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DECLARATION

I, Md Modasser Hossain Khan, declare that this thesis is a result of my research investigations and findings. Sources of information other than my own have been acknowledged and a reference list has been appended. This work has not been previously submitted to any other university for award of any type of academic degree.

Signature………………………………..

Date…………………………………………

DEDICATION

I dedicate this thesis to my parents who inspired me throughout the data collection and writing period and encouraged me until the end, to complete the hard work successfully.

Without them, this would not have been possible.

ACKNOWLEDGEMENT

First and foremost, I would like to extend my sincere thanks and greatest appreciation to my supervisor, Prof. Ian Bryceson, for his valuable guidance, advice and support. He has been extremely helpful throughout the research period. Without his encouragement and guidance, this thesis could not have materialized. I am also thankful to Ass. Prof. Siri Eriksen, for her thoughtful advice and guidance, which helped me a lot throughout the research period. Special thanks to my study coordinator Ingunn Bohmann for her kind support and help during the whole research period.

Special thanks also go to Dr. Ubydul Haque of IMT department, for his guidance and for helping me throughout the image analysis procedure. I would also like to thank Hafizur Rahman, PhD student of IPM department for his support and help during the writing period.

The work leading to this study was supported by a research grant from Noragric, and this financial help is greatly acknowledged. Without the financial support, it would not be possible for me to conduct the fieldwork. I would like to thank all the members of Noragric for their cooperation's.

ABSTRACT

Natural disasters and land-use change are major concerns all over the world, and if these two concerns exist together in a coastal area, then the consequences for people and the environment may be severe. This study investigated the changes in land-use in the past 10 years in Shyamnagar Upazila of the south-west coastal area of Bangladesh. The drivers of land-use change and the occurrence of disasters were explored in relation to their effects on social and ecological systems. Satellite images were analyzed to detect changes in land-cover in the last 13 years. Three areas were selected for on-the-ground data collection. Household surveys were conducted to discover the type, level and effects of disasters. Focus Group Discussions and personal interviews were also conducted to explore the drivers behind changes in land-use. Probability regression analysis was performed to assess the relationship between various disasters with overall income, agricultural production and outward migration. Results from image analysis showed an overall 21 percent increase in shrimp culture ponds in the past 13 years. Agricultural land and forest resources decreased by 48 and 3 percent, respectively, while barren and built up areas increased by 71 percent. Analysis of household data showed that cyclones and tidal floods had significant effects on income, agricultural production and migration. Social, economic and political factors combined with natural causes were found to be the main drivers behind land-use changes. These empirical findings suggest that social and ecological resilience was reduced and vulnerabilities increased in this part of coastal Bangladesh for these reasons between 1999 and 2012.

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LIST OF ACRONYMS

NDRI	Natural Disaster Risk Index
MWR	Ministry of Water Resources
BBS	Bangladesh Bureau of Statistics
UNISDR	United Nations International Strategy for Disaster Reduction
UNEP	United Nations Environment Programme
UN-HABITAT	United Nations Human Settlements Programme
USGS	United States Geological Survey
ENVI	ENvironment for Visualizing Images
IDL	Interactive Data Language
TM	Thematic Mapper
ETM+	Enhanced Thematic Mapper Plus
DN	Digital Number
RMSE	Root Mean Squire Error
FGD	Focus Group Discussion
SAAO	Sub-Assistant Agricultural Officer
RA	Resilience Alliance
HYV	High Yielding Varity

1. INTRODUCTION

1.1 Background

Bangladesh is a country of low-lying deltaic floodplain with a coastline of about 710km (MWR 2005). The coastal areas of the country are exposed to various natural hazards such as cyclones, storm surges, sea level rise, floods and droughts due to its vulnerable topography and geographical location. The Natural Disasters Risk Index (NDRI 2010) ranked Bangladesh as the country most vulnerable to natural disasters. Various anthropogenic activities such as pollution, deforestation and water logging have also adversely affected the country. Both natural and anthropogenic activities together intensify damage to the ecosystem and hamper the economy, livelihoods and development of the coastal areas of Bangladesh (MWR 2005). In the last 50 years, many major changes have been made in land-use in the coastal areas of Bangladesh, due to interests competing over land and various natural resources. Major changes have happened in the agricultural sector due to salinisation and embankments (Islam 2006) and several natural disasters (Kumar et al. 2010).

According to the Millennium Ecosystem Assessment, modification of land-use by several anthropogenic activities affects social-ecological systems and therefore, loss of biodiversity (Sarukhán & Whyte 2005). Over time, changes in land-use have occurred and, as a result, social-ecological resilience of coastal areas has been affected (Atwell et al. 2008).The purpose of this study was to investigate changes in land-use practices in coastal areas of Bangladesh over the past 13 years and to explore how social and ecological resilience has been affected. Remote sensing technology was used to detect land-use changes in the study area. Remote sensing technology has the capability to extract spatial data by analyzing satellite images (Tayyebi et al. 2008).

1.2 Research Questions

What changes have occurred in the agriculture, fisheries and forestry sectors in Shaymnagar Upazila (sub-district) of Bangladesh over the past 13 years? What are the main drivers of these changes?

1.3 Objectives

- To detect how land-use has changed over the past 13 years in the study area by using satellite images;
- To investigate the main drivers of land-use changes by conducting on-the-ground fieldwork;
- To collect data regarding occurrences of natural disasters and their impacts over the past 13 years on the coastal area of Bangladesh.

1.4 Hypotheses of the study

- Vegetation and agricultural land are being converted into aquaculture ponds;
- Vegetation is being converted into agricultural land;
- Migrations are taking place due to occurrences of natural disasters.

1.5 Conceptual Framework

Resilience is adopted as an analytical approach for understanding linked social-ecological systems and their changing processes (Berkes & Folke 2000). The concept of resilience in terms of disasters is defined as “the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner through the preservation and restoration of its essential basic structures and functions” (UNISDR 2004). Livelihood strategies of communities are employed according to their ability to cope with risks that come from shocks by both natural and human factors, and by their relative vulnerability to disasters. Vulnerability is a concept that links the relationship that people have with their environment to social forces and institutions and the cultural values that sustain and contest them. “The concept of vulnerability expresses the multidimensional effects of disasters by focusing attention on the totality of relationships in a given social situation which constitute a condition which, in combination with environmental forces, produces a disaster” (Bankoff et al. 2004).

