from a gender perspective using matrix framework, coastal community's perception to the hazards and local coping methods are also given in this chapter. In **Chapter Four** the study area and sample size of survey are presented. **Chapter Five** presents the results where survey result on LVI major component, LVI indices, vulnerability of Water Resource from gender perspective are analyzed. People's perception to hazards and their coping methods are discussed in **Chapter Six**. **Chapter Seven** summarizes the findings of the study and suggests some recommendations for future research.

CHAPTER II

Literature Review

2.1 General

Bangladesh is one of the coastal marginal countries of the Bay of Bengal. The southern part of Bangladesh is bordered by about 710 km long coastal belt, which has the continental self-up to 50m deep with an area of about 37,000 square km. The Exclusive Economic Zone (EEZ) of Bangladesh lies from the base line to 200 nautical miles. The coastal zone of Bangladesh includes coastal plain islands, tidal flats, and estuaries, neurotic and offshore waters.

2.2 Geo-Social Context of Bangladesh's Coast

A vast river network, a dynamic estuarine system and a drainage basin intersect the coastal zone, which made coastal ecosystem as a potential source of natural resources, diversified fauna and flora composition, though there also have immense risk of natural disasters. Due to its diversified nature, the coast of Bangladesh broadly divided into three geo-morphological regions:

- The western region includes the Sundarban, the world's largest patch of naturally occurring mangroves.
- The central region is situated between eastern and western region. Most of the combined flow of the Ganges-Brahamputra-Meghna (GBM) system is discharged through this low laying area. The lower Meghna river estuary is highly influenced by tidal interactions and consequential backwater effect. Heavy sediment inputs from the river results in a morphologically dynamic coastal zone. Cyclones and storm surges bring about most catastrophic damage.
- The eastern region extending from Feni River to Badar Mokam, the southern tip of the main land. This part is more or less unbroken, characterized by flat muddy and sandy beaches, a degraded natural mangrove forests in the estuarine areas of the Matamuhuri River.

The coastal areas of Bangladesh are different from rest of the country not only because of its unique geo-physical characteristics but also for different socio-political consequences that often limits people's access to endowed resources and perpetuate risk and vulnerabilities. There is a close proximity between livelihoods of the coastal people and such vulnerabilities, because the way of livelihood earning of one people became the catastrophes to others. Although effect of natural catastrophes i.e. flood, cyclone, tidal surge etc. are common for all but coping with these is quite different among different class of people, as the coping capacity is a function of the asset base (both ownership and access too). The poor are more vulnerable as their asset base is weak and scanty (Shamsuddoha, 2008).

2.3 Bangladesh's Coast: The Worst Victim to Natural Disasters

The coastal geomorphology of Bangladesh is characterized by its funnel shaped, vast network of river, strong tidal and wind action and enormous river discharge

laden with bed and suspended sediments. Therefore, the geo-climatic environment of the coastal areas is strongly influenced by the Bay of Bengal situated in the southern part of Bangladesh, and is dominated by following three main factors, which are considered as the major causes of natural catastrophes.

- Wind direction
- Precipitation and
- River and terrestrial runoff

Aside with these, wide and open coast, strong current and wind, dynamics of erosion and siltation, natural slopping of the continent etc. are considered as the silent features behind the causing of natural disasters. The poverty monitoring survey done by Bangladesh Bureau of Statistics (BBS) in 1999 identified different natural disasters like cyclone, river bank erosion, salinity intrusion, water stagnation, heavy rainfall etc. as the main causes of perpetuating coastal poverty (Shamsuddoha, 2008).

2.4 Cyclone and Bangladesh's Coast

The entire coastal zone is prone to violent storm and tropical cyclones during pre-monsoon and post monsoon season. Sometimes cyclone associated with tidal waves caused great loss of lives and property. Nearly one million people have been killed in Bangladesh by cyclones since 1820. The physiology, morphology and other natural conditions have made it vulnerable to disaster, cyclonic storms and floods that are very devastating and cause immense suffering and damage to people, property and the environment. Cyclonic storms have always been a major concern to coastal plains and offshore island of Bangladesh.

From the historical records it can be seen that there are two peaks in the annual distribution of the tropical cyclone formation in the Bay of Bengal, one is May and another is the November within the peak seasons pre-monsoon (April-May) and post monsoon (Oct- Nov) respectively. During 1891-1990, 700 cyclones occurred, of which 62 in pre and 192 in Post-monsoon season. Figure 2.1 shows the season wise cyclone distribution in Bangladesh (Shamsuddoha, 2008).

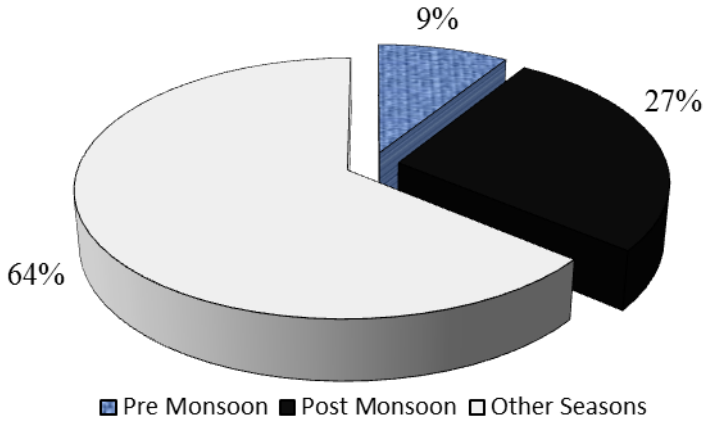


Figure 2.1: Season wise Cyclone Distribution (Shamsuddoha, 2008)

2.5 Historical Background

2.5.1 Cyclone 1970, 1991

Number of devastating cyclones hit Bangladesh's coast in 1797, 1822, 1876, 1897, 1901, 1941, 1960, 1961, 1963, 1965, 1969, 1970, 1985, 1991 and 1996, among which cyclones of 1970 and 1991caused huge loss of lives and assets. A study conducted by the Bangladesh Bureau of Statistics in 1991showed, people aged between 15 and 49 managed to secure themselves, while children, elderly people, women were died more. During 1970 the coastal areas were not well protected with encircling embankment. Even early warning and cyclone tracking system was not so modern and adequate, which caused huge loss of lives After 1970 cyclone, though government constructed coastal embankment and modernized cyclone forecasting and tracking system but these couldn't save coastal people when another diabolic cyclone hit in 1991, because appropriate preparedness measures were not taken and people also were reluctant to find place. Still level of cyclone preparedness is not so adequate, there have political as well as policy negligence in this relation (Shamsuddoha, 2008).

2.5.2 Cyclone Sidr and Aila

Cyclone Aila (IMD designation: BOB 02, JTWC designation: 02B, also known as Severe Cyclonic Storm Aila) was the second tropical cyclone of the 2009 North Indian Ocean cyclone season. A relatively strong tropical cyclone, it caused extensive damage in India and Bangladesh. Late on the 21st of May 2009, the Joint Typhoon Warning Center reported that a Tropical Disturbance had persisted about 950 kilometers (590 mi) to the south of Kolkata, in India and had developed within the Southwest Monsoon. The disturbance at this time had a broad and poorly organized area of deep convection, which was located to the southeast of the low level circulation center which had consolidated into a single circulation during the previous 12 hours. Environmental analysis indicated that the system was in an area of favorable conditions to develop with low vertical wind shear and warm sea surface temperatures. During 22 May 2009, the disturbance developed further with a Tropical Cyclone Formation Alert being issued early the next day by the JTWC as the low level circulation center had become stronger and more defined. Later that morning RSMC New Delhi designated the disturbance as Depression BOB 02 (Wikipedia, 2013).

Cyclone Sidr (JTWC designation: 06B, also known as Very Severe Cyclonic Storm Sidr) was the strongest named cyclone in the Bay of Bengal, resulting in one of the worst natural disasters in Bangladesh. The fourth named storm of the 2007 North Indian Ocean cyclone season, Sidr formed in the central Bay of Bengal, and quickly strengthened to reach peak 1-minute sustained winds of 260 km/h (160 mph), making it a Category-5 equivalent tropical cyclone on the Saffir-Simpson Scale. The storm eventually made landfall in Bangladesh on November 15, 2007, causing large-scale evacuations. 3,447 deaths were blamed on the storm. On November 9, an area of disturbed weather developed southeast of the Andaman Islands, with a weak low-level circulation near the Nicobar Islands. Initially moderate upper-level wind shear inhibited organization, while strong influence aloft aided in developing convection. Vertical shear decreased greatly as the circulation became better defined, and a Tropical Cyclone Formation Alert was issued on November 11 while located a short

distance south of the Andaman Islands. Around the same time, the India Meteorological Department (IMD) designated the system as Depression BOB 09. The Joint Typhoon Warning Center (JTWC) upgraded it to Tropical Cyclone 06B after Dvorak estimates indicated winds of 65 km/h (40 mph). Later that day, it intensified into a deep depression as it moved slowly north-westward (Wikipedia, 2013).

2.5.3 River Bank Erosion

The Ganges Brahamputra Meghna (GBM) river system carries immense volume of water silt. During the monsoon, GBM system carries about 1.7 billion tons of silts per year causing severe turbulence the rivers. This results in gradual undercutting of riverbanks leading to erosion. In coastal areas wave action and tidal force are also significant causes of erosion. By riverbank erosion Bhola has suffered from a net loss of about 227 sq. km in the last 50 years, Hatiya has reduced from 1000 sq. km to only 21 sq km over 350 years and Swandip has lost 180 sq km in the last 100 years. Such erosion adversely affects the ecosystem, navigation, planned agriculture development and drainage system. It has also effect on inland navigational route as of shifting and migration of channels. Factors those are accelerating riverbank and land erosion are: (a) destruction of coastal mangroves for shrimp farming and (b) unplanned dam and cross road construction etc.

Apart from this, in each year the GMB river system carries 6 million cusecs of water with 2179 million metric tons of sediments resulting water logging in the rainy season and causes flooding. Siltation raises river bed up that reduces the intensity of water flowing as well as hampering the breeding and nursing ground of Hilsa Ilisa, the major open water fishery in Bangladesh. As force of upstream water flow reduces, seawater tends to flow upstream. Such intrusion of saline water affect to the coastal agriculture. Top dying disease of Sundari tree in the Sundarban Mangrove forest is also caused for saline water intrusion in the fresh water areas.

During July to September 2004, a research work on riverbank erosion has been conducted in Bhola district, which reveals the followings;

- 3332 families lost their houses for river erosion.
- Among the homeless families 48.23% families took shelter beside the embankment, 39.89% took shelter on the river bank and, only 3.48% had their own land to shift their houses.
- 21 schools were affected, 7 were abolished completely and 14 were under constant risk of being eroded. There are no available resources like land, construction materials etc. to rebuild the school somewhere in the community (Shamsuddoha, 2008)

2.6 Coastal Hazards, Vulnerabilities and Management Efforts

Out of a total of 147570 square kilometer of territory, Bangladesh has 47201 square kilometer of coastal area, which is one-third of the country and accommodates 28% of the country's population (MoWR 2006; Islam 2004). This large population is relatively more vulnerable than any part of the country, since more than half of them are poor and landless. Along with the socio-economic deprivation, relentless efforts to cope with the numerous coastal hazards have enhanced their vulnerabilities. The

Fourth Assessment Report of the IPCC (2007), recognized the coastal areas of Bangladesh as one of the most vulnerable areas of the country (and the world as well) due to the recurrent coastal hazards and the threats of climate change-induced impacts. The nature and types of coastal hazards and vulnerabilities have been well documented by the IPCC, NAPA, the World Bank and various researchers. Especially the writings of Islam (2004 and 2008) have made a great contribution in this regard. A brief overview of coastal hazards and vulnerabilities in Bangladesh has been made with the help of all these documents. The coastal areas of Bangladesh are divided into three geo-morphological regions (eastern, western and central), which also face different hydro-morphological process (Islam, 2004). These geological and hydrological variations have made variation both in opportunities and threats in different parts of the coast. Table 2.1 shows a brief but clear view of the different hazards in different parts of coastal areas.

Table 2.1: Hazard in Coastal Bangladesh (Islam, 2008)

Type of hazard	Vulnerable areas	Remarkable events
Cyclone and Storm surges	Islands and exposed upazillas, central coast especially vulnerable	In the last 200 years, at least 70 major cyclones have hit the coastal areas and killed about 900000 people. There are records of six tsunamis in the Bay of Bengal during the last 250 years
Land erosion	Meghna and other estuaries, islands and coastal rivers	In Meghna estuary, a total 86366 ha of land eroded from 1973-2000
Flooding (tidal flood mainly)	Exposed islands	123 polders with 5017 km embankment have been constructed to protect coastal areas
Drainage congestion or water logging	Khulna, Jessore (western coastal zone), Noakhali and also Bhola, Patuakhali, Pirojpur, and Barguna districts	Khulna-Jessore Drainage Rehabilitation Project was begun in 1973 with ADB's funding, but an evaluation report prepared by ADB in 2007 found that the project was unsuccessful in many respects
Salinity intrusion	Western exposed upazilas	70% of the 2.35 million ha of agricultural land of the south-western division are affected by soil salinity
Type of hazard	Vulnerable areas	Remarkable events
Drought	Satkhira district (western coastal zone) and also Bagerhat, Khulna, and Pirojpur districts	In Kharif season (June/July to October) some of the south-eastern coastal districts face severe drought
Earthquake	Chittagong	Though coastal areas are less vulnerable to earthquake recently incidents felt; 40 registered during 2002

Type of hazard	Vulnerable areas	Remarkable events
Shortage of drinking water and arsenic contamination	Entire area	About 53% of tube-wells in coastal areas contain arsenic above the permissible level. Nationally, this Figure is 29%
Ecosystem degradation	Marine, Sundarban	Sundarban has been declared a World Heritage Site, but some species are affected by different diseases like top-dying, root rot, die back
Pollution	Chittagong, Khulna (sea port areas)	Oil spills, domestic effluents, and dismantling old ships (average 90 vessels a year) cause adverse impact on flora and fauna and thus degradation of valuable ecosystem
Climate change	Entire area	The coastal area of Bangladesh is at great risk from climate change. By 2030, the estimated sea level rise will be 30 cm and temperature will be 0.7^0C in monsoon and 1.3^0C in winter

Four key vulnerabilities have been identified in the coastal areas of Bangladesh. These are saline water intrusion, drainage congestion, extreme events, and changes in coastal morphology. It is forecasted that these vulnerabilities would be acute due to the combined effects of climate changes, sea level rise, subsidence, and change of upstream river drainage, cyclones, and coastal embankments. Recognizing these acute impacts, both governmental and NGOs with the financial and technical support of donors and international bodies have undertaken diversified programs and projects. A brief summary of their efforts to minimize the impacts of coastal hazards is presented below.

Since independence of the country in 1971, segregated efforts have been made by different ministries of government and also by different organizations to address diversified problems and hazards in coastal areas. However, the attempt of Integrated Coastal Zone Management (ICZM) was only introduced in 2OO2. Significant attempts of ICZM are: (a) the delineation of coastal zones, (b) the inventory of projects and initiatives in coastal zones, updated in 2004, (c) the formulation of the Coastal Zone Policy in 2005, (d) the creation of "Priority Investment Programs" in coastal areas in 2005, and (f) the formulation of the Coastal Development Strategy in 2006.

The Coastal Zone Policy (CZP) has established a number of development objectives to be achieved, including economic growth, basic needs, vulnerabilities, sustainable development, equitable distribution and empowerment and conservation of ecosystem all issues are highlighted. To address all of these objectives, the CZP has been translated into nine strategic priorities (MoWR 2006). Furthermore, priority investment programs also have been listed out, but unfortunately all of these policies, strategies, and priority projects are lacking proper attention towards a local

community's perceptions and vulnerabilities, their indigenous knowledge, and various coping methods to deal with the different hazards that occur. Without adequate incorporation of local knowledge and perception, almost all ministries of government have some programs as priority investment in coastal areas. The Ministry of Water Resources (MoWR), the Ministry of Environment and Forest (MoEF), the Ministry of Local Government, Rural Development and Cooperatives (MoLGRDC) have the highest number of programs (WARPO, 2005). In addition to government programs, a large number of NGOs are working in coastal areas. The report titled 'Inventory of Projects and Initiatives in Coastal Zone', noted that about 400 NGOs are active in coastal areas. These NGOs have undertaken hundreds of development projects addressing socio-economic and physical environment of coastal communities (Ali, 2004). The Poverty Reduction Strategy Paper (PRSP) of Bangladesh has also acknowledged the coastal zone as a special focus area and suggested special attention be given to it. It is expected that with the integration of the factors of community perception, knowledge, and efforts all of these attempts emphasizing coastal zones, their vulnerabilities and hazards, would assist to making a better future for the coastal communities (Parvin *et. al.*, 2008)

2.7 Disaster Preparedness in Bangladesh

After 1970's cyclone the government of Bangladesh constructed 238 cyclone shelters under IDA credit, each of which can accommodate 800 people. Since 1985, the Bangladesh Red Crescent Society has constructed 60 shelters, which can accommodate over 499 people each. But during 1991 cyclone there were only 3 hundred cyclones shelters in Bangladesh whereas requirement was 5 thousand, and at that time many people, especially women and elderly people, didn't find any shelter to save themselves Presently many cyclone shelters were broken down and there is no regular repairing and maintenance.

However, the weather department of the government of Bangladesh forecasts weather bulletin and early warning signal but people have little trust on these, because forecasted news, in many cases, treated as fake, had been forecast in '91 but lack of public awareness and cyclone shelter a huge number of death happened. On the other hand, the language of weather bulletin is fair and the outreach coastal people often can't follow and understand the bulletin as they are used to communicate in local language (Shamsuddoha, 2008).

2.8 Climate Change Vulnerability

The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as: the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity. Marshall *et al.* (2009) drew the IPCC definition of vulnerability to describe vulnerability as a function of three elements: exposure, sensitivity, and adaptive capacity (Figure 2.2). Understanding these elements can help to evaluate the nature and magnitude of the

climate change threat as well as detect the key sources of vulnerability. The elements of vulnerability are described in more detail below.

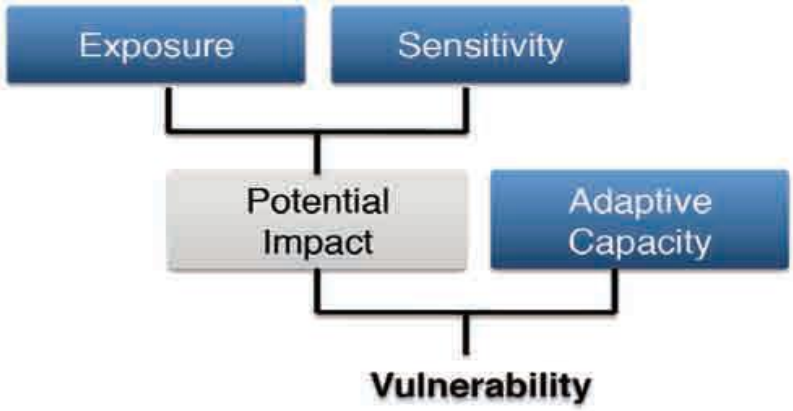


Figure 2.2. The framework for components of vulnerability (Marshall *et al.* 2009)

2.8.1 Exposure

Exposure represents the important climate events and patterns that affect the system, but it also includes other changes in linked systems that might be induced by climate effects. In a practical sense, exposure is the extent to which a region, resource or community experiences changes in climate (IPCC, 2007). It is characterized by the magnitude, frequency, duration and/or spatial extent of a weather event or pattern.

2.8.2 Sensitivity

Sensitivity is the degree to which a system is affected by, or responsive to, climate changes. The sensitivity of ecological systems to climate change is normally described in terms of physiological tolerances to change and/or variability in physical and chemical conditions. Examples include certain corals that are highly sensitive to increases in sea temperatures or harvested crab species that are sensitive to drought periods (Johnson and Marshall, 2007). The sensitivity of social systems depends on economic, political, cultural and institutional factors (Fenton *et al.*, 2007). For example, social systems are more likely to be sensitive to climate change if they are highly dependent on a climate vulnerable natural resource (Marshall *et al.*, 2007).

2.8.3 Adaptive capacity

Adaptive capacity describes the ability to respond to challenges through learning, managing risk and impacts, developing new knowledge and devising effective approaches. It requires amongst many other things, the flexibility to experiment and adopt novel solutions (Gunderson, 2000).

2.9 Climate Change Vulnerability Assessment

Vulnerability assessment describes a diverse set of methods used to systematically integrate and examine interactions between humans and their physical and social surroundings. Vulnerability assessments have been used in a variety of contexts

including the USAID Famine Early Warning System (FEWS-NET) (USAID, 2007), the World Food Programme's Vulnerability Analysis and Mapping tool for targeting food aid (World Food Programme, 2007), and a variety of geographic analyses combining data on poverty, health status, biodiversity, and globalization. A common thread is an attempt to quantify multidimensional issues using indicators as proxies. These are often combined into a composite index allowing diverse variables to be integrated. The Human Development Index, for example, incorporates life expectancy, health, education, and standard of living indicators for an overall picture of national wellbeing (UNDP, 2007). Several methods have been used to combine indicators. The gap method (Gillis *et al.,* 1987) was used by Sullivan (2002, p. 1204) to assess ''by how much water provision and use deviates from a predetermined standard'' for the Water Poverty Index. Both the Human Development Index and the Water Poverty Index are examples of composite indices calculated using weighted averages of individual indicators. Weighting methods vary. Eakin and Bojorquez-Tapia (2008) note that equal weighting makes an implicit judgment about the degree of influence of each indicator and propose a complex fuzzy logic-based weighting method as a more objective approach. Vincent (2004, 2007) and Sullivan *et al.* (2002) suggest expert opinion and stakeholder discussion, respectively, to determine weighting schemes. The field of climate vulnerability assessment has emerged to address the need to quantify how communities will adapt to changing environmental conditions. Various researchers have tried to bridge the gap between the social, natural, and physical sciences and contributed new methodologies that confront this challenge (Polsky *et al.,* 2007). Many of these rely heavily on the IPCC working definition of vulnerability as a function of exposure, sensitivity, and adaptive capacity (IPCC, 2001). Exposure in this case is the magnitude and duration of the climate-related exposure such as a drought or change in precipitation, sensitivity is the degree to which the system is affected by the exposure, and adaptive capacity is the system's ability to withstand or recover from the exposure (Ebi *et al.,* 2006). Fussel and Klein (2006) divide available studies into first-generation vulnerability assessments based on climate impact assessments relative to baseline conditions, and second-generation assessments that incorporate adaptive capacity. Of the second-generation studies, there are a multitude of interpretations about how best to apply exposure, sensitivity, and adaptive capacity concepts to quantify vulnerability (Sullivan, 2002; O'Brien *et al.,* 2004; Vincent, 2004; Ebi *et al.,* 2006; Thornton *et al.,* 2006).

2.10 The Livelihood Vulnerability Index

The Sustainable Livelihoods Approach, which looks at five types of household assets- natural, social, financial, physical, and human capital (Chambers and Conway, 1992), is an approach used to design development programming at the community level (United Nations General Assembly, 1997). The approach has proven useful for assessing the ability of households to withstand shocks such as epidemics or civil conflict. Climate change adds complexity to household livelihood security. The Sustainable Livelihoods Approach to a limited extent addresses the issues of sensitivity and adaptive capacity to climate change, but a new approach for vulnerability assessment that integrates climate exposures and accounts for household adaptation practices is needed in order to comprehensively evaluate livelihood risks resulting from climate change.

The approach for assessing livelihood vulnerability index (LVI) by Hahn *et al.* (2009) uses composite index approach developed by Sullivan *et al.* (2002) and an alternative method for calculating LVI that incorporates IPCC vulnerability definition known as IPCC framework approach. By composite index method the Livelihoods Vulnerability Index for the Coastal Districts of Bangladesh is measured by Toufique and Yunus (2013). A matrix framework had been developed by Yates (2010) to quantify vulnerability based on IPCC working definition of vulnerability which can be used for vulnerability assessment of any natural system from gender context. It helps in assessing context specific vulnerability (i.e. event wise and extreme wise) and total vulnerability (with average value of exposure, sensitivity and adaptive capacity due to events and extremes).

The LVI uses multiple indicators to assess exposure to natural disasters and climate variability, social and economic characteristics of households that affect their adaptive capacity, and current health, food, and water resource characteristics that determine their sensitivity to climate change impacts. Three approaches are presented: the first expresses the LVI as a composite index comprised of seven major components and the second expresses LVI as IPCC's definition comprised of three contributing factors to vulnerability-exposure, sensitivity, and adaptive capacity while the third expresses the LVI as a function of exposure, sensitivity, and adaptive capacity that diverges from the LVI–IPCC while LVI is determined from the contributing factors. The study uses and extend the scope of this index to measure and explain the livelihood vulnerability index of most vulnerable parameters with the adaptation of local people and their opinion about the problem caused by the natural disasters. We also explore the vulnerability of water resource in the study area from a gender perspective using vulnerability assessment matrixes.

CHAPTER III

Methodology

3.1 General

In this chapter the plan of action is discussed in accordance with three approaches. The first is LVI as a composite index named as SLVI; the second is LVI as IPCC vulnerability definition named as LVI-IPCC and the third is LVI by Yates approach named as YLVI. The vulnerability of water resource from a gender perspective and the coastal community's perception to the hazards and their vulnerabilities and local coping methods against the effect of various coastal hazards are also discussed in this Chapter. The study area and percent of population surveyed as well as sample of survey questions are presented in this chapter.

3.2 Study Area

Figure 3.1 shows the nine locations of the study area in South West Coastal belt of Bangladesh. The selected areas were Laksmikhali village of Morrelganj upazila, Golbunia village of Mongla upazila, and Uttar Rajapur village of Sarankhola upazila, Dash Ani of Bagerhat Sadar upazila, Nalian villalge of Dacope upazila, Bhagba village of Koira upazila, Rajapur village of Rupsa upazila, Baintala village of Assasunni upazila and Herinnagor village of Sayamnagor upazila. In the selected villages, households' questionnaire survey were conducted. Based on this survey result, Livelihood Vulnerability Indices are determined. At the same time it is also analyzed the impact and coping methods of local people to various natural hazards. Focus Group Discussion (FGD) conducted from gender perspective in three areas namely Uttar Rajapur village of Sarankhola upazilas, Dash Ani of Bagerhat Sadar upazilas and Herinnagor village of Sayamnagor upazila. Table 3.1 represents the number of households' surveyed from every village and the percentage of household's surveyed with respect to total households.

Table 3.1: Percentage of households surveyed during field investigation.

Districts	Upazila	Union	Village	Total households	Households Surveyed	% of households surveyed
Bagerhat	Mongla	Sundarban	Golbunia	103	50	48.54
	Morrel ganj	Jiudhara	Lakshmi khali	502	100	19.92
	Saran khola	Rayenda	Uttar Rajaur	917	50	5.45
	Sadar	Bagerhat Paurashava	Dash Ani	313	100	31.94
Khulna	Dacope	Sutarkhali	Nalian	1633	100	6.12
	Koira	Mahesh waripur	Bhagba	610	100	16.4
	Rupsa	Aijganti	Rajapur	2141	100	4.67
Satkhira	Syamnagor	Munshi gonj	Herinnagor	3235	150	4.63
	Assasunni	Baradal	Baintala	464	100	21.5

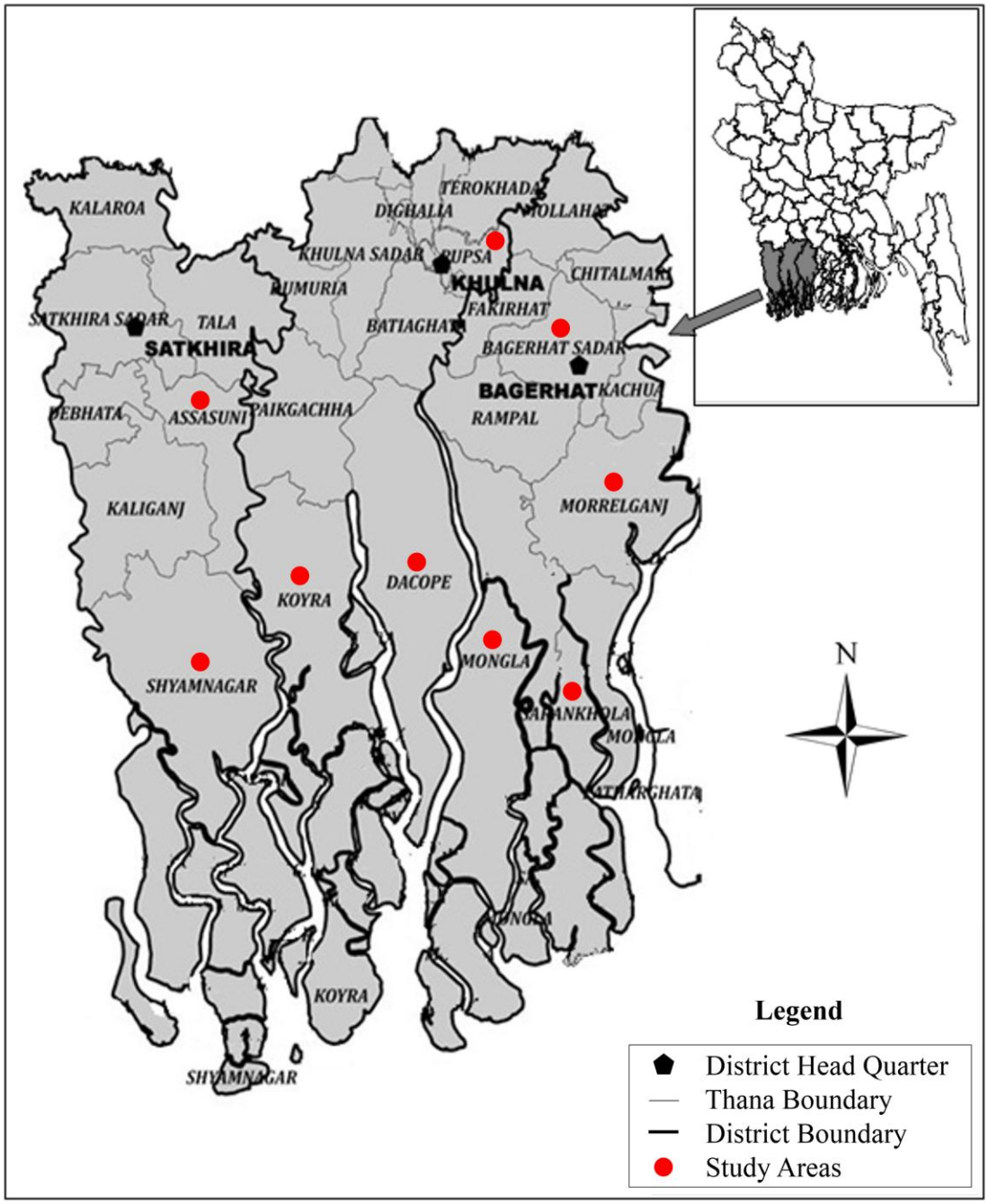


Figure 3.1: Location of study areas in South-west Coastal belt of Bangladesh

3.3 Calculating LVI: Composite Index Approach (SLVI)

The LVI includes seven major components; Socio-demographic Profile, Livelihood Strategies, Social Networks, Health, Food, Water and Natural Disasters and Climate Variability. Each is consisting of several indicators or sub-components (Table 3.2). These were developed bases on a review of the literature on each major component, for example studies on Sayamnagor water sector, as well as the practicality of collecting the needed data through household surveys. Table includes an explanation

of how each sub-component was quantified, the survey question used to collect the data, the original source of the survey question, and potential sources of bias.

The LVI uses balance weighted average approach (Sullivan *et al.*, 2002) where each sub-component contributes equally to the overall index even through each major component is comprised of a different number of sub-components. The LVI formula uses the simple approach of applying equal weights to all major components. This weighting scheme could be adjusted by future users as needed.

Since each of the sub-components is measured on a different scale, it was first necessary to standardize each as an index. The equation is used for this conversion was adapted from that used in the human development index to calculate the life expectancy index, which is the ratio of the difference of the actual life expectancy and a pre-selected minium and the range of pre-determined maximum life expectancy (UNDP, 2007):

$$index_{s_d} = \frac{s_d - s_{min}}{s_{max} - s_{min}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where S_d is the original sub-component for district d, S_{min} and S_{max} are the minimum and maximum values, respectively for each sub-component. For example, the 'the average time travel to primary water source' sub-component ranged from 1 to 160 min in the districts i surveyed. These minimum and maximum values were used to transform this indicator in to a standardized index so it could be integrated into the water component of the LVI. Some sub-components such as the 'average agricultural livelihood diversity index' were created because an increase in the crud indicator, in this case the number of livelihood activities undertaken by a household, was assumed to decrease vulnerability.

