

**DEVELOPMENT OF A SUSTAINABLE LIVELIHOOD SECURITY MODEL  
FOR STORM SURGE HAZARD IN COASTAL AREA**

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**MASTER OF SCIENCE IN WATER RESOURCES DEVELOPMENT**



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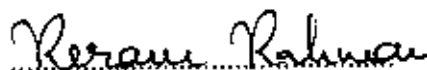
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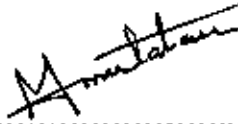


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## **LIST OF ABBREVIATIONS**

<b>AHP</b>	<b>Analytic Hierarchy Process</b>
<b>BBS</b>	<b>Bangladesh Bureau of Statistics</b>
<b>BIDS</b>	<b>Bangladesh Institute of Development Studies</b>
<b>BUET</b>	<b>Bangladesh University of Engineering and Technology</b>
<b>BWDB</b>	<b>Bangladesh Water Development Board</b>
<b>CARDMA</b>	<b>Coastal Area Resource Development &amp; Management Association</b>
<b>CDP</b>	<b>Coastal Development Plan</b>
<b>CDS</b>	<b>Coastal Development Strategy</b>
<b>CEGIS</b>	<b>Centre for Environment and Geographic Information System</b>
<b>CERP</b>	<b>Coastal Embankment Rehabilitation project</b>
<b>CLA</b>	<b>Coastal Livelihoods Analysis</b>
<b>CI</b>	<b>Consistency Index</b>
<b>CR</b>	<b>Consistency Ratio</b>
<b>CPP</b>	<b>Cyclone Preparedness Program</b>
<b>DFID</b>	<b>Department for International Development</b>
<b>DOE</b>	<b>Department of Environment</b>
<b>ESCAP</b>	<b>Economic and Social Commission for Asia and the Pacific</b>
<b>FHDM</b>	<b>Fuzzy Hierarchical Decision Making</b>
<b>GDP</b>	<b>Gross Domestic Product</b>
<b>ICZM</b>	<b>Integrated Coastal Zone Management</b>
<b>IWM</b>	<b>Institute of Water Modeling</b>
<b>JSCE</b>	<b>Japan Society of Civil Engineering</b>
<b>LGED</b>	<b>Local Government Engineering Department</b>
<b>MCDM</b>	<b>Multi-Criteria Decision Making</b>
<b>NWMP</b>	<b>National Water Management Plan</b>
<b>PDO-ICZMP</b>	<b>Program Development Office for Integrated Coastal Zone Management Plan</b>
<b>PDSCL</b>	<b>Perception of Direct Stakeholder on Coastal Livelihoods</b>
<b>PSF</b>	<b>Pond Sand Filter</b>
<b>SLF</b>	<b>Sustainable Livelihoods Framework</b>
<b>UN</b>	<b>United Nations</b>
<b>UP</b>	<b>Union Parishad</b>
<b>WARPO</b>	<b>Water Resources Planning Organization</b>
<b>WB</b>	<b>World Bank</b>

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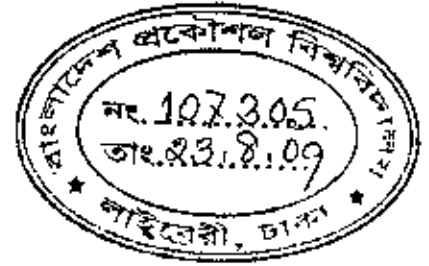
## ABSTRACT

The resourceful coastal zone is ever dynamic and the security of a coastal dweller's life and livelihood depend on the availability of terrestrial and marine resources in terms of ownership and access. In Bangladesh coastal resources and their dependent livelihoods are at great risk due to recent aggravating of storm surges. Cyclone induced storm surge hazards threat the coastal livelihoods by damaging the inland, marine and forest resource system. In this study, a total of seven marginal livelihood groups have been identified in the coastal areas which not only enjoy the resource oriented opportunities but also face the extreme vulnerability due to storm surges. Farmer, fisher (jele), fry (shrimp) collector, salt farmer, dry fisher, forest resource extractor (bawalis, mouals, golpata collectors etc.) and daily wage laborer are the identified livelihood groups in the study sites. Their livelihood system has been defined as adequate and sustainable access to income and resources to meet their basic needs with function of five capitals (natural, physical, financial, social and human) to recover from the vulnerabilities due to any natural shock to the coastal environment. The aim of the study was to develop a livelihood security model based on an indicator framework. The indicator framework, containing 48 qualitative and quantitative indicators representing coastal livelihood security against storm surge risk, has been formed based on literature review and field observation. In the model, livelihood security has been defined as an arrangement of five household security options such as security of food, income, life and health, house and properties and water. The indicator response to individual security option has been evaluated by AHP (Analytical Hierarchy Process), a multi-criteria decision making system. Measurements of indicator have been conducted through coastal livelihood system analysis by Focus Stakeholder Meetings and household questionnaire survey with reasonable sampling size. The Livelihood Security Model has been used to predict the security level of the livelihood groups against the vulnerability from storm surges in sindy area. Different levels of livelihood security have been found for various livelihood groups. For example, highest livelihood security level has been found for salt farmer as 45.13% in Cox's bazaar where the lowest security level has been measured for wage laborer as 11.43% in Satkhira. Variation has been shown in security level of a livelihood group in alternate

study site such as farmer group keeps 41.89% livelihood security in Cox's bazaar and 33.99% in Satkhira. The model result has ultimately shown that the levels of security for livelihood groups are higher in Cox's bazaar than that of in Satkhira except for fry collector. A strong correlation between income security and overall livelihood security has been found from the model application in both study sites. The model has been recommended to be used for improving development activities and sustainable management plan for coastal community in Bangladesh.

# CHAPTER ONE

## INTRODUCTION



### 1.1. General Concept

The world is warming. Burning of fossil fuels, largely by the industrialized nations, has begun to trigger more extreme weather that in turn gives birth to more severe disasters – cyclone, storm surge and flood damages in coastal area. The impact of such damages is exacerbated by environmental degradation. The global natural system analyzers are strongly concerned about the Integrated Management of Coastal Zone in the earth. Economically and politically powerful countries in the world are able to keep proper approaches to protect their coastal zone, resources and related livelihood groups. But scientists predict that more destructive coastal hazards impact mostly poor developing nations least able to afford to manage them (CDP, 2003). As a result of these trends, a large number of populations in that zone of developing and under developed countries like Bangladesh, are suffering much and facing more insecurity over their living system.

Livelihood security is an integrating concept where a livelihood comprises of the capabilities, assets (including both all material and social resources) and activities required for a means of living (Scoones, 1998). A livelihood system is sustainable if it can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets, and provide sustainable livelihood opportunities for the next generation (Chambers and Conway, 1992). Livelihoods are secured when households have secure ownership of, or access to resources and income earning activities, including reserves and assets, to offset risks, ease shocks and meet contingencies (Chambers, 1989). Generally a Sustainable Livelihood Security Model may enhanced by one or a combination of the three intervention strategies at household level such as Livelihood promotion (development oriented programming), Livelihood protection (rehabilitation/mitigation oriented programming) and Livelihood provisioning (relief-oriented programming) (Frankenberger and McCaston, 1998).

Livelihood in the coastal area differs from rest of the country. In Bangladesh, coastal livelihood pattern largely depends on what resources (both in land and the sea) are available at the household level in terms of ownership and access (Soussan, 2001). Sustainability of resources and securities of livelihoods in coastal area may hamper due to regular frequency of natural disasters and thus make vulnerabilities to people's well-being. Livelihood security against those vulnerabilities is defined in relation to the essential well-being associated securities of coastal community with perfect combination of food security; water security; income security; health and personal security and security of household properties. Livelihood Security Model can be developed to improve measurement of impacts of certain vulnerability at household level and also to improve development programme in coastal area.

## **1.2. Background of the Study**

How do women and men who live and work in the coastal zone make their living and keep it secured? How do they consider their main resources, options, vulnerabilities and constraints to ensure their livelihood security? - those questions have developed the idea of livelihood security model formation for coastal livelihood groups with the specific natural issue.

Coastal people enjoy higher opportunities and access to natural resources but face more vulnerabilities or risks in their field of employment and property. In Bangladesh coastal people hold something special at the way of living because they are fully dependent on both terrestrial and marine ecosystem with some extent of vast mangroves, large estuaries, coral reefs etc. Natural hazards and induced vulnerabilities affect that coastal community much more than the rest of the nation.

The natural hazard cyclone, a tropical storm or atmospheric turbulence involving circular motion of winds, occurs in Bangladesh almost every year. About one tenth of the global tropical cyclones with storm surge occur in the Bay of Bengal (World Bank, 1993). About one sixth of tropical cyclones developed in the the Bay of Bengal had landfall on the Bangladesh coast. The Bay cyclones also move towards the eastern coast of India,

towards Myanmar and occasionally into Sri Lanka. But storm surge causes the maximum damage when they come into Bangladesh, West Bengal and Orissa of India (BUET, 2008). The situation is created by the physical placement of the country. More damages caused mainly by natural and some anthropogenic issues such as low flat terrain, high density of population and poorly built houses. Cyclones and associated storm surges are unique threat to the coastal resources and living activities of Bangladesh. Cyclone generally having high wind speeds up to 225 km/hr, but above all the consequent rise of sea water levels (surges) that can reach heights of 9 m, can create enormous damage to life, properties and ecosystems. The combined wind and surge effects make the coastal population extremely vulnerable, limiting them in their activities and development.

The coastal region of Bangladesh consists of southern deltaic zones and is mainly formed by the Ganges, Brahmaputra and Meghna estuaries. It dissolves huge natural (both land and sea environment) resources and covers the parts of 19 sea and estuary facing administrative districts (PDO-ICZM, 2001). The socio-economic and ecological setting of the coastal area is complex, and its developmental challenges are tough but instead of drawing more attention to the coastal region and its people, they have suffered from utter neglect and a high level of vulnerability to natural calamities and their associated risks (PDO-ICZM, 2003). Coastal communities comprises of a large part of the national population with livelihoods directly related depending on resources in coastal and marine ecosystem in Bangladesh. But due to improper management and poor understanding of natural systems and hazards the coastal resources are being depleted and biodiversity is degraded that will result in increased risks and vulnerabilities as well as shrinking options to support livelihoods and improve the quality of living (Islam, 2004). The Coastal communities directly attached with local product are mostly poor, land less, unorganized and disadvantaged groups of people in the society. They depend on the advantaged groups of people like the boat/gear owner, money lender and are exposed to manmade and natural hazards including depletion of coastal resources on which they depend for their livelihoods. They do not have social, institutional and financial capacity to address those issues for sustainability and security in their livelihoods.



People in Coastal zone want security to their livelihood; it is the most important statement for the welfare of coastal community of the most developing countries in the present situation when the intensity of cyclonic storm surge is increasing in the world due to rapid change of climatic condition of the earth. After SIDR (the cyclone and storm surge in November 2007) coastal people on the Bay of Bengal especially in Bangladesh coast feel their livelihood vulnerabilities more. In this situation coastal zone management system should include different environmental and socio-economic techniques which bear close resemblance to the coastal planning and management tools. Coastal livelihood security model for storm surge would be an essential tool to identify the level of safety of life and properties of coastal people with better conditions of their resource base activities and sustainable opportunities for livelihood system of households as well as the wider community in certain area.

### **1.3. Coastal Zone**

Coast, a geographical term that refers to the transition where land and ocean meet to form a unique environment including the features of inshore waters, inter-tidal areas and extensive tracts of land (Davies 1978). Since ancient times, river deltas and coastal areas have been the site of economic and commercial activities and were of fundamental importance to civilization. Coastal formations are continually changing because of the dynamic interaction between the oceans and the land. The coastal zone is described as a site of complex natural system where intense interactions occur among land, sea and atmosphere with all the biological and physical processes of both the terrestrial and the marine environments and defined broadly for the purpose of natural resources management legally or administratively (Kay and Alder, 1999). The term Coastal zone, usually applied to the area of real concern is that region where human activities are interlinked with the natural systems of bays, estuaries, deltas, marshes, dunes and beaches. Scientifically a coastal zone can be defined as the band of dry land and adjacent ocean space (water and submerged land) in which terrestrial process and land uses directly affect oceanic processes and vice versa (Kay and Alder, 1999).

The coastal zone is one of the nation's greatest environmental, social, and economic assets. It is a nexus for tourism and industry activities that include shipping and boating, fishing, oil and other resource exploration, and the recreational use of beaches. The coastal zone also encompasses forests, rivers and streams, wetlands, beaches, barrier islands, and ocean habitat. Proper maintenance of this complex area ensuring public safety, managing resources, building roads, maintaining beaches or parks, ensuring safe navigation and acting to understand how natural and manmade forces are interacting and affecting processes in the system. Coastal livelihood security analysis may form some better decisions in navigation, homeland security, coastal hazards, resource management and other areas—decisions that could save lives, preserve livelihoods, and save the nation.

#### **1.4. Objectives of the Study**

The general objective of the study was to undertake a detailed understanding about the accessible form of coastal livelihood security in Bangladesh concerning storm surge hazard. The specific objectives of the study were:

- To prepare a list of existing livelihood groups in the coastal area of Bangladesh
- To identify the livelihood security indicators for the coastal community against storm surge
- To develop a sustainable livelihood security model for storm surge in coastal community of Bangladesh

**Outcome of the study:** The study findings express a clear idea about the coastal livelihood groups focusing their household access or opportunities and show a guide line for livelihood security level analysis in coastal area against storm surge hazard. The established model shows the level of security for existing livelihood groups in coastal area.

### **1.5. Justification of the Study**

Idea of this study has been developed under the concept of Integrated Water Resource Management focusing the impact management of a severe water related natural hazard. In present years, it has been found that storm surge hazard occurs in increasing frequency and causes great damage to coastal resources and life in Bangladesh. Storm surge is a natural process and human are not able to stop it but they can manage the effects of that environmental issue. It has also been realized that integrated approaches will effect positively to the nation when the coastal management options have to be designed on the basis of social, economic and environmental indicator assessment. Through this research, it has been tried to show a way to assess the security level of coastal livelihood groups and risks of their socio-economic infrastructures in Bangladesh.

### **1.6. Scope of the Study**

- Livelihood Security Model would be helpful for assessing the household security of coastal livelihood groups against the risk of storm surge hazard.
- The model results provide the security of livelihood resources and would be used as an effective tool of coastal management and development strategy.
- The model can support the policy development and protection initiatives in the vulnerable area.

### **1.7. Limitations of the Study**

The limitations of the study are as follows:

- ❖ In some cases the study has suffered from lack of adequate information from the people, due to their unawareness in remote coastal area
- ❖ This study has been conducted in only three unions in two coastal districts which is inadequate to portray the overall scenario of coastal livelihood

- ❖ The calculation of security standard has been hampered from the lack of emergency reference data about the coastal livelihood system
- ❖ It was difficult to consider all large and small coastal livelihood groups for the study and for that only resource based groups have been considered.

## **1.8. Organization of the Thesis**

This thesis is divided into eight chapters.

**Chapter one** provides a general concept of the idea, detailed background with general information on coastal zone, objective, justification, scope and limitations of the study.

**Chapter two** documented a review of the literature on the current study. It includes literature on coastal zone of Bangladesh, coastal livelihoods and its resources, storm surge: a water base natural hazard, storm surges in Bangladesh coast, indicator development and multi-criteria decision making process.

**Chapter three** describes the details methodology for the present study. The methodology is divided into three phase: methodology of identification of marginal livelihood groups in the coast and their residence as the area of present study, methods and materials for formulating a livelihood security model and finally the model application.

**Chapter four** contains detailed information on the identified coastal livelihood groups with specific study are. The description of study area includes geology, soils and topography, climate, hydrology and land use, biological habitats, local community and stakeholders of two different study sites.

**Chapter five** describes the Livelihood Security Model established for coastal people against the storm surge hazard. It includes the details of model components such as indicator development concerning the surge hazard and coastal livelihood system,

standard valuation of indicator and finally selection of them to different security options and their possible responses due to storm surges.

**Chapter six** contains the result of field survey under the heading of coastal livelihood system analysis. That finds the value of model input data.

**Chapter seven** provides the model application and discussion for two different study sites in the coastal area of Bangladesh.

**Chapter eight** includes the conclusions and recommendations of the study.

**Appendix A** contains the sample questionnaire for household survey and information collection sheet in primary data collection method of the study.

**Appendix B** includes the check list for stakeholder meeting and participatory approaches.

**Appendix C** shows the selection of indicators with response to different livelihood security options by AHP (Analytical Hierarchy Process) with details calculation.

**Appendix D** shows the calculation table with detail calculation of model application for livelihood security assessment.

**Appendix E** shows some important photographs of the field study.

## **CHAPTER TWO**

### **LITERATURE REVIEW**

#### **2.1. Introduction**

The literature is initially directed to an overview of the coastal Environment of Bangladesh with special concern to the population, their activities and natural resources in that zone. It also includes the highlighted texts relate with coastal livelihoods and resources, natural vulnerabilities in coast, storm surges in coastal area of Bangladesh and concept of livelihood security. It describes the primary information about analytical tools use in the study.

#### **2.2. Coastal Zone of Bangladesh**

Coastal zone is a geographically delineated area which is distinctly characterized by the aggregation of interacting coastal environments and corresponding natural and man-made structural systems in which management is fundamentally a 'production function' that combines inputs to produce desired outputs ((Kay and Alder, 1999).

Bangladesh is located in the north-east of the South Asian Sub-continent with a total area of 1, 47,570 sq. km with an estimated population of 140 million where the coastal zone lies within the tropical zone between 21-23° N and 89-93° E (Banglapedia, 2008). The coastal area of Bangladesh is an active delta of Ganges- Brahmaputra- Meghna river systems, rich in water and land resources. The area is characterized by a constantly changing geographic and geomorphologic situation. In this region landownership is more skewed than in other parts of the country. Most parts of the area are, therefore, low lying which can be subjected to inundation even under ordinary circumstances of tides. The three basic natural system processes and events that govern opportunities and vulnerabilities of the coastal zone of Bangladesh are: Tidal fluctuation; salinities (both surface and ground water) and cyclone and storm surge risks (Islam, 2004). A tidal surge accompanied by a cyclonic storm makes the situation alarming which is further

exacerbated by the triangular shape of the BAY OF BENGAL. The wide shallow continental shelf is conducive to amplification of surges causing wide spread flood (CEGIS, 2007).

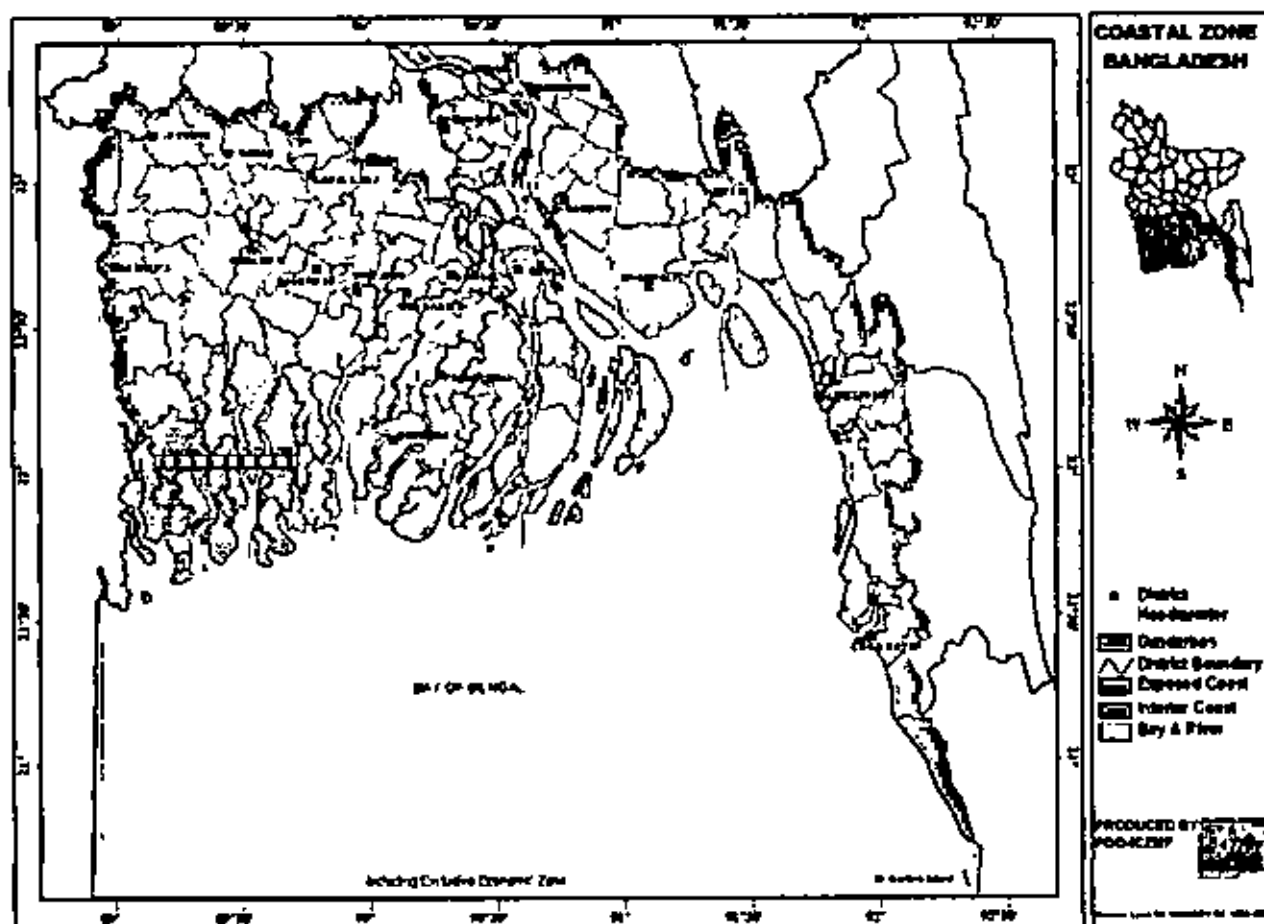


Fig. 2.1. Coastal Zone of Bangladesh.

Source: PDO-ICZM, 2002.

Based on available information of the geomorphologic conditions and hydrological features, the nineteen coastal districts of Bangladesh can be broadly divided into that three defined regions (PDO-ICZM, 2002b):

- a. The eastern region
- b. The central region
- c. The western region

These regions have definite characteristics influencing the overall coastal morphology of Bangladesh. Although Bangladesh coast have been divided into three broader regions, the coast is highly heterogeneous in character lacking homogeneity

### **THE EASTERN REGION**

Morphologically the eastern coastline of Bangladesh from the big Feni River to Badar Mokam (Southernmost tip of the mainland) along Chittagong as a Pacific type coast running parallel to young mountain ranges including the St. Martin Island. The east coast is regular and unbroken and is protected along the sea coast by mud flats and sub-merged sands. A continuous strip of sand runs from Cox's Bazar to Badar Mokam and forms the longest sea beach of about 145 Km (Islam, 2004). The main Rivers of the eastern coast (Karnaphuli, Sangu, Matamuhuri and Naf) play a vital role to the action of the nature.

### **THE CENTRAL REGION**

Central coastal region runs east from Tetulia River to the Big Feni River estuary and includes the mouth of the Meghna River. It also locates in the coastal region of Feni, Noakhali, Patuakhali, Bargona, Barisal, Pirojpur, Chadpur and Comilla districts including some charlands, islands. Estuarine river delta of Bangladesh characterized by heavy sediment input and river bank erosion. This region is the most dynamic area and having the fannel shaped apex of Bay of Bengal in which the rivers and channels amplifying into the Bay change their courses rapidly. It is the area of more vulnerability and variability of natural environment (CDS, 2006).



## **THE WESTERN REGION**

The western part covers the coastline from the Tetulia River to the international boarder located at the Hariabhanga River. This coastal region can be termed as Atlantic type in which the coastline in general is transverse to the structure of the continental margin. This is a stable region and is mostly covered by mangrove forests which lessen bank erosion so that scouring action is confined to the river channels which are in generally deeper than other region (GOB, 1999a). Accretion does not occur much in this region because sediments carried by rivers flow almost directly to the Swatch of No Ground which exert a great influence on tidal characteristics, sediment movement and deposition with other hydrodynamic and morphological phenomena. The coast of the districts Khulna, Bagerhat and Satkhira and the sundarbans (cover altogether about 6017 square km of Bangladesh) denote the southwest coastal zone in Bangladesh (CDP, 2002).

### **2.3. Coastal Livelihoods and Resources**

The concept of livelihood is dynamic, recognizing that the conditions and composition of people's livelihoods changes, sometimes rapidly, over time. Livelihoods are complex, with households in the developing world undertaking a wide range of activities (Ellis, 1998). Livelihood is synonymous to occupation that means to sustain a person or a household. This includes a range of occupations/activities, such as, farming, fishing, industry, etc., that generate proceeds, income and wealth. Livelihood assets create the base for livelihood options and activities for a household (PDO-ICZMP, 2002).

According to the Sustainable Livelihood Framework, all household assets/resources are broadly grouped into five categories, which include: human, natural, financial, technical and social/institutional resources (Carney, 1999). Ownership/control of or access to these assets/resources is vital for decision making for livelihood activities. A livelihood comprises of the capabilities, assets (stores, resources, claims and access) and activities required for a means of living; a livelihood is sustainable when it can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets and provide sustainable livelihood opportunities for the next generation: and which

contributes net benefits to other livelihoods at the local and global levels and in the short and long term (Chambers and Conway, 1992). The stability of people's livelihoods depends largely on their vulnerabilities and the resources that they depend on and Livelihoods must differ in different social, ecological and institutional settings. The coastal livelihood analysis provides a better understanding of coastal livelihood conditions at present and in future. This understanding has been instrumental in preparing a meaningful coastal zone policy, and would guide the formulation of a pragmatic coastal development strategy and a feasible investment program for enhancement of livelihoods of the coastal people, particularly the disadvantaged groups (PDO-ICZMP, 2004).

In the concrete situation of the Bangladesh coastal zone, it was endeavored to know what are considered as resources in the perception of the people and which resources are available at the household level. Using the selected assets/ resources, people then undertake a series of activities which generate income (goods, services and cash), which can be spent on: (i) investments in livelihood assets (land, training) and activities (hiring labor, buying pesticides); (ii) social payments (membership fees, taxes); and consumption (food, clothes) (PDO-ICZM, 2002).

A household with a diversified asset base has obviously more options and is in a better position to maximize household well-being by attaining a higher level of income, consumption, comfort and security, and diversifying risk as well. Activities are of different nature. Some are directly cash earning (cow selling, agriculture labor) and some are cost saving (boat maintenance, net repairing); some are related to self-employment (farming on own land, crab collection, horticulture) and some correspond to wage employment (agriculture labor, industrial labor, paddy husking); some contribute directly to household income (farming, fishing) while some relate to housekeeping for comfort of all household members (house cleaning, cooking). All these together define human existence in a particular setting.

Livelihood activities in the coastal zone may be clustered into some broad categories (PDO-ICZMP, 2004).

- Natural resource based activities, such as: agriculture, salt making, fishing, aquaculture, shrimp fry collection, fuel collection, extraction of forest products, etc; and
- Human resource based activities, such as: livestock and poultry keeping, boat building (carpentry), net making, *kantha* making, fish processing, trading, etc.

Coastal zone-specific activities are those, which stem from special geo-physical specialty of the area conditioned by its natural systems and the opportunities unique to the area. Some occupations can be exclusively attributed to the coastal zone and some are prevalent in the coastal districts to a greater extent than other areas.

Livelihood conditions of the people largely depend on what resources are available at the household level in terms of ownership and access. The coastal zone of Bangladesh is rich in natural resources offering many tangible and intangible benefits to the nation. The coastal zone has several ecosystems that have important conservation value: mangrove, marine, estuary, islands, coral, sandy beaches which provides habitat for an abundance of plant species as well as an array of fish and wildlife. The world's largest uninterrupted stretch of mangrove ecosystem, the Sundarbans, has been declared in 1997 as Ramsar Site, a World Heritage needs to be conserved (CEGIS, 2007). The mangroves (with spectacular wildlife and wide biodiversity), fisheries (> 80% of total marine catch with 28 species of shrimps and 187 species of fish), shrimp culture activities (around 11,500 ha of the coastal area), tourism (Cox's Bazaar with 145 km long beach offers attractive place for sea, sand and sun), shipping and inland navigations, ship breaking, oil and gas exploration, etc are some examples of these benefits (Banglapedia, 2008). There are strong interactions between components of the natural systems, between users and ecosystems; and between various users. Nevertheless, its natural resources face multiple and critical problems including non-sustainable resource uses and natural calamities, set within a human context of wide-spread poverty.

Household asset base provides the necessary condition for selection of livelihood option, going for gainful activities and coping with all odds. Table 2.1. presents an indicative list of such assets (PDO-ICZM, 2002a).

**Table 2.1: Livelihood assets for coastal people**

Cluster	Assets
Human	Household members, health, education, training, skills
Social	Organizations, cooperative groups, network/connections etc.
Natural	Land, water, common property resources (CPR)
Physical	House, tube well, latrine, electricity, cattle, poultry, tools and utilities etc.
Financial	Savings, credit, food/cash assistance (safety nets) etc.

Source: PDO-ICZM, 2002a.

In Bangladesh Livelihood in the coastal area differs from the rest of the country and more than a quarter of the population of the country lives in a coastal environment with multiple vulnerabilities and opportunities (CDP, 2003). Population density in the coastal districts is slightly higher than the national average, and the rate of increase is also similar to the national trend (BBS, 2001). In addition to the permanent coastal population, there are a significant number of new and seasonal migrants to the coastal areas, especially to the newly emerging chars. Those people depend on natural resources in both land and sea for their living. Continued access to fishery and forestry resources represents insurance against agricultural risks, providing livelihood security for coastal households having little or no land. For example, about 90% of the population meets its fuel needs from forest and flooded forest products; local fisheries resources contribute towards much of the daily economic requirements and provide food security for coastal people (Ahmed, 2003).

#### **2.4. Natural Vulnerability Issues for Coastal Livelihoods**

Coastal Livelihoods are often affected and threatened by a host of incidents and processes. These together define the vulnerability context of the households followed by cyclone, storm surge, flood, water logging, coastal erosion, salinity intrusion etc. Those issues are responsible to rapid declining of natural resources as well as the livelihood

system in coast. The context as perceived by the people may vary from household to household and also among members within a household, as different people are affected in different ways. Short descriptions of main coastal natural issues are defined here.

**Cyclone and storm surge:** Cyclonic storms are an important feature of the climate and have caused great suffering to people and damage to structures in the cyclone path. The storms usually form in the south-east portion of the Bay of Bengal, move in a northerly or north-westerly direction and often turn north-easterly or easterly towards the east coast of Bangladesh. Two different types of cyclones form in the bay - one is the tropical cyclone, which forms during the pre- and post-monsoon seasons, and the other is the monsoonal depression, which develops during the south-east monsoon season (Islam, 2004). Dynamically they are different. Tropical cyclones are the most destructive. Storm winds move at speeds of up to 240 km per hour and cause widespread damage. The most destructive element, however, is the water surge caused by a large mass of water at and around the storm center accumulating in a mound higher than the normal sea level and progressing with the storm as a wind driven storm surge (GOB, 1999a).

**Flood:** There are various types of floods; monsoon or fluvial floods, flash flood and tidal floods. Monsoon floods usually do not cause much problem in coastal zone. Tidal flood is typical for the coastal zone. Coastal area consists of large estuarine channels, extensive tidal flat and low lying islands. High tide regularly inundate large tract of these area. During extreme monsoon storms fresh water run off from big rivers, combined with wind and wave set up caused by strong southern winds, raise the sea surface in the Bay of Bengal (PDO-ICZMP, 2004b).

**Water logging:** Water logging is especially experienced in the southwest and south central areas. They are aggravating due to number of reasons such as siltation of water ways, reduction of storage capacity of downstream water bodies; shrinking water bodies due to settlements, construction of polders and so on. Localized drainage congestions are reported throughout the coastal belt. Inundation regimes, duration and temporal

variation vary but all congestion affect coastal livelihood because of crop damage, water born diseases and other health related issues (PDO-ICZMP, 2004b).

**Coastal erosion:** In a deltaic region, the premature decline and death of old rivers or sudden rise and violence of new ones are natural features of the Landscape. Erosion and accretion were found prominent in the coastal area of Bangladesh when major changes of river courses took place either by natural phenomena such as geological activities of subsidence or upliftment or by human interference, such as cross-dam, embankment, sluices etc (Islam, 2004). Major stable accretions were found in the coastal belt of Patuakhali and southern part of Bhola district. Both erosion and accretion in the Meghna estuary region (i. e. northern part of Bhola district, Lakshmipur, Noakhali and Feni coastal belt, Hatiya and Sandwip area) were found to be prominent. Major threat of erosion in the next 25 years may be in the region of northern part of Bhola, Lakshmipur coastline, north and northeastern parts of Hatiya, north and western parts of Sandwip. Slow accretion may take place in the southern parts of Hatiya and Noakhali mainland. Erosion and accretion in the Feni coastal belt is expected to be insignificant (GOB, 1999a).

**Salinity intrusion:** Water and soil salinity is a common problem in many parts of the coastal zone affecting agricultural and Industrial activities. Saline water intrusion is highly seasonal. It is at its minimum during the monsoon (June-October) when the main rivers discharge about 80 percent of the annual fresh water flow. In dry season months, the saline front begins to penetrate inland, and the affected areas rise sharply from 10 percent in the monsoon to over 40 percent. 70% of the 2.35 million hectares within the Khulna and Barisal Divisions is affected by different degree of soil salinity (PDO-ICZM, 2004). In the South western coastline shrimp farming is familiar industry which has increased the soil salinity in the Bagherhat, Satkhira, Khulna and Cox's Bazar coastal belt in Bangladesh. Several studies have shown that soil salinity has been increased due to the extensive shrimp farming in this region and has destroyed the soil fertility in these regions significantly.

## 2.5. Storm Surges: Most Destructive Water Based Hazard in Bangladesh Coast

Bangladesh is part of the humid tropics, with the Himalayas on the north and the funnel-shaped coast touching the Bay of Bengal on the south. This peculiar geography of Bangladesh brings not only the life-giving monsoons but also catastrophic cyclones, Northwesterly storms, tornadoes and floods. It is denoted that the Bay of Bengal is a favorable breeding ground of tropical cyclones and Bangladesh is the worst suffer of all cyclonic storms casualties in the world. About 5.5% cyclonic storms (wind speed greater than or equal to 62 km/hr) form in the Bay of Bengal and about 1% cyclonic storm of the global total hit Bangladesh (Ali, 1996, 1999a, 1999b). On the other hand, if the tropical cyclone disasters due to each of which the minimum death tolls were 5,000 are considered, then it is found that a death toll of about 53% of the global total occurred in Bangladesh (Ali, 1999a).

Coastal cyclonic surges are the most dangerous hazards in the coastal areas of Bangladesh. When the annual cyclones roar in, hundreds and sometimes thousands of people are swept away. Counter-clockwise cyclonic surges are created offshore due to low atmospheric pressure, which pushes a wall of water with a height of up to 10 m and a wind velocity of about 150-200 km/hour to the land causing both death and property damage (Khalequzzaman, 1988). From 1797 to 1998, 67 major cyclone storms and tidal surges have been reported (CERP, 1999). These indicate that Bangladesh is prone to frequent destructive tropical cyclones associated with tidal surge, particularly in pre-monsoon months of April-May and post-monsoon months of October-November (CDL, 1992). Because of frequent cyclonic storm surges every year, the low-lying coastal areas are particularly vulnerable, thus placing these population, infrastructure, agriculture, livestock and economic development in a high-risk situation.

**Table 2.2:** Major cyclonic storms in Bangladesh coast.

Storm surge	Overview
2009 (25 May), Aila	Ripped through the south-western coast of Bangladesh on 25 May. According to government figures, 352 unions and 62 upazilas in 14

	<p>districts--Barisal, Bhola, Pirojpur, Patuakhali, Barguna, Jhalakathi, Khulna, Bagerhat, Satkhira, Chittagong, Cox's Bazar, Laxmipur, Feni and Noakhali have been affected (Times online, 2009).</p> <p>In eight worst affected districts over 3,300,000 people were affected. Around 100,000 were taken to safe shelters under an evacuation campaign by volunteers and law enforcement agencies. At least 32 people have been reported killed in Satkhira, 25 in Noakhali, 20 in Khulna, 13 in Bhola, nine in Barisal, seven in Patuakhali, six in Laxmipur, two each in Bagerhat and Cox's Bazar, and one in Magura, according to reports from the affected areas. The cyclone triggered a 3 meter tidal surge in the region caused damage to thousands of households, washed away scores of river embankments, uprooted huge numbers of trees and caused extensive damage to standing crops. At least 90 percent of thatched houses and mud huts have been demolished by the Aila-fed tidal surge (around 25,000 according to government estimates), forcing thousands of people to take shelter in nearby buildings and cyclone centers</p>
2007 (14-15 November) SIDR	<p>The most devastating Cyclonic storm slammed into the southwestern coast in Bangladesh, destroying thousands of houses, 650,000 villagers fled to shelters with wind speed 240km/h. Officials said that another 3 million people were affected much with their living resources . In the coastal districts of Barguna, Bagerhat, Barisal and Bhola thousands of flimsy straw and mud huts were flattened as the cyclone flooded low lying areas and uprooted trees and electricity and telephone poles. Road, rail and river transport was also affected</p>
1998 (19-22 November)	<p>Offshore islands and chars of Khulna, Barisal and Patuakhali; cyclonic storm with maximum wind speed of 90 km/hr, storm surge of 1.22 to 2.44m</p>
1998 (16-20 May)	<p>Offshore islands and chars of Chittagong, Cox's Bazar and Noakhali; severe cyclonic storm (hurricane) with a wind speed of 150 km/hr, storm surge of 1.83 to 2.44m</p>



1997 (25-27 September)	Offshore islands and chars of Chittagong, Cox's Bazar, Noakhali and Bhola; severe cyclonic storm (hurricane) with a wind speed of 150 km/hr, storm surge of 1.83 to 3.05m
1997 (16-19 May)	The most devastating Cyclonic storm slammed into the southwestern coast in Bangladesh, destroying thousands of houses, 650,000 villagers fled to shelters with wind speed 240km/h. Officials said that another 3 million people were affected much with their living resources . In the coastal districts of Barguna, Bagerhat, Barisal and Bhola thousands of flimsy straw and mud huts were flattened as the cyclone flooded low lying areas and uprooted trees and electricity and telephone poles. Road, rail and river transport was also affected
1995 (21-25 November)	Offshore island and chars of Cox's Bazaar; severe cyclonic storm with maximum wind speed of 210 km/hr, about 650 people killed, 17,000 cattle head perished
1991 (29 April)	The Great Cyclone of 1991, crossed the Bangladesh coast during the night. It originated in the Pacific about 6,000 km away and took 20 days to reach the coast of Bangladesh. It had a dimension of more than the size of Bangladesh. The central overcast cloud had a diameter exceeding 600 km. The maximum wind speed observed at Sandwip was 225 km/hr. The wind speeds recorded at different places were as follows: Chittagong 160 km/hr, Khepupara (Kalapara) 180 km/hr, Kutubdia 180 km/hr, Cox's Bazar 185 km/hr, and Bhoia 178 km/hr. The maximum wind speed estimated from NOAA-11 satellite picture obtained at 13:38 hours on 29 April was about 240 km/hr. It turned into a cyclonic storm on 25 April. The cyclone in its initial stage moved slightly northwest and then north. From 28 April it started moving in a north-easterly direction and crossed the Bangladesh coast north of Chittagong port during the night of the 29th April. The cyclone started affecting the coastal islands like Nijhum Dwip,

	Manpura, Bhola and Sandwip from the evening of that day. The maximum storm surge height during this cyclone was estimated to be about 5 to 8m.
1988 (24-30 November)	Jessore, Kushtia, Faridpur, offshore islands and chars of Barisal, Satkhira, Bagherhat and Khulna; severe cyclonic storm with core wind speed 162 km/hr, storm surge of 4.5m at Mongla point; killed 5,708 persons and lot of wild animals - deer 15,000, Royal Bengal Tiger 9, cattle 65,000 and crops damaged worth about Tk 9.41 billion
1986 (8-9 November)	Offshore island and chars of Chittagong, Barisal, Patuakhali and Noakhali; cyclonic storm hit 110 km/hr at Chittagong and 90/hr at Khulna; 14 persons killed, damaged 97,200 ha of paddy fields, damage to schools, mosques, warehouses, hospitals, houses and buildings at Amtali upazila in Barguna
1985 (24-25 May)	Chittagong, Cox's Bazar, Noakhali and their offshore islands (Sandwip, Hatiya, and Urirchar); severe cyclonic storm, wind speed Chittagong 154 km/hr, Sandwip 140 km/hr, Cox's Bazar 100 km/hr and storm surge of 3.0-4.6m; about 11,069 persons killed, 94,379 houses damaged, livestock lost 135,033 and road damaged 74 km, embankments damaged
1983 (5-9 November)	Chittagong, Cox's Bazar coast near Kutubdia and the low lying areas of St Martin's Island, Teknaf, Ukhia, Moipong, Sonadia, Barisal, Patuakhali and Noakhali; severe cyclonic storm (hurricane) with a wind speed of 136 km/hr and a storm surge of 1.52m height; 300 fishermen with 50 boats missing and 2,000 houses destroyed
1977 (9-12 May)	Khulna, Noakhali, Patuakhali, Barisal, Chittagong and offshore islands; cyclonic storm with a wind speed of 112.63 km/hr; exact figures of the loss of lives and cattle are not available
1975 (9-12 May)	Bhola, Cox's Bazar and Khulna; severe cyclonic storm with a wind speed of 96.5 to 112.6 km/hr, 5 persons killed and a number of fishermen missing

1974 (24-28 November)	Coastal belt from Cox's Bazar to Chittagong and offshore islands; severe cyclonic storm with a wind speed of 161 km/hr and storm surge of 2.8-5.2 m; 200 people killed, 1000 cattle lost and 2,300 houses perished
1971 (28-30 November)	Sundarban coast; cyclonic storm with a wind speed of 97-113 km/hr and storm surge of less than 1m; Khulna district experienced stormy weather and low lying areas of Khulna town inundated
1970 (12-13 November)	The most deadly and devastating cyclonic storm that caused the highest casualty in the history of Bangladesh. Chittagong was battered by hurricane winds. It also hit Barguna, Khepupara, Patuakhali, and north of Char Burhanuddin, Char Tazumuddin and south of Majidi, Haringhata and caused heavy loss of lives and damage to crops and property. Officially the death figure was put at 500,000 but it could be more. A total of 38,000 marine and 77,000 inland fishermen were affected by the cyclone. It was estimated that some 46,000 inland fishermen operating in the cyclone affected region lost their lives. More than 20,000 fishing boats were destroyed; the damage to property and crops was colossal. Over one million cattle head were reported lost. More than 400,000 houses and 3,500 educational institutions were damaged. The maximum recorded wind speed of the 1970 cyclone was about 222 km/hr and the maximum storm surge height was about 10.6m and the cyclone occurred during high-tide

Source: Banglapedia, (2008) web site; SEHD, 2002; Times online, 2007 and news papers, 2007 & 2008.

## **2.6. Livelihood Security**

Household Livelihood Security (HLS) is defined as adequate and sustainable access to income and resources to meet basic needs (including adequate access to food, potable water, health facilities, educational opportunities, housing and time for community participation and social integration) with concerning all opportunities and vulnerabilities. The Household Livelihood Security assessment is a holistic and multi-disciplinary analysis which recognizes that poor families commonly suffer more than one problem at a time and often have to make significant sacrifices to meet their basic needs' (CARE, 2002).

Livelihood security concept for coastal area of Bangladesh addresses the coastal vulnerabilities and livelihoods characteristics. It shows the importance of livelihood safety dimension covered within the broad umbrella of livelihood resource security. It also aims to enhance understanding about coastal livelihood systems, economic, socio-cultural and political systems and the constraints, vulnerabilities, marginalization, and risks of poor families living within this context; it treats differences intra and inter-household as well (Scoones, 1998). A household with a diversified asset base keeps better position to maximize household well-being by attaining a higher level of income, consumption, comfort and security, and diversifying risk as well. People in the coast are always active to save their living and make control over their resources or assets which is the base of their livelihood (Chambers, 1989). Livelihood insecurity in coastal area of Bangladesh is highly related to storm surge vulnerability in recent period.

## **2.7. Indicator Development and Multi-Criteria Decision Making**

An indicator is a parameter or a value derived from parameters, which points to; provides information about and describes the state of an environment with significance extending beyond that directly associated with the parameter value (OECD, 1998). Indicators are used to systematize the definition and description of information needs and collection of information from different national, international, institutional management levels. An

indicator can be defined as a variable or an aggregate set of variables giving information of a system, process or state and which has significance beyond its face value. Indicators simplify, quantify and communicate information for a variety of purpose including policy assessment and development.

Indicator must help to clarify objectives and set priorities; they are explanatory tools (Hardi & Barg, 1997; World Bank, 1997) which contribute to the translation of the sustainability concept into practical terms. Indicators are becoming increasingly important in summarizing progress of development-related activities and researches. However, there continues to be a lack of consensus on both definition and application of indicators. Whilst there is basic agreement that indicators “serve to indicate or give a suggestion of something; an indication”, there is still disagreement as to what form that indication takes. Another area of disagreement is over the respective merits of qualitative or quantitative indicators (Chadwick *at al*, 2003).

Multi-Criteria Decision Making (MCDM) has been one of the fastest growing problem areas in many disciplines. The central problem is how to evaluate a set of alternatives in terms of a number of criteria. Multi Criteria Decision Making (MCDM) methods provide a framework for rational choice of different alternatives by identifying relevant criteria, evaluating a weighted score for each alternative that reflects its strength of preference (Goodwin and Wright, 1998). The most useful MCDM methods for social management sector are-

- a) AHP and
- b) FHDM

**AHP-** Analytic Hierarchy Process (Saaty, 1982) is a popular and pragmatic quantitative decision method. It provides a practical method to transform comparative descriptions of the problem elements into weights for the selection criteria and scores for the alternatives. The AHP technique is based on the premise that given a set of alternatives, a decision-maker chooses the alternative that provides the largest aggregate value for the benefits. It

ignores the case where AHP is used to compute costs of the alternatives (Malhotra, 2001).

**FHDM-** Fuzzy Hierarchical Decision Making is a method of suitability judgment or optimal solution determination in decision problems and mathematical programs (Zimmermann, 1990). This method is more applicable for Technology choice.

In assessment of livelihood security, indicators development emanates from the necessity to operationally the term of sustainable livelihood security and evaluates the development followed on the basis of environmental and socio-cultural criteria besides the economic ones. So it is needed to describe an approach for the identification of suitable indicators, by linking with the research objectives to develop a livelihood security model for a specific field.

# 1

## CHAPTER THREE

### METHODOLOGY

#### 3.1. Selection of Coastal Livelihood Groups

Livelihoods in rural Bangladesh are rapidly diversifying (Toufique and Turton, 2002) and the pre-study field observation confirms that it is more applied for the coastal zone. Livelihoods differ strongly in different environmental, social and institutional settings along the coast. Individuals of the coastal community engage in a variety of activities that means one day a man may spend working as a day laborer for a medium farmer, another day moving earth in a GOB project, then he may go off to the city to sell cattle, return to catch fish or save cash by repairing their house. The senior women in that household is likely to be involved in a number of cash-saving activities such as collecting cow dung, firewood, or if these are not available leaves for fuel.

Member of Coastal households perform a host of activities to earn their living. Choices are conditioned by the extent of respective asset base : a more diversified asset base provides more options and is in a better position of maximize household well being by attaining a heigher level of income, consumption, comfort and security.