This study utilized both resilience and vulnerability concepts to gain an overview of the situation in the study area. These concepts helped to analyze and understand the changes that occurred in land-use during the last 13 years due to various factors (shocks) and the present condition (responses) of the social-ecological systems.

2. REVIEW OF LITERATURE

2.1 Land-use and land-cover changes

Land-use has been seen as a product of interactions between a society's cultural background, skills and physical needs on the one hand, and the natural potential of land on the other hand (Nagamani & Ramachandran 2003). According to the United Nations Food and Agriculture Organization "Land use is characterized by the arrangements, activities and inputs people undertake in a certain land cover type" (FAO 2000). According to this definition, land-use reflects human activities such as the use of the land in industrial zones, residential zones and agricultural fields. Quentin and coworkers define land-use change as a "type of change (physical, chemical or biological) that relates to management like conversion from grazing to crop land, irrigation installation, improvement of drainage systems, building dams, land degradation and pollution, plantation, removal of vegetation, weeds and exotic species increase and conversion to non-agricultural uses" (Quentin et al. 2006). Conversion and modification are two broad categories of land-use and land-cover changes. Conversion refers to changes from one category of land-use to another. Modification includes changing the components of any existing land-use category (Baulies & Szejwach 1997). Significant changes in land-use and land-cover are occurring worldwide (Xing et al. 2006). Land-use dynamics could play a major role in driving changes in the global environment during the next decades (Baulies & Szejwach 1997)

2.2 Detection of land-use and land-cover changes using satellite imagery

Information regarding land-use change is necessary for many applications, such as the monitoring, management and planning of natural resources. It is also important for applications like agriculture, hydrology, forestry, and ecology (Ellis 2010). It has become a central component of current strategies for managing natural resources and monitoring environmental changes. Studies of land-use change have become very important because of the rapid development of land-use mapping (Stathakis et al. 2010). Use of satellite imagery for change detection is a convenient approach to obtaining accurate information on land-use change, because change detection is a major application in digital image processing. Karanja defines change detection as "a technique that is used to highlight conversion of land from one use to another within a given time frame" (Karanja 2002). Land-cover can be determined by analyzing satellite and aerial imagery. Land-use cannot be determined from satellite imagery. Information obtain from land-cover maps help investigators best understand the current landscape. Change detection can be done digitally using satellite images if the images are classified and compared for changes. The overall objective of classification is to categorize all pixels of an image into land-use classes. There are several methods to obtain information about the earth but the most efficient and economical method is through satellite data (Stathakis et al. 2010).

There are two main methods of image classification: unsupervised and supervised classification (Hasmadi et al. 2009). Simple methods such as unsupervised classification of images for change detection suffer from poor accuracy (Hegde 2003). Unsupervised classification is often inappropriate in geographical and remote-sensing sciences (Hegde 2003). To avoid these problems, this study will use supervised classification.

2.3 Land-use practices in coastal areas of Bangladesh

Land-use and land-cover changes in coastal areas of Bangladesh are diverse. Land in these areas is used intensively for agriculture, settlements, forests, shrimp ponds, water bodies and fisheries, salt production, industrial and infrastructure developments and tourism (Islam 2006). Moreover, construction of dams or polders in the coastal areas is considered as one of the main land-use activities that has changed the stability of the area. The sedimentation process in the coastal areas was greatly hampered by the implementation of the coastal embankment project in the 1960s. A total of 97 polders were constructed, of which 37 were in the southwest coastal region. The primary purpose of the project was to protect the agricultural lands from yearly inundation by floods and to free the wetlands from saline water. These polders restricted the river water from entering the wetlands and, as a result, tidal sediments increased the height of these river beds instead of the wetlands. Most river beds became higher than the adjacent wetlands, creating water logging in the surrounding areas. The water logging problem has become more severe and extensive due to saline water intrusion into the surrounding areas at high tides.

The dense population of the country results in a high human-land ratio of about 0.124 hectare per person (BBS 2001). The population of coastal Bangladesh is expected to increase to 43.9 million by2015, compared with 36.8 million in 2001 (Islam 2006). Almost 54 percent of the population is functionally landless in coastal Bangladesh. Among these, 30 percent are absolutely landless (Islam 2006). Almost 71 percent of the 6.85 million households of coastal areas are small-scale farmers, fisher folk, agricultural laborers and the urban poor (Ahmad 2004). This has a significant influence on the quality of land and also on land-use. Almost 50 percent of the coastal lands have lost their effective usefulness due to different degrees of saline inundation (Islam 2006).

2.4 Disasters in coastal areas of Bangladesh

Natural disasters are defined as "a serious disruption of the functioning of society, causing widespread human, material or environmental losses which exceed the capacity of the affected society to cope using only its own resources" (UNISDR 2004). The coastal areas of Bangladesh are disaster prone because of their geographical location, land characteristics and funnel-shaped characteristics (UNEP 2001). The country has been impacted by a range of natural disasters throughout its history, including cyclones, tidal surges, floods, droughts, tornadoes and river bank erosion. Bangladesh remains one of the worst sufferers of cyclonic casualties in the world. Nearly 70 major cyclones have hit the coastal areas of Bangladesh during the last 200 years (Mallick et al. 2009). Almost 900,000 people have died in last 35 years due to catastrophic cyclones (Islam & Ahmed 2001). The number and severity of cyclones in Bangladesh and the associated human mortalities have varied greatly during the past 50 years. For example, the deadliest cyclone occurred in 1970 with a wind speed of 222 kilometers per hour and a surge height of 5.5 meters, causing almost 500,000 deaths, and the most recent severe cyclone of 2007, with a wind speed up to 240 kilometers per hour and a surge height of 5 meters, caused 4,234 deaths (Haque et al. 2011). In addition, many other hazards affect the country, such as earthquake, tsunami, high arsenic levels in ground water, water logging and salinity intrusion. Among these, cyclonic surges, tornadoes and droughts are caused by natural processes. On the other hand, river bank erosion, coastline erosion, salinity intrusion, water logging and decreases in groundwater levels are caused by a combination of both natural and anthropogenic activities. Most man-made coastal disasters have been further accelerated by the upstream diversion of the Ganges in India. The flood situation all over the country, including low lying coastal areas, has accelerated due to damming, polders and the Farakka Barrage of the Ganges in India (Khalequzzaman 1989).