Table 3.2: Major components and sub-components comprising the Livelihood Vulnerability Index (LVI)

Major components	Sub-components	Explanation of sub-components	Survey question	Source
Socio-demographic profile	Dependency ratio	Ratio of the population under 15 and over65 years of age to the population between 19 and 64 years of age.	Could you please list the ages and sexes of every person who eats and sleeps in this house? If you had a visitor who ate and slept here for the last 3 days, please include them as well.	Adapted from DHS (2006); Hahn *et al.* (2009)

Major components	Sub-component	Explanation of sub-components	Survey question	Source
	Percent of female-headed households	Percentage of house- holds where the Primary adult is female. If a male head is away from the home >6 months per year the female is counted as the head of the household.	Are you the head of the household?	Adapted from DHS (2006); Hahn *et al.* (2009)
	Average age of household heads	Average age of head of households	Household roster collected information on age of each member, including the head of the household	Toufique and Yunus (2013) Measurement of Livelihoods Vulnerability Index for the Coastal Districts of Bangladesh
	Percent of illiteracy	Percent of illiteracy of the district		Developed for the purposes of questionnaire.
	Percent of households where head of house hold has not attended school	Percentage of house -holds where the head of the household reports that they have attended 0 years of school.	Did you ever go to school?	Adapted from DHS (2006); Hahn *et al.* (2009)
Livelihood strategies	Percent of households with family member working in a different community	Percentage of households that report at least 1 family member who works outside of the community for their primary work activity.	How many people in your family go to a different community to work?	Adapted from World Bank (1998); Hahn *et al.* (2009)
	Percent of households dependent solely on	Percentage of households that report only agriculture as a	Do you or someone else in your household raise animals?	Adapted from World Bank (1998); Hahn *et al.* (2009)

Major components	Sub-component	Explanation of sub-components	Survey question	Source
	agriculture as a source of income	source of income.	Do you or someone else in your household grow crops? Do you or someone else in your household collect something from the bush, the forest, or lakes and rivers to sell?	
	Average Agricultural Livelihood Diversification Index	The inverse of (the number of agricultural livelihood activities +1) reported by a household, e.g., A household that farms, raises animals, and collect natural resources will have a Livelihood Diversification Index = 1/ (3 + 1) = 0.25.	Same as above	Adapted from DHS (2006); Hahn *et al.* (2009)
	Natural resource and Livestock index	The inverse of the number of natural resource and livestock ownership+1 reported by a household. For example, a household that has livestock, poultry and tree will have a natural resource and livestock index = 1/ (3 + 1) = 0.25	What are the different livestock or natural resources that you own? What are they? How many?	Toufique and Yunus (2013) Measurement of Livelihoods Vulnerability Index for the Coastal Districts of Bangladesh

Major components	Sub-component	Explanation of sub-components	Survey question	Source
Health	Average time to health facility (minutes)	Average time it takes the house holds to get to the nearest health facility.	How long does it take you to get to a health facility?	Adapted from DHS (2006); Hahn *et al.* (2009)
	Percent of households with family member with chronic illness	Percentage of house- holds that report at least 1 family member with chronic ill-ness. Chronic ill-ness was defined subjectively by respondent.	Is anybody in your family chronically ill (they get sick very often)?	Adapted from DHS (2006); Hahn *et al.* (2009)
	Percent of households where a family member had to miss work or school in the last 2 weeks due to illness	Percentage of households that report at least 1 family member who had to miss school of work due to illness in the last 2 weeks.	Has anyone in your family been so sick in the past 2 weeks that they had to miss work or school?	Adapted from World Health Organization/ Roll back Malaria (2003); Hahn *et al.* (2009)
	Access to sanitary latrine	Percentage of households without a sanitary latrine	What is the type of latrine you use? The response "no latrine" is reckoned here	Toufique and Yunus (2013) Measurement of Livelihoods Vulnerability Index for the Coastal Districts of Bangladesh
Social networks	Average Receive: Give ratio	Ratio of (the number of types of help received by a household in the past month + 1) to (the number of types of help given by a household to someone else in the past month + 1)	In the past month, did relatives or friends help you and your family: (e.g., Get medical care or medicines, Sell animal products or other goods produced by family, Take care of children).	Adapted from World Bank (1997); Hahn *et al.* (2009)

Major components	Sub-component	Explanation of sub-components	Survey question	Source
	Average Borrow: Lend Money ratio	Ratio of a household borrowing money in the past month to a household lending money in the past month, e.g., If a household borrowed money but did not lend money, the ratio = 2:1 or 2 and if they lent money but did not borrow any, the ratio = 1:2 or 0.5.	Did you borrow any money from relatives or friends in the past month? Did you lend any money to relatives or friends in the past month?	Adapted from DHS (2006); Hahn *et al.* (2009)
	Availability of amenities	Inverse of the total number of types of amenity available. For example, if the village has primary school and primary health care centre, amenity= 1/ {1+ (1+1) =0.33	Do you have primary school, high/junior school, primary health care, doctor's chamber, Cyclone shelter, general hospital, bazar, fire Services in your village?	Toufique and Yunus (2013) Measurement of Livelihoods Vulnerability Index for the Coastal Districts of Bangladesh
	Percent of households that have not gone to their local government for assistance in the past 12 months	Percentage of households that reported that they have not asked their local government for any assistance in the past12 months.	In the past 12 months, have you or someone in your family gone to your community leader for help?	Adapted from WHO/RBM (2003); Hahn *et al.*, (2009)
Food	Percent of households dependent on family farm for food	Percentage of households that get their food primarily from their personal farms.	Where does your family get most of its food?	Hahn *et al.*, (2009); The Livelihood Vulnerability Index: A pragmatic approach to assessing risks from climate variability and

Major components	Sub-component	Explanation of sub-components	Survey question	Source
				change-A case study in Mozambique
	Average number of months' households struggle to find food	Average number of months' households struggle to obtain food for their family	Does your family have adequate food the whole year, or are there times during the year that your family does not have enough food? How many months a year does your family have trouble getting enough food?	Adapted from DHS (2006); Hahn et al. (2009)
	Average Crop Diversity Index	The inverse of (the number of crops grown by a household +1). e.g., A household that grows pumpkin, maize, beans and cassava will have a Crop Diversity Index = 1/ (4 + 1) = .20.	What kind of crops does your household grow?	Adapted from DHS (2006); Hahn *et al.*, (2009)
	Percent of households that do not save crops	Percentage of households that do not save crops from each harvest.	Does your family save some of the crops you harvest to eat during a different time of year?	Hahn *et al.*, (2009); The Livelihood Vulnerability Index: A pragmatic approach to assessing risks from climate variability and change-A case study in Mozambique.
	Percent of households that do not save seeds	Percentage of households that do not have seeds from year to year.	Does your family save seeds to grow the next year?	Hahn *et al.* (2009); The Livelihood Vulnerability

Major components	Sub-component	Explanation of sub-components	Survey question	Source
				Index: A pragmatic approach to assessing risks from climate variability and change-A case study in Mozambique
Water	Percent of households that utilize a natural water source	Percentage of households that report a creek, river, lake, pool, or hole as their primary water source.	Where do you collect your water from?	Adapted from DHS (2006); Hahn *et al.*, (2009)
	Time to travel the source of natural water	Self-Explanatory	How time is required to fetch of drinking water from your home?	Toufique and Yunus (2013) Measurement of Livelihoods Vulnerability index for the Coastal districts of Bangladesh.
	Percent of households that do not have a consistent water supply	Percentage of households that report that water is not available from water source every day.	Is this water available every day?	Adapted from DHS (2006); Hahn *et al.*, (2009)
	Inverse of the average number of liters of water stored per household	The inverse of (the average number of liters of water stored by each household + 1).	What containers do you usually store water in? How many? How many liters are they?	Hahn *et al.*, (2009); The Livelihood Vulnerability Index: A pragmatic approach to assessing risks from climate variability and change-A case study in Mozambique

Major components	Sub-component	Explanation of sub-components	Survey question	Source
Natural disasters and climate variability	Average number of flood, drought, and cyclone events in the past 6 years	Total number of floods, droughts, and cyclones that were reported by households in the past 6 years.	How many times has this area been affected by a flood/cyclone /drought in 2006-2013	Adapted from Williamsburg Emergency Mgmt. (2004) Household Natural Hazards Preparedness Questionnaire.
	Percent of households that did not receive a warning about the pending natural disasters	Percentage of households that did not receive a warning about the most severe flood, drought, and cyclone event in the past 6 years.	Did you receive a warning about the flood/cyclone/ drought before it happened?	Adapted from Williamsburg Emergency Management (2004)
	Percent of households with an injury or death as a result of the most severe natural disaster in the past 6 years	Percentage of house -holds that reported either an injury to or death of one of their family members as a result of the most severe flood, drought, or cyclone in the past 6 years	Was anyone in your family injured in the flood/cyclone drought? Did anyone in your family die during the flood/ cyclone/drought?	Hahn *et al.* (2009); The Livelihood Vulnerability Index: A pragmatic approach to assessing risks from climate variability and change-A case study in Mozambique
	Mean standard deviation of the daily average maximum temperature by month	Standard deviation of the average daily maximum temperature by month between 2008 and 2013 was averaged for each district	2008–2013: district data; Bangladesh Agricultural Research Council.	Instituto Nacional de Estatistica (2007)
	Mean standard deviation of the daily average minimum temperature by month	Standard deviation of the average daily maximum temperature by month between 2008 and 2013	2008–2013: district data; Bangladesh Agricultural Research Council.	Instituto Nacional de Estatistica (2007)

Major components	Sub-component	Explanation of sub-components	Survey question	Source
		was averaged for each district.		
	Mean standard deviation of average precipitation by month	Standard deviation of the average monthly precipitation between 2008 and 2013 was averaged for each district.	2008–2013: district data; Bangladesh Agricultural Research Council.	Instituto Nacional de Estatistica (2007)

The maximum and minimum values were also transformed following this logic and eq. (1) used to standardize these sub-components. After each was standardized, the sub-components were averaged using Eq. (2) to calculate the value of each major component:

$$M_d = \frac{\sum_{i=1}^{n} index_{S_d i}}{n} \quad \text{..... (2)}$$

Where M_d=one of the seven major components for district d [Socio-Demographic Profile (SDP), Livelihood Strategies (LS), Social Network (SN), health (H), Food (F), Water (W), or Natural disasters and Climate Variability (NDCV)], index $s_d i$ represents the sub-components, indexed by i that make up each major component , and n is the number of sub-components in each major component.

Once values for each of the seven major components for a district were calculated, they were averaged using Eq. (3) to obtain the district-level LVI:

$$LVI_d = \frac{\sum_{i-1}^{7} w_{M_i} M_{di}}{\sum_{i-1}^{7} w_{M_i}} \quad \text{..... (3)}$$

This can also be expressed as

$$LVI_d = \frac{w_{SDP} SDP_d + w_{LS} LS_d + w_{SN} SN_d + w_H H_d + w_F F_d + w_W W_d + w_{NDC} NDCV_d}{w_{SDP} + w_{LS} + w_{SN} + w_H + w_F + w_W + w_{NDCV}} \quad \text{..... (4)}$$

LVI_d is the Livelihood Vulnerability Index for district d, equals the average of the seven major components. The weights of each major component, w_{M_i}, are determine by the number of sub-components that make up each major component and are included to ensure that all sub-components contribute equally to the overall LVI (Sullivan *et al.*, 2002). In this approach, the LVI is scaled from 0 (least vulnerable) to 0.6 (most vulnerable). For informative purposes, a detailed example for calculating the LVI of major component food is presented in Appendix A.

3.4 Calculating the LVI: IPCC Framework Approach (LVI-IPCC)

In this approach an alternative method for calculating the LVI is developed that incorporates the IPCC vulnerability definition. Table 3.3 shows the organization of seven major components in the LVI (IPCC) framework. Exposure of the study population is measured by the number of natural disasters that occurred in the past 6 years, while climate variability is measured by the average standard deviation of the maximum and minimum monthly precipitation over 6 years period. Adaptive capacity is quantified by the demographic profile of a district (e.g., percent of female-headed households), the type of livelihood strategies employed (e.g. predominately agricultural, or also collect natural resources to sell in the market), and the strength of social networks (e.g. percent of residents assisting neighbors). Sensitivity is measured by assessing the current state of food and water security and health status. The same sub-components outlined in Table 2 as well as Equations. (1) - (3) were used for calculation of the LVI (SLVI). The LVI-IPCC diverges from the SLVI when the major components are combined. They are first combined by the equation (5) as given below:

$$CF_d = \frac{\sum_{i-1}^{n} w_{M_i} M_{di}}{\sum_{i-1}^{n} w_{M_i}} \quad \text{..... (5)}$$

Where CF_d is an IPCC-defined contributing factor (exposure, sensitivity, or adaptive capacity) for district d; M_{di} are the major components for district d indexed by i; w_{M_i} is the weight of each major components in each contributing factor.

Once exposure, sensitivity, and adaptive capacity were calculated, the three contributing factors were combined using the Eq. (6) to obtain the LVI-IPCC:

$$LVI(IPCC_d) = (e_d - a_d) * s_d \quad \text{..... (6)}$$

$LVI(IPCC_d)$ is the LVI for district *d*, which is expressed using the IPCC vulnerability framework, "e_d" is the calculated exposure score, "a_d" is the calculated adaptive capacity score and "s_d" is the calculated sensitivity score for district d. Here the scales of LVI-IPCC varies from -1 (least vulnerable) to 1 (most vulnerable).

Table 3.3: Categorization of major components into contributing factors from the IPCC vulnerability definition

IPCC contributing factors to vulnerability	Major components
Exposure	Natural disasters and climate variability
Adaptive capacity	Socio-demographic profile Livelihood strategies Social networks
Sensitivity	Health Food Water

For informative purposes, a detailed example of calculating the contributing factor of the LVI – IPCC is presented in Appendix B.

3.5 Calculating LVI: Yates framework approach (YLVI)

Further an alternative method for calculating the LVI is used that also incorporates the IPCC vulnerability definition (but in different orientation of contributing factors in the equation) named here as YLVI developed by Yates (2010). Nahian *et al.* (2013) used this approach for determination of vulnerability of water resources. The YLVI diverges from the LVI–IPCC, where LVI is determined as equation (7) through contributing factors named exposure, sensitivity and adaptive capacity.

$$YLVI_d = \frac{(e_d) \times (s_d)}{a_d} \quad \text{.....(7)}$$

3.6 Vulnerability Assessment for Water Resources by Matrix Framework

To determine the vulnerability of any natural system to climate change impacts, it is very important to understand its exposure to gradual change and extreme events, associated sensitivity and inbuilt adaptive capacity. The exposure of water resources to climate change was assessed by identifying the direct impact due to climate variability and change as well as additional extreme events. The sensitivity of water resource was accessed summarizing the effect due to direct impact from climate change in its bio-physical and socio-economic regime. Any impact from climate change affects the bio physical regime of water resources and considering the gender perspective, the effect due to climatic impact is also felt in various socio-economic activities, centered on water or depends directly or indirectly on water resource. So, the effect due to direct climatic impact was summarized under sensitivity heading. Then, in adaptive capacity, coping mechanism of water resource itself and practiced adaptation and mitigation options in human society were summarized and ranked as per their effectiveness.

The matrix framework (Table 3.4) vulnerability assessment helps in quantifying vulnerability using simple ranking procedure based on community's perception. It also helps in assessing:

i) context specific vulnerability (i.e. event wise and extreme wise) and
ii) total vulnerability (with average value of exposure, sensitivity and adaptive capacity due to events and extremes).

Vulnerability assessment matrix developed by Yates (2010) in terms of exposure, sensitivity and adaptive capacity is used in this study for vulnerability assessment of water resources. In this analysis, each of the contributing factors exposure, sensitivity and adaptive capacity will be ranked with a score of 0~3 based on severity and strength of impact, where 0 denotes no impact and 1~3 defines impact from less to moderate and then severe.

Table 3.4: Vulnerability Assessment Matrix for Water resource

Total vulnerability (E x S) /A																
Specific vulnerability (E x S) /A																
Adaptive capacity	Overall adaptive capacity															
		Alternative use of water in human society														
		Coping mechanism in nature														
Sensitivity	Overall sensitivity															
	Effect on socio-economic regime	Fishing														
		Shrimp culture														
		Navigation														
		Cultivation														
		Standard of living														
		Impact on domestic water use														
		Impact on drinking water supply														
	Effect on bio-physical regime	Impact on water dependent ecosystem														
		Impact on water quality														
		Impact on in stream water demand														
		Impact on water recharge														
Exposure	Overall exposure															
		Salinity intrusion														
		Change in water availability														
		Change in rainfall pattern														
Context			Long duration summer	Increased temperature in summer	Short duration monsoon	Monsoon with heavier rainfall	No/less rainfall in pre/post monsoon	Erratic rainfall	Average seasonal change	Increase in cyclone storm surge frequency-intensity	Increase in tidal surge height	Water logging	River erosion	Average extreme events		

(Score: 0=no impact; 1=less impact; 2=moderate impact; 3= severe impact)

The primary equation of "Vulnerability = Exposure (E) x Sensitivity(S)/ Adaptive capacity (A)" has been used in calculating vulnerability. The questionnaire survey for vulnerability assessment had been carried out in Focus Group Discussion (FGD) sessions ensuring participation from women community only. In water resource management, women represent the majority of the gender community and hence, women had been considered as the primary focus group of the study. Total numbers of three FGDs were carried out in the study - one in Uttar Rajapur village of Sarankhola upazila (17 participants), one at Dash Ani of Bagerhat Sadar upazilas (13 participants) and another one at Herinnagor village of Sayamnagor upazila (19 participants). Vulnerability assessments were carried out during FGD sessions. FGDs were conducted with women participants.

3.7 People's Perception to Hazards and Local Coping Methods

To analyze the local coping methods, a brief overview was assembled on the coastal hazard and the current efforts to minimize the adverse impacts of the hazards. On the other hand, an intensive field investigation was carried out in the selected coastal areas to examine people's perception on coastal hazards and their coping methods.

In the questionnaire survey, people were questioned about their various livelihood parameters. They were questioned about their socio-economic condition such as number of family member, their age group, gender distribution, educational background, housing condition, sanitation system, occupation and their income level per month.

Table 3.5: Parameters and its subcomponent regarding questionnaire survey

Parameters	Survey considerations
Socio-economic condition	Age group, gender distribution, education, housing condition, toilet condition, occupation, income level per month
Hazard type	Cyclone, tidal surge, flood, riverbank erosion, drought, etc.
Shelter condition	Existing housing pattern, impact of hazards, coping methods.
Water supply system	Sources of water, usability of water, impact of hazards, coping methods etc.
Sanitation system	Existing toilet condition, impact of hazards, coping methods
Health condition	Type of diseases during hazard, treatment methods, stocking medicine, etc.
Food management	Availability of food, food storage during hazard, coping methods

People were also questioned about the change of intensity and their livelihood vulnerability, percentage of occurrence of various natural disasters and their coping methods. They were questioned about the impact of natural hazards on shelter, water supply system, sanitation system, health condition and food. The base line condition of each parameter is surveyed. During hazards, their local coping methods against the mentioned livelihood parameters were questioned as a part of the survey. Besides the structural questionnaire survey, discussions with key informants were conducted. Furthermore, focused group discussions were organized in different villages where people from different professions and strata attended and shared their experiences and sufferings during natural disaster. Along with the questionnaire survey these discussions provided wide views and opinions of people at grass root level and enriched the data bank of this research. Table 3.5 demonstrates those parameters and their sub-components regarding questionnaire survey.

CHAPTER IV

Coastal Vulnerability Assessment

4.1 General

In this chapter the vulnerability indices are presented and discussed, which were calculated based on survey results as explained previous chapters. The major contributing components such as Socio-demographic profile, Livelihood strategies, Social network, Health, Food, Water, Natural disaster and climate variability are compared among nine villages including the subcomponents of the Livelihood Vulnerability Index (LVI). The vulnerability of water resource from gender perspective and the people's perception concerning coastal hazards and their coping strategies in various hazards are also discussed in this chapter.

4.2 Survey Result on LVI Major Component

After completion of questionnaire survey in the selected area, the survey data was calculated in tabular form, which is presented in the Table 4.1. The LVI sub-component values for each district as well as the minimum and maximum values for both combined are presented in Table 4.2. Table 4.3 represent the major components value and the composite LVI for each district. As discussed before, the Livelihood Vulnerability Index (LVI) is composed of seven major components. Parameter-wise results are explained below:

4.2.1 Socio-Demographic Profile (SDP)

Table 5.2 shows that the dependency ratio index is higher for Rupsa (0.514) than Morrelganj (0.308), Mongla (0.389), Sarankhola (0.353), Dacope (0.346), Koira (0.278) Assasunni (0.309), Sayamnagor (0.409) and Bagerhat Sadar (0.471). Koira respondents reported a highest proportion of female-headed households (22%) and Mongla respondents reported a lowest proportion of female-headed households (2%). The highest proportion of household heads that attended school is in Dacope (42%) and the highest percentage of illiteracy rate is in Sayamnagor (51.4%). The average reported age of household heads is maximum in Bagerhat Sadar 46.3 years and minimum in Assasunni 36.22 years. However, for overall vulnerability, Sayamnagor (SDP 0.361) showed greater vulnerability on the Socio-Demographic Profile (SDP) index than Rupsa (SDP 0.355), Morrelganj (SDP 0.266), Mongla (SDP 0.297), Sarankhola (SDP 0.317), Dacope (SDP 0.339), Koira (SDP 0.330) Assasunni (SDP 0.318), and Bagerhat Sadar (SDP 0.301). Figure 5.1 shows comparison of the Socio-Demographic Profile among various study sites.

Table 4.1: Livelihood Vulnerability Index (LVI) sub-component values with their minimum and maximum for selected nine study areas

Major component	Sub component	Units	Morrelganj	Mongla	Sarankhola	Dacope	Koira	Assasunni	Sayamnagor	Bagerhat Sadar	Rupsa	Max value	Min value
Socio-demographic profile	Dependency ratio	Ratio	0.46	0.58	0.53	0.52	0.42	0.46	0.60	0.71	0.77	1.5	0.0
	Percent of female-headed households	Percent	6.0	2.0	8.0	10.0	22.0	14.0	18.0	4.0	18.0	100.0	0.0
	Average age of household heads	Average	36.5	37.2	39.7	38.7	40.2	36.2	37.8	46.30	40.48	60.0	25.0
	Percent of illiteracy	Percent	39.3	42.8	41.1	44.0	39.6	50.2	51.4	36.4	41.8	100.0	0.0
	Percent of households where head of household has not attended school	Percent	24.0	30.0	32.0	42.0	32.0	32.0	34.0	2.00	22.0	100.0	0.0
Livelihood strategies	Percent of households works in different community	Percent	34.0	44.0	30.0	54.0	62.0	78.0	74.0	14.0	42.0	100.0	0
	Percent of households dependent solely on agriculture as a source of income	Percent	30.0	6.0	42.0	12.0	10.0	8.0	6.0	10.0	14.0	100.0	0
	Average Agricultural Livelihood Diversification Index (range: 0.20–1)[a]	1/ # livelihoods	0.62	0.75	0.60	0.80	0.72	0.74	0.65	0.87	0.72	1.0	0.1
	Natural resource and Livestock index	1/ # resource	0.56	0.54	0.61	0.66	0.59	0.62	0.60	0.90	0.71	3.0	0

Health	Average time to health facility (minutes)	Minutes	35.9	29.9	40.8	42.4	31.1	32.4	45.1	12.36	13.40	60	5
	Percent of households with family member with chronic illness	Percent	10.0	12.0	18.0	4.0	8.0	26.0	12.0	6.0	14.0	100	0
	Percent of households where a family member had to miss work or school in the last 2 weeks due to illness	Percent	2.00	0.0	0.0	18.0	4.0	8.0	6.0	8.0	4.0	100	0
	Access to sanitary latrine	Percent	26.0	22.0	16.0	44.0	30.0	40.0	42.0	14.0	28.0	100.0	0
Social networks	Average Receive: Give ratio	Ratio	1.03	0.97	1.21	1.11	1.14	1.02	1.13	1.16	0.99	4	0.25
	Average Borrow: Lend Money ratio (range: 0.5–2)	Ratio	0.96	1.09	1.06	1.12	1.13	1.19	1.03	1.04	1.20	2	0.5
	Availability of amenities	1/ # amenities	0.28	0.32	0.29	0.33	0.29	0.31	0.29	0.11	0.10	1	0.1
	Percent of households that have not gone to their local government for assistance in the past 12 months	Percent	74.0	56.0	54.0	32.0	40.0	28.0	52.0	72.0	48.0	100	0
Food	Percent of households dependent solely on family farm for food	Percent	28.0	10.0	24.0	26.0	30.0	26.0	28.0	12.0	8.0	100.0	0
	Average number of months households struggle to find food (range: 0–12)	Months	2.40	1.66	2.04	2.96	3.38	2.12	1.55	0.18	0.14	12.0	0
	Average Crop Diversity Index (range: >0–1)[a]	1/ # crops	0.56	0.78	0.57	0.61	0.58	0.55	0.60	0.83	0.80	1.0	0.1
	Percent of households that do not save crops	Percent	88.0	96.0	84.0	90.0	92.0	96.0	98.0	96.0	92.0	100.0	0
	Percent of households that do	Percent	94.0	98.0	82.0	88.0	94.0	98.0	94.0	94.0	98.0	100.0	0

	not save seeds												
Water	Percent of households that utilize a natural water source	Percent	76.0	80.0	84.0	78.0	72.0	72.0	74.0	34.0	58.0	100.0	0
	Time to travel the source of natural water	Minutes	9.74	10.4	10.4	10.0	10.2	9.44	9.63	4.72	9.68	15.0	5
	Percent of households that do not have a consistent water supply	Percent	12.0	16.0	20.0	24.0	16.0	8.0	10.0	10.0	2.0	100.0	0
	Inverse of the average number of liters of water stored per household (range:>0–1)	1/ # liters	0.10	0.02	0.08	0.12	0.04	0.10	0.02	0.16	0.0	1.0	0
Natural disasters and climate variability	Average number of flood, drought, and cyclone events in the past 6 years	Count	3.26	4.36	4.28	5.36	3.72	4.46	5.31	4.0	3.22	6.0	0
	Percent of households that did not receive a warning about the pending natural disasters	Percent	14.0	2.0	14.0	18.0	16.0	16.0	14.0	4.0	11.0	100.0	0
	Percent of households with an injury or death as a result of the most severe natural disaster in the past 6 years	Percent	6.0	8.0	32.0	10.0	0.00	8.00	28.0	4.0	8.0	100.0	0
	Mean standard deviation of the daily average maximum temperature by month	Celsius	3.25	3.25	3.25	3.36	3.36	3.40	3.40	3.25	3.36	3.76	2.96
	Mean standard deviation of the daily average minimum temperature by month	Celsius	4.64	4.64	4.64	4.86	4.86	5.94	5.94	4.64	4.86	8.32	4.27
	Mean standard deviation of average precipitation by month	Millimeters	161.2	161.2	161.2	159.3	159.3	142.8	142.8	161.2	159.3	231.2	106.0

Table 4.2: Indexed sub-component values of LVI for selected nine study areas (calculated using eq^{n} 1)

Major component	Sub component	Morrelganj	Mongla	Sarankhola	Dacope	Koira	Assasunni	Sayamnagor	Bagerhat Sadar	Rupsa
Socio-demographic profile	Dependency ratio	0.308	0.389	0.353	0.346	0.278	0.309	0.403	0.47	0.51
	Percent of female-headed households	0.060	0.020	0.08	0.100	0.220	0.140	0.180	0.04	0.18
	Average age of household heads	0.327	0.349	0.367	0.391	0.434	0.321	0.367	0.61	0.44
	Percent of illiteracy	0.393	0.428	0.411	0.440	0.396	0.502	0.514	0.36	0.42
	Percent of households where head of household has not attended school	0.240	0.300	0.320	0.420	0.320	0.320	0.340	0.02	0.22
Livelihood strategies	Percent of households works in different community	0.34	0.44	0.30	0.54	0.62	0.78	0.74	0.14	0.42
	Percent of households dependent solely on agriculture as a source of income	0.300	0.060	0.420	0.120	0.100	0.080	0.060	0.10	0.14
	Average Agricultural Livelihood Diversification Index (range: 0.20–1)[a]	0.580	0.717	0.559	0.780	0.689	0.709	0.616	0.85	0.69
	Natural resource and Livestock index	0.188	0.178	0.202	0.220	0.197	0.207	0.201	0.30	0.24

Health	Average time to health facility (minutes)	0.562	0.453	0.651	0.680	0.475	0.498	0.729	0.13	0.15
	Percent of households with family member with chronic illness	0.100	0.120	0.180	0.040	0.080	0.260	0.120	0.06	0.14
	Percent of households where a family member had to miss work or school in the last 2 weeks due to illness	0.020	0.000	0.000	0.180	0.040	0.080	0.060	0.08	0.04
	Access to sanitary latrine	0.260	0.220	0.160	0.440	0.300	0.400	0.420	0.14	0.28
Social networks	Average Receive: Give ratio	0.209	0.191	0.255	0.230	0.238	0.206	0.236	0.24	0.20
	Average Borrow: Lend Money ratio (range: 0.5–2)	0.307	0.393	0.373	0.413	0.420	0.460	0.354	0.36	0.47
	Availability of amenities	0.200	0.239	0.211	0.259	0.207	0.228	0.206	0.01	0.0008
	Percent of households that have not gone to their local government for assistance in the past 12 months	0.740	0.560	0.540	0.320	0.400	0.280	0.520	0.72	0.48
Food	Percent of households dependent on family farm for food	0.280	0.100	0.240	0.26	0.300	0.260	0.280	0.12	0.08
	Average number of months households struggle to find food (range: 0–12)	0.200	0.138	0.170	0.247	0.282	0.177	0.129	0.02	0.01
	Average Crop Diversity Index (range: >0–1)[a]	0.516	0.752	0.519	0.564	0.529	0.503	0.551	0.81	0.78
	Percent of households that do not save crops	0.88	0.96	0.84	0.90	0.92	0.96	0.98	0.96	0.92
	Percent of households that do not save seeds	0.94	0.98	0.82	0.88	0.94	0.98	0.94	0.94	0.98

Water	Percent of households that utilize a natural water source	0.760	0.800	0.840	0.78	0.720	0.720	0.740	0.34	0.58
	Time to travel the source of natural water	0.474	0.540	0.540	0.500	0.520	0.444	0.463	0.06	0.15
	Percent of households that do not have a consistent water supply	0.120	0.160	0.200	0.24	0.160	0.080	0.100	0.10	0.02
	Inverse of the average number of liters of water stored per household (range:>0–1)	0.102	0.016	0.082	0.124	0.038	0.105	0.024	0.16	0.00
Natural disasters and climate variability	Average number of flood, drought, and cyclone events in the past 6 years	0.543	0.727	0.713	0.89	0.620	0.743	0.884	0.67	0.54
	Percent of households that did not receive a warning about the pending natural disasters	0.140	0.020	0.140	0.18	0.160	0.160	0.140	0.04	0.11
	Percent of households with an injury or death as a result of the most severe natural disaster in the past 6 years	0.060	0.080	0.320	0.10	0.000	0.080	0.280	0.04	0.08
	Mean standard deviation of the daily average maximum temperature by month	0.361	0.361	0.361	0.503	0.503	0.549	0.549	0.36	0.50
	Mean standard deviation of the daily average minimum temperature by month	0.092	0.092	0.092	0.147	0.147	0.414	0.414	0.09	0.15
	Mean standard deviation of average precipitation by month	0.441	0.441	0.441	0.426	0.426	0.294	0.294	0.44	0.43

Table 4.3: Indexed major-component and overall LVI values for the selected nine study areas of South-west Coastal belt (calculated using eq^{n} 2)

Major component	Sub component	Morrelganj	Mongla	Sarankhola	Dacope	Koira	Assasunni	Sayamnagor	Bagerhat Sadar	Rupsa
Socio-demographic profile	Dependency ratio	0.266	0.297	0.317	0.339	0.330	0.318	0.361	0.301	0.355
	Percent of female-headed households									
	Average age of household heads									
	Percent of illiteracy									
	Percent of households where head of household has not attended school									
Livelihood strategies	Percent of households works in different community	0.352	0.349	0.370	0.415	0.401	0.444	0.404	0.348	0.371
	Percent of households dependent solely on agriculture as a source of income									
	Average Agricultural Livelihood Diversification Index (range: 0.20–1)[a]									
	Natural resource and Livestock index									

Health	Average time to health facility (minutes)	0.235	0.198	0.248	0.335	0.224	0.310	0.332	0.103	0.153
	Percent of households with family member with chronic illness									
	Percent of households where a family member had to miss work or school in the last 2 weeks due to illness									
	Access to sanitary latrine									
Social networks	Average Receive: Give ratio	0.364	0.346	0.345	0.306	0.316	0.294	0.329	0.335	0.287
	Average Borrow: Lend Money ratio (range: 0.5–2)									
	Availability of amenities									
	Percent of households that have not gone to their local government for assistance in the past 12 months									
Food	Percent of households dependent on family farm for food	0.584	0.597	0.518	0.570	0.594	0.576	0.576	0.568	0.553
	Average number of months households struggle to find food (range: 0–12)									
	Average Crop Diversity Index (range: >0–1)[a]									
	Percent of households that do not save crops									
	Percent of households that do not save seeds									

Water	Percent of households that utilize a natural water source	0.364	0.379	0.415	0.411	0.360	0.337	0.332	0.166	0.186
	Time to travel the source of natural water									
	Percent of households that do not have a consistent water supply									
	Inverse of the average number of liters of water stored per household (range:>0–1)									
Natural disasters and climate variability	Average number of flood, drought, and cyclone events in the past 6 years	0.273	0.287	0.345	0.375	0.309	0.373	0.427	0.273	0.299
	Percent of households that did not receive a warning about the pending natural disasters									
	Percent of households with an injury or death as a result of the most severe natural disaster in the past 6 years									
	Mean standard deviation of the daily average maximum temperature by month									
	Mean standard deviation of the daily average minimum temperature by month									
	Mean standard deviation of average precipitation by month									
Overall LVI		**0.348**	**0.354**	**0.367**	**0.396**	**0.365**	**0.383**	**0.401**	**0.306**	**0.323**

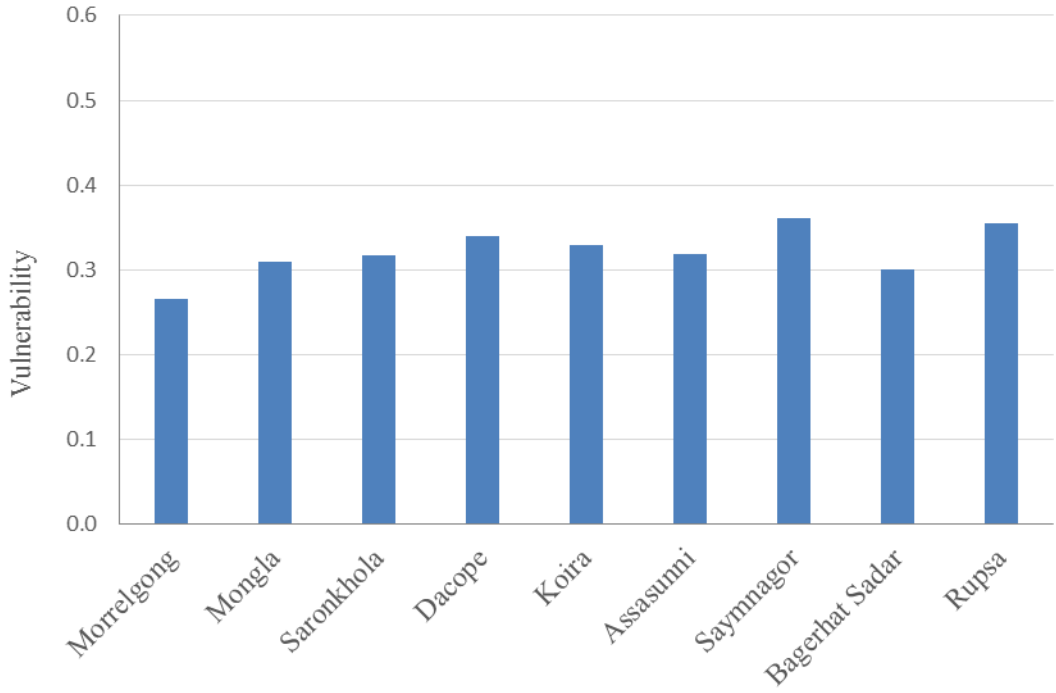


Figure 4.1: Comparison of LVI for Socio-demographic profile component

4.2.2 Livelihood Strategies Vulnerability (LSV)

Assasunni showed greater vulnerability on the Livelihood Strategies component (0.444) than Rupsa (0.371), Morrelganj (0.352), Mongla (0.349), Sarankhola (0.370), Dacope (0.413), Koira (0.401), Sayamnagor (0.404) and Bagerhat Sadar (0.348). A higher percentage of Sarankhola households reported relying solely on agriculture for income [agriculture dependency index: Sarankhola (0.42), Rupsa (0.14), Morrelganj (0.38), Mongla (0.060), Dacope (0.120), Koira (0.10) Assasunni (0.080), Sayamnagor (0.060) and Bagerhat Sadar (0.10)]. This is reflected in the livelihood diversification indices: the value of Sarankhola (0.559) is lower than Rupsa (0.72), Morrelganj (0.58), Mongla (0.717), Dacope (0.780), Koira (0.689) Assasunni (0.709), Sayamnagor (0.616) and Bagerhat Sadar (0.87). Although Dacope had higher vulnerability scores for two of the Livelihood Strategies indicators (average agricultural livelihood diversification index value 0.78 and natural resource and livestock index value 0.22), when the three sub-components were averaged, the overall Livelihood Strategies Vulnerability (LSV) score was higher for Assasunni (LS 0.444) than Sarankhola (LS 0.370), Rupsa (LS 0.371), Morrelganj (LS 0.352), Mongla (LSV 0.349), Dacope (LSV 0.413), Koira (LSV 0.401), Sayamnagor (LSV 0.404) and Bagerhat Sadar (LSV 0.348). Comparison of the Livelihood Strategies profile among various study sites are shown in Figure 5.2.