Considering that situation the first step of the study entailed an analysis of existing information sources which provide preliminary understanding of the livelihood pattern in the coastal area of Bangladesh. This part of the study tried to identify the major livelihoods around the main occupation of the poorer section (marginal people) of coastal society and the major livelihood groups of coastal people have been listed for this study:

- I. Fisher
- II. Farmer
- III. Dry Fisher
- IV. Fry collector
- V. Salt farmer
- VI. Forest extractor
- VII. Wage laborer

Mentioned coastal livelihood groups have been selected based on the following points:

- Activities of these groups are of seasonal nature (main product extracted specific time of the year) and cyclonic storm surge generally occur in the pre monsoon and post monsoon which are the peak time of production
- All these groups depend on natural coastal resources for their basic income and cyclone accompanied by tidal surges are the most damaging natural disaster which takes a heavy toll on life and property of these groups in following ways
  - Agro-products and salt are washed away from the field
  - Fishers cannot go to the sea
  - Houses are damaged
  - The daily life of the people is severely disturbed they cannot collect fodder, fuel and water and cannot perform other chores like cooking and washing
  - Sanitation systems are also damaged

Actually it was quite difficult to consider all livelihoods of Bangladesh coast for such short term study. So, when the issue is specified as storm surge, considering all secondary information and field observation (Initial survey), that list of major coastal livelihoods has been selected to make progress in next part of the study.

### **3.2. Selection of Sampling Area**

The level of livelihood insecurity (caused by storm surge hazard) can be determined through establishing a true concept about the location on the coast where the define livelihood groups live (CEGIS, 2004). In present study, the vast coast of Bangladesh has been divided based on its physical and geographic settings. The western part of the coast has been defined as area protected by the Sundarbans and rest part as open zone along the Bay of Bengal including estuaries and beaches.



The area has been selected considering the following representative criteria:

- The area should be within high or moderate storm surge risk zone
- The area should have remarkable vulnerabilities on livelihood resources due to cyclonic storm surge
- The area should have represented the residence of selected livelihood groups totally or partially

So within the 19 districts, the partial coastal area of two main coastal districts of Bangladesh have been selected primarily for the study in which people of the defined coastal occupational categories are found (Ahmed, 2003); one is Satkhira district (mangrove protected) and another is Cox's bazaar district (open shore). Cox's bazaar Sadar thana of Cox's bazaar district (nearer to the Bay of Bengal) and Shyamnagar thana of Satkhira district (nearest to the Sundarbans) have been selected depending on literature survey. Those are fully different with their physical and biological characteristics but the defined livelihood groups are in danger due to certain water based issue.

**Table 3.1:** Selected study areas.

District	No. of Thana	Selected Thana	No. of Unions	No. of Selected Union	Name of Union	No. of villages	No. of selected village	Selected villages
Satkhira	7	Shamnagar	13	1	Munshiganj	18	2	Harinagar Shinghortoli
Cox's bazar	7	Cox's bazaar Sadar	10	2	Khurushkul Jhilonja	7 6	1 1	Gazir dail Nazirartek

Source: Survey 2008.

The selected field has been fixed as two villages in two unions from Cox's bazaar Sadar of Cox's bazaar district and two villages in one union from Shyamnagar of Saikhira district where diversified coastal livelihood groups have been located. It has been finalized through certain thana level reconnaissance survey.

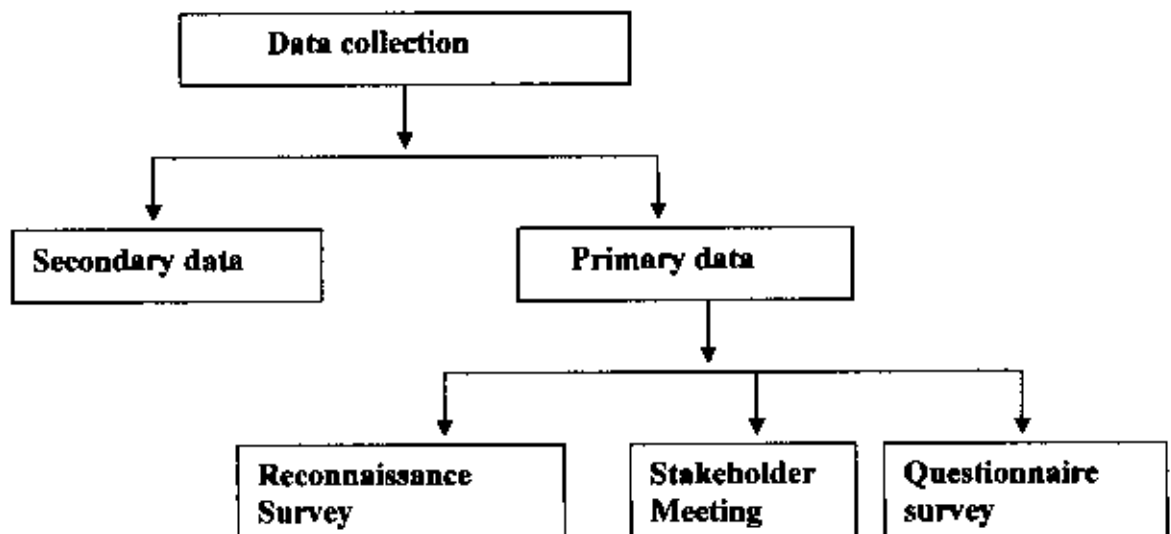
### 3.3. Methodology of Model Formulation

Livelihood security model has been introduced as a tool of facilitating asset creation, capacity building and access to various opportunities. It has been developed with viewing aim of reducing vulnerabilities and promotes Livelihood Security for coastal community of Bangladesh against the devastating hazard defined by Storm surge.

In this study, the methodology has been formed to develop a model to assess the level of livelihood security with better understand of storm surge adaptation or more precisely to address the living system of coastal community in vulnerable environmental condition.

#### 3.3.1. Methodology of data collection

Data collection of this study has been conducted through the following methods:



### 3.3.1.1. Literature review and secondary data collection

Secondary data regarding location and geography of the study area, demography, land use and livelihood practices in coastal zone of Bangladesh were collected from relevant books, News paper reports and publications. Other required specific information were also collected from different published and unpublished reports/research reports/journals of Bangladesh Bureau of Statistics; Local Government Engineering Department (Dhaka); PDO-Integrated Coastal Zone Management office; Asian Development Bank; CEGIS-Bangladesh; Bangladesh Academy for Rural Development (BARD), Comilla; Bangladesh University of Engineering and Technology, relevant websites and other government and non-government organizations.

### 3.3.1.2. Primary data collection

A combination of methods has been used for primary data and information collection. The principal methods used were direct observation, questionnaire survey and key informants interview, Focus Stakeholder Meeting (FSM), etc. The pair wise ranking of indicators for AHP has also been conducted through FSM.

#### Reconnaissance Survey

The reconnaissance survey has been conducted in exposed coastal part of both south-west (Satkhira) and south- east (Cox's bazar) coastal districts to invent the livelihood options of the coast. It was done to get the initial impression of the study area in order to facilitate the research technique. In this study coastal settings and environmental concerns were considered specifically.

The major concern areas for the survey were:

- The resource system in and around the coastal area
- The livelihood pattern inventory in the coastal community
- The condition and extend of storm surge in study area
- The major vulnerabilities and opportunities in coastal living system

*Preparation of questionnaire and checklist*

The questionnaire has been prepared based on the reconnaissance survey findings in order to collect necessary data. The major concerned areas for collecting data through questionnaire were:

- The population size and structure of the area
- Livelihood activities per household unit
- Availability of household assets (Natural, Economic, Social and Human) of coastal people
- Access to common coastal resources (Social, institutional etc.) of the livelihood groups
- Impacts of storm surge (Two at recent time) on the community and the environment
- Experience during SIDR (Devastating cyclonic storm surge at 2007)
- Preparedness program to face the Storm surge hazard

In addition, there were a checklist for Stakeholder Meetings (Appendix-B) and an Information Collection Sheet (Appendix-A) for finding some special information from officials and people work with relevant issue in that area.

*Selection of sampling unit*

Households have been selected as sampling unit because in a livelihood system household is the unit of economic and social activities, vulnerabilities and opportunities. People of each household have been defined as the principal respondent and main source of data and information. During the survey, an attempt has been taken to interview the head of the household and marked it as group of his or her occupation. It has been framed because most of the household having some subsidiary activities of different member of the family but not play major roll in their living. In absence of the head of the household; the next senior most member of the family has been selected.

Sample size determination

For questionnaire survey in order to assess the vulnerability due to storm surge hazard on coastal livelihood systems and options in the selected study area, simple stratified random sampling method has been followed. Sample has been proportionately random based on the size of the population of the study area.

The sample size for the study was obtained from the following equation (Kothari, 2001).

$$n = z^2 pqN / \{e^2 (N-1) + z^2 pq\} \dots\dots\dots (a)$$

Where,

n is the sample size considering the finite Household

z is the level of confidence desired

p is the true proportion of the population with attribute to be determined

q = 1-p

e = the sampling error permitted

N = Total household of the study area

This study has been conducted considering about 20% households of Munshiganj union were found in the selected two villages with the risk of storm surge and in both two union of Cox's bazaar.

Where;

z = 1.96 (For 95% confidence level the value of z)

e = 0.1 [Since the error margin estimate should be within 10% of the true value]

P = 25% of the household (i.e. 0.25)

q = 0.75 and

N = 20054 (For Cox's bazaar)

N = 6566 (For Satkhira)

According to the above equation the sample size for this study were 70 households in Munshiganj, Salkhira and 70 households in Kuruskul and Jilangja, Cox's bazaar with random survey.

#### Focus Stakeholder Meeting (FSM)

Member of different organization such as Local Government, NGO of related field and others have been selected for collecting relevant data and justifying the information received from principal stakeholders. FSMs were conducted to receive qualitative information as to understand the concern factors in livelihood system for development of a livelihood security indicator frame work for coastal area. The focus group comprises of livelihood group members (Min. 3 from each group including 1 woman), local UP member or chairman, and two members from each local development organization or NGOs. In each subproject area two FSMs were conducted in each area with the above mentioned participants. First FSMs have been conducted to understand the situation of local livelihood system and indicator frame work has been developed from that. The second FSMs s have been conducted to find out the standard value of indicators as well as to keep the support for indicator selection strategy AHP by pair wise ranking of indicators to different security options. The checklist for Focus Stakeholder Meeting (FSM) is attached in Appendix-B and pair wise ranking sheets also attached in Appendix-C.

#### Questionnaire survey

Questionnaire survey has been conducted to identify information related to the study area, conceptual frameworks and to major concepts treated in the study (storm surge, adaptation, environment conditions, livelihood resources and opportunities, disaster risks, social access etc.). The effects of recent storm surge on the define livelihood systems were estimated at household level for each different livelihood groups. Information has also been collected and justified from Union Parisad Chairmen, Word Commissioners, NGOs' and people of relevant management activities.

### **3.3.2 Methodology of indicator development and selection**

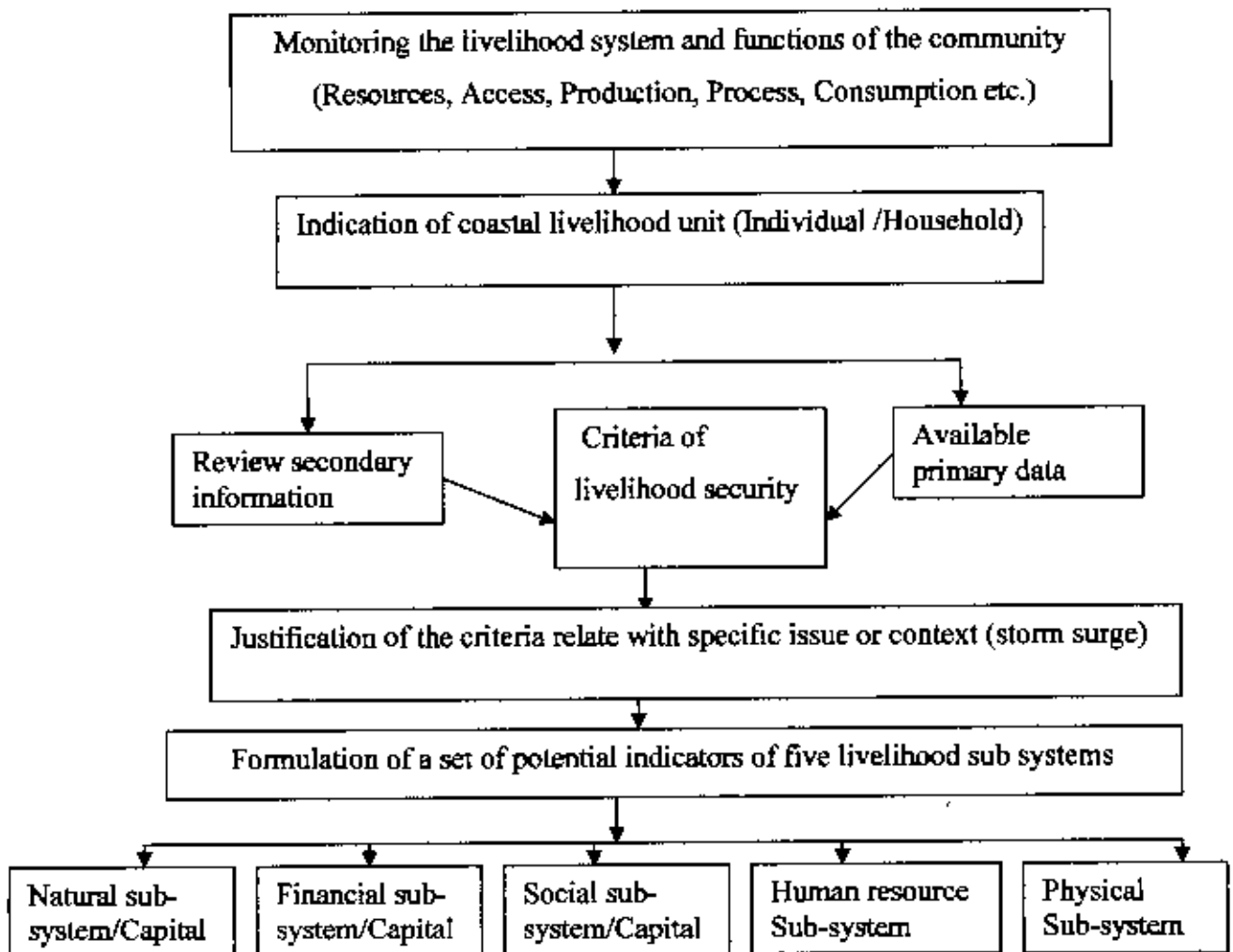
The livelihood activities of coastal population are multidimensional and the livelihood security is a concept to define the real scenario of coastal community with all the risks and vulnerabilities in multiple resources and that idea is closely related to the sustainable development of the coastal community. Based on household assets (ownership and/ or access), members engage in a host of activities to earn their living. Choices are conditioned by the extent of the respective asset base.

In this study the livelihood security model has been constructed through the identification of different livelihood groups of the coastal zone and their area of insecurity caused by storm surge hazard. The measurement of livelihood security has been based on the indicators under different dimensions of livelihood assets and their options in defined coastal areas of Bangladesh.

#### **3.3.2.1. Development of indicator framework**

Based on preliminary field observation, SMs and author's perception with secondary data, documentation and journal review, a set of indicators has been developed. The indicator development process has been continued along the primary field survey because it was dependent on the availability of relevant data and data sources from principal stakeholders. It was important to look at the status of each of the capitals available to households to determine their status due to storm surge issue. Indicators can be grouped under different security approaches considering the resource options such as natural capital, human capital, social capital, institutional capital, physical capital, and economic capital of livelihood groups.

Schematic representation of indicator development process



The final method was-

- ❖ Identification of components of livelihood system that represent the endogenous characteristics of households regarding coastal livelihood assets.
- ❖ Indication of exogenous vulnerability context –storm surge hazard (through literature survey).
- ❖ Identification of storm surge risk on coastal livelihood assets (through literature & field survey).
- ❖ Identification of indicators which represents the security options.



### 3.3.2.2. Selection of indicators to different security options

Indicator choice is a complex decision problem involving many criteria. Livelihood security indicators against storm surge hazard have been selected by applying an established decision-aiding method AHP (Saaty, 1982); a Multi Criteria Decision Making method for each of the defined approaches. This method provides a framework for rational choice of different alternatives (initially developed indicators) by identifying relevant criteria, evaluating a weighted score for each alternative that reflects its strength of preference (Goodwin and Wright, 1998). It also provides a systematic, explicit and robust mechanism for eliciting and quantifying the subject judgment.

**The steps of AHP (Analytic Hierarchy Process) are as follows:**

- ❖ Define the decision criteria in the form of a hierarchy of objectives. This hierarchical structure consists of different levels. The top level is the objective to be achieved. This top level consists of intermediate levels of criteria which depend on subsequent levels. The lowest level consists of list of the alternatives (Indicators).
- ❖ Indicators have been selected from defined livelihood security indicator framework by applying an established decision-aiding method AHP (Saaty, 1982); a Multi Criteria Decision Making method with different livelihood security dimensions such as:
  1. Food security,
  2. Income security,
  3. Health and Personal security,
  4. House and Properties and
  5. Water security
- ❖ For making pair wise comparisons, structure a matrix of size  $(n \times n)$ . the number of judgments required to develop the set of matrix is given by  $n(n-1)/2$ .

- ❖ Obtain the importance of the criteria from experts' judgment by making pair wise comparison. This comparison is made for all levels. Verbal judgment of preferences is shown in Table 3.2.
- ❖ The weight of each criterion has been determined based on field response. By hierarchical synthesis, the priority vectors are calculated. These values are normalized vectors of the matrix.
- ❖ The consistency is determined by using the value,  $\lambda_{\max}$ . For finding the consistency index (CI), the used formula is  $CI = (\lambda_{\max} - n) / (n-1)$ , where n is the size of the matrix.

**Table 3.2.** Pair wise comparison scale for AHP preferences

Numerical Rating	Verbal Judgments of Preference
9	Extremely preferred / important
8	Very strongly to extremely
7	Very strongly preferred / important
6	Strongly to Very strongly
5	Strongly preferred / important
4	Moderately to Strongly
3	Moderately preferred / important
2	Equally to Moderately
1	Equally preferred / important

- ❖ The judgment consistency ratio (CR) is checked from the appropriate value in Table 3.3.
- ❖ The judgment consistency ratio (CR) is simply the ratio of CI to average Random Consistency (RI). The CR is acceptable, if it does not exceed 0.10. if it more, the judgment matrix is inconsistent; then matrix has to be reviewed. These are calculated for the entire matrix structured from the hierarchy.

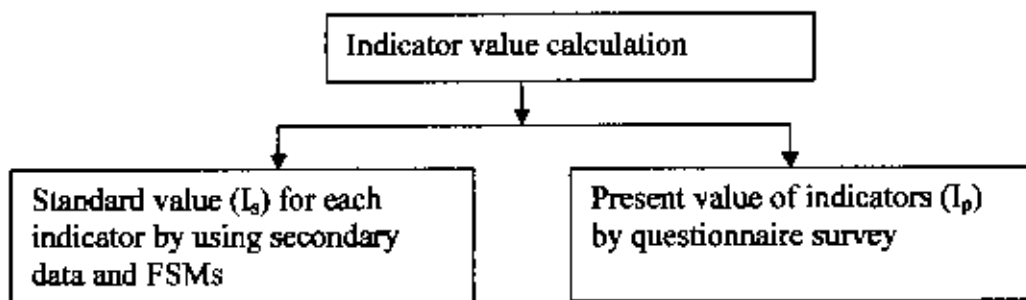
**Table 3.3: Average Random Consistency**

Size of matrix	1	2	3	4	5	6	7	8	9	10
Random Consistency	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Finally top ranked indicators have been selected in each individual security approaches and also have been introduced as the input or initial data of the model.

### 3.3.3. Data analysis

After completing the field survey, all the interview schedules have been grouped and interpreted according to the goal of the research. The collected data have been checked and verified. The quantitative data have been selected out and tabulated into different data sheet. After that these data have been entered in statistical software (such as Microsoft Excel etc.) for calculating the value of developed indicators with standard measurement unit in household level in two steps.



- Calculation the standard value of developed indicators in household level for Coastal area of Bangladesh (Using data from FSMs and Census of Local and National Authority).
- Calculation of the present value of developed indicators in household level of individual livelihood groups which represents the vulnerable situations and their area of insecurity for storm surge risk (using data from questionnaire survey and public opinion).

### 3.3.4. Methodology of security index calculation

Household security of a livelihood group has been measured based on livelihood security Index. In this study, the livelihood security has been considered as a collective form of security approaches such as food and water security, financial security, life and health security and social security that were calculated from the values of related indicators. Initially each security approach have been expressed by qualitative (High, moderate and low) and quantitative form of indicators. All indicators used in the study were not in same units. So there values have been standardized.

**Table 3.4:** Direction for security scores.

Mode	Option
Positive (+)	Security
Negative (-)	Insecurity

The standardization process has transformed the indicator data into one scale having alternative direction (following positive and negative sign) (Table 3.4).

**Table 3.5:** Scale of security

Difference level	Score
High	3
Moderate	2
Low	1

The standard scale has been assigned with the level of difference between Standard value and measured value (Survey data of study area) of selective indicators for unit household (either a percentage scale of difference level were highest to lowest or a 3 point scale) (Table 3.5).

Firstly Livelihood Security Index of a household for individual security aspect has been developed; secondly a composite security index for that household consisting of different aspects is designed.

The household level livelihood security model has been formed conceptually and physically using the index that discussed details in Model Development chapter. It has been tried to use the model by defining the different degree of livelihood security of diversified group in coastal Bangladesh.

## **CHAPTER FOUR**

### **LIVELIHOOD GROUPS IN THE STUDY AREA**

#### **4.1. Introduction**

Livelihood is synonymous to occupation and means to sustain a person or a household. Based on assets and access to resources and opportunities, households decide what activities it will pursue for living. The composition of resources at the disposal of a household generally determines the choice of activities. In present study, the unique livelihood system of coastal community of Bangladesh has been defined based on different reviewed literature. It also has been found that People's access to different levels and combinations of assets had a major influence on the choice of livelihood. Different livelihood activities have different requirements.

According to Population Census 2001, there are 6.85 million households in the coastal zone of Bangladesh with a population of 35.1 million (BBS 2001). The pattern of household livelihood distribution of that coast is different from the rest of the country. Coastal livelihood groups are those who earn their living from activities defined by coastal conditions. The livelihood activities of coastal population are multidimensional.

The livelihoods of coastal people develop depending on marine resources, beach resources, estuary, rivers and forest resources with combination of relevant activities. They often vary from each other in terms of production relations and marketing. Some work independently (fry collector), some work as lessee or sharecropper (salt farmer, shrimp farmer) and some are contractual laborer. Some live on exploitation of natural resources (salt farmer, fry collector, fisher, honey collector) and some live on skill-based human resources (boat-building carpentry, net making). For this study, livelihood groups have been identified base on vulnerability of storm surge. The storm surge risk is dominant for the people who live in marginal level in coast and fully depend on natural resources of coast. The profiles of selected livelihood groups in the coastal zone of Bangladesh are briefly presented below.

## 4.2. Selected Livelihood Groups

The selected livelihood groups are defined as follows:

- **Farmer Group**

Farmers are defined by their major income from agriculture sector. A specific characteristic of this category is that they are often least able/willing to diversify their livelihood activities in coastal area. Because they have to regularly maintain their crops and livestock they do not easily accept daily wage employment. Even if such work were flexible and available nearby, social reasons sometimes make it difficult for these households to work for others. In the marginal level farmers keep higher household resources. On the other hand, natural disaster like storm surges cause great damage to them in coast because of their income or production pattern. So that their numbers and precarious position around the poverty line deserve a closer look. There are 1.72 million small farmer households in the coastal zone, constituting 32.1 percent of the coastal rural households; the percentage of farmer is higher mostly in Pirojpur, Barisal, Shariatpur, Narail, Jessore, Satkhira, Patuakhali and Barguna, which is about 30% and above. On the other hand, lower proportion of farmers is found in Chittagong and Chandpur districts.

- **Fisher Group**

Eight percent of rural households in Bangladesh live on fishing (ICZMP, 2004). But in the coastal zone, fishing is the predominant source of livelihood for 14 percent farm households (BBS, 2001). They operate in the estuary, on coastal waters and sometimes in the deep sea. The estimated number of fisher households as of 2001 is over half a million with a population of about 2.65 million. Monsoon months are the main fishing season characterized by inclement weather (Islam, 2004). In Bangladesh the marginal fisher group is generally live near the coast line without any protection structure and they are more vulnerable by both natural and social aspect. A small stratum of *Makazon* (boat-owners), who also own nets, and liquid cash, control fishers' lives. With increasing poverty at one end (landlessness) and growing entrepreneurship at the other end (investments in boat and gear), more and more people are encroaching into the domain of traditional fishers, and fish resources along the coast are dwindling fast. The percentage

of fishermen is almost equal throughout the coastal region with slight higher in Cox's Bazaar, Bhola, Barisal Patuakhali and south-western coastal districts.

- **Salt Farmer Group**

Coastal people of Bangladesh had a tradition of producing salt by boiling sea water. The first commercially salt production was started in 1947 in the area of Cox's bazaar and Chittagong district (CDS, 2006). Since then the salt production rate is gradually increasing to meet the ever-growing demand. Now salt farming is overwhelmingly concentrated in Sadar upazila; Ramu, Maheshkhali, Kutubdia, Chakaria, Teknaf upazila in Cox's bazaar district and Bashkhali upazila of Chittagong district. About 15 percent of total rural households of Cox's bazaar district are salt farmers. They meet bulk of the demand for raw salt in the country. Salt farmers are mostly poor and operate on a small scale. Their average size of farm is 0.62 ha (PDO-ICZMP, 2004). They work under adverse conditions. This is a hardworking job that interests only the poor and the landless. Many of them lease in land from others. They are in close proximity to the open sea and often face all the hazards coming from the sea. Sometimes the whole output is washed away by heavy rain and storm surge because of lack of proper warning system and storage facility.

- **Fry Collector Group**

Estimated number of fry collectors in the coastal zone was about half a million (Frankenberger, 2002). The number has now come down almost to fifty percent. A large number of them are children and women. The cycle of fry collection is from mid-February to mid-August. In Satkhira-Khulna region, the main period of fry collection is mid-November to mid-July. However, *golda* fry is collected round the year, though the peak season is April-May. Collectors substantially depend on the shrimp sector deriving 41 percent of their household income (PDO-ICZMP, 2004). The number of fry collectors is high in some districts, which indicate the dependence of poor people on this particular activity. Although shrimp farms are more concentrated in the greater Cox's bazaar district, there are fewer fry collectors from other region. Opportunity (or lack of



opportunity) for gainful employment in other activities is plausible explanation for this employment pattern.

- **Dry Fisher Group**

People of coastal Bangladesh keep another traditional activity defined as drying fish. In the previous period the fisher groups involved in that opportunity only. But now it can be defined as an individual livelihood group because a large percentage of coastal people live depending on that only. The dry fisher lives generally in the area of open shore and in Char area. They largely work in dry season when there is higher sun shine without huge rainfall. Cox's bazaar sadar, St. martin, Moheshkhali, Chokoria etc. are the main field of dry fish. Chittagang and Char districts are also under the opportunity. This group of people earns their living through collecting fishes from fisher groups, processing them and sale to local and national market. Some dry fishers involves in direct fishing. In Chittagang and Cox's bazaar districts a lot of Shutki mahals (Fish drying yard) are found in the dry season of the year.

- **Forest Resource Extractor Group**

In Bangladesh coast many households depend on forest resources for their livelihood because of its mangrove rich coast line. In the impact zone of Sundarban (in surrounding upazilas), 18 percent households are dependent ou Sundarban resources. The proportion of Sundarban dependent households varies in South-west coast from Pirojpur district to Satkhira district. Among them the main sub-groups are *bawalies* (Wouidcutter), golpata collectors, shell/crab collectors *mawalies* (honey collector), and medicinal plant collectors and some jele (fisher), (SBCP, 2001). Many poor households depend on recently planted forests in *chars* and islands in Patuakhali, Bhola and Noakhali for fuel wood and materials for house construction. They are to work amidst various insecurities corresponding to threats from natural hazard, wild animals, and intimidation from public institutions.

- **Wage Labor Group**

People working in agriculture and non-agriculture sectors, either in urban or rural areas, are considered as wage labors, who earn their livings on daily basis. As per population census 2001, 0.15 million household constitute “labor” group, which is about 24% of total household in coastal zone. They are one of the largest occupational groups in coastal rural households. Generally the proportion of agricultural and shrimp field labor is higher in rural areas and non-agriculture labor is higher in urban areas. For the present study, the rural wage group has been selected mainly. They are engaged in diverse activities. Majority of them (55%) are small farmers (with operated area less than 1 ha) and 43 percent are landless (owning less than 0.02 ha) (PDO-ICZMP, 2003). Distinct livelihood conditions of this group are characterized by: Seasonal employment/ unemployment; Low demand for labor in most periods of the year in most parts of the coast, as vast areas are single-cropped; Low wage in the lean season (period between plantation and harvesting); Discriminatory wage for women; and Chronic indebtedness. Spatially, the proportion of labor is almost similar on all over the region, except higher percentage in Cox’s Bazaar, Patuakhali, Chandpur and Jessore and Satkhira districts.

In this research, the study area has been selected depending on diversified geographic location and level of storm surge vulnerability of the coastal districts. It has also considered that the presence of selected livelihood groups in that area. The details of study area have given here.

### **4.3. Study Area**

The remote coastal parts of Cox’s bazaar and Satkhira district have been selected as the study area as both of the sites are located within the path of cyclonic storm which occurred recent years (1988-2008). The geographical setting is also an important term of concern such as the district Cox’s bazaar along on open sea shore (the longest beach of the world) on the other side the coast line of district Satkhira is fully covered by the largest mangroves Sundarban. Those geographical variations also influence the development of varieties of coastal livelihood groups in those areas.

**Site 1:**

- a. Cox's Bazar Upazilla – Jhilonja Union: 79205 people from 14018 households
- b. Cox's Bazar Upazilla – Khurushkul Union: 38615 people from 6036 households

The study area of Cox's bazaar Sadar Upazila of Cox's bazaar district, located in the far south-eastern corner of Bangladesh with a latitude between  $20^{\circ}$ -  $21^{\circ}$ N and a longitude of  $92^{\circ}$ E, the site generally lies along the western coastal zone of the Teknaf Peninsula near the open beach along the Bay of Bengal (CWBMP, 2006). As at open shore, the area is being denoted as higher risk area for cyclone and storm surge (WARPO, 2004).

The sites of western and southern boundaries are delineated by waterways – the western boundary by the Moheshkhali Channel from the Bay of Bengal up the channel as far as Ghorokghata; the southern boundary by the beach along the Bay of Bengal. The river Backkhali is blowing over the area and meets to Moheshkhali Channel (Survey, 2008). The study area covers part of two unions of Cox's bazaar Upazila named by Khurushkul and Jhilonja (Fig 4.1) having diversified livelihood groups of marginal coastal community in Bangladesh.

**Site 2:**

Shyamnagar Upazilla – Munshiganj Union: 33,700 people from 6566 households.

The study area of Shyamnagar upazila of Satkhira district, located in the south-west boarder of Bangladesh with a latitude between  $21^{\circ} 50''$ - $22^{\circ} 50''$ N and a longitude of  $89^{\circ}$  E, along the Sundarbans (Banglapedia, 2008). The site's and south-eastern corner boundary is delineated by Malancha River and the total eastern part is lined by mangrove Sundarban. The area is naturally protected by the mangroves and the area is located as moderate risk zone in disaster map of Bangladesh (WARPO, 2004). The specific study area is defined as the Munshiganj union of Shyamnagar Upazila as shown in Fig 4.1.

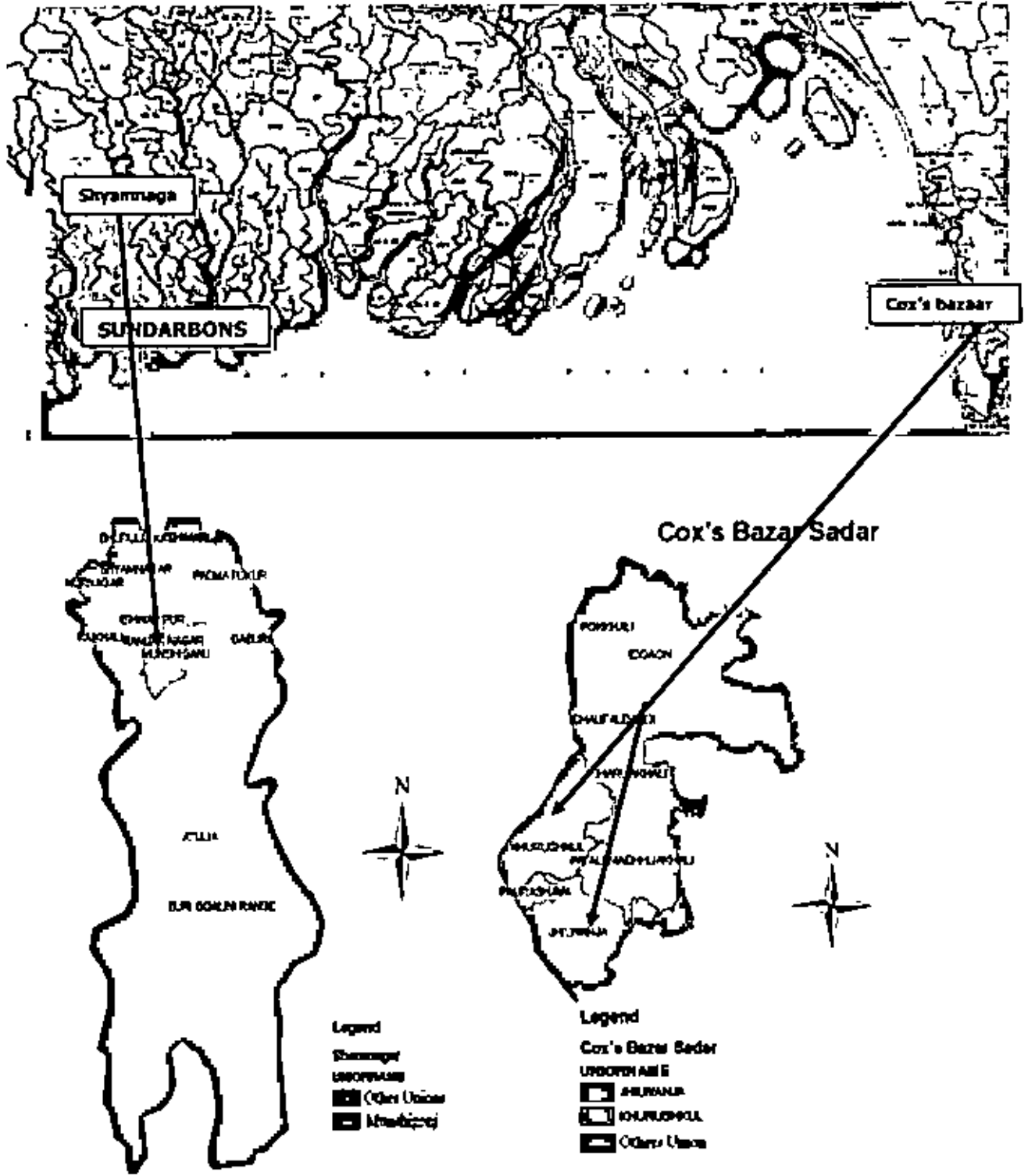


Fig 4.1: Location map of the both study sites in Coastal Zone of Bangladesh.

#### 4.3.1. Cox's bazaar district

Administration of Cox's Bazar Sadar was established under Cox's bazaar district in 1854 and was turned into an Upazila in 1983 (CWBMP 2006). It consists of 10 Union Parishads, 1 municipality, 37 mouzas and 140 villages from which two unions have been selected partially for the study.

The other details are in below-

**Climate:** The climate of Cox's bazaar is as moist tropical maritime with high rainfall concentrated during monsoon (usually June-September) and a dry period of 4-5 months. Average annual rainfall for Cox's Bazaar for 1987-1996 varied from 2,867 mm to 4,684 mm. The temperature remains high year-round with small seasonal differences – the mean annual maximum and minimum temperatures recorded at Cox's Bazaar for 1987-1996 were 30.3°C – 33.0°C and 19.3°C-22.4°C respectively. Humidity remains relatively high throughout the year; it averaged 79.7% at Cox's Bazaar for 1987-1996. From November-February the prevailing winds are from the north-west, from March-May from the south-west and from June-September from the south-east. The site is particularly susceptible to cyclones and tidal surges (CWBMP 2006). Cyclonic storms develop in the Bay, generally in April-May and October-November, occasionally coming to shore and causing severe damage to human settlements and vegetation. As a result of climate change, sea level rises of up to 43 cm are expected by 2050 and more frequent and extensive cyclones and tidal effects are expected. Historical tidal data for the 22 years to 2005 at the Cox's Bazaar coastal station has shown a sea level rise of 7.8 mm/annum, which is many times more than the mean rate of global sea level rises over the past 100 years (MoEF, 2005a).

**Hydrology and Land use:** The Moheshkhali Channel and Bak-khali and Naaf Rivers are the main waterways. The Moheshkhali Channel flows into the Bay of Bengal near Cox's Bazaar and forms the north western boundary of the site. The Bak-khali River originates in the Chittagong Hill Tracts and also flows into bay near Cox's Bazaar. The site's eastern boundary includes approximately 10 km of the 30 km Naaf River estuary, which

forms the boundary between Bangladesh and Myanmar. On the coastal side of the site, five main canals run from the Peninsula's hilly hinterland to the bay including the Reju, Inani, Mankhali, Rajarchora and Mathabhanga Canals. In Cox's bazaar the total cultivable land is estimated as 8881.02 hectares, land for salt production 1011.74 hectares, land for shrimp cultivation 1214.08 hectares, forest area 7703.36 hectares, fallow land 270.74 hectares; single crop 32.63%, double crop 65.6%, triple crop 1.77%. Rubber dam has been installed on the Bakkhali and Idgah rivers for irrigation purposes (POUSH, 2005).

**Biological Habitats/Communities:** The area acts as a corridor between terrestrial and marine biodiversity, with the site's habitats including sand dunes and heaches, mudflats, mangrove and estuaries. The sandy beach extends the length of the site from Moheshkhali Channel in the north to the tip of the Teknaf Peninsula in the south. Sand dunes occur along the beach, with dune vegetation distinguishable between several zones (Rahman, *et al.*, 2001). Vegetation is relatively sparse with few plants in the open pioneer zone immediately preceding the drift line.

The vegetation is denser in the herbaceous zone with some mat forming herbs, and a mixture of herbaceous plants and shrubs including climbing species occurs in the middle mixed or bushy zone. Tree species interspersed with patches of low marshy areas dominate the inner inland zone, which merges into the hinterland of wastelands and cultivated fields. Inter-tidal mudflats along the Naaf River are suitable wader feeding ground. Sparse patches of naturally occurring mangrove occur along the estuarine muddy banks of *khals* running down the hills, adjacent to the sand dunes along the coast line. Small patches of natural mangrove thickets occur sporadically along the Naaf River riverbanks. The major estuaries of the site include the Moheshkhali Channel and Bakkhali River in the north which provide significant habitat for flora and fauna including mudflats and mangrove.

**Local community and stakeholders:** The results of a stake holder analysis for the study conducted by Primary stakeholders – the local community. The site has a total population of 330,313 people in 49,736 households (POUSH, 2006b).The population is a mix of religions, ethnic and social groups, including refugees from Myanmar (Rohingya) (DOE, 1999). The main livelihoods among the local community include:

. Farming	Laboring
. Fishing	Shrimp fry collecting
. Fish drying	Salt production

Without that resource base livelihoods there are some skill base acts such as Fish business, Hunting and poaching, Timber business, Boat operation, net repairing and others. However, of the resource depending livelihoods, fishing, farming and Wage labor are the main occupations comprising 42%, 24% and 17% of occupations respectively. However in terms of household income fishing provided by far the highest income (almost double that of the next highest income source), then remittances, followed by farming then fish business, then labour (CWBMP 2006).

Socio-economic indicators for that part of Teknaf Peninsula (DOE, 1999) showed a literacy rate of between 28 - 48% depending on the area within the site (19.9- 30% for females) and 67 % had some type of sanitation facility. The general observation survey found 20% of the population was poor (can work in rural site, slightly smaller family, own very small amount of land), 60% were middle class (have land and fishing boats of their own, involved in shrimp projects/trade) and 20% were rich (no definition provided) (DOE, 1998). For the present study the people of rural settings has been consider as the storm surge vulnerable groups.

### 4.3.2. Satkhira district

Administration of Satkhira subdivision was established in 1861 under Jessore district. It was included into Khulna district in 1882. The subdivision was turned into a district in 1984 as a result of the administrative decentralisation. The district consists of 2 municipalities, 18 wards, 41 mahallas, 7 upazilas, 79 union parishads, 953 mouzzas and 1436 villages. The upazilas are SATKHIRA SADAR, ASSASUNI, DEBHATA, KALAROA, KALIGANI, SHYAMNAGAR and TALA (Banglapedia, 2008).

The other details is in below-

**Climate:** The climate of Satkhira district falls on south-western climatic sub-zone of Bangladesh. It is as moist tropical region with high rainfall concentrated during monsoon (usually June-September) and a dry period of 4-5 months. Average annual rainfall for Satkhira varied from 197.7 cm per year (CDP, 2003). But in recent time rainfall rate tremendously decreasing within last four years. The temperature remains maximum 31<sup>o</sup>C and minimum 16<sup>o</sup>C with great seasonal differences in that area (Banglapedia, 2008). Humidity remains relatively high throughout the year; it averaged 79.7% at Satkhira at 1988-1999. From November-February the prevailing winds are from the north-west, from March-May from the south-west and from June-September from the south-east. The site is in moderate risk to cyclones and tidal surges (Karim and Tutu, 2005). But Cyclonic storms develop in the Bay, generally in April-May and October-November, occasionally coming to land area and causing severe damage to human settlements and vegetation.

**Hydrology and Land use:** The Shingortoli Channel and Malancha River are the main waterways in the specific union in study area. The other main rivers are of Kalindi, Kobadak, Mother Kholpetua, Arpangachia, Malancha, Hariabhanga and Chuna. South Talpatti Island at the estuary of the Hariabhanga is notable. The river and channels have decreased their own capacity more in that area because of improper management system and lack of environmental law and regulation (DOE, 1999). The disturbed hydrological system is more influencing to the risk of storm surge. There are a lot of ponds and extend shrimp farms are found here in the following area. The land use patterns keep mainly agricultural land and shrimp fields (Field survey, 2008).



**Biological Habitats/Communities:** The area acts as a corridor between terrestrial and marine biodiversity, with the site's habitats including mudflats, mangrove and estuaries. The vegetation is largely of mangrove type and encompasses a variety of plants including trees, shrubs, grasses, epiphytes, and lianas. Being mostly evergreen, they possess more or less similar physiological and structural adaptations. Most trees have pneumatophores for aerial respiration. The ecological diversity of the Sundarbans supports a large variety of birds. Among the total number of species recorded, most are resident. Over 50 species are known to be migratory and are mostly represented by the waterfowls (Sarkar, 2004). The egrets, storks, herons, bitterns, sandpipers, curlew, and numerous other waders are seen along the muddy banks.

**Local community and stakeholders:** The population is a mix of religions, ethnic and social groups. The main livelihoods among the local community include:

Farming	Laboring
Fishing	Shrimp fry collecting
Forest Extractor	

Without that resource base livelihoods there are some skill base acts such as Fish business, Hunting and poaching, Timber business, Boat operation, net repairing and others. However, of the resource depending livelihoods, fishing, farming, forest extracting and Wage labor are the main occupations and in terms of household income Farmer and forest extractor provided by far the highest income. Socio-economic indicators for that part showed a literacy rate of between 14 - 38% depending on the area within the site (9.0- 20% for females) and 56 % had some type of sanitation facility (CDP, 2003). The stockholders of that coast traditionally depend on agriculture and the forest (Field survey, 2008).

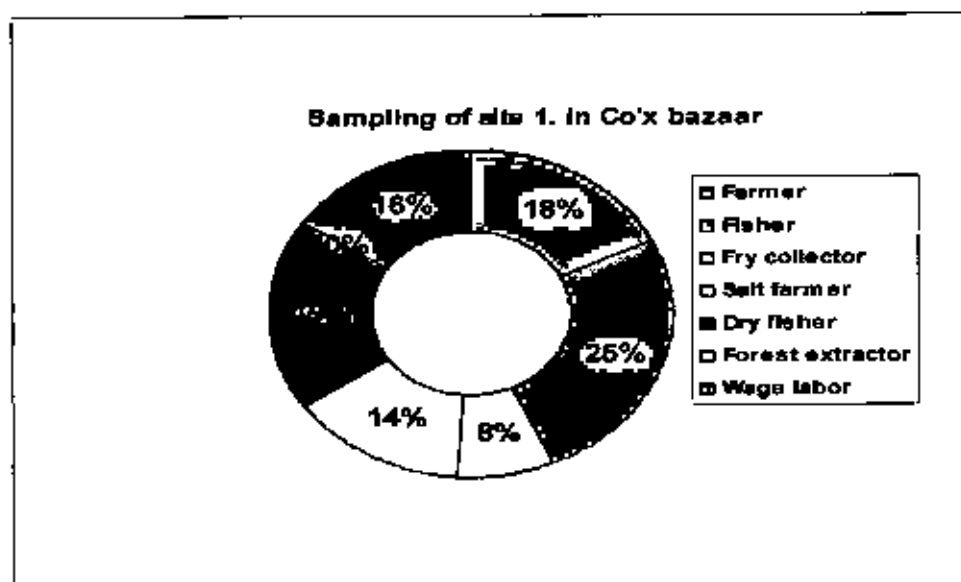
#### 4.4. Sample Size for Field Study

- ❖ Questionnaire survey has been occurred randomly considering the calculated sample size in study site 1. of Cox's bazaar through 90 households of different livelihood groups (Table 4.1.).

**Table 4.1.** Households of different livelihood groups for questionnaire survey in site 1.

Livelihood group	Household No.
Farmer	16
Fisher	23
Fry collector	7
Salt farmer	13
Dry fisher	17
Forest extractor	0
Wage labor	14
<b>Total Sample</b>	<b>90</b>

After that survey the following scenario (Fig 4.2) has been found.



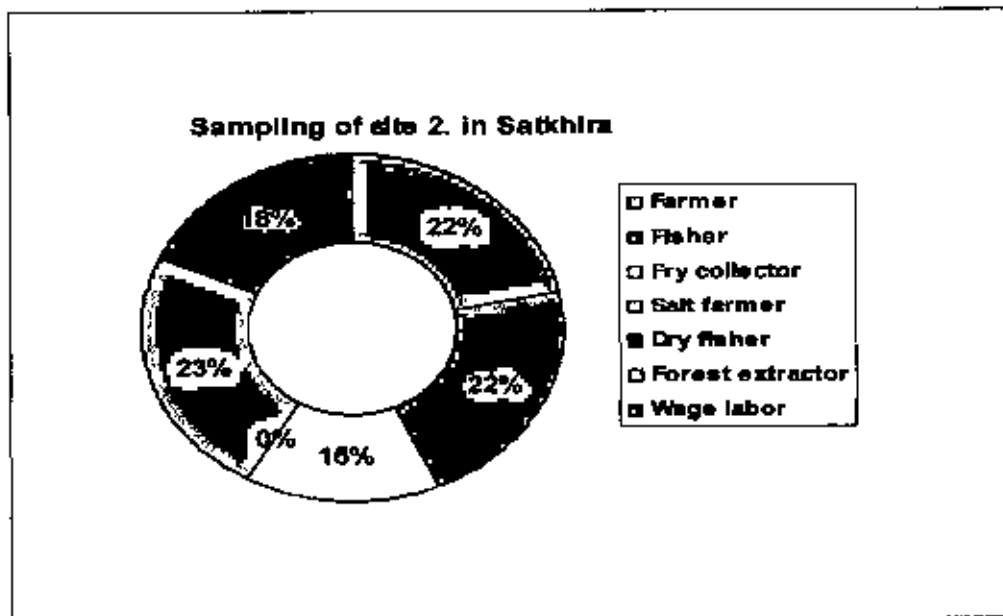
**Fig 4.2:** Sampling percentage of house hold according to livelihood groups in Cox's bazaar.