2.5 Vulnerability and resilience in terms of disasters and land-use changes

The effects of natural disasters are shaped by the nature of the vulnerability surrounding particular land governance types (UN-HABITAT 2010). Land and land-use maybe affected differently by various types of disaster. Large areas maybe left uninhabitable by long-term inundation through flood, storm surge and tsunamis. Cyclones, tornados and other big wind events do not necessarily have a large physical effect on land but may cause destruction of houses and resources and displacement of a large number of people (UN-HABITAT 2010).Wind and tidal action have immediate or short-term effects, but the effect of erosion and saltwater intrusion may be long-term, varying from months to years (Wisner et al. 2004). Disasters such as floods, drought and tropical cyclones can have potentially severe biological and epidemiological consequences as secondary effects (Wisner et al. 2004).

Different types of natural disaster and social and political disturbances have various effects on the social-ecological system. The social-ecological system is an ecological system that is intricately linked with and affected by one or more social systems (Anderies et al. 2004). The social-ecological system is a process related to the idea that human action and society are linked with nature, and that it is thus unreasonable to make any distinction between natural and social systems (Adger 2006). Vulnerability covers those characteristics of a social system that influences the ability to predict, deal with, resist and recover from the impact of a natural hazard (Wisner et al. 2004). Vulnerability depends on both the sensitivity and resilience of any system that comes in contact with the hazard (Turner et al. 2003). Sensitivity is the degree to which a system is affected, and exposure refers to the inventory of elements in an area in which hazard events may occur (UNISDR 2004). Any system can therefore be highly resilient, but if its sensitivity and exposure are high then it is vulnerable (Miller et al. 2010). Exposed ecosystems with low resilience might still be able to maintain functions and generate resources and other necessary ecosystem services. If the ecosystem faces disturbances similar to high intensity events, then it might shift to a less desirable state and might exceed critical thresholds. Thresholds are the points at which a relatively small change in external conditions causes a rapid change in the structure or function of the ecosystem (Walker & Meyers 2004) As social-ecological systems are linked, changes in one system may lead to impacts on another, resulting in shifts in both ecosystems and social systems at many different spatial and temporal scales. Social and ecological development maybe significantly interrupted, and livelihood options may be reduced, leading to environmental refugees, as a result of the impact on the ecosystem's life-support (Folke et al. 2002). The Stockholm Resilience Centre suggests that "human adaptation has caused loss of resilience and pushed many ecosystems close to thresholds."

(http://www.stockholmresilience.org/research/researchthemes/adaptivegovernancenetworksandlearning/multilevelgovernance.4.aeea46911a3127427980007069.html). Loss of resilience implies that a small disturbance that could previously be absorbed and generate renewal may instead move a community over a threshold into other stability domains. Such change has been referred to as 'regime shifts' (Scheffer et al. 2001) and a system with lower resilience tends to shift more easily than a system with ample resilience. These shifts occur in nature but tend to be exacerbated by humans (Scheffer et al. 2001).

Hazards in coastal areas may become disasters due to loss of resilience created by either environmental changes or human actions (Adger et al. 2005). For example, in 1992 Florida was affected by a Category 5 storm, Hurricane Andrew, which destroyed $26.5 billion of property and caused the death of 23 people. However, in 1991 Bangladesh was struck by a same category tropical cyclone and as a result 100,000 people lost their lives and a million others lost their houses and properties due to widespread flooding (Adger et al. 2005). This may be due to Florida's strong social resilience which led them to deal with the crisis while on the other hand Bangladesh, with weak resilience and social vulnerability, was susceptible to the large-scale destruction of human life.

In countries with a large, dense population and considerable inequality in land-use and income, rural concentrations in high-risk coastal areas can vary greatly. In these cases, local poor people continue to remove protective vegetation, destroy buffer zones and increase their vulnerability to disasters because of the extreme pressure on the land (Wisner et al. 2004). In various natural disasters, the vulnerability of human populations is based on where they have settled, their use of natural resources and the resources they have with which to cope (Adger 2006). A vulnerable society may find it hard to rebuild their livelihoods after a disaster, and subsequently become more vulnerable to the next hazard event (Wisner et al. 2004).

3. METHODS

3.1 Selection of the study area

The study area is Shyamnagar Upazila in the Sathkhira district of Bangladesh. Natural disasters such as cyclones, storm surges, tidal floods, saline water intrusion and water logging are prominent features of this area. In addition, land-use and land-cover change is another major concern. The human-induced shrimp farming initiates salinity that seriously affects agricultural production and makes the region vulnerable to unsafe drinking water.

3.2 Description of the study area

Shyamnagar (Figure 3.1) is the largest Upazila, of Satkhira district. This Upazila occupies an area of 1968.24 km^2, including 1,622.65 km^{2}offorest area. It consists of 13 unions, and the total population of this Upazila is 313,789 (BBS 2001). Household income predominantly depends on agriculture. Almost 65 percent of the total population is involved in agriculture and 38 percent depend on cropping, livestock, forestry and fisheries as their main source of income, whilst 27 percent derive their income from selling agricultural labor. The total cultivable land is 38,552 hectares, with 6,258 hectares of fallow land. Among the total population, 19 percent are landless, 30 percent landed but small, 28 percent are marginal, 16.5 percent intermediate and 6.5 percent are wealthy (BBS 2001).