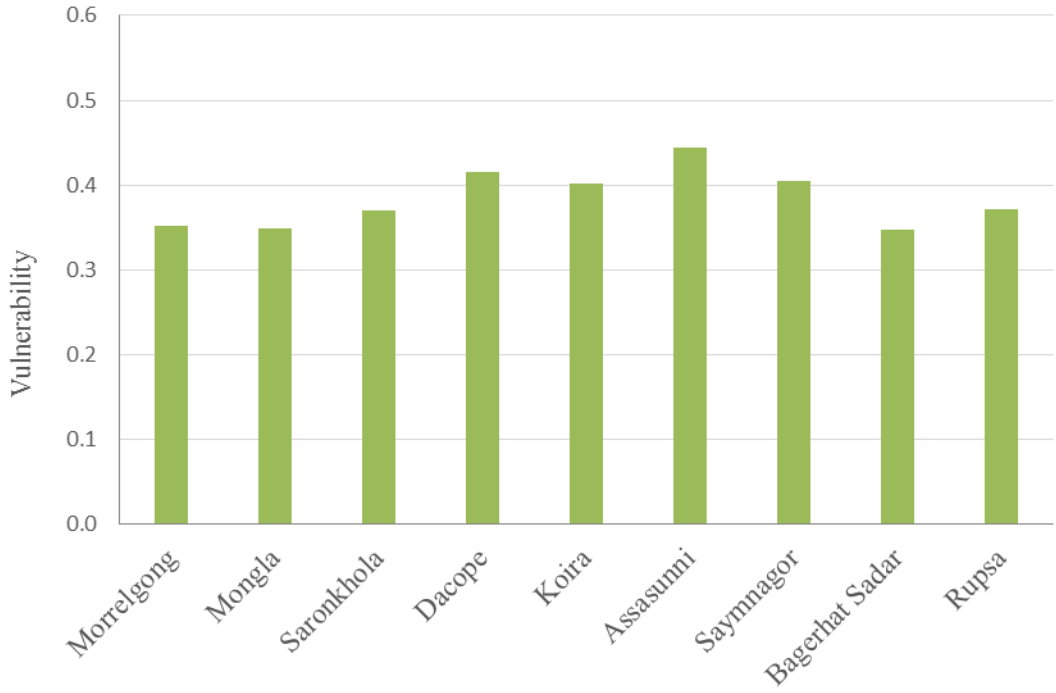


Figure 4.2: Comparison of LVI for Livelihood strategies component

4.2.3 Social Network Vulnerability (SNV)

The Social Networks indicators represents that the majority percent of households have not gone to their local government for assistant in the past 12 months. About 72% of Bagerhat Sadar, 56% of Mongla, 74% of Morrelganj, 32% of Dacope, 54% of Sarankhola, 48% of Rupsa, 40% of Koira, 28% of Assasunni and 52% of Sayamnagor households said they had not approached their local government for assistance in the past months. Rupsa households reported borrowing money more frequently and Sarankhola households receiving more in-kind assistance from family and friends than Morrelganj, Mongla, Dacope, Koira, Assasunni, Sayamnagor and Bagerhat Sadar households. The Morrelganj households reported that the number of times they lent money and the households of Mongla provided assistance in the past month more than Sarankhola, Dacope, Koira, Assasunni, Sayamnagor, Bagerhat Sadar, and Rupsa (borrow: lend ratio Morrelganj 0.96 Mongla 1.09, Sarankhola 1.06, Dacope 1.12, Koira 1.13, Assasunni 1.19, Sayamnagor 1.03, Bagerhat Sadar 1.04, Rupsa 1.20 and receive: give ratio: Morrelganj 1.03, Mongla 0.97, Sarankhola 1.21, Dacope 1.11, Koira 1.14, Assasunni 1.02, Sayamnagor 1.13, Bagerhat Sadar 1.16, Rupsa 0.99). Overall, Morrelganj households were more vulnerable than Mongla, Sarankhola, Dacope, Koira, Assasunni, Sayamnagor, Bagerhat Sadar and Rupsa households on the Social Networks Vulnerability (SNV) component (SNV of Morrelganj 0.364, SNV of Mongla 0.346, SNV of Sarankhola 0.345, SNV of Dacope 0.306, SNV of Koira 0.316, SNV of Assasunni 0.294, SNV of Sayamnagor 0.329, SNV of Bagerhat Sadar 0.335, SNV of Rupsa 0.287). Figure 4.3 shows comparison of the Social Networks profile among various study sites.

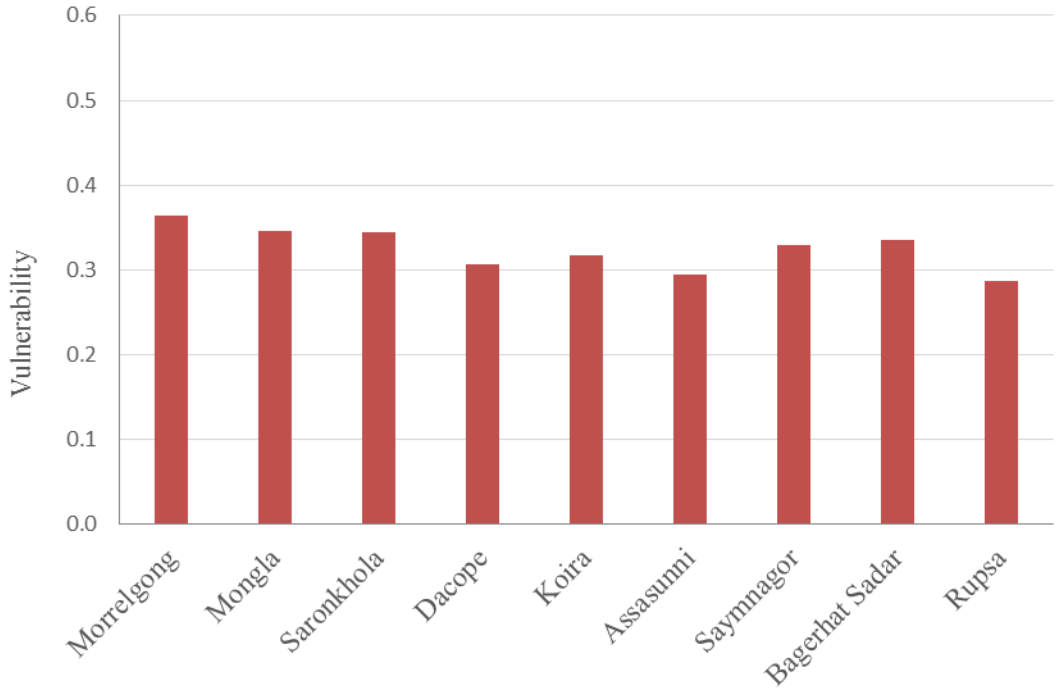


Figure 4.3: Comparison of LVI for Social network component

4.2.4 Health Vulnerability (HV)

Sayamnagor households reported traveling an average of 45.1 minutes to a health facility while Morrelganj households reported an average of 35.90 min, Mongla households reported an average of 29.0 min, Sarankhola households reported an average of 40.8 min, Dacope households reported an average of 42.4 min, Koira households reported an average of 31.1 min, Assasunni households reported an average of 32.4 min, Sayamnagor households reported an average of 45.1min, Bagerhat Sadar households reported an average of 12.36 min and Rupsa households reported an average of 13.40 min. Chronic illness was reported by 26% of households in Assasunni compared to 10% in Morrelganj, 12% in Mongla, 18% in Sarankhola, 4% in Dacope, 8% in Koira, 12% in Sayamnagor, 6% in Bagerhat Sadar and 14% in Rupsa. Although Assasunni households are more chronically ill but the 18% of Dacope households report that a family member missed work due to illness in the past 2 weeks compared to 2% of Morrelganj households, 4% of Koira households, 8% of Assasunni households, 6% of Sayamnagor households, 8% of Bagerhat Sadar households and 4% of Khulna Sadar households. The households of Mongla and Sarankhola reported that there were no households that a family member missed work due to illness in the past 2 weeks. Dacope households also reported that about 44% of households not having sanitary latrine whereas 26% of Morrelganj, 22% of Mongla, 16% of Sarankhola, 30% of koira, 40% of Assasunni, 42% of Sayamnagor, 14% of Bagerhat Sadar and 28% of Rupsa households do not have sanitary latrine. In spite of being two health indicators highest in Sayamnagor, (indices are: average time to health facility is 0.747 and access to sanitary latrine is 0.42). The overall Health Vulnerability (HV) was found highest for Dacope (HV 0.335) compared to the score of Morrelganj (HV 0.235), Mongla (HV 0.198), Sarankhola (HV 0.248), Koira (HV 0.224), Assasunni (HV 0.310), Sayamnagor (HV 0.332), Bagerhat Sadar (HV 0.103) and Rupsa (HV 0.153). Figure 4.4 shows the comparison of Health profile among various study sites.

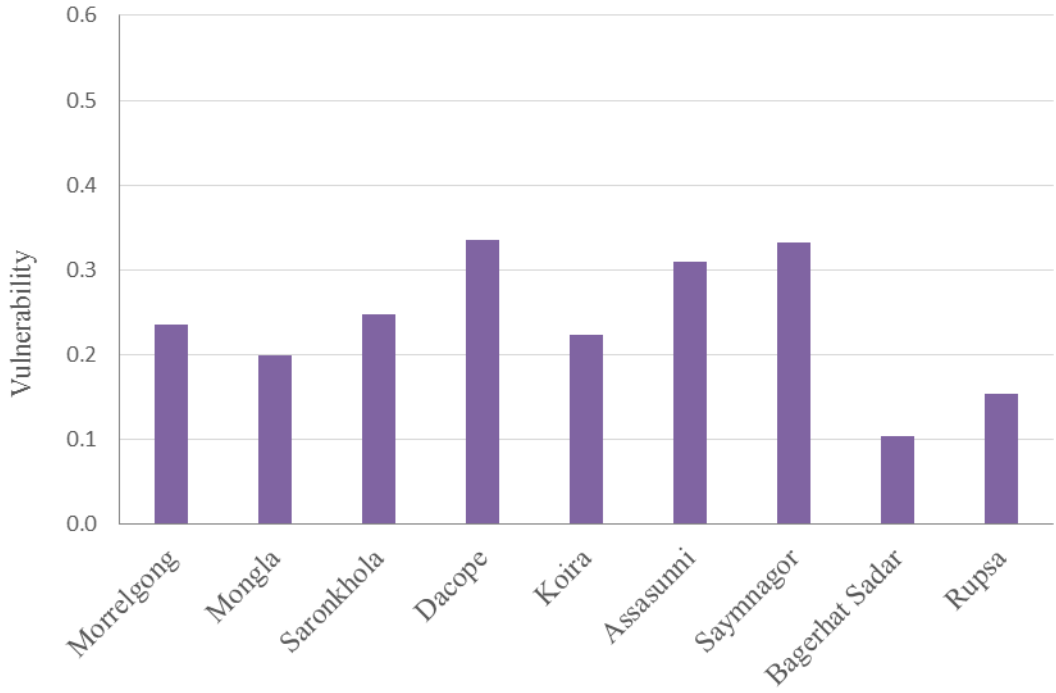


Figure 4.4: Comparison of LVI for Health component

4.2.5 Food Vulnerability (FV)

Koira households reported struggling to find adequate food for their families 3.38 months per year on average compared to 2.40 months in Morrelganj, 1.66 months in Mongla, 2.04 months in Sarankhola, 2.96 months in Dacope, 2.12 months in Assasunni, 1.55 months in Sayamnagor, 0.18 months in Bagerhat Sadar and 0.10 months in Rupsa. A smaller percentage of Rupsa households (8.0%) reported relying solely on their farm for food compared to 28% of Morrelganj households, 10% of Mongla households, 24% of Mongla Sarankhola households, 26% of Dacope households, 30% of Koira households, 26% of Assasunni households, 28% of Sayamnagor households and to 12% of Bagerhat Sadar households while Rupsa households reported growing 1.1 types of crops on average compared to 2.1 types of crops on average in Morrelganj households, 0.7 types of crops on average in Mongla households, 2.3 types of crops on average in Sarankhola households, 2.13 types of crops on average in Dacope households, 2.1 types of crops on average in of Koira households, 2.3 types of crops on average in Assasunni households, 2.3 types of crops on average in of Sayamnagor households and 0.54 types of crops on average in Bagerhat Sadar households. The households of Sarankhola reported that they storing crops and saving seeds more than to Morrelganj, Mongla, Koira, Dacope, Assasunni, Sayamnagor, Bagerhat Sadar and Rupsa households (not storing crops index: Sarankhola 0.84, Morrelganj 0.88, Mongla 0.96, Dacope 0.90, Koira 0.92, Assasunni 0.96, Sayamnagor0.98, Bagerhat Sadar 0.96 and Rupsa 0.92; not saving seeds index: Sarankhola 0.82, Morrelganj 0.94, Mongla 0.98, Dacope 0.88, Koira 0.94, Assasunni 0.98, Sayamnagor 0.94, Bagerhat Sadar 0.94 and Rupsa 0.98). The overall Food Vulnerability (FV) scores for Sarankhola (FV 0.518) are lower than that for Morrelganj (FV 0.584), Mongla (FV 0.597), Dacope (FV 0.570),

Koira (FV 0.594), Assasunni (FV 0.576), Sayamnagor (FV 0.576), Bagerhat Sadar (FV 0.568) and Rupsa (FV 0.553). Figure 4.5 shows the comparison of Food profile among various study sites.

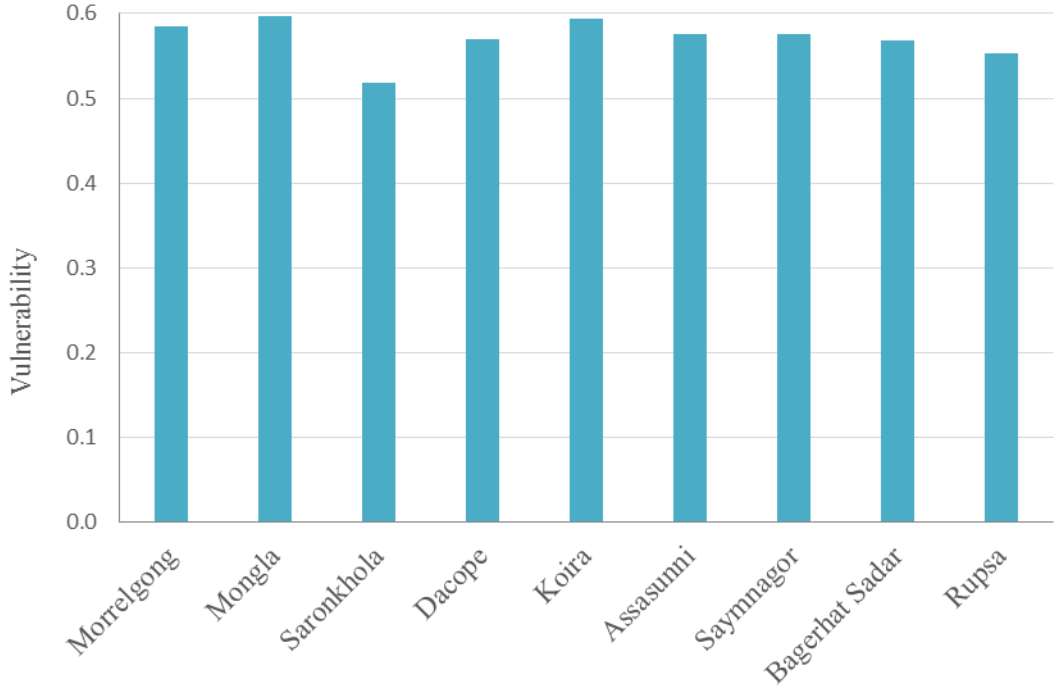


Figure 4.5: Comparison of LVI for Food component

4.2.6 Water Vulnerability (WV)

In Mongla and Sarankhola about 80% and 88% households respectively utilize natural water source. About 76% of households in Morrelganj, 78% of households in Dacope, 72% of households in Koira, 74% of households in Sayamnagor, 72% of households in Assasunni, 34% of households in Bagerhat Sadar and 58% of households in Rupsa reported using of natural water source. Bagerhat Sadar households reported storing 492L L of water on average compared to 127.14 L in Morrelganj, 202.34 L in Mongla, 87.7 L in Sarankhola, 70.04 L in Dacope, 143.54 L in Koira, 69.14 L in Assasunni, 53.71 L in Sayamnagor and 432 L in Rupsa. As a result, 98% of households in Rupsa have a consistent water supply while 90% of Bagerhat Sadar households, 88% of Morrelganj households, 84% of Mongla households, 80% of Sarankhola households, 76% of Dacope households, 84% of Koira households, 92% of Assasunni households and 90% of Sayamnagor households have water every day. Similarly, Mongla and Sarankhola households reported traveling 10.40 min on average to get water compared to 9.74 min in Morrelganj, 10. 0 min in Dacope, 10.20 min in Koira, 9.44 min in Assasunni, 9.63 min in Sayamnagor, 4.72 min in Bagerhat Sadar and 9.68 min in Rupsa. Figure 5.6 shows the comparison of Water profile among various study sites. The overall, Water Vulnerability (WV) scores for Bagerhat Sadar (WV 0.166), Morrelganj (W V 0.364), Mongla (WV 0.379), Sarankhola (WV 0.415), Dacope (WV 0.411), Koira (WV 0.360), Assasunni (WV 0.337), Sayamnagor (WV 0.332) and Rupsa (WV 0.186).

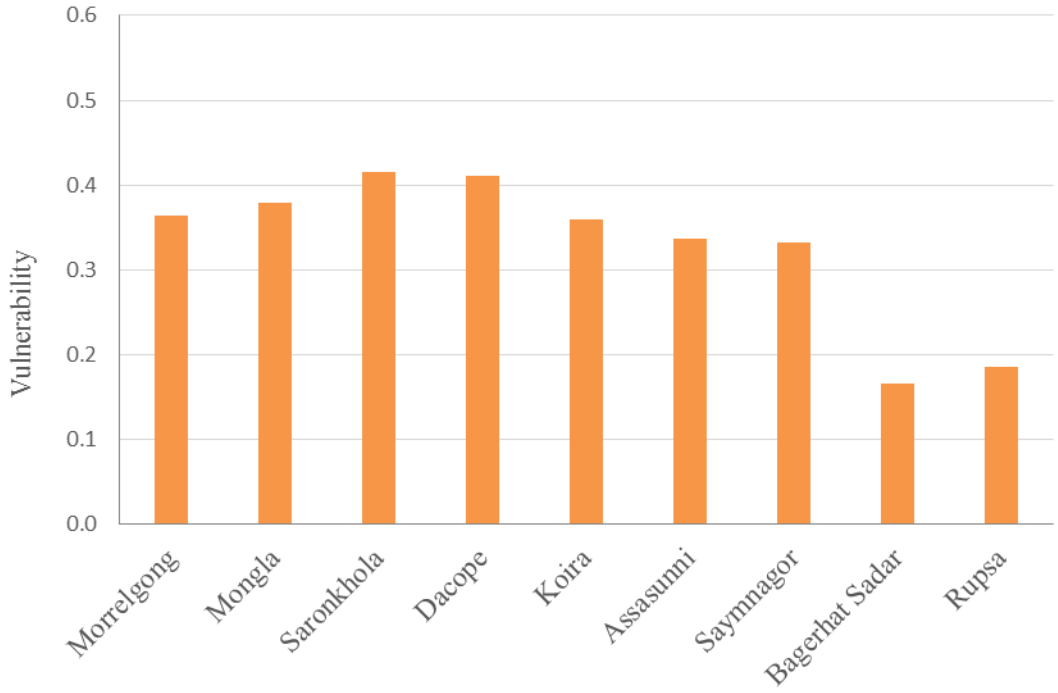


Figure 4.6: Comparison of LVI for Water component

4.2.7 Natural Disaster and Climate Variability (NDCV)

Based on the average reported number of flood, drought and cyclone events the past 6 years, Sayamnagor districts have the highest scores (0.884) compared to Morrelganj (0.543), Mongla (0.727), Sarankhola (0.713), Dacope (0.890), Koira (0.620), Assasunni (0.743), Bagerhat Sadar (0.670) and Rupsa (0.54). The households of Dacope reported that about 18% of households did not receive warning while Koira and Assasunni households reported only 16% did not receive warning. Sarankhola, Morrelganj and Sayamnagor households reported only 14% did not receive warning while Mongla, Bagerhat Sadar and Rupsa reported that did not receive warning about 2%, 4% and 10% respectively. About 32% of households in Sarankhola reported a disaster-related injury or death while there is no disaster-related injury or death in Koira households. Although Morrelganj, Mongla, Sarankhola and Bagerhat Sadar have the same climate variability scores along with same score of Dacope, Koira, Rupsa and same score of Assasunni and Sayamnagor, when climate variability was integrated into Natural Disaster index however, The Sayamnagor households were more vulnerable (NDCV 0.427) than Morrelganj (NDCV 0.273), Mongla (NDCV 0.287), Sarankhola (NDCV 0.345), Dacope (NDCV 0.375), Koira (NDCV 0.309), Assasunni (NDCV 0.373), Bagerhat Sadar (NDCV 0.273) and Rupsa (NDCV 0.281). Figure 4.7 shows comparison of Natural Disaster and Climate Variability profile among various study sites.

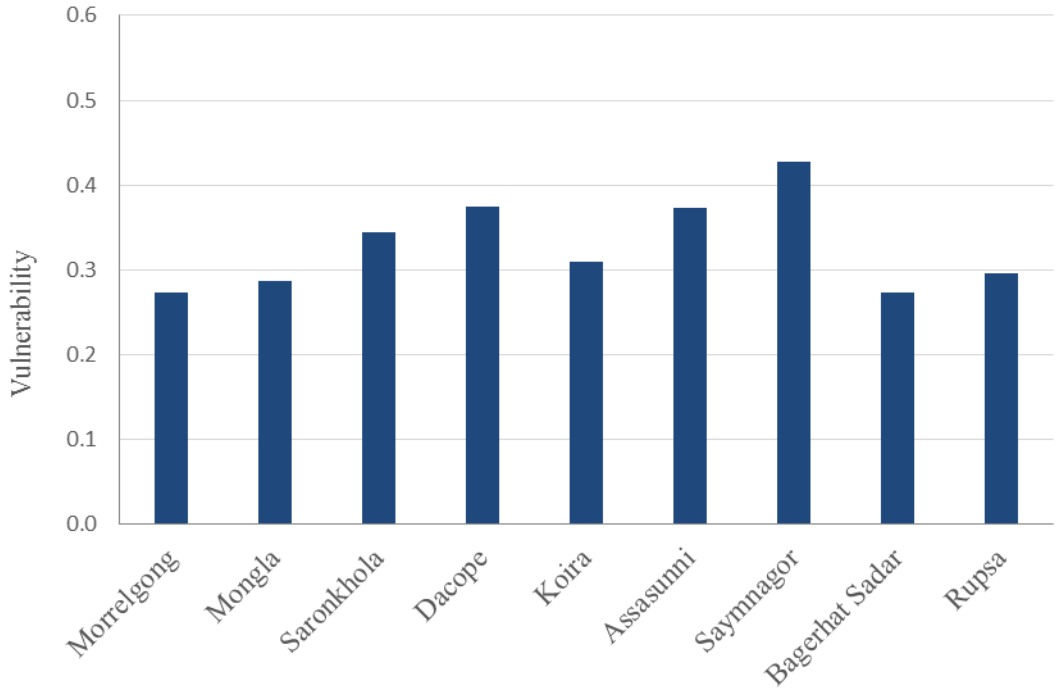


Figure 4.7: Comparison of LVI for Natural disaster and climate variability component

Parameter wise seven major components of livelihood vulnerability indices for different sites are discussed above individually from Figure 4.1 to Figure 4.7. Figure 4.8 shows comparison of LVI for all major components among different study sites.

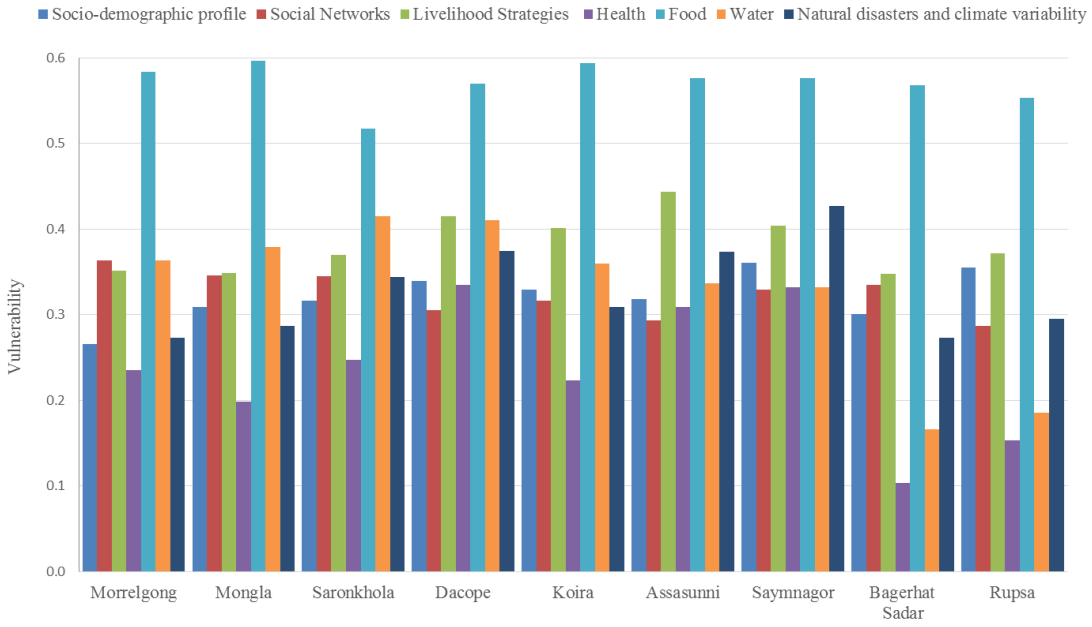


Figure 4.8: Comparison of LVI for all major components among different study sites

4.3 LVI Assessment: Composite Index Approach (SLVI)

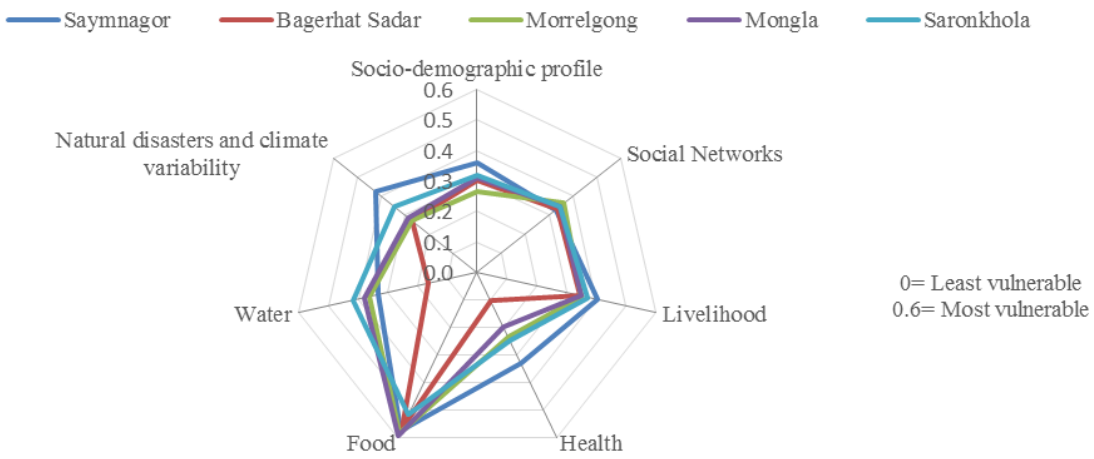
4.3.1 LVI Assessment

Overall, Sayamnagor had a higher LVI than Dacope, Assasunni, Sarankhola, Koira, Mongla, Morrelganj, Rupsa and Bagerhat Sadar (0.401, 0.396, 0.383, 0.367, 0.365, 0.354, 0.348, 0.322, and 0.306 respectively), indicating relatively greater vulnerability to climate Change impacts. The results of the major component are presented collectively in spider diagram in Figure 5.2. In overall vulnerability index, Sayamnagor is found to be most vulnerable and Bagerhat Sadar is least vulnerable among the studied areas. Therefore, the indices of other areas are compared with that of Sayamnagor and Bagerhat Sadar in Figure 5.2 (a) to 5.2 (c). The scale of the diagram ranges from 0 (less vulnerable) at the center of the web, increasing to 0.6 (more vulnerable) at the outside edge in 0.1 unit increments. It is found that Sayamnagor is more vulnerable in terms of socio-demographic profile and natural disaster and climate variability indicator (0.361 and 0.427 respectively), while Morrelganj is more vulnerable in terms of social network profile (0.364), Sarankhola is more vulnerable in terms of water resources (0.415), Dacope is more vulnerable in terms of health profile (0.340), Assasunni is more vulnerable in terms of livelihood strategies (0.444) and Mongla is more vulnerable in terms of food profile (0.597).