- ❖ Household survey has also been occurred in site 2. of Satkhira with the certain sampling 60 households ( Table 4.2.).

**Table 4.2.** Households of different livelihood groups for questionnaire survey in site 2.

Livelihood group	Household No.
Farmer	13
Fisher	13
Fry collector	9
Salt farmer	0
Dry fisher	0
Forest extractor	14
Wage labor	11
<b>Total Sample</b>	<b>60</b>

It shows the sampling as follows as Fig. 4.3.



**Fig 4.3:** Sampling percentage of house hold according to livelihood groups in Satkhira.

Base on the survey report the study has been continued and the livelihood system has been analyzed.

## **CHAPTER FIVE**

### **LIVELIHOOD SECURITY MODEL**

#### **5.1. Introduction**

The livelihood security model is generally enhanced by one or a combination of the three intervention strategies in household level such as Livelihood promotion (development oriented programming), Livelihood protection (rehabilitation/mitigation oriented programming) and Livelihood provisioning (relief-oriented programming) (Frankenberger and McCaston, 1998). The current work tends to define the prerequisites and the idea of the conceptual model in order to assess the required livelihood protection and provision for coastal community due to storm surge hazard.

Livelihood in the coastal area differs from the rest of the country and in Bangladesh coastal livelihood pattern and its security largely depends on vulnerability as well as opportunity. The storm surge is certainly a major vulnerability factor to make insecurity in coastal environment and livelihood system. It is also defined that resources (both in land and the sea) are available opportunities at the household level in terms of ownership and access. Household security of specific livelihood group is defined as adequate and sustainable access to income and resources to meet basic needs including adequate access to food, potable water, health facilities, educational opportunities, housing, time for community participation and social integration. Livelihood Security Model has been developed to improve storm surge risk measurement at household level in coastal community.

This chapter will demonstrate a conceptual model for livelihood security against storm surge with identification of livelihood security options, standard value of livelihood security indicators or security standard and other tools of security level assessment for individual livelihood groups in the coastal part of Bangladesh.

## 5.2. The Model Concept

As shown in the figure 5.1, there are three major elements in coastal livelihood security model: context, livelihood system and strategy and livelihood security outcomes. Contextual factors place the household and community into a situated perspective. The present model has been constructed to identify the insecurity and risk of coastal people due to storm surge hazard. At that sense storm surge and its destructive actions has been defined as the key contextual factor affecting livelihoods.

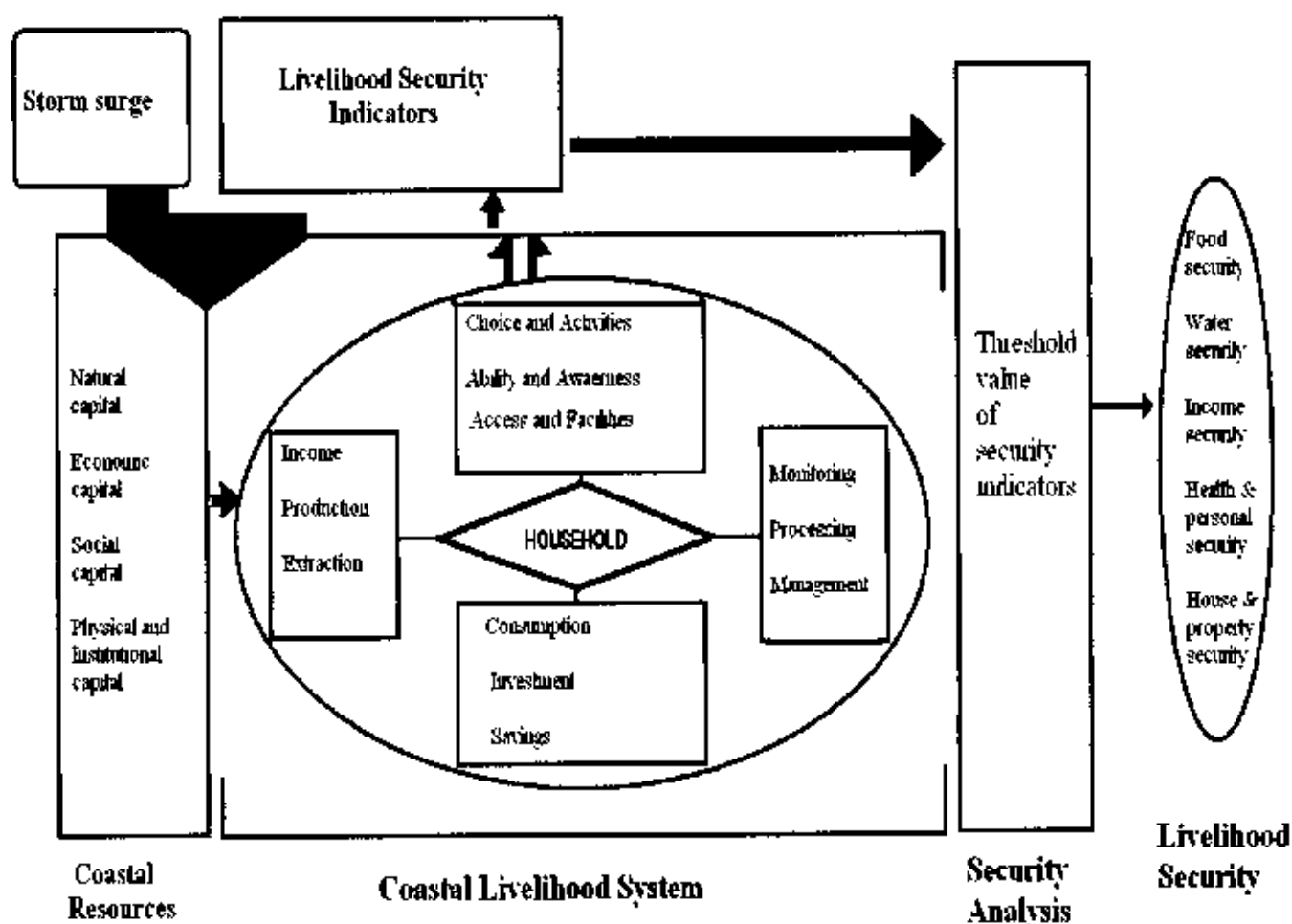


Fig 5.1: Concept of "Livelihood Security Model" for storm surge hazard for coastal area .

The coastal livelihood system and stockholders has been presented as one of the basic element of the model. It has been defined as the subject of vulnerability in that certain study field. In that portion of the model, the affected party i.e. the coastal livelihood groups have been introduced including their household activities, resources and strategies. At the level of livelihood strategy, the aim of the analysis was to understand the typical levels of human, social, economic and natural capital that are possessed by different types of households, and the nature of production, income and exchange activities on which storm surge affects more. That part has been designed to develop the household base livelihood security indicators which are the analytical input of the model. According to the conceptual model, the numerical valuation of the coastal livelihood system, sub-system and the status of livelihood groups have been occurred by calculating selective indicators with specific unit. The livelihood security index for household has been measured by comparing the value of indicators against their standard limits. Finally consumption activities for each household have been summarized in terms of the livelihood security outcomes status for different options of household security.

### **5.2.1. Storm surge: the background issue**

For the model description, as the exogenous factor the storm surge study has been gotten logical attention and from that continuity, it has been found that 40% of storm surges that occur throughout the globe affect Bangladesh. It also has been reviewed that almost 10% area of the Bangladesh is vulnerable to cyclonic and surge hazard (BUET-BIDS, 1993). Storms surges cause great sufferings to coastal people and their livelihood system in Bangladesh.

In Bangladesh, cyclones generally take place either at April-May or September-December. Most of the damage has occurred in the coastal regions of Khulna, Bagerhat, Shatkhira, Patuakhali, Barisal, Noakhali Cox's bazaar and Chittagong and the offshore islands of Bhola, Hatiya, Sandwip, Manpura, Kutubdia, Maheshkhali, Nijhum Dwip, Urir Char and other newly formed islands. Astronomical tides in combination with cyclonic surges lead to higher water levels and hence severe flooding. Surge-heights increase with the increase of wind speed. Storm winds move at speed of up to 240Km/h and caused

widespread damage (Kabir, *at al*, 2007). The most destructive element, however, is the surge caused by a large mass of water at and around the storm center accumulating in a mound higher than normal sea level and progressing with the storm as a wind driven storm surge. In the most case, the main risk factors have been defined as the frequency of surge in particular area, the tidal condition during surge, surge height and finally the duration of surge occurs. All those factors control the range of damages as well as sufferings of the people and that indicate the security level of certain livelihood system of the area. From this study, it has also been found that the frequently increasing rate of storm surge during recent years change that vulnerability rate tremendously and caused insecurity to coastal people and their living.

### **5.2.2. Coastal livelihood system**

Coastal Livelihood System has been defined around a household's livelihood strategy; the household members, the assets and resources to which they have access, as well as their access to information or to influence others and their ability to claim from relatives, the state or others actors. Production and income activities have been means to improving livelihoods and not an end in them. In this study, coastal livelihood system has been analyzed to evaluate what changes would be taking place in the marginal livelihood systems during storm surge risk. It also has been monitored (focusing on the production and consumption processes and assets of households including the status of its members) for the better and sustainable measure of that shocks.

#### **❖ Livelihood resources**

According to DFID livelihood asset model, each livelihood group has five types of assets – (i) Natural assets, (ii) Financial assets, (iii) Human assets, (iv) Physical and institutional assets, and (v) Social assets (Islam,2004 ). The dependency of livelihood on these assets defines the vulnerability of livelihood. In this point of view, the selected livelihood groups in this study have characterized by their dependency on the local resources with relation to their main source of production, income and saving system. Farmers, Marine

Fishers, Fry collector and Salt farmer are directly dependent to natural land and water resources, whereas the daily wage group is indirectly dependent on natural resources. Culture fisher and dry fisher groups are dependent on natural resources with some anthropogenic initiatives. It was observed that all livelihood groups put importance on their natural assets according to their economic and social needs. Among the natural assets, farmers and wage labors put the higher priority on agriculture land whereas fishermen emphasized on fish and water bodies. Some livelihood assets vary with geographical variation and cultural settings. For instance, shrimp farming and forest resource extraction are prominent in Satkhira region whereas salt farming and dry fish is prominent in some places of Cox's bazar region. Furthermore, agriculture land and fisheries are the main assets that govern the economy of the region. Therefore, impact of storm surge on agriculture and fisheries would define the impact on each livelihood group directly or indirectly in Bangladesh coast.

❖ **Concerned sectors for coastal livelihood security**

As the indicator framework is to assess the security level against impacts on the resources due to storm surge in certain coastal area, the key affected sectors of livelihood system are the main concern-

- a. Natural System: Natural disaster
- b. River, vegetation etc.
- c. Household Population size
- d. Access and ownership
- e. Rate of Income and savings
- f. Literacy rate and personal skill
- g. Health care and Medical facilities
- h. Women activities
- i. Institutional act and Public Awareness
- j. Water Supply and Safety



- k. Sanitation facilities
- l. Housing Infrastructure
- m. Protection, Shelter and mitigation measure
- n. Institutional and Organizational support

Different criteria and actions related to coastal livelihood system and its sub-systems have been considered to form the security indication tools for the certain community due to that specific issue. In the model formation procedure, those types of tools have been used as the input data of the model.

### **5.2.3. Livelihood security indicators: model input data**

A conceptual livelihood security model for coastal people has been developed depending on some indicators, as tools to assess the impacts of natural hazard on livelihood of coastal community and its management policies. So it was needed to describe an approach for the identification of suitable indicators, by linking with the research objectives and revised livelihood structure in the relevant area.

- **Development of an indicator framework**

Development of livelihood security indicators has been performed through the specific understanding of the coastal livelihood varieties and livelihood system which always walk with risk of storm surge. The information of previous destructive actions of storm surge issue of the specific area has been considered for vulnerability assessment of the defined livelihood groups in coastal area of Bangladesh in which household members engage in a host of activities to earn their living based on its assets (ownership and/ or access). Livelihood security indicators have been formed as the functional unit of the coastal livelihood system includes the physical and socio-economic and environmental part of the system. For this study the concern livelihood system has been expressed as the affected area due to storm surge hazard in coastal districts. So the set of indicators has

been defined to represent the function of storm surge issues and different types of coastal vulnerabilities and opportunities for different livelihood groups in certain area of coast. Livelihood security indicators for livelihood groups have been developed based on areas in which they live, observed living status, their individual access to local resources and their capacity to prevent, prepare for or respond to the shock of storm surge. The safety of unique resources such as the Sundarbans, the shrimp fields, the marine ecosystem and huge numbers of river and channels in the study area has been major concern in indicator development. Secondary information has been used to form the link between livelihood indicator and livelihood security indicator for storm surge hazard of the community:

Actually indicators have been developed by the secondary and primary information related to the storm surge issue. The storm surges act destructively on the household practices, household properties and other process to live. The hazards also hit all social and institutional facilities of special livelihood groups of Bangladesh coast. Indicators for the security of coastal livelihoods against storm surge in BD coast have been identified from different dimensions of livelihood capitals and livelihood system of that community. Under different livelihood capital and relevant action such as natural capital, social capital, economic capital and physical or institutional capital, indicators have been defined with specific unit of measurement. Each indicator has been defined depending on specific reason. It has been tried to show relative, reliable, representative and logical cause behind each one.

A set of indicators (Shown in Table 5.1.) has been formed based on secondary information and information from general field observation of the selected coastal area. Some data have been collected from coastal management report from national level research work (WARPO and others). Initially the indicators have been arranged on the basis of livelihood asset or capital of household living.

**Table 5.1.** An indicator framework for coastal livelihoods against storm surge.

<b>Natural Capital</b>			
<b>No.</b>	<b>Background Criteria</b>	<b>Indicator</b>	<b>Unit</b>
1.	Possibility of occurring storm surge within each year	Frequency of Storm surge (Irregular/regular)	Binary
2.	Coincidence of the storms' passes with high or low tides would tend to increase or moderate the damage.	Storm surge Period (Low tide/ high tide)	Binary
3.	Tidal action turns to surge when it crosses the normal scenario or becomes up to Mean Sea Level	Surge height from mean sea level (Low/High)	Binary
4.	The rate of damages depends on how much time storm surge stay or act over the area	Duration of storm surge (Short term/ long term)	Binary
5.	Vegetation would be a great and natural protection against storm surge	Rate of vegetation around the area	%
6.	Production would be seasonal or over the year. The production period is important for security	Time frame for resource collection/ production	Months
7.	Condition and management capacity of Rivers, canals (khal) can control the surge action and level	Performance of natural drainage system	%
8.	Natural or anthropogenic activities may act against loss and improve the resource capacity	Possible improvement of resource in each year	%
9.	Coastal people having multiple-opportunity depending on number of resources in the locality.	Access to alternative resource base	No.
10.	Supply of energy is not available in rural part of coast.	Access to energy/fuel supply	%
<b>Financial Capital</b>			
<b>No.</b>	<b>Background Criteria</b>	<b>Indicator</b>	<b>Unit</b>
11.	People have scope to earn from livestock, poultry, vegetable gardening or others.	Household production	% of TI
12.	Access or ownership of production that means how much /share of product they have owned.	Ownership on production	%
13.	If a household having food product more than their normal demand, they can store it for future.	Scope of food storage	Binary
14.	If household can save any from their regular income, it must be effective to face the risk.	Rate of saving	% of TI

15.	Type of saving system or easy access to saving system make confidence of HH.	Reliability of saving system (Yes/No)	Binary
16.	It is an effective economic opportunity for HH and skilled women do better for their family.	Access of women to economic activities	%
17.	Economic activities except the fixed living option give confidence to face the shock.	Scope of alternative economic activities	Binary
18.	Easy loan access from govt. or other organizations keep up their capacity to face certain risk	Access to financial loan (Yes/ No)	Binary
19.	If people have any access to earn from outside of the surge prone area, it shows an option of HH safety.	Portion of HH income earned from rest of the country	%
<b>Human Capital</b>			
<b>No.</b>	<b>Background Criteria</b>	<b>Indicator</b>	<b>Unit</b>
20.	Literate people are able to protect themselves from risk	Rate of education/literacy	%
21.	Idea of primary treatment must be needed during disaster	Knowledge on first aid	%
22.	Information availability on storm surge action and protection initiatives help to keep safety	Knowledge on storm surge risk	%
23.	If it is possible to communicate with nearest town (Time and Distance basis), it gives some living facilities.	Access to nearest district town (Yes/No)	Binary
24.	Physical treatment facilities is essential to face the certain risk	Access to doctor service (No. of doctor / 100 Household)	No.
25.	Physically and mentally fit people can safe their family and properties	HH Population having training on Surge protection	%
26.	Active people can move to shelter and it may easy to adopt in the situation.	Active population of HH	%
27.	Active and skilled people are aware and take initiatives to fight with hazard.	Response to early warning system	%
28.	People should be willing to adjust with the protection techniques.	Response to adaptation technology	%
29.	People of other side of the country are safe from the risk. It is an alternative option of HH development.	Rate of out migration of HH member	%

<b>Physical / Infrastructural Capital</b>			
<b>No.</b>	<b>Background Criteria</b>	<b>Indicator</b>	<b>Unit</b>
30.	The safety of house infrastructure depends on building materials and placement.	Safe housing infrastructure/ condition	%
31.	Availability of medicine, treatment and service from the authority.	Performance of hospital /Health center	Scale
32.	Number of cyclone shelter, distance from house and condition of cyclone center and others.	Performance of/access to cyclone shelter	%
33.	Available source of water and possible quality.	Availability of drinking water (Safe water)	%
34.	Sanitation structure and awareness.	Sanitation facilities	%
35.	Communication system with the rest of the country.	Access of media connection / Radio / TV/ Cell phone	%
36.	Constructed and well conditioned road.	Availability of paved road	%
37.	Quality and quantity of transport.	Transportation facilities	%
38.	No. or length of polder or other protection structures	Part of area under protection structure	%
39.	Present condition of polder or other protection structures	Fitness of protection structure	%
<b>Social Capital</b>			
<b>No.</b>	<b>Background Criteria</b>	<b>Indicator</b>	<b>Unit</b>
40.	Weather news collection and serve to the people actively	Performance of weather forecasting	Scale
41.	Local community cooperation may the most important help to face the shock.	Community participation practice	%
42.	Help from Govt. and Govt. organizations	Activeness of local GO	Scale
43.	Help from NGO's	Interrelationship with NGO	Scale
44.	Social safety and awareness	Performance social law and regulation	Scale
45.	Political activities and help from political group	Political influence on social group/ committee(Yes/No)	Binary
46.	Activity and responsibility of local Govt. and powerful stakeholders	Performance of local disaster management committee	Scale
47.	Social community of the dwellers	Activeness of social organization of livelihood groups	%
48.	Activities or workshop from different organ specially Govt.	Awareness program on protection measure (No./Y)	No.

Source : Field study 2008-2009.

In indicator development process for the livelihood assets or resources in coastal zone have been classified based on reviewed literatures and field survey data. The components of those assets base have been focused approaching the importance of particular products for individual household. Through this continuity the concern sectors for storm surge vulnerability were marine ecosystem and land use, peoples live and living, production system and extractive activities, water availability and quality, economic, social and institutions performances etc. The observation showed that the household security must have dependence on the ownership and accessibility to the assets, entitlements and resources provides a household with the basic infrastructure to make choices, which were translated into livelihood activities of community people.

The approach of livelihood security indicators development has expressed as most relevant idea from the perspective of the security assessment for livelihood groups at the study area. The indicator framework has been formed with 46 individual indicators which should represent the state of the resources and opportunities in certain environment and the form of different sub-system and system on which their livelihoods depend.

#### **5.2.4. Livelihood security standard for coastal people**

Livelihood security should be measured by proper judgment of the define situation. So the livelihood security approach due to storm surge has been constructed through the idea of a comparative study between the vulnerable coastal livelihood systems and the expected safety of living in the coastal zone of Bangladesh.

The livelihood security standard has been defined from the standard value of all livelihood security indicators. The standard values have been shown by collected data through a local FGD (Focus Group Discussion) programme in each defined thana. The developed indicator framework has been discussed to the participants. Some example values such as rate of income savings, rate of literacy, health facilities etc. have also been explained for their idea development. Those example values have been collected from the national census (Population census 2001) and published data from local government authority. The standard value for individual indicators (Table 5.2.) has been developed by

using the participants' opinions, expectations and demands in different sector of coastal livelihood system due to risk of storm surge. Finally those values have been calculated from combined data of FGDs and researchers' perceptions about the certain situation with help of local area concern.

**Table 5.2.** Standard value of indicators.

<b>Capital</b>	<b>Indicator</b>	<b>Unit</b>	<b>Standard</b>
<b>Natural</b>	Frequency of Storm surge (Irregular/regular)	Binary	1
	Storm surge Period (Low tide/ high tide)	Binary	1
	Surge height from mean sea level (low/high)	Binary	1
	Duration of storm surge (Short term/ long term)	Binary	1
	Rate of vegetation around the area	%	25
	Time frame for resource collection/ production	Months	12
	Performance of natural drainage system	%	80
	Rate of possible resource quality improvement	%	50
	Access to alternative resource base	No.	3
	Available energy /fuel supply	%	90
<b>Financial</b>	Homestead production	% of TI	40
	Ownership on main production or income	%	75
	Scope of food storage (Yes/No)	Binary	1
	Rate of saving	% of TI	25
	Reliability of saving system	Binary	1
	Access of women to economic activities	%	50
	Scope of alternative economic activities(Yes/No)	Binary	1
	Access to financial loan(Yes/No)	Binary	1
	Portion of HH income earned from rest of the country	%	20
<b>Human</b>	Rate of education/literacy	%	80
	Knowledge on first aid	%	70
	Knowledge on storm surge risk	%	80
	Access to nearest district town (Yes/No)	Binary	1
	Access to doctor service (No. of doctor / 50 Household)	No.	2
	HH Population having training on Surge protection	%	50

	Active population of HH	%	50
	Response to early warning system	%	65
	Response to adaptation technology	%	75
	Rate of out migration of HH member	%	10
<b>Physical/ Institutional</b>	Safe housing infrastructure/ condition	%	60
	Performance of hospital /Health center	Scale	3
	Performance of/access to cyclone shelter	%	90
	Availability of drinking water (Safe water)	%	90
	Sanitation facilities	%	90
	Access of Radio/TV/ Cell phone	%	75
	Availability of paved road	%	60
	Transportation facilities	%	60
	Part of area under protection structure	%	80
	Fitness of protection structure	%	80
<b>Social</b>	Performance of weather forecasting	Scale	3
	Community participation practice	%	80
	Activeness of local GO	Scale	2
	Interrelationship with NGO	Scale	2
	Performance social law and regulation	Scale	2
	Political influence on social group/ committee(Yes/No)	Binary	1
	Performance of local disaster management committee	Scale	2
	Activeness of social organization of livelihood groups	%	80
	Awareness program on protection measure (No./Y)	No.	2

Source: Literature review and Field study 2008-2009.

The table shows the standard value of individual security indicators for coastal livelihoods to face the risk of storm surge in Bangladesh. The value units are as same as the define indicator framework. The standard values have been calculated considering the situation of total study area. This measurement has been used as a main parameter of the Model.



### **5.3. Livelihood Security Options**

Coastal people are generally well known to the vulnerability of their livelihood system due to storm surge. The present field study noticed that most of them take it as a usual phenomenon in their area of living. Coastal community treats it as their part of life and tries to survive from their individual position of living opportunity. However with the trend of climate change and present increasing intensity of tropical cyclone, the reality of the storm surge vulnerabilities is likely to grow rapidly in Bangladesh coast. These changes affect the assets and securities of life and thus affect people's well-being. This study analyzed the vulnerabilities in relation to the essential well-being in livelihood system and related securities, which are identified to be: food; water; income; health and personal safety; and safety of properties. So the concept of livelihood security of coastal people has been defined by the highlighted security options from their individual livelihood perspectives.

#### **Food security**

Food security depends on such interrelated issues as: crop production; crop loss as well as any type of product generation and its use, food availability; flow of income and family size. The food security of different livelihood groups has been denoted through their livelihood pattern and types of resources in certain coastal area. Within the coastal livelihood system the household productivity, demand, storage, income and purchasing ability in food allocation and distribution was evident. The study denoted that storm surge caused great damage in quality food supply to the coastal root level people for last few years in certain area. In that time storm surge took place in post or pre monsoon time of the year and caused damage to most of the Amon and Boro field of the affected area. It washed the shrimp field and destroyed forest resources. People of the study area stated that in surge period they had minimum scope to store or collect food. So, they ate less and meals were of lower quality in surge time. Because of the losses of resources and lack of preventive actions, the coastal community suffered much and substantially became more vulnerable for the unavailability of food product.

### **Income security**

Income is the most important functional element in the basic livelihood system. The household income of coastal livelihood groups depends on their access to natural resources, related activities, production, collection and supply of different types of product. This study discussed the income sources and opportunities of different livelihood groups. Each livelihood groups were defined by some specific options and income dimension. But it also stated that storm surge of recent years caused great loss to coastal resources. The loss of household assets, e.g., the loss of crop, cattle and poultry as well as damage in common resource base impacted the income security of both men and women. The storm surge in coastal environment reduced agricultural production. According to public statement coastal surge changed land use pattern that makes uncertainty in income sector of people. Storm surge destroyed forest flora and fauna. It ruled restriction to marine resources. Both of the coastal asset were the main income source of several livelihood groups in the define area.

### **Health and personal security**

In the coastal areas both men and women are living in a poor health status. Poverty, frequency of natural disasters, water pollution, lack of health and sanitation facilities, lack of awareness and superstitions are major factors behind health insecurity. This study found that there was a significant problem associated with the storm surge hazard in certain coast of Bangladesh during last storm surge. When storm surge took place most of the people needed shelter but they didn't so. Lot of people was injured. Numbers of people were in life risk. Old men, women and children were in great danger. Women suffered more. Primary medical treatment and hospital facilities were not sufficient in the selective area. People died for lack of proper treatment and communication facilities. This survey found that due to storm surge coastal rivers and other water bodies were washed out by sea water and high dose of salinity caused large damage in fisheries. The development of aquaculture in certain coastal areas became in risk and salinity caused loss to adjacent agricultural land. All of these changes have tended to reduce the carrying capacity of the coastal environment, thus reducing the benefits of wild harvesting and making the livelihoods of the ever increasing poor more difficult to sustain.

**Security of house and property**

The important components of this security approach are house materials, product storage capacity, communication and quick response. The prevailing lack of awareness, communication and warning system causes a decline in resources and loss of assets. As a result, there occur much threat over resources and men face the risk of destroying household properties and also decrease access to common resource base. This study notified that people of different livelihood groups lost their all properties during the disaster period because they were not alert to the warning. According to people concept, the last storm surge period the major losses were in certain livelihood activities such as fishing at sea. From the community research it was found that the loss of assets as a consequence of storm surge (e.g. house, poultry, and cattle) and their limited resilience to such disasters, affect marine resource base livelihood group and daily wage group profoundly. However, at the time of a storm surge and afterwards, people face severe hygiene and sanitation difficulties along with a lack of food, income and secure shelter. In case of a storm surge threats people try to get information from their neighborhood, go far to see the flag or listen to the radio for storm surge warning. During the storm surge they go to a cyclone shelter (if available) and afterwards they do what they can to regain the loss of assets. The impacts of storm surge on livelihood groups vary according to their resources, activities and options.

**Water security**

In coastal areas, the availability of safe drinking water has been mentioned as one of the major problems. This holds true for both the dry and the wet season and especially for storm surge period. The study described that most of the people used community tube well and some of them took pond water for domestic use. When storm surge took place, it was difficult to find fresh water in the both sources. So lack of potable water affects the men and women differently. According to the public statement, women faced more difficulties in water fetching, fulfilling domestic tasks, bathing and maintaining reproductive hygiene and sanitation. For lack of sufficient non saline water the normal activities were stopped and livelihood system of various groups was in great risk.

#### 5.4. Selection of Indicator for Individual Security

The indicator framework has been distributed into different security aspects according to their response and logical application to that sector of livelihood security. Indicators have been selected finally by using Multi Criteria Decision Making method specifically defined as Analytical Hierarchy Process (AHP). In the following method primarily developed indicators of each capital groups have been analyzed individually to select the appropriate indicator for relevant sector of livelihood security.

In this study, the AHP has been used for alternative indicators under individual capital. For example, when AHP has been used for natural capital base indicators, it formed a nine by nine (9 x 9) priority matrix for pair wise comparison of alternatives (Individual Indicator). The priorities of alternative indicator have been fixed base on FGD participants' opinions and present coastal livelihood research study in that specific area.

The indicators of other capital base have also been selected by following same method of decision making according to their weight of relative response. The defined five livelihood security aspects have been used as basic criteria of indicators which are measurable, achievable, utile, flexible and acceptable from the specific point of security aspect. Those have been clarified to justify the sensitivity or reliability of developed indicators to the specific aspect. The same method has been used to select security aspect of indicators under each livelihood capital.

**Table 5.3.** Selected indicators for individual household security options.

Capital	Indicator	Security				
		Food	Income	Health and Personal	House and properties	Water
Natural Capital	Frequency of Storm surge (Irregular/regular)	√	√	√	√	√
	Storm surge Period (Low tide/ high tide)	√	√	√	√	√
	Surge height from mean sea level (Low/High)	√	√	√	√	√
	Duration of storm surge (Short term/ long term)	√	√	√	√	√

	Rate of vegetation around the area		√	√	√	√
	Time frame for resource collection/ production	√	√			
	Performance of natural drainage system			√	√	√
	Rate of possible resource quality improvement	√	√			
	Access to alternative resource base	√	√	√	√	√
	Access to energy/fuel supply	√	√	√		√
<b>Financial Capital</b>	Homestead production	√	√	√	√	√
	Ownership on main production or income	√	√	√	√	√
	Scope of food storage (Yes/No)	√		√		
	Rate of saving	√	√	√	√	√
	Reliability of saving system	√	√	√	√	√
	Access of women to economic activities	√	√		√	
	Scope of alternative economic activities(Yes/No)	√	√		√	
	Access to financial loan(Yes/No)	√	√	√	√	√
	Portion of HH income earned from rest of the country	√	√		√	
<b>Human Capital</b>	Rate of education/literacy	√	√	√	√	√
	Knowledge on first aid	√		√		√
	Knowledge on storm surge risk	√	√	√	√	√
	Access to nearest district town (Yes/No)	√	√	√	√	√
	Access to doctor service (No. of doctor / 50Household)			√		√
	HH Population having training on Surge protection	√	√	√	√	√
	Active population of HH	√	√	√	√	√
	Response to early warning system	√	√	√	√	√
	Response to adaptation technology	√	√	√	√	√
	Rate of out migration of HH member		√		√	
<b>Physical/ Infrastructural Capital</b>	Safe housing infrastructure/ condition	√	√	√	√	√
	Performance of hospital /Health center			√		√

	Availability of drinking water (Safe water)	√		√		√
	Sanitation facilities	√		√		√
	Access of Radio/TV/ Cell phone		√	√	√	√
	Availability of paved road	√	√		√	
	Transportation facilities	√	√	√	√	√
	Average area with protection structure		√		√	√
	Fitness of protection structure		√	√	√	
<b>Social Capital</b>	Performance of weather forecasting	√	√	√	√	√
	Community participation practice	√	√	√	√	√
	Activeness of local GO	√	√	√	√	√
	Interrelationship with NGO	√	√	√	√	√
	Performance social law and regulation			√	√	√
	Political influence on social group/ committee(Yes/No)	√	√		√	
	Performance of local disaster management committee	√	√	√	√	√
	Activeness of social organization of livelihood groups	√	√	√	√	√
	Awareness program on protection measure (No./Y)	√	√	√	√	√

Source: Field survey 2008-09.

“√” sign shows the selection of indicator for individual security option.

An estimated priority weight of individual indicator has been found from AHP application for each security aspects. Now, Indicators having higher weight under that specific security aspect have been selected. This method has been used for every division of livelihood security indicator. Table 5.3. shows the weighted indicators or response of indicators to different security options. The livelihood security Model has been developed by following the selected frame of coastal livelihood indicators.

### 5.5. Livelihood Security Model

The livelihood security model has been developed base on an indicator framework which is the representative of coastal household security criteria against the storm surge hazard. The analytical model has been shown as the form of livelihood security index where the required input parameters would be shown as follows-

**Table 5.4.** Parameters used in constructed model.

Parameters	Unit	Denoted by
Measured /Present Value of Individual Indicator	Specific unit	$I_p$
Standard Value of Individual Indicator	Specific unit	$I_s$
Difference between present value of indicator and standard value of individual indicator.	%	$I_d$

- **Livelihood Security Index**

**Step 1:** Two types of value for each selected indicators have been calculated through analyzing some secondary data, FGD and household interview data in the selected coastal area. Then the comparative security value foe selected indicator have been invented individually under different security aspects by using the equation-

$$|I_d| = \{(I_p - I_s) / (I_p + I_s)\} * 100 \text{ -----} I.$$

Here,

$I_p$  = Present value of individual indicator

$I_s$  = Standard value of individual indicator

$I_d$  = Percentage of unit difference between present value of indicator and standard value of individual indicator.

**Step 2:** The security score of individual indicator has been found by a defined scaling because  $I_d$  represents two alternative directions i.e. either positive (+) or negative (-). Here, the positive direction shows security and negative direction shows insecurity.

**Table 5.5.** Security scoring system.

Positive $I_d = \text{Security}$		Negative $I_d = \text{Insecurity}$	
Security score (X)	(+)Value range (%)	Insecurity score (Y)	(-)Value range (%)
+	0 - 30	-	0 - 30
++	31 - 60	--	31 - 60
+++	61 - Above	---	61 - Above

Here, X= Security score for individual indicator.

Y = Insecurity score for individual indicator.

**Step 3:** Each individual indicator has been shown sensitive to different security aspects. The security index of a household for single aspect can be calculated by the following formula:

$$SI_j = \left\{ \frac{\sum_{i=1}^n X_{ij}}{M_j} \right\} * 100 \text{----- II.}$$

Where,

SI<sub>j</sub>= Security index under jth individual aspect;

X<sub>ij</sub> = Positive score of ith indicators under jth aspect;

The value of X for different indicator (i=1 to n) has been calculated by counting the numbers of positive (+) signs.

n= Number of individual indicators sensitive for individual aspect.

M<sub>j</sub> = Maximum possible score of total indicators under jth aspect.

j = Different security aspects.

Security of household (in percentage) for individual livelihood security aspect at risk of storm surge in define coast of Bangladesh has been measured by solving the formula.



Now, The over all livelihood security in household level of coastal community for the issue (storm surge) has been defined through combining the security of every denoted security aspects. The composite security index consisting of different aspects has been expressed as follows:

$$SI = \sum_{j=1}^N SI_j/N \text{-----III.}$$

Where;

SI = Composite livelihood security index of a household in percentage;

N= Number of security aspects considered in the composite index;

#### • Model Output

Finally the livelihood security model for household in the coast has been formed conceptually and physically using the above index. The model will provide a result by defining the livelihood security level of individual coastal livelihood groups to face the storm surge risk in coastal Bangladesh.

#### 5.6. Model Use for Livelihood Security Assessment

For measuring the livelihood Security of coastal people due to storm surge effect through the model, the steps to be followed are:

- ❖ To enter the standard limit of security indicators as the threshold value for model application;
- ❖ To enter the present value of indicators calculated from survey to households of different livelihood groups;
- ❖ To calculate the security score (Step 1) for each indicators according to their response to different security options;
- ❖ To calculate the security level under each security aspect through Step 2;

- ❖ To calculate the overall security level of different livelihood groups for storm surge hazard in coastal area;

The Model must be applied for individual affairs of different coastal livelihood groups.

### **5.7. Summary**

The model would be applicable depending on the sensitivity of developed indicators and their appropriate priority analysis. The Model would become more logical if the standard value of indicators have been collected from national statistics. From the modeling study, it can be concluded that the model can play a vital role in coastal resource management and livelihood development program due to storm surge hazard.

## **CHAPTER SIX**

### **COASTAL LIVELIHOOD SYSTEM ANALYSIS**

#### **6.1. Introduction**

Bangladesh is a densely populated but small country having a unique coastal topography. The largest mangroves (Sundarban), the longest sandy beach, a resourceful coral island etc. make that coast as the area of multiple opportunities. But at the same time, the coastal area of Bangladesh is in great risk of storm surge hazard (Flood and some others also roughly active here) during pre monsoonal and post monsoonal period in every year. Storm surges generally caused by tropical cyclonic action in a typical geological settings. The regular frequencies of storm surge occurrences have been seen in current years. The coastal people as well as their resource base livelihood system are in a dangerous situation due to continuous surge effects. This chapter will generate a scene of group wise coastal livelihood systems which have been identified as in great risk of storm surge.

#### **6.2. Coastal Livelihood System with Storm Surge Risk**

Storm surges cause serious problems in the livelihood system of the community living in coastal part of Bangladesh. Conducting survey in the study area, several livelihood situations and different degrees of their sufferings have been discovered. The storm surge risks have become visible consequences for Bangladesh coast. Storm surge would be a serious threat to the total livelihood system which has been found as a combination of different resource base sub-systems –

- ❖ Natural sub-system
  - ✓ Component of marine ecosystem
  - ✓ Component of terrestrial ecosystem
  - ✓ Forest area
  - ✓ River system
  - ✓ Land use pattern
  - ✓ Production season

- ❖ Financial sub-system
  - ✓ Productivity / income generation
  - ✓ Access and ownership
  - ✓ Savings and saving system
  - ✓ Women empowerment
  - ✓ Multiple financial opportunity- Poultry, Livestock etc.
  - ✓ Financial loan access
- ❖ Human sub-system
  - ✓ Literacy rate
  - ✓ Personal skill / Knowledge
  - ✓ Health care
  - ✓ Supportive services and technology
  - ✓ Awareness to risk protection or mitigation
- ❖ Physical / Infrastructural sub-system
  - ✓ Population size and quality
  - ✓ Housing Infrastructure
  - ✓ Shelter / Protection structure
  - ✓ Institutional act
  - ✓ Water Supply /Sanitation facilities
- ❖ Social sub-system
  - ✓ Community Act
  - ✓ Performance of social or other organizations etc.

### **6.2.1. Storm surge risks for security of coastal livelihood**

The study found that about 90% of cyclone casualties are caused by storm surge. More than one severe cyclonic storm hit Bangladesh coast every year and the accompanying surge can reach as far as 200 km inland (BUET,2008). Those storms usually form in the south east portion of the Bay of Bengal, move in a northerly or north-westerly direction and often turn north-easterly or easterly towards the east coast of the country. It has found that about 9 strong and moderate range storm surges took place in our coast within last twenty years in which most devastating actions have been estimated during 1988, 1991,

2007(SIDR) and finally 2009 (AILA). Cyclone SIDR was born in Bay of Bengal on 11<sup>th</sup>, November, 2007 and disappeared on 17<sup>th</sup>. It landed on around 18:30 of November 15<sup>th</sup> at almost the same place as the cyclone in 1970 had landfall as seen in Fig.6.1.

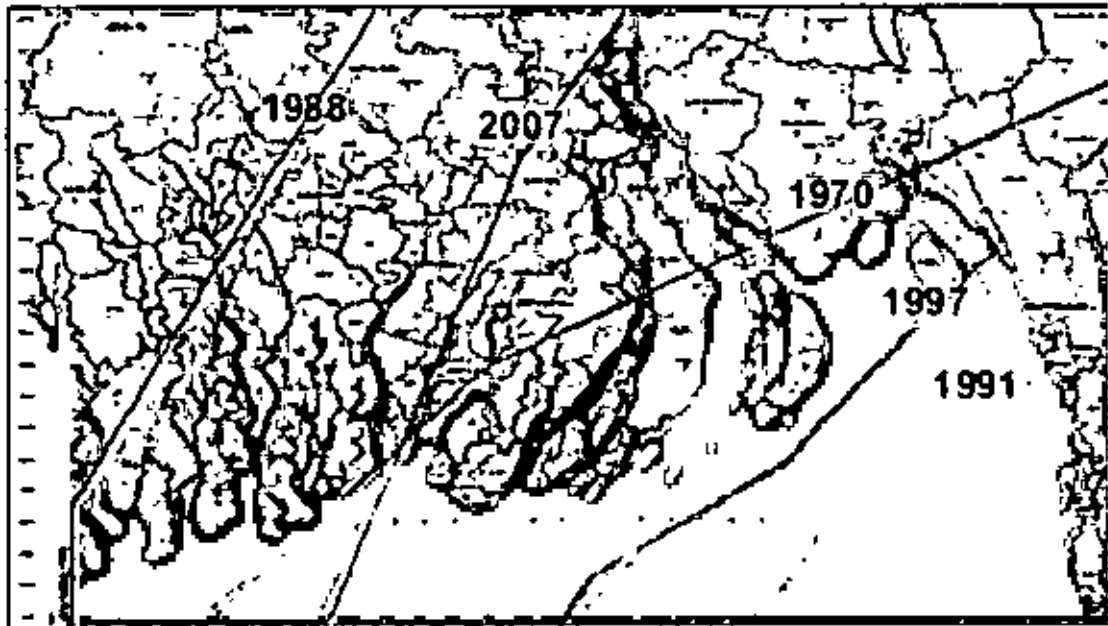


Fig.6.1. Courses of recent major cyclones. (Source: IWM, 2008).

This Fig. shows the path way of major cyclones to Bangladesh coast except BULI (2008) and AILA (2009), because those are the most recent one. The secondary data shows that maximum wind speed of SIDR was 69m/s (250 km/h, average for one minute), and the lowest atmospheric pressure was 944hPa where the maximum inundation height of the surge was 9.6m (the inundation depth 6.5m) in the coastal area (JSCE, 2008). In past data, the cyclone in 1991, which is known as the strongest cyclone to cause about 140 thousand fatalities, recorded the maximum wind speed 72m/s (260 km/h); the average surge height was 6.50 m and the lowest atmospheric pressure 898hPa on 29th April. The cyclone at 1988 took place at SW coast having atmospheric pressure 966hPa and the recorded maximum wind speed was about 71m/s (205 km/h) with average surge height 5.50 on 12th November (BBS, 2002). The cyclonic storm surge SIDR mainly hit the entire cities of Patuakhali, Barguna and Jhalokati Districts over 5 meters (16 ft) height tide. About a quarter of the world heritage Sunderbans (Bagerhat site) were damaged.

The present study has been conducted partially (Shatkhira) on the direct path of the recent cyclone AILA. The storm surge of 1988 also directly hit that district of south west coast. On the other hand storm surges of 1991, 1997 were more destructive for the study area in Cox's bazaar. The study has shown that the risk of storm surge and its rate of damage generally depend on some factors (Table 6.1) or characteristics.

**Table 6.1:** The statistics of storm surges in the coast of Bangladesh within last few years.

Year	Month	Ave.Wind Speed (Km/hr)	Ave. Surge Height (Meter)	Duration (hrs)	Main Affected area
2009	May	100	4.5	10	South -west
2008	April	70	1.6	6	Central
2007	November	240	6.05	18	Central and South-west
1998	November	90	1.83	6	Central and south-west
1998	May	150	2.14	6-8	South-east
1997	September	150	2.44	6	South-east
1997	May	225	3.05	8	South-east
1995	November	210	2.55	12	South-east
1991	April	240	6.50	16	South -west
1988	November	182	5.50	12	South-west

(Source: Banglapedia, (2008) web site; SEHD, 2002; Times online, 2007 and news papers, 2007 & 2008).

Table 6.1. Shows characteristics of Storm surge hazards occurred during last 20 years in Bangladesh coast including their average criteria. The most destructive storm surges for South east coast were at 1991, 1997 etc. where as storm surges of 1988, 2007 and finally 2009 caused a great damage in the Central and South west coast. In the span of little over one and a half year two major cyclones have struck Bangladesh. In November 2007 it was cyclone SIDR- the meanest hurricane of all time, seen by the people of Bangladesh, which took the lives of more than thousand people. And now it is the infamous cyclone AILA. AILA swept away many areas, which were still recovering from the cyclone SIDR.

The strength of storm surges depends on the speed of wind in the way of cyclone. Surge height also depends on it. The ultimate losses due to those storm surges depended on surge height and surge duration. But it is also true that storm surges are part of natural system, so the security of coastal environment and people depends barely on the positive performance of stakeholders and the authority. As the coastal community and their livelihood pattern is the main party of sufferings due to storm surge in that coastal area of Bangladesh, so primary data was the main basis of storm surge risk prediction and livelihood security assessment in this study.

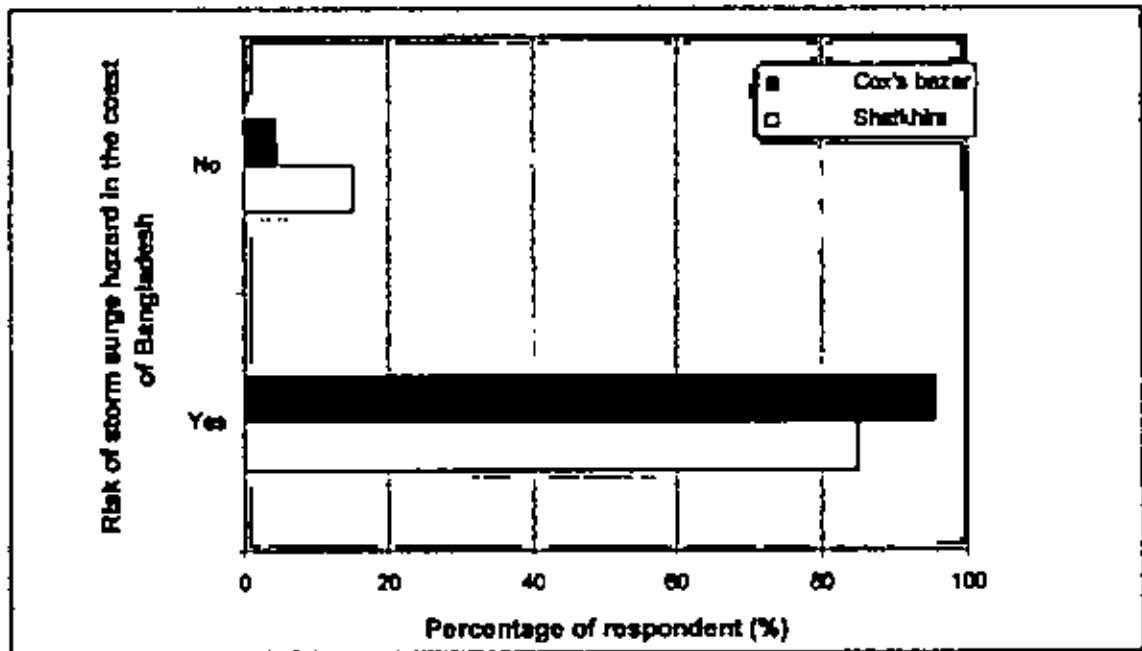


Fig 6.2. Storm surge vulnerability/risk prediction in study area.