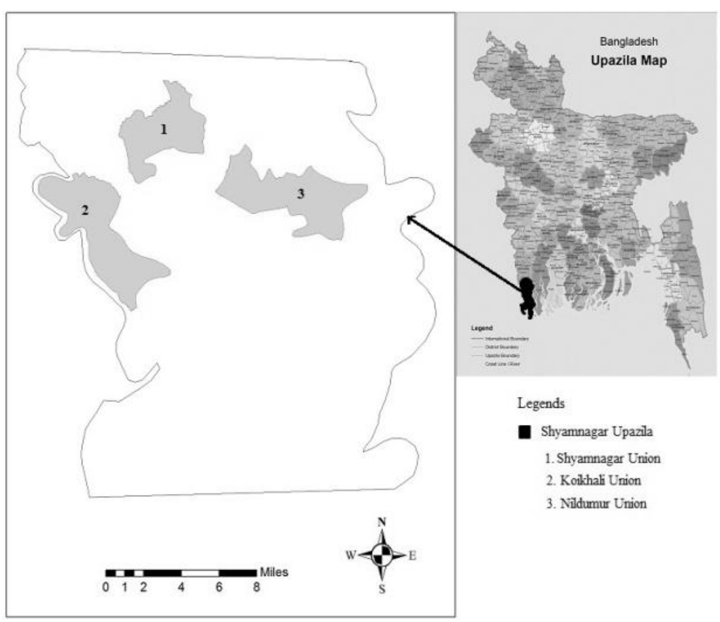

Figure 3.1: Map of Shyamnagar upazila of Bangladesh (1, 2 and 3 indicates those areas where field survey was conducted)

3.3 Satellite Image analysis

Satellite images have been analyzed to answer the research questions and fulfill the objectives of the study. Images have been obtained from the United States Geological Survey (USGS). Two sets of satellite images, dated1999 and 2012, have been used for the analysis. Images obtained in 2012 had a gap mask due to the Scan Line Connector of Landsat ETM+ being offline (SLC off). The mosaicking method was applied to fill those gaps using ENVI\IDL TM. For minimizing the differences in the Digital Number (DN) value of each pixel, radiometric correction procedure was applied; then Ground Control Points were collected to register these two images. The root mean square error (RMSE) was 0.3. Supervised classification with a maximum likelihood algorithm was applied for image classification. Later, two classified images were used for change detection. Figure 3.2 represents the overall steps used for the image analysis procedure.

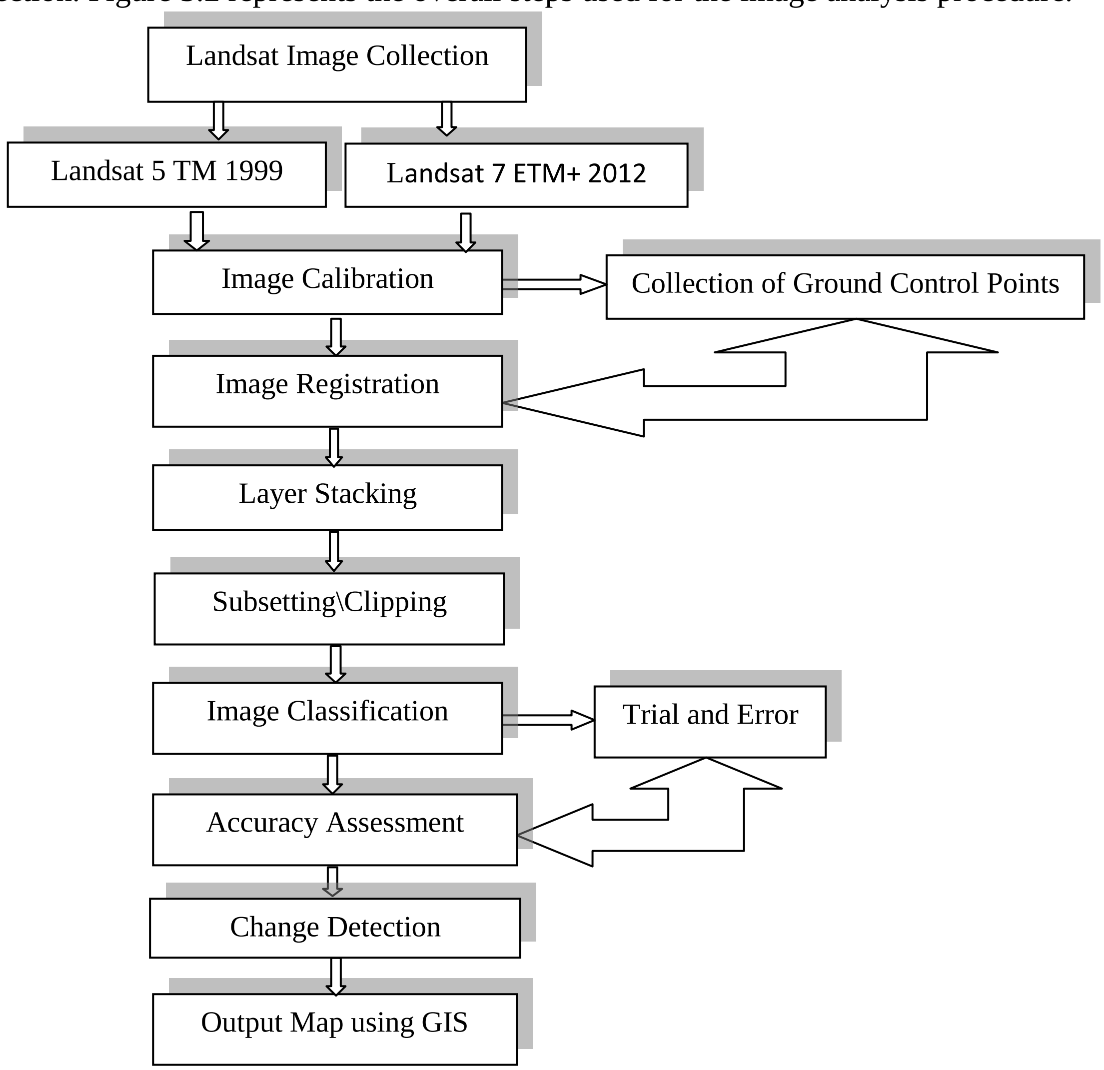

Figure 3.2: Image analysis procedure

3.4 Data collection and analysis

A questionnaire survey was conducted to fulfill the objectives and prove the study's hypothesis. The questionnaire survey was completed between February and March 2012. A semi-structured household-level questionnaire was developed to investigate the effects of natural disasters, which was pre-tested before conducting the survey. To clarify the purpose of the survey, informed consent was agreed upon with the respondents. A total of 144 household-level questionnaire surveys were conducted in three unions, namely Shyamnagar, Koikhali and Nildumur (Figure 3.1), with 55, 45 and 44 responses respectively. These three unions were selected because natural disasters are common in them, while the impact level of disasters is different. Non-probability random sampling procedures were followed for the household surveys (Bryman 2004). All the households were selected as the researcher walked through the roads of those areas.