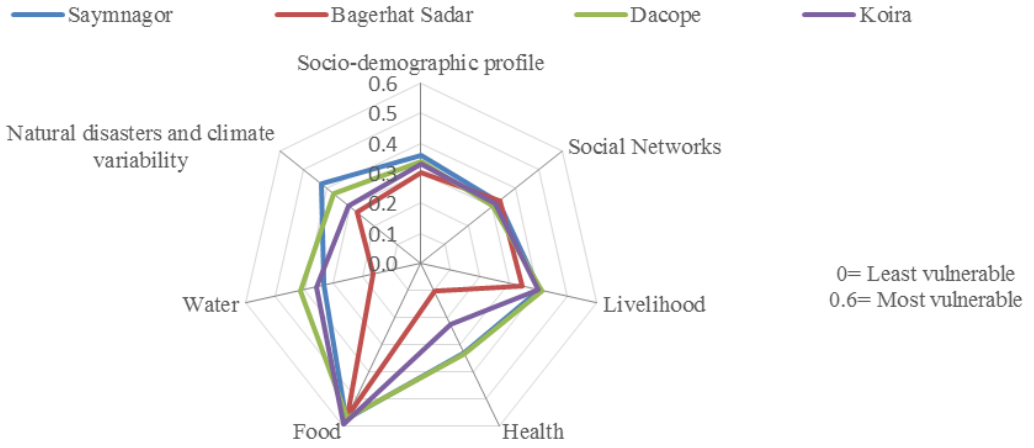
4.3.2 LVI Comparison and Practical Implications

The major vulnerability components presented in Figure 5.9 provides the information on which household characteristics contribute most to climate change vulnerability in each district. These in turn might be useful for community assistance. It is observed that the local governments of Rupsa installed deep tube-well in different places, and in Bagerhat Sadar almost every household have own tube-well. This might help to explain the shorter time that Bagerhat Sadar and Rupsa households reported traveling to a water source. These water management practices have likely decreased the vulnerability of the water sector in Bagerhat Sadar along with Rupsa and are reflected in its low Water vulnerability score despite drought conditions. This suggests that resources that may have been spent on water assistance in a drought-prone area might be reallocated to a more vulnerable sector.

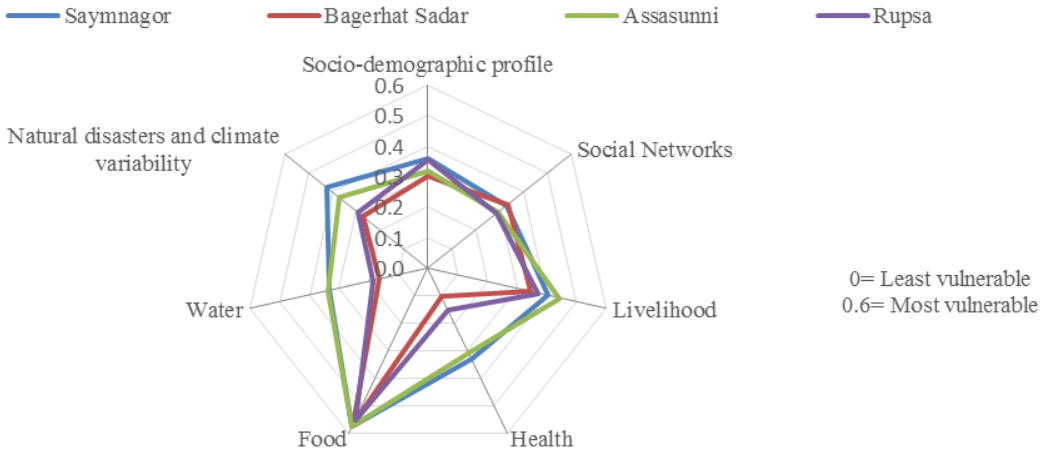
Similarly, the Bagerhat Sadar and Rupsa households reported struggling to find food only few months per year than Mongla, Morrelganj, Sarankhola, Dacope, Koira, Assasunni and Sayamnagor households. The majority households of Bagerhat Sadar and Rupsa don’t depend solely on family firm food and a smaller proportion reported engaging in seed storage and other food management practices compared to Mongla, Morrelganj, Sarankhola, Dacope, Koira, Assasunni and Sayamnagor households. The Bagerhat Sadar and Rupsa households did not report the same level of food insecurity as Mongla, Morrelganj, Sarankhola, Dacope, Koira, Assasunni and Sayamnagor households do but it had a higher vulnerability score. This suggests that inspiration for food production, education on storage, crop diversification, and seed preservation might constitute an appropriate intervention for the Bagerhat Sadar and Rupsa households despite their current secure food status relative to Mongla, Morrelganj, Sarankhola, Dacope, Koira, Assasunni and Sayamnagor.



(a) Vulnerability spider diagrams of Morrelganj, Mongla, Sarankhola, Sayamnagor and Bagerhat Sadar



(b) Vulnerability spider diagrams of Dacope, Koira, Sayamnagor and Bagerhat Sadar



(c) Vulnerability spider diagrams of Assasunni, Rupsa, Sayamnagor and Bagerhat Sadar

Figure 4.9: Vulnerability spider diagrams of the major components

Morrelganj, Sayamnagor, Dacope and Sarankhola households also reported diversifying their income sources beyond farming by collecting natural resources to sell in the market and raising livestock such as cow, goats, Ducks, chickens. Another coping strategy used largely by Assasunni families is to send their sons and husbands outside the community to work. Although this migration may fill immediate income needs.

This widely studied phenomenon was the rationale for assigning higher vulnerability scores to households reporting family members working outside the community. Despite of these practices, Assasunni was found more vulnerable than Mongla, Morrelganj, Sarankhola, Dacope, Koira, Assasunni and Sayamnagor, Bagerhat Sadar and Rupsa in terms of the Livelihood Strategies index.

The households of Sayamnagor reported a longer average time to health facilities and a higher prevalence of chronic illness. Dacope households reported that the highest proportion of households don't have sanitary latrine compared to Mongla, Morrelganj, Sarankhola, Koira, Assasunni, Sayamnagor, Bagerhat Sadar and Rupsa. The percent of people who were so sick in the past 2 weeks that they had to miss work in Dacope was also higher compared to the percent in Mongla, Morrelganj, Sarankhola, Koira, Assasunni, Sayamnagor, Bagerhat Sadar and Khulna Sadar. Based on these findings, targeted sanitary latrine installation and a follow-up health assessment to determine the diseases causing people to miss work might be advisable for Dacope.

Further analysis of location and quality of health facilities in Sayamnagor might help uncover reasons why Sayamnagor households reported long traveling times to seek health care.

The ratios of borrow money to lend money and receive assistance to give assistance were calculated to measure the degree to which households rely on family and friends for financial assistance and in-kind help. It is observed that a household that receives money or in-kind assistance often but offers little assistance to others is more insecure and vulnerable compared to those with excess money and time to help others. The finding that Rupsa households had higher borrowed to lend ratio than Assasunni, Koira, Dacope, Mongla, Sarankhola, Bagerhat Sadar, Sayamnagor and Morrelganj households while Sarankhola households had higher receive to give ratios than Bagerhat Sadar, Koira, Sayamnagor, Dacope, Rupsa, Assasunni and Mongla households may be related to the higher proportion of female-headed households in that district.

Community bonds and high levels of trust among households are important for decreasing vulnerability to climate change impacts (Thomas *et al.*, 2005); however, these social characteristics can be more difficult to measure than food security and health indicators. Despite the challenges in quantifying social networks, their inclusion in climate vulnerability assessments is essential as many adaptation behaviors rely on collective insurance mechanisms such as agricultural cooperatives.

Finally, although Dacope households reported a higher absolute number of natural disasters over the past 6 years, the variability in the monthly average precipitation have been greater in Morrelganj, Mongla, Sarankhola and Bagerhat Sadar. Further the variability in the monthly average minimum and maximum daily temperature have been greater in Assasunni and Sayamnagor along with not receiving a warning about the pending natural disasters and more injury or death as a result of recent natural disasters resulting in a higher natural disaster and climate variability (NDCV) score for Sayamnagor and Assasunni. Early warning systems and community preparedness plans may help communities in the districts prepare for extreme weather events. Seasonal weather forecasts distributed through local farming associations may help farmers in timing their plantings and prevent diversion of scarce water resources for irrigation. It is chosen 6 years as the recall window for the natural disaster indicator because respondents would not accurately report disasters earlier than that. This question may have been subject to recall bias if households that were less able to withstand the impacts of a natural disaster were more likely to report the occurrence of these events. A natural disaster database would be a more accurate indicator of natural disaster exposure if it were available at the district level. Incorporation of data on the duration and severity of natural disasters may also contribute to the NDCV component. A final limitation is that our temperature and precipitation analyses were limited to the available data for districts only. It would be more appropriate if the data are available in the study area.

4.4 LVI Assessment: IPCC Approach (LVI-IPCC) and Yates Approach (YLVI)

4.4.1 LVI Assessment

Table 4.4 shows the vulnerability indices calculated based on IPCC approach (LVI-IPCC) and Yates approach (YLVI). The individual indices for LVI contributing factors are also shown in the table. Figure 5.3 shows vulnerability triangle diagram, which plots the contributing factor scores for exposure, adaptive capacity, and sensitivity. The triangle illustrates that Sayamnagor may be more exposed (0.427) to climate change and variability impacts than Morrelganj (0.273), Mongla (0.287), Sarankhola (0.345), Dacope (0.375), Koira (0.309), Assasunni (0.373), Rupsa (0.273) and Bagerhat Sadar (0.281). However, accounting for the current health status as well as food and water security, Dacope may be more sensitive (0.449) to climate change impacts than Morrelganj, Mongla, Sarankhola, Sayamnagor, Koira, Assasunni, Rupsa and Bagerhat Sadar (0.409, 0.407, 0.403, 0.426, 0.408, 0.421, 0.317 and 0.302 respectively). Based on demographics, livelihoods, and social networks, Dacope showed a higher adaptive capacity (0.356) than Morrelganj (0.321), Mongla (0.332), Sarankhola (0.342), Koira (0.350), Assasunni (0.354), Sayamnagor (0.334), Rupsa (0.342) and Bagerhat Sadar (0.325). The overall LVI–IPCC and LVI-YLVI scores indicate that Sayamnagor households are more vulnerable than, Assasunni, Sarankhola, Koira, Mongla, Morrelganj, Rupsa and Bagerhat Sadar households respectively.

Table 4.4: LVI-IPCC and YLVI Contributing Factors

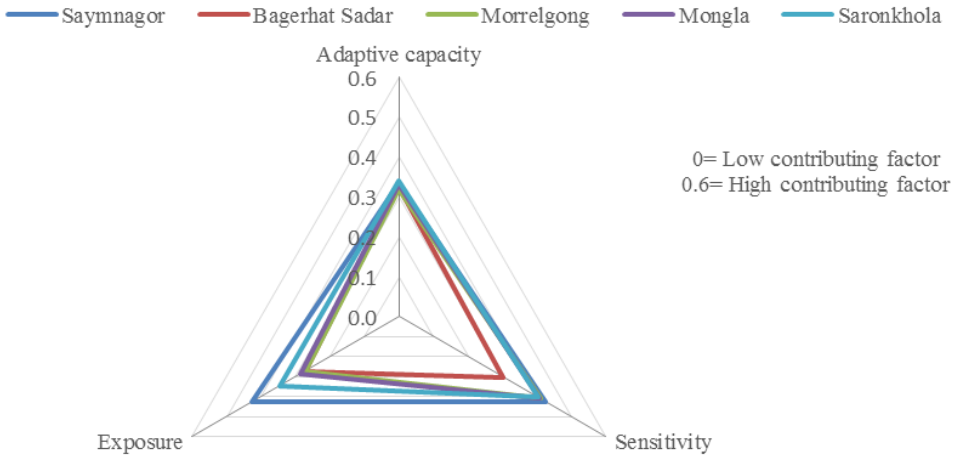
IPCC contributing factor	Morrelganj	Mongla	Sarankhola	Dacope	Koira	Assasunni	Sayamnagor	Bagerhat Sadar	Rupsa
Adaptive capacity	0.321	0.332	0.342	0.356	0.350	0.354	0.334	0.325	0.342
Sensitivity	0.409	0.407	0.403	0.449	0.408	0.421	0.426	0.302	0.317
Exposure	0.273	0.287	0.345	0.375	0.309	0.373	0.427	0.273	0.295
LVI-IPCC	-0.020	-0.018	0.001	0.009	-0.017	0.008	0.040	-0.016	-0.015
YLVI	0.348	0.351	0.406	0.473	0.361	0.444	0.544	0.253	0.274

4.4.2 LVI Comparison and Practical Implications

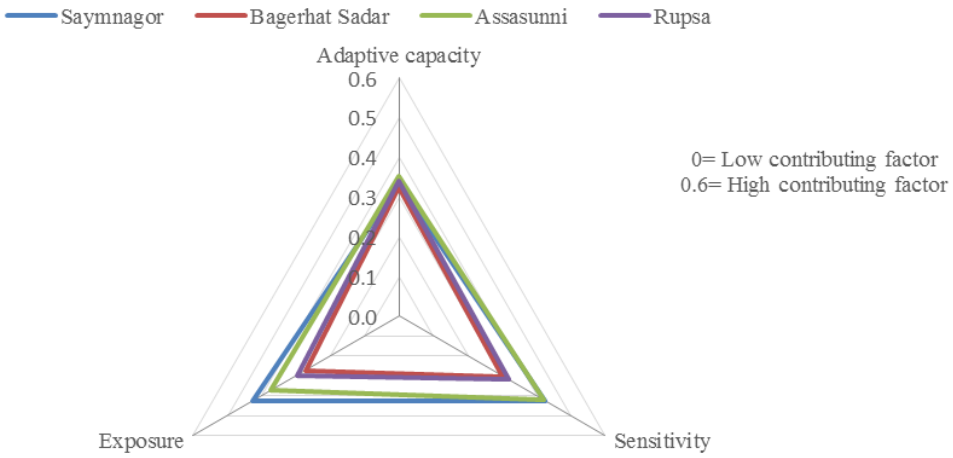
Vulnerability triangle diagram of the contributing factors of the LVI-IPCC for Morrelganj, Mongla, Sarankhola, Dacope, Koira, Assasunni, Sayamnagor, Bagerhat Sadar and Rupsa is shown in Figure 4.10. This plot represents the contributing factor values for exposure, adaptive capacity and sensitivity of the villages. Due to the low estimated adaptive capacity of Sayamnagor households compared to Sarankhola, Dacope and Rupsa households, which was resulting from demographic imbalance and adaptation practices such as livelihood diversification and food, natural disaster and water storage increased Sayamnagor's overall LVI–IPCC score. It is possible that these strategies will only be able to compensate for climate change within a narrow band of possible climate variation. Although, Morrelganj, Mongla, Sarankhola, Dacope, Koira, Assasunni, Bagerhat Sadar and Rupsa households didn't report similar adaptation strategies, they also didn't report the same demographic pressures or same rates of school attendance prevalent like Sayamnagor.

Figure 4.11 shows the overall adaptive capacity among the villages. Based on socio-demographic profile, livelihood strategies and social networks parameters, Rupsa showed a higher adaptive capacity than Morrelganj, Mongla, Sarankhola, Dacope, Koira, Assasunni, Sayamnagor and Bagerhat Sadar. Morrelganj is more vulnerable in terms of social network parameters, Sayamnagor is more vulnerable in terms of socio-demographic profile and Assasunni is more vulnerable in terms of livelihood strategies parameter.

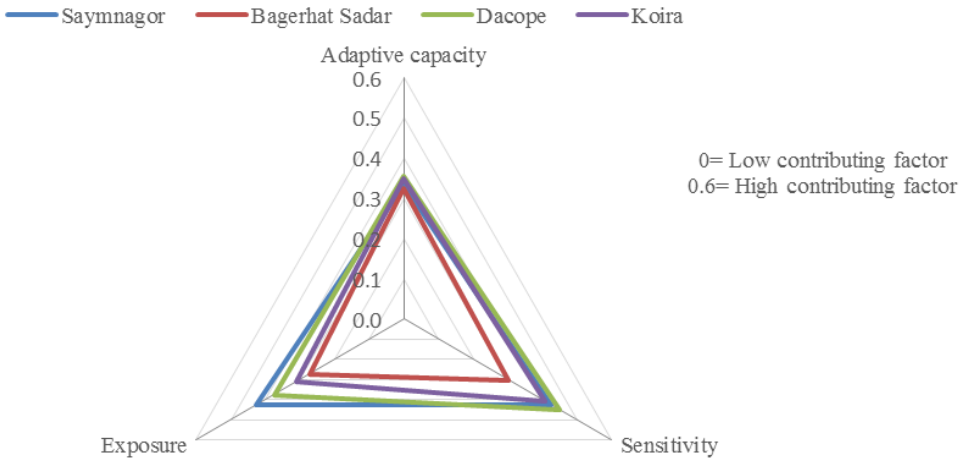
The vulnerability triangle diagram for sensitivity (Figure 4.12) shows the sensitivity vulnerability indicators among the study area. Accounting for the current health status as well as food and water security, Dacope is more sensible to climate change impacts compared to Morrelganj, Mongla, Sarankhola, Koira, Assasunni, Sayamnagor, Bagerhat Sadar and Rupsa. On the other hand, Bagerhat Sadar is quite less sensible to water security, food and health component.



(a) Vulnerability triangle diagram of Morrelganj, Mongla, Sarankhola, Sayamnagor and Bagerhat Sadar

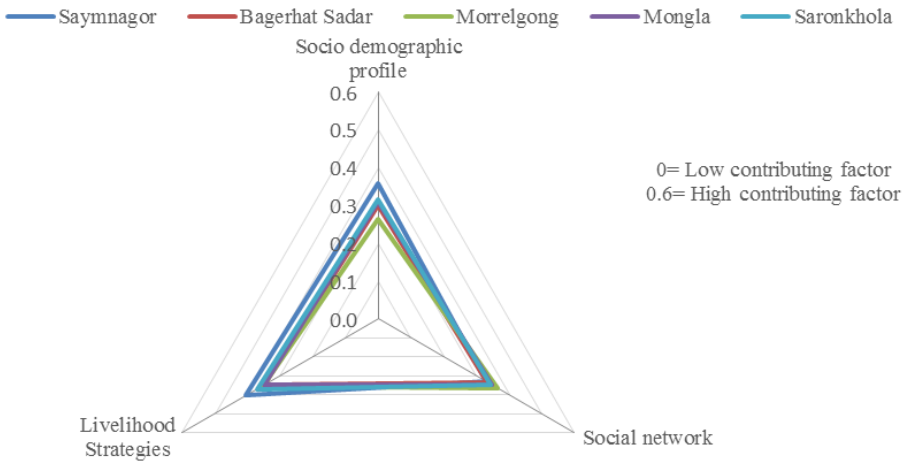


(b) Vulnerability triangle diagram of Assasunni, Rupsa, Sayamnagor and Bagerhat Sadar

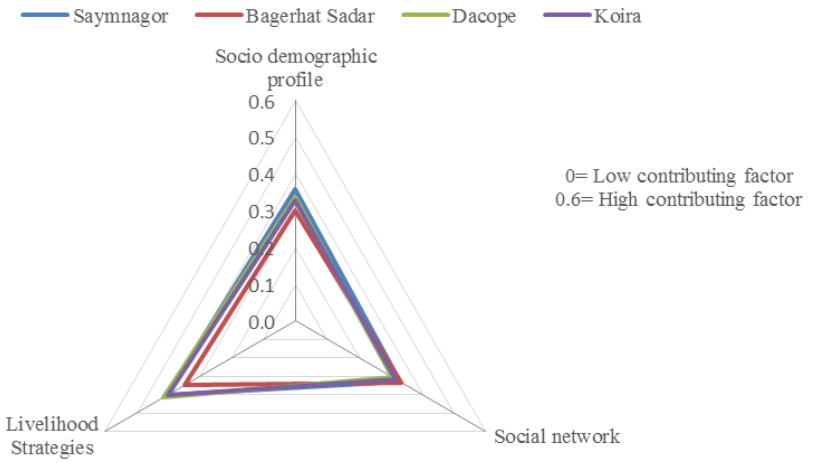


(c) Vulnerability triangle diagram of Dacope, Koira, Sayamnagor and Bagerhat Sadar

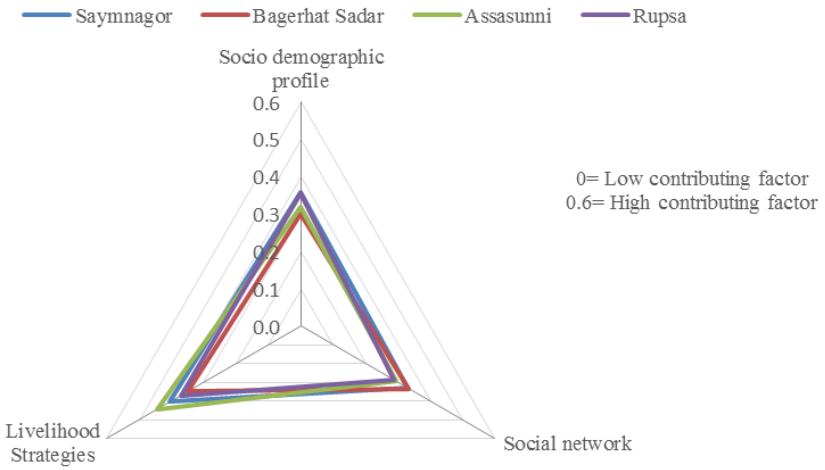
Figure 4.10: Vulnerability triangle diagram of the contributing factors of the LVI-IPCC



(a) Vulnerability triangle diagram for adaptive capacity of Morrelganj, Mongla, Sarankhola, Sayamnagor and Bagerhat Sadar

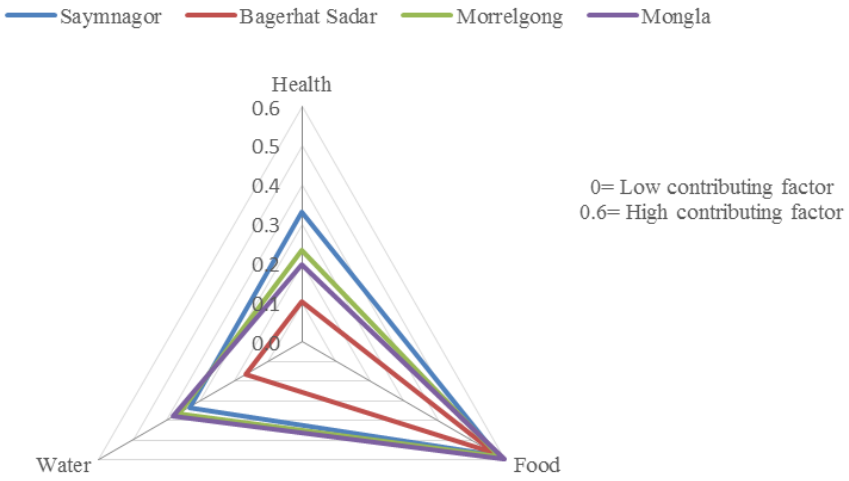


(b) Vulnerability triangle diagram for adaptive capacity of Dacope, Koira, Sayamnagor and Bagerhat Sadar

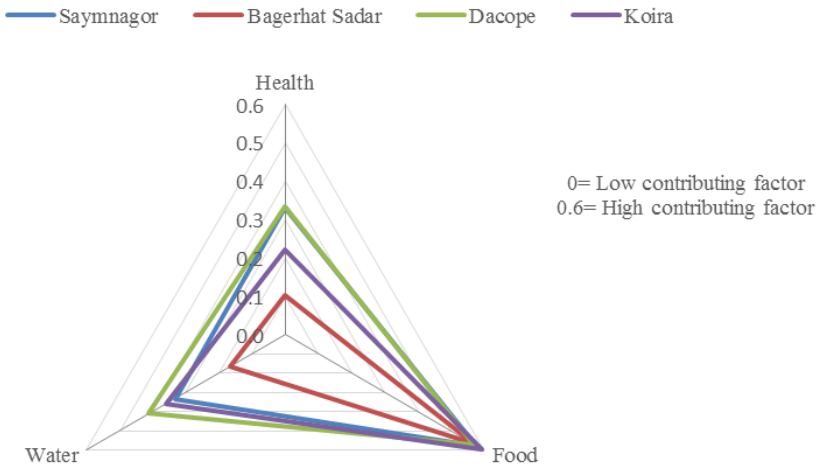


(c) Vulnerability triangle diagram for adaptive capacity of Assasunni, Rupsa, Sayamnagor and Bagerhat Sadar

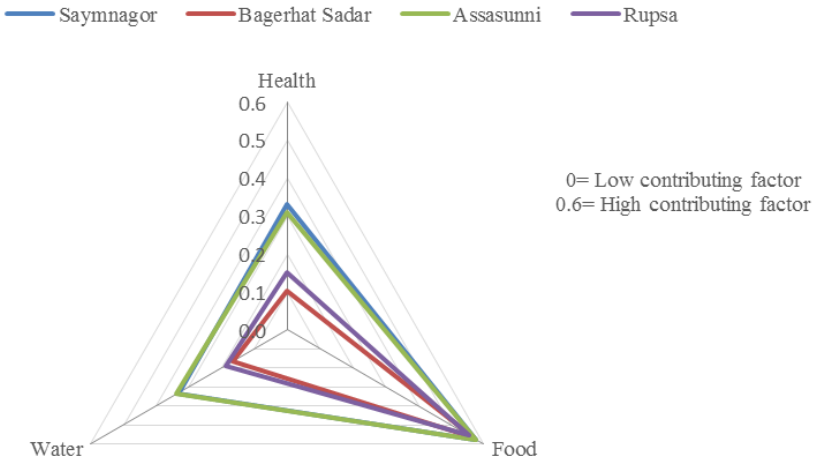
Figure 4.11: Vulnerability triangle diagram of contributing factors for adaptive capacity



(a) Vulnerability triangle diagram for sensitivity of Morrelganj, Mongla, Sarankhola, Sayamnagor and Bagerhat Sadar



(b) Vulnerability triangle diagram for sensitivity of Dacope, Koira, Sayamnagor and Bagerhat Sadar



(c) Vulnerability triangle diagram for sensitivity of Assasunni, Rupsa, Sayamnagor and Bagerhat Sadar

Figure 4.12: Vulnerability triangle diagram of sensitivity

Since exposure consists only one parameter (Natural disasters and climate variability), hence no triangle diagram is possible for this contributing factor. Figure 4.13 shows the variation of vulnerability for exposure in different study areas in bar chart. It is found from the Figure that Sayamnagor is more vulnerable compared to other study places in terms of natural disasters and climate variability induced exposure.

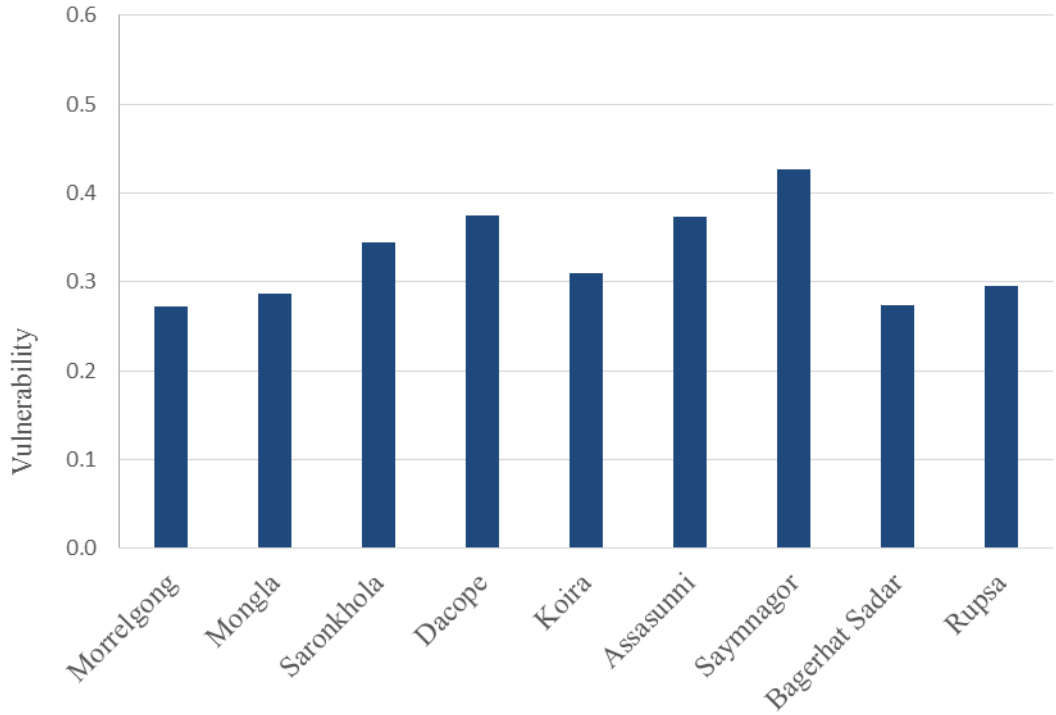


Figure 4.13: Vulnerability Bar chart for exposure in different study areas

4.4.3 Comparison of Overall LVIs among three methods

It can be noted that the scale of contributing factors (exposure, sensitivity and adoptive capacity) varies from 0 (least vulnerable) to 0.6 (most vulnerable). Therefore, LVI-IPCC varies from -0.36 to +0.36. If this scale is subdivided into four equal ranges and named as less vulnerable (-0.36< LVI-IPCC < -0.18), moderately vulnerable (-0.18< YLVI < 0.0), highly vulnerable (0 < YLVI < 0.18) and extremely vulnerable (0.18< YLVI < 0.36), then it is found from the Figure 4.14 that Morrelganj, Mongla, Koira, Bagerhat Sadar and Rupsa lie in the range of moderately vulnerable areas while Sayamnagor, Assasunni, Dacope and Sarankhola lie in the range of highly vulnerable areas.

However, SLVI varies from 0 to 0.6. If this scale is subdivided into four equal ranges and named as less vulnerable (0 <YLVI < 0.15), moderately vulnerable (0.15< YLVI < 0.3), highly vulnerable (0.3 < YLVI < 0.45) and extremely vulnerable (0.45< YLVI < 0.6), then it is found from the Figure 4.15 that all the study areas lie in the range of highly vulnerable areas.

Again YLVI varies from 0 to 0.6. If this scale is subdivided into four equal ranges and named as less vulnerable (0 <YLVI < 0.15), moderately vulnerable (0.15< YLVI < 0.3), highly vulnerable (0.3 < YLVI < 0.45) and extremely vulnerable

(0.45< YLVI < 0.6), then it is found from the Figure 4.16 that Sayamnagor and Dacope lie in the range of extremely vulnerable areas and Morrelganj, Mongla, Sarankhola, Koira and Assasunni lie in the range of highly vulnerable areas as well as Bagerhat Sadar and Rupsa lie in the range of moderately vulnerable areas.