(Source: Field survey 2008)

Fig. 6.2. Reveals that the people of the study area were concern about the situations and their opinion defined the storm surges as a destructive issue for their life, resources and living system in the coast. The level of storm surge risk is different in the defined study sites. As for reason it is known that the area of Cox's bazar is in higher risk zone because of open sea shore but the area of Satkhira is in moderate risk zone for the protection of Sundarbans (DMB, 2004). The people of study site in Sathkira said that Sundarbans save them and their livelihood resources from Ban (Local term of Storm Surge) and also act as a great opportunity for their living.

### 6.2.2. Natural sub-system for security of coastal livelihoods

The natural sub-system of coastal livelihoods is mainly defined by the direct access to both marine and terrestrial resources and their combined acts in the total environment and population. Sustainable management of livelihood resources in marginal level people refers to sensible use of renewable natural wealth and maintenance of local ecosystems to face the risk action of storm surge. So that the security of resource base livelihood system against storm surges are described by the performances of natural components of the coast.

- **Resource bases**

The study area encompassed a highly diverse and robust like coast and shoreline; ecosystem of estuaries, islands and coral reef; char lands, deltaic plain, mangroves, marine system, etc. The aquatic systems include saline water, brackish water and fresh water while the land area of the zone includes mud flat, sandy beach, sand dunes, flat lands and undulating terrain. A large number of flora and fauna including their genetic varieties supports this coastal ecosystem, which in turn contributes to the marginal people according to their livelihood variation.

**Table 6.2:** Natural resources for living of different livelihood groups in coastal area.

Livelihood groups	Resource alternatives
Farmer	Agricultural crop land, Poultry and Livestock, Homestead garden, Shrimp field, local forest, River etc.
Fisher	Sea or marine ecosystem, River, Wet lands, Mangrove forest, Shrimp field, Poultry and livestock
Wage Labor	Poultry and Livestock, local forest etc.
Fry collector	Sea or marine ecosystem, River, Wet lands, Mangrove forest, Poultry and Livestock
Dry fisher	Sea or marine ecosystems, River, Wet lands, Agricultural crop land, Poultry and Livestock
Salt farmer	Salt field, Shrimp field, Agricultural crop land, Poultry and Livestock
Forest extractor	Mangrove forest, River, Poultry and Livestock, Sea or marine ecosystem

Source: Field survey, 2008-2009.



Table 6.2. Shows that the accesses to different coastal resource base were not same for all community members in the coast. Those varied according to their living sites and livelihood categories. Generally coastal livelihood groups use some fixed resources that are related to their main occupation. With that continuity, it also has been found that the livelihoods of both study sites contain almost same options with few exceptions. As an example, Sundarbans is one of the rich resource bases in Satkhira where Salt fields are only in Cox's bazar district still now.

- **Performance of rivers and channels**

Bangladesh is the country of thousand rivers and channels. The rivers come from upstream of the country and run away to the Bay through the coastal area. With the main river systems, lot of tributaries, distributaries and channels are active here. The study sites are also partially bounded by numbers of rivers and channels. The active river system would be the controller to the long term impacts of storm surge to the land use pattern. If the river and channels are flowing without any barrier, the surge water can not log over the area. But the entire natural channels of the study area (Tributaries and distributaries) have lost their normal flow because of sedimentation and man made barrier on them.

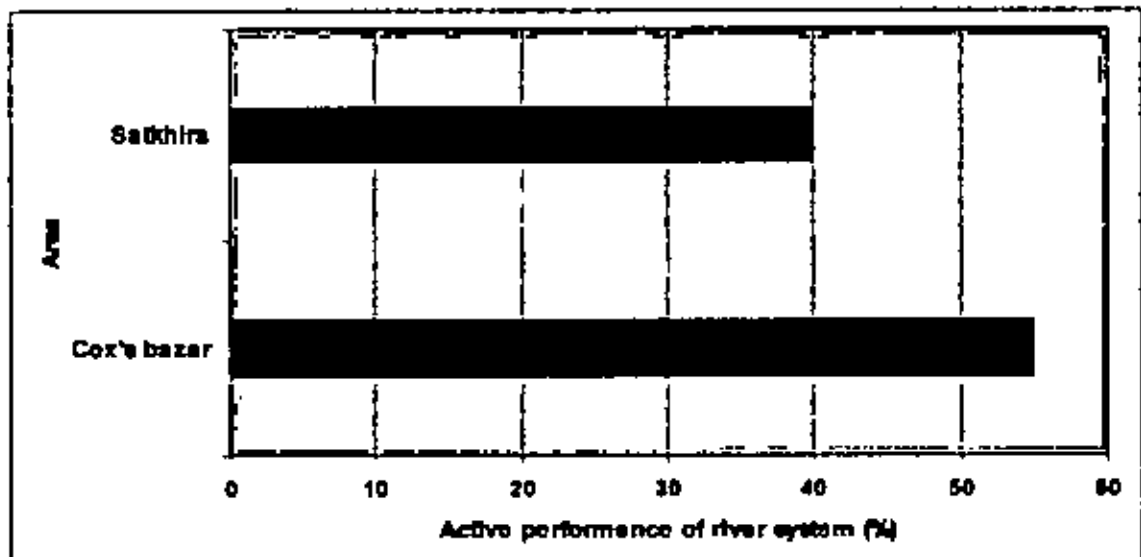


Fig-6.3. The performance of natural drainage channels in the study site of the coast.

Source: Field survey, 2008-2009.

Fig 6.3 reveals that in both study sites, there are numbers of river systems and channels. In Cox's bazaar area the quantity of rivers and channels are not huge but their flow rate and supportive performance make satisfaction to stockholders. The river Bakkhali and Moheskhali channel act a vital role in their communications and business sectors and drain out the tidal or surge water to the Bay. But in the area of Satkhira district the quantitatively rich channel system can not perform so because of anthropogenic actions and lack of management initiatives.

- **Land use pattern**

Land use pattern of an area is very much important for not only productivity but also for protection and prevention from natural hazard.

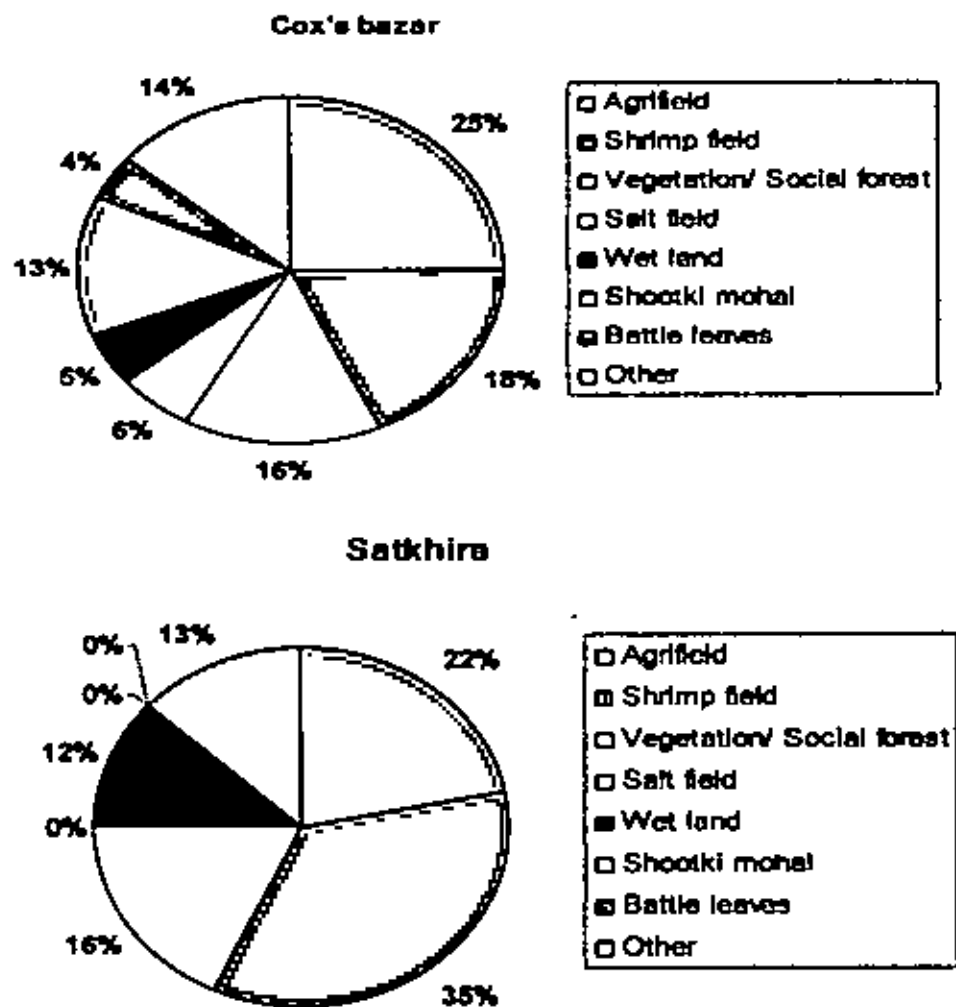


Fig-6.4. The land use pattern of the study area. (Source: Survey 2008-2009)

Fig 6.4. Shows the land use pattern of two different study sites in certain coastal districts. In Cox's bazaar site the land use options are quantitatively higher than that of Satkhira because of livelihood groups' diversified types and size. Most of the land is used as shrimp field at Munshiganj in Satkhira but the marginal people have no direct access to that field. Another large portion of that site is covered by Paddy field and a very few is under the social forestry. At the present situation, excess salinity in soil and water reduces the rate of vegetation in certain area.

In Cox's bazaar, the shrimp field is also used as salt field in winter season. There is some special vegetation (Pine, Coconut etc.) found near open sea which has a great role to storm surge protection. Agricultural fields are used for rice, wheat, vegetable and especially for Betel leaf production. To address the security measure the most concern land use pattern is vegetation. Fig 6.4. Shows the rate of vegetation at Satkhira is 18% of the total land area which is slightly higher than that of Cox's bazaar. The statistics do not include Sundarbans because it is out of the survey area.

- **Production**

The category of products is dynamic in both sites according to the livelihood groups of coastal area. Different livelihood groups produce or extract suitable products from their access to natural resources. The quality and quantity of production and withdrawal depend on the condition of their alternative resource bases, the risk factors, the seasonal variation and harvesting time (Fig-6.5) of their main products. Most of the coastal production patterns are seasonal and few are over the year. The annual rate of production also depends on the use of improved or proper system, skilled application and damage protection approaches against storm surge. The natural protection, improvement practice (capacity to recover the damage of resources) and Regeneration capacity are very important here.

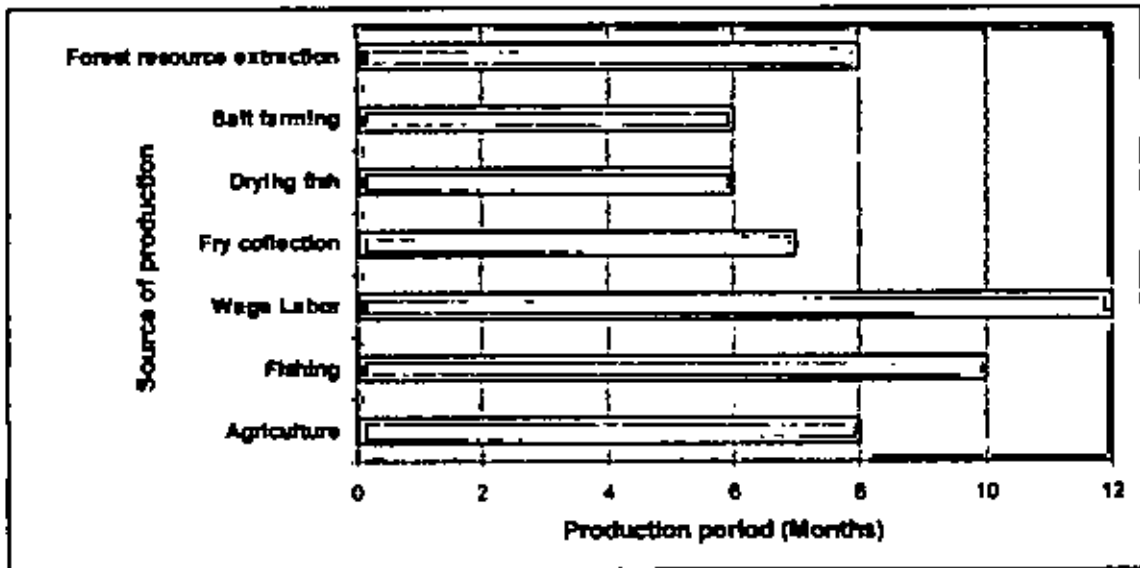


Fig-6.5. The general resource exploiting time frame of coastal livelihood groups. (Source: Survey 2008-2009).

Fig 6.5. shows that all livelihood groups in coastal area are not fully active in production all over the year. Most of them maintain their time frame based on types of products, land use capacity, climatic conditions and others. Only wage labors work all over the year. But other acts on their main occupation through specific time. As for example, the peak time of forest resource extraction in Sundarban is February to May. The people work there about two to four months depending on weather and other social risk. Most of the agricultural products generally grow two times in recent year and the duration is about four months in each session. The salt farming, fish drying, shrimp fry collection etc. are seasonal work.

The production time has become important because the seasonal activities are in great risk. If any storm surge comes in an area and does great damages to properties and accesses, it needs initiatives to get immediate response and try to improve the short falls earlier. The effects of storm surges need considerable time and technical helps to mitigate the losses on natural resources and household capitals. The capacity of livelihood groups to improve their production system and rate of product collection has been shown in Fig 6.6.

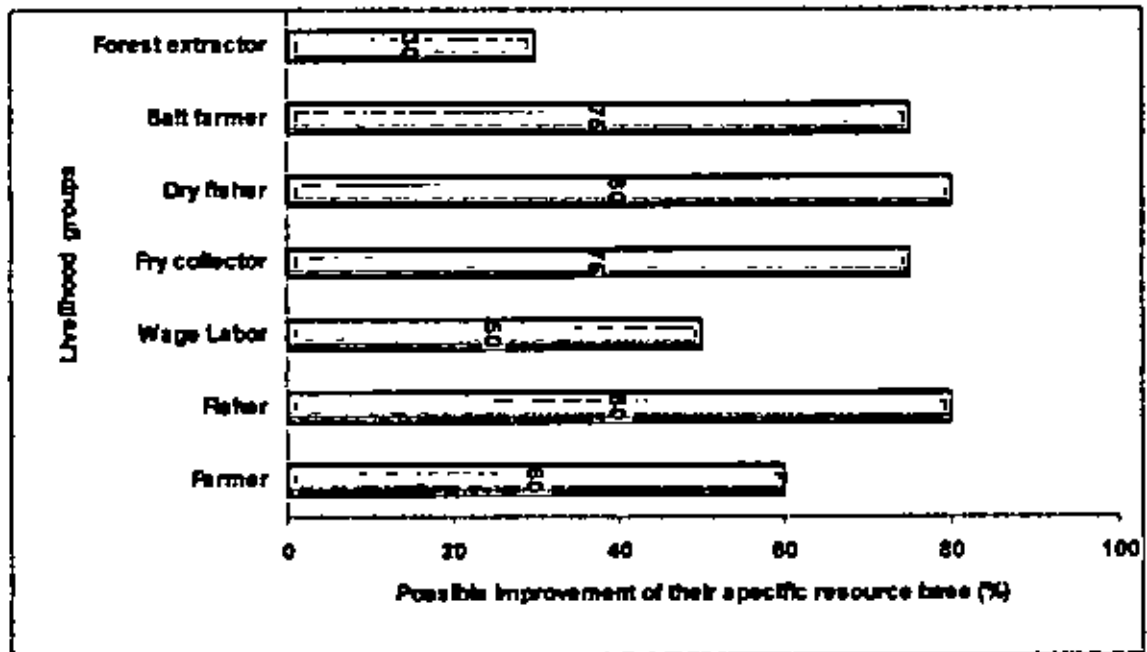


Fig- 6.6. The probable rate of regeneration or reformation of resource base after storm surge. (Source: Survey 2008-2009)

Fig 6.6. expresses the ability of different livelihood groups to recover from the losses due to storm surges in their field of resource alternatives. The fishery sector is fully depends on the quickly renewable marine biological system. The group of dry fisher and fry collectors also depends on that source and recovers immediately. The farmer's capacity to renewed their field and product is moderately high as it almost depends on various natural or man made factors. The access of forest extractors need comparatively long time because there is some legal or policy restriction to forest resource extraction just after the damages. The all natural resource options also act directly or indirectly in the field of financial sub-system of livelihoods.

### 6.2.3. Financial sub-system for coastal livelihood security

The financial livelihood sub-system of coastal community includes possession /dispossession of cash and items that are readily transformed into cash. Few activities that brings cash and relative purpose have also been perceived as financial capital such as

income generation activities, savings /saving system, credit, insurance, production tools and others.

- **Income vs expenditure**

The coastal zone is relatively income poor in comparison to the rest of the country. With some other reasons the frequent occurrence of natural disasters is one of the most important factors here. The costal livelihood groups are in diversified status of income because of their dynamic sources and opportunities.

**Table 6.3:** The alternative scopes of livelihood groups in the economic field of coastal living system.

Livelihood Group	Economic Activities	Livelihood Group	Economic Activities
Farmer	Agriculture	Salt farmer	Salt production
	Fish/ Shrimp /Fishing in river		Agriculture/Shrimp
	Poultry & Livestock		Small business
	Small business		Fishing
Fisher	Fishing in river and sea/ Shrimp	Forest extractor	Honey / Wax collection
	Small business/ Boatman		Wood/Ghoolpata collection
	Agriculture		Fishing
	Drying fish/ Salt Farming (Small scale)		Fry collection
	Net servicing/ preparation		Boat making/repairing
	Boat preparation/ servicing		Crab collection/ supply
Dry fisher	Drying fish / Boating and fishing/ Fish marketing/ Small business	Wage labor	Agriculture works/ Vegetable farming
			Labor in shrimp farm/ Small industry/ Salt farm/ Fishing boat/ Construction works/ Wood works/ Mechanic
Fry collector	Shrimp fry collection/ Crab collection/ Labor in shrimp field and agricultural field		Labor in fish drying
			Small business/ Dry fish Business/ Crab business

(Source: Survey 2008-2009)

Table 6.3. shows the possible alternative economic activities including main occupation of each vulnerable livelihood groups in the coastal zone. The financial process of farmers usually concentrated to land and water resource based activities such as agriculture, fisheries, salt farming, etc. Similarly fishermen are engaged mainly in fisheries, agriculture, fish related business, salt farming, etc. The economic activities of wage labors are more diversified than other groups, although most of them are engaged in agriculture works. Woman are usually engaged in household based works like homestead gardening, poultry and livestock farming, cottage industry, small business, fish fry collection, etc. The storm surge can make great loss at any time in Bangladesh coast and it is not possible to avoid that shock. So the community people try to adapt with different financial process of income and consumption in household level.

If there are multiple income sources, then the household is able to rescue themselves immediately and progressively from the vulnerability of storm surges. In that case, cash savings of household is an important security option. The income and expenditure difference be used to calculate the rate of annual savings which is expressed for different livelihood groups of coast in Fig. 6.7.

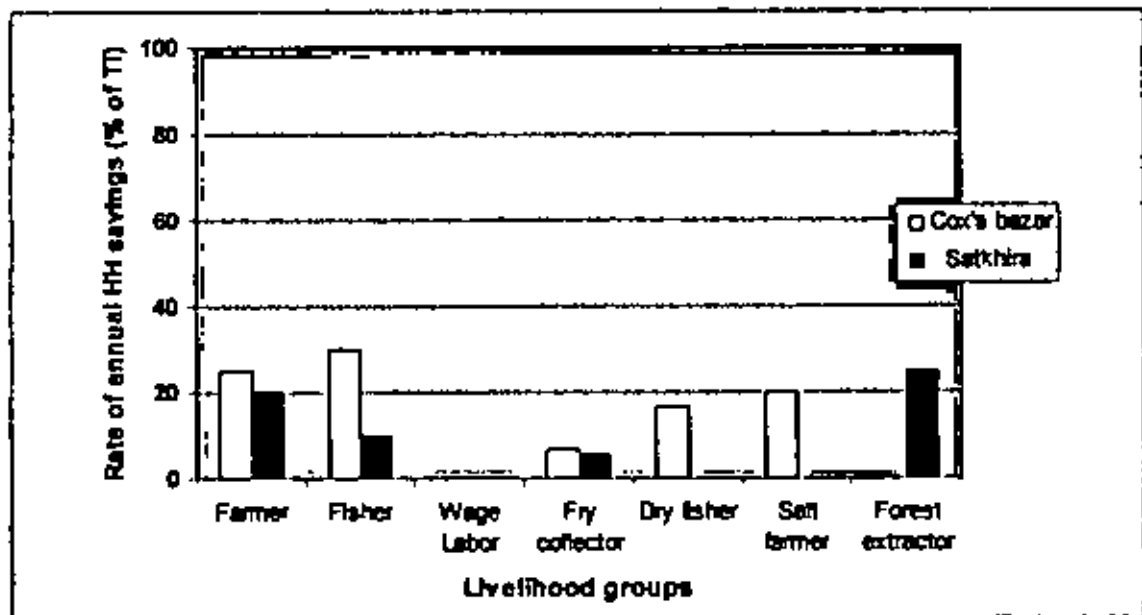
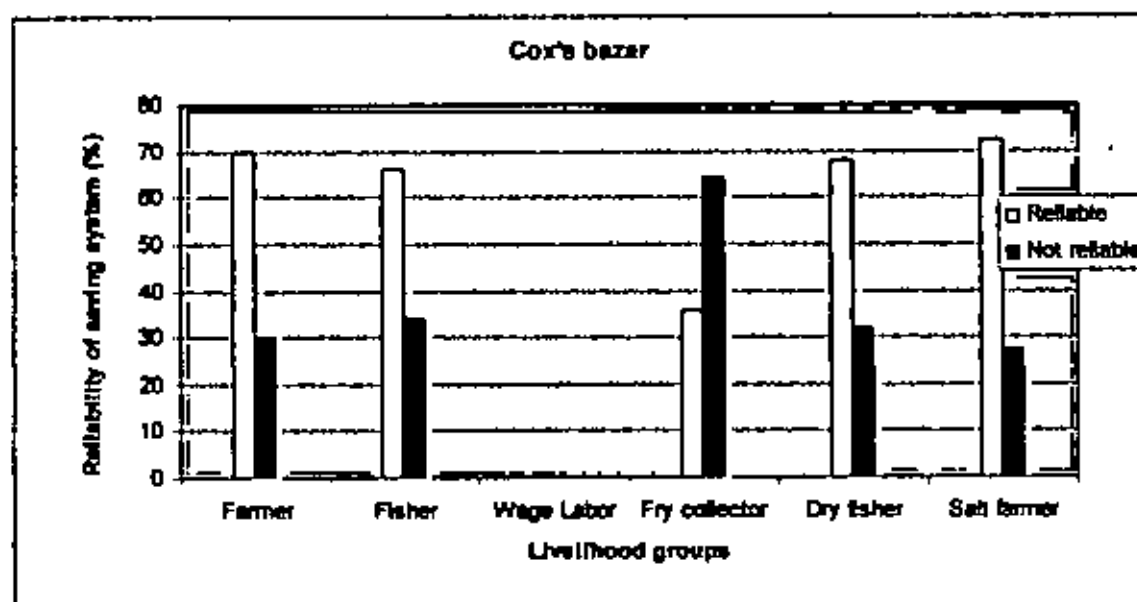


Fig 6.7. The household saving capacity of the livelihood groups in study sites.

(Source: Survey 2008-2009)

Fig 6.7. shows the average annual savings of livelihood groups which is calculated from the ratio of per capita household income and living expense of different livelihood groups. Fig 6.7. shows the diversification of livelihood groups in different study sites and expresses their comparative financial capacity and scope of savings. In Salkhira area the forest resource extractors are in a better position because the products' market prices are higher. They earn seasonally and try to save some income (about 25% of their yearly income) for vulnerable situation. It is the real fact that it is not easy for the vulnerable groups to save from their limited income. But fishers of Cox's bazaar save 30% of total income where as farmer saves 20% in Salkhira and the fisher group saves 25% in Cox's bazaar.

Here another security concern is the reliability of saving system in local community. The most of the marginal livelihood groups do not take the service or help from available banking system. They save their income with traditional way in house or to *Mohazon* (Local power). In present time few organizations or *Somiti* act in that sites. Fig 6.8 shows the trend of reliability of saving system within the marginal limit of coastal livelihood groups based on stakeholder's opinion in the study area.





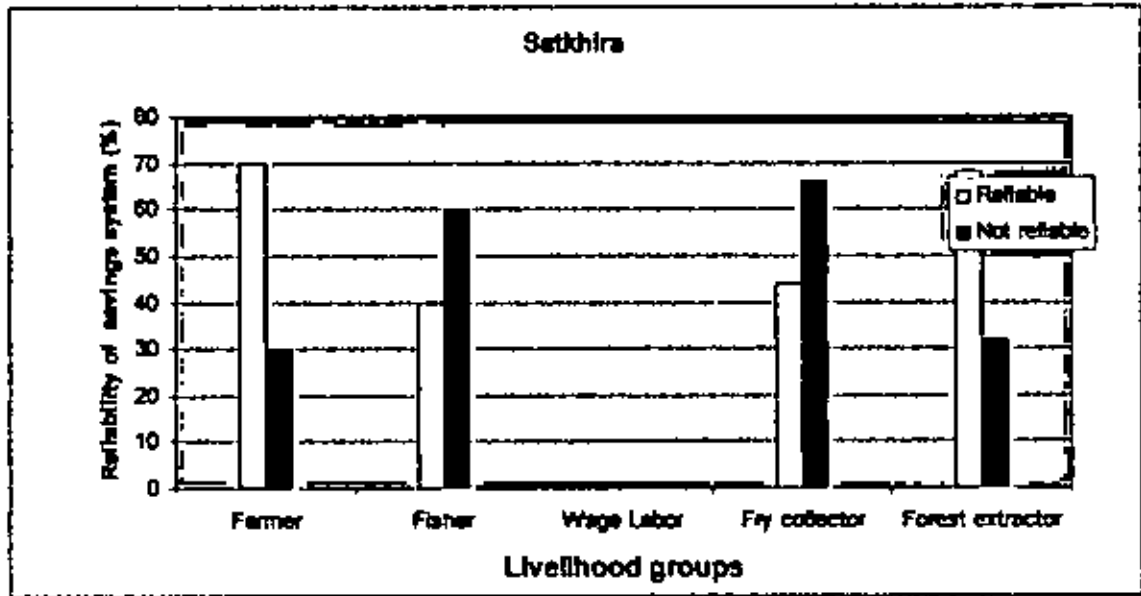


Fig: 6.8. The response of participant on the reliability of their saving system.

(Source: Survey 2008-2009)

Fig 6.8. reveals that in both sites the wage labor group does not have any saving capacity. In Cox's bazaar site farmer, fisher, salt farmer and dry fisher households' have responded positive in the question of system reliability where as positive response have found in only for farmer and forest extractors in Satkhira. Most of them depend on NGOs as member of local *Somiti*. Grameen Bank and Krishi (Agriculture) Bank have been found at service.

- **Access and ownership**

Each coastal livelihood groups keeps different options in their household level. Except their main source of income they have either little or more access in home ground and that is very important for certain losses due to risk issues.

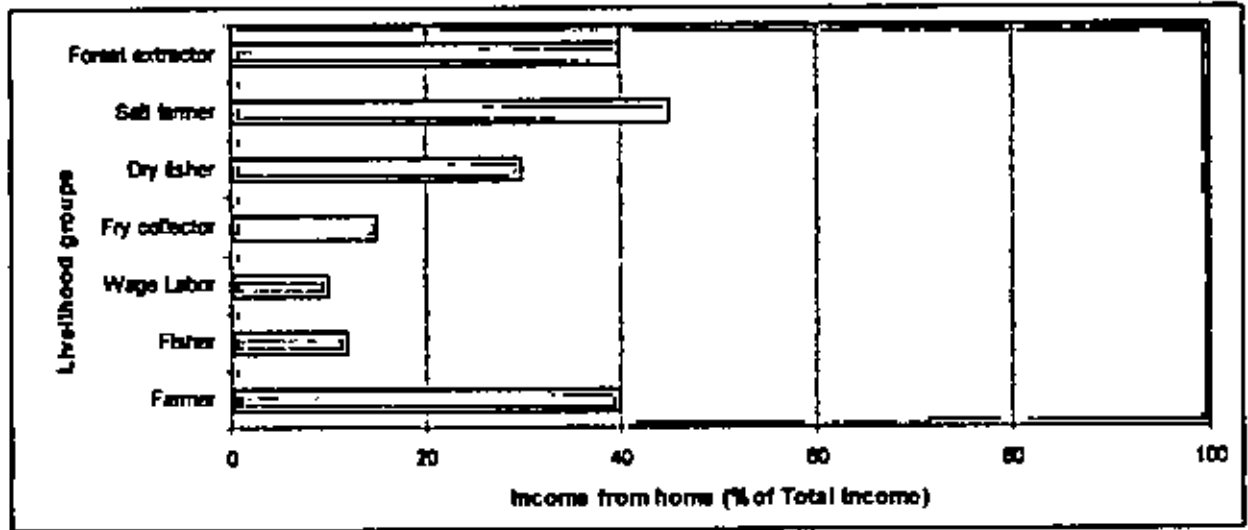


Fig- 6.9. Rate of household income from home ground for individual livelihood groups. (Source: Survey 2008-2009)

Fig 6.9. Shows the home base income rate of individual livelihood groups in coastal sites. The practices of homestead income activities have been defined by highlighted the contribution of women in income generation. The salt farmers have found as the higher economic group and keep the highest rate of homestead income as 45% where the farmer and forest extractor get 40% of the total income.

The income of coastal livelihood groups mainly depends on the local resources which are in their access. The access or opportunities would be different according to area or livelihood categories. The ownership on production has not found the same for household as an example, people who owned any land for cultivation but another parson (land less farmer) use that; in this situation the land owner gets a fixed share of production per year. On the other hand the people, who cultivate their own land, keep 100% ownership on production.

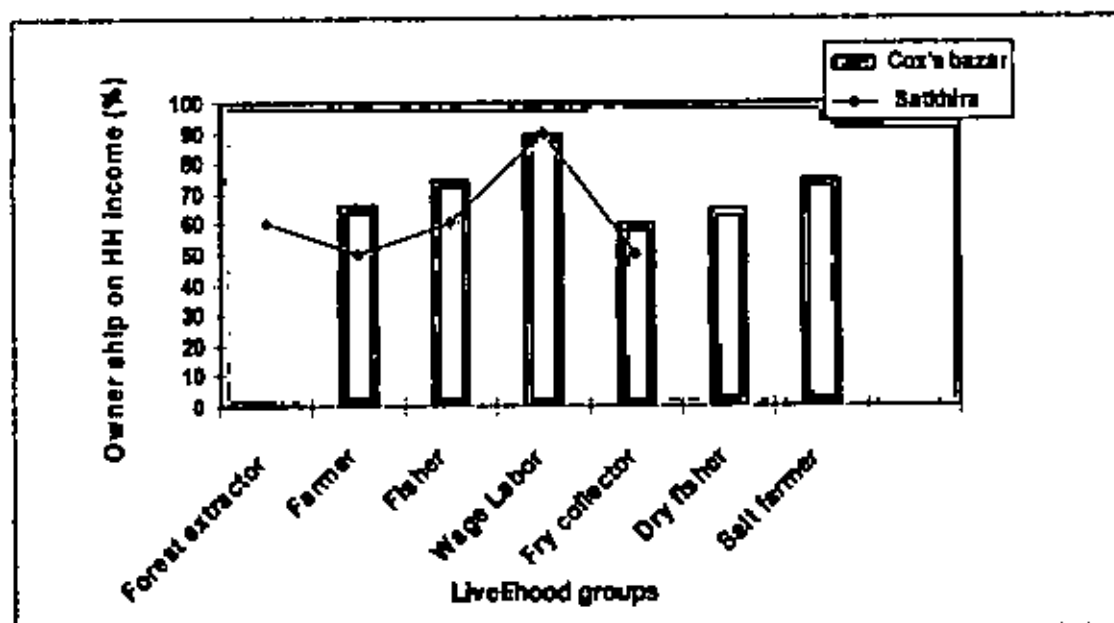


Fig: 6.10. Ownership on their overall income source for different livelihood groups in coastal area. (Source: Survey 2008-2009)

A large part of coastal rural poor keep access there as wage labor. But they have lowest ownership on their source of income. The farmer keeps 60% to 75% on their total income where salt farmer keeps 70%. The forest extractors have 60% ownership on their total income options. In coastal Bangladesh, most of the people keep free access to natural resources but it has found an especial view in financial system. The root level people are bound to some power and those powerful part take share from them.

- **Financial support**

The level of financial security due to natural hazard strongly depends on the support from outside of the vulnerable region. There would be financial loan from Government or Non Government organizations as well as income support from rest of the country for household development. The micro-credit system is now a famous and effective system for rural people in Bangladesh. But in emergency people need some thing special to repair their living systems in their own area.

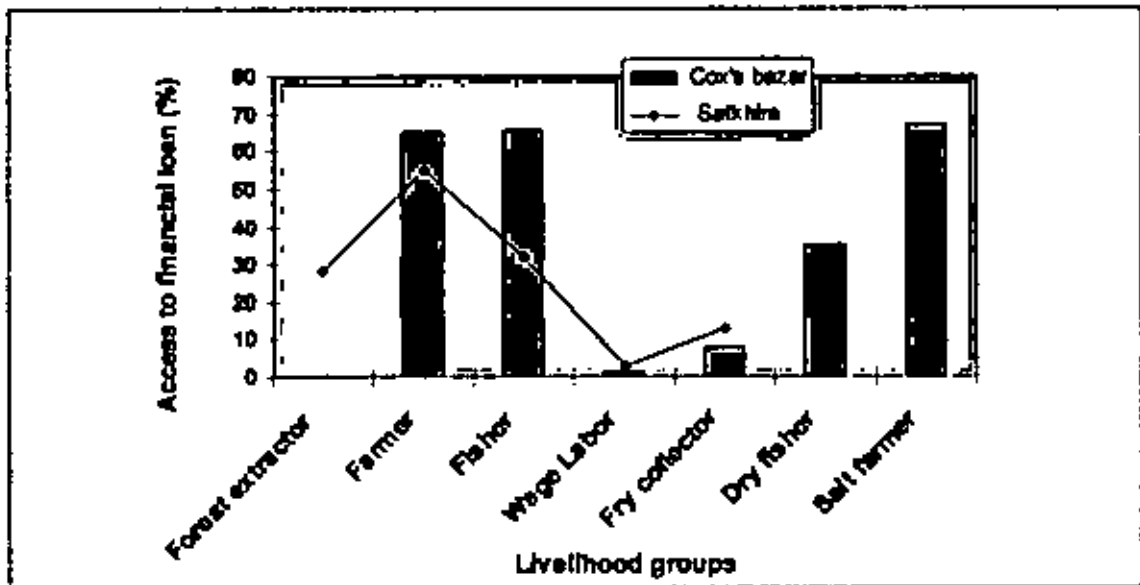


Fig: 6.11. Scope of financial loan in different livelihood groups in the study sides. (Source: Survey 2008-2009)

Fig 6.11. Shows that people having some fixed assets, get access to financial loan. The present study found that about 65% farmer have access to financial loan from GO, NGOs or others in Satkhira and that rate is 55% in Cox's bazaar because in both sites farmers are stronger among the marginal groups. In Cox's bazaar that rate is highest 67% for salt farmer.

There are some people of coastal households who are involved with economic activities in other part of the country. If Household members have access to out migration, it may act to fill the losses. The rate of out migration can increase the income access and make safety during risk period. In the study area almost every groups have access to out side financial support but the rate differ more among different them in different sites of the coast.

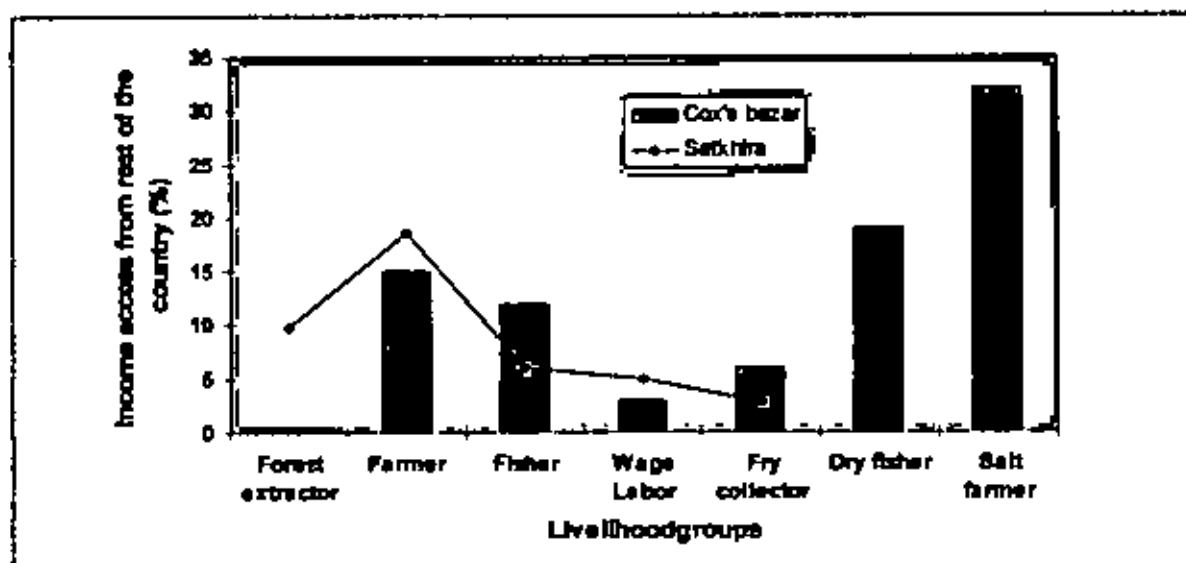


Fig 6.12. The income access from rest of the country for study area. (Source: Survey 2008-2009)

Fig 6.12 shows that in Cox's bazaar site the salt farmer group have capability to earn an of average 32% of total income from rest of the country where as the dry fisher earns 19 %. The highest value is 18.65% for farmer group in Satkhira. The lowest access is for wage labor in both sites.

- **Women activities**

In coastal community active women can play a vital role in their field of income generation and household security. The active and skilled women keep their family with special care in every crisis. Generally major part of women acts at home in Bangladesh but in recent time they have found progressive in every field of income generation.

In coastal area they are also at leading position in different fields of living. Women have found as energetic and hard working. Women take part in agricultural activities mainly during harvesting, boiling and storing. A large part of fisher women are active with fish drying and processing. The activeness of women of coastal community is shown in Fig- 6.13.

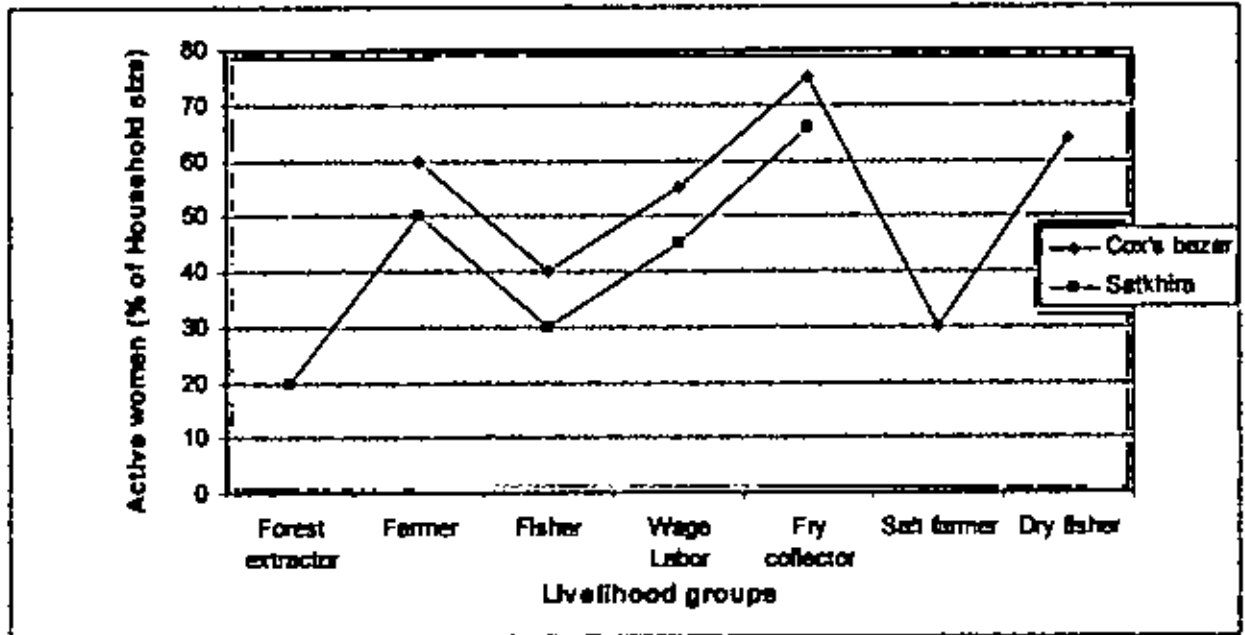


Fig: 6.13. The rate of woman activeness in different livelihood groups in coastal area. (Source: Survey 2008-2009)

In Bangladesh coast, most active women participation has been found in the sector of fry collection. Children are also part of that. In fry collector households, average women activeness varies from 66% to 75% where as in farmer household it is 50% to 60% respectively in both study sites in Bangladesh coast. The less woman participation is found in Forest extraction (20%) and in salt farming (30%). The active performances of livelihood financial sub-system and its components play significant role in coastal livelihood security.

#### 6.2.4. Human resources sub-system for coastal livelihood security

Human sub-system is mainly comprised of selected household members along with some indicators reflecting quality of life, such as, health, education and training, which transform a human being into a human resource within the livelihood system. Perceptions with regard to human capital are similar among all strata of households.

- **Rate of literacy**

Education is perceived an important human asset. It has been analyzed in terms literacy rate. The define literacy rate has been measured by the level of education from primary to high school in coastal livelihood groups. Fig 6.14. shows that the rate of literacy in household level differs according to varieties of livelihood groups and also changes with area coverage. A household with educated members can ensure their security in different sector of life and properties.

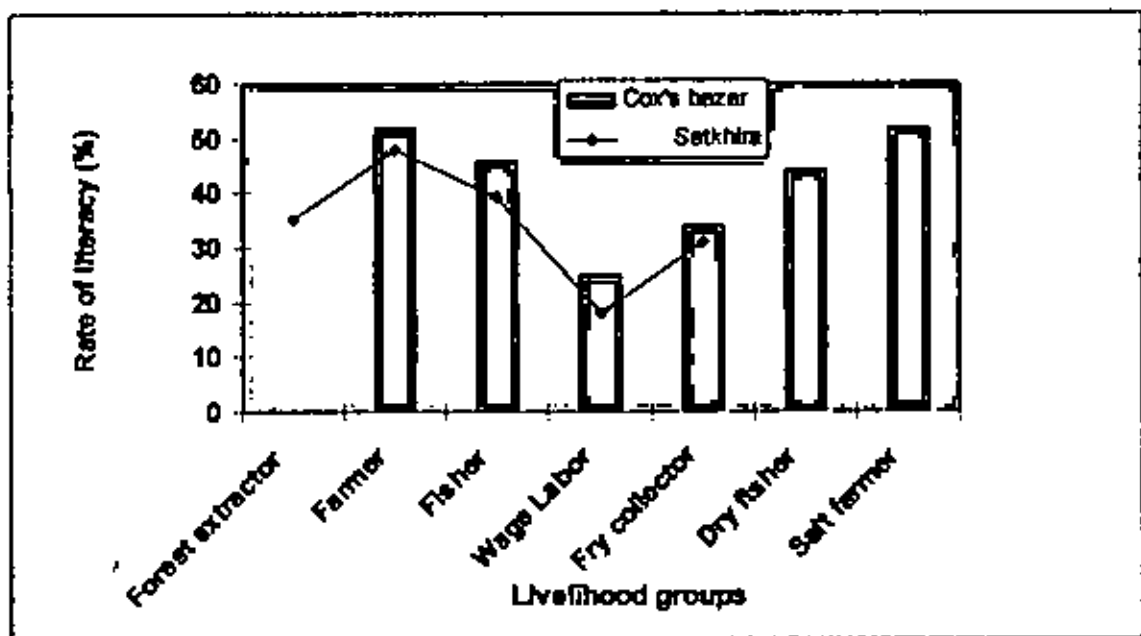


Fig 6.14. Literacy rate in different livelihood groups in coastal Bangladesh.

(Source: Survey 2008-2009)

Here, fig 6.14 shows the average literacy rate of farmer household is 52% in Cox's bazar but it is 48% in Satkhira. At the same time fisher group keeps literacy rate of 46% in Cox's bazar and 39% in Satkhira. Ultimately the highest rate of literacy is denoted by 52% in salt farmer household in Cox's bazar. The overall quality of a household is mainly defined by its educational quality for every livelihood groups. That quality expresses the skill and active performance of household both in regular and risk period. Not only academic education, but also indigenous knowledge and common sense is important for risk management and improvement of household.

- **Health care**

Human health is one of the important indicators for the livelihood system. Health is very much dependent on the availability of medical facilities and public awareness. In Bangladesh, the medical facilities are commonly defined by number of doctor or health worker and structural view of hospital. For coastal people that known type of medical facilities are not available so. It was found that, some medical centers exist without sufficient doctors' presence. Some times especially in risk period the medicines have not been found.

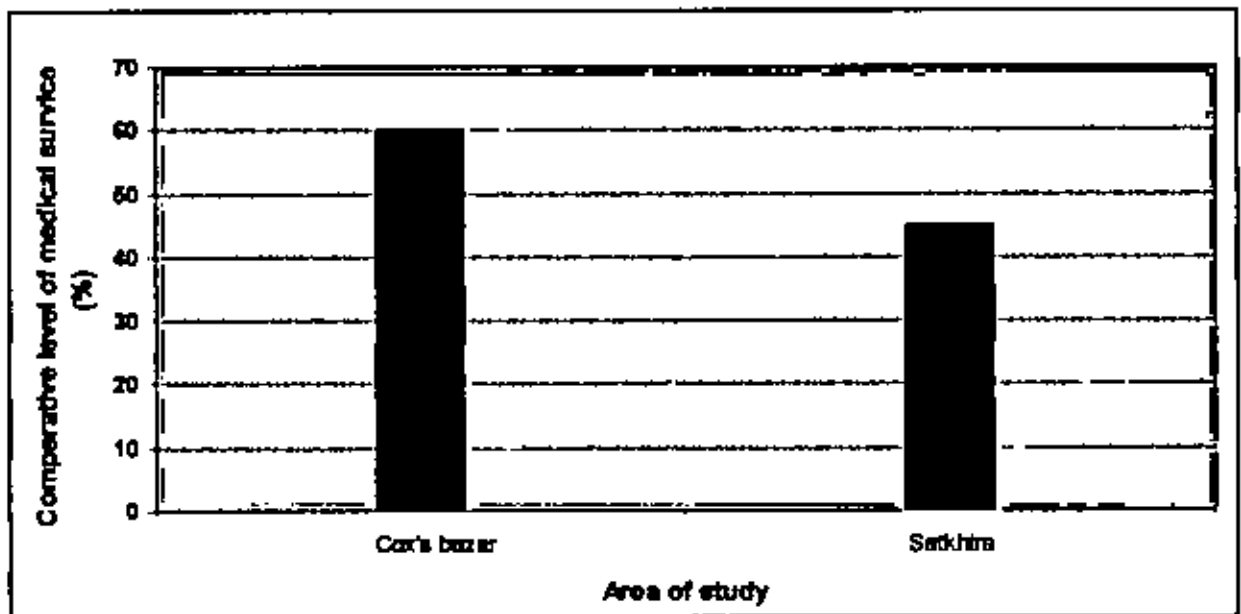


Fig: 6.15. The Performance of medical services in study sites of different districts.