Three focus group discussions (FGD) were conducted to investigate the reasons behind the land-use and land-cover changes that had occurred in the study area. In each union, one FGD has been conducted where both agricultural farmers and shrimp farmers were the main focus. The numbers of participants in the FGD were 9, 8 and 9 for each of the three unions respectively. Four individual informal interviews were conducted through a semi-structured questionnaire; these comprised two government and two non-government officials.

Some secondary data were collected in order to obtain an overview of the occurrence of disasters and their impact on the study area. These data were collected from the Internet, the Local Government Engineering Department, the Upazila Agriculture Extension Office, the Upzila Fisheries Office and the Meteorological Department of Dhaka, Bangladesh.

Frequency tests were utilized in order to compare categorical data, such as age, sex and occupation, across the three unions. Probit regression analysis was performed to prove the hypothesis of the study because all the variables collected from household survey showed normal distribution. The level of significance for the analysis was set to $p<0.08$.

3.5 Limitations

As the leaders of rural households in Bangladesh are male, the participation of female respondents was relatively less.

4. RESULTS

4.1 Land-cover change detection

Satellite images of Landsat TM and ETM+ were analyzed in order to achieve an overview of land-cover changes which had occurred between 1999 and 2012 in the study area. Figure 4.1 represents the true and false color Landsat satellite images of Shyamnagar Upazila and its surrounding areas. From these images, it can be seen that the changes that have occurred in land-cover are visible and separable. Further analysis was done by classifying these images using supervised classification.

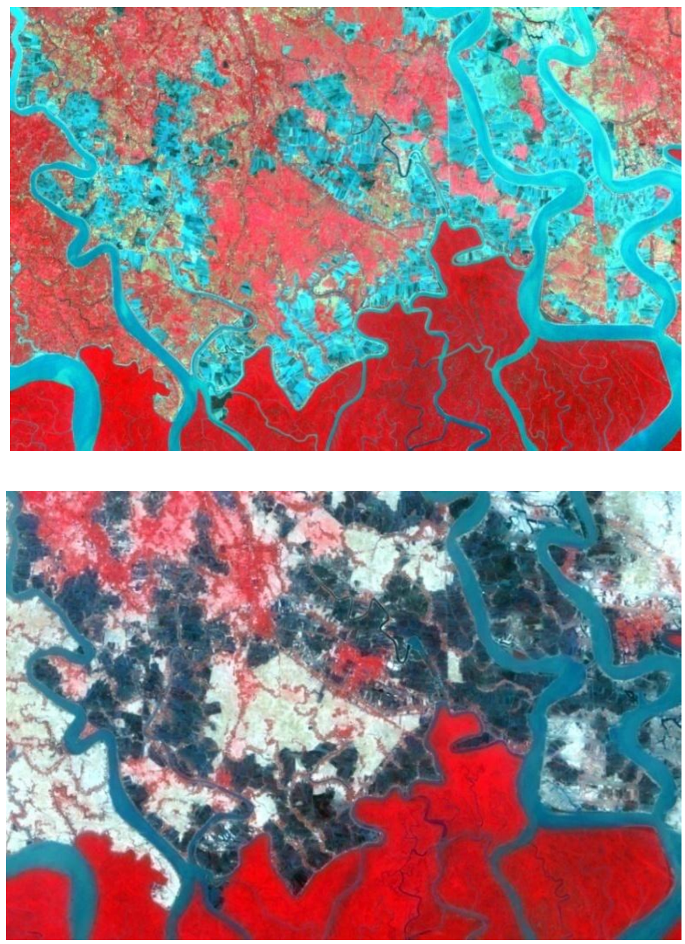

Figure 4.1: False color images of Shyamnagar and its surrounding areas from year 1999 (up) and 2012 (down)

It is visible from the classified map that in the year 1999, dominant land-use practice on that area was paddy culture, represented by the color yellow. The color blue represents rivers, canals, ponds and shrimp culture farms. Unused and built-up lands are represented by a pink color and vegetation by a green color, including mangrove forest and other vegetation (Figures 4.2 and 4.3).