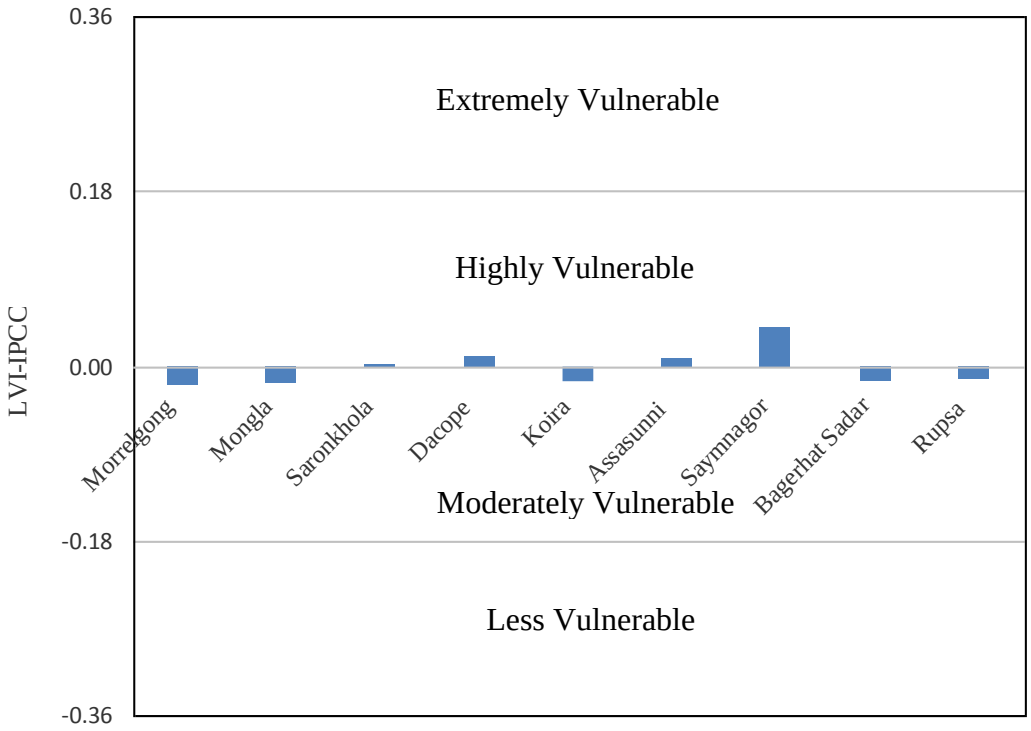


Figure 4.14: Overall Livelihood Vulnerability Indices for different areas using IPCC approach (LVI-IPCC)

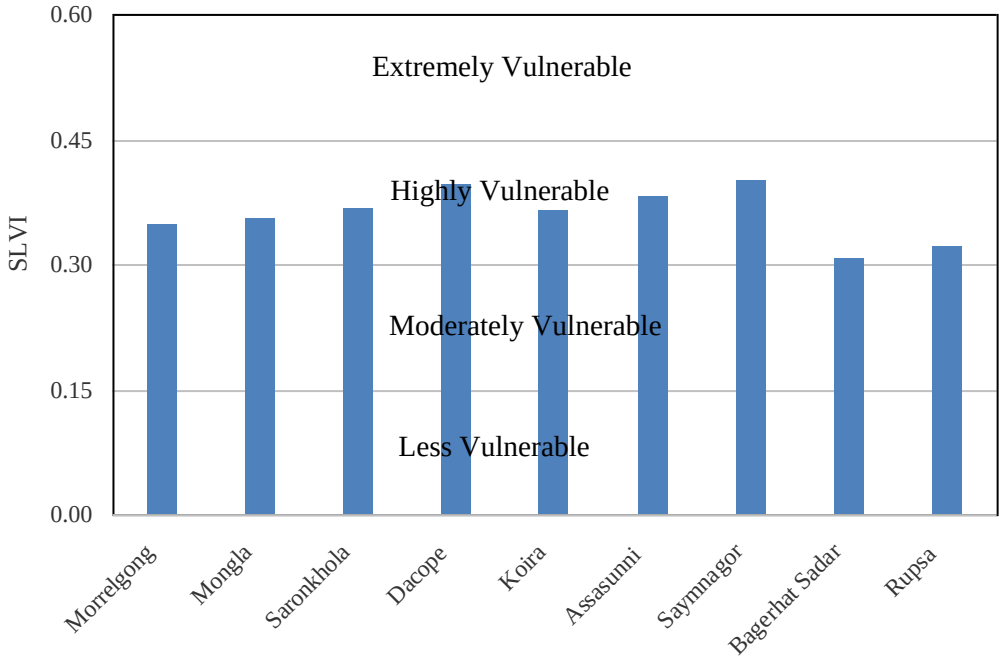


Figure 4.15: Overall Livelihood Vulnerability Indices for different areas using Composite index approach (SLVI)

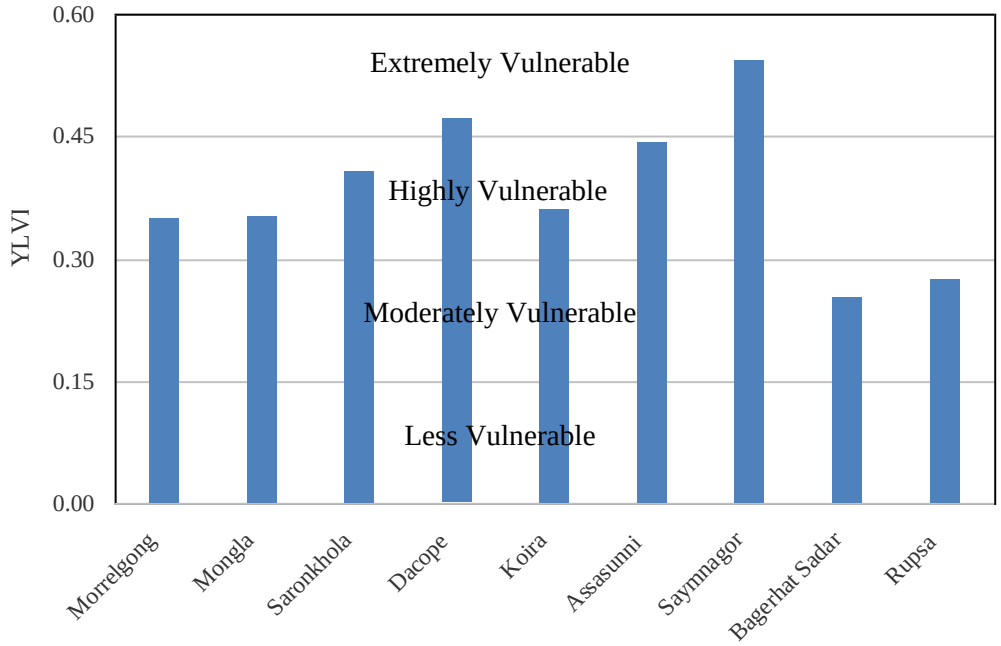


Figure 4.16: Overall Livelihood Vulnerability Indices for different areas using Yates approach (YLVI)

4.5 **Comparison of Overall LVI Results with Previous Studies**

Many researchers have tried to evaluate the livelihood vulnerability indices in various places in the world. Many of them rely on the composite index approach while many of them rely heavily on IPCC working definition of vulnerability as a function of exposure, sensitivity, and adaptive capacity.

Hahn *et al.* (2009) calculated the livelihood vulnerability indices in the Mabote and Moma Districts of Mozambique based on both composite index approach and LVI-IPCC approach. They obtained the indices based on composite approach in the Mabote and Moma Districts and the index values were found as 0.326 and 0.316, respectively. They also obtained the indices based on LVI-IPCC approach and the obtained values are -0.074 and +0.005 for Moma and Mabote, respectively.

Shah *et al.* (2013) evaluated the livelihood vulnerability index in Trinidad and Tobago, a country that is expected to bear some of the most severe impacts of climate change. They evaluated the livelihood vulnerability indices using both composite index approach and LVI-IPCC approach at Nariva and Caroni communities in Trinidad and Tobago, respectively. They obtained the indices in Nariva and Caroni based on composite index approach are 0.41 and 0.36, respectively. They also obtained the indices in Nariva and Caroni based on LVI-IPCC are -0.03 and 0.02, respectively.

Madhuri *et al.* (2014) calculated the livelihood vulnerability indices in the context of Bihar at Narayanpur, Bihpur, Rangra Chowk, Gopalpur, Ismailpur, Naugachia and Kharik. They obtained the indices based on composite index approach are, Narayanpur (0.34), Bihpur (0.34), Rangra Chowk (0.34), Gopalpur (0.33), Ismailpur

(0.31), Naugachia (0.30) and Kharik (0.33). The obtained indices based on LVI-IPCC are Narayanpur (0.07), Bihpur (0.06), Rangra Chowk (0.08), Gopalpur (0.012), Ismailpur (0.06), Naugachia (-0.07) and Kharik (0.06).

Toufique and Yunus (2013) calculated the livelihood vulnerability index of the coastal districts in Bangladesh. They relied on the composite index approach in determining the livelihood vulnerability. The obtained the Livelihood Vulnerability Index (LVI) for coastal areas as 0.348.

In this study, the Livelihood Vulnerability Index (LVI) based on composite index is found as 0.348 for Morrelganj, 0.354 for Mongla, 0.367 for Sarankhola, 0.396 for Dacope, 0.365 for Koira, 0.383 for Assasunni, 0.401 for Sayamnagor, 0.306 for Bagerhat Sadar and 0.322 for Rupsa. Using LVI-IPCC approach the indices are found as Morrelganj (-0.02), Mongla (-0.018), Sarankhola (0.001), Dacope (0.009), Koira (-0.017), Assasunni (0.008), Sayamnagor (0.040), Bagerhat Sadar (-0.016) and Rupsa (-0.015). Using Yate's approach (YLVI), the indices are found as 0.348 for Morrelganj, 0.351 for Mongla, 0.406 for Sarankhola, 0.473 for Dacope, 0.361 for Koira, 0.444 for Assasunni, 0.544 for Sayamnagor, 0.253 for Bagerhat Sadar and 0.273 for Rupsa.

It is appeared from the above mentioned research work that the result of the present study is compatible with previous research. Moreover, as far as the author's knowledge, Yates approach was used for water resource vulnerability analysis and not used previously for the livelihood vulnerability analysis. However, in this study it is revealed that this approach can explain the result more explicitly than other methods.

4.6 Water Resource Vulnerability Assessment

Vulnerability of water resource had been accessed for Uttar Rajapur village of Sarankhola upazila and Dash Ani of Bagerhat Sadar upazila along with Hrinnagor village of Sayamnagor upazila from gender view point (i.e. primary user is women). The each of the contributing factors exposure, sensitivity and adaptive capacity is ranked with a score of 0~3 based on severity and strength of impact, where 0 denotes no impact and 1~3 defines impact from less to moderate and then severe. The value of the contributing factors and the vulnerability for Sarankhola, Sayamnagor and Bagerhat Sadar is presented in Table 4.5, Table 4.6 and Table 4.7, respectively. It is found that the vulnerability score is 2.03 for Sarankhola, 1.04 Bagerhat Sadar and 2.18 for Sayamnagor. This reflects that, water resource of Sayamnagor is more vulnerable as perceived by women respondents.

The respondents perceived that, water resource in Sayamnagor is more vulnerable to climate change induced disaster events whereas in Bagerhat Sadar and Sarankhola respondents perceived that water resource is more vulnerable to climate associated gradual changes.

For Sayamnagor, the specific vulnerability due to average seasonal change is lesser than total vulnerability and the specific vulnerability due to average change in induced disaster events is greater than total vulnerability. On the other-hand for the Sarankhola and Bagerhat Sadar, the specific vulnerability due to average seasonal

change is greater than total vulnerability and the specific vulnerability due to average change in induced disaster events is lesser than total vulnerability. Also, interestingly, women from Sarankhola and Bagerhat Sadar perceived that they are more vulnerable to climate change associated gradual changes whereas in the case of Sayamnagor, women perceived that their vulnerability is greatly associated with climate change induced disasters. However, the difference in perception might also be linked to the geo-physical context of the study areas and security of livelihood generation option in the face of climate change.

Similar type of study have been performed by Nahian *et al.* (2013) for Satkhira and Khulna district. They found the vulnerability index as 2. 01 for Khulna district and 1.52 for Satkhira district. In comparison with this study, it can be concluded that the result of present study are compatible with the reported previous studies.

Table 4.5: Vulnerability Assessment Matrix for Water resource-Sarankhola

Total vulnerability (E x S) /A			2.03											
Specific vulnerability (E x S) /A			2.64							1.41				
Adaptive capacity	Overall adaptive capacity		1.5							1.25				
		Alternative use of water in human society	2	1	2	1	1	1		1	1	2	0	
		Coping mechanism in nature	2	1	2	2	1	2		2	2	2	0	
Sensitivity	Overall sensitivity		1.88							1.32				
	Effect on socio-economic regime	Fishing	3	1	2	2	1	2		3	0	1	0	
		Shrimp culture	3	3	2	3	1	2		3	3	3	1	
		Navigation	2	0	0	1	0	0		1	0	0	0	
		Cultivation	3	2	3	3	3	2		3	2	3	1	
		Standard of living	2	2	1	3	2	2		3	2	3	2	
		Impact on domestic water use	3	2	2	1	1	1		2	0	2	0	
		Impact on drinking water supply	3	3	3	2	2	1		3	1	2	0	
	Effect on bio-physical regime	Impact on water dependent ecosystem	3	2	2	1	2	2		2	0	1	0	
		Impact on water quality	2	1	2	2	2	1		3	1	3	0	
		Impact on in stream water demand	3	0	3	1	2	2		0	0	0	0	
		Impact on water recharge	3	0	3	1	2	2		0	1	3	0	
Exposure	Overall exposure		2.11							1.33				
		Salinity intrusion	3	1	2	2	3	2		3	2	3	2	
		Change in water availability	3	2	2	2	2	2		2	0	3	0	
		Change in rainfall pattern	2	0	3	3	2	2		1	0	0	0	
Context			Long duration summer	Increased temperature in summer	Short duration monsoon	Monsoon with heavier rainfall	No/less rainfall in pre/post monsoon	Erratic rainfall	Average seasonal change	Increase in cyclone storm surge frequency-intensity	Increase in tidal surge height	Water logging	River erosion	Average extreme events

(Score: 0=no impact; 1=less impact; 2=moderate impact; 3= severe impact)

Table 4.6: Vulnerability Assessment Matrix for Water resource- Herinnagor, Sayamnagor , Satkhira

Total vulnerability (E x S) /A			2.21												
Specific vulnerability (E x S) /A			2.20							2.23					
Adaptive capacity	Overall adaptive capacity		1.83							1.13					
		Alternative use of water in human society	3	2	2	1	1	3		1	1	1	0		
		Coping mechanism in nature	2	1	2	2	1	2		2	2	1	1		
Sensitivity	Overall sensitivity		1.91							1.43					
	Effect on socio-economic regime	Fishing	3	1	2	2	1	2		3	0	1	0		
		Shrimp culture	3	3	2	3	1	2		3	3	3	1		
		Navigation	2	0	2	2	0	0		2	0	0	0		
		Cultivation	3	2	3	3	3	2		3	2	3	2		
		Standard of living	2	2	1	3	2	2		3	2	3	2		
		Impact on domestic water use	3	2	2	1	1	1		2	0	2	0		
		Impact on drinking water supply	3	2	3	2	2	1		3	1	3	0		
	Effect on bio-physical regime	Impact on water dependent ecosystem	3	2	2	1	2	2		2	0	1	1		
		Impact on water quality	2	1	2	2	2	1		3	1	3	1		
		Impact on in stream water demand	3	0	3	1	2	2		0	0	0	0		
		Impact on water recharge	3	0	3	1	2	2		0	1	3	0		
Exposure	Overall exposure		2.11							1.75					
		Salinity intrusion	3	1	2	2	3	2		3	3	3	3		
		Change in water availability	3	2	2	2	2	2		3	2	2	0		
		Change in rainfall pattern	2	0	3	3	2	2		2	0	0	0		
Context			Long duration summer	Increased temperature in summer	Short duration monsoon	Monsoon with heavier rainfall	No/less rainfall in pre/post monsoon	Erratic rainfall	Average seasonal change	Increase in cyclone storm surge frequency-intensity	Increase in tidal surge height	Water logging	River erosion	Average extreme events	

(Score: 0=no impact; 1=less impact; 2=moderate impact; 3= severe impact)

Table 4.7: Vulnerability Assessment Matrix for Water resource- Dash Ani, Bagerhat Sadar, Bagerhat

Total vulnerability (E x S) /A			1.04												
Specific vulnerability (E x S) /A			1.71							0.36					
Adaptive capacity	Overall adaptive capacity		0.67							0.88					
		Alternative use of water in human society	1	0	0	1	0	0		1	0	1	0		
		Coping mechanism in nature	1	2	1	2	0	0		2	1	2	0		
Sensitivity	Overall sensitivity		0.89							0.75					
	Effect on socio-economic regime	Fishing	0	0	0	0	0	0		3	0	0	0		
		Shrimp culture	2	2	1	0	0	1		1	2	2	0		
		Navigation	2	0	0	2	0	0		2	0	0	0		
		Cultivation	2	1	2	2	1	1		1	0	2	0		
		Standard of living	3	3	2	3	2	2		2	1	3	0		
		Impact on domestic water use	1	0	1	0	0	0		1	1	1	0		
		Impact on drinking water supply	1	1	0	0	0	0		1	0	0	0		
	Effect on bio-physical regime	Impact on water dependent ecosystem	3	2	1	0	1	1		0	0	2	0		
		Impact on water quality	1	2	1	1	1	1		1	2	2	0		
		Impact on in stream water demand	1	0	0	1	0	0		0	0	2	0		
		Impact on water recharge	1	0	1	1	1	0		0	0	1	0		
Exposure	Overall exposure		1.28							0.42					
		Salinity intrusion	1	0	2	2	0	1		0	0	2	0		
		Change in water availability	1	0	1	1	1	1		1	0	0	0		
		Change in rainfall pattern	2	0	3	3	2	2		2	0	0	0		
Context			Long duration summer	Increased temperature in summer	Short duration monsoon	Monsoon with heavier rainfall	No/less rainfall in pre/post monsoon	Erratic rainfall	Average seasonal change	Increase in cyclone storm surge frequency-intensity	Increase in tidal surge height	Water logging	River erosion	Average extreme events	

(Score: 0=no impact; 1=less impact; 2=moderate impact; 3= severe impact)

CHAPTER V

People's Perception to Hazards and Local Coping Methods

5.1 General

Results were prepared based on the survey conducted at Laksmikhali village of Morrelganj upazila, Golbunia village of Mongla upazila, and Uttar Rajapur village of Sarankhola upazila, Dash Ani of Bagerhat Sadar upazila, Nalian villalge of Dacope upazila, Bhagba village of Koira upazila, Rajapur village of Rupsa upazila, Baintala village of Assasunni upazila and Herinnagor village of Sayamnagor upazilas which are cyclone affected areas in Bangladesh. The people in these areas are bound to face cyclone almost every year. Since the shelter, food, water supply, sanitation and health issues are the most sensitive and crucial during cyclone, this study concentrates on these issues only. In this chapter focus has been given to the extent and types of impacts of cyclone of these crucial issues and people's coping method to minimize the adverse impact.

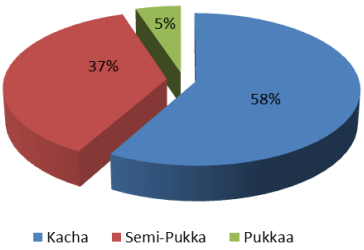
5.2 Case Study of Bagerhat District

5.2.1 Socio-Demographic Profile

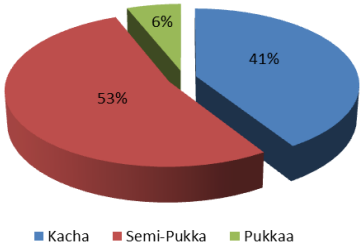
Bagerhat is located in the south east side of Bagerhat in Bangladesh. It is one of the most vulnerable areas to natural hazard. Almost every year various disasters hit on this area. Table 5.1 shows the socio-economic conditions of Lakshmikhali village of Morrelganj Upazila, Golbunia village of Mongla Upazila, Uttar Rajaur village of Sarankhola Upazila, and Dash Ani of Bagerhat Sadar upazilas under studied. Generally socio-economic condition consists of different parameters such as age group, gender distribution, education, housing condition, toilet condition, occupation, income level per month etc. This research reveals that about 18% households of Morrelganj, about 11% households of Mongla and 14% households of Sarankhola have income within Tk. 5000 per month, which is below the poverty line whereas only 2% households of Bagerhat Sadar have the same level of income. The overwhelming majority of them live in temporary housing systems that are in a poor condition and they also use unsanitary hanging latrines. Figure 5.1 shows that 58% of the total houses in Morrelganj, 40% in Mongla and 41% in Sarankhola are temporary structures (made of bamboo, wood and mud). Such kind of housing are the most vulnerable to the natural hazards.

Table 5.1: Socio-economic condition of the households selected for the questionnaire survey Bagerhat district

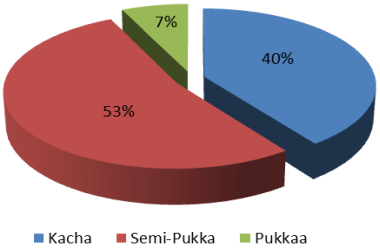
Socio-economic parameters	Population (%) Morrelganj	Population (%) Mongla	Population (%) Sarankhola	Population (%) Bagerhat Sadar
Age group				
Below 15 year	31.15	39.37	39.50	38.00
15-60 years	59.85	54.63	55.04	53.39
Above 60 years	9.00	7.00	5.46	9.00
Gender distribution				
Male	51.7	48.3	48.9	50.6
Female	48.3	51.7	51.1	49.4
Education				
Illiterate	36.5	27.9	47.1	28.6
Literate	63.5	72.1	52.9	71.4
Housing condition				
Kacha	58	41	40	0
Semi-Pukka	37	53	53	31
Pukka	5	6	7	69
Toilet condition				
Sanitary latrine	74	78	84	86
Pit latrine	19	20	12	14
Hanging latrine	7	2	4	0
Occupation				
Business	24	47	23	37
Service holder	12	7	11	32
Farmer	55	18	53	10
Day labor	7	25	12	2
Others	2	3	1	19
Income level per month				
2000-5000	18	11	14	2
5000-10000	49	50	44	37
Above 10000	33	39	42	61



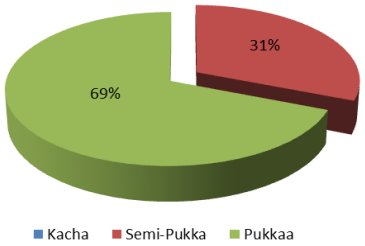
Existing housing pattern in Morrelganj



Existing housing pattern in Mongla



Existing housing pattern in Sarankhola



Existing housing pattern in Bagerhat Sadar

Figure 5.1: Existing housing pattern in Bagerhat district

5.2.2 People's Perception Regarding Hazard and Vulnerability

Unlike the environmentalists and researchers, the coastal community of Morrelganj, Mongla, Sarankhola and Bagerhat Sadar has built a strong perception about the hazard types and dealing with these hazards is an everyday occurrence. During field investigations, people were asked what the common hazard in their community were, the type of changes they have noticed over the decades, and what factors are playing a role in their vulnerabilities. Table 5.2 shows their perceptions related to the change in hazard intensity and people's vulnerability in terms of frequency and intensity of hazards and vulnerability to hazards along with considering socio-economic factors responsible for vulnerability. Regarding the trend of coastal hazards in Sarankhola, almost (more than 90%) all people perceived that both the intensity of hazards and vulnerabilities of the people have increased considerably over the last few decades, where more than 80% people of Morrelganj and Mongla as well as more than 60% people of Bagerhat Sadar perceived that both the intensity of hazards and vulnerabilities of the people have increased considerably over the last few decades. Increasing cost of living and increasing rate of population density are found to be most responsible socio-economic factor for increasing vulnerability. In addition to this, people also perceived that decreasing income, increasing population density, decreasing crop yield and scarcity of job opportunities are similarly responsible for vulnerabilities. It is found that almost all people in Bagerhat perceived that increasing cost of living and increasing population density also responsible for vulnerability. Interestingly people of Mongla reported that crops yield decreasing is the most vulnerable Socio-economic factor that responsible for vulnerability increase while Morrelganj, Sarankhola and Bagerhat Sadar people perceived increasing cost of living is most responsible for increasing vulnerability.

Table 5.2: Perceptions related to the change in hazard intensity and people's vulnerability in Bagerhat district.

Perceptions related to the change in hazard intensity	People's perception in Morrelganj	People's perception in Mongla	People's perception in Sarankhola	People's perception in Bagerhat Sadar
Perception about frequency and intensity of hazards:				
Increasing	83	86	97	63
Decreasing	17	14	3	37
Perception about vulnerability to hazards:				
Increasing	87	88	92	67
Decreasing	13	12	8	33
Socio-economic factors responsible for vulnerability increase:				
Decreasing income	49	54	51	29
Increasing cost of living	86	85	78	89
Increasing population density	69	60	62	69
Crops yield decreasing	56	86	65	38
Scarcity of job opportunity	43	48	57	57

Different parts of coastal areas face different types of hazards, though the common types of hazards are shown in Figure 5.2. Almost all (100%) the inhabitants of Morrelganj, Mongla and Sarankhola perceived that the most prevalent coastal hazard is cyclone, while the people of Bagerhat Sadar perceived that the most prevalent coastal hazard is Flood rather than Cyclone. Flood is the second prevalent hazard in Morrelganj, Mongla and Sarankhola; and Tidal Surge is the third prevalent hazard. Among others, the tidal surge is the considerable natural hazards in Mongla and Sarankhola and drought are also the considerable natural hazards in Morrelganj. Riverbank erosion hazard is found to be zero in Bagerhat Sadar i.e. there is no effect of Riverbank erosion in Bagerhat Sadar upazila, according to the people' perception.

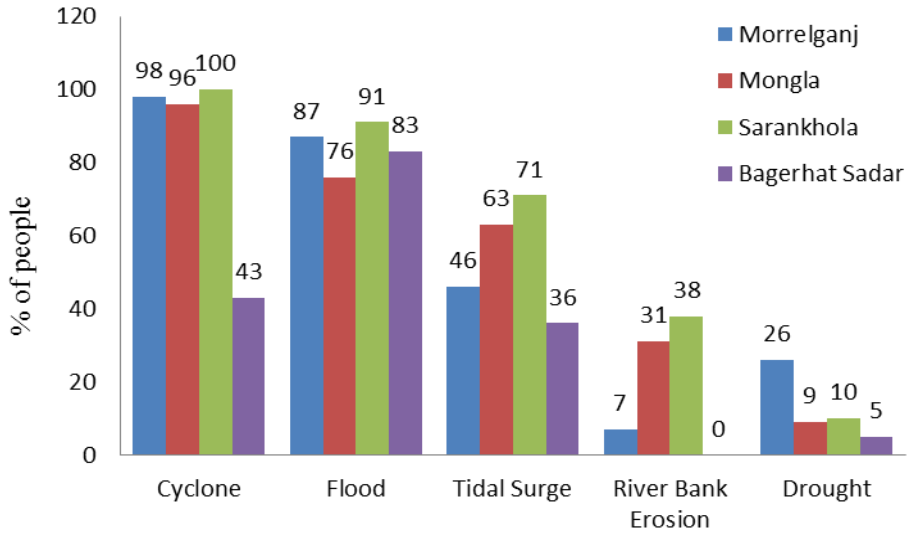


Figure 5.2: People's perceptions of the most prevalent coastal hazards in Bagerhat district

5.2.3 Shelter-Related Coping Methods

The coastal community in Bagerhat undertakes various coping methods using their abilities, resources and knowledge. For different hazards people adopt different coping methods to protect themselves and their belongings (Table 5.3). For instance, for different natural hazards approximately about half of people can't go to cyclone shelter because of large distance from their house. So most of people have to stay in their own house applying their indigenous knowledge or go to their relative's house or neighbor's house.

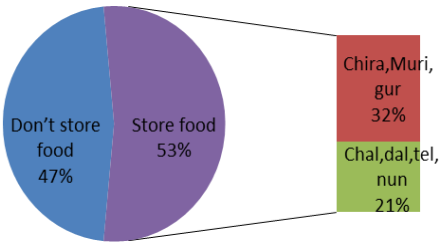
Regarding coping methods, more than half of the people (51%) in Morrelganj, 48% and 44% people in Mongla and Sarankhola people take shelter at cyclone centers. In Bagerhat Sadar upazila it is found that there is no person who takes shelter in at cyclone shelter. Again investigation reveals that more than one third of the people in Morrelganj, Mongla and Sarankhola upazilas adopt their self-supporting indigenous knowledge while the majority of people (93%) in Bagerhat Sadar adopt Self-support indigenous knowledge to adopt in hazards. In addition to these coping techniques, people are also taking shelter on neighbor's house to protect themselves from the hazards. On the other hand, more than half of the inhabitants of Morrelganj, Mongla and Sarankhola live in house that made of mud, straw bamboo and wood as well as Kacha house and a few proportion of people (5%) live in pukka house whereas most of the people (69%) in Bagerhat Sadar live in pukka house. After any hazard, if needed, they repair or rebuilt their houses themselves with available local materials without spending much money.

Table 5.3: Shelter-related coping methods for different coastal hazards in Bagerhat district

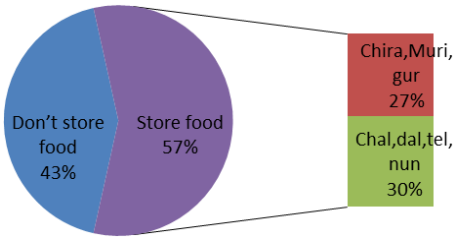
Coping methods	People's perception in Morrelganj	People's perception in Mongla	People's perception in Sarankhola	People's perception in Bagerhat Sadar
Self-support using indigenous knowledge	38	36	37	93
Taking emergency shelter on relative's or neighbor's land	8	11	10	7
Taking shelter at a cyclone shelter	51	48	44	0
Others	3	5	9	0

5.2.4 Food Crisis during Flood and Coping Methods

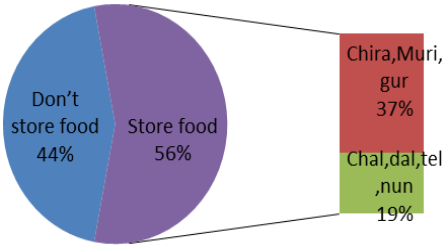
Foods are the basic needs and it becomes scarce during every cyclone, flood, tidal surge or any other disasters and large amount of households have to suffer for lack of adequate food due to failure of income source. During natural hazard expenses for food also increase. Therefore, it deteriorates food consumption, especially for rural poor both in quality and quantity and eventually leads them to the malnutrition and health problem. Field investigation revealed that during natural hazard many people don't store food. Generally, the people in Morrelganj, Mongla and Sarankhola store dry food such as *chira*, *muri*, *gur(molasses)* and chal(rice), dal(pulse), tel(oil), nun(salt). In the study it is found that more than 50% households in Morrelganj, Mongla and Sarankhola stored some dry food before hazards off which more than 30% *chira-muri-gur and about 20% chal-dal-tel- nun* (Figure 5.3) in Morrelganj and Sarankhola. It is found that the people in Mongla and Bagerhat Sadar store more *chal-dal-tel- nun compared to chira-muri-gur (molasses).* The households that are not able to store food before hazard, they had to follow different adaptation mechanism including buying food on credit or cash from adjacent shop at higher price, borrowing from adjacent neighbors or relatives to face food crisis. Sometimes the people reduce their food consumption in order to survive against food shortage.



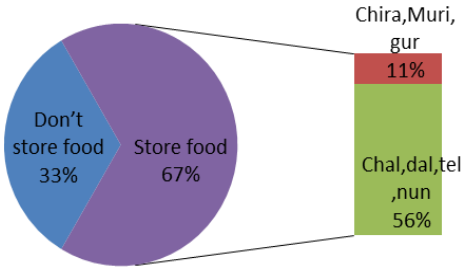
Distributions of households according to storage of food in Morrelganj



Distributions of households according to storage of food in Mongla



Distributions of households according to storage of food in Sarankhola

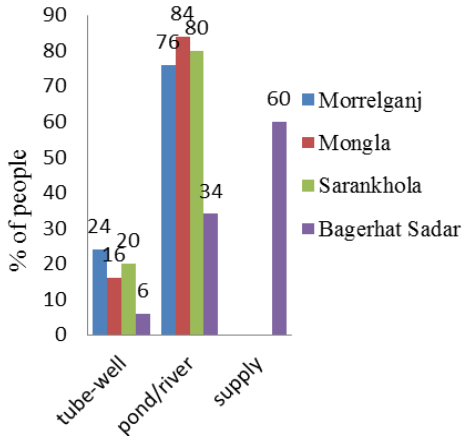


Distributions of households according to storage of food in Bagerhat Sadar

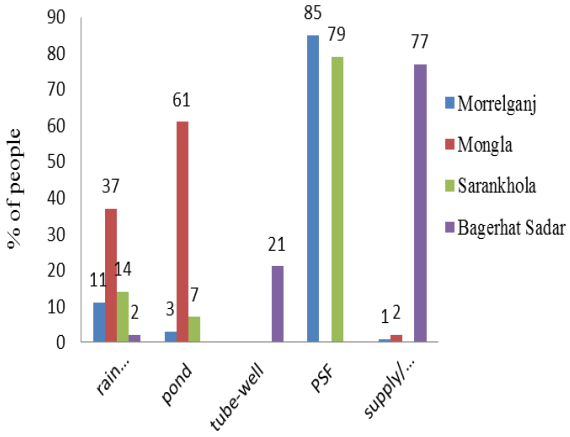
Figure 5.3: Distributions of households according to storage of food

5.2.5 Impact and Coping Method Related to Water Supply During Natural Hazard

In the period of various natural hazards (cyclone, flood, tidal surge etc.), most of the tube-well and other safe water sources become submerged; as a result, safe water become scarce. The scarcity of pure water becomes very acute , specially in the rural area. The water sources in the rural are contaminated by the various ways including human excreata, rubbish and contaminated soil mix with water and pollutes both surface and ground water. Investigation reveas that most of the people in Morrelgonj area use pond as source of water for drinking and daily activities. The main source of water for daily activities is pond/river in Morrelganj, Mongla and Sarankhola whereas supply water is the main source for Bagerhat Sadar people. The mjority people of the Mongla use pond water and rain water for drinking purposes whereas PSF is the main source of drinking water Morrelganj and Sarankhola. Some poeple of Bagerhat Sadar also use tube-well along with supply/buy water for drinking purpose. Figure 5.4 shows that most of the poeple (84%) depend on pond or river water, 20% poeple of Sarankhola depend on tube-well and 60% poeple of Bagerhat Sadar depend on supply water for their daily activities. On the other hand, 61% poeple of Mongla use pond water, 85% poeple of Morrelganj and 79% poeple of of Sarankhola use PSF for drinking water whereas 60% poeple of Bagerhat Sadar use supply water or buy water for drinking purpose.