(Source: Survey 2008-2009)

Fig. 6.15. shows that the performance of medical services in Cox's bazaar and Satkhira defined by the doctor's duty and quality of treatment in those locality. In Cox's bazaar, the calculated rate is 60% where as in Satkhira it is 45%. To calculate that rate, the study found that both of the area skilled and responsible medical team for emergency does not exist properly.

In the question of health care the personal or household awareness would be more significant especially in crisis period. During surge period, it has great risk of physical



injury and epidemic diseases and it may also become difficult to contact doctor or hospital because of poor communication system. So practices of indigenous knowledge and first aid training have been found as a very necessary security indicator in coastal disaster management programmes.

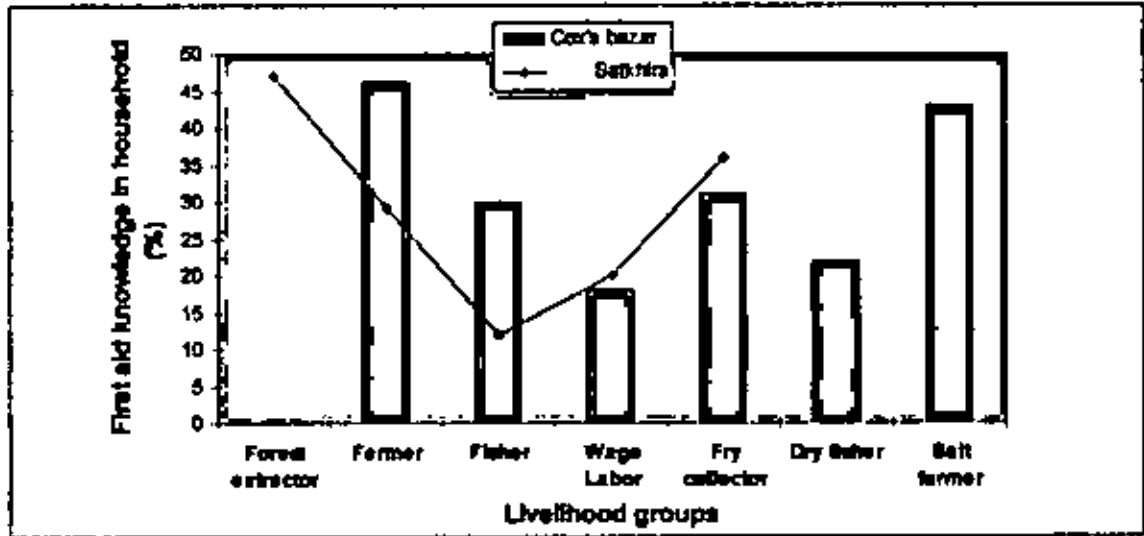


Fig : 6.16. The rate of first aid trained person in household of livelihood groups. (Source: Survey 2008-2009)

Fig 6.16 shows the level of knowledge on first aid is not satisfactory in the defined field but they have practices of general health (indigenous knowledge) care in the household of different livelihood groups. The first aid knowledge has been found higher in farmers' household (46%) in study sites of Cox's bazar and in Satkhira the forest resource extractors' households shows higher practice of health care because of their most challenging profession. The fry collector group has also been with good practice of indigenous knowledge.

#### • Awareness

To face any crisis, people must need to be aware and active. In coastal area people needs training, awareness program, workshop on adaptation technology and other programs to make them active in crisis moment. Under the project of integrated coastal zone management, there are few programs were held in last decade but the rate is very poor

compare to the huge population size of Bangladesh coast. That information of community awareness and knowledge of livelihood groups have been measured according to their result of direct questionnaire survey in the study sites of the coast.

#### 6.2.5. Infrastructural resources for coastal livelihood security

Among physical capitals a wide range of infrastructures, fixtures, tools, services and utilities are included that contribute to household livelihood and comfort. However, households of all strata consider house, cattle and poultry as assets. Cyclones and storm surges are mentioned again and again by people as the main reason for a decline in their physical assets.

- **Housing infrastructure**

The housing status and strength is very much important for security from storm surges in coastal area. The statistics must be dependent on the construction materials of house infrastructure. The table 6.4. Shows the scenario of house infrastructure base on district boundary.

**Table 6.4:** Housing condition in coastal area with their security performance.

Materials used		Safety Performance (%)	
Walls	Roofs	Cox's bazar	Satkhira
Straw/ bamboo	Straw/ bamboo/ Ghool pata	28	22
Straw/ bamboo	Metal sheets (Tin)/tiles	13	10
Mud/Unburned brick	Straw/ bamboo/ Ghool pata	17.5	35
Mud/Unburned brick	Metal sheets (Tin)/tiles	9	7.7
Metal sheets (Tin)	Metal sheets (Tin)/tiles	7	2.5
Wood	Straw/ bamboo/ Ghool pata	13	12
Brick and cement	Straw/ bamboo/ Ghool pata	9.9	8.9
Brick and cement	Metal sheets (Tin)/tiles /Cement	2.6	1.9

(Source: Survey 2008-2009)

With the area base status the quality performance of housing infrastructure play a vital role in livelihood security of different livelihood groups in study area on coast. The security of life and household properties depends on the strength of house during storm surge in coastal area.

Most of the marginal livelihood groups live in traditional house made by mud, bamboo and wood. Few people live in break build house in the coast.

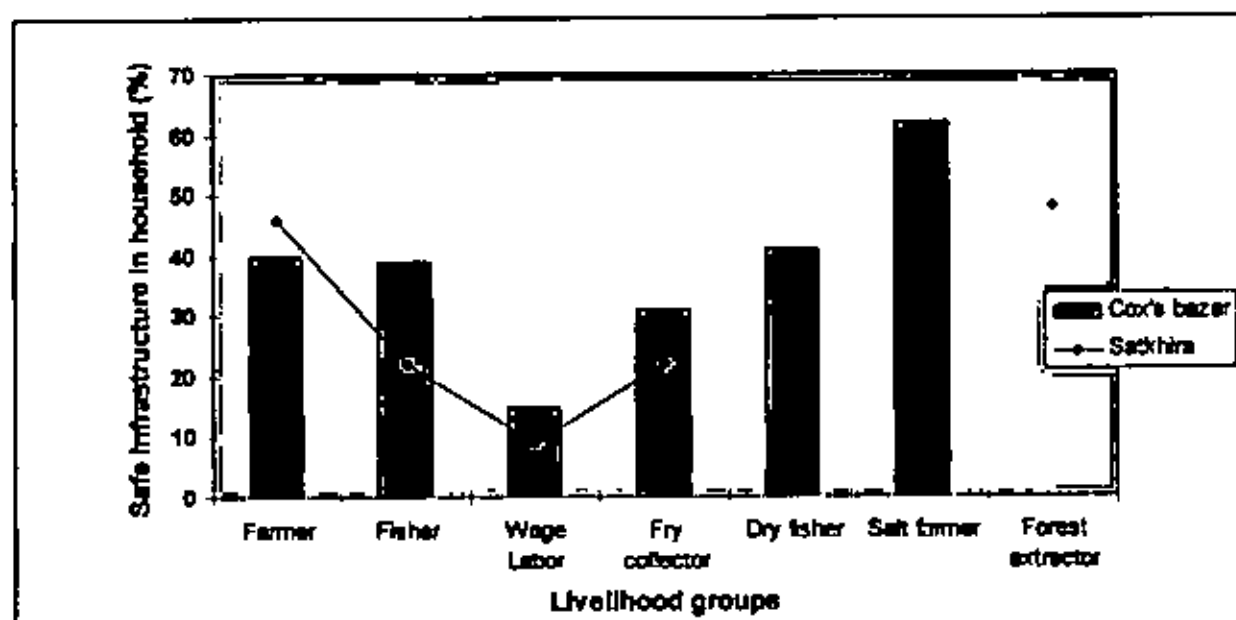


Fig 6.17. Performance of housing infrastructure among the different livelihood groups. (Source: Survey 2008-2009)

Fig 6.17 describes the household safety through the strength of house infrastructure according to the socio-economic condition of livelihood groups. The houses of salt farmers are best (62%) in Cox's bazar site. In Sakhira the forest extractor groups hold the highest position of 46% safe house against surge effect.

- **Protection and Shelter**

Cyclone and associated tidal surges are important vulnerability encountered by the people of coastal region. The need to provide safety for the inhabitants of the area has long been recognized. In Bangladesh coast, the structural protection system is not satisfactory. The

Polders (BWDB) and embankments (Beribadh) are not sufficient with their capacity. The present performance of those structures is not good because of operation and maintenance fault. Fig-6.18 shows the protected area in study sites according to public opinion and information from local Govt. authority .

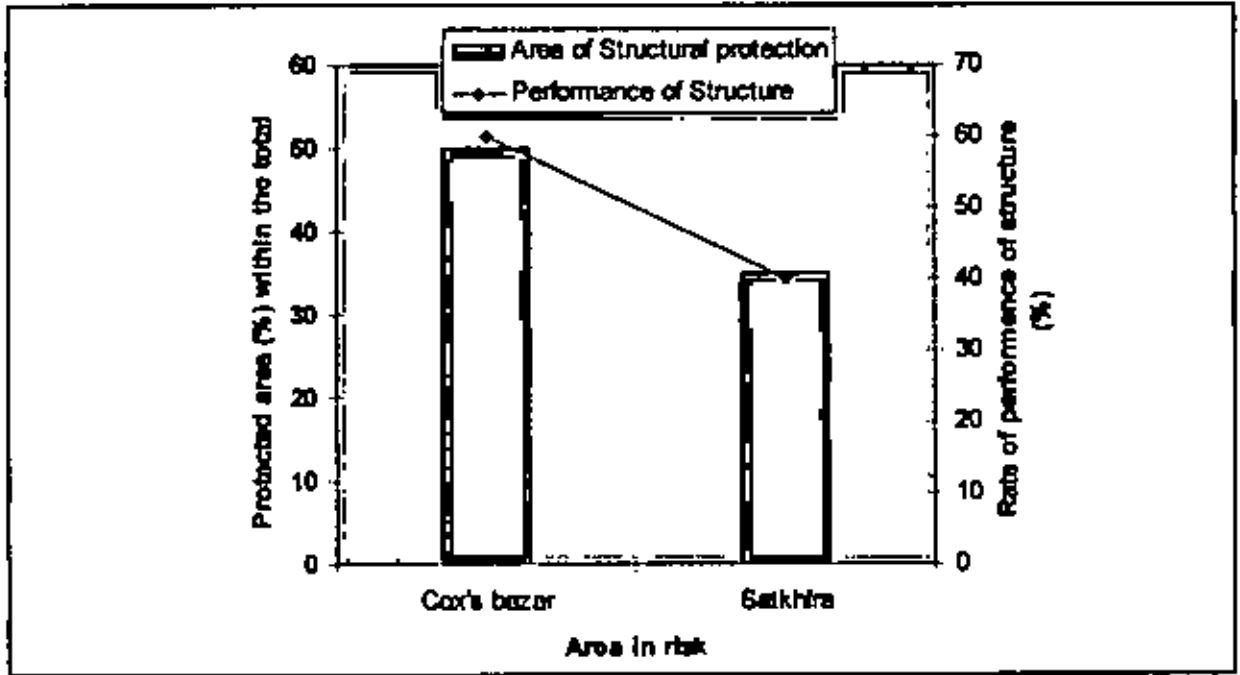


Fig-6.18. The structural protection in the coast of study area. (Survey 2008-09).

Fig 6.18. shows the scenario of structural protection and its performance in study sites. The 50% area under Cox's bazar site is structurally protected where as that value is 35% in Satkhira. The active performance of protection structure has been found 60% in Cox's bazar site and 40% in Satkhira with their best capacity and height.

The construction of cyclone shelters is considered as one of the six cyclone mitigation measures along with embankments, afforestation, early warning systems, awareness raising and communications. The coastal people take shelter in different construction during surge period. The traditional and improve shelter options in Bangladesh coast are given in the table 6.5. The table also shows the carrying capacity of those shelter options according to the size of population in defined areas.

Table- 6.5: Type of structure in where people take shelter during surge time.

Shelter options	Capacity of alternative Shelter for affected people (%)	
	Cox's bazar	Satkhira
Cyclone center	53	37
School/ colleges	21	29
High way/road/embankment	9	12
Well constructed house	7.2	2
Without shelter	9.8	20

(Source: Survey 2008-2009)

The performance of overall shelter program in local level is measured by the number of cyclone shelter, the availability to households or population, the quality and capacity to run in a risk period. Fig 6.19 shows that the performance of area base cyclone centers and other usable structures are comparatively better in Cox's bazar area than that of in Satkhira.

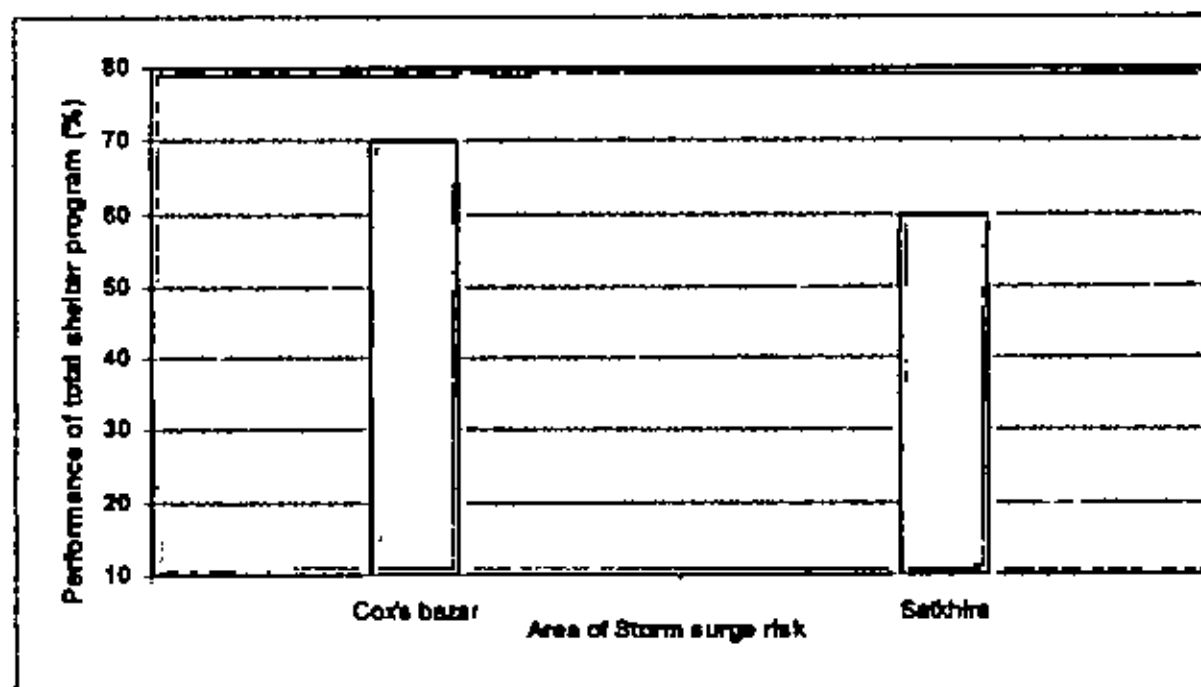


Fig- 6.19. Performance of shelter structure in coastal area. (Source: Survey 2008-2009)

In that perspective another concern factor is the easy communication system between affected area and the district town. In this study, it has been found that people of the study area in Cox's bazaar have that facility (70%). This has been found from the analysis of cyclone centers and other infrastructures, their condition and distance against household number and population size.

- **Transportation and Communication**

Generally Roads and Transportation system of rural Bangladesh is not well constructed and a large portion depends on water base options of transportation system such as Engine boats, trawlers and different types of country boats in most part of the coastal area. But a good road network has been developed in the coastal region during the last decade (BBS, 2003). As the road network is not bad but the number and fitness of transports are not sufficient for the large size of population. The qualitative and quantitative situation of road and transportation system of the study area has been given in table 6.6.

**Table 6.6: Road and transportation facilities in coastal area.**

Study Area	Paved road (Km)	Performance (%)	Muddy road (Km)	Performance (%)
<b>Cox's bazaar</b>	35	60	40.5	40
<b>Satkhira</b>	24	65	36	30

(Source: Survey 2008-2009)

Some manually used transports such as van; bye-cycle etc. and a few three wheelers (Tempo) are used to move from one place to another in the study area. During storm surge people can not avail proper transportation facility. So, lack of modern transport facilities and poor road structure affect the surge prone area.

Under cyclone preparedness program, different Government and Non-government organizations work in different sector in coastal area. The cyclone preparedness program (CPP, 2000) operates an extensive network of radio communications facilities in coastal area. The radio stations and telecommunication system always active to deliver the news

and warning to cyclone or surge risk. But the problem is that an important part of marginal livelihood groups are not aware about the warning and some are always out from the network. As for example, the forest extractor and fisher in Sundarban do not use radio/mobile because of forest burglar. The poorer groups have limited communication access in both study sites.

- **Water and Sanitation**

In the study area, about 88% of the house hold use tube-wells, deep tube wells or Pond Sand Filter (PSF) for their domestic purpose. That may change between districts but the system act with different capacity or performance to safe water supply during the surge vulnerability. The rates of utilization differ according to the household status such as livelihood pattern of coastal people.

**Table-6.7:** Types of safe water sources and their use in coastal area.

Area of study	Use of water sources for drinking purpose (%)				
	Tub-well	Deep TW	PSF	Rain Water Harvesting/water hole	Other (Not safe)
Cox's bazaar	38	17	7	26	12
Satkhira	31	12	36	10	11

(Source: Survey 2008-2009)

Table-6.7: shows that higher portion of people in Cox's bazaar use tube –well as their safe water source. Some people use indigenous way such as water hole to meet their domestic demand. The area does not show 100 present water safeties at normal time. In Satkhira area use of PSF becomes higher at present time. But the situation is not so during surge time. The safe water access during surge period is different between location and livelihood status as shown in Fig- 6.20.

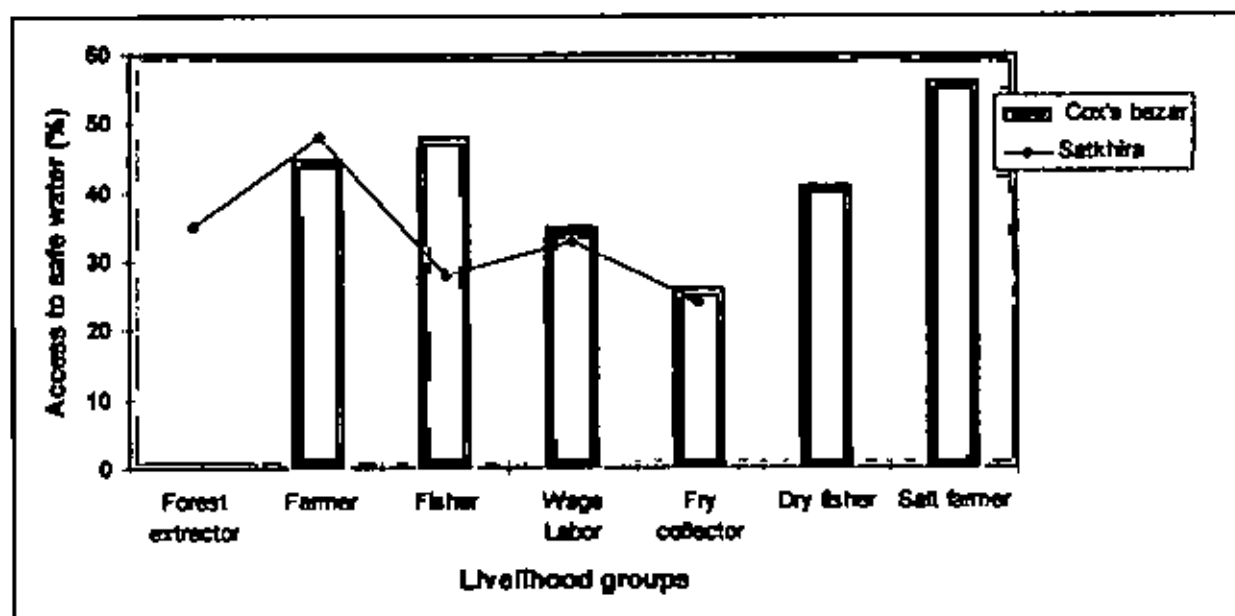


Fig-6.20. Availability and access of livelihood groups to safe water sources. (Source: Survey 2008-2009)

Fig-6.20. shows that water safety is not good in the surge prone area of the coast. In Satkhira the farmer group is the safest (about 48%) and in Cox's bazar the salt farmer is the safest (56%). So, it is clear that within resource base marginal livelihood groups few people are able to use safe water during surge time.

The field survey shows that the sanitation system of the coastal site is not well as others because of knowledge lacking and socio-economic status or livelihood patterns. It also has found that the overall sanitation facilities are higher in Cox's bazar region than that of Satkhira. The sanitation facilities between different livelihood groups are shown in Fig-6.21.



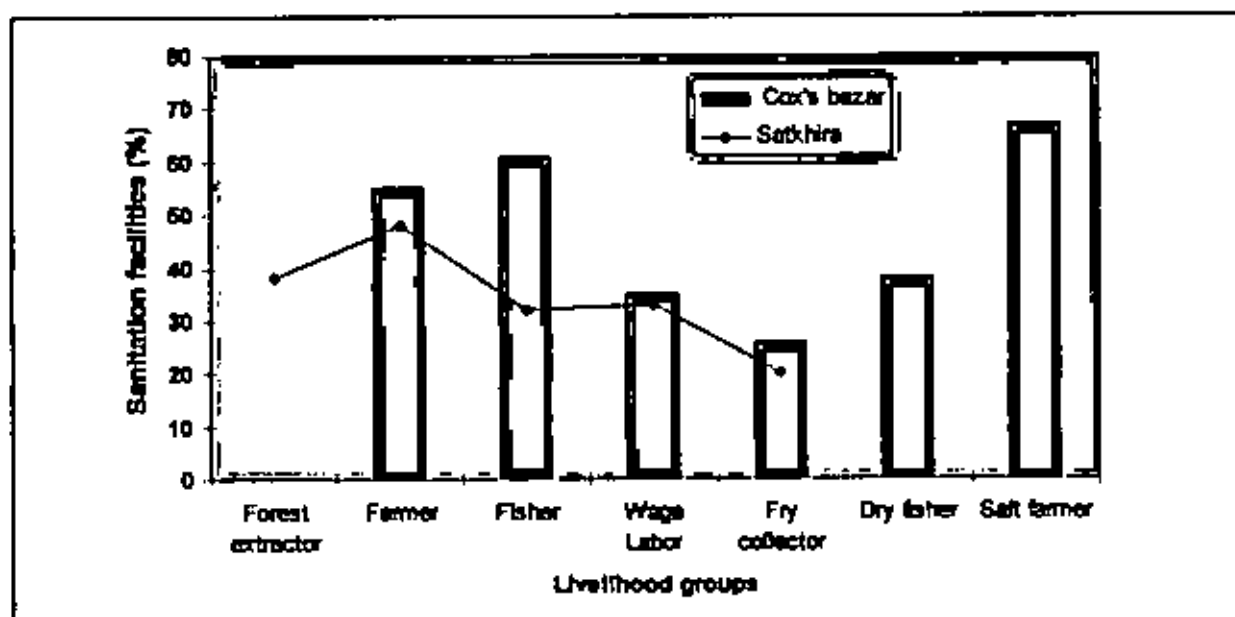


Fig-6.21. Sanitation facilities of different livelihood groups in coastal area.  
(Source: Survey 2008-2009)

Fig:6.21. shows that in Cox's bazaar region Salt farmer and fisher groups enjoy better of sanitation facilities, farmers are in moderate condition and dry fisher and others are in condition. On the other hand, in Satkhira farmer and forest resource extractor groups enjoy better sanitation facilities. In general the situation is not in a good condition in both sites for coastal rural and marginal livelihood groups.

#### 6.2.6. Social resources for coastal livelihood security

Among social/institutional assets there are various formal and informal associations and coalitions from which an individual or a household tends to derive certain benefit, privilege or power in coastal community. In crisis period the social sub-system mostly act some collective role for the security of livelihood groups in specific area.

• **Local and National Organizations**

Development activities and all other management act in the coastal zone are carried out by different Govt. organization traditionally. But in present time NGOs' of Local and National level act a vital role with presence of some international development organizations. In Bangladesh coast the active organizations are BWDB, LGED, DOF, DOE, DMB and others in Govt. level.

**Table 6.8:** The Performance of different organizations in risk management for the area.

Area	Organization and Performance					
	GO		NGOs		Other DO	
	Concern	Performance	Concern	Performance	Concern	Performance
<b>Cox's bazar</b>	Shelter, Protection measure, health care, sanitation awareness, warning system and rescue operation	<b>58%</b> From Public opinion.	Water supply and sanitation, medical treatment, food relief, micro-credit or financial lone.	<b>60%</b> From Public opinion and observation.	Community development, Social awareness development, minimize social conflict, Law and regulation	<b>44%</b> Perception of Stakeholder
<b>Satkhira</b>	Shelter, Protection measure, health care, sanitation awareness, warning system and rescue operation	<b>41%</b> From Public opinion.	Water supply and sanitation, medical treatment, food relief, micro-credit or financial lone	<b>47%</b> From Public opinion and observation	Community development, Social awareness development, minimize social conflict, Law and regulation	<b>30%</b> Perception of Stakeholder

(Source: Survey 2008-2009)

Table 6.8. shows the ultimate activities and performance of different Government institutions, Non-government organizations and other development organization in the defined study sites in Coastal Bangladesh based on field survey and secondary data. The defined organizations act effectively at pre-disaster period to reduce the damages

probability. To face the vulnerable situations and keep mitigation measure during storm surge as well as the post disaster period those are essential. Help from those organizations would be the proper way to reform the system of coastal livelihoods.

- **Community participation**

During the crisis period local community structure should be the tools to face the risk. It also be defined as the collective protection strategy against the damage of livelihoods in coastal area. Community base organizations (CBOs) stick mostly stronger to their social principles, so their acts to livelihood system protection become more effective than other. In study sites, community participation practice or action of CBOs do not act significantly.

The chapter briefly presents an overview of a part of the conceptual model (Livelihood Security Model) for understanding the livelihood system and also for measuring the statistics of livelihood security indicators for storm surge prone coastal areas of Bangladesh.

## **CHAPTER SEVEN**

### **MODEL APPLICATION AND DISCUSSION**

#### **7.1. Introduction**

As the storm surge risk in coastal area has been define as extremely destructive; it needs to assess the security level to face the challenge properly as well as effectively. The established livelihood security model can act as a scientific way to the security level assessment program. The model application has been initiated through identifying the relativity among indicators of different livelihood groups. In this chapter, the livelihood security level for storm surge hazard in the study area are measured in comparison with a standard security level for each livelihood groups considering all the livelihood security indicators and their response.

#### **7.2. Livelihood Security Against Storm Surge**

A livelihood is sustainable when it can cope with and recover from the stress and shocks, maintain its capability and assets, and provide sustainable livelihood opportunities for the next generation (Chambers and Conway 1992). It also true for coastal livelihoods in the question of their sustainability and security from storm surge hazard in Bangladesh coast. The livelihood security of different coastal livelihood groups against storm surge is calculated as per the model application methodology mentioned in the previous chapter 5.

##### **7.2.1. Input data calculation**

Methodologically the established indicators have been used as the input data in the constructing the model for both qualitative and quantitative requirements. The indicator values have been analyzed under specific units or scales such as percentage, number, degree and binary options. Some indicator values have been calculated from relevant data base and some have been defined from direct household interview in the study area. Table 7.1a. shows the measured value of indicators ( $I_p$ ) for different livelihood groups in the study site of Cox's bazaar district.

**Table 7.1a. Input data for livelihood groups in Cox's bazaar.**

Indicators	Farmer	Fisher	Fry collector	Salt Farmer	Dry fisher	Wage labor
Frequency of Storm surge (Irregular/regular)	0	0	0	0	0	0
Storm surge Period (Low tide/ high tide)	0	0	0	0	0	0
Surge height from mean sea level	0	0	0	0	0	0
Duration of storm surge (Short term/ long term)	0	0	0	0	0	0
Rate of vegetation around the area	15	15	15	15	15	15
Time frame for resource collection/ production	8	10	7	6	6	12
Performance of natural drainage system	55	55	55	55	55	55
Possible improvement of resource in each year	60	80	75	75	80	50
Access to alternative resource base	6	6	5	4	5	2
Access to energy/fuel supply	70	50	60	60	60	60
Household production	40	12	15	45	30	10
Ownership on production	75	50	60	60	60	18
Scope of food storage	1	1	0	1	1	0
Rate of saving	25	30	6.67	20	16.67	0
Reliability of saving system (Yes/No)	1	1	0	1	1	0
Access of women to economic activities	60	40	75	30	65	45
Scope of alternative economic activities	1	1	1	1	1	1
Access to financial loan	1	1	0	1	1	0
Portion of HH income earned from rest of the country	15	12	6	32	19	3
Rate of education/literacy	52	46	34	44	52	25
Knowledge on first aid	46.22	30	31	43	22	18
Knowledge on storm surge risk	66.9	82	66	80	67.97	43
Access to nearest district town (Yes/No)	1	1	1	1	1	1
Access to doctor service (No. of doctor / 100)	2	2	2	2	2	2
HH Population having training on Surge protection	30	43	17	47	41	7
Active population of HH	52	46	34	44	52	25
Response to early warning system	63	67	48	65	68	50
Response to adaptation technology	75	76	54	80	77	38
Rate of out migration of HH member	10	11	6	12	9	3
Safe housing infrastructure/ condition	40	39	31	62	41	14.89
Performance of hospital /Health center	2	2	2	2	2	2
Performance of/access to cyclone shelter	70	70	70	70	70	60
Availability of drinking water (Safe water)	45	48	26	56	41	35
Sanitation facilities	55	61	26	67	38	35
Access of media connection/Radio/TV/ Cell phone	80	65	48	75	56	38
Availability of paved road	60	60	60	60	60	60
Transportation facilities	60	60	60	60	60	60
Part of area under protection structure	50	50	50	50	50	50
Fitness of protection structure	60	60	60	60	60	60
Performance of weather forecasting	2	2	2	2	2	1
Community participation practice	75	80	65	85	80	40
Activeness of local GO	2	65	40	62	60	30
Interrelationship with NGO	2	75	88	55	70	80
Performance social law and regulation	2	2	1	3	3	1
Political influence on social group/ committee(Yes/No)	1	1	0	1	1	0
Performance of local disaster management committee	2	2	2	2	2	2
Activeness of social organization of livelihood groups	60	80	50	85	80	45
Awareness program on protection measure (No./Y)	2	2	2	2	2	2

(Source: Survey 2008-09)

Table 7.1b. Input data for livelihood groups in Satkhira.

Indicators	Farmer (M)	Fisher (M)	Fry collector (M)	Forest Extractor	Wage labor
Frequency of Storm surge (Irregular/regular)	0	0	0	0	0
Storm surge Period (Low tide/ high tide)	0	0	0	0	0
Surge height from mean sea level	0	0	0	0	0
Duration of storm surge (Short term/ long term)	0	0	0	0	0
Rate of vegetation around the area	18	18	18	18	18
Time frame for resource collection/ production	8	10	7	8	12
Performance of natural drainage system	40	40	40	40	40
Possible improvement of resource in each year	60	80	75	30	50
Access to alternative resource base	6	6	5	4	2
Access to energy/fuel supply	45	25	25	25	25
Household production	40	12	15	40	10
Ownership on production	70	70	60	60	20
Scope of food storage	0	0	0	1	0
Rate of saving	20	10	5.33	25	0
Reliability of saving system (Yes/No)	1	0	0	1	0
Access of women to economic activities	50	30	66	20	55
Scope of alternative economic activities	1	1	1	1	1
Access to financial loan	1	1	1	1	0
Portion of HH income earned from rest of the country	18.65	6	2.75	9.68	5
Rate of education/literacy	48	39	31	35	18
Knowledge on first aid	29.1	12	36	47	20
Knowledge on storm surge risk	52	63	65	72	46
Access to nearest district town (Yes/No)	0	0	0	0	0
Access to doctor service (No. of doctor / 100)	1	1	1	1	1
HH Population having training on Surge protection	25	38	18	56	5
Active population of HH	48	39	31	35	18
Response to early warning system	55	65	42	67	47
Response to adaptation technology	62	46	47	64	52
Rate of out migration of HH member	8	5	2.75	8	1.5
Safe housing infrastructure/ condition	46	22	22	48	9
Performance of hospital /health center	2	2	2	2	2
Performance of access to cyclone shelter	60	60	60	60	70
Availability of drinking water (Safe water)	48	28	24	35	33
Sanitation facilities	48	32	20	38	33
Access of media connection/Radio/TV/ Cell phone	78	35.5	30	30	40
Availability of paved road	65	65	65	65	65
Transportation facilities	55	55	55	55	55
Part of area under protection structure	35	35	35	35	35
Fitness of protection structure	40	40	40	40	40
Performance of weather forecasting	1	1	1	3	1
Community participation practice	65	60	50	60	40
Activeness of local GO	1	40	35	45	30
Interrelationship with NGO	2	80	90	65	80
Performance social law and regulation	1	1	1	3	1
Political influence on social group/ committee(Yes/No)	1	1	0	1	0
Performance of local disaster management committee	1	1	1	1	1
Activeness of social organization of livelihood groups	50	60	55	70	50
Awareness program on protection measure (No/Y)	0	0	0	0	0

(Source: Survey 2008-09)

Table 7.1b. shows the measured value of indicators ( $I_p$ ) for different livelihood groups in the study site of Satkhira.

The indicator framework contains two major criteria indicators, firstly indicators having common values for every livelihood groups (area base) and finally indicators with different value for individual group in each area. The second type actually indicates the household components, their approaches and actions against storm surge hazard for specific livelihood groups and the first type shows the collective security status for overall community people.

### 7.2.2. Security scoring for individual indicators

The indicators show the scenario of coastal livelihoods and describe the vulnerability of coastal people during the season of cyclone and storm surges. Considering the risk factors and all natural, financial, physical and social options the model calculated the livelihood security level for different occupational groups in marginal level in the coastal Bangladesh.

A complex analysis, through AHP methods, can help to identify which the most relevant indicators are, and these can then be taken up in quantitative surveys. The selective relevant indicators have been used for measuring security under individual security options such as food security, income security and so one for each livelihood groups.

The security score under individual indicators has been estimated from the comparative analysis between present field survey data ( $I_p$ ) (Table 7.1.) and referred standard values ( $I_s$ ) (Table 5.2.) by using the first step (Equation no. 1) of the model. From the difference of individual indicator's values the security scores (Sample calculation in table 7.2) have been found (Appendix-D) under different security options. Table 7.2. shows the input data calculation in the livelihood security measurement of coastal households.

**(Step 1 and 2 of the model)****Table 7.2.** Sample calculation for security scoring for individual indicator (For farmer in Cox's bazaar)

Indicators	Unit	I <sub>s</sub>	I <sub>p</sub>	I <sub>d</sub> (%)	Direction	Food security (j=1)	Income Security (j=2)
Duration of storm surge (Short term/ long term)	Binary	1	0	100.0	Negative	---	---
Rate of vegetation around the area	%	25	15	25.00	Negative		-
Time frame for resource collection/ production	Months	12	8	20.00	Negative	-	-
Rate of possible resource quality improvement	%	50	60	9.09	Positive	+	+
Access to alternative resource base	No.	3	6	33.33	Positive	++	++
$\sum X$						3	3
<b>M</b>						7	8

Source: Model result, 2008-09

Here, the first one (i1) is an individual indicator selected (Table 5.3) for food security aspect j1. For farmer livelihood group in Cox's bazaar, the present value of i1 is 0 where the security standard (Table 5.2) is 1. Now the value difference (I<sub>d</sub>) is about 100% with negative direction that means i1 shows food insecurity with score 3 (Table 5.5). In the same process 4<sup>th</sup> and 5<sup>th</sup> indicators i4 and i5 show food security with score 1 and 2. So the total scores in certain aspect is 3 (M<sub>1</sub> =7, where j=1) and the security score  $\sum X_1 = 3$ .

**7.2.3. Calculation of security level for individual security options**

The level of different security options have been measured by using equation (2) (Appendix-D) under Step 3:

$$SI_1 = (\sum X_1 / M_1) * 100 = (3/7) * 100 \quad j = 1, \text{ define food security} \\ = 42.86\%$$

So, for only those indicators the food security of farmer household is 42.86%.



Table 7.3a. and 7.3b. show the measured value of security in percentage under individual security aspect ( $SI_j$ ) for the selected livelihood groups in study area.

**Table 7.3a.** Individual security level for livelihood groups in Cox's bazaar.

Security options (j)	Farmer	Fisher	Wage Labor	Fry collector	Dry fisher	Salt farmer
Food security $SI_1$	41.67	41.18	19.35	16.13	40.82	45.83
Income security $SI_2$	44.68	42.86	23.08	17.86	39.58	47.92
Health and personal security $SI_3$	38.30	37.25	13.79	11.48	35.42	42.55
Security of house and properties $SI_4$	45.65	42.86	18.87	15.79	40.43	48.94
Water security $SI_5$	39.13	35.29	14.29	13.56	34.69	40.43

(Source: Model result, 2008-09)

Table 7.3a. shows the values of household security in different livelihood security aspects individually for the selected livelihood groups in Cox's bazaar area. According to the above table the individual food security is highest for salt farmer household defined by 45.83 % where as lowest is in fry collector's household 16.13%. The another statistics also show the household security of different coastal livelihood groups in aspect of Income security  $SI_2$ , Health and personal security  $SI_3$ , Security of house and properties  $SI_4$  and Water security  $SI_5$ .

In a similar way of calculation, the individual security statistics have been calculated for livelihood groups in Satkhira that is shown in table -7.3b.

**Table 7.3b.** Individual security level for livelihood groups in Satkhira.

Security options (j)	Farmer	Fisher	Wage Labor	Fry collector	Forest extractor
Food security $SI_1$	34	27.27	13.43	17.54	26.92
Income security $SI_2$	37.25	28.30	16.39	18.18	25.93
Health and personal security $SI_3$	30.77	18.18	6.15	12.73	22.41
Security of house and properties $SI_4$	36.54	26.92	13.11	18.52	29.09
Water security $SI_5$	31.37	20	8.06	13.73	21.43

(Source: Model result 2008-09)

Table 7.3b. shows the values of household security in different livelihood security aspects individually for the selected livelihood groups in Satkhira area. According to the above table the individual food security is highest for Farmer household defined by 34 % where as that is lowest in wage labor's household (13.43 %).

#### 7.2.4. Calculation of Overall Security Level of Livelihood Groups

Now, the overall security level of defined coastal livelihood group has been measured by using equation (III) under third step of the model, Livelihood Security Model (5.5). The household livelihood security level analysis has been shown in Appendix-D with total data calculation and scaling.

The livelihood groups are not same in Satkhira to Cox's bazaar because of variation of geographical settlement. The household securities of selected livelihood groups have been calculated by entering the necessary data from the study into the developed model. The Fig 7.1a. and Fig 7.1b show the household security level of different livelihood groups for the sustainable storm surge management approach in the define coastal part of Bangladesh.

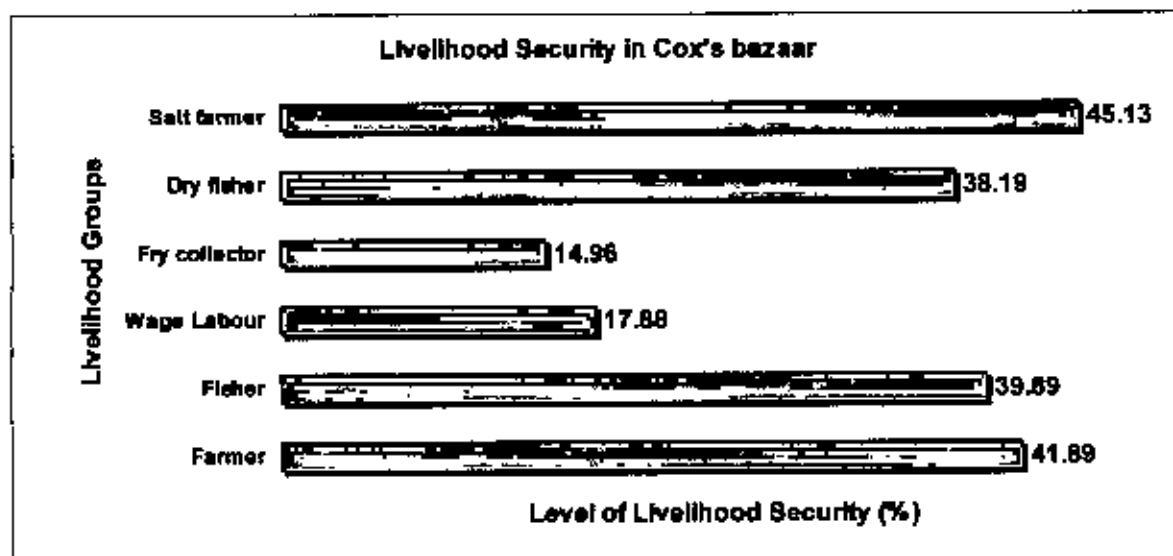


Fig 7.1a. Level of overall livelihood security for selected livelihood groups in Cox's bazaar. (Source: Model result 2008-09)

Fig 7.1a shows the level of livelihood security in Cox's bazaar area. It expresses that in the coast of Cox's bazaar the most vulnerable livelihood group is fry collector due to storm surge risk. On the other hand the less vulnerable groups are salt farmer group and the farmer.

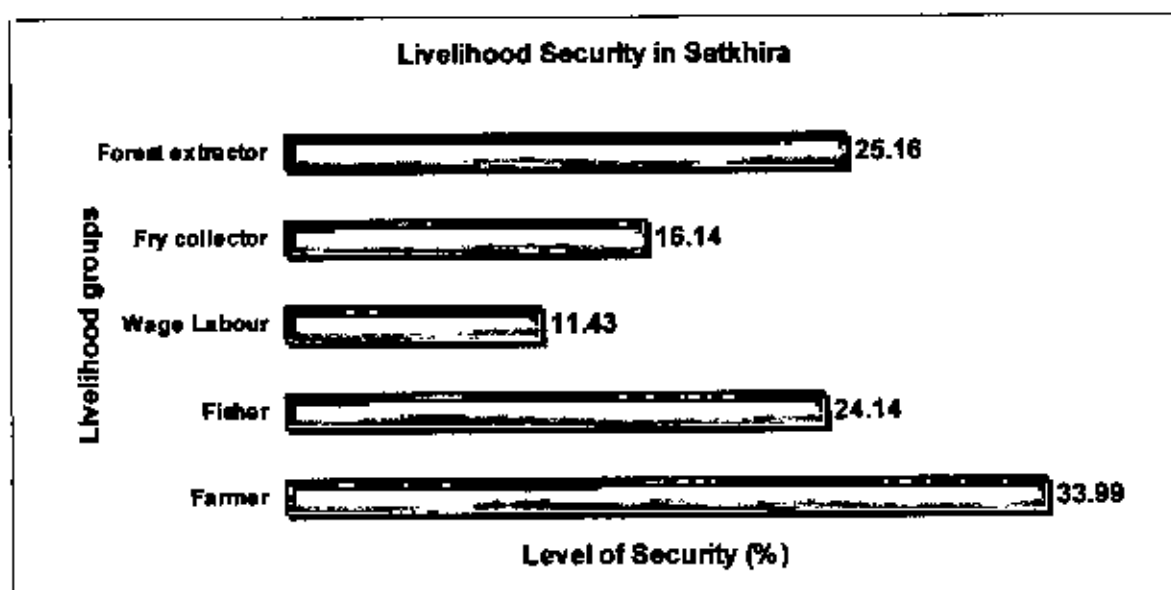


Fig 7.1b. Level of overall livelihood security for selected livelihood groups in Satkhira. (Source: Model result, 2008-09)

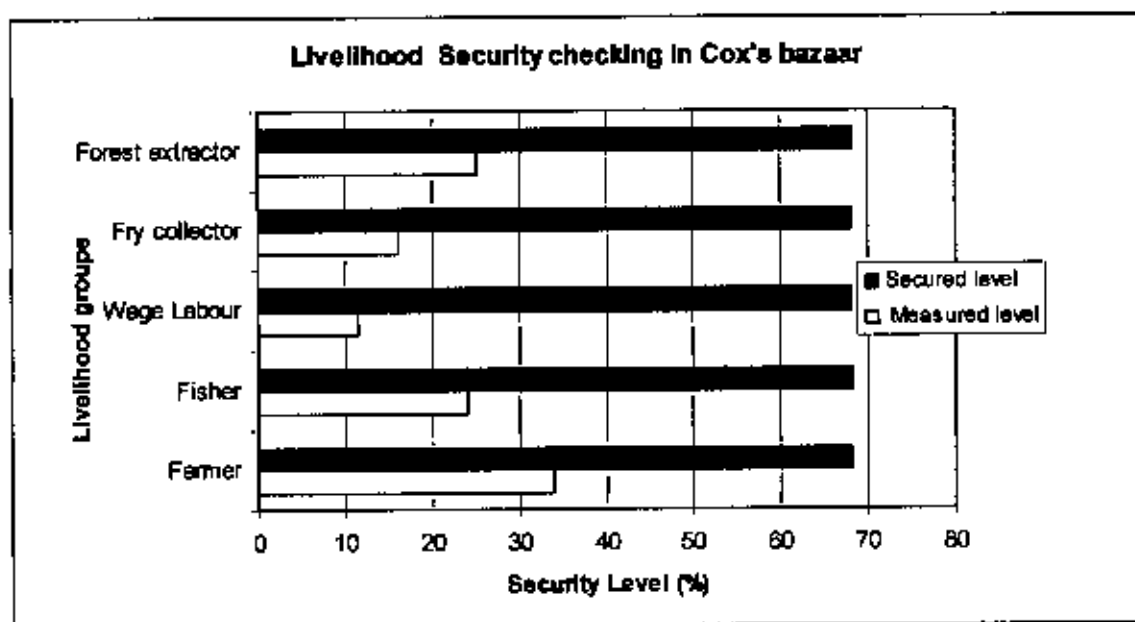
Fig 7.1b. reveals the security level of selected livelihood groups in Satkhira coast. In that site the more vulnerability is found in wage labor's house and comparatively less risk is found for the farmer groups. Less risk also shown in forest extractor's house. The overall scenario represents the area base livelihood security levels due to storm surge in the coastal part of Bangladesh.

### 7.3. Discussion

#### 7.3.1. Discussion on livelihood security level in individual study site

Adaptation of a livelihoods security model, in rural contexts of coastal area, led to two main outcomes. First, it introduced a holistic analytical model for livelihood security. And second, it resulted in the evolution of the livelihood security level by using that model as an improvement tools in the field of livelihood system development and protection due to any

defined risk. In this study, it has been tried to check the actual security (degree of safety) status of household in coastal livelihood groups according to the area boundary.



**Fig.7.2.** Level of overall livelihood security for selected livelihood groups comparing with a standard household security frame in Cox's bazaar. (Source: Model result 2008-09)

Fig 7.2. Shows a standard line graph that expresses the security line of an individual household due to storm surge hazard in Bangladesh coast specified for Cox's bazaar coast where the security value is 66.01%.

This statistic has been collected from a household in study area of district Cox's bazaar which faced numbers of storm surge threat last few years safely and the local people response positive to their security level.

Following the same methodology, Fig 7.3. Shows a standard line graph that expresses the actual security line due to storm surge hazard in Bangladesh coast specified for Satkhira coast where the security value is 68.23% (measured by study on an individual household having higher confidence on security).