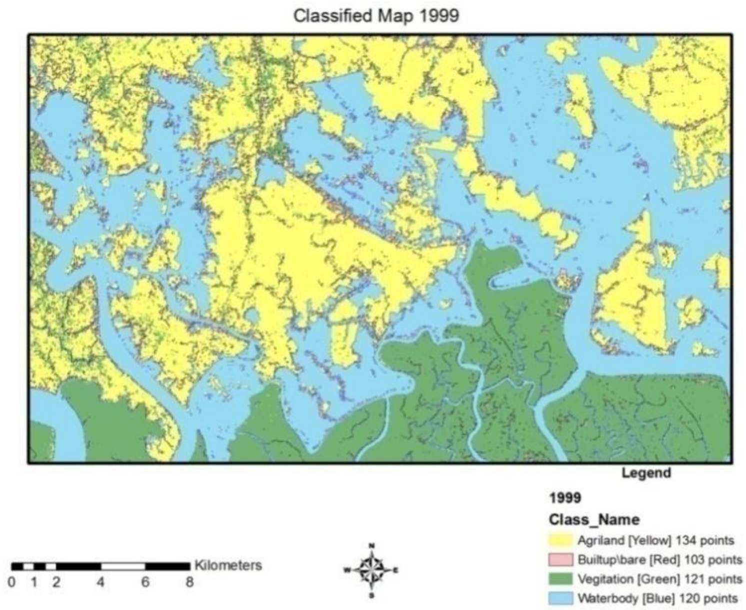

Figure 4.2: Classified map of the study area from the year 1999

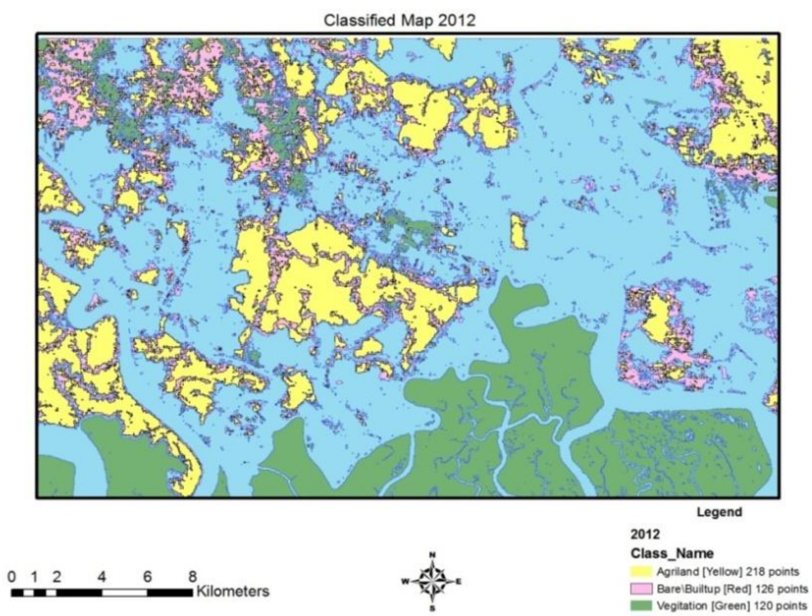

Figure 4.3: Classified map of the study area from the year 2012

The positive changes which have occurred in bare land and built-up areas and also the negative changes which have occurred in agriculture, water bodies and vegetation between 1999 and 2012. The majority of water bodies have been occupied by bare and built-up areas due to population pressures resulting in expansion of built-up areas. Some lands have been converted to bare lands due to the effects of water logging and salinity intrusion (Figure 4.4).

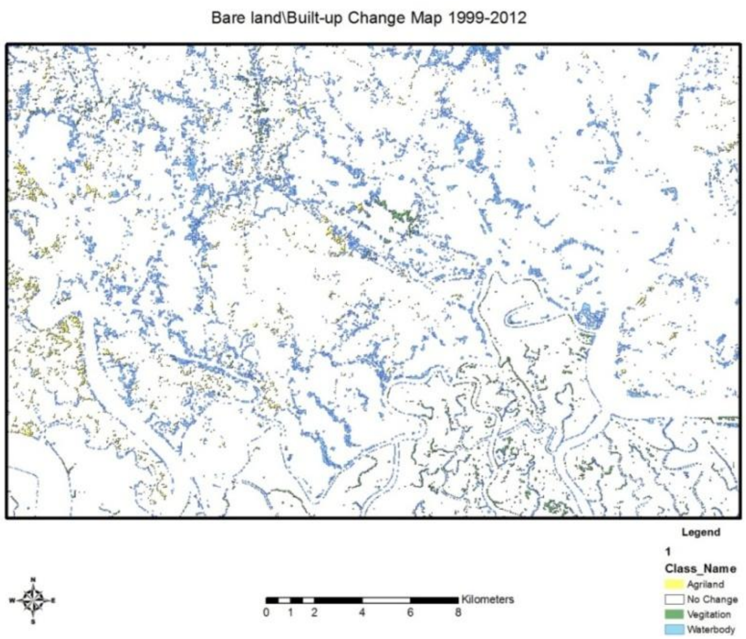

Figure 4.4: Change map bare land and built-up areas from1999-2012

Those changes occurring from water body to other land cover categories during 1999 to 2012 presented in Figure 4.5. Red represents those areas which converted to a bare land or built-up category from the water body category. Yellow represents those areas which converted to the agricultural land category, and green represents those areas where water body was converted to the vegetation category.

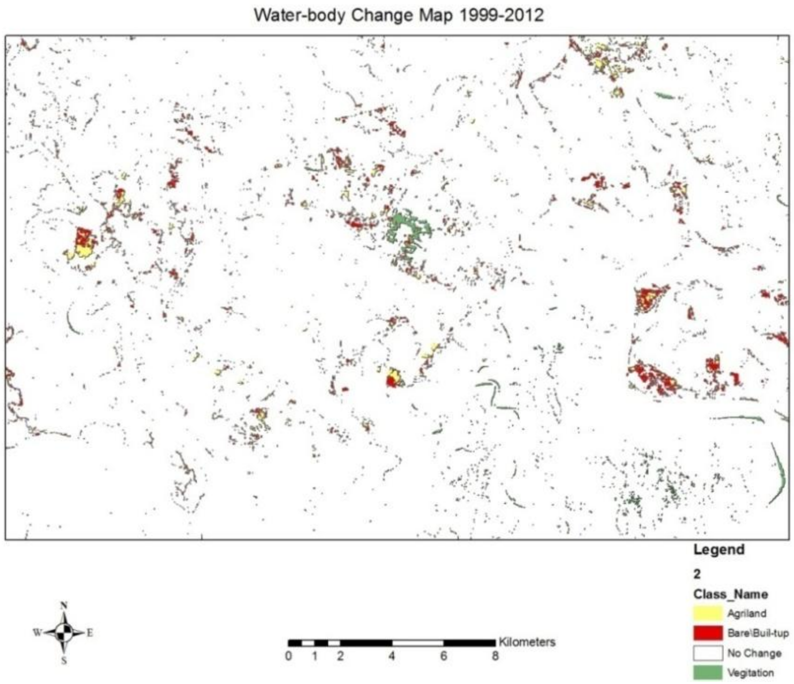

Figure 4.5: Water body change map 1999-2012

Figure 4.6 represents those negative changes occurring in agricultural land use from 1999 to 2012. Blue represents those areas which converted to the water body category from other categories of land-covers. Red and green represent those areas which converted to the bare land or built up category and to vegetation, respectively.