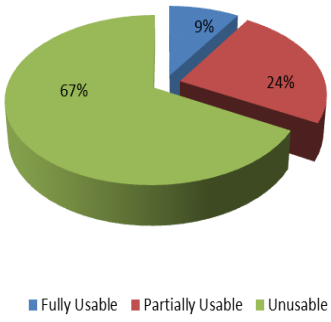
Water use for daily activities



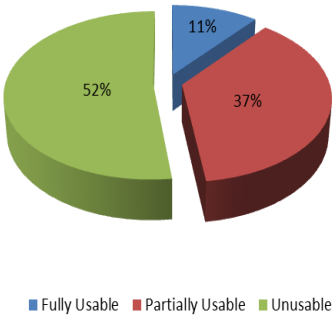
Water consumption for drinking purposes

Figure 5.4: Percentage of usage of source of water for daily activities and drinking purposes

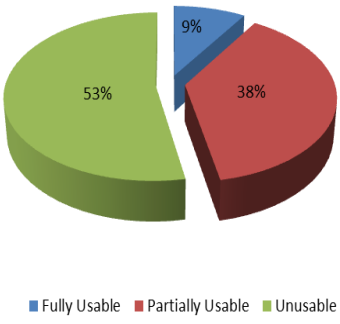
As mentioned earlier, in the consequences of natural hazards most of the water sources become unusable due to contamination or disruption of access to safe water sources. The percentage of usability of these water sources during and after hazards are represented in Figure 5.5. With respect to the usability of water sources of 100% before natural hazards, the percentage of fully usable water sources during and after natural hazards in Morrelganj, Mongla, Sarankhola and Bagerhat Sadar are 9%,11%,9% and 91% resectively and more than two-third (67%) of the water sources in Morrelganj and more than half (52% and 53%) of the water sources in Mongla and Sarankhola respectively water sources become unusable and a small fraction is partially usable.



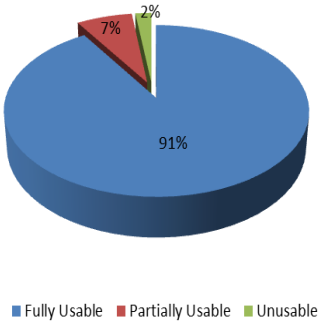
(a) Morrelganj



(b) Mongla



(c) Sarankhola



(d) Bagerhat Sadar

Figure 5.5: Distribution of household according to the usability of water sources

Generally, in natural hazards, the people adopt different ways for drinking or daily activities due to the unusable condition of the previous water source. Storing pure water before hazards or disaster and the use of water purification by Fitkari are the common practices among the people in hazards areas. People can't boil water for decontamination due to shortage of dry cooking places as well as of fuel and very few people adopt water boiling (Table 5.4) to decontaminate the water. It is found that most of the Bagerhat Sadar people (90%) store pure water in hazards while 75% people of Morrelganj and 73% people of Sarankhola purify water by the use of Fitkari in natural hazards.

Table 5.4: Different sources of water during natural hazard

Water supply related coping method during hazard	People's perception in Morrelganj	People's perception in Mongla	People's perception in Sarankhola	People's perception in Bagerhat Sadar
Store pure water before hazards	2	26	9	90
Use water purification (Fitkari)	75	65	73	7
Water boiling	2	3	2	0
Need to travel long distance	29	6	26	3

5.2.6 Impact and Coping Methods Regarding Sanitation

Regarding the trend of practicing sanitation, a large number of the people in Morrelganj, Mongla and Sarankhola (26%, 22% and 16% respectively) used unhygienic latrine. The distribution of people according to the usage of different type of toilet is represented in Figure 6.6. It is found that about 74% people of Morrelganj, 78% people of Mongla, 84% 78% people of Sarankhola and 86% 78% people of Bagerhat Sadar generally use sanitary latrine. It is also found that a small amount of people uses hanging latrine while people of Bagerhat Sadar don't use hanging latrine.

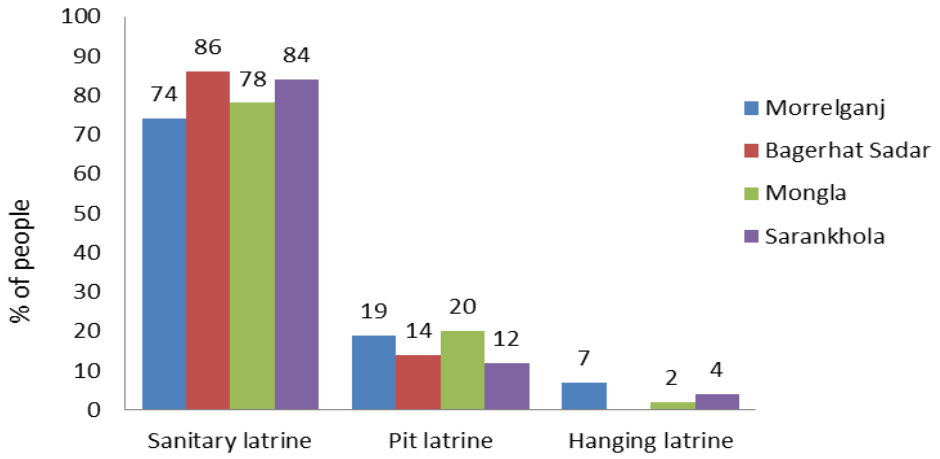
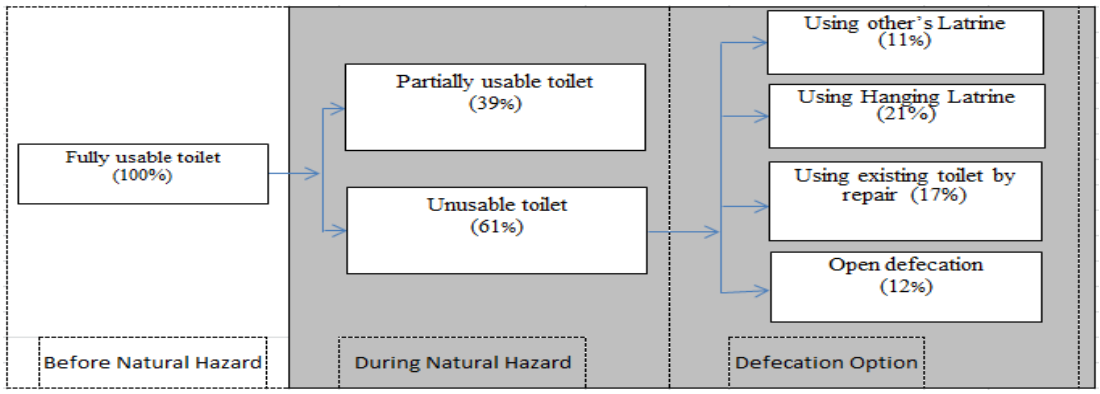
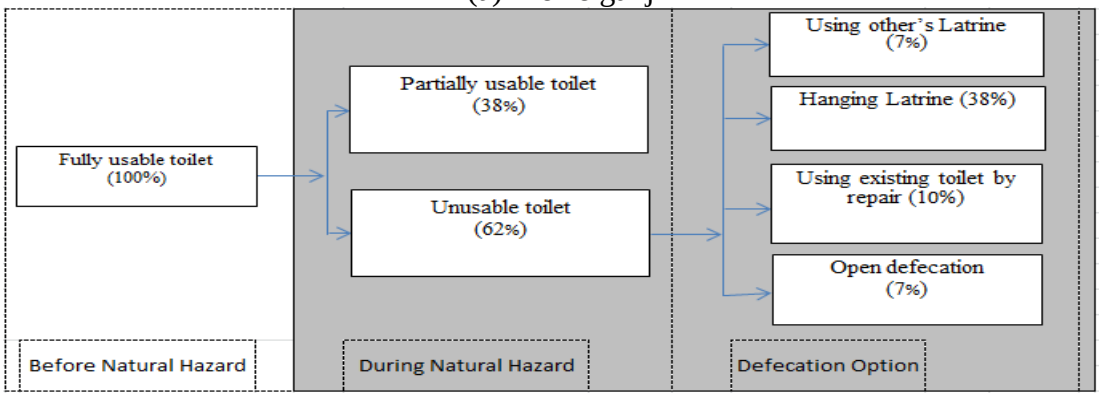


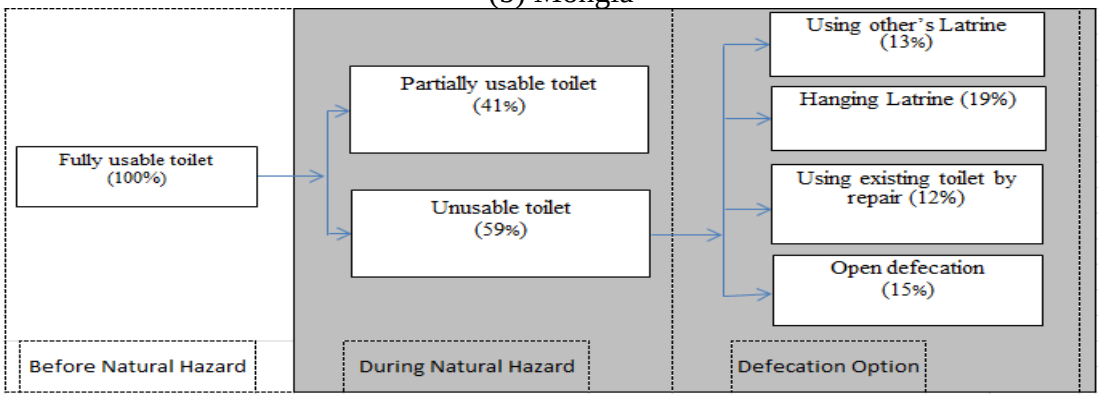
Figure 5.6: Distributions of people according to the usage of different type of toilet



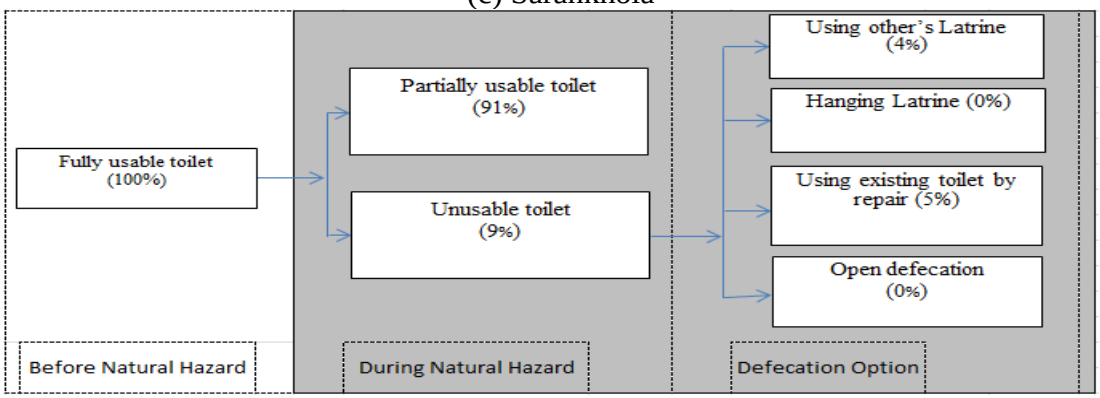
(a) Morrelganj



(b) Mongla



(c) Sarankhola



(d) Bagerhat Sadar

Figure 5.7 Defecation practice before and during natural disaster

From the field investigation, it can be observed that, maximum toilets become unusable in hazards of Morrelganj, Mongla and Sarankhola. It was found that about two-third of the total toilets; 61% in Morrelganj, 62% in Mongla and 59% in Sarankhola become unusable during natural hazards and only 39% toilets in Morrelganj, 38% toilets in Mongla and 41% toilets in Sarankhola are usable while Majority toilets (91%) in Bagerhat Sadar is partially usable and only 9% toilets are unusable in natural hazards (Figure 5.7).

In that consequences large number of people defecated directly to water. During hazards about 12% people of Morrelganj, 7% people of Mongla and 15% people of Bageraht Sadar practiced defecation openly using boats or floats while there is no open defecation in Bagerhat Sadar upazila. It is also found that about 21% people of Morrelganj, 38% people of Mongla and 19% people of Sarankhola build temporary hanging latrines which are connected to water bodies while people of Bagerhat Sadar do not build temporary hanging latrines. Besides, 17% people of Morrelganj, 10% people of Mongla, 12% people of Sarankhola amd 5% people of Bagerhat Sadar use thier own toilet by reparing and rest of the people shared neighbours' or relatives latrine.

5.2.7 Impact on Health and Coping Method

Due to various natural hazards the people, especially in the rural areas become affected by different diseases. Among those diseases the water borne diseases such as diarrhea, dysentery, jaundice, cold and cough and skin diseases are very common in Morrelganj, Mongla, Sarankhola and Bagerhat Sadar. It is found from the investigation that the people from 66% households of Morrelganj, people from 73% households of Mongla, people from 86% households of Sarankhola and people from 39% households of Bagerhat Sadar were affected by diarrhea whereas people from 58% households of Morrelganj, people from 67% households of Mongla, people from 73% households of Sarankhola and people from 16% households of Bagerhat Sadar were affected by dysentery. Besides, a large number of people suffered from skin diseases along with jaundice and cold and cough as shown in Figure 5.8.

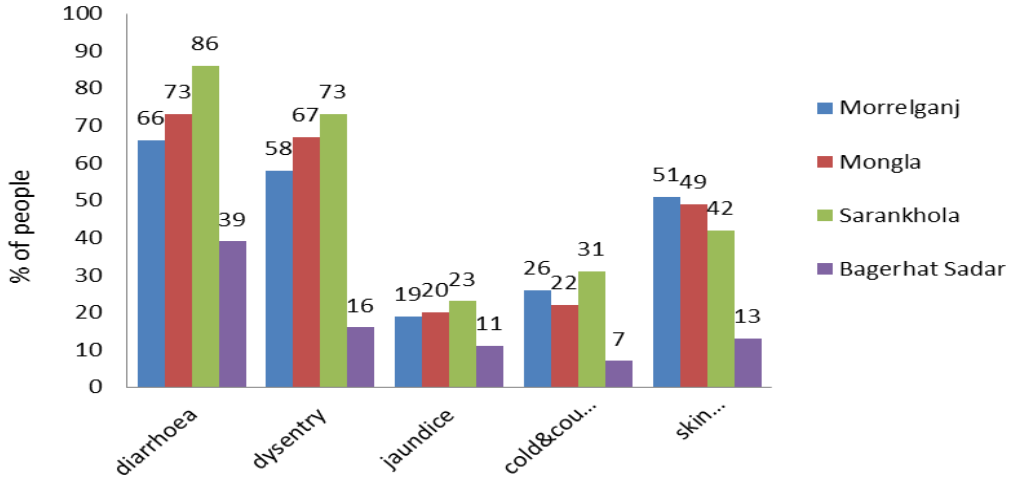
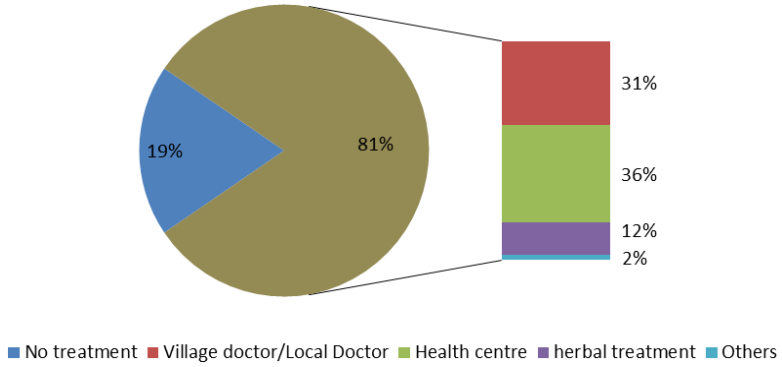
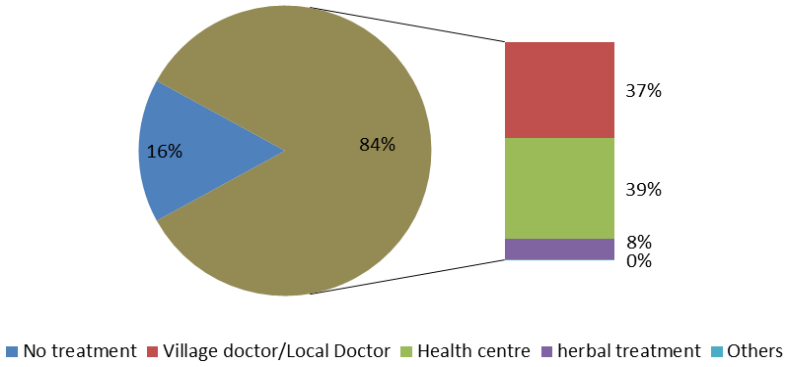


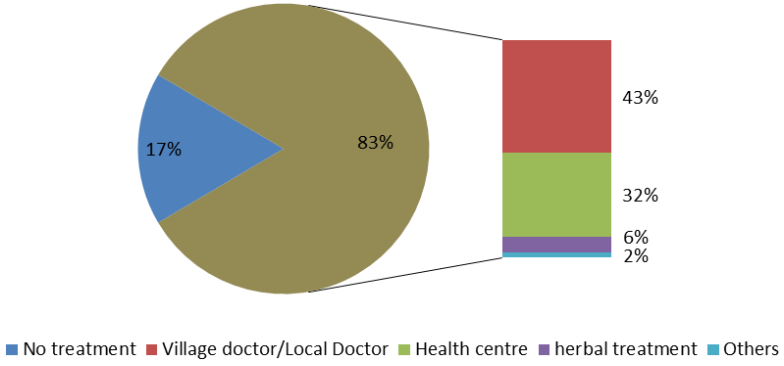
Figure 5.8: Comparisons among diseases according to affected household



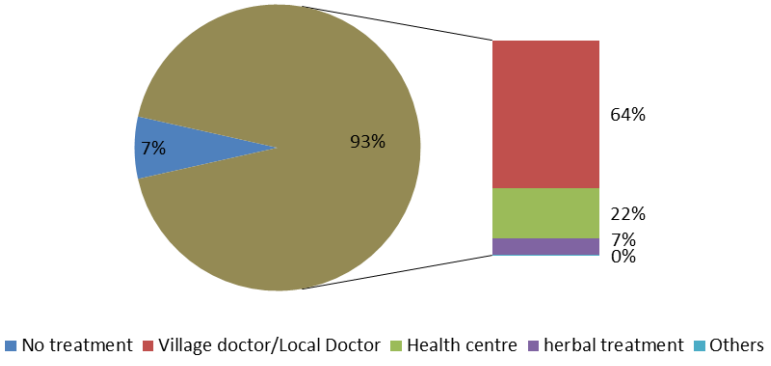
(a)Morrelganj



(b) Mongla



Sarankhola



Bagerhat Sadar

Figure 5.9: Distribution of household according to treatment

Though overwhelming majority suffered from different health problems. It is found that many of the people; suffered from diseases did not take any treatment. Those who took treatment, used to go to mostly village doctor because they could avail this easily during natural hazard or to health center. Besides some people took treatments form health center and herbal treatment. From the Figure 5.9, it is appeared that 19% people of Morrelganj, 16% people of Mongla, 17% people of Sarankhola and 7% people of Bagerhat Sadar did not take any type of treatment in suffering from diseases. In Morrelganj, 81% people take treatment from village doctor (31%), health Centre (36%), and herbal treatment (12%) whereas in Mongla, 84% people take treatment from village doctor (37%), health Centre (39%), and herbal treatment (8%). Similarly, in Mongla, 43% people take treatment from village doctor, 32% people take treatment form health Centre and 6% people take herbal treatment whereas in Bagerhat Sadar, 94% people take treatment from local doctor (64%), health Centre (22%) and 7% people take herbal treatment.

Before starting of natural hazard taking preventive measure for health problem is not common among rural people. Few of those who are a bit aware and careful about health try to store some simple medicines for first aid. Figure 5.10 shows the percent amount of people according to stocking of emergency medicine. Figure illustrates that about 6% of household of Morrelganj, 17% households of Mongla, 7% households of Sarankhola and 19% households of Bagerhat Sadar stock emergency medicine before natural hazard and majority of people do not stock emergency medicine.

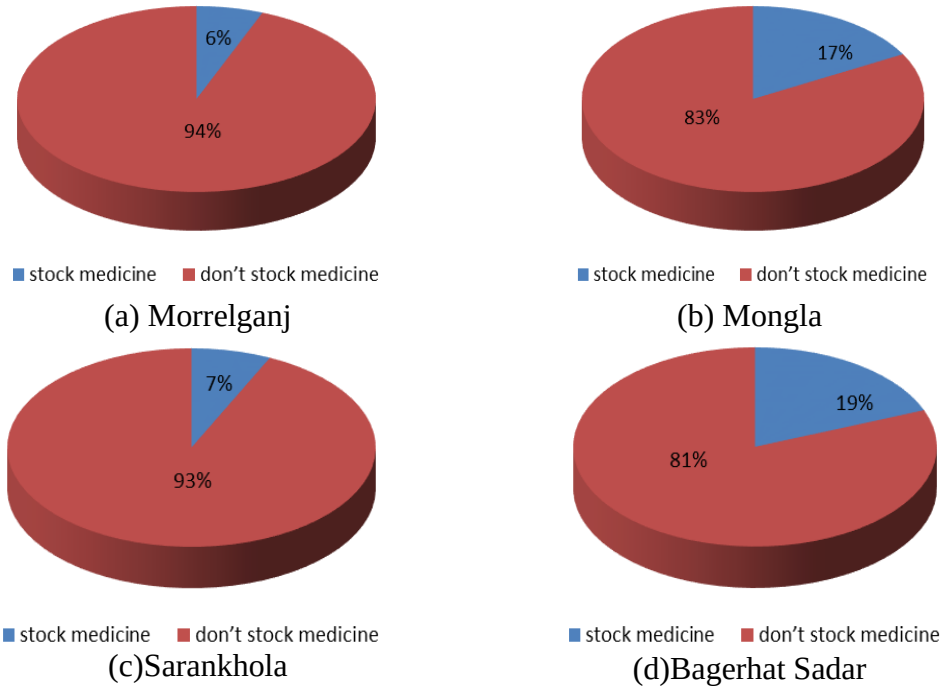


Figure 5.10: Distributions of households according to stocking of emergency medicine

5.3 Case Study of Khulna District

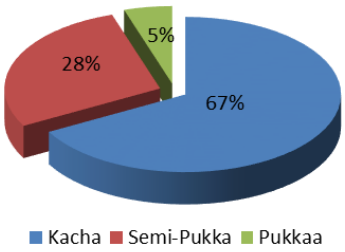
5.3.1 Socio-Demographic Profile

Khulna is located in the south west side of Bangladesh. It is one of the most vulnerable areas to natural hazard. Almost every year various disasters hit on this area. Table 5.5 shows the socio-economic conditions of Nalian village of Dacope upazila, Bhagba village of Koira upazila and Rajapur village of Rupsa upazila under studied. Generally socio-economic condition consists of different parameters such as age group, gender distribution, education, housing condition, toilet condition, occupation, income level per month etc. This research reveals that about 54% households of Dacope, about 17% households of Koira and 5% households of Rupsa have income within Tk. 5000 per month, which is below the poverty line whereas only 2% households of Bagerhat Sadar have the same level of income.

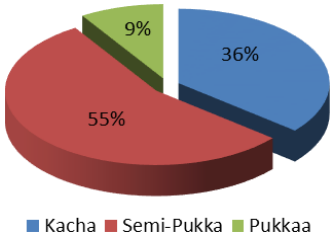
Table 5.5: Socio-economic condition of the households selected for the questionnaire survey Khulna district

Socio-economic parameters	Population (%) Dacope	Population (%) Koira	Population (%) Rupsa
Age group			
Below 15 year	46.94	42.30	34.98
15-60 years	49.06	51.70	57.22
Above 60 years	5.00	7.00	9.00
Gender distribution			
Male	50.62	50.47	50.4
Female	49.38	49.53	49.6
Education			
Illiterate	61.8	51.5	20.2
Literate	38.2	48.2	79.8
Housing condition			
Kacha	67	36	0
Semi-pukka	28	55	26
Pukka	5	9	74
Toilet condition			
Sanitary latrine	56	70	91
Pit latrine	39	18	9
Hanging latrine	5	12	0
Occupation			
Business	19	27	32
Service holder	7	10	42
Farmer	36	34	7
Day labor	27	26	3
Others	11	3	16
Income level per month			
2000-5000	54	17	5
5000-10000	27	47	32
Above 10000	19	36	63

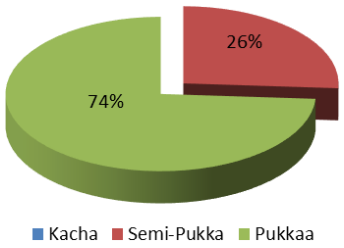
The majority people of Dacope and Koira live in temporary housing systems that are in a poor condition and they also use unsanitary hanging latrines. From the Figure 5.11, it is found that 67% of the total houses in Dacope and 36% of the total houses in Koira are temporary structures (made of bamboo, wood and mud). Such kind of houses are the most vulnerable to the natural hazards. It is also found that there is no kacha housing in Rupsa Upazila under study and more than two third of total houses are of pukka.



Existing housing pattern in Dacope



Existing housing pattern in Koira



Existing housing pattern in Rupsa

Figure 5.11: Existing housing pattern in Khulna district

5.3.2 People's Perception Regarding Hazard and Vulnerability

Unlike the environmentalists and researchers, the coastal community has built a strong perception about the hazard types and dealing with these hazards is an everyday occurrence. During field investigations, people were asked what the common hazard in their community were, the type of changes they have noticed over the decades, and what factors are playing a role in their vulnerabilities. Table 5.6 shows their perceptions related to the change in hazard intensity and people's vulnerability in terms of frequency and intensity of hazards and vulnerability to hazards along with considering socio-economic factors responsible for vulnerability.

Regarding the trend of coastal hazards in Dacope and Koira almost (more than 80%) all people perceived that both the intensity of hazards and vulnerabilities of the people have increased considerably over the last few decades, while more than 50% people of Rupsa perceived that both the intensity of hazards and vulnerabilities of the people have increased considerably over the last few decades. Increasing cost of living and increasing rate of population density are found to be most responsible socio-economic factor for increasing vulnerability. It is found that, more than 80% people of Dacope, Koira and Rupsa perceived that increasing cost of living and more than70% people perceived increasing population density responsible for vulnerability. In addition to this, people also perceived that decreasing income,

increasing population density, decreasing crop yield and scarcity of job opportunities are similarly responsible for vulnerabilities.

Table 5.6: Perceptions related to the change in hazard intensity and people's vulnerability in Khulna district

Perceptions related to the change in hazard intensity	People's perception in Dacope	People's perception in Koira	People's perception in Rupsa
Perception about frequency and intensity of hazards:			
Increasing	89	79	56
Decreasing	11	21	44
Perception about vulnerability to hazards:			
Increasing	84	83	60
Decreasing	16	17	40
Socio-economic factors responsible for vulnerability increase:			
Decreasing income	62	60	27
Increasing cost of living	81	80	92
Increasing population density	62	76	76
Crops yield decreasing	53	66	42
Scarcity of job opportunity	49	42	63

Different parts of coastal areas face different types of hazards, though the common types of hazards are shown in Figure 5.12. Almost all (100%) the inhabitants of Dacope and Koira perceived that the most prevalent coastal hazard is cyclone while the people of Rupsa perceived that the most prevalent coastal hazard is Flood rather than Cyclone. Flood is the second prevalent hazard in Dacope and Koira. Among others, the tidal surge is the considerable natural hazards in Dacope, Koira and Rupsa. It is also found that 67% people of Dacope perceived; riverbank erosion is one of the major hazards along with Cyclone, Flood and Tidal Surge.

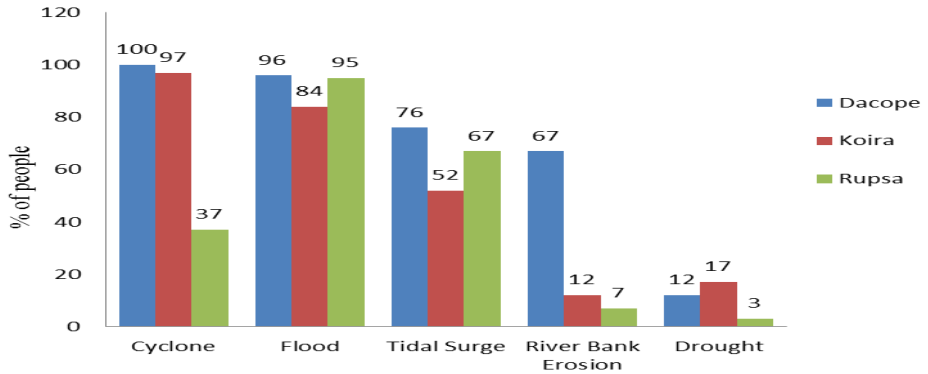


Figure 5.12: People's perceptions of the most prevalent coastal hazards in Khulna district

5.3.3 Shelter-Related Coping Methods

The coastal community in Bagerhat undertakes various coping methods using their abilities, resources and knowledge. For different hazards people adopt different coping methods to protect themselves and their belongings (Table 5.7). For instance, for different natural hazards approximately about half of people can't go to cyclone shelter because of large distance from their house. So most of people have to stay in their own house applying their indigenous knowledge or go to their relative's house or neighbor's house.

Regarding coping methods, approximately half of the people (49%) in in Dacope and 44% people in Koira take shelter at cyclone centers while taking shelter at cyclone shelter is found zero in Rupsa upazila. Again investigation reveals that most of the people (96%) in Rupsa upazilas adopt their self-supporting indigenous knowledge while only 28% of people in Dacope and 33% of people in Koira adopt Self-support indigenous knowledge to adopt in various hazards. In addition to these coping techniques, people are also taking shelter on neighbor's house to protect themselves from the hazards.

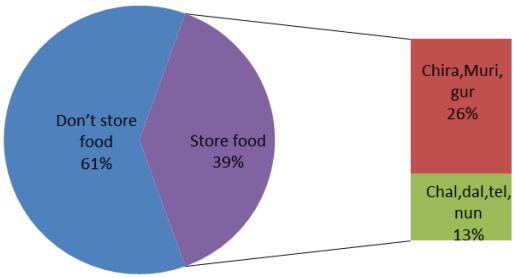
Table 5.7: Shelter-related coping methods for different coastal hazards in Khulna district

Coping methods	People's perception in Dacope	People's perception in Koira	People's perception in Rupsa
Self-support using indigenous knowledge	28	33	96
Taking emergency shelter on relative's or neighbor's land	16	18	4
Taking shelter at a cyclone shelter	49	44	0
Others	7	5	0

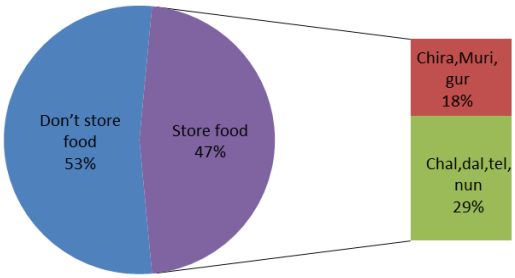
5.3.4 Food Crisis during Flood and Coping Methods

Foods are the basic needs and it becomes scarce during every cyclone, flood, tidal surge or any other disasters and large amount of households have to suffer for lack of adequate food due to failure of income source. During natural hazard expenses for food also increase. Therefore, it deteriorates food consumption, especially for rural poor both in quality and quantity and eventually leads them to the malnutrition and health problem. Field investigation revealed that during natural hazard many people don't store food. Generally, the people of Dacope, Koira and Rupsa store dry food such as *chira, muri, gur(molasses)* and chal(rice), dal(pulse), tel(oil), nun(salt). In the study it is found that 39% households of Dacope and 47% households of Koira stored some dry food before hazards off which 26% *chira-muri-gur and* about 13%

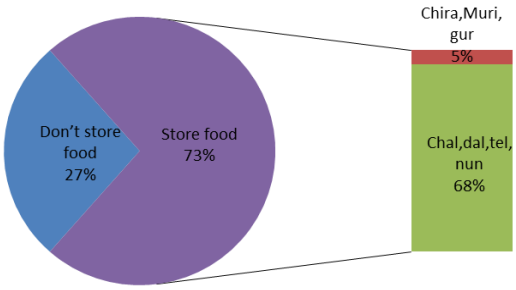
chal-dal-tel- nun (Figure 5.13) and 18% *chira-muri-gur* and about *29% chal-dal-tel- nun* respectively in Dacope and Koira. It is found that the households of Rupsa store more food (73%) in hazards compared to Dacope and Koira households. It is also found that the households of Rupsa store more *chal-dal-tel- nun* (68%) compared to Dacope and Koira.