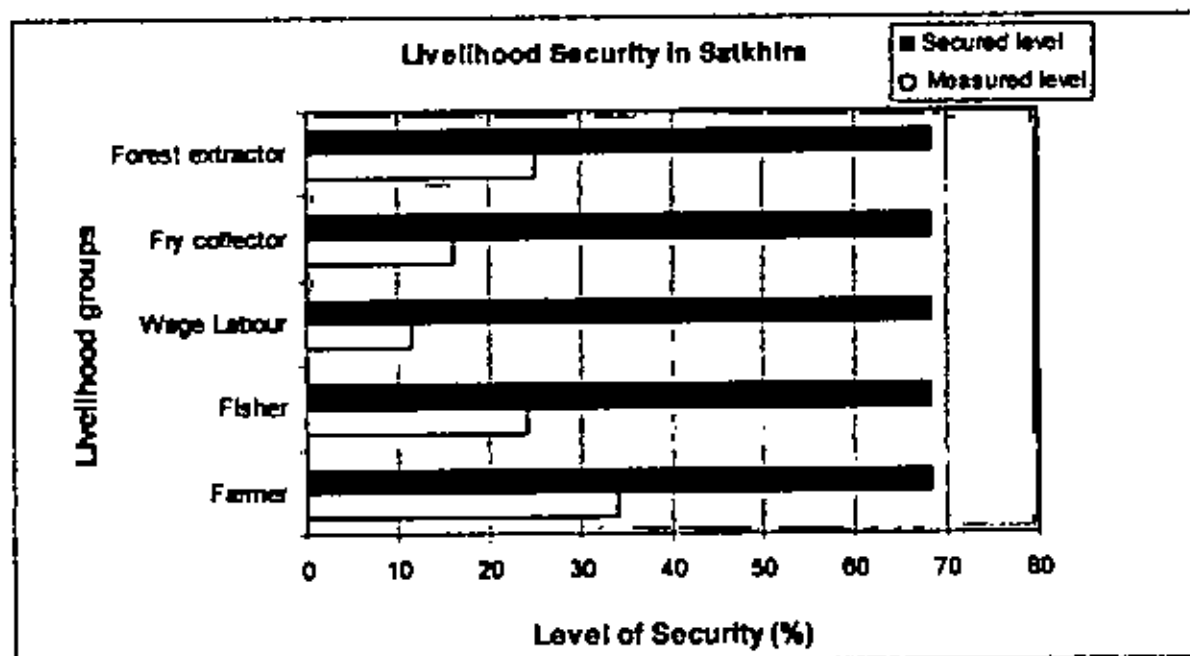


Fig 7.3. Level of overall livelihood security for selected livelihood groups comparing with a standard household security frame in Satkhira. (Source: Model result, 2008-09)

Fig 7.3. shows that the coastal livelihood groups in Satkhira are not secured against storm surge risk. According the graphical analysis, the model shows farmer group keeps highest security about 33.99% or 40% in that area but with respect of standard scales that do not show the security standard.

The total graphical presentation expresses that, as in storm surge risk the total livelihood system is not secured and that insecurity scale is higher with comparing the standard concept of security in coastal zone of Bangladesh.

### 7.3.2. Discussion of livelihood security among two study sites

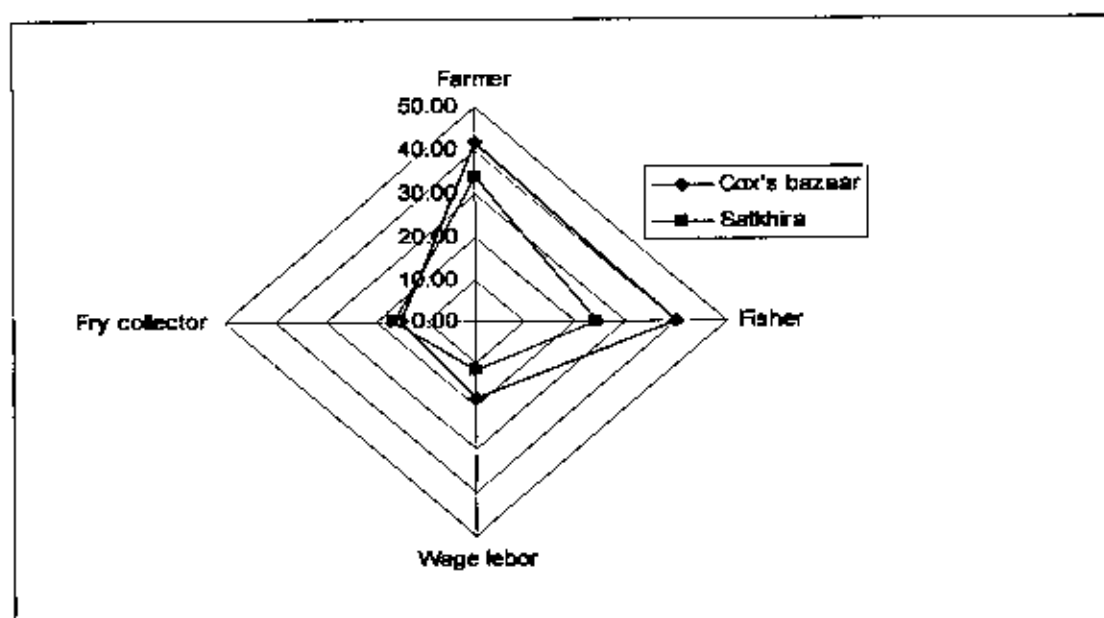
The levels of livelihood security due to storm surge hazard for different livelihood groups are not same in both sites of the study area. The measured levels of security of common livelihood groups in both area (farmer, fisher, fry collector and wage laborer) show variation in different area boundary. Table 7.4. shows the actual scenario of that.

**Table-7.4.** Security level for livelihood groups in both sites of the study area.

Livelihood Security	Forest Extractor	Farmer		Fisher		Fry collector		Wage labor		Salt Farmer	Dry fisher
	Satkhira	Cox's bazaar	Satkhira	Cox's bazaar	Satkhira	Cox's bazaar	Satkhira	Cox's bazaar	Satkhira	Cox's bazaar	Cox's bazaar
Food security	26.92	41.67	34	41.18	27.27	16.13	17.54	19.35	13.43	45.83	40.82
Income security	25.93	44.68	37.25	42.86	28.30	17.86	18.18	23.08	16.39	47.92	39.58
Health and Life	22.41	38.30	30.77	37.25	18.18	11.48	12.73	13.79	6.15	42.53	35.42
House and properties	29.09	45.65	36.54	42.86	26.92	15.79	18.52	18.87	13.11	48.94	40.43
Water security	21.43	39.13	31.37	35.29	20	13.56	13.73	14.29	8.06	40.43	34.69
<b>Overall security</b>	<b>25.16</b>	<b>41.89</b>	<b>33.99</b>	<b>39.89</b>	<b>24.14</b>	<b>14.96</b>	<b>16.14</b>	<b>17.88</b>	<b>11.43</b>	<b>45.13</b>	<b>38.19</b>

(Source: Model result 2008-09)

Table-7.4. defines that average level of security for farmer group is 41.89% where that of in Satkhira is 33.99%. So farmers are more secured in Cox's bazaar than that of in Satkhira.

**Fig- 7.4.** Comparative analysis of livelihood security in different study sites.

(Source: Model result 2008-09)

Fig 7.4. shows that the same conditions are also found for Fisher and wage laborer groups. But the fry collector's level of security is 14.96 % in Cox's bazaar where in Satkhira, it shows the value 16.14%. So fry collector group keeps better position in

Satkhirn. The over all livelihood security for storm surge issue of different livelihood groups must defined by the combination of their level of security of five options such as food security, income security, health security, house security and water security.

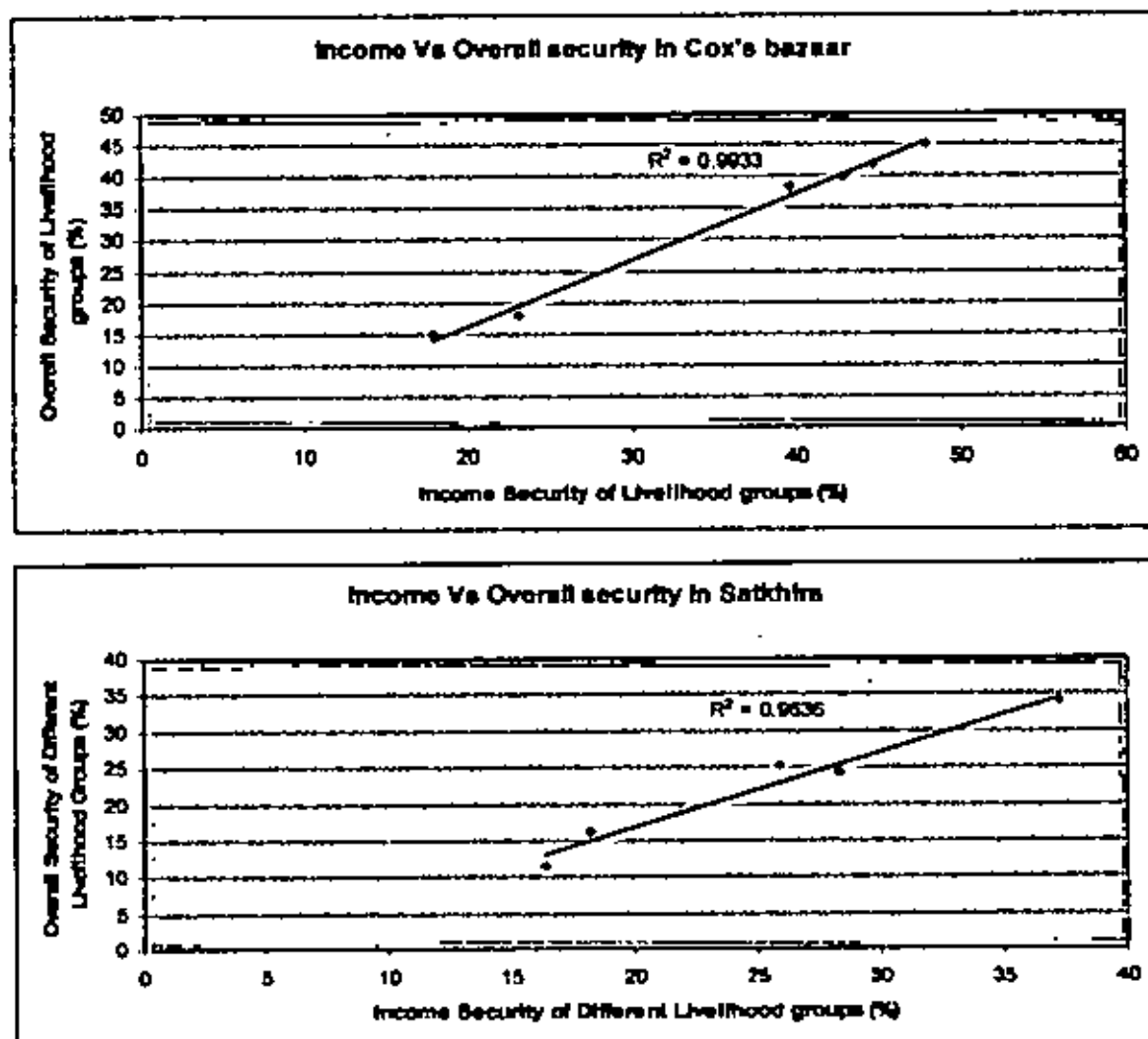


Fig-7.5. Correlation among income security and livelihood security of coastal livelihood groups. (Source: Model result 2008-09)

But the livelihood system may define as a process of income for living. So there is a close contact between income and livelihood. Fig-7.4. and Fig-7.5. show that livelihood security has a direct relation to income security significantly. In both study side strong correlation has been found among trend of income security level and livelihood security level of coastal groups.

## **CHAPTER EIGHT**

### **CONCLUSIONS AND RECOMMENDATIONS**

#### **8.1. Conclusion**

Bangladesh is one of the critically vulnerable countries to natural hazards. Bangladesh lies in a very active cyclone corridor that transects the Bay of Bengal. Cyclone and storm surge hazard frequently visits different coastal part of the country most of the recent years and causes great disturbance to the nature and the human community. The coastal livelihood security concept has become more prominent in the study due to not only the sensitive nature of the physiographic and socio-economic condition of the coastal area but also its importance to the nation. To start with initiatives to establish a sustainable livelihood security model against storm surge hazard the study has been concluded with the followings:

- The storm surge vulnerability in Bangladesh has been defined by the study depending on the feature of recent storm surges from the year 1988 to 2009.
- Totally 7 marginal livelihood groups in coastal part of Cox's bazaar (6) and Sakhira (5) have been identified including their specific livelihood opportunities and resources in coastal environment under a great risk of storm surges.
- The over all exposure to such risk has been enhanced by the higher population and population density in that vulnerable coastal areas of Bangladesh.
- The livelihood security has been defined in this study, as an adequate and sustainable access to income and resources to meet basic needs (including adequate access to food, potable water, health facilities, educational opportunities, housing, community participation and social integration) during the storm surge period in risk area.
- In this study, a model has been developed with an indicator framework (having 48 indicators) to make the numerical valuation of livelihood security of coastal



people due to storm surge hazard by the comparative analysis of different security options for livelihood groups in Bangladesh coast.

- The vulnerable coastal livelihood system has been analyzed by indicator measurement approaches showing the possible protection and adaptation capacity of its stakeholders.
- Within 6 livelihood groups at site 1. in Cox's bazaar, the model application showed the maximum livelihood security as 45% for salt farmer where as the lowest security level exist 14.96% for fry collector group.
- At site 2. in Satkhira, the highest level of average livelihood security has been found as 33.99% for farmer group where the lowest is calculated as 11.43% for wage laborer.
- The measured security value of coastal livelihoods for storm surge hazard does not show significant level of security. Few households have been identified as probably secured individually but in an average, each and every marginal livelihood groups live below the satisfactory level in those areas against the recent forms of storm surges.
- The level of security differs depending on geographical position and environmental settings of the sites.
- The security levels of livelihood groups against storm surges also vary with people's access to coastal resource and income opportunities. A strong correlation has been found in between the individual income security and overall livelihood security of individual groups in both study sites.

## **8.2. Recommendations**

- The modeling for coastal livelihood security for storm surge hazard can act as a tool for sustainable coastal resource management and may also provide the adaptation concepts for coastal livelihood system with priority in integrated coastal zone management policy of Bangladesh.

- The framework of livelihood security indicators can be disseminated among the users with explanations and possible use to assess and monitor the performances of livelihood capitals in both household and community level for another coastal issue.
- The model concept can be instrumental in formulating strategies by various agencies and/or the strategy making bodies in the field of coastal community development and livelihood system management.
- The established model assesses the security level of different livelihood groups and can be used as a management tool in coastal development strategies and policy making.

### **8.3. Recommendations for Further Study**

The recommendations for farther studies are as follows:

- More technical study is needed to make another simplified application of the existing model for its first and significant use in practical sites.
- It is recommended to assess the security and resiliency of coastal livelihood groups by using such type of mathematical model against other water related issues.
- Research is also needed to analyze the risk and adaptation capacity of coastal community in Bangladesh due to climate change effect.

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## APPENDIX A

### QUESTIONNAIRE FOR HOUSE HOLD SURVEY Research for M.Sc Thesis IWFM, BUET.

#### A. Basic Information

Sample no/ID: ----- Date.....  
Vill/ Mohollah: ----- Holding No: -----  
Union/Word: ----- Thana: ----- District: -----

#### B. Family Information

1.	Name:	Age:		
2.	Education:	Occupation:		
3.	Fathers Name :			
4.	Marital status:			
5.	Your position in family:			
6.	No. of Family members:	Male:	Female:	Chilled:
7.	No. of Earning Members of the house	Male:	Female:	
8.	Education of family members:			

#### C. Livelihood information

9. How long do you stay in this area?

10. How long Experience do you have in this living activities?

11. a) Have you any alternative source of income? Yes / No

b) If yes, which sources are those?

-----  
-----

c) How many people of your family are stays in rest of the country?

d) What is their contribution to the household income? (Tk. pr year / percentage of TI)

**12. Household Income:**

a) Rate of income- (TK. per capita)

Daily  Monthly  Yearly  Seasonal 

b) Rate of daily expense (TK./person)

c) What is the saving system-

House  Samity (NGO)  Bank  Other **13. Land ownership:**

a) Have you any owned land? Yes / No

b) If yes, how much land area is in your family ownership?

**14. Product / Production-**

a) Which is the main source of production in your household?

b) Does the main product satisfy the dweller's basic annual needs? Yes/No

c) If no, which are the alternative sources of production?

e) Production technique-

Traditional  Improve 

f) Type of product ownership-

 Self  Leased  Product sharing

g) Homestead production-

 Cattle:  Poultry:  Garden:  Others:

h) Within which period the household products are being harvested?

**15. Water and sanitation-**

o What is the main source of drinking and potable water?

o Is that sufficient for your locality? Show the level of satisfaction.

- o Which type of toilet (latrine) is used in your house holds?
- o What is the height of toilet/bathroom from surface level?

16. Which type of materials is used for house construction?

**17. Medical facilities-**

- No. of doctor / paramedic/ health adviser per 100 household
- No. of hospital/ health center in the locality
- Do you get free medicine or other services?
- What is the condition of health service in those center?
- What is the distance between your house and the hospital?

**18. Transportation facilities –**

- o Length of road-  
Paved  Mud
- o What is the condition of road network?
- o Which types of transports are used normally?
- o Which type of transport you use to go to the health centre?

**D. Information of storm surge hazard**

19.a. No. of storm surge occurred during your lifetime:

No.	Month & Year	Storm Height	Duration	Major damages

b) Warning System:

c) Comments (Open):

**20. Disaster preparation:**

a. Have you any training / experience on preparation for disaster?

b. What types of preparation do you have to face the disaster?

Pre-

During-

Post-

c. Do you have any first aid training?

d. Do you take part in any disaster awareness programme in your locality?

**21. Shelter**

a. Where do you get shelter, when there is any disaster/ cyclone warning?

b. How many cyclone centers are in your locality?

c. Is that sufficient for your locality?

d. What is the infrastructural condition of that cyclone center?

**22. Protection for Coast**

a) Types of protection system-

b) Area under protection-

c) Rate of Vegetation in the locality-

Natural forest  Social forest

d) Condition of protection system-

e) Is it sustainable?

f) Is the protection beneficial for root level people?

**23. Disaster management options:**

a. Is there any disaster management committee in your locality?

b. Have you any access to easy financial loan at crisis period?

c. Do you get help from any organization?

GO

NGOs

Other

d. Which NGOs are active in your locality?

e. How do they help you?

## Information Collection Sheet

### 1. Study area

- General Area Description:

- Population:

- Road:

Materials	Length

- Communication system

- Product processing and preservation

- Product market

a) Normal time

b) Post disaster

### 2. Natural and anthropogenic resources

#### 3. Infrastructure

a) Social

b) Economic

c) Educational

#### 3. Development activities

a) Warning system:

b) Awareness programme:

c) Shelter:

- d) Post disaster activities:

#### **4. Protection for Coast**

- a) Types of protection system
- b) Area under protection
- c) Condition of protection system:
- d) Is it sustainable?
- e) Is the protection beneficial for root level people?

#### **5. Damage Caused by storm surge during recent storm surges period:**

- a) Natural resources
- b) Infrastructural
- c) Human life and Health

## APPENDIX-B

### Study on the security modeling through the participation of marginal livelihood groups in the coastal area Checklist for Focus Stakeholder Meeting (FSM)

**District: Satkhira**

**Date: 09.09.2008**

**Venue: Harinagar Sushilan Office**

**Vill: Harinagar**

**Union: Munshiganj**

**Upazilla: Shamnagar**

**Starting time: 9.00 AM**

**Ending time: 10.30 AM**

**Facilitating NGO: Sushilan, Kaliganj, Satkhira.**

#### Role of Team Member

**Organizer: Mahmuda Mutahara and Md. Mahbubar Rahman (Sushilan, Shyamnagar.)**

**Moderator: Mahmuda Mutahara, IWF, BUET.**

**Reporting: Mahmuda Mutahara, IWF, BUET.**

#### List of Participants:

SL No.	Participant	Age	Occupation	Education
1	Mahmuda Mutahara	26	Student	M. Sc.
2	Mahbubar Rahman	28	Service (NGO)	B. Sc.
3	Abu Zaber Morol	38	Up member	H. Sc
4	Md. Manik	38	Service (NGO)	B. Sc.
5	M. Motiar Rahman	52	Farmer	Class-Two
6	Farid Gazi	40	Farmer	Illiterate
7	Ahsan Morol	30	Farmer	Class-Two
8	Subol Sarkar	46	Wage labor	Illiterate
9	Rabiul	38	Forest Extract	Illiterate
10	Samsul Morol	28	Fisher	Class-Two
11	Mala Rani	38	Fisher	Class-Two
13	Noni Bala	38	Wage laborer	Class-Two
14	Rina Mondol	52	Wage laborer	Class-Three
15	Rabia	34	Fisher	Class-Two
16	Chandra	48	Forest Extract	
17	Maksud	55	Forest Extract	Class-Two
18	Abul Gazi	44	Fry collector	Illiterate
19	Rahim Uddin	38	Fry collector	Class-Two
20	Poran	37	Fry collector	Class-Three



**Focus Stakeholder Meeting Agenda:**

- ✓ Introduction
- ✓ Identification of major assets of livelihood groups.
- ✓ Identification of assets in five categories; natural, financial, human, physical and social as the component of coastal livelihood system.
- ✓ Identification of economic activities of livelihood groups and seasonality.
- ✓ Identification of major storm surge hazards in the study area and their ranking.
- ✓ Vulnerability factors on assets of livelihood groups due to storm surge hazards.

**Major Findings from Focus Stakeholder Meeting:**

1. Stakeholders are aware of storm surge and increasing occurrence of that natural hazard.
2. The storm surge hazards damage household capital and livelihood resources more destructively.
3. The storm surge hazards are affecting agriculture, shrimp farms and mangrove forest.
4. Livelihood system is under developed and people are helpless.
5. Farmer are taking several initiatives to reduce their loss from hazards such, land raising, embankment to protect high tidal flooding, forestation for protection, irrigation by Tube-well, fresh water reserve in ponds etc.
6. There is a lack of institutional activities and mitigation measure.
7. Poor protection system.

**Study on the security modeling through the participation of marginal livelihood groups in the coastal area**  
**Checklist for Focus Stakeholder Meeting (FSM)**

**District: Satkhira**

**Date: 25.12.2008**

**Venue: Munshiganj Sushilan Office**

**Vill: Munshiganj**

**Union: Munshiganj**

**Upazilla: Shamnagar**

**Starting time: 10.30. AM**

**Ending time: 12.00 AM**

**Facilitating NGO: Sushilan, Kaliganj, Satkhira.**

**Role of Team Member**

Organizer: Mahmuda Mutahara and Md. Mahbubar Rahman (Sushilan, Shyamnagar.)

Moderator: Mahmuda Mutahara, IWFM, BUET.

Reporting: Mahmuda Mutahara, IWFM, BUET.

**List of Participants:**

Sl. No.	Participant	Age	Occupation	Education
1	Mahmuda Mutahara	26	Student	M. Sc.
2	Mahbubar Rahman	28	Service	M. Sc.
3	Jotindronath Mondal	45	Vill. Doctor	B. Sc
4	Lalita Rani Mondal	23	Service	B. Sc
5	Suvash Mondal	39	Farmer	Class-Nine
6	Kashem Gazi	46	Farmer	Illiterate
7	Nasima begam	29	Farmer	Class-Seven
8	Haran Mondal	42	Wage labor	Class-Five
9	Rezaul Karim	50	Forest Extract	Class-Two
10	Krisna Rani	30	Fisher	Illiterate
11	Ismail Hossain	46	Fisher	Class-Two
13	Babur Ali	38	Wage labor	Illiterate
14	Selina	28	Wage labor	Illiterate
15	Puti Rani	38	Fisher	Class-Two
16	Azmal Sardar	38	Forest Extract	Class-Two
17	Sofed Gazi	52	Forest Extract	Class-Three
18	Komol Sarker	34	Fry collector	Class-Two
19	Rumi Das	36	Fry collector	Signature
20	Md. Rafik	20	Fry collector	Class-Five

**Focus Stakeholder Meeting Agenda:**

- ✓ Introduction.
- ✓ Coastal livelihood system.
- ✓ Affected activities and insecurity of livelihood groups.
- ✓ Livelihood security indicators and their rational.
- ✓ Expected living standard coping strategies of livelihood groups.
- ✓ Selection of indicator (Pair-wise priority function).
- ✓ Present and future adaptation options for storm surge hazards.

**Major Findings from Focus Stakeholder Meeting:**

1. Livelihood system is not developed much and most of the marginal groups are in great danger.
2. Developed indicator framework is logical and significant.
3. Standard value of indicators.
4. Pair-wise weight / priority weight of indicators.
5. Socio-economic development and future plan to survive.

**Study on the security modeling through the participation of marginal livelihood groups in the coastal area**  
**Checklist for Focus Stakeholder Meeting (FSM)**

**District: Cox's bazaar**

**Date: 08.01.2009**

**Venue: Khurushkul Union Parisad**

**Union: Khurushkul**

**Upazilla: Cox's bazaar Sadar**

**Starting time: 10.30. AM**

**Ending time: 12.00 AM**

**Facilitating NGO: SARPV Bangladesh.**

**Role of Team Member**

**Organizer: Mahmuda Mutahara and Md. Abidur Rahman (SARPV Bangladesh).**

**Moderator: Mahmuda Mutahara, IWFM, BUET.**

**Reporting: Mahmuda Mutahara, IWFM, BUET.**

**List of Participants:**

Sl No.	Participant	Age	Occupation	Education
1	Mahmuda Mutahara,	26	Student	M. Sc.
2	Abidur Rahman	34	Service	M. Sc.
3	Abdul Mabud	48	Chairman	B.Sc.
4	Abdul Khalek	55	Farmer	Class-Two
5	Sabir Ali	44	Salt farmer	Class-Four
6	Rawson Ali	38	Salt farmer	Class-Nine
7	Modhu Bala	37	Dry Fisher	Illiterate
8	Abdul Lotif	40	Dry fisher	Class-Seven
9	Faez Uddin	28	Dry fisher	Class-Five
10	Lal Mohan	45	Fry collector	Class-Two
11	Nasima	35	Fry collector	Illiterate
13	Monirul Islam	48	Farmer	Illiterate
14	Momotaj Khatun	37	Farmer	Class-Two
15	Abu Taleb	38	Fisher	Class-Four
16	Md. Atik	56	Fisher	S. S. C.
17	Saheda Khatun	38	Wage laborer	Class-Two
18	Boli Mohan	45	Wage laborer	Class-Three
19	Moen Gazi	40	Fisher	Class-Two
20	Gopal Dee	38	Salt Farmer	Class-Five

**Focus Stakeholder Meeting Agenda:**

- ✓ Introduction
- ✓ Identification of major assets of livelihood groups.
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- ✓ Identification of major storm surge hazards in the study area and their ranking.
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**Major Findings from Focus Stakeholder Meeting:**

1. Stakeholders are aware of storm surge and increasing occurrence of that natural hazard.
2. The storm surge hazards damage household capital and livelihood resources more destructively.
3. The storm surge hazards are affecting agriculture, salt field, shutki mohal and others.
4. Livelihood system is under developed and people are helpless.
5. Farmer are taking several initiatives to reduce their loss from hazards such, land raising, embankment to protect high tidal flooding, forestation for protection, irrigation by Tube-well, fresh water reserve in ponds etc.
6. There is a lack of institutional activities and mitigation measure.

**Study on the security modeling through the participation of marginal livelihood groups in the coastal area**  
**Checklist for Focus Stakeholder Meeting (FSM)**

**District: Cox's bazaar**

**Date: 05.02.2009**

**Venue: Jilonja Union Parisad**

**Union: Jilonja**

**Upazilla: Cox's bazaar Sadar**

**Starting time: 10.30. AM**

**Ending time: 12.00 AM**

**Facilitating NGO: SARPV Bangladesh.**

**Role of Team Member**

Organizer: Mahmuda Mutahara and Md. Abidur Rahman (SARPV Bangladesh).

Moderator: Mahmuda Mutahara, IWF, BUET.

Reporting: Mahmuda Mutahara, IWF, BUET.

**List of Participants:**

SL No.	Participant	Age	Occupation	Education
1	Mahmuda Mutahara,	26	Student	M. Sc.
2	Abidur Rahman	34	Service	M. Sc.
3	Md. Rashid Ahmed	42	Up member	B. Sc.
4	Abdul Khalek	55	Farmer	Class-Two
5	Solaiman Ali	35	Farmer	S. S. C.
6	Momena Khatun	35	Fry collector	Illiterate
7	Nurul Haque	45	Fry collector	Class-Three
8	Abdul Lotif	40	Fisher	Class-Seven
9	Lota Rani	38	Fisher	Class-Two
10	Prosanto Kumar	56	Fisher	Signature
11	Nepal dee	48	Wage laborer	Class-Two
13	Md. Eunus	40	Dry Fisher	Class-Four
14	Kabir Ahmed	36	Dry Fisher	Class-Three
15	Sahara Khatun	32	Dry Fisher	Class-Two
16	Md. Aslam	36	Wage laborer	Signature
17	Shunil	32	Salt farmer	Class-Seven
18	Hossain Ali	40	Salt farmer	Class-Four
19	Hamid Hossain	16	Fry collector	Class Five
20	Durga Bala	28	Wage laborer	Signature

**Focus Stakeholder Meeting Agenda:**

- ✓ Introduction.
- ✓ Coastal livelihood system.
- ✓ Affected activities and insecurity of livelihood groups.
- ✓ Livelihood security indicators and their rational.
- ✓ Expected living standard coping strategies of livelihood groups.
- ✓ Selection of indicator (Pair-wise priority function).
- ✓ Present and future adaptation options for storm surge hazards.

**Major Findings from Focus Stakeholder Meeting:**

1. Livelihood system is not developed much and most of the marginal groups are in great danger.
2. Developed indicator framework is logical and significant.
3. Standard value of indicators.
4. Pair-wise weight / priority weight of indicators.
5. Socio-economic development and future plan to survive.

## APPENDIX-C

**Selection of indicators with response to different livelihood security options by AHP  
(Analytical Hierarchy Process)**

**Step-1: Pair wise comparison matrix for 1<sup>st</sup> level criteria for Security Indicator Selection.**

	Food security	Income security	Life &health security	Property and personal	Water security
Food security	1	8	5	8	1/5
Income security		1	5	6	1/2
Life &health security			1	9	1/5
Property and personal				1	4
Water security					1

**Pair wise comparison matrix for 2<sup>nd</sup> level criteria in Indicator Selection for Food Security.**

**Pair wise comparison matrix for 2<sup>nd</sup> level criteria (Natural Capital indicators under food security)**

**Step-2: Transform the comparison into weight**

	FSS	SSP	SHML	DOSS	RVAA	TFPP	PNDS	RRQI	APRB	AEFS
FSS	1	1	7	7	8	1/9	9	1/9	1/9	1/8
SSP		1	8	8	8	1/8	9	1/8	1/8	1/7
SHML			1	8	8	1/9	9	1/8	1/9	1/9
DOSS				1	9	1/7	9	1/5	3	3
RVAA					1	1/9	1	1/9	1/8	1/4
TFRP						1	7	1	1	1
PNDS							1	1/9	1/8	1/8
RRQI								1	7	6
APRB									1	6
AEFS										1

**Computational process of priority vector (1<sup>st</sup> level criteria)**

	Food security	income security	Life &health security	Property and personal	Water security
Food security	1	8	5	8	1/5
Income security	1/8	1	5	6	1/2
Life &health security	1/5	1/5	1	9	1/5
Property and personal	1/8	1/6	1/9	1	4
Water security	5	2	5	1/4	1
Column sum	6.5	11.4	16.1	24.3	5.9



Computational process of priority vector for 2<sup>nd</sup> level criteria (Natural Capital indicators under food security)

	FSS	SSP	SHML	DOSS	RVAA	TFRP	PNDS	RRQI	APRB	AEFS
FSS	1	1	7	7	8	1/9	9	1/9	1/9	1/8
SSP	1	1	8	8	8	1/8	9	1/8	1/8	1/7
SHML	1/7	1/8	1	8	8	1/9	9	1/8	1/9	1/9
DOSS	1/7	1/7	1/8	1	9	1/7	9	1/5	3	3
RVAA	1/8	1/8	1/8	1/9	1	1/9	1	1/9	1/8	1/4
TFRP	9	9	8	7	9	1	7	1	1	1
PNDS	1/9	1/9	1/9	1/9	1	1/7	1	1/9	1/8	1/8
RRQI	9	9	8	5	9	1	9	1	7	6
APRB	9	9	8	1/3	4	1	8	1/6	1	6
AEFS	8	8	7	1/3	8	1	8	1/7	1/6	1
COLUMN SUM	37.522	37.504	47.361	36.889	65	4.744	70	3.093	12.764	17.754

**Step-3: Formation of a matrix through dividing each cell by column sum**

Matrix for 1<sup>st</sup> level criteria

	Food security	Income security	Life & health security	Property and personal	Water security
Food security	0.155	0.704	0.310	0.330	0.034
Income security	0.019	0.088	0.310	0.247	0.085
Life & health security	0.031	0.018	0.062	0.371	0.034
Property and personal	0.019	0.015	0.007	0.041	0.678
Water security	0.775	0.176	0.310	0.010	0.169

Matrix for 2<sup>nd</sup> level criteria (Natural Capital indicators under food security)

	FSS	SSP	SHML	DOSS	RVAA	TFRP	PNDS	RRQI	APRB	AEFS
FSS	0.027	0.027	0.148	0.190	0.123	0.023	0.129	0.036	0.009	0.007
SSP	0.027	0.027	0.169	0.217	0.123	0.026	0.129	0.040	0.010	0.008
SHML	0.004	0.003	0.021	0.217	0.123	0.023	0.129	0.040	0.009	0.006
DOSS	0.004	0.004	0.003	0.027	0.138	0.030	0.129	0.065	0.235	0.169
RVAA	0.003	0.003	0.003	0.003	0.015	0.023	0.014	0.036	0.010	0.014
TFRP	0.240	0.240	0.169	0.190	0.138	0.211	0.100	0.323	0.078	0.056
PNDS	0.003	0.003	0.002	0.003	0.015	0.030	0.014	0.036	0.010	0.007
RRQI	0.240	0.240	0.169	0.136	0.138	0.211	0.129	0.323	0.548	0.338
APRB	0.240	0.240	0.169	0.009	0.062	0.211	0.114	0.054	0.078	0.338
AEFS	0.213	0.213	0.148	0.009	0.123	0.211	0.114	0.046	0.013	0.056

**Step-4: Calculate row sum for each factor and normalize these values by dividing each factor value by column sum**

Matrix of normalized value for 1<sup>st</sup> level criteria

	Row sum	Normalized weight
Food security	1.532991116	0.306598223
Income security	0.7498869655	0.149973931
Life & health security	0.515704351	0.10314087
Property and personal	0.760142368	0.152028474
Water security	1.441292509	0.288258502
Sum	5	1

Matrix of normalized value for 2<sup>nd</sup> level criteria (Natural Capital indicators under food security)

Indicators from Natural Capital		Row sum	Normalized weight
Frequency of Storm surge (Irregular/regular)	FSS	0.718	0.072
Storm surge Period (Low tide/ high tide)	SSP	0.775	0.078
Surge height from mean sea level	SHML	0.576	0.058
Duration of storm surge (Short term/ long term)	DOSS	0.803	0.080
Rate of vegetation around the area	RVAA	0.125	0.013
Time frame for resource collection/ production	TFRP	1.746	0.175
Performance of natural drainage system	PNDS	0.124	0.012
Rate of possible resource quality improvement	RRQI	2.472	0.247
Access to alternative resource base	APRB	1.515	0.151
Available energy /fuel supply	AEFS	1.147	0.115
Sum		10	1

**Step-5: Priority vector of Natural Capital indicator under food security. (Multiplying normalized value of alternatives with normalized security vector)**

Food security	Normalized priority vector	Overall priority vector (Response)
0.307	0.072	0.02
	0.078	0.02
	0.058	0.02
	0.08	0.02
	0.013	0.00
	0.175	0.05
	0.012	0.00
	0.247	0.08
	0.151	0.05
	0.115	0.04

Same Process has been followed to select Indicator According to Their Priority or Level of Response.

Pair wise comparison matrix for 2<sup>nd</sup> level criteria (Financial indicators under food security)

	HP	OP	SFS	RS	RSS	AWEA	SAEC	AFL	HIRC
HP	1	9	8	7	6	5	4	3	2
OP	1/9	1	9	8	7	6	5	4	3
SFS	1/8	1/9	1	9	8	7	6	5	4
RS	1/7	1/8	1/9	1	9	8	7	6	5
RSS	1/6	1/7	1/8	1/9	1	9	8	7	6
AWEA	1/5	1/6	1/7	1/8	1/9	1	9	8	7
SAEC	1/4	1/5	1/6	1/7	1/8	1/9	1	9	8
AFL	1/3	1/4	1/5	1/6	1/7	1/8	1/9	1	9
HIRC	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	1
<b>Column sum</b>	2.829	11.329	18.996	25.746	31.546	36.379	40.236	43.111	45.000

Matrix of normalized value for 2<sup>nd</sup> level criteria

Indicators		Row sum	Normalized
Homestead production	HP	2.382	0.265
Ownership on main production or income	OP	1.583	0.176
Scope of food storage	SFS	1.256	0.140
Rate of saving	RS	1.036	0.115
Reliability of saving system	RSS	0.856	0.095
Access of women to economic activities	AWEA	0.694	0.077
Scope of alternative economic activities	SAEC	0.539	0.060
Access to financial loan	AFL	0.391	0.043
Portion of HH income earned from rest of the country	HIRC	0.264	0.029
<b>Sum</b>		9	1

Pair wise comparison matrix for 2<sup>nd</sup> level criteria (Human Capital indicators under food security)

	RE	NFA	KSR	NST	ADS	TSP	APH	REWS	RAT	ROM
RE	1	1	1/7	9	8	1	1/8	1/7	1/7	7
NFA	1	1	5	9	5	1	5	6	7	5
KSR	7	1/5	1	9	8	6	6	5	8	8
NST	1/9	1/9	1/9	1	8	1/7	7	5	3	5
ADS	1/8	1/8	1/5	1/8	1	1/7	1/7	1/5	1/3	2
TSP	1	1	1	7	7	1	7	5	6	1
APH	8	8	1/5	1/7	7	1/7	1	5	3	3
REWS	7	7	1/6	1/5	5	1/5	1/5	1	6	5
RAT	7	7	1/7	1/3	1/2	1	1/3	1/5	1	3
ROM	1/7	1/5	1/8	1/5	3	1/6	1/3	1/6	1/3	1
<b>Column sum</b>	32.378	25.636	8.0884	36.001	52.5	10.795	27.1345	27.709	34.809	40

Matrix of normalized value for 2<sup>nd</sup> level criteria

Indicator		Row sum	Normalized weight
Rate of education/literacy	RE	0.77142579	0.077
Knowledge on first aid	NFA	1.852810721	0.185
Knowledge on storm surge risk	KSR	2.137183011	0.214
Access to nearest district town	NST	0.864494469	0.086
Access to doctor service (No. of doctor / 50 Household)	ADS	0.14127446	0.014
HH population having training on Surge protection	TSP	1.24971288	0.125
Active population of HH	APH	1.112875172	0.111
Response to early warning system	REWS	0.969993593	0.097
Response to adaptation technology	RAT	0.741550007	0.074
Rate of out migration of HH member	ROM	0.158679896	0.016
Sum		10	1

Pair wise comparison matrix for 2<sup>nd</sup> level criteria (Physical/ infrastructural Capital indicators under food security)

	SHI	PHC	PCS	ADW	SF	ARTC	APR	TF	AUPS	FPS
SHI	1	9	9	8	8	9	9	5	9	9
PHC	1/9	1	1/9	1/9	1/9	1/5	1/9	1/9	2	1/2
PCS	1/9	9	1	5	5	6	6	5	8	4
ADW	1/8	9	1/5	1	4	9	7	5	3	5
SF	1/8	9	1/5	1/4	1	9	6	3	4	6
ARTC	1/9	5	1/6	1/9	1/9	1	1/9	1/9	2	2
APR	1/9	9	1/6	1/7	1/6	9	1	5	1	3
TF	1/5	9	1/5	1/5	1/3	9	1/5	1	6	5
AUPS	1/9	1/2	1/8	1/3	1/4	1/2	1	1/6	1	3
FPS	1/9	2	1/4	1/5	1/6	1/2	1/3	1/5	1/3	1
Column sum	2.117	62.500	11.419	15.348	19.139	53.200	30.756	24.589	36.333	38.50

Matrix of normalized value for 2<sup>nd</sup> level criteria

Indicators		Row sum	Normalized weight
Safe housing infrastructure/ condition	SHI	3.490	0.349
Performance of hospital /Health center	PHC	0.171	0.017
Performance of/access to cyclone shelter	PCS	1.706	0.171
Availability of drinking water (Safe water)	ADW	1.307	0.131
Sanitation facilities	SF	1.041	0.104
Access of Radio/TV/ Cell phone	ARTC	0.294	0.029
Availability of paved road	APR	0.740	0.074
Transportation facilities	TF	0.798	0.080
Part of area under protection structure	AUPS	0.260	0.026
Fitness of protection structure	FPS	0.192	0.019
Sum		10	1

Pair wise comparison matrix for 2<sup>nd</sup> level criteria (Social Capital indicators under food security)

	PWF	CPP	ALG	NGO	SLR	PI	DMC	ASO	APP
PWF	1	8	8	6	9	7	8	7	7
CPP	1/8	1	8	5	9	5	5	9	7
ALG	1/8	1/8	1	7	8	7	6	7	7
NGO	1/6	1/5	1/7	1	8	1/6	1/5	8	1/7
SLR	1/9	1/9	1/8	1/8	1	1/9	1/7	1/7	1/9
PI	1/7	1/5	1/7	6	9	1	1/7	5	1/9
DMC	1/8	1/5	1/6	5	7	7	1	7	8
ASO	1/7	1/9	1/7	1/8	7	1/5	1/7	1	9
APP	1/7	1/7	1/7	7	9	9	1/8	1/9	1

Matrix of normalized value for 2<sup>nd</sup> level criteria

Indicators		Row sum	Normalized weight
Performance of weather forecasting	PWF	2.930	0.326
Community participation practice	CPP	1.635	0.182
Activeness of local GO	ALG	1.253	0.139
Interrelationship with NGO	NGO	0.453	0.050
Performance social law and regulation	SLR	0.106	0.012
Political influence on social group/ committee	PI	0.542	0.060
Performance of local disaster management committee	DMC	0.929	0.103
Activeness of social organization of livelihood groups	ASO	0.459	0.051
Awareness program on protection measure (No./Y)	APP	0.694	0.077
Sum		9	1

Pair wise comparison matrix for 2<sup>nd</sup> level criteria (Natural Capital indicators under income security)

	FSS	SSP	SHML	DOSS	RVAA	TFPP	PNDS	RRQI	APRB	AEFS
FSS	1	1	7	7	7	1/9	7	1/9	1/9	9
SSP	1	1	8	6	8	1/9	8	1/9	1/8	9
SHML	1/7	1/8	1	5	8	1/8	7	1/7	1/8	9
DOSS	1/7	1/7	1/5	1	9	1/8	9	1/8	1/9	9
RVAA	1/7	1/7	1/8	1/9	1	1/9	8	1/9	1/9	9
TFPP	9	9	9	8	9	1	7	5	6	9
PNDS	1/7	1/7	1/8	1/9	1/8	1/7	1	1/9	1/8	1/7
RRQI	9	9	9	8	9	1/5	9	1	1	1/7
APRB	9	9	8	9	1/9	1/9	7	7	1	7
AEFS	1/9	1/9	1/9	1/9	9	1/6	8	1	1/7	1
Column sum	29.683	29.665	42.561	44.333	60.236	2.204	71.000	14.712	8.851	62.286

Matrix of normalized value for 2<sup>nd</sup> level criteria

Indicators		Row sum	Normalized weight
Frequency of Storm surge (Irregular/regular)	FSS	0.820	0.082
Storm surge Period (Low tide/ high tide)	SSP	0.853	0.085
Surge height from mean sea level	SHML	0.602	0.060
Duration of storm surge (Short term/ long term)	DOSS	0.535	0.054
Rate of vegetation around the area	RVAA	0.359	0.036
Time frame for resource collection/ production	TFRP	2.862	0.286
Performance of natural drainage system	PNDS	0.120	0.012
Rate of possible resource quality improvement	RRQI	1.549	0.155
Access to alternative resource base	APRB	1.850	0.185
Available energy /fuel supply	AEFS	0.450	0.045
Sum		10	1

Pair wise comparison matrix for 2<sup>nd</sup> level criteria (Financial Capital indicators under income security)

	HP	OP	SFS	RS	RSS	AWEA	SAEC	AFL	HIRC
HP	1	1/9	8	9	9	8	8	8	5
OP	9	1	9	8	7	6	5	4	3
SFS	1/8	1/9	1	1/9	1/8	1/4	1/7	2	1/9
RS	1/9	1/8	9	1	9	1/9	1/8	1/9	1/8
RSS	1/9	1/7	8	1/9	1	9	8	7	6
AWEA	1/8	1/6	4	9	1/9	1	9	8	7
SAEC	1/8	1/5	7	8	1/8	1/9	1	9	8
AFL	1/8	1/4	1/2	9	1/7	1/8	1/9	1	9
HIRC	1/5	1/3	9	8	1/6	1/7	1/8	1/9	1
<b>Column sum</b>	<b>10.922</b>	<b>2.440</b>	<b>55.500</b>	<b>52.222</b>	<b>26.671</b>	<b>24.740</b>	<b>31.504</b>	<b>39.222</b>	<b>39.236</b>

Matrix of normalized value for 2<sup>nd</sup> level criteria

Indicators		Row sum	Normalized weight
Homestead production	HP	1.700	0.189
Ownership on main production or income	OP	2.391	0.266
Scope of food storage	SFS	0.150	0.017
Rate of saving	RS	0.595	0.066
Reliability of saving system	RSS	1.202	0.134
Access of women to economic activities	AWEA	1.037	0.115
Scope of alternative economic activities	SAEC	0.847	0.094
Access to financial loan	AFL	0.564	0.063
Portion of HH income earned from rest of the country	HIRC	0.515	0.057
Sum		9	1

Pair wise comparison matrix for 2<sup>nd</sup> level criteria (Human indicators under income security)

	RE	NFA	KSR	NST	ADS	TSP	APH	REWS	RAT	ROM
RE	1	9	9	5	9	5	1	5	5	5
NFA	1/9	1	1/8	1/7	5	1/7	1/9	1/9	1/9	1/9
KSR	1/9	8	1	7	9	5	1	1	5	1/7
NST	1/5	1/5	1/7	1	7	6	7	5	5	1/7
ADS	1/9	1/9	1/5	1/7	1	1/8	1/8	1/7	1/7	1/7
TSP	1/5	1/5	7	1/6	8	1	7	5	6	7
APH	1	1	9	1/7	8	1/7	1	5	5	7
REWS	1/5	1/5	9	1/5	7	1/5	1/5	1	6	5
RAT	1/5	1/5	9	1/5	7	1/7	1/7	1/5	1	5
ROM	1/5	1/5	9	7	7	1/6	1/5	1/6	1/5	1
Column sum	3.333	20.111	53.468	20.995	68.000	17.920	17.779	22.621	33.454	30.540