Areas which converted to other land cover categories from the vegetation category between the years 1999 to 2012 represented in Figure 4.7. Red represents those areas which converted to bare land from vegetation. Also, some vegetation land converted to agricultural land and water body are represented by yellow and blue, respectively.

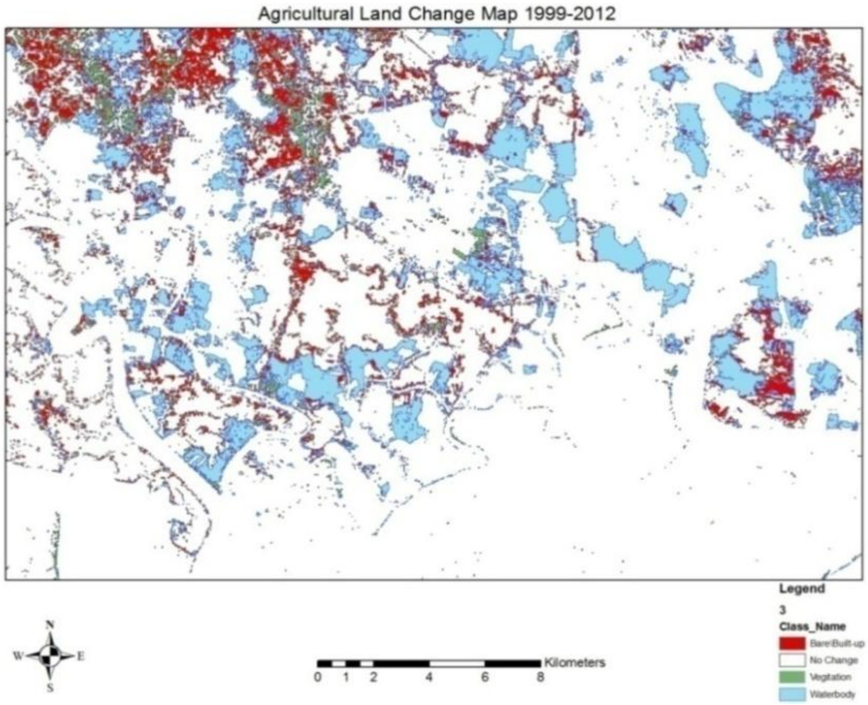

Figure 4.6: Agriculture land change map from 1999-2012

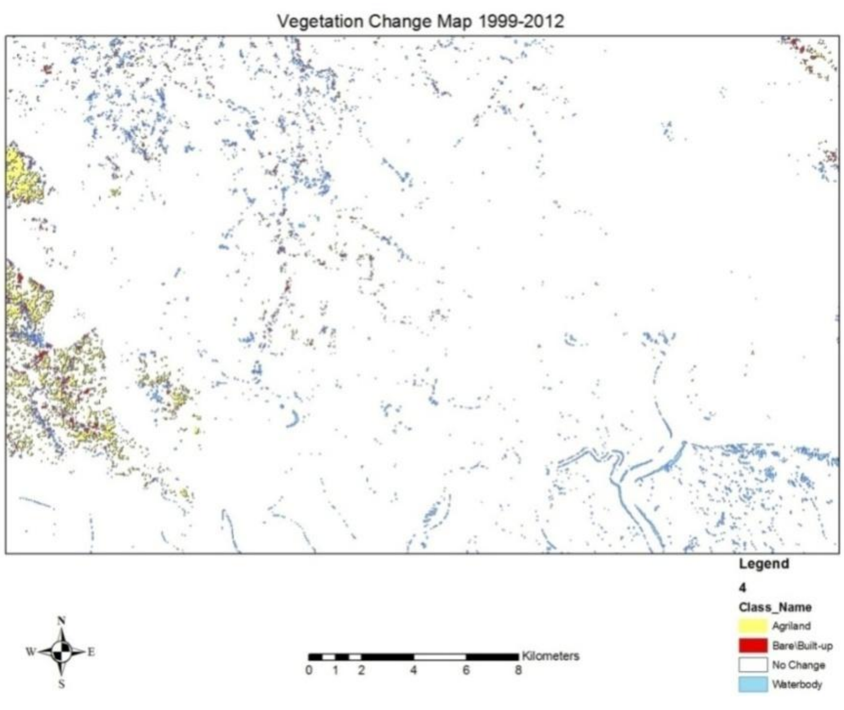

Figure 4.7: Vegetation change map 1999-2012

4.1.1 Change detection Statistics

Chang detection statistics represents the percentage of differences in pixels between two classified images of the tear 1999 and 2012 (Table 4.1). The main changes occurred in bare land and built-up areas, which increased by almost 73 percent. Almost 48 percent of the agricultural land converted to other land cover categories within the last 13 years; 29 percent of agricultural land has been converted to the water body category and 23 percent of agricultural land converted to the bare land and built-up category. The second most significant change occurred in the water body category, which increased by almost 31 percent. Vegetation and tree species decreased by 3 percent within the last 13 years; 6 percent of vegetation has been converted to agricultural land and 4 percent to the water body category.

Table 4.1: Change detection Statistics from year 1999 to 2012

Categories	Percentage					
	Built-up\bare land	Water body	Agriculture land	Vegetation	Row Total	Class Total
Bare land\Built-up	31	5	23	4	100	100
Water body	47	93	29	4	100	100
Agriculture land	11	1	44	6	100	100
Vegetation	11	1	4	86	100	100
Class Total	100	100	100	100	0	0
Class Change	69	7	56	14	0	0
Image Difference	73	30	-48	-3	0	0

4.2 General characteristics of respondents

Baseline characteristics of the studied population are represented in the Table 4.2, where most of the respondents were male (83 percent), 62 percent of the population were in their middle age (25–30 years), and the major occupations were farming and fishing (17 percent in both cases). Only 17 percent of total respondents had shrimp culture farms. Findings revealed that 90 percent of the total respondents were affected by disasters; where all households were in the Nildumur union, (100 percent)

Table 4.2: Baseline characteristics of the study population(N indicates number of respondents)