(a) Distributions of households according to storage of food in Dacope



(b) Distributions of households according to storage of food in Koira



(c) Distributions of households according to storage of food in Rupsa

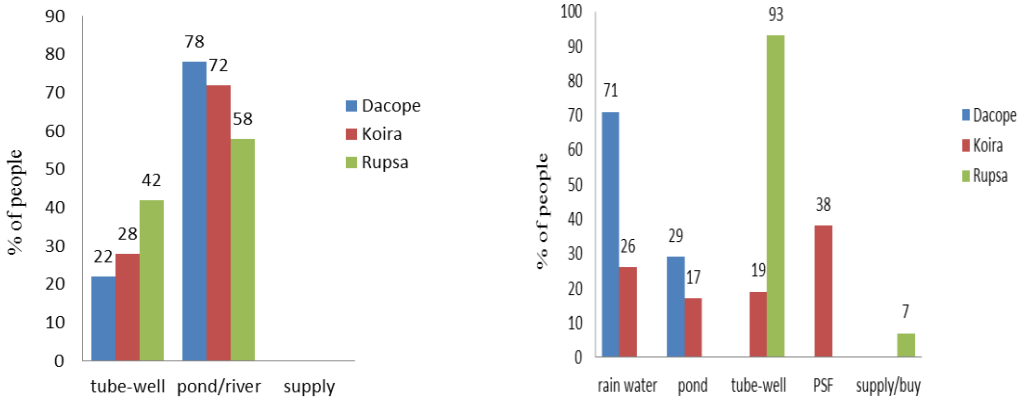
Figure 5.13: Distributions of households according to storage of food

The households that are not able to store food before hazard, they had to follow different adaptation mechanism including buying food on credit or cash from adjacent shop at higher price, borrowing from adjacent neighbors or relatives to face food crisis. Sometimes the people reduce their food consumption in order to survive against food shortage.

5.3.5 Impact and Coping Method Related to Water Supply During Natural Hazard

During the period of various natural hazards (cyclone, flood, tidal surge etc.), most of the tube-well and other safe water sources become submerged; as a result, safe water become scarce. The scarcity of pure water becomes very acute , specially in the rural area. The water sources in the rural are contaminated by the various ways including human excreata, rubbish and contaminated soil mix with water and pollutes both surface and ground water. Investigation reveas that most of the people in Morrelgonj area use pond as source of water for drinking and daily activities. The main source of water for daily activities is pond/river along with tube-well in Dacope, Koira and Rupsa. The mjority people of the Rupsa use tube-well water for drinking purposes whereas rain water and pond water is the only source of drinking water for Dacope people. Some poeple of Koira also use PSF along with pond and rain water for drinking purpose. Figure 5.14 shows that 78% poeple of Dacope,

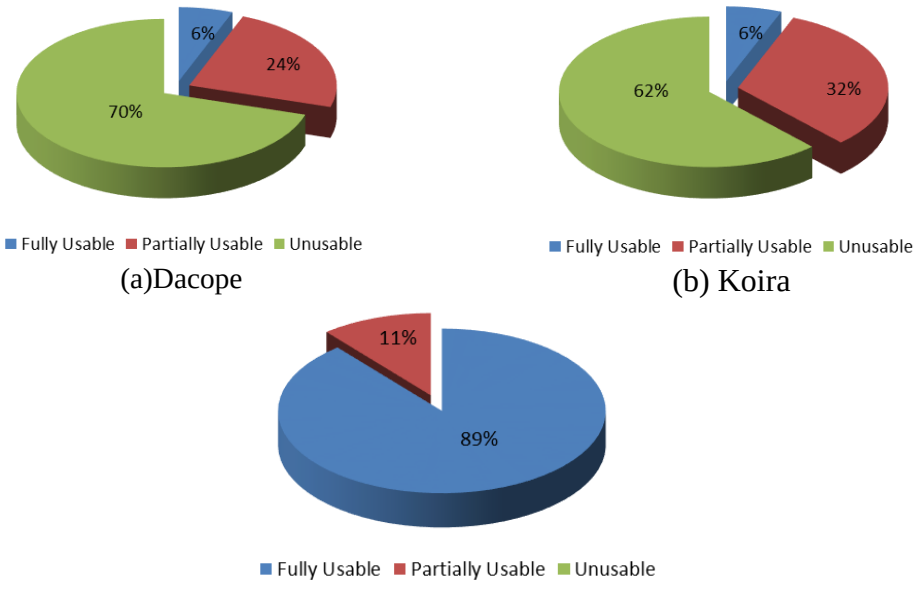
72% people of Koira and 58% people of Rupsa generally use pond water for their daily activities. It is also found that 22% people of Dacope, 28% people of Koira and 42% people of Rupsa use tube-well water along with Pond water.



Water use for daily activities Water consumption for drinking purposes

Figure 5.14: Percentage of usage of source of water for daily activities and drinking purposes

As mentioned earlier, in the consequences of natural hazards most of the water sources become unusable due to contamination or disruption of access to safe water sources. The percentage of usability of these water sources during and after hazards are represented in Figure 5.15. With respect to the usability of water sources of 100% before natural hazards, the percentage of fully usable water sources during and after natural hazards in Dacope, Koira and Rupsa are 6%, 6% and 89% respectively and more than two-third (70%) of the water sources in Dacope and more than two third (62%) of the water sources in Koia become unusable. According to the report of the Rupsa households; 11% water sources become partially usable due to hazards.



(a)Dacope (b) Koira

(c) Rupsa

Figure 5.15: Distribution of household according to the usability of water source

Generally, in natural hazards, the people adopt different ways for drinking or daily activities due to the unusable condition of the previous water source. Storing pure water before hazards or disaster and the use of water purification by Fitkari are the common practices among the people in hazards areas. People can't boil water for decontamination due to presence of salinity in water along with shortage of dry cooking places as well as of fuel and few people need to travel long distance (Table 5.8) to fetch water in hazards. It is found that most of the Rupsa people (89%) store pure water in hazards while 43% people of Dacope and 17% people of Koira store pure water before hazards. It is also found that most of the people of Dacope and Koira (45% and 54% respectively) purify water by the use of Fitkari in natural hazards.

Table 5.8: Different sources of water during natural hazard

Water supply related coping method during hazard	People's perception in Dacope	People's perception in Koira	People's perception in Rupsa
Store pure water before hazards	43	17	89
Use water purification (Fitkari)	45	54	4
Water boiling	0	0	0
Need to travel long distance	18	38	7

5.3.6 Impact and Coping Methods Regarding Sanitation

Regarding the trend of practicing sanitation some number of the people of Dacope, Koira and Sarankhola (44%, 30% and 9% respectively) use unhygienic latrine. The distribution of people according to the usage of different type of toilet is represented in Figure 5.16. It is found that about 56% people of Dacope, 70% people of Koira and 91% people of Rupsa generally use sanitary latrine. It is also found that a small number of people use hanging latrine in Dacope and Koira while people of Rupsa don't use hanging latrine.

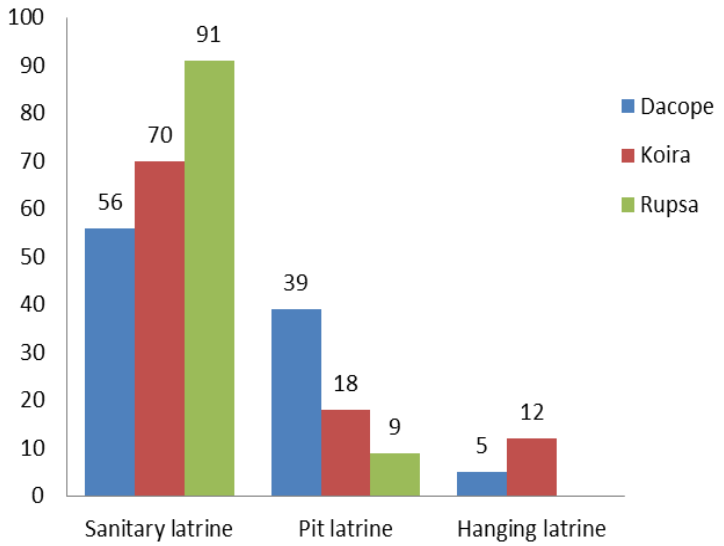
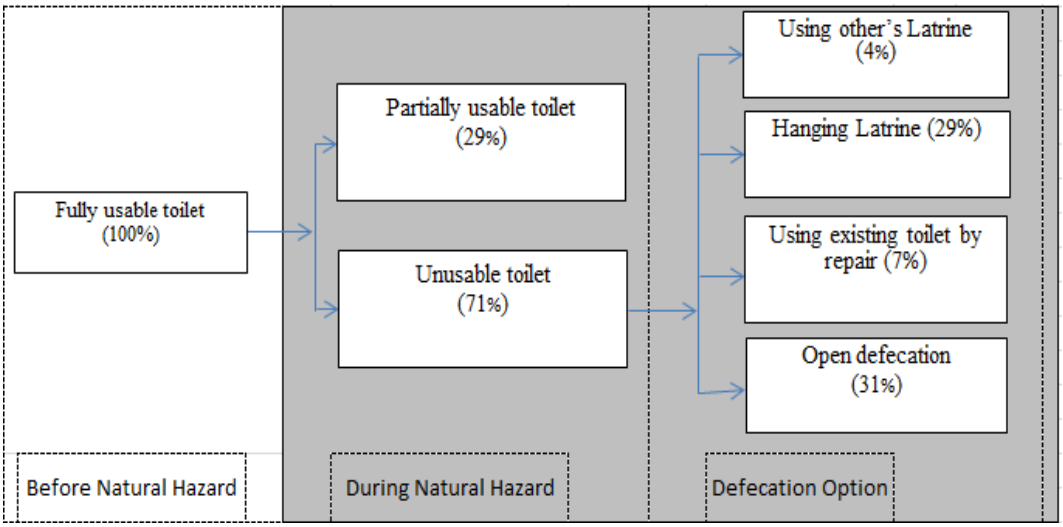
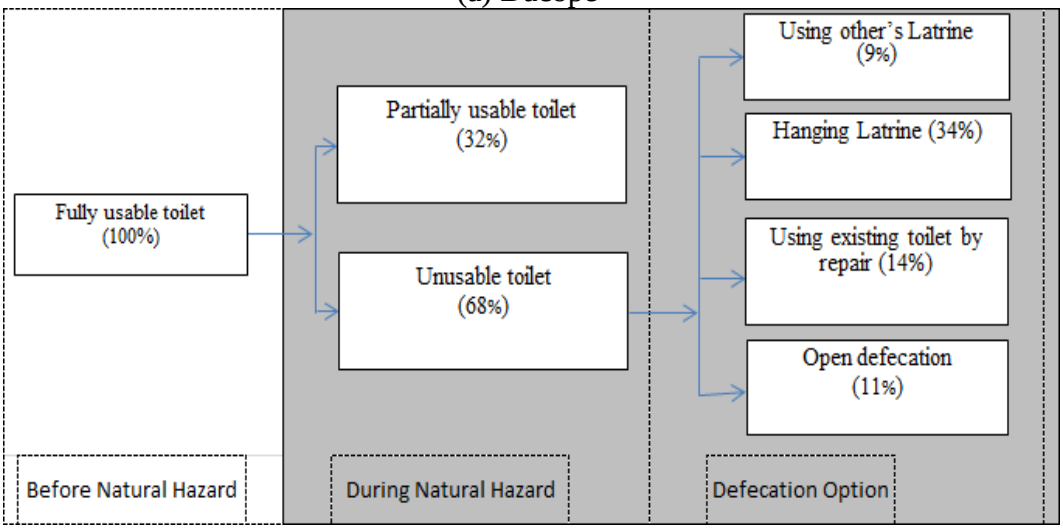


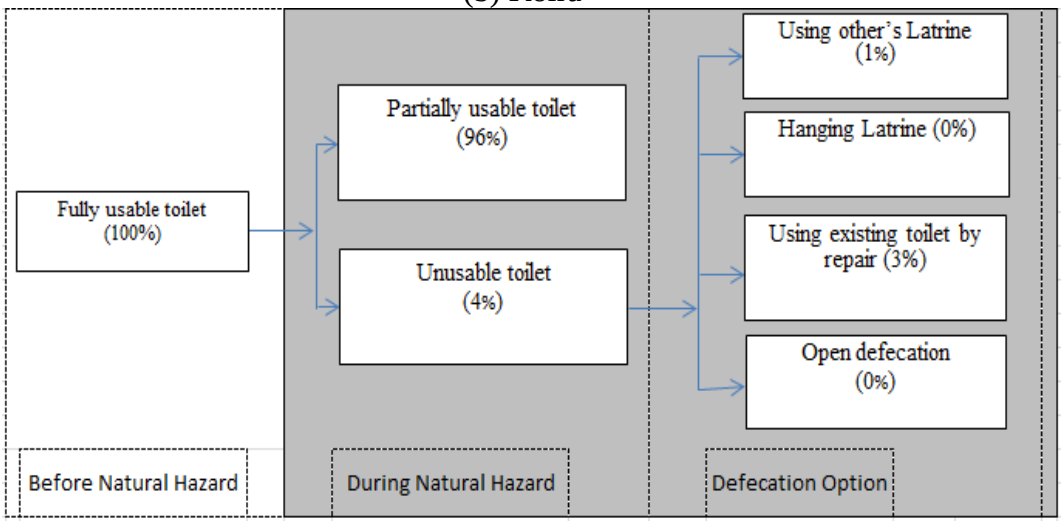
Figure 5.16: Distributions of people according to the usage of different type of toilet



(a) Dacope



(b) Koira



(c) Rupsa

Figure 5.17: Defecation practice before and during natural disaster

From the field investigation, it can be observed that, maximum toilets become unusable in hazards of Dacope and Koira while maximum toilets are usable condition in Rupsa.It is found that more than two-third of the total toilets; 71% in Dacope and 68% in Koira become unusable during natural hazards while in Rupsa only 4% toilets become unusable during natural hazards and 29% toilets in Dacope, 32% toilets in Koira and 96% toilets in Rupsa are usable (Figure 5.17). In this consequences large number of people defecated directly to water. During hazards about 31% people of Dacope and 11% people of Koira practiced defecation openly using boats or floats while there is no open defecation in Rupsa upazila. It is also found that about 29% people of Dacope and 34% people of Koira build temporary hanging latrines which are connected to water bodies while people of Bagerhat Sadar do not build temporary hanging latrines. Besides, 7% people of Dacope, 14% people of Koira and 3% people of Rupsa use thier own toilet by reparing and rest of the people shared neighbours' or relatives latrine those become usable.

5.3.7 Impact on Health and Coping Method

Due to various natural hazards the people, especially in the rural areas become affected by different diseases. Among those diseases the water borne diseases such as diarrhea, dysentery, jaundice, cold and cough and skin diseases are very common in Morrelganj, Mongla, Sarankhola and Bagerhat Sadar. It is found from the investigation that the people from 61% households of Dacope, people from 74% households of Koira and people from 28% households of Rupsa were affected by diarrhea whereas people from 59% households of Dacope, people from 56% households of Koira and people from 13% households of Rupsa were affected by dysentery. Besides, a large number of people suffered from skin diseases along with jaundice and cold and cough as shown in Figure 5.18.

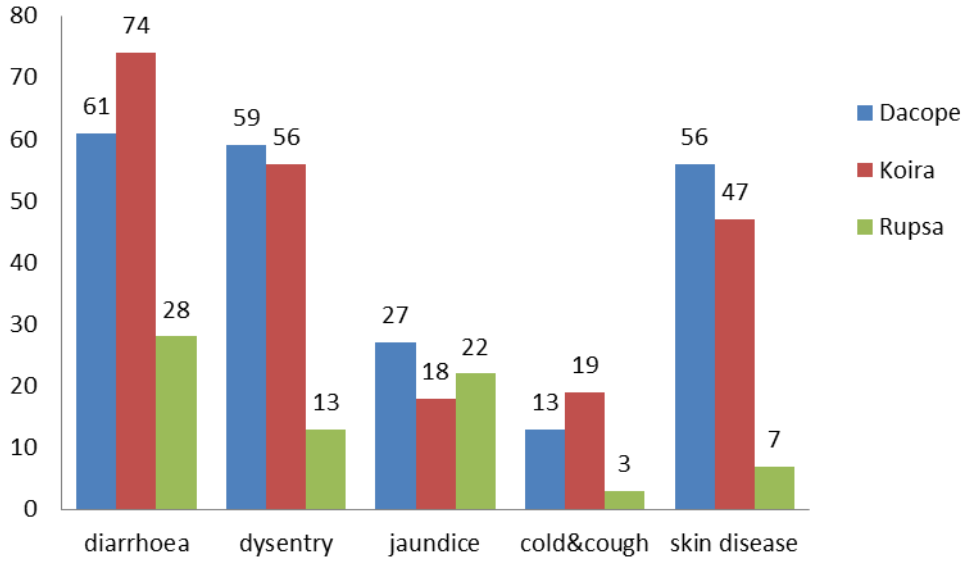
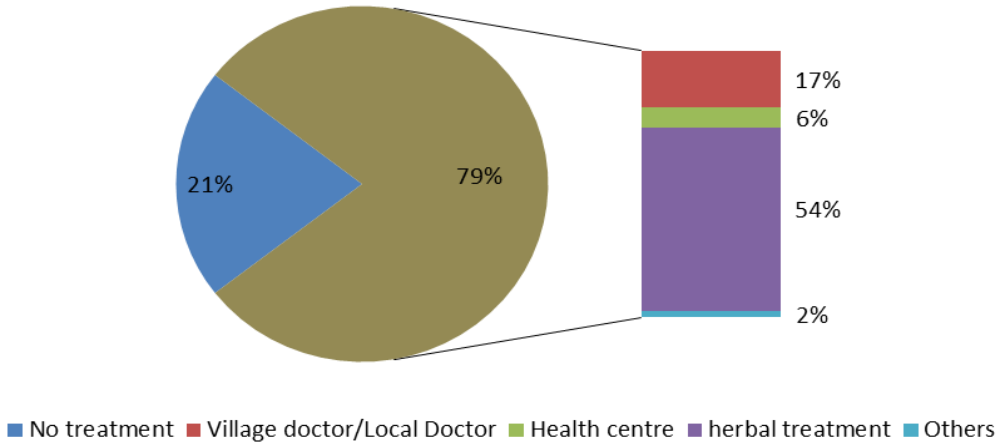
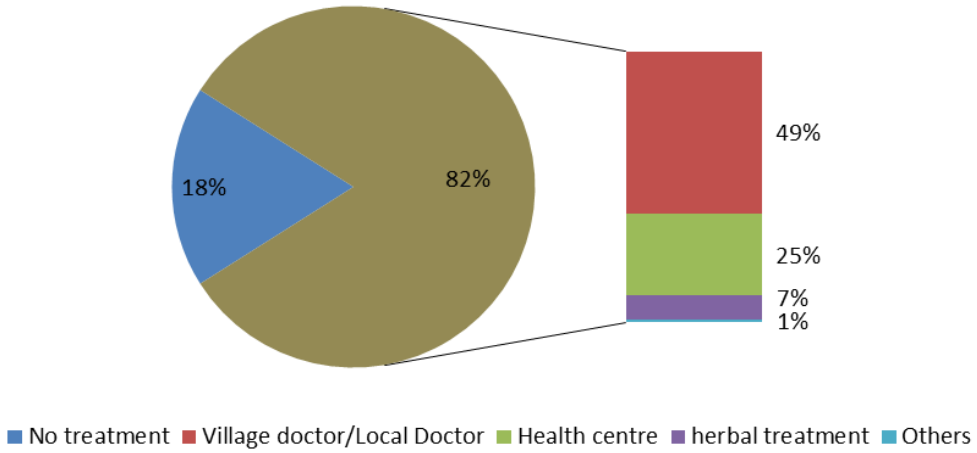


Figure 5.18: Comparisons among diseases according to affected household

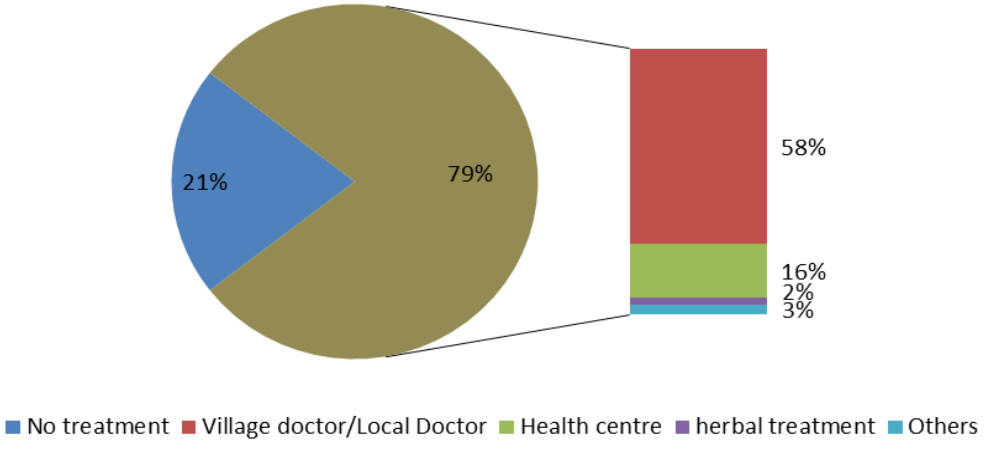
Though overwhelming majority suffered from different health problems it is found that many of the people; suffered from diseases did not take any treatment. Those who took treatment, used to go to mostly village doctor because they could avail this easily during natural hazard or to health center.



(a) Dacope



(b) Koira

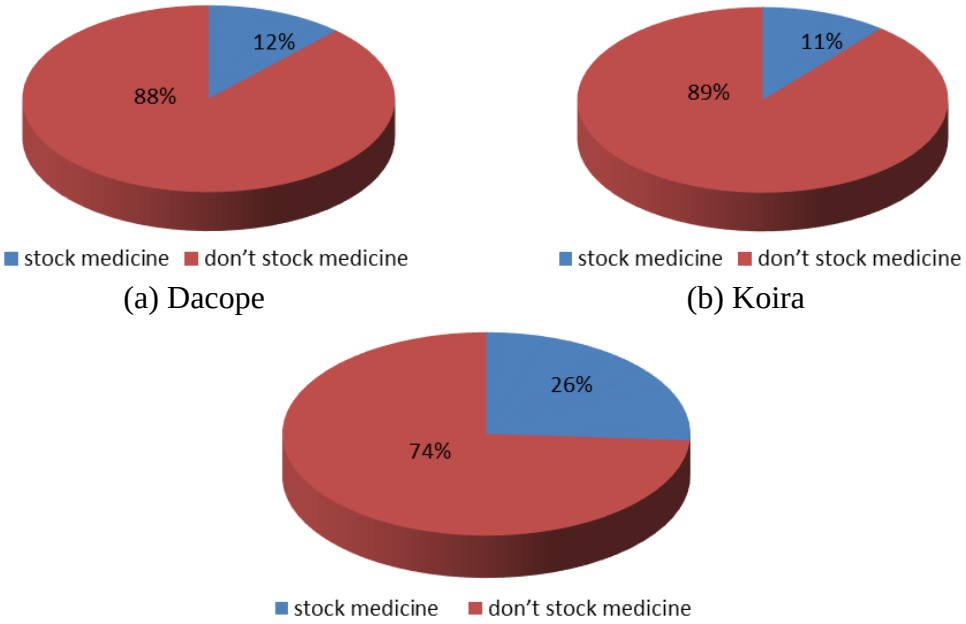


(c) Rupsa

Figure 5.19: Distribution of household according to treatment

Besides some people took treatments form health center and herbal treatment. From the Figure 5.19, it is appeared that 21% people of Dacope, 18% people of Koira and 5% people of Rupsa did not take any type of treatment in suffering diseases. In Dacope, 79% people take treatment from village doctor (17%), health Centre (6%), and herbal treatment (54%) whereas in Koira, 82% people take treatment from village doctor (49%), health Centre (25%), and herbal treatment (7%). Similarly, in Rupsa, 95% people take treatment in which 66% people take treatment from village doctor, 24% people take treatment form health Centre and 5% people take herbal treatment.

Before starting of natural hazard taking preventive measure for health problem is not common among rural people. Few of those who are a bit aware and careful about health try to store some simple medicines for first aid. Figure 5.20 shows the percent amount of people according to stocking of emergency medicine. Figure illustrates that about 12% of household of Dacope, 11% households of Koira and 26% households of Rupsa stock emergency medicine before natural hazard and majority of people do not stock emergency medicine.



(a) Dacope (b) Koira

(c) Rupsa

Figure 5.20: Distributions of households according to stocking of emergency medicine

5.4 Case Study of Satkhira

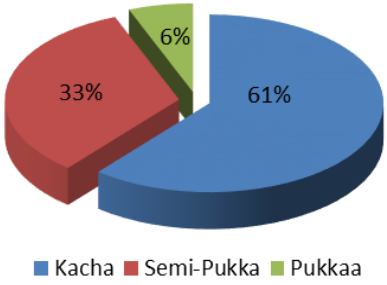
5.4.1 Socio-Demographic Profile

Satkhira is located in the south west side of Bangladesh. It is one of the most vulnerable areas to natural hazard. Almost every year various disasters hit on this area. Table 5.9 shows the socio-economic conditions of Herinnagor village of Sayamnagor and Baintala village of Assasunni Upazila under studied. Generally socio-economic condition consists of different parameters such as age group, gender distribution, education, housing condition, toilet condition, occupation, income level per month etc. This research reveals that about 47% households of Sayamnagor and 40% households of Assasunni have income within Tk. 5000 per month, which is below the poverty line whereas only 2% households of Bagerhat Sadar have the same level of income.

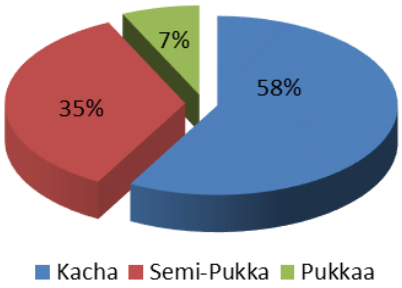
Table 5.9: Socio-economic condition of the households selected for the questionnaire survey in Satkhira district

Socio-economic parameters	Population (%) Sayamnagor	Population (%) Assasunni
Age group		
Below 15 year	43.32	41.00
15-60 years	58.68	51.00
Above 60 years	8.00	8.00
Gender distribution		
Male	48	50.4
Female	52	49.6
Education		
Illiterate	50.4	38.1
Literate	49.6	61.9
Housing condition		
Kacha	61	58
Semi-pukka	33	35
Pukka	6	7
Toilet condition		
Sanitary latrine	42	60
Pit latrine	45	31
Hanging latrine	13	9
Occupation		
Business	14	29
Service holder	9	9
Farmer	37	48
Day labor	33	13
Others	7	1
Income level per month		
2000-5000	47	40
5000-10000	37	48
Above 10000	16	12

The majority people of Sayamnagor and Assasunni live in temporary housing systems that are in a poor condition and they also use unsanitary hanging latrines. Figure 5.21 shows that that 33% houses in Sayamnagor and 35% houses in Assasunni are temporary structures (made of bamboo, wood and mud). Such kind of housing are the most vulnerable to the natural hazards.



Existing housing pattern in Sayamnagor



Existing housing pattern in Assasunni

Figure 5.21: Existing housing pattern in Satkhira district

5.4.2 People's Perception Regarding Hazard and Vulnerability

Unlike the environmentalists and researchers, the coastal community of Satkhira has built a strong perception about the hazard types and dealing with these hazards is an everyday occurrence. During field investigations, people were asked what the common hazard in their community were, the type of changes they have noticed over the decades, and what factors are playing a role in their vulnerabilities. Table 5.10 shows their perceptions related to the change in hazard intensity and people's vulnerability in terms of frequency and intensity of hazards and vulnerability to hazards along with considering socio-economic factors responsible for vulnerability. Regarding the trend of coastal hazards in Sayamnagor and Assasunni, almost (approximately 90%) all people perceived that the intensity of hazards and vulnerabilities of the people have increased considerably over the last few decades. Increasing cost of living and increasing rate of population density are found to be most responsible socio-economic factor for increasing vulnerability. It is found that, more than 70% people of Sayamnagor and Assasunni perceived that increasing cost of living is responsible for vulnerability while 68% people of Sayamnagor and 67% people of Assasunni perceived that increasing population density is responsible for vulnerability. In addition to this, people also perceived that decreasing income, increasing population density, decreasing crop yield and scarcity of job opportunities are similarly responsible for vulnerabilities.

Table 5.10: Perceptions related to the change in hazard intensity and people's vulnerability in Satkhira district.

Perceptions related to the change in hazard intensity	People's perception in Sayamnagor	People's perception in Assasunni
Perception about frequency and intensity of hazards:		
Increasing	93	91
Decreasing	7	9
Perception about vulnerability to hazards:		
Increasing	89	83
Decreasing	11	17
Socio-economic factors responsible for vulnerability increase:		
Decreasing income	53	56
Increasing cost of living	76	72
Increasing population density	68	67
Crops yield decreasing	67	65
Scarcity of job opportunity	46	49

Different parts of coastal areas face different types of hazards, though the common types of hazards are shown in Figure 5.22. All (100%) the inhabitants of Sayamnagor and 93% inhabitants of Assasunni perceived that the most prevalent coastal hazard is cyclone. Flood is the second prevalent hazard in Sayamnagor and Assasunni. Among others, the tidal surge is the considerable natural hazards in Sayamnagor and Assasunni along with Riverbank Erosion and Drought.

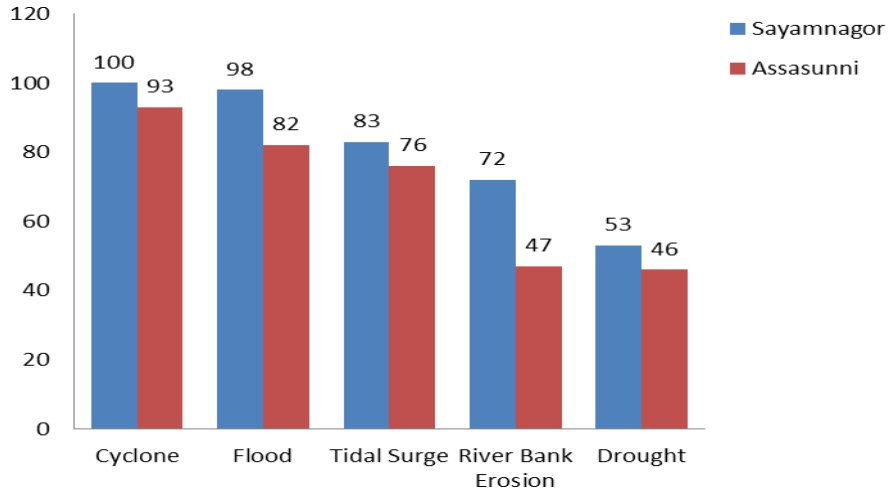


Figure 5.22: People's perceptions of the most prevalent coastal hazards in Satkhira district

5.4.3 Shelter-Related Coping Methods

Like many other coastal communities, Satkhira's population also undertakes various coping methods using their abilities, resources and knowledge. For different hazards people adopt different coping methods to protect themselves and their belongings (Table 5.11). For instance, for different natural hazards approximately about half of people can't go to cyclone shelter because of large distance from their house. So most of people have to stay in their own house applying their indigenous knowledge or go to their relative's house or neighbor's house.

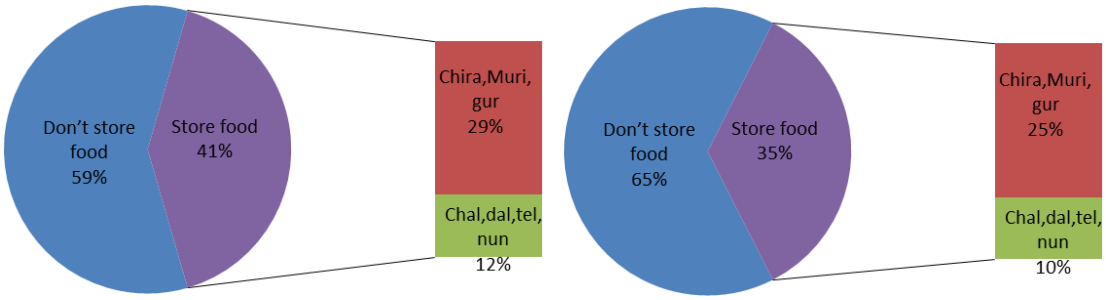
Regarding these coping methods, more than half of the people (57%) in in Sayamnagor and 45% people in Assasunni take shelter at cyclone centers. Again investigation reveals that most of the people (31%) of Sayamnagor upazilas adopt their self-supporting indigenous knowledge while 25% of people in Assasunni adopt Self-support indigenous knowledge to adopt in various hazards. In addition to these coping techniques, people are also taking shelter on neighbor's house to protect themselves from the hazards.