Matrix of normalized value for 2<sup>nd</sup> level criteria

		Row sum	weight
Rate of education/literacy	RE	2.155	0.215
Knowledge on first aid	NFA	0.191	0.019
Knowledge on storm surge risk	KSR	1.449	0.144
Access to nearest district town	NST	1.326	0.132
Access to doctor service (No. of doctor / 50 Household)	ADS	0.093	0.009
HH population having training on Surge protection	TSP	1.405	0.140
Active population of HH	APH	1.306	0.130
Response to early warning system	REWS	0.760	0.076
Response to adaptation technology	RAT	0.56	0.056
Rate of out migration of HH member	ROM	0.741	0.074
Sum		10	1

Pair wise comparison matrix for 2<sup>nd</sup> level criteria (Physical/ infrastructural Capital indicators under income security)

	SHI	PHC	PCS	ADW	SF	ARTC	APR	TF	AUPS	FPS
SHI	1	9	9	9	9	8	7	5	8	1/2
PHC	1/9	1	1/9	5	5	1/8	1/8	1/8	1/8	1/9
PCS	1/9	9	1	7	8	6	6	5	8	4
ADW	1/9	1/5	1/7	1	6	1/5	1/7	1/9	1/7	1/4
SF	1/9	1/5	1/8	1/6	1	1/4	1/8	3	1/4	1/5
ARTC	1/8	8	8	5	4	1	7	5	6	1
APR	1/7	8	1/6	7	8	1/7	1	5	1	3
TF	1/5	8	1/5	9	1/3	1/5	1/5	1	6	5
AUPS	1/8	8	1/8	7	4	1/6	1	1/6	1	3
FPS	2	9	1/4	4	5	1	1/3	1/5	1/3	1
Column sum	4.037	60.400	19.121	54.167	50.333	17.085	22.928	24.603	30.851	18.061

Matrix of normalized value for 2<sup>nd</sup> level criteria

Indicators		Row sum	Normalized weight
Safe housing infrastructure/ condition	SHI	2.476	0.248
Performance of hospital /Health center	PHC	0.270	0.027
Performance of/access to cyclone shelter	PCS	1.814	0.181
Availability of drinking water (Safe water)	ADW	0.217	0.022
Sanitation facilities	SF	0.222	0.022
Access of Radio/TV/ Cell phone	ARTC	1.571	0.157
Availability of paved road	APR	0.918	0.092
Transportation facilities	TF	0.898	0.090
Part of area under protection structure	AUPS	0.637	0.064
Fitness of protection structure	FPS	0.978	0.098
Sum		10	1

Pair wise comparison matrix for 2<sup>nd</sup> level criteria (Social Capital indicators under income security)

	PWF	CPP	ALG	NGO	SLR	PI	DMC	ASO	APP
PWF	1	1/7	1/9	1/5	5	1/7	1/7	1/7	1/8
CPP	7	1	1/7	5	8	5	8	1	8
ALG	9	7	1	9	8	5	7	7	7
NGO	5	1/5	1/9	1	9	8	7	6	1/9
SLR	1/5	1/8	1/8	1/9	1	1/7	1/6	1/7	1/7
PI	7	1/5	1/5	1/8	7	1	9	8	7
DMC	7	1/8	1/7	1/7	5	1/9	1	1/7	1/7
ASO	7	1	1/7	1/6	7	1/8	7	1	9
APP	8	1/8	1/7	9	7	1/7	7	1/9	1
Column sum	51.2	9.9	2.1	24.7	57.0	19.7	46.3	23.5	32.5

Matrix of normalized value for 2<sup>nd</sup> level criteria

Indicators		Row sum	Normalized weight
Performance of weather forecasting	PWF	0.202	0.022
Community participation practice	CPP	1.363	0.151
Activeness of local GO	ALG	2.776	0.308
Interrelationship with NGO	NGO	1.185	0.132
Performance social law and regulation	SLR	0.119	0.013
Political influence on social group/ committee	PI	1.179	0.131
Performance of local disaster management committee	DMC	0.348	0.039
Activeness of social organization of livelihood groups	ASO	0.911	0.101
Awareness program on protection measure (No./Y)	APP	0.917	0.102
Sum		9	1



Pair wise comparison matrix for 2<sup>nd</sup> level criteria (Natural Capital indicators under Health security)

	FSS	SSP	SHML	DOSS	RVAA	TFRP	PNDS	RRQI	APRB	AEFS
FSS	1	1	7	7	1/8	9	1/8	8	1/9	1/7
SSP	1	1	8	6	1/7	8	1/7	8	1/8	1/6
SHML	1/7	1/8	1	8	1/7	8	1/8	9	1/8	9
DOSS	1/7	1/7	1/8	1	9	7	9	9	1/9	9
RVAA	8	8	7	1/9	1	9	5	8	1/9	6
TFRP	1/9	1/9	1/8	1/7	1/9	1	1/8	1	1/7	1/8
PNDS	8	8	7	1/9	1/5	8	1	9	1/8	7
RRQI	1/8	1/8	1/8	1/9	1/8	1	1/9	1	1	1/7
APRB	9	9	8	9	1/6	8	1/7	7	1	7
AEFS	7	7	6	1/9	9	7	8	1	1/7	1
<b>Column sum</b>	<b>34.522</b>	<b>34.504</b>	<b>44.375</b>	<b>31.587</b>	<b>20.013</b>	<b>66.000</b>	<b>23.772</b>	<b>61.000</b>	<b>2.994</b>	<b>39.577</b>

Matrix of normalized value for 2<sup>nd</sup> level criteria

Indicator		Row sum	Normalized weight
Frequency of Storm surge (Irregular/regular)	FSS	0.757	0.076
Storm surge Period (Low tide/ high tide)	SSP	0.740	0.074
Surge height from mean sea level	SHML	0.834	0.083
Duration of storm surge (Short term/ long term)	DOSS	1.389	0.139
Rate of vegetation around the area	RVAA	1.341	0.134
Time frame for resource collection/ production	TFRP	0.107	0.011
Performance of natural drainage system	PNDS	1.164	0.116
Rate of possible resource quality improvement	RRQI	0.394	0.039
Access to alternative resource base	APRB	1.748	0.175
Available energy /fuel supply	AEFS	1.526	0.153
Sum		10	1

Pair wise comparison matrix for 2<sup>nd</sup> level criteria (Financial indicators under Health security)

	HP	OP	SFS	RS	RSS	AWEA	SAEC	AFL	HIRC
HP	1	5	1/9	1/8	1/7	9	9	1/9	6
OP	1/5	1	9	8	7	8	8	4	3
SFS	9	1/9	1	9	8	7	8	1/4	4
RS	8	1/8	1/9	1	9	8	7	6	5
RSS	7	1/7	1/8	1/9	1	9	8	7	6
AWEA	1/9	1/8	1/7	1/8	1/9	1	4	1/9	7
SAEC	1/9	1/8	1/8	1/7	1/8	1/4	1	1/9	8
AFL	9	1/4	4	1/6	1/7	9	9	1	9
HIRC	1/6	1/3	1/4	1/5	1/6	1/7	1/8	1/9	1
<b>Column sum</b>	<b>34.59</b>	<b>7.21</b>	<b>14.87</b>	<b>18.87</b>	<b>25.69</b>	<b>51.39</b>	<b>54.13</b>	<b>18.69</b>	<b>49.00</b>

Matrix of normalized value for 2<sup>nd</sup> level criteria

Indicators		Row sum	Normalized weight
Homestead production	HP	1.2116	0.135
Ownership on main production or income	OP	2.0250	0.225
Scope of food storage	SFS	1.5102	0.168
Rate of saving	RS	1.3674	0.152
Reliability of saving system	RSS	1.0952	0.122
Access of women to economic activities	AWEA	0.2833	0.031
Scope of alternative economic activities	SAEC	0.2339	0.026
Access to financial loan	AFL	1.1568	0.129
Portion of HH income earned from rest of the country	HIRC	0.1164	0.013
Sum		9	1

Pair wise comparison matrix for 2<sup>nd</sup> level criteria (Human Capital indicators under Health security)

	RE	NFA	KSR	NST	ADS	TSP	APH	REWS	RAT	ROM
RE	1	1/9	1	5	1/9	1	5	5	5	9
NFA	9	1	5	3	6	1	5	6	7	9
KSR	1	1/5	1	5	1/8	1	5	5	1/7	9
NST	1/5	1/3	1/5	1	1/9	5	1	5	1/8	7
ADS	9	1/6	8	9	1	8	7	6	7	9
TSP	1	1	1	1/5	1/8	1	7	5	6	8
APH	1/5	1/5	1/5	1	1/7	5	1	1/7	7	9
REWS	1/5	1/6	1/5	1/5	1/6	1/5	7	1	8	9
RAT	1/5	1/7	7	8	1/9	1/8	1/9	1/9	1	9
ROM	1/9	1/9	1/9	1/7	1/7	1/6	1/7	1/8	1/9	1
Column sum	21.91	3.43	23.71	32.54	8.04	22.49	38.25	33.38	41.38	79.00

Matrix of normalized value for 2<sup>nd</sup> level criteria

Indicators		Row sum	Normalized weight
Rate of education/literacy	RE	0.847381014	0.0847381
Knowledge on first aid	NFA	2.389884089	0.23898841
Knowledge on storm surge risk	KSR	0.757629429	0.07576294
Access to nearest district town	NST	0.649119821	0.06491198
Access to doctor service (No. of doctor / 50 Household)	ADS	2.19923491	0.21992349
HH population having training on Surge protection	TSP	1.024421826	0.10244218
Active population of HH	APH	0.660166118	0.06601661
Response to early warning system	REWS	0.622112979	0.0622113
Response to adaptation technology	RAT	0.755514862	0.07555149
Rate of out migration of HH member	ROM	0.094534951	0.0094535
Sum		10	1

Pair wise comparison matrix for 2<sup>nd</sup> level criteria (Physical/ infrastructural Capital indicators under Health security)

	SHI	PHC	PCS	ADW	SF	ARTC	APR	TF	AUPS	FPS
SHI	1	9	9	8	8	8	7	5	8	8
PHC	1/9	1	5	3	6	1	5	6	7	5
PCS	1/9	1/5	1	7	4	6	6	5	8	5
ADW	1/8	1/3	1/7	1	4	6	7	5	3	5
SF	1/8	1/6	1/4	1/4	1	5	6	1/5	4	6
ARTC	1/8	1	1	1/6	1/5	1	7	5	6	1/9
APR	1/7	1/5	1/6	1/7	1/6	1/7	1	1/2	1	1/6
TF	1/5	1/6	1/5	1/5	5	1/5	2	1	6	1/4
AUPS	1/8	1/7	1/8	1/3	1/4	1/6	1	1/6	1	3
FPS	1/8	1/5	1/5	1/5	1/6	9	6	4	1/3	1
<b>Column sum</b>	<b>2.190</b>	<b>12.410</b>	<b>17.085</b>	<b>20.293</b>	<b>28.783</b>	<b>36.510</b>	<b>48.000</b>	<b>31.867</b>	<b>44.333</b>	<b>33.528</b>

Matrix of normalized value for 2<sup>nd</sup> level criteria

Indicators		Row sum	Priority
Safe housing infrastructure/ condition	SHI	3.322	0.332
Performance of hospital /Health center	PHC	1.407	0.141
Performance of/access to cyclone shelter	PCS	1.385	0.139
Availability of drinking water (Safe water)	ADW	0.954	0.096
Sanitation facilities	SF	0.670	0.067
Access of Radio/TV/ Cell phone	ARTC	0.680	0.068
Availability of paved road	APR	0.172	0.017
Transportation facilities	TF	0.521	0.052
Part of area under protection structure	AUPS	0.244	0.024
Fitness of protection structure	FPS	0.635	0.063
Sum		10	1

Pair wise comparison matrix for 2<sup>nd</sup> level criteria (Social Capital indicators under Health security)

	PWF	CPP	ALG	NGO	SLR	PI	DMC	ASO	APP
PWF	1	8	8	7	8	7	7	8	1
CPP	1/8	1	9	8	7	8	5	4	5
ALG	1/8	1/9	1	9	8	9	6	5	1/7
NGO	1/7	1/8	1/9	1	9	8	7	6	5
SLR	1/8	1/7	1/8	1/9	1	9	8	7	6
PI	1/7	1/8	1/9	1/8	1/9	1	1/7	1/8	1/8
DMC	1/7	1/5	1/6	1/7	1/8	7	1	7	8
ASO	1/8	1/4	1/5	1/6	1/7	8	1/7	1	9
APP	1	1/5	7	1/5	1/6	8	1/8	1/9	1
<b>Column sum</b>	<b>2.929</b>	<b>10.154</b>	<b>25.714</b>	<b>25.746</b>	<b>33.546</b>	<b>65.000</b>	<b>34.411</b>	<b>38.236</b>	<b>35.268</b>

Matrix of normalized value for 2<sup>nd</sup> level criteria

		Row sum	
Performance of weather forecasting	PWF	2.500	0.278
Community participation practice	CPP	1.525	0.169
Activeness of local GO	ALG	1.128	0.125
Interrelationship with NGO	NGO	0.998	0.111
Performance social law and regulation	SLR	0.820	0.091
Political influence on social group/ committee	PI	0.100	0.011
Performance of local disaster management committee	DMC	0.631	0.070
Activeness of social organization of livelihood groups	ASO	0.494	0.055
Awareness program on protection measure (No./Y)	APP	0.804	0.089
Sum		9	1

Pair wise comparison matrix for 2<sup>nd</sup> level criteria (Natural Capital indicators under House security)

	FSS	SSP	SHML	DOSS	RVAA	TFRP	PNDS	RRQI	APRB	AEFS
FSS	1	1	7	7	1/9	9	1/8	8	1/9	8
SSP	1	1	8	6	1/9	8	1/7	8	1/8	7
SHML	1/7	1/8	1	8	1/9	8	1/8	9	1/8	9
DOSS	1/7	1/7	1/8	1	1/7	9	1/8	9	1/7	9
RVAA	9	9	9	7	1	9	1	8	8	9
TFRP	1/9	1/9	1/8	1/9	1/9	1	1/8	1	1/7	8
PNDS	8	8	7	8	1	8	1	9	7	7
RRQI	1/8	1/8	1/8	1/9	1/8	1	1/9	1	1	8
APRB	9	9	8	7	1/9	1/8	1/7	1/8	1	7
AEFS	1/8	1/8	1/7	1/9	1/8	7	1/7	1	1/7	1
Column sum	28.65	28.63	40.52	44.33	2.95	60.13	3.04	54.13	17.79	73.00

Matrix of normalized value for 2<sup>nd</sup> level criteria

Indicators		Row sum	Normalized weight
Frequency of Storm surge (Irregular/regular)	FSS	0.893	0.089
Storm surge Period (Low tide/ high tide)	SSP	0.871	0.087
Surge height from mean sea level	SHML	0.723	0.072
Duration of storm surge (Short term/ long term)	DOSS	0.572	0.057
Rate of vegetation around the area	RVAA	2.547	0.255
Time frame for resource collection/ production	TFRP	0.245	0.024
Performance of natural drainage system	PNDS	2.369	0.237
Rate of possible resource quality improvement	RRQI	0.294	0.029
Access to alternative resource base	APRB	1.225	0.123
Available energy /fuel supply	AEFS	0.281	0.028
Sum		10	1

Pair wise comparison matrix for 2<sup>nd</sup> level criteria (Financial Capital indicators under House security)

	HP	OP	SFS	RS	RSS	AWEA	SAEC	AFL	HIRC
HP	1	9	9	1/9	1/9	1/5	4	1/9	5
OP	1/9	1	9	8	7	6	5	4	5
SFS	1/9	1/9	1	1/9	1/7	1/4	1/9	1/8	1/9
RS	9	1/8	9	1	9	8	7	6	1/4
RSS	9	1/7	7	1/9	1	9	8	7	6
AWEA	5	1/6	4	1/8	1/9	1	9	8	7
SAEC	1/4	1/5	9	1/7	1/8	1/9	1	9	8
AFL	9	1/4	8	1/6	1/7	1/8	1/9	1	9
HIRC	1/5	1/5	9	4	1/6	1/7	1/8	1/9	1
<b>Column sum</b>	<b>33.672</b>	<b>11.196</b>	<b>65.000</b>	<b>13.768</b>	<b>17.800</b>	<b>24.829</b>	<b>34.347</b>	<b>35.347</b>	<b>41.361</b>

Matrix of normalized value for 2<sup>nd</sup> level criteria

		Row sum	
Homestead production	HP	1.235	0.137
Ownership on main production or income	OP	1.827	0.203
Scope of food storage	SFS	0.064	0.007
Rate of saving	RS	1.697	0.189
Reliability of saving system	RSS	1.390	0.154
Access of women to economic activities	AWEA	0.938	0.104
Scope of alternative economic activities	SAEC	0.663	0.074
Access to financial loan	AFL	0.687	0.076
Portion of HH income earned from rest of the country	HIRC	0.499	0.055
Sum		9	1

Pair wise comparison matrix for 2<sup>nd</sup> level criteria (Human Capital indicators under House security)

	RE	NFA	KSR	NST	ADS	TSP	APH	REWS	RAT	ROM
RE	1	7	1	7	9	1	5	5	5	5
NFA	1/7	1	1/5	1/7	5	1/8	1/7	1/8	1/8	1/9
KSR	1	5	1	1/6	7	1	5	5	5	6
NST	1/7	7	6	1	7	5	5	5	1/8	1
ADS	1/9	1/5	1/7	1/7	1	1/7	1/5	1/5	1/7	1/9
TSP	1	8	1	1/5	7	1	7	5	6	6
APH	1/5	7	1/5	1/5	5	5	1	1/7	7	1
REWS	1/5	8	1/5	1/5	5	1/5	7	1	8	4
RAT	1/5	8	1/5	8	7	1/6	1/7	1/8	1	4
ROM	1/5	9	1/6	1	9	1/6	1	1/4	1/4	1
<b>Column sum</b>	<b>4.197</b>	<b>60.200</b>	<b>10.110</b>	<b>18.052</b>	<b>62.000</b>	<b>13.801</b>	<b>31.486</b>	<b>21.843</b>	<b>32.643</b>	<b>28.222</b>

Matrix of normalized value for 2<sup>nd</sup> level criteria

Indicators		Row sum	Normalized weight
Rate of education/literacy	RE	1.776898512	0.17768985
Knowledge on first aid	NFA	0.186076015	0.0186076
Knowledge on storm surge risk	KSR	1.368322834	0.13683228
Access to nearest district town	NST	1.70137569	0.17013757
Access to doctor service (No. of doctor / 50 Household)	ADS	0.102143603	0.01021436
HH population having training on Surge protection	TSP	1.514158644	0.15141586
Active population of HH	APH	0.925904825	0.09259048
Response to early warning system	REWS	0.96145777	0.09614578
Response to adaptation technology	RAT	0.951089835	0.09510898
Rate of out migration of HH member	ROM	0.512572271	0.05125723
Sum		10	1

Pair wise comparison matrix for 2<sup>nd</sup> level criteria (Physical/ infrastructural Capital indicators under House security)

	SHI	PHC	PCS	ADW	SF	ARTC	APR	TF	AUPS	FPS
SHI	1	9	9	9	9	8	7	8	8	1/5
PHC	1/9	1	1/5	5	6	1/9	1/8	1/8	1/8	1/9
PCS	1/9	5	1	8	9	6	6	5	8	5
ADW	1/9	1/5	1/8	1	6	1/5	1/7	1/9	1/7	1/4
SF	1/9	1/6	1/9	1/6	1	1/8	6	1/8	1/4	1/5
ARTC	1/8	9	9	5	8	1	7	5	6	1
APR	1/7	8	1/6	7	1/6	1/7	1	5	1	3
TF	1/8	8	1/5	9	8	1/5	1/6	1	6	5
AUPS	1/8	8	1/8	7	4	1/6	1	1/6	1	3
FPS	5	9	1/5	4	5	1	1/3	1/5	1/3	1
Column sum	6.962	57.367	20.128	55.167	56.167	16.946	28.801	24.728	30.851	18.761

Matrix of normalized value for 2<sup>nd</sup> level criteria

Indicators		Row sum	Normalized weight
Safe housing infrastructure/ condition	SHI	2.380	0.238
Performance of hospital /Health center	PHC	0.267	0.027
Performance of/access to cyclone shelter	PCS	1.748	0.175
Availability of drinking water (Safe water)	ADW	0.190	0.019
Sanitation facilities	SF	0.285	0.028
Access of Radio/TV/ Cell phone	ARTC	1.607	0.161
Availability of paved road	APR	0.736	0.074
Transportation facilities	TF	0.993	0.099
Part of area under protection structure	AUPS	0.605	0.061
Fitness of protection structure	FPS	1.189	0.119
Sum		10	1

Pair wise comparison matrix for 2<sup>nd</sup> level criteria (Social Capital indicators under House security)

	PWF	CPP	ALG	NGO	SLR	PI	DMC	ASO	APP
PWF	1	7	8	7	7	9	5	5	1/5
CPP	1/7	1	7	8	7	6	5	1/5	7
ALG	1/8	1/7	1	9	8	7	6	7	8
NGO	1/7	1/8	1/9	1	9	8	7	6	7
SLR	1/7	1/7	1/8	1/9	1	9	1/7	7	6
PI	1/9	1/6	1/7	1/8	1/9	1	9	7	7
DMC	1/5	1/5	1/6	1/7	7	1/9	1	9	1/5
ASO	1/5	5	1/7	1/6	1/7	1/7	1/9	1	9
APP	5	1/7	1/8	1/7	1/6	1/7	5	1/9	1
Column sum	7.065	13.920	16.813	25.688	39.421	40.397	38.254	42.311	45.400

Matrix of normalized value for 2<sup>nd</sup> level criteria

Indicators		Row sum	Priority
Performance of weather forecasting	PWF	2.046	0.227
Community participation practice	CPP	1.436	0.160
Activeness of local GO	ALG	1.313	0.146
Interrelationship with NGO	NGO	0.980	0.109
Performance social law and regulation	SLR	0.592	0.066
Political influence on social group/ committee	PI	0.624	0.069
Performance of local disaster management committee	DMC	0.482	0.054
Activeness of social organization of livelihood groups	ASO	0.634	0.070
Awareness program on protection measure (No./Y)	APP	0.894	0.099
Sum		9	1

Pair wise comparison matrix for 2<sup>nd</sup> level criteria (Natural Capital indicators under Water security)

	FSS	SSP	SHML	DOSS	RVAA	TFPP	PNDS	RRQI	APRB	AEFS
FSS	1	1	7	7	8	9	1/8	8	5	1/7
SSP	1	1	8	6	8	8	1/7	8	3	1/8
SHML	1/7	1/8	1	8	8	8	1/8	9	5	1/7
DOSS	1/7	1/7	1/8	1	8	9	1/8	9	5	1/8
RVAA	1/8	1/8	1/8	1/8	1	3	1/7	3	1/5	3
TFPP	1/9	1/9	1/8	1/9	1/3	1	1/8	1	1/7	1/9
PNDS	8	8	7	8	7	8	1	9	7	5
RRQI	1/8	1/8	1/8	1/9	1/3	1	1/9	1	1	1/9
APRB	1/5	1/5	1/3	1/5	1/3	9	1/5	9	1	5
AEFS	7	7	8	8	5	7	1/7	1	1/5	1
Column sum	17.847	17.829	31.833	38.547	46.000	63.000	2.240	58.000	27.543	14.758

Matrix of normalized value for 2<sup>nd</sup> level criteria

Indicators		Row sum	Normalized weight
Frequency of Storm surge (Irregular/regular)	FSS	1.2153	0.1215
Storm surge Period (Low tide/ high tide)	SSP	1.1391	0.1139
Surge height from mean sea level	SHML	0.9571	0.0957
Duration of storm surge (Short term/ long term)	DOSS	0.7636	0.0764
Rate of vegetation around the area	RVAA	0.4166	0.0417
Time frame for resource collection/ production	TFRP	0.1282	0.0128
Performance of natural drainage system	PNDS	2.7982	0.2798
Rate of possible resource quality improvement	RRQI	0.1546	0.0155
Access to alternative resource base	APRB	0.8078	0.0808
Available energy /fuel supply	AEFS	1.6195	0.1620
Sum		10	1

Pair wise comparison matrix for 2<sup>nd</sup> level criteria (Financial Capital indicators under Water security)

	HP	OP	SFS	RS	RSS	AWEA	SAEC	AFL	HIRC
HP	1	1/9	9	1/9	1/9	1/9	4	1/9	8
OP	9	1	9	8	7	6	9	4	9
SFS	1/9	1/9	1	1/9	1/9	1/9	2	1/9	2
RS	9	1/8	9	1	9	8	7	6	5
RSS	9	1/7	9	1/9	1	9	9	7	6
AWEA	9	1/6	9	1/8	1/9	1	9	8	7
SAEC	1/4	1/9	1/2	1/7	1/9	1/9	1	1/9	2
AFL	9	1/4	9	1/6	1/7	1/8	9	1	9
HIRC	1/8	1/9	1/2	1/5	1/6	1/7	1/2	1/9	1
Column sum	46.486	2.129	56.000	9.968	17.754	24.601	50.500	26.444	49.000

Matrix of normalized value for 2<sup>nd</sup> level criteria

Indicators		Row sum	Normalized weight
Homestead production	HP	0.503	0.056
Ownership on main production or income	OP	2.778	0.309
Scope of food storage	SFS	0.179	0.020
Rate of saving	RS	1.813	0.201
Reliability of saving system	RSS	1.420	0.158
Access of women to economic activities	AWEA	1.116	0.124
Scope of alternative economic activities	SAEC	0.158	0.017
Access to financial loan	AFL	0.901	0.100
Portion of HH income earned from rest of the country	HIRC	0.134	0.015
Sum		9	1



Pair wise comparison matrix for 2<sup>nd</sup> level criteria (Human indicators under Water security)

	RE	NFA	NSR	ANDT	ADS	TSP	APH	REWS	RAT	ROM
RE	1	1/9	1	5	1/9	1	5	5	5	9
NFA	9	1	5	3	6	1	5	6	7	9
KSR	1	1/5	1	5	1/8	1	5	5	1/7	9
NST	1/5	1/3	1/5	1	1/9	5	1	5	1/8	7
ADS	9	1/6	8	9	1	8	7	6	7	9
TSP	1	1	1	1/5	1/8	1	7	5	6	8
APH	1/5	1/5	1/5	1	1/7	5	1	1/7	7	9
REWS	1/5	1/6	1/5	1/5	1/8	1/5	7	1	8	9
RAT	1/5	1/7	7	8	1/9	1/8	1/9	1/9	1	9
ROM	1/9	1/9	1/9	1/7	1/7	1/6	1/7	1/8	1/9	1
<b>Column sum</b>	21.911	3.432	23.711	32.543	8.036	22.492	38.254	33.379	41.379	79.000

Matrix of normalized value for 2<sup>nd</sup> level criteria

		Row sum	
Rate of education/literacy	RE	0.847381014	0.0847381
Knowledge on first aid	NFA	2.389884089	0.23898841
Knowledge on storm surge risk	KSR	0.757629429	0.07576294
Access to nearest district town	NST	0.649119821	0.06491198
Access to doctor service (No of doctor / 50 Household)	ADS	2.19923491	0.21992349
HH population having training on Surge protection	TSP	1.024421826	0.10244218
Active population of HH	APH	0.660166118	0.06601661
Response to early warning system	REWS	0.622112979	0.0622113
Response to adaptation technology	RAT	0.755514882	0.07555149
Rate of out migration of HH member	ROM	0.094534951	0.0094535
Sum		10	1

Pair wise comparison matrix for 2<sup>nd</sup> level criteria (Physical indicators under Water security)

	SHI	PHC	PCS	ADW	SF	ARTC	APR	TF	AUPS	FPS
SHI	1	9	9	8	8	8	7	8	9	8
PHC	1/9	1	5	3	6	1/9	9	6	9	7
PCS	1/9	1/5	1	7	4	6	9	5	8	4
ADW	1/8	1/3	1/7	1	4	6	9	5	9	9
SF	1/8	1/6	1/4	1/4	1	5	9	1/4	9	6
ARTC	1/8	9	9	1/6	1/5	1	9	5	9	1
APR	1/7	1/9	1/9	1/9	1/9	1/9	1	1/9	1	2
TF	1/8	1/6	1/5	1/5	4	1/5	9	1	6	5
AUPS	1/9	1/9	1/8	1/9	1/9	1/9	1	1/8	1	3
FPS	1/8	1/7	1/4	1/9	1/6	1	1/2	1/5	1/3	1
<b>Column sum</b>	2.101190	20.231	25.078	19.95	27.588	27.533	63.5	30.727	61.333	46

Matrix of normalized value for 2<sup>nd</sup> level criteria

		Row sum	
Safe housing infrastructure/ condition	SHI	2.952	0.295
Performance of hospital /Health center	PHC	1.309	0.131
Performance of/access to cyclone shelter	PCS	1.338	0.134
Availability of drinking water (Safe water)	ADW	1.142	0.114
Sanitation facilities	SF	0.735	0.074
Access of Radio/TV/ Cell phone	ARTC	1.388	0.139
Availability of paved road	APR	0.171	0.017
Transportation facilities	TF	0.619	0.062
Part of area under protection structure	AUPS	0.180	0.018
Fitness of protection structure	FPS	0.166	0.017
Sum		10.000	1.000

Pair wise comparison matrix for 2<sup>nd</sup> level criteria (Social Capital indicators under Water security)

	PWF	CPP	ALG	NGO	SLR	PI	DMC	ASO	APP
PWF	1	1/9	5	5	4	9	7	5	1/8
CPP	9	1	9	8	7	8	5	5	1/7
ALG	1/5	1/9	1	9	8	9	6	6	5
NGO	1/5	1/8	1/9	1	9	8	7	5	1/8
SLR	1/4	1/7	1/8	1/9	1	9	8	8	8
PI	1/9	1/8	1/9	1/8	1/9	1	1/7	1/8	1/8
DMC	1/7	1/5	1/6	1/7	1/8	7	1	5	3
ASO	1/5	1/5	1/6	1/5	1/6	9	1/5	1	5
APP	8	7	1/5	8	1/6	8	1/3	1/5	1
Column sum	19.104	9.015	15.881	31.579	29.569	66.000	34.676	33.325	20.560

Matrix of normalized value for 2<sup>nd</sup> level criteria

		Row sum	
Performance of weather forecasting	PWF	1.1675	0.130
Community participation practice	CPP	2.0612	0.229
Activeness of local GO	ALG	1.3739	0.153
Interrelationship with NGO	NGO	0.8466	0.094
Performance social law and regulation	SLR	0.9131	0.101
Political influence on social group/ committee	PI	0.0655	0.007
Performance of local disaster management committee	DMC	0.4798	0.053
Activeness of social organization of livelihood groups	ASO	0.4705	0.052
Awareness program on protection measure (No./Y)	APP	1.6220	0.180
Sum		9	1

Priority calculation under different security options (Selected indicators by AHP).

Capital	Indicator	Priority/response to different Security options				
		Food	Income	Health and Personal	House and properties	Water
Natural Capital	Frequency of Storm surge (Irregular/regular)	0.02	0.01	0.01	0.01	0.04
	Storm surge Period (Low tide/ high tide)	0.02	0.01	0.01	0.01	0.03
	Surge height from mean sea level	0.02	0.01	0.01	0.01	0.03
	Duration of storm surge (Short term/ long term)	0.02	0.01	0.01	0.01	0.02
	Rate of vegetation around the area	0.00	0.01	0.01	0.04	0.01
	Time frame for resource collection/ production	0.05	0.04	0.00	0.00	0.00
	Performance of natural drainage system	0.00	0.00	0.01	0.04	0.06
	Rate of possible resource quality improvement	0.08	0.02	0.00	0.00	0.00
	Access to alternative resource base	0.06	0.03	0.02	0.02	0.02
	Access to energy/fuel supply	0.04	0.01	0.02	0.00	0.05
Financial Capital	Homestead production	0.08	0.03	0.01	0.02	0.02
	Ownership on main production or income	0.05	0.04	0.02	0.03	0.09
	Scope of food storage (Yes/No)	0.04	0.00	0.02	0.00	0.00
	Rate of saving	0.04	0.01	0.02	0.03	0.08
	Reliability of saving system	0.03	0.02	0.01	0.02	0.05
	Access of women to economic activities	0.02	0.02	0.00	0.02	0.04
	Scope of alternative economic activities(Yes/No)	0.02	0.01	0.00	0.01	0.00
	Access to financial loan(Yes/No)	0.01	0.01	0.01	0.01	0.03
Human Capital	Portion of HH income earned from rest of the country	0.01	0.01	0.00	0.01	0.00
	Rate of education/literacy	0.02	0.03	0.01	0.03	0.02
	Knowledge on first aid	0.08	0.00	0.02	0.00	0.07
	Knowledge on storm surge risk	0.06	0.02	0.01	0.02	0.02
	Access to nearest district town (Yes/No)	0.03	0.02	0.01	0.03	0.02
	Access to doctor service (No. of doctor /	0.00	0.00	0.02	0.00	0.05
	HH Population having training on Surge protection	0.04	0.02	0.01	0.02	0.03
	Active population of HH	0.03	0.02	0.01	0.01	0.02
	Response to early warning system	0.03	0.01	0.01	0.01	0.02
Response to adaptation technology	0.02	0.01	0.01	0.01	0.02	
Physical / Infrastructural Capital	Rate of out migration of HH member	0.00	0.01	0.00	0.01	0.00
	Safe housing infrastructure/ condition	0.11	0.04	0.03	0.04	0.09
	Performance of hospital /Health center	0.00	0.00	0.01	0.00	0.04
	Performance of/access to cyclone shelter	0.05	0.03	0.01	0.03	0.04
	Availability of drinking water (Safe water)	0.04	0.00	0.01	0.00	0.03
	Sanitation facilities	0.03	0.00	0.01	0.00	0.02
	Access of Radio/TV/ Cell phone	0.00	0.02	0.01	0.02	0.04
	Availability of paved road	0.02	0.01	0.00	0.01	0.00
	Transportation facilities	0.06	0.01	0.01	0.02	0.02
	Average area with protection structure	0.00	0.01	0.00	0.01	0.01
Social Capital	Fitness of protection structure	0.00	0.01	0.01	0.02	0.00
	Performance of weather forecasting	0.10	0.00	0.03	0.03	0.04
	Community participation practice	0.08	0.02	0.02	0.02	0.07
	Activeness of local GO	0.04	0.05	0.01	0.02	0.04
	Interrelationship with NGO	0.02	0.02	0.01	0.02	0.03
	Performance social law and regulation	0.00	0.00	0.01	0.01	0.03
	Political influence on social group/	0.02	0.02	0.00	0.01	0.00
	Performance of local disaster management committee	0.03	0.01	0.01	0.01	0.02
Activeness of social organization of livelihood groups	0.02	0.02	0.01	0.01	0.01	
Awareness program on protection measure (No/Y)	0.02	0.02	0.01	0.02	0.05	

## Appendix-D

### Model Application and Coastal Livelihood Security Calculation

#### 1.1. a. Livelihood security assessment in a coastal site of Cox's bazaar district. (Farmer group)\*

Capital	Indicator	Unit	I <sub>1</sub>	I <sub>2</sub>	I <sub>3</sub> (%)	Security				
						Food	Income	Health	House	Water
Natural	Frequency of Storm surge (Irregular/regular)	Binary	1	0	-100	---	---	---	---	---
	Storm surge Period (Low tide/ high tide)	Binary	1	0	-100	---	---	---	---	---
	Surge height from mean sea level	Binary	1	0	-100	---	---	---	---	---
	Duration of storm surge (Short term/ long term)	Binary	1	0	-100	---	---	---	---	---
	Rate of vegetation around the area	%	25	15	-25	0.00	-	-	-	-
	Time frame for resource collection/ production	Months	12	8	-20	-	-	0.00	0.00	0.00
	Performance of natural drainage system	%	80	55	-18.52	0.00	0.00	-	-	-
	Rate of possible resource quality improvement	%	50	60	9.09	+	+	0.00	0.00	0.00
	Access to alternative resource base	No.	3	6	33.33	++	++	++	++	++
	Access to energy/fuel supply	%	90	70	-12.50	-	-	-	0.00	-
Financial	Homestead production	% of TI	40	40	0.00	+	+	+	+	+
	Ownership on main production or income	%	75	75	0.00	+	+	+	+	+
	Scope of food storage (Yes/No)	Binary	1	1	0.00	+	0.00	+	0.00	0.00
	Rate of saving	% of TI	25	25	0.00	+	+	+	+	+
	Reliability of saving system	Binary	1	1	0.00	+	+	+	+	+
	Access of women to economic activities	%	50	60	9.09	+	+	0.00	+	+
	Scope of alternative economic activities(Yes/No)	Binary	1	1	0.00	+	+	0.00	+	0.00
	Access to financial loan(Yes/No)	Binary	1	1	0.00	+	+	+	+	+
	Portion of HH income earned from rest of the country	%	20	15	-14.29	-	-	0.00	-	0.00
Human	Rate of education/literacy	%	80	52	-21.21	-	-	-	-	-
	Knowledge on first aid	%	70	46.22	-20.46	-	0.00	-	0.00	-
	Knowledge on storm surge risk	%	80	66.9	-8.92	-	-	-	-	-
	Access to nearest district town (Yes/No)	Binary	1	1	0.00	+	+	+	+	+
	Access to doctor service (No. of doctor / 50Household)	No.	2	2	0.00	0.00	0.00	+	0.00	+
	HH Population having training on Surge protection	%	50	30	-25.00	-	-	-	-	-
	Active population of HH	%	50	52	1.96	+	+	+	+	+
	Response to early warning system	%	65	63	-1.56	-	-	-	-	-
	Response to adaptation technology	%	75	75	0.00	+	+	+	+	+
	Rate of out migration of HH member	%	10	10	0.00	0.00	+	0.00	+	0.00
Physical/infrastructural	Safe housing infrastructure/ condition	%	60	40	-20.00	-	-	-	-	-
	Performance of hospital / health center	Scale	3	2	-20.00	0.00	0.00	-	0.00	-
	Performance of/access to cyclone shelter	%	90	70	-12.50	-	-	-	-	-
	Availability of drinking water (Safe water)	%	90	45	-33.33	--	0.00	--	0.00	--
	Sanitation facilities	%	90	55	-24.14	-	0.00	-	0.00	-
	Access of Radio/TV/ Cell phone	%	75	80	3.23	0.00	+	+	+	+
	Availability of paved road	%	60	60	0.00	+	+	0.00	+	0.00
	Transportation facilities	%	60	60	0.00	+	+	+	+	+
	Average area with protection structure	%	80	50	-23.08	0.00	-	0.00	-	-
	Fitness of protection structure	%	80	60	-14.29	0.00	-	-	-	0.00
Performance of weather forecasting	Scale	3	2	-20.00	-	0.00	-	-	-	

Community participation practice	%	80	75	+3.23	+	-	-	+	+
Activeness of local CO	Scale	2	2	0.00	+	+	+	+	+
Interrelationship with NGO	Scale	2	2	0.00	+	+	+	+	+
Performance social law and regulation	Scale	2	2	0.00	0.00	0.00	+	+	+
Political influence on social group/ committee(Yes/No)	Binary	1	1	0.00	-	-	0.00	-	0.00
Performance of local disaster management committee	Scale	2	2	0.00	+	+	+	+	+
Activeness of social organization of livelihood groups	%	80	60	-14.29	-	-	-	-	-
Awareness program on protection measure	No.	2	2	0.00	+	+	+	+	+

HH- Household, NH-Normal tidal height, TI- Total household income, LT- Low tide, HT High tide, TP-Total household size, Scale – 1 (low), 2 (moderate), 3(high).

\* By using 1st and 2<sup>nd</sup> Steps of the Livelihood Security Model, (equation 1 and Scoring)

$$|L_d| = \{(I_p - I_s) / (I_p + I_s)\} * 100 \text{ ----- 1.}$$

### 1.1. b. Livelihood security of Farmer in Cox's bazaar during storm surge hazard\*

Parameter	Food Security j=1	Income Security j=2	Health Security j=3	House Security j=4	Water Security j=5	$\sum SI_j$	SI
$\sum X$	20	21	18	21	18		
Y	28	26	29	25	28		
M	48	47	47	46	46		
$SI_j$	41.66666667	44.68085106	38.29787234	45.65217391	39.13043478	209.428	41.8856

By using 3<sup>rd</sup> step of the Livelihood Security Model, (equation 2 and 3)

$$SI_j = \left( \frac{\sum_{i=1}^n X_{ij}}{M_j} \right) * 100 \text{ ----- 2.}$$

$$SI = \sum_{j=1}^N SI_j / N \text{ ----- 3.}$$

Following the same calculation another results have been given below:

## 1.2. a. Livelihood security assessment in a coastal site of Cox's bazaar district. (Fisher group)

Capita	Indicator	Unit	I <sub>1</sub>	I <sub>p</sub>	I <sub>d</sub>	Security				
						Food	Income	Health	House	Water
Natural	Frequency of Storm surge (Irregular/regular)	Binary	1	0	-100.0	---	---	---	---	---
	Storm surge Period (Low tide/ high tide)	Binary	1	0	-100.0	---	---	---	---	---
	Surge height from mean sea level	Binary	1	0	-100.0	---	---	---	---	---
	Duration of storm surge (Short term/ long)	Binary	1	0	-100.0	---	---	---	---	---
	Rate of vegetation around the area	%	25	15	-25.0	0.00	-	-	-	-
	Time frame for resource collection/ production	Months	12	10	+9.1	-	-	0.00	0.00	0.00
	Performance of natural drainage system	%	80	55	-18.5	0.00	0.00	-	-	-
	Rate of possible resource quality improvement	%	50	80	23.1	+	+	0.00	0.00	0.00
	Access to alternative resource base	No.	3	6	33.3	++	++	++	++	++
	Access to energy/fuel supply	%	90	50	-28.6	-	-	-	0.00	-
Financial	Homestead production	% of TI	40	12	-53.8	-	-	-	-	-
	Ownership on main production or income	%	75	50	-20.0	-	-	-	-	-
	Scope of food storage (Yes/No)	Binary	1	1	0.0	+	0.00	+	0.00	0.00
	Rate of saving	% of TI	25	30	9.1	+	+	+	+	+
	Reliability of saving system	Binary	1	1	0.0	+	+	+	+	+
	Access of women to economic activities	%	50	40	-11.1	-	-	0.00	+	+
	Scope of alternative economic	Binary	1	1	0.0	+	+	0.00	+	0.00
	Access to financial loan(Yes/No)	Binary	1	1	0.0	+	+	+	+	+
Human	Portion of HH income earned from rest of the	%	20	12	-25.0	-	-	0.00	-	0.00
	Rate of education/literacy	%	80	46	-27.0	-	-	-	-	-
	Knowledge on first aid	%	70	30	-40.0	--	0.00	--	0.00	--
	Knowledge on storm surge risk	%	80	82	1.2	+	+	+	+	+
	Access to nearest district town (Yes/No)	Binary	1	1	0.0	+	+	+	+	+
	Access to doctor service (No. of doctor /	No.	2	2	0.0	0.00	0.00	+	0.00	+
	HH Population having training on Surge	%	50	43	-7.5	-	-	-	-	-
	Active population of HH	%	50	46	-4.2	-	-	-	-	-
	Response to early warning system	%	65	67	1.5	+	+	+	+	+
	Response to adaptation technology	%	75	76	0.7	+	+	+	+	+
Physical	Rate of out migration of HH member	%	10	11	4.8	0.00	+	0.00	+	0.00
	Safe housing infrastructure/ condition	%	60	39	-21.2	-	-	-	-	-
	Performance of hospital /Health center	Scale	3	2	-20.0	0.00	0.00	-	0.00	-
	Performance of access to cyclone shelter	%	90	70	-12.5	-	-	-	-	-
	Availability of drinking water (Safe water)	%	90	48	-30.4	-	0.00	-	0.00	-
	Sanitation facilities	%	90	61	-19.2	-	0.00	-	0.00	-
	Access of Radio/TV/ Cell phone	%	75	65	-7.1	0.00	-	-	-	-
	Availability of paved road	%	60	60	0.0	+	+	0.00	+	0.00
	Transportation facilities	%	60	60	0.0	+	+	+	+	+
	Average area with protection structure	%	80	50	-23.1	0.00	-	0.00	-	-
Social	Fitness of protection structure	%	80	60	-14.3	0.00	-	-	-	0.00
	Performance of weather forecasting	Scale	3	2	-20.0	-	0.00	-	-	-
	Community participation practice	%	80	80	0.0	+	+	+	+	+
	Activeness of local GO	Scale	2	2	0.0	+	+	+	+	+
	Interrelationship with NGO	Scale	2	2	0.0	+	+	+	+	+
	Performance social law and regulation	Scale	2	2	0.0	0.00	0.00	+	+	+
	Political influence on social group/	Binary	1	1	0.0	+	+	0.00	+	0.00
	Performance of local disaster management	Scale	2	2	0.0	+	+	+	+	+
Activeness of social organization of livelihood	%	80	80	0.0	+	+	+	+	+	
Awareness program on protection measure	No.	2	2	0.0	+	+	+	+	+	

HH- Household, NH-Normal tidal height, TI- Total household income, LT- Low tide, HT High tide, TP-Total household size, Scale – 1 (low), 2 (moderate), 3 (high).

### 1.2.b. Livelihood security of Fisher in Cox's bazaar during storm surge hazard

Paraméter	Food Security j=1	Income Security j=2	Health Security j=3	House Security j=4	Water Security j=5	$\sum SI_j$	SI (%)
$\sum X$	21	21	19	21	18		
Y	30	28	32	28	33		
M	51	49	51	49	51		
$SI_j$	41.1764706	42.85714	37.254902	42.85714	35.2941176	199.439776	39.89

## 1.3. a. Livelihood security assessment in a coastal site of Cox's bazaar district. (Fry collector)

Capit	Indicator	Unit	I <sub>1</sub>	I <sub>p</sub>	I <sub>2</sub> (%)	Security				
						Food	Incom e	Health	House	Water
Natural	Frequency of Storm surge (Irregular/regular)	Binary	1	0	-100.0	---	---	---	---	---
	Storm surge Period (Low tide/ high tide)	Binary	1	0	+100.0	---	---	---	---	---
	Surge height from mean sea level	Binary	1	0	-100.0	---	---	---	---	---
	Duration of storm surge (Short term/ long	Binary	1	0	-100.0	---	---	---	---	---
	Rate of vegetation around the area	%	25	15	-25.0	0	-	-	-	-
	Time frame for resource collection/ production	Months	12	7	-26.3	-	-	0	0	0
	Performance of natural drainage system	%	80	55	-18.5	0	0	-	-	-
	Rate of possible resource quality improvement	%	50	75	20.0	+	+	0	0	0
	Access to alternative resource base	No.	3	5	25.0	++	++	++	++	++
Access to energy/fuel supply	%	90	60	-20.0	-	-	-	0	-	
Financial	Homestead production	% of TI	40	15	-45.5	--	--	--	--	--
	Ownership on main production or income	%	75	60	-11.1	-	-	-	-	-
	Scope of food storage (Yes/No)	Binary	1	0	-100.0	---	0	---	0	0
	Rate of saving	% of TI	25	6	-57.9	+	+	+	+	+
	Reliability of saving system	Binary	1	0	-100.0	+	+	+	+	+
	Access of women to economic activities	%	50	75	20.0	+	+	0	+	+
	Scope of alternative economic	Binary	1	1	0.0	+	+	0	+	0
	Access to financial loan(Yes/No)	Binary	1	0	-100.0	---	---	---	---	---
	Portion of HH income earned from rest of the	%	20	6	-53.8	--	--	0	--	0
Human	Rate of education/literacy	%	80	34	-40.4	-	-	-	-	-
	Knowledge on first aid	%	70	31	-38.6	--	0	--	0	--
	Knowledge on storm surge risk	%	80	66	-9.6	-	-	-	-	-
	Access to nearest district town (Yes/No)	Binary	1	1	0.0	+	+	+	+	+
	Access to doctor service (No. of doctor /	No.	2	2	0.0	0	0	+	0	+
	HH Population having training on Surge	%	50	17	-49.3	-	-	-	-	-
	Active population of HH	%	50	34	-19.0	-	-	-	-	-
	Response to early warning system	%	65	48	-15.9	-	-	-	-	-
	Response to adaptation technology	%	75	54	-16.3	-	-	-	-	-
Physical/	Rate of out migration of HH member	%	10	6	-25.0	0	-	0	-	0
	Safe housing infrastructure/ condition	%	60	31	-31.9	-	-	-	-	-
	Performance of hospital /Health center	Scale	3	2	-20.0	0	0	-	0	-
	Performance of/access to cyclone shelter	%	90	70	-12.5	-	-	-	-	-
	Availability of drinking water (Safe water)	%	90	26	-55.2	--	0	--	0	--
	Sanitation facilities	%	90	26	-55.2	--	0	--	0	--
	Access of Radio/TV/ Cell phone	%	75	48	-22.0	0	-	-	-	-
	Availability of paved road	%	60	60	0.0	+	+	0	+	0
	Transportation facilities	%	60	60	0.0	+	+	+	+	+
Social	Average area with protection structure	%	80	50	-23.1	0	-	0	-	-
	Fitness of protection structure	%	80	60	-14.3	0	-	-	-	0
	Performance of weather forecasting	Scale	3	2	-20.0	-	0	-	-	-
	Community participation practice	%	80	65	-16.3	-	-	-	-	-
	Activeness of local GO	Scale	2	2	0.0	+	+	+	+	+
	Interrelationship with NGO	Scale	2	1	-33.3	--	--	--	--	--
	Performance social law and regulation	Scale	2	1	-33.3	0	0	--	--	--
	Political influence on social group/	Binary	1	1	0.0	+	+	0	+	0
	Performance of local disaster management	Scale	2	2	0.0	+	+	+	+	+
Activeness of social organization of livelihood	%	80	50	-23.1	-	-	-	-	-	
Awareness program on protection measure	No.	2	2	0.0	+	+	+	+	+	



HH- Household, NH-Normal tidal height, TI- Total household income, LT- Low tide, HT High tide, TP-Total household size, Scale – 1 (low), 2 (moderate), 3 (high).