Area	Shyamnagar Union		Koikhali Union		Nildumur Union		All
Characteristics	N	%	N	%	N	%	%
Gender							
Male	41	74	41	89	38	88	83
Female	14	26	5	11	5	12	17
Age							
25-50	34	62	30	65	25	58	62
50-70	19	34	12	26	15	35	31
>70	2	4	4	9	3	7	7
Major Occupation							
Business	7	13	3	7	10	23	14
Farmer	9	16	15	33	1	2	17
Fisherman	0	0	8	17	16	37	17
Housewife	6	11	5	11	4	9	10
Labor	7	13	6	13	3	7	11
Van Puller	7	13	0	0	0	0	5
Student, Teacher, Service Holder, Doctor, Retired	9	16	2	4	3	7	10
All Other	10	18	7	15	6	15	16
Family size							
2 - 4	29	53	12	26	11	26	36
5 - 6	15	27	20	44	19	44	38
>6	11	20	14	30	13	30	26
Education among respondents (class)							
0	6	11	4	9	5	12	11
1 -5	44	80	36	78	33	77	78
6 - 10	5	9	6	13	5	11	11
Shrimp Culture pond							
Yes	5	9	5	11	14	33	17
No	50	91	41	89	29	67	83
Disaster Affected							
Yes	42	76	44	96	43	100	90
No	10	18	2	4	0	0	8
N\A	3	6	0	0	0	0	2

4.3 Changes in land-use and their causes

Respondents from FGDs mentioned, about those major changes in the local practices and their reasons (Table 4.3). They mentioned that positive changes (increase) occurred in cropping pattern, shrimp culture, deforestation, and urbanization. Whereas, negative changes (decrease) occurred in the paddy culture, dam or polders and drainage sector.

Table 4.3: Changes in local practices and their causes according to respondents

Local practices	Changes (pos+, Neg-)	Reasons
Cropping pattern	++	Introduced new varieties of crops to combat with salinity problem and to increase overall production rate.
Shrimp culture	++++	Economically profitable
Paddy culture	- -	Salinity intrusion due to shrimp culture and Storm surge
Deforestation	++	Storm surge and shrimp culture
Urbanization	+++	Increasing population
Dam (polders)	-	Decreased due to river bank erosion and storm surge
Land degradation	++	Decreased fertility of land due to salinity, adulterant in fertilizers (up to 50 percent)
Drainage	-	Due to congestion and grabbing

Land status of the study area before shrimp cultivation is represented in Table 4.4. The analysis showed that a considerable portion which converted to shrimp culture pond was from agricultural land; this was mentioned by almost 20 percent of respondents. Conversion from forest, vegetation, and bare land to shrimp culture ponds was also mentioned by the respondents.

Table 4.4: Land status of study area before shrimp cultivation

Before Shrimp cultivation	Frequency	Percent (Multiple Value)
Forest	7	4.8
Agricultural land	29	20
Other (Bare land, Vegetation)	6	4.1
Don’t know	102	70

4.4 Factors responsible behind major land-use changes

Conversion of agriculture and other land-use to shrimp culture ponds were the main changes occurring in the study area. Respondents from FGDs mentioned that economic factors are the main drivers behind these changes (Table 4.5), as shrimp farming is more beneficial than paddy culture. They also mentioned other factors behind significant changes in land-use, including social, political and natural changes.

Table 4.5: Factors responsible for land-use changes

Factors	Priority	Description
Political	3	Land grabbing in terms of power and conversion to shrimp farm
Economical	1	Shrimp culture is profitable comparing to paddy culture
Natural	4	Water logging due to storm surge and cyclone resulting in declining agriculture production; decrease of cattle and tree species.
Social	2	One person start shrimp culture in the paddy field at the beginning then others bound to convert their traditional practice to shrimp culture due to salinity intrusion

4.5 Disasters in the study area and their effects according to respondents

4.5.1 Salinity level of the study area

During the past few decades, the salinity level of the study area has increased significantly. Salinity level of the Satkhira area, including Shyamnagar, where within the last 40 years salinity has increased by 3 percent (Table 4.6).

Table 4.6: Level of Salinity in study area

	Salinity Level				Salinity increase over 4 decades	
Year	S1 2-4 dS/m	S2 4.1-8 dS/m	S3 8.1-16 dS/m	S4 >16 dS/m	Area (000'ha)	%
1973	26.50	85.60	34.50	10.90	4.76	3.02
2000	29.03	39.01	60.55	22.01		
2009	31.00	32.96	69.72	28.58		

Source: Miah, (2010). *S1 slightly saline, S2 Moderately Saline, S3 Saline and S4 Highly saline

4.5.2 Type and level of disasters on the study area

To identify the category of disasters occurring in the study area and their levels of impact, frequency tests of household data were utilized (Table 4.7). Almost 28 percent of respondents from the Nildumur union mentioned that cyclones affected them severely; almost 46 percent of respondents from the Nildumur union mentioned tidal flood as a severe effect on them, while nearly 44 percent of respondents from the Koikhali union mentioned salinity as a severe problem in their area. The majority of respondents from the Shaymnagar and Koikhali unions (42 and 37 percent, respectively) mentioned water logging as severely affecting those areas.

Table 4.7: Type of disasters in study area

Disasters	Area	Shaymnagar Union		Koikhali Union		Nildumur Union		All
	Level	Frequency	%	Frequency	%	Frequency	%	%
Cyclone	Severe	10	18	3	7	12	28	18
	High	10	18	5	11	17	40	22
	Moderate	9	16	14	30	11	26	24
	Low	8	15	11	24	2	4	15
	No Impact	18	33	13	28	1	2	21
Tidal flood	Severe	10	18	5	11	20	47	24
	High	19	35	20	44	11	25	35
	Moderate	17	31	12	25	9	21	26
	Low	2	4	6	13	2	5	7
	No Impact	7	12	3	7	1	2	8
Salinity	Severe	9	16	20	44	7	16	25
	High	11	20	12	26	10	23	23
	Moderate	5	9	4	9	17	40	18
	Low	5	9	4	9	2	5	8
	No Impact