Table 5.11 Shelter-related coping methods for different coastal hazards in Satkhira district

Coping methods	% People's perception in Sayamnagor	% People's perception in Assasunni
Self-support using indigenous knowledge	31	25
Taking emergency shelter on relative's or neighbor's land	13	12
Taking shelter at a cyclone shelter	45	57
Others	11	6

5.4.4 Food Crisis during Flood and Coping Methods

Foods are the basic needs and it becomes scarce during every cyclone, flood, tidal surge or any other disasters and large amount of households have to suffer for lack of adequate food due to failure of income source. During natural hazard expenses for food also increase. Therefore, it deteriorates food consumption, especially for rural poor both in quality and quantity and eventually leads them to the malnutrition and health problem. Field investigation revealed that during natural hazard many people don't store food. Generally, the people of Sayamnagor and Assasunni store dry food such as *chira, muri, gur(molasses)* and chal(rice), dal(pulse), tel(oil), nun(salt). In the study it is found that 41% households of Sayamnagor and 35% households of Assasunni stored some dry food before hazards in which 29% *chira-muri-gur and about 12% chal-dal-tel- nun* (Figure 5.23) and 25% *chira-muri-gur and about 10% chal-dal-tel- nun* respectively in Sayamnagor and Assasunni.



Distributions of households according to storage of food in Sayamnagor

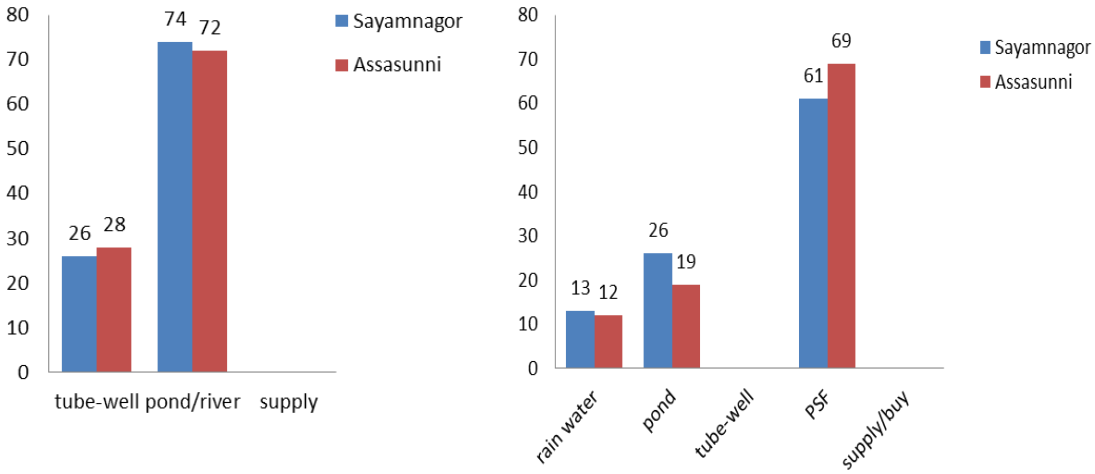
Distributions of households according to storage of food in Assasunni

Figure 5.23: Distributions of households according to storage of food

The households that are not able to store food before hazard, they had to follow different adaptation mechanism including buying food on credit or cash from adjacent shop at higher price, borrowing from adjacent neighbors or relatives to face food crisis. Sometimes the people reduce their food consumption in order to survive against food shortage.

5.4.5 Impact and Coping Method Related to Water Supply During Natural Hazard

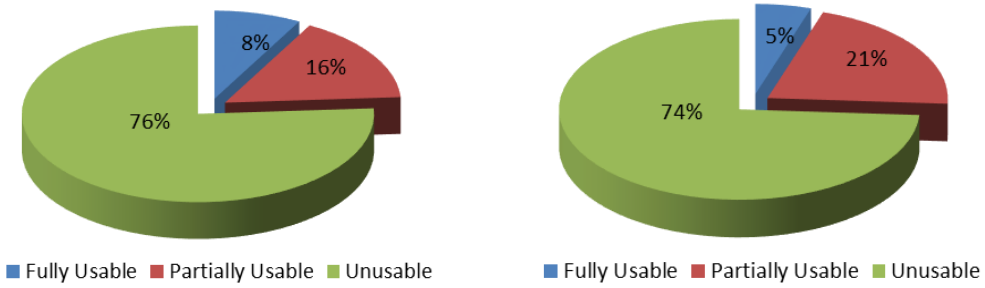
In the period of various natural hazards (cyclone, flood, tidal surge etc.), most of the tube-well and other safe water sources become submerged; as a result, safe water become scarce. The scarcity of pure water becomes very acute , specially in the rural area. The water sources in the rural are contaminated by the various ways including human excreata, rubbish and contaminated soil mix with water and pollutes both surface and ground water. Investigation reveas that the main source of water for daily activities is pond/river along with tube-well in Sayamnagor and Assasunni. The most of the people of Sayamnagor and Assasunni use PSF water for drinking purposes whereas only few people use rain water and pond water for drinking purpose. Figure 5.24 shows that74% poeple of Sayamnagor and 72% people of Assasunni generally use pond water for their daily activities whereas 26% poeple of Sayamnagor and 28% poeple of Assasunni use tube-well water for their daily activities. It is also found that 61% people of Sayamnagor and 69% people of Assasunni PSF water for drinking along with Pond and rain water.



Water use for daily activities Water consumption for drinking purposes

Figure 5.24: Percentage of usage of source of water for daily activities and drinking purposes

As mentioned earlier, in the consequences of natural hazards most of the water sources become unusable due to contamination or disruption of access to safe water sources. The percentage of usability of these water sources during and after hazards are represented bellow (Figure 5.25). With respect to the usability of water sources of 100% before natural hazards, the percentage of fully usable, partially usable and unusable water sources during and after natural hazards are 8%, 16% and 76% respetively in Sayamnagor whereas the percentage of fully usable, partially usable and unusable water sources during and after natural hazards are 5%, 21% and 74% respetively in Assasunni.



(a) Sayamnagor (b) Assasunni

Figure 5.25: Distribution of household according to the usability of water source during natural hazard

Generally, in natural hazards, the people adopt different ways for drinking or daily activities due to the unusable condition of the previous water source. Storing pure water before hazards or disaster and the use of water purification by Fitkari are the common practices among the people in hazards areas. People can't boil water for decontamination due to presence of salinity in water and shortage of dry cooking places. Some people need to travel long distance (Table 5.12) to fetch water in hazards. It is found that some people of Sayamnagor and Assasunni (18% and 13% respectively) store pure water in hazards. It is also found that most of the people of

Sayamnagor and Assasunni (59% and 69% respectively) purify water by the use of Fitkari in natural hazards and 23% people of Sayamnagor need to travel long distance while 17% people of Assasunni need to travel long distance for water.

Table 5.12: Different sources of water during natural hazard

Water supply related coping method during hazard	Percentage of people (%) in Sayamnagor	Percentage of people (%) in Assasunni
Store pure water before hazards	18	13
Use water purification (Fitkari)	59	69
Water boiling	0	1
Need to travel long distance	31	24

5.4.6 Impact and Coping Methods Regarding Sanitation

Regarding the trend of practicing sanitation, it is found that 58% people of Sayamnagor and 40% people of Assasunni use unhygienic latrine. The distribution of people according to the usage of different type of toilet is represented in Figure 5.26. It is also found that about 42% people of Sayamnagor and 60% people of Assasunni generally use sanitary latrine while a small number of people use hanging latrine in the both areas.

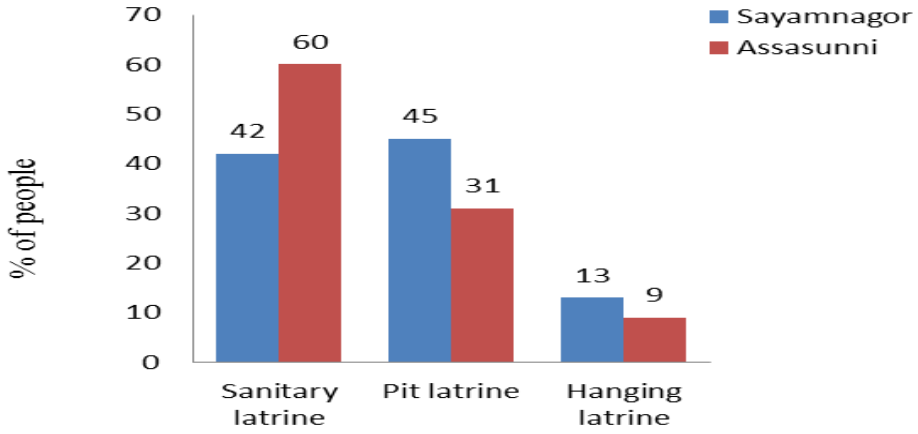
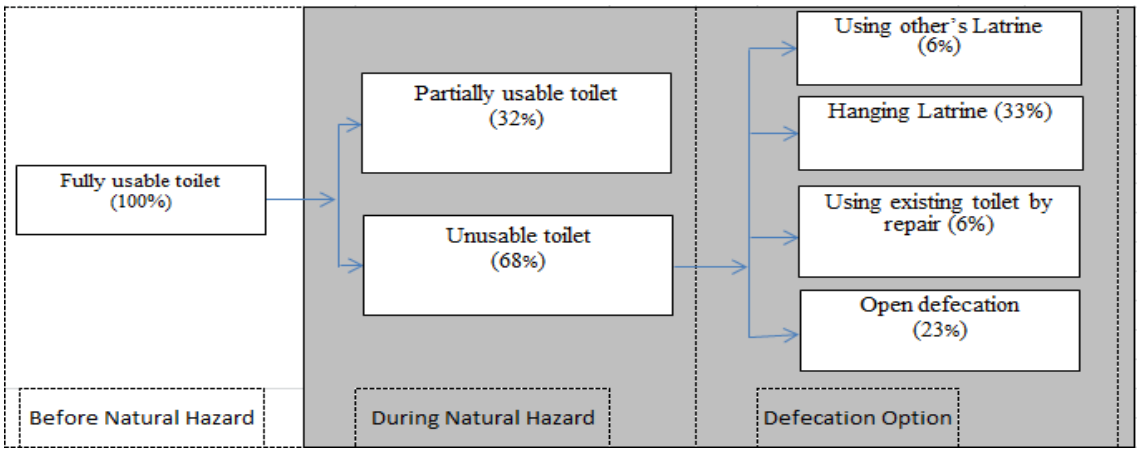
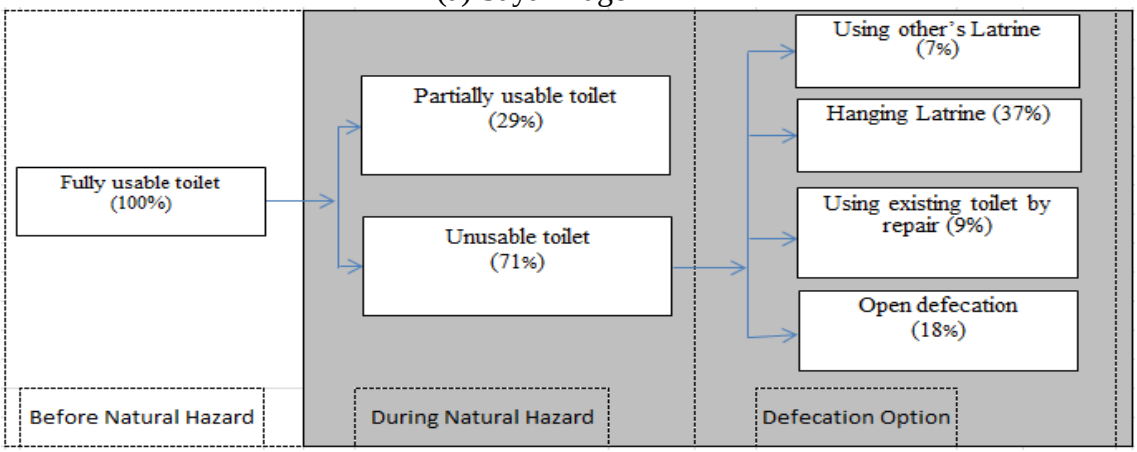


Figure 5.26: Distributions of people according to the usage of different type of toilet

From the field investigation, it can be observed that, maximum toilets become unusable in hazards of Sayamnagor and Assasunni. It is found (Figure 5.27) that more than two-third of the total toilets; 68% in Sayamnagor and 71% in Assasunni become unusable during natural hazards. In this consequences large number of people defecated directly to water. During hazards about 23% people of Sayamnagor and 18% people of Assasunni practiced defecation openly using boats or floats. It is also found that about 33% people of Sayamnagor and 37% people of Assasunni build temporary hanging latrines which are connected to water bodies. Besides, 6% people of Sayamnagor, 9% people of Assasunni use thier own toilet by reparing and rest of the people shared neighbours' or relatives latrine.



(a) Sayamnagor



(b) Assasunni

Figure 5.27: Defecation practice before and during natural disaster

5.4.7 Impact on Health and Coping Method

Due to various natural hazards the people, especially in the rural areas become affected by different diseases. Among those diseases the water borne diseases such as diarrhea, dysentery, jaundice, cold and cough and skin diseases are very common in Sayamnagor and Assasunni. It is found from the investigation that the people from 76% households of Sayamnagor and people from 84% households of Assasunni were affected by diarrhea whereas people from 90% households of Sayamnagor and people from 76% households of Assasunni were affected by dysentery. Besides, a large number of people suffered from skin diseases in Sayamnagor and Assasunni (67% and 37% respectively) along with jaundice and cold and cough as shown in Figure 5.28.

Though many people suffered from different health problems it is found that many of the people that are suffered from diseases did not take any treatment. Those who took treatment, used to go to mostly village doctor because they could avail this easily during natural hazard or to health center. Besides some people took treatments form health center and herbal treatment.

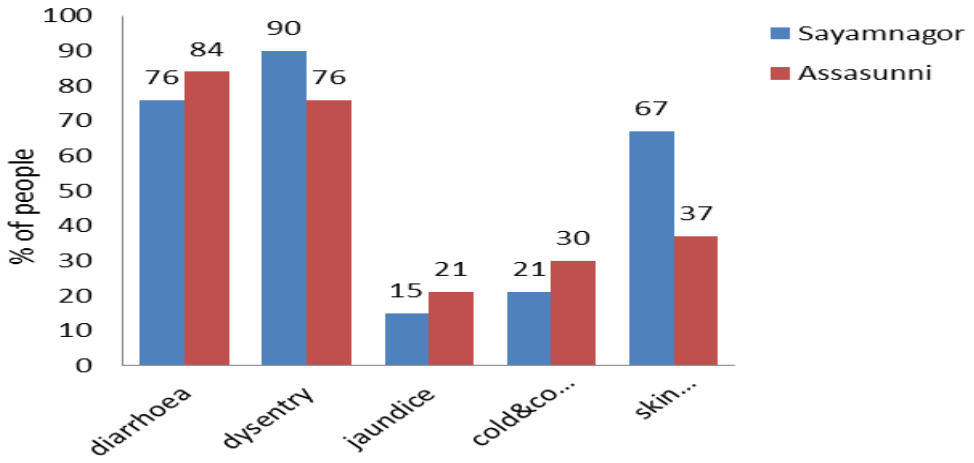
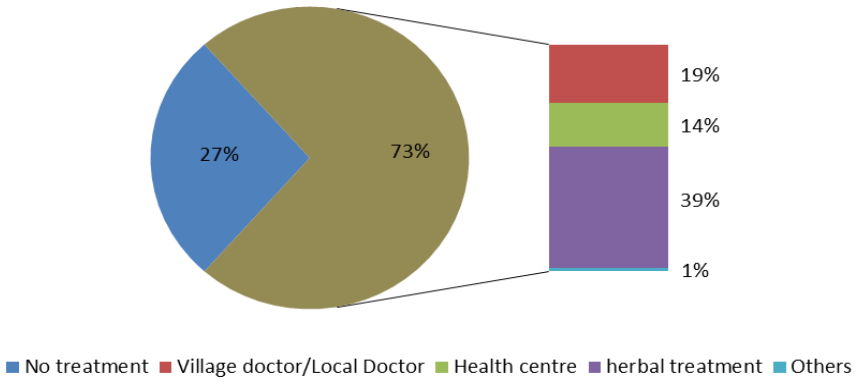
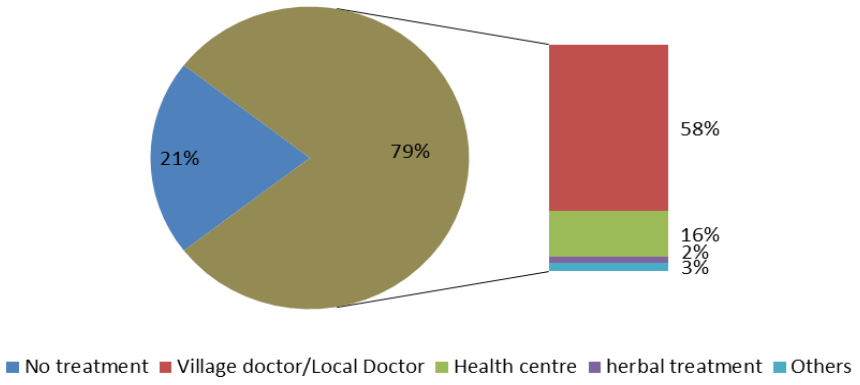


Figure 5.28: Comparisons among diseases according to affected household

Figure 5.29 shows that 27% people of Sayamnagor and 21% people of Assasunni did not take any type of treatment in suffering diseases. In Sayamnagor, 73% people take treatment from village doctor (19%), health Centre (14%), and herbal treatment (39%) whereas in Assasunni, 79% people take treatment from village doctor (58%), health Centre (16%), and herbal treatment (2%). So, it is appeared that most of the people of Sayamnagor take herbal treatment whereas most of the people of Assasunni take treatment from local doctor as well as village doctor.



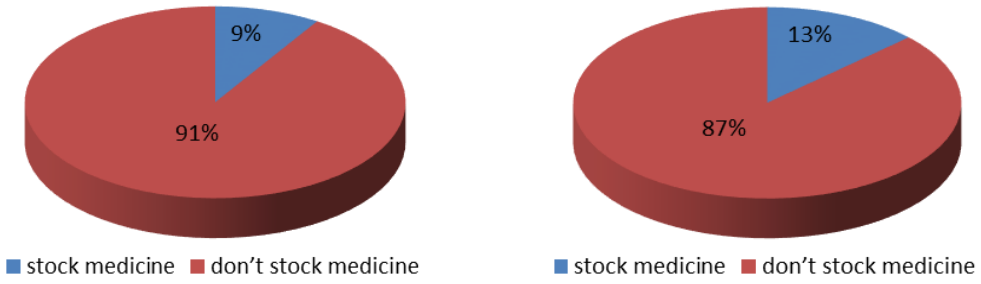
(a) Sayamnagor



(b) Assasunni

Figure 5.29: Distribution of household according to treatment

Before starting of natural hazard taking preventive measure for health problem is not common among rural people. Few of those who are a bit aware and careful about health try to store some simple medicines for first aid. Figure 5.30 shows the percent amount of people according to stocking of emergency medicine. Figure illustrates that only 9% of household of Sayamnagor and 13% households of Assasunni stock emergency medicine before natural hazard and majority people of Sayamnagor and Assasunni (91% and 87% respectively) do not stock emergency medicine.



(a) Sayamnagor (b) Assasunni

Figure 5.30: Distributions of households according to stocking of emergency medicine

CHAPTER VI

Conclusion and Recommendation

6.1 General

In this study the Livelihood Vulnerability indices were determined using three methods: the composite index approach developed by *Sullivan et al.* (2002) named as SLVI, IPCC (2001) framework approach named as LVI-IPCC and Yates approach (2010) named as YLVI. The study area includes Laksmikhali village of Morrelganj upazila, Golbunia village of Mongla upazila, and Uttar Rajapur village of Sarankhola upazila, Dash Ani of Bagerhat Sadar upazila, Nalian villalge of Dacope upazila, Bhagba village of Koira upazila, Rajapur village of Rupsa upazila, Baintala village of Assasunni upazila and Herinnagor village of Sayamnagor upazila. The Vulnerability of Water Resource based on matrix framework from gender perspective were determined in the selected study areas. The coastal community's perception to the hazards and their vulnerabilities as well as local coping methods against the effect of various coastal hazards were also examined. Based on the study, the summary of the key findings are discussed below.

6.2 Summary of the Findings

The major components indices of Livelihood Vulnerability Index (LVI) such as Socio-demographic profile, Livelihood strategies, Social network, Health, Food, Water, Natural disaster and climate variability were calculated based on survey data. The vulnerability scores for the major component varies from 0 (least vulnerable) to 1 (most vulnerable). Results recommend that Morrelganj may be more vulnerable in terms of social networks profile compared to Mongla, Sarankhola, Dacope, Koira, Assasunni, Sayamnagor, Bagerhat Sadar and Rupsa. The vulnerability scores are Morrelganj: 0.364, Mongla: 0.346, Sarankhola: 0.345, Dacope: 0.306, Koira: 0.316, Assasunni: 0.294, Sayamnagor: 0.329, Bagerhat Sadar: 0.335 and Rupsa: 0.287. The vulnerability scores for food are found as Morrelganj: 0.584, Mongla: 0.597, Sarankhola: 0.518, Dacope: 0.570, Koira: 0.594, Assasunni: 0.576, Sayamnagor: 0.576, Bagerhat Sadar: 0.568 and Rupsa: 0.553. This means that, in terms of food security, Mongla may be more vulnerable. Sarankhola may be more vulnerable in terms of water resources and the vulnerability scores are, Morrelganj: 0.364, Mongla: 0.379, Sarankhola: 0.415, Dacope: 0.411, Koira: 0.360, Assasunni: 0.337, Sayamnagor: 0.332, Bagerhat Sadar: 0.116 and Rupsa: 0.186. In terms of health facility, Dacope may be more vulnerable based on vulnerability score, Morrelganj: 0.253, Mongla: 0.198, Sarankhola: 0.248, Dacope: 0.335, Koira: 0.224, Assasunni: 0.310, Sayamnagor: 0.332, Bagerhat Sadar: 0.103 and Rupsa: 0.153. Assasunni may be more vulnerable in terms of livelihood strategies. The vulnerability scores for livelihood strategies are, Morrelganj: 0.352, Mongla: 0.349, Sarankhola: 0.370, Dacope: 0.415, Koira: 0.401, Assasunni: 0.444, Sayamnagor: 0.404, Bagerhat Sadar: 0.348 and Rupsa: 0.371. Sayamnagor may be more vulnerable in terms of two major vulnerability components; socio demographic profile and natural disaster and climate variability. The vulnerability scores of socio-demographic profile and natural disaster and climate variability are, Morrelganj: 0.266, 0.273, Mongla: 0.309,

0.287, Sarankhola: 0.317, 0.345, Dacope: 0.339, 0.375, Koira: 0.330, 0.309, Assasunni: 0.318, 0.373, Sayamnagor: 0.361, 0.427, Bagerhat Sadar: 0.301, 0.273 and Rupsa: 0.355, 0.295, respectively. The vulnerability of households differs because of differences in the households' sensitivity, adaptive capacity and exposure to natural disaster. In Dacope upazila, both adaptive capacity and sensitivity score found higher than Mongla, Morrelganj, Sarankhola, Koira, Assasunni, Sayamnagor, Bagerhat Sadar and Rupsa. The scores of adaptive capacity and sensitivity are, Morrelganj: 0.321, 0.409, Mongla: 0.332, 0.407, Sarankhola: 0.342, 0.403, Dacope: 0.356, 0.449, Koira: 0.350, 0.408, Assasunni: 0.354, 0.421, Sayamnagor: 0.334, 0.426, Bagerhat Sadar: 0.325, 0.302 and Rupsa: 0.342, 0.317, respectively. The exposure to natural disaster and climate variability is higher in Sayamnagor upazila and the scores are Morrelganj: 0.273, Mongla: 0.287, Sarankhola: 0.345, Dacope: 0.375, Koira: 0.309, Assasunni: 0.373, Sayamnagor: 0.427, Bagerhat Sadar: 0.273 and Rupsa: 0.295. The overall Livelihood Vulnerability Index (LVI) based on three methods is found higher for Sayamnagor compared to others district. The obtained scores of SLVI, LVI-IPCC and YLVI are, Morrelganj: 0.348, -0.020 and 0.340, Mongla: 0.345, -0.18 and 0.351, Sarankhola: 0.367, 0.001 and 0.406, Dacope: 0.396, 0.009 and 0.473, Koira: 0.365,-0.017 and 0.361, Assasunni: 0.383, 0.008 and 0.444, Sayamnagor: 0.401, 0.04 and 0.544, Bagerhat Sadar: 0.306, -0.016 and 0.253, Rupsa: 0.322 -0.015 and 0.274, respectively. It can be noted that the vulnerability score for SLVI ranges from 0 to 1. That of LVI-IPCC and YLVI ranged from -1 to +1 and 0 to 1, respectively.

The Vulnerability score of water resources from gender perspective are determined based on matrix framework with a score ranges from o to 3 (0= no impact, 1= less impact, 2= moderate impact and 3= severe impact). The vulnerability score obtained as Sayamnagor: 2.21, Sarankhola: 2.03 and Bagerhat Sadar: 1.04. It reflects that Sayamnagor is more vulnerable compared to Sarankhola and Bagerhat Sadar upazilas. Sayamnagor is found to be more vulnerable to climate change induced disaster events compared to other places based on women's perception and the specific vulnerability scores due to average extreme events are Sayamnagor: 2.23, Sarankhola: 1.41 and Bagerhat Sadar: 0.36. Sarankhola is found more vulnerable to climate associated gradual changes and the specific vulnerability score due to average seasonal change are Sayamnagor: 2.20, Sarankhola: 2.64, Bagerhat Sadar: 1.71. In Sayamnagor, the total vulnerability (2.21) is found greater than the specific vulnerability (2.20) due to average seasonal change and smaller than disaster induced vulnerability (2.23). On the contrary, Sarankhola and Bagerhat Sadar show that the specific vulnerability due to average seasonal change (2.64 and 1.71, respectively in Sarankhola and Bagerhat Sadar) is greater than total vulnerability (2.03 and 1.04, respectively in Sarankhola and Bagerhat Sadar) and the specific vulnerability due to average change in induced disaster events (1.41 and 0.36, respectively in Sarankhola and Bagerhat Sadar) is smaller than total vulnerability. However, the overall water resource vulnerability is higher in Sayamnagor than Sarankhola and Bagerhat Sadar.

The people' perception regarding their vulnerabilities to coastal hazards and their coping strategies show that people perceived an increase in both the intensity of hazards and their vulnerabilities. In spite of having a number of socio-economic and location factors enhancing their vulnerabilities, the community is creating their ways

to cope with these hazards. For different aspects of life like food and shelter, water supply, sanitation, and health, communities are found to apply different coping methods that vary with the types of hazards. According to the people' perceptions, the most prevalent coastal hazards in the study areas are cyclone, flood, and tidal surge. In case of shelter system, there are more kacha houses in Dacope upazila than Morrelganj, Mongla, Sarankhola, Koira, Assasunni, Bagerhat Sadar and Rupsa. Therefore Dacope is more vulnerable in case of existing housing pattern. In case of water supply system during natural hazard, Sayamnagor, Dacope and Assasunni is found more vulnerable compared to other areas as more than 70% of water sources were found to be unusable due to the hazard. In case of sanitation system, people from Sayamnagor use more unhygienic latrine (about 58%) than Morrelganj, Mongla, Sarankhola, Dacope, Koira, Assasunni, Bagerhat Sadar and Rupsa. In this case, the sanitation system of Sayamnagor became more unusable than Morrelganj, Mongla, Sarankhola, Dacope, Koira, Assasunni, Bagerhat Sadar and Rupsa. In case of health impact, people are suffered from various kinds of diseases due to the impact of natural hazards. Diarrhea, dysentery and Skin diseases are the most prevalent disease during disaster. Before starting hazards, taking preventive measure for health problem is not common in the study areas. It is observed that more than 80% people do not stock emergency medicine before hazards starting. On the other hand, generally in every locality of the surveyed area, as a preparation for natural hazards, the households store dry food such as chira-muri, gur (molasses) and chal (rice), dal (pulse), tel (oil), nun (salt) etc.

6.3 Conclusions

In this study, it is observed that for the LVI-IPCC approach, although the contributing factors (exposure, sensitivity and adaptive capacity) individually show variations in their indices from one village to another, no major variation is observed for total livelihood index. However, the designed SLVI and YLVI shows variation among the studied nine villages. Therefore, it can be concluded that SLVI and YLVI approaches are suitable for community or district level whereas the LVI-IPCC is suitable for regional level evaluation. Knowledge and understanding of households' vulnerability acquired from such study may provide government and other relevant agencies with critical information for proper distribution of relief materials. Households' local adaptation strategies for resilience help them in implementing non-structural mitigation measures, which also benefit overall development through capacity building. Furthermore, households with low levels of human, financial, social and physical capital are found to have less capacity to meet the challenges of a disaster. Moreover, this study will help the development organizations, policymakers and public health practitioners with a practical tool to understand demographic, social and health factors contributing to climate vulnerability at the district or community level.

6.4 Recommendations for Further Study

Recommendations for future study are outlined as follows:

- Formulas for calculating the SLVI, YLVI and LVI–IPCC were designed to be straightforward in order to reach a diverse set of users. Additional information can be gained when more study areas are compared using vulnerability spider and triangle diagrams.
- Limitations of LVI calculation approach include the subjectivity involved in selecting sub-components and the directionality of the relationship between the sub-components and vulnerability, the masking of extreme values by utilizing means to calculate the indices and possible selection bias due to empty households left out of the sample.
- Replication of the study in the same location over time might provide information about how the exposure, adaptive capacity and sensitivity of districts change as adaptation practices are initiated. Future work might include refinement of the Social Networks sub-components in order to more accurately evaluate social bonds.
- As in different aspects of life community coping varies with the variation of the hazard, the efforts of both governmental and non-governmental entities should consider this variation.
- Community-coping methods should be supported and guided by local governmental and NGOs to make it both more effective and environmentally friendly (e.g., proper knowledge of water storage before hazards occur and methods to reduce water-borne diseases in drinking water).
- The Coastal Management Policy and Development Strategies of the government should incorporate the method of coordination and partnership among the development, NGOs, and communities.

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Appendix A

Calculating the health major component for the LVI for Sarankhola, Bagerhat

Sub-components for Health major component	Sub component values	Max sub-component value	Min sub-component value	Index value	Health major component values
Average time to health facility (H_1)	40.8	60	5	0.651	0.248
Percent of households with family member with chronic illness (H_2)	18.0	100	0	0.18	
Percent of households where a family member had to miss work or school in the last 2 weeks due to illness (H_3)	0.0	100	0	0.00	
Access to sanitary latrine (H_4)	16.0	100.0	0	0.16	

Step 1: (repeat for all sub-component indicators): Health $(H_1)_{\text{Sarankhola}} = \frac{40.8 - 5}{60 - 5} = 0.651$

Step 2: (repeat for all major components): $\text{Health}_{1\ \text{Sarankhola}} = \frac{\sum_{i=1}^{n} index_{s_d} i}{n}$

$= \frac{H_1 + H_2 + H_3 + H_4}{4} = \frac{0.651 + 0.18 + 0.0 + 0.16}{4} = 0.248$

Step 3: (repeat for all study areas): $\text{LVI}_{\text{Sarankhola}} =$

$$\frac{0.317*5 + 0.345*4 + 0.370*4 + 0.248*4 + 0.518*5 + 0.415*4 + 0.345*6}{5+4+4+4+5+4+6} = 0.367$$

Appendix B

Calculating LVI–IPCC for Sarankhola, Bagerhat

Contributing factors	Major components	Major component values	Number of sub-components Per major component	Contributing factor values	LVI–IPCC value
Adaptive capacity	Socio-demographic profile	0.317	5	0.342	0.001
	Livelihood strategies	0.370	4		
	Social networks	0.345	4		
Sensitivity	Health	0.248	4	0.403	
	Food	0.518	5		
	Water	0.415	4		
Exposure	Natural disasters and climate variability	0.345	6	0.345	

Step 1: (calculate indexed sub-component indicators and major components as shown in Appendix A).

Step 2: (repeat for all contributing factors: exposure, sensitivity, and adaptive capacity):

Adaptive Capacity$_{\text{Sarankhola}}$ $= \frac{\sum_{i=1}^{n} w_{m_i} M_{id}}{\sum_{i=1}^{n} w_{M_i}}$

$= \frac{(0.317*5 + 0.370*4 + 0.345*4)}{5+4+4} = 0.342$

Step 3: (repeat for all study areas): LVI –IPCC$_{\text{Sarankhola}}$ = $(e_{Sarankhola} - a_{Sarankhola}) * s_{Sarankhola}$

= (0.345-0.3420)*0.403 = 0. 001