### 1.3.b. Livelihood security of Fry collector in Cox's bazaar during storm surge hazard

Parameter	Food Security j=1	Income Security j=2	Health Security j=3	House Security j=4	Water Security j=5	$\sum SI_j$	SI (%)
X	10	10	7	9	8		
	52	46	54	48	51		
	62	56	61	57	59		
	16.1290323	17.85714286	11.47541	15.78947368	13.55932203	74.810381	14.962

## 1.4. a. Livelihood security assessment in a coastal site of Cox's bazaar district. (Salt farmer)

Capital	Indicator	Unit	I <sub>s</sub>	I <sub>p</sub>	I <sub>d</sub> (%)	Security				
						Food	Income	Health	House	Water
Natural	Frequency of Storm surge	Binar	1	0	-100	---	---	---	---	---
	Storm surge Period (Low tide/ high tide)	Binar	1	0	-100	---	---	---	---	---
	Surge height from mean sea level	Binar	1	0	-100	---	---	---	---	---
	Duration of storm surge (Short term/ long	Binar	1	0	-100	---	---	---	---	---
	Rate of vegetation around the area	%	25	15	-25.0	0	-	-	-	-
	Time frame for resource collection/	Mont	12	6	-33.3	-	-	0	0	0
	Performance of natural drainage system	%	80	55	-18.5	0	0	-	-	-
	Rate of possible resource quality	%	50	75	20.0	+	+	0	0	0
	Access to alternative resource base	No.	3	4	14.3	++	++	++	++	++
	Access to energy/fuel supply	%	90	60	-20.0	-	-	-	0	-
Financial	Homestead production	% of	40	45	5.9	-	-	-	-	-
	Ownership on main production or income	%	75	60	-11.1	-	-	-	-	-
	Scope of food storage (Yes/No)	Binar	1	1	0.0	+	0	+	0	0
	Rate of saving	% of	25	20	-11.1	+	+	+	+	+
	Reliability of saving system	Binar	1	1	0.0	+	+	+	+	+
	Access of women to economic activities	%	50	30	-25.0	-	-	0	+	+
	Scope of alternative economic	Binar	1	1	0.0	+	+	0	+	0
	Access to financial loan(Yes/No)	Binar	1	1	0.0	+	+	+	+	+
Portion of HH income earned from rest of	%	20	32	23.1	-	-	0	-	0	
Human	Rate of education/literacy	%	80	44	-29.0	-	-	-	-	-
	Knowledge on first aid	%	70	43	-23.9	--	0	--	0	--
	Knowledge on storm surge risk	%	80	80	0.0	+	+	+	+	+
	Access to nearest district town (Yes/No)	Binar	1	1	0.0	+	+	+	+	+
	Access to doctor service (No. of doctor /	No.	2	2	0.0	0	0	+	0	+
	HH Population having training on Surge	%	50	47	-3.1	-	-	-	-	-
	Active population of HH	%	50	44	-6.4	-	-	-	-	-
	Response to early warning system	%	65	65	0.0	+	+	+	+	+
	Response to adaptation technology	%	75	80	3.2	+	+	+	+	+
Rate of out migration of HH member	%	10	12	9.1	0	+	0	+	0	
Physical	Safe housing infrastructure/ condition	%	60	62	1.6	-	-	-	-	-
	Performance of hospital /Health center	Scale	3	2	-20.0	0	0	-	0	-
	Performance of/access to cyclone shelter	%	90	70	-12.5	-	-	-	-	-
	Availability of drinking water (Safe water)	%	90	56	-23.3	-	0	-	0	-
	Sanitation facilities	%	90	67	-14.6	-	0	-	0	-
	Access of Radio/TV/ Cell phone	%	75	75	0.0	0	-	-	-	-
	Availability of paved road	%	60	60	0.0	+	+	0	+	0
	Transportation facilities	%	60	60	0.0	+	+	+	+	+
	Average area with protection structure	%	80	50	-23.1	0	-	0	-	-
	Fitness of protection structure	%	80	60	-14.3	0	-	-	-	0
Social	Performance of weather forecasting	Scale	3	2	-20.0	-	0	-	-	-
	Community participation practice	%	80	85	3.0	+	+	+	+	+
	Activeness of local GO	Scale	2	2	0.0	+	+	+	+	+
	Interrelationship with NGO	Scale	2	2	0.0	+	+	+	+	+
	Performance social law and regulation	Scale	2	3	20.0	0	0	+	+	+
	Political influence on social group/	Binar	1	1	0.0	+	+	0	+	0
	Performance of local disaster management	Scale	2	2	0.0	+	+	+	+	+
	Activeness of social organization of	%	80	85	3.0	+	+	+	+	+
Awareness program on protection measure	No.	2	2	0.0	+	+	+	+	+	

### 1.4. b. Livelihood security of Salt Farmer in Cox's bazaar during storm surge hazard

Parameter	Food Security j=1	Income Security j=2	Health Security j=3	House Security j=4	Water Security j=5	$\sum SI_j$	SI (%)
$\sum X$	22	23	20	23	19		
Y	26	25	27	24	28		
M	48	48	47	47	47		
$SI_j$	45.833333	47.91666667	42.55319149	48.93617021	40.42553191	225.664894	45.132

## 1.5.a. Livelihood security assessment in a coastal site of Cox's bazaar district. (Dry fisher group)

Capital	Indicator	Unit	I <sub>s</sub>	I <sub>p</sub>	I <sub>d</sub> (%)	Security				
						Food	Income	Health	House	Water
Natural	Frequency of Storm surge (Irregular/regular)	Binary	1	0	-100.0	---	---	---	---	---
	Storm surge Period (Low tide/ high tide)	Binary	1	0	-100.0	---	---	---	---	---
	Surge height from mean sea level	Binary	1	0	-100.0	---	---	---	---	---
	Duration of storm surge (Short term/ long)	Binary	1	0	-100.0	---	---	---	---	---
	Rate of vegetation around the area	%	25	15	-20.0	0	-	-	-	-
	Time frame for resource collection/ production	Month	12	6	-33.3	-	-	0	0	0
	Performance of natural drainage system	%	80	55	-18.3	0	0	-	-	-
	Rate of possible resource quality improvement	%	50	80	23.1	+	+	0	0	0
	Access to alternative resource base	No.	3	3	25.0	++	++	++	++	++
Financial	Access to energy/fuel supply	%	90	60	-20.0	-	-	-	0	-
	Homestead production	% of	40	30	-14.3	-	-	-	-	-
	Ownership on main production or income	%	75	60	-11.1	-	-	-	-	-
	Scope of food storage (Yes/No)	Binary	1	1	0.0	+	0	+	0	0
	Rate of saving	% of	25	16.67	-20.0	+	+	+	+	+
	Reliability of saving system	Binary	1	1	0.0	+	+	+	+	+
	Access of women to economic activities	%	50	65	13.0	-	-	0	+	+
	Scope of alternative economic	Binary	1	1	0.0	+	+	0	+	0
	Access to financial loan(Yes/No)	Binary	1	1	0.0	+	+	+	+	+
Human	Portion of HH income earned from rest of the	%	20	19	-2.6	-	-	0	-	0
	Rate of education/literacy	%	80	52	-21.2	-	-	-	-	-
	Knowledge on first aid	%	70	22	-52.2	--	0	--	0	--
	Knowledge on storm surge risk	%	80	67.97	-4.1	+	+	+	+	+
	Access to nearest district town (Yes/No)	Binary	1	1	0.0	+	+	+	+	+
	Access to doctor service (No. of doctor /	No.	2	2	0.0	0	0	+	0	+
	HH Population having training on Surge	%	50	41	-9.9	-	-	-	-	-
	Active population of HH	%	50	52	2.0	-	-	-	-	-
	Response to early warning system	%	65	64	2.3	+	+	+	+	+
Physical	Response to adaptation technology	%	75	77	1.3	+	+	+	+	+
	Rate of out migration of HH member	%	10	9	-5.3	0	+	0	+	0
	Safe housing infrastructure/ condition	%	60	41	-18.8	-	-	-	-	-
	Performance of hospital /Health center	Scale	3	2	-20.0	0	0	-	0	-
	Performance of access to cyclone shelter	%	90	70	-12.5	-	-	-	-	-
	Availability of drinking water (Safe water)	%	90	41	-37.4	-	0	-	0	-
	Sanitation facilities	%	90	38	-40.6	-	0	-	0	-
	Access of Radio/TV/ Cell phone	%	75	56	-14.5	0	-	-	-	-
	Availability of paved road	%	60	60	0.0	+	+	0	+	0
Social	Transportation facilities	%	60	60	0.0	+	+	+	+	+
	Average area with protection structure	%	80	50	-23.1	0	-	0	-	-
	Fitness of protection structure	%	80	60	-14.3	0	-	-	-	0
	Performance of weather forecasting	Scale	3	2	-20.0	-	0	-	-	-
	Community participation practice	%	80	80	0.0	+	+	+	+	+
	Activeness of local GO	Scale	2	2	0.0	+	+	+	+	+
	Interrelationship with NGO	Scale	2	2	0.0	+	+	+	+	+
	Performance social law and regulation	Scale	2	3	20.0	0	0	+	+	+
	Political influence on social group/	Binary	1	1	0.0	+	+	0	+	0
Social	Performance of local disaster management	Scale	2	2	0.0	+	+	+	+	+
	Activeness of social organization of livelihood	%	80	80	0.0	+	+	+	+	+
	Awareness program on protection measure	No.	2	2	0.0	+	+	+	+	+

### 1.5. b. Livelihood security of dry fisher in Cox's bazaar during storm surge hazard

Parameter	Food Security j=1	Income Security j=2	Health Security j=3	House Security j=4	Water Security j=5	$\sum SI_j$	SI (%)
$\sum X$	20	19	17	19	17		
Y	29	29	31	28	32		
M	49	48	48	47	49		
$SI_j$	40.816327	39.58333333	35.41666667	40.42553191	34.69387755	190.935736	38.187

## 1.6. a. Livelihood security assessment in a coastal site of Cox's bazaar district. (Wage laborer)

Capital	Indicator	Unit	I <sub>1</sub>	I <sub>p</sub>	I <sub>0</sub> (%) †	Security				
						Food	Inco me	Heal th	House	Water
Natural	Frequency of Storm surge (Irregular/regular)	Binary	1	0	-100.0	---	---	---	---	---
	Storm surge Period (Low tide/ high tide)	Binary	1	0	-100.0	---	---	---	---	---
	Surge height from mean sea level	Binary	1	0	-100.0	---	---	---	---	---
	Duration of storm surge (Short term/ long)	Binary	1	0	-100.0	---	---	---	---	---
	Rate of vegetation around the area	%	25	13	-23.0	0	-	-	-	-
	Time frame for resource collection/ production	Month	12	12	0.0	+	+	0	0	0
	Performance of natural drainage system	%	80	55	-18.5	0	0	-	-	-
	Rate of possible resource quality improvement	%	50	50	0.0	+	+	0	0	0
	Access to alternative resource base	No.	3	2	-20.0	-	-	-	-	-
Financial	Access to energy/fuel supply	%	90	60	-20.0	-	-	-	0	-
	Homestead production	% of	40	25	-23.1	-	-	-	-	-
	Ownership on main production or income	%	75	18	-61.3	--	--	--	--	--
	Scope of food storage (Yes/No)	Binary	1	0	-100.0	---	0	+	0	0
	Rate of saving	% of	25	8	-51.5	+	+	+	+	+
	Reliability of saving system	Binary	1	0	-100.0	+	+	+	+	+
	Access of women to economic activities	%	50	45	-5.3	-	-	0	+	+
	Scope of alternative economic	Binary	1	1	0.0	+	+	0	+	0
	Access to financial loan(Yes/No)	Binary	1	1	0.0	+	+	+	+	+
Human	Portion of HH income earned from rest of the	%	20	3	-73.9	-	-	0	-	0
	Rate of education/literacy	%	80	25	-52.4	-	-	-	-	-
	Knowledge on first aid	%	70	18	-59.1	--	0	--	0	--
	Knowledge on storm surge risk	%	80	43	-30.1	+	+	+	+	+
	Access to nearest district town (Yes/No)	Binary	1	1	0.0	+	+	+	+	+
	Access to doctor service (No. of doctor /	No.	2	2	0.0	0	0	+	0	+
	HH Population having training on Surge	%	50	24	-35.1	-	-	-	-	-
	Active population of HH	%	50	25	-33.3	-	-	-	-	-
	Response to early warning system	%	65	50	-13.0	+	+	+	+	+
Physical	Response to adaptation technology	%	75	38	-32.7	+	+	+	+	+
	Rate of out migration of HH member	%	10	6	-25.0	0	+	0	+	0
	Safe housing infrastructure/ condition	%	60	14.89	-60.2	-	-	-	-	-
	Performance of hospital /Health center	Scale	3	2	-20.0	0	0	-	0	-
	Performance of/access to cyclone shelter	%	90	60	-20.0	-	-	-	-	-
	Availability of drinking water (Safe water)	%	90	35	-44.0	-	0	-	0	-
	Sanitation facilities	%	90	35	-44.0	-	0	-	0	-
	Access of Radio/TV/ Cell phone	%	75	38	-32.7	0	-	-	-	-
	Availability of paved road	%	60	60	0.0	+	+	0	+	0
Social	Transportation facilities	%	60	60	0.0	+	+	+	+	+
	Average area with protection structure	%	80	50	-23.1	0	-	0	-	-
	Fitness of protection structure	%	80	60	-14.3	0	-	-	-	0
	Performance of weather forecasting	Scale	3	1	-50.0	--	0	--	--	--
	Community participation practice	%	80	40	-33.3	--	--	--	--	--
	Activeness of local GO	Scale	2	2	0.0	+	+	+	+	+
	Interrelationship with NGO	Scale	2	2	0.0	+	+	+	+	+
	Performance social law and regulation	Scale	2	1	-33.3	0	0	+	+	+
	Political influence on social group/	Binary	1	1	0.0	+	+	0	+	0
Performance of local disaster management	Scale	2	2	0.0	+	+	+	+	+	
Activeness of social organization of livelihood	%	80	45	-28.0	-	-	-	-	-	
Awareness program on protection measure	No.	2	2	0.0	+	+	+	+	+	

**1.6. b. Livelihood security of Wage laborer in Cox's bazaar during storm surge hazard**

Parameter	Food Security j=1	Income Security j=2	Health Security j=3	House Security j=4	Water Security j=5	$\sum SI_j$	SI (%)
$\sum X$	12	12	8	10	8		
Y	50	40	50	43	48		
$\mu$	62	52	58	53	56		
$SI_j$	19.354839	23.07692308	13.79310345	18.86792453	14.28571429	89.378504	17.875

## 2.1. a. Livelihood security assessment in a coastal site of Satkhira district. (Farmer group)

Capital	Indicator	Unit	I <sub>0</sub>	I <sub>p</sub>	I <sub>d</sub>	Security				
						Food	Incom e	Heal th	House	Water
Natural	Frequency of Storm surge (Irregular/regular)	Binary	1	0	-100.0	---	---	---	---	---
	Storm surge Period (Low tide/ high tide)	Binary	1	0	-100.0	---	---	---	---	---
	Surge height from mean sea level	Binary	1	0	-100.0	---	---	---	---	---
	Duration of storm surge (Short term/ long term)	Binary	1	0	-100.0	---	---	---	---	---
	Rate of vegetation around the area	%	25	18	-16.3	0	-	-	-	-
	Time frame for resource collection/ production	Month	12	8	-20.0	-	-	0	0	0
	Performance of natural drainage system	%	80	40	-33.3	0	0	-	-	-
	Rate of possible resource quality improvement	%	50	60	9.1	+	+	0	0	0
	Access to alternative resource base	No.	3	6	33.3	++	++	++	++	++
Access to energy/fuel supply	%	90	60	-20.0	-	-	-	0	-	
Financial	Homestead production	% of	40	40	0.0	+	+	+	+	+
	Ownership on main production or income	%	75	70	-3.4					
	Scope of food storage (Yes/No)	Binary	1	1	0.0	+	0	+	0	0
	Rate of saving	% of	25	25	0.0	+	+	+	+	+
	Reliability of saving system	Binary	1	1	0.0	+	+	+	+	+
	Access of women to economic activities	%	50	50	0.0	+	+	0	+	+
	Scope of alternative economic activities(Yes/No)	Binary	1	1	0.0	+	+	0	+	0
	Access to financial loan(Yes/No)	Binary	1	1	0.0	+	+	+	+	+
	Portion of HH income earned from rest of the	%	20	18.65	-3.3	-	-	0	-	0
Human	Rate of education/literacy	%	80	48	-25.0	-	-	-	-	-
	Knowledge on first aid	%	70	29.1	-41.3	--	0	--	0	--
	Knowledge on storm surge risk	%	80	52	-21.2	-	-	-	-	-
	Access to nearest district town (Yes/No)	Binary	1	0	-100.0	---	---	---	---	---
	Access to doctor service (No. of doctor /	No.	2	1	-33.3	0	0	--	0	--
	HH Population having training on Surge protection	%	50	25	-33.3	--	--	--	--	--
	Active population of HH	%	50	60	9.1	+	+	+	+	+
	Response to early warning system	%	65	55	-4.3	-	-	-	-	-
	Response to adaptation technology	%	75	62	-9.5	-	-	-	-	-
Rate of out migration of HH member	%	10	10	0.0	0	+	0	+	0	
Physical	Safe housing infrastructure/ condition	%	60	46	-13.2	-	-	-	-	-
	Performance of hospital /Health center	Scale	3	2	-20.0	0	0	-	0	-
	Performance of/access to cyclone shelter	%	90	60	-20.0	-	-	-	-	-
	Availability of drinking water (Safe water)	%	90	48	-20.4	-	0	-	0	-
	Sanitation facilities	%	90	48	-20.4	-	0	-	0	-
	Access of Radio/TV/ Cell phone	%	75	78	2.0	0	+	+	+	+
	Availability of paved road	%	60	65	4.0	+	+	0	+	0
	Transportation facilities	%	60	60	0.0	+	+	+	+	+
	Average area with protection structure	%	80	35	-39.1	0	--	0	--	--
Social	Fitness of protection structure	%	80	40	-33.3	0	--	--	--	0
	Performance of weather forecasting	Scale	3	1	-50.0	--	0	--	--	--
	Community participation practice	%	80	65	-10.3	-	-	-	-	-
	Activeness of local GO	Scale	2	1	-33.3	--	--	--	--	--
	Interrelationship with NGO	Scale	2	2	0.0	+	+	+	+	+
	Performance social law and regulation	Scale	2	1	-33.3	0	0	-	-	-
	Political influence on social group/	Binary	1	1	0.0	+	+	0	-	0
	Performance of local disaster management	Scale	2	1	-33.3	--	--	--	--	--
	Activeness of social organization of livelihood	%	80	50	-23.1	-	-	-	-	-
Awareness program on protection measure	No.	2	1	-33.3	-	-	-	-	-	



### 2.1. b. Livelihood security of Wage labor in Satkhira during storm surge hazard

Parameter	Food Security j=1	Income Security j=2	Health Security j=3	House Security j=4	Water Security j=5	$\sum SI_j$	SI (%)
$\sum X$	17	19	16	19	16		
Y	33	32	36	33	35		
M	50	51	52	52	51		
$SI_j$	34	37.25490	30.76923077	36.53846154	31.37254902	169.94	33.987

## 2.2. a. Livelihood security assessment in a coastal site of Satkhira district. (Fisher group)

	Indicator	Unit	I <sub>a</sub>	I <sub>p</sub>	I <sub>d</sub> (%)	Security				
						Food	Income	Health	House	Water
Natural	Frequency of Storm surge (Irregular/regular)	Binar	1	0	-100.0	---	---	---	---	---
	Storm surge Period (Low tide/ high tide)	Binar	1	0	-100.0	---	---	---	---	---
	Surge height from mean sea level	Binar	1	0	-100.0	---	---	---	---	---
	Duration of storm surge (Short term/ long)	Binar	1	0	-100.0	---	---	---	---	---
	Rate of vegetation around the area	%	25	18	-16.3	0	-	-	-	-
	Time frame for resource collection/	Month	12	12	0.0	+	+	0	0	0
	Performance of natural drainage system	%	80	40	-33.3	0	0	--	--	--
	Rate of possible resource quality	%	50	80	23.1	+	+	0	0	0
	Access to alternative resource base	No.	3	6	33.3	++	++	++	++	++
	Access to energy/fuel supply	%	90	70	-12.5	-	-	-	0	-
Financial	Homestead production	% of	40	22	-29.0	-	-	-	-	-
	Ownership on main production or income	%	75	70	-3.4	-	-	-	-	-
	Scope of food storage (Yes/No)	Binar	1	0	-100.0	---	0	---	0	0
	Rate of saving	% of	25	10	-42.9	--	--	--	--	--
	Reliability of saving system	Binar	1	0	-100.0	---	---	---	---	---
	Access of women to economic activities	%	50	42	-8.7	-	-	0	-	-
	Scope of alternative economic	Binar	1	1	0.0	+	+	0	+	0
	Access to financial loan(Yes/No)	Binar	1	1	0.0	+	+	+	+	+
	Portion of HH income earned from rest of the	%	20	6	-53.8	--	--	0	--	0
	Human	Rate of education/literacy	%	80	39	-34.5	--	--	--	--
Knowledge on first aid		%	70	42	-25.0	-	0	-	0	--
Knowledge on storm surge risk		%	80	63	-11.9	+	+	+	+	+
Access to nearest district town (Yes/No)		Binar	1	0	-100.0	---	---	---	---	---
Access to doctor service (No. of doctor /		No.	2	2	0.0	0	0	+	0	+
HH Population having training on Surge		%	50	38	-13.6	-	-	-	-	-
Active population of HH		%	50	65	13.0	-	-	-	-	-
Response to early warning system		%	65	65	0.0	+	+	+	+	+
Response to adaptation technology		%	75	46	-24.0	-	-	-	-	-
Rate of out migration of HH member		%	10	8	-11.1	0	-	0	-	0
Physical/ Infrastructural	Safe housing infrastructure/ condition	%	60	32	-30.4	-	-	-	-	-
	Performance of hospital /Health center	Scale	3	2	-20.0	0	0	-	0	-
	Performance of access to cyclone shelter	%	90	60	-20.0	-	-	-	-	-
	Availability of drinking water (Safe water)	%	90	35	-44.0	--	0	--	0	--
	Sanitation facilities	%	90	32	-47.5	--	0	--	0	--
	Access of Radio/TV/ Cell phone	%	75	35	-33.7	0	-	-	-	-
	Availability of paved road	%	60	65	4.0	+	+	0	+	0
	Transportation facilities	%	60	67	5.5	+	+	+	+	+
	Average area with protection structure	%	80	35	-39.1	0	-	0	-	-
	Fitness of protection structure	%	80	40	-33.3	0	-	-	-	0
Social	Performance of weather forecasting	Scale	3	1	-50.0	-	0	-	-	-
	Community participation practice	%	80	60	-14.3	-	-	-	-	-
	Activeness of local GO	Scale	2	1	-33.3	-	-	-	-	-
	Interrelationship with NGO	Scale	2	2	0.0	+	+	+	+	+
	Performance social law and regulation	Scale	2	1	-33.3	0	0	+	+	+
	Political influence on social group/	Binar	1	1	0.0	+	+	0	+	0
	Performance of local disaster management	Scale	2	1	-33.3	-	-	-	-	-
	Activeness of social organization of	%	80	60	-14.3	-	-	-	-	-
Awareness program on protection measure	No.	2	2	0.0	+	+	+	+	+	

### 2.2. b. Livelihood security of Fisher in Satkhira during storm surge hazard

Parameter	Food Security j=1	Income Security j=2	Health Security j=3	House Security j=4	Water Security j=5	$\sum SI_j$	SI (%)
$\sum X$	15	15	10	14	10		
Y	40	38	45	38	40		
IM	55	53	55	52	50		
$SI_j$	27.27273	28.30188679	18.18181818	26.92307692	20	120.68	24.136

## 2.3. a. Livelihood security assessment in a coastal site of Satkhira district. (Fry collector group)

Capital	Indicator	Unit	I <sub>a</sub>	I <sub>p</sub>	I <sub>d</sub> (%)	Security				
						Food	Income	Health	House	Water
Natural	Frequency of Storm surge (Irregular/regular)	Binary	1	0	-100.0	---	---	---	---	---
	Storm surge Period (Low tide/ high tide)	Binary	1	0	-100.0	---	---	---	---	---
	Surge height from mean sea level	Binary	1	0	-100.0	---	---	---	---	---
	Duration of storm surge (Short term/ long)	Binary	1	0	-100.0	---	---	---	---	---
	Rate of vegetation around the area	%	25	18	-16.3	0	-	-	-	-
	Time frame for resource collection/	Months	12	7	-26.3	-	-	0	0	0
	Performance of natural drainage system	%	80	40	-33.3	0	0	--	--	--
	Rate of possible resource quality improvement	%	50	75	20.0	+	+	0	0	0
	Access to alternative resource base	No.	3	3	25.0	+	+	+	+	+
Access to energy/fuel supply	%	90	25	-56.5	--	--	--	0	--	
Financial	Homestead production	% of TI	40	15	-45.5	--	--	--	--	--
	Ownership on main production or income	%	75	60	-11.1	-	-	-	-	-
	Scope of food storage (Yes/No)	Binary	1	0	-100.0	---	0	---	0	0
	Rate of saving	% of TI	25	53.3	44.9	--	--	--	--	--
	Reliability of saving system	Binary	1	0	-100.0	---	---	---	---	---
	Access of women to economic activities	%	50	66	13.8	+	+	0	+	+
	Scope of alternative economic	Binary	1	1	0.0	+	+	0	+	0
	Access to financial loan(Yes/No)	Binary	1	1	0.0	+	+	+	+	+
	Portion of HH income earned from rest of the	%	20	2.75	-75.8	--	--	0	--	0
Human	Rate of education/literacy	%	80	31	-44.1	--	--	--	--	--
	Knowledge on first aid	%	70	36	-32.1	--	0	--	0	--
	Knowledge on storm surge risk	%	80	65	-10.3	-	-	-	-	-
	Access to nearest district town (Yes/No)	Binary	1	0	-100.0	---	---	---	---	---
	Access to doctor service (No. of doctor /	No.	2	1	-33.3	0	0	-	0	-
	HH Population having training on Surge	%	50	18	-47.1	-	-	-	-	-
	Active population of HH	%	50	31	-23.5	-	-	-	-	-
	Response to early warning system	%	65	42	-21.5	+	+	+	+	+
	Response to adaptation technology	%	75	47	-23.0	+	+	+	+	+
Rate of out migration of HH member	%	10	2.75	-56.9	0	+	0	+	0	
Physical	Safe housing infrastructure/ condition	%	60	22	-46.3	-	-	-	-	-
	Performance of hospital /Health center	Scale	3	2	-20.0	0	0	-	0	-
	Performance of/access to cyclone shelter	%	90	60	-20.0	-	-	-	-	-
	Availability of drinking water (Safe water)	%	90	24	-57.9	-	0	-	0	-
	Sanitation facilities	%	90	20	-63.6	-	0	-	0	-
	Access of Radio/TV/ Cell phone	%	75	30	-42.9	0	-	-	-	-
	Availability of paved road	%	60	65	4.0	+	+	0	+	0
	Transportation facilities	%	60	67	5.3	+	+	+	+	+
	Average area with protection structure	%	80	35	-39.1	0	-	0	-	-
Social	Fitness of protection structure	%	80	40	-33.3	0	-	-	-	0
	Performance of weather forecasting	Scale	3	1	-50.0	-	0	-	-	-
	Community participation practice	%	80	50	-23.1	-	-	-	-	-
	Activeness of local GO	Scale	2	1	-33.3	--	--	--	--	--
	Interrelationship with NGO	Scale	2	1	-33.3	--	--	--	--	--
	Performance social law and regulation	Scale	2	1	-33.3	0	0	--	--	--
	Political influence on social group/	Binary	1	0	-100.0	---	---	---	---	---
	Performance of local disaster management	Scale	2	1	-33.3	--	--	--	--	--
	Activeness of social organization of	%	80	55	-18.5	-	-	+	-	-
Awareness program on protection measure	No.	2	2	0.0	+	+	+	+	+	

### 2.3. b. Livelihood security of Fry collector in Satkhira during Storm surge hazard

Parameter	Food Security j=1	Income Security j=2	Health Security j=3	House Security j=4	Water Security j=5	$\sum SI_j$	SI (%)
$\sum X$	10	10	7	10	7		
Y	47	45	48	44	44		
M	57	55	55	54	51		
$SI_j$	17.54386	18.1818	12.7272	18.5185	13.7254	80.697	16.139

## 2.4. a. Livelihood security assessment in a coastal site of Satkhira district. (Forest extractor group)

Capital	Indicator	Unit	I <sub>a</sub>	I <sub>b</sub>	I <sub>c</sub>	Security				
						Food	Income	Health	House	Water
Natural	Frequency of Storm surge (Irregular/regular)	Binary	1	0	-100.0	---	---	---	---	---
	Storm surge Period (Low tide/ high tide)	Binary	1	0	-100.0	---	---	---	---	---
	Surge height from mean sea level	Binary	1	0	-100.0	---	---	---	---	---
	Duration of storm surge (Short term/ long term)	Binary	1	0	-100.0	---	---	---	---	---
	Rate of vegetation around the area	%	25	18	-16.3	0	-	-	-	-
	Time frame for resource collection/ production	Month	12	8	-20.0	-	-	0	0	0
	Performance of natural drainage system	%	80	40	-33.3	0	0	-	-	-
	Rate of possible resource quality improvement	%	50	30	-25.0	+	+	0	0	0
	Access to alternative resource base	No.	3	4	14.3	-	-	-	-	-
	Access to energy/fuel supply	%	90	35	-24.1	-	-	-	0	-
Financial	Homestead production	% of	40	40	0.0	+	+	+	+	+
	Ownership on main production or income	%	75	60	-11.1	-	-	-	-	-
	Scope of food storage (Yes/No)	Binary	1	1	0.0	+	0	+	0	0
	Rate of saving	% of	25	25	0.0	+	+	+	+	+
	Reliability of saving system	Binary	1	1	0.0	+	+	+	+	+
	Access of women to economic activities	%	50	20	-42.9	-	-	0	-	-
	Scope of alternative economic activities(Yes/No)	Binary	1	1	0.0	+	+	0	+	0
	Access to financial loan(Yes/No)	Binary	1	1	0.0	+	+	+	+	+
	Portion of HH income earned from rest of the	%	20	9.68	-34.8	-	-	0	-	0
	Rate of education/literacy	%	80	35	-39.1	--	--	--	--	--
Human	Knowledge on first aid	%	70	47	-19.1	-	0	-	0	-
	Knowledge on storm surge risk	%	80	72	-5.3	-	-	-	-	-
	Access to nearest district town (Yes/No)	Binary	1	0	-100.0	-	-	-	-	-
	Access to doctor service (No. of doctor /	No.	2	1	-33.3	0	0	+	0	+
	HH Population having training on Surge protection	%	50	56	5.7	+	+	+	+	+
	Active population of HH	%	50	35	-17.6	-	-	-	-	-
	Response to early warning system	%	65	67	1.5	+	+	+	+	+
	Response to adaptation technology	%	75	64	-7.9	-	-	-	-	-
	Rate of out migration of HH member	%	10	8	-11.1	0	-	0	-	0
	Safe housing infrastructure/ condition	%	60	48	-11.1	-	-	-	-	-
Physical	Performance of hospital /Health center	Scale	3	2	-20.0	0	0	-	0	-
	Performance of/access to cyclone shelter	%	90	60	-20.0	-	-	-	-	-
	Availability of drinking water (Safe water)	%	90	35	-44.0	-	0	-	0	--
	Sanitation facilities	%	90	38	-40.6	-	0	--	0	-
	Access of Radio/TV/ Cell phone	%	75	30	-42.9	0	--	-	--	-
	Availability of paved road	%	60	65	4.0	+	+	0	+	0
	Transportation facilities	%	60	65	4.3	+	+	+	+	+
	Average area with protection structure	%	80	35	-39.1	0	--	0	--	--
	Fitness of protection structure	%	80	40	-33.3	0	--	--	--	0
	Performance of weather forecasting	Scale	3	3	0.0	+	0	-	+	+
Social	Community participation practice	%	80	60	-14.3	-	-	-	-	-
	Activeness of local GO	Scale	2	1	-33.3	-	-	-	-	-
	Interrelationship with NGO	Scale	2	1	-33.3	-	-	-	-	-
	Performance social law and regulation	Scale	2	3	20.0	0	0	+	+	+
	Political Influence on social group/	Binary	1	1	0.0	+	+	0	+	0
	Performance of local disaster management	Scale	2	1	-33.3	-	-	-	-	-
	Activeness of social organization of livelihood	%	80	70	-6.7	+	-	+	+	-
	Awareness program on protection measure	No.	2	2	0.0	+	+	+	+	+

#### 2.4. b. Livelihood security of Forest extractor in Satkhira during storm surge hazard

Parameter	Food Security j=1	Income Security j=2	Health Security j=3	House Security j=4	Water Security j=5	$\sum SI_j$	SI (%)
$\sum X$	14	14	13	16	12		
Y	38	40	45	39	44		
M	52	54	58	55	56		
$SI_j$	26.923	25.9259	22.4137	29.0909	21.428	125.78	25.956

## 2.5. a. Livelihood security assessment in a coastal site of Satkhira district. (Wage labor)

Capital	Indicator	Unit	I <sub>s</sub>	I <sub>p</sub>	I <sub>d</sub>	Security				
						Food	Income	Health	House	Water
Natural	Frequency of Storm surge (Irregular/regular)	Binary	1	0	-100.0	---	---	---	---	---
	Storm surge Period (Low tide/ high tide)	Binary	1	0	-100.0	---	---	---	---	---
	Surge height from mean sea level	Binary	1	0	-100.0	---	---	---	---	---
	Duration of storm surge (Short term/ long term)	Binary	1	0	-100.0	---	---	---	---	---
	Rate of vegetation around the area	%	25	18	-16.3		-	-	-	-
	Time frame for resource collection/ production	Month	12	12	0.0	+	+			
	Performance of natural drainage system	%	80	40	-33.3			--	--	--
	Rate of possible resource quality improvement	%	50	50	0.0	+	+			
	Access to alternative resource base	No.	3	2	-20.0	-	-	-	-	-
	Access to energy/fuel supply	%	90	52	-26.8	-	-	-	-	-
Financial	Homestead production	% of	40	22	-29.0	-	-	-	-	-
	Ownership on main production or income	%	75	20	-57.9	--	--	--	--	--
	Scope of food storage (Yes/No)	Binary	1	0	-100.0	---	---	---	---	---
	Rate of saving	% of	25	0	-100.0	---	---	---	---	---
	Reliability of saving system	Binary	1	0	-100.0	---	---	---	---	---
	Access of women to economic activities	%	50	55	4.8	+	+		+	+
	Scope of alternative economic activities(Yes/No)	Binary	1	1	0.0	+	+		+	
	Access to financial loan(Yes/No)	Binary	1	0	-100.0	---	---	---	---	---
	Portion of HH income earned from rest of the	%	20	5	-60.0	--	--	--	--	--
	Rate of education/literacy	%	80	18	-63.3	--	--	--	--	--
Human	Knowledge on first aid	%	70	20	-55.6	--	--	--	--	--
	Knowledge on storm surge risk	%	80	46	-27.0	-	-	-	-	-
	Access to nearest district town (Yes/No)	Binary	1	0	-100.0	---	---	---	---	---
	Access to doctor service (No. of doctor /	No.	2	1	-33.3					
	HH Population having training on Surge protection	%	50	22	-38.9	-	-	-	-	-
	Active population of HH	%	50	60	9.1	+	+	+	+	+
	Response to early warning system	%	65	70	3.7	+	+	+	+	+
	Response to adaptation technology	%	75	75	0.0	+	+	+	+	+
	Rate of out migration of HH member	%	10	10	0.0		+		+	
	Safe housing infrastructure/ condition	%	60	18	-53.8	--	--	--	--	--
Physical	Performance of hospital /Health center	Scale	3	2	-20.0			-	-	-
	Performance of access to cyclone shelter	%	90	70	-12.5	-	-	-	-	-
	Availability of drinking water (Safe water)	%	90	33	-46.3	--	--	--	--	--
	Sanitation facilities	%	90	35	-44.0	--	--	--	--	--
	Access of Radio/TV/ Cell phone	%	75	40	-30.4		-	-	-	-
	Availability of paved road	%	60	65	4.0	+	+		+	
	Transportation facilities	%	60	55	-4.3	-	-	-	-	-
	Average area with protection structure	%	80	35	-39.1		-	-	-	-
	Fitness of protection structure	%	80	40	-33.3		-	-	-	-
	Performance of weather forecasting	Scale	3	1	-50.0	-	-	-	-	-
Social	Community participation practice	%	80	40	-33.3	--	--	--	--	--
	Activeness of local GO	Scale	2	1	-33.3	--	--	--	--	--
	Interrelationship with NGO	Scale	2	1	-33.3	--	--	--	--	--
	Performance social law and regulation	Scale	2	1	-33.3	--	--	--	--	--
	Political influence on social group/	Binary	1	0	-100.0	---	---	---	---	---
	Performance of local disaster management	Scale	2	1	-33.3	--	--	--	--	--
	Activeness of social organization of livelihood	%	80	50	-23.1	-	-	-	-	-
	Awareness program on protection measure	No.	2	2	0.0	+	+	+	+	+



### 2.5. b. Livelihood security of Wage Labor in Satkhira during Storm surge hazard

Parameter	Food Security j=1	Income Security j=2	Health Security j=3	House Security j=4	Water Security j=5	$\sum SI_j$	SI (%)
$\sum X$	9	10	4	8	5		
Y	58	51	61	53	57		
M	67	61	65	61	62		
$SI_j$	13.4328	16.3932	6.1538	13.1147	8.0645	57.159	11.431

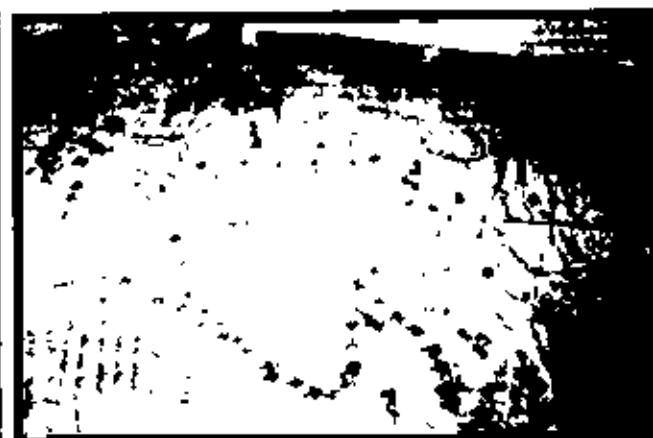
**Appendix-E**  
**PHOTOGRAPHS**



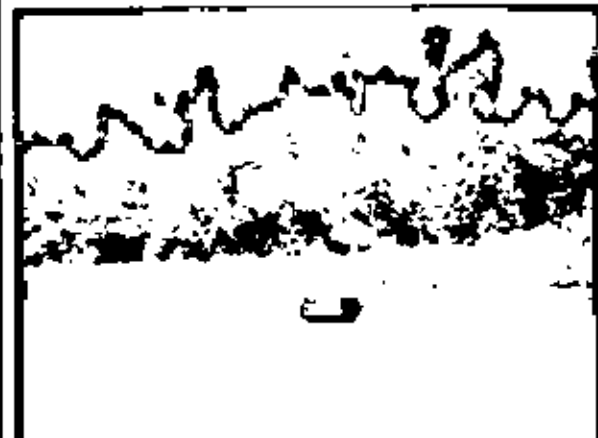
**Photo-1.** Sketch of Khurushkul Union in Cox's bazaar.



**Photo-2.** Sketch of Jilongja Union in Cox's bazaar.



**Photo-3.** Sketch of Munshiganj Union in Satkhira.



**Photo-4.** The Sundarban in Satkhira.

Source: Field survey, 2008-09.



Photo-5. FSM at Harinagar Sushilon Office, Sakhira.



Photo-6. Discussion with Women at household, Cox's bazaar.



Photo-7. Interview of Fisher group in Cox's bazaar.



Photo-8. Interview of farmer group in Cox's bazaar.



Photo-9. Interview of Salt farmer in Cox's bazaar.



Photo-10. Interview of wage laborer in fish drying field in Cox's bazaar



Photo-11. Interview of Fisher in Satkhira.



Photo-12. Discussion with marginal groups in Satkhira



Photo-13. Fry collector in Cox's bazaar.



Photo- 14. Fry collector in Satkhira.



Photo- 15. Salt farmer is working in his field (Cox's bazaar).



Photo-16. Forest resource extractors in Sundarban in Satkhira.



Photo-17. Farmer's house in Satkhira.

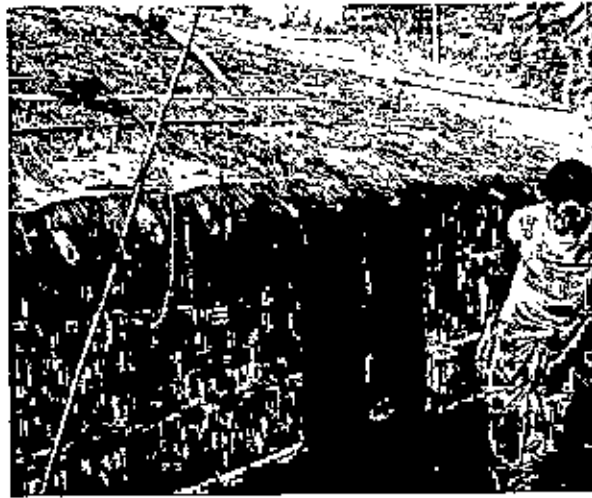


Photo-18. Farmer's house in Cox's bazaar.



Photo-19. Fisher's house in Satkhira.



Photo-20. Fisher's house in Cox's bazaar.

Source: Field survey, 2008-09.

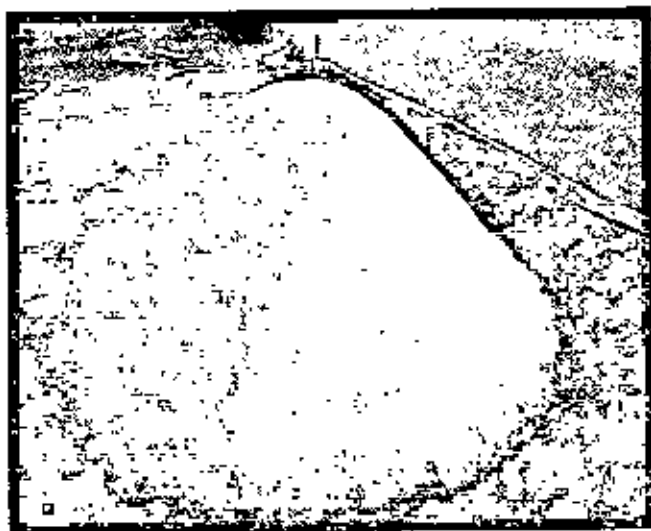


Photo-21. Salt production in field in Cox's bazaar.

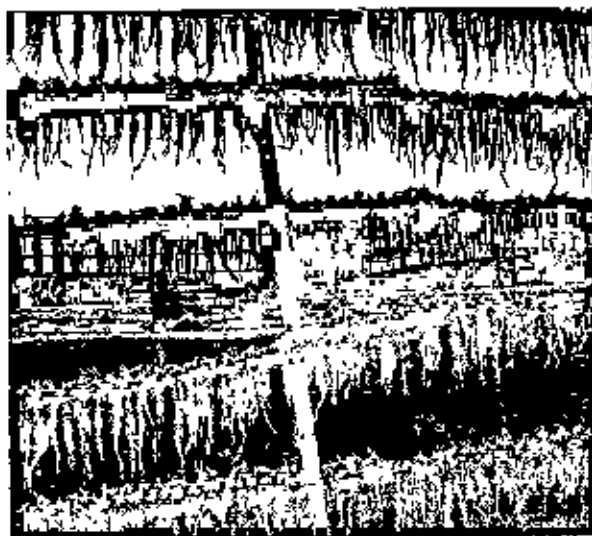


Photo- 22. Fish drying in Cox's bazaar.



Photo-23. Cyclone center in Cox's bazaar.



Photo-24. Cyclone center in Satkhira.

Source: Field survey, 2008-09.

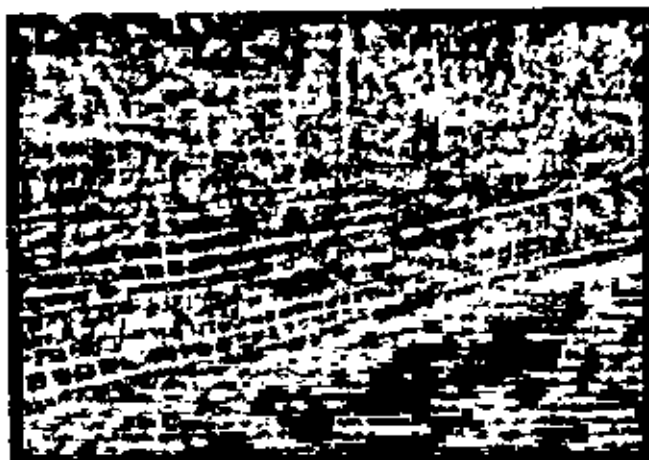


Photo-25. Household protection in Site1.



Photo-26. Structural protection in Site2.



Photo-27. Boats for forest resource collection in Satkhira.



Photo-28. Water use for Household activities in Satkhira.

Source: Field survey, 2008-09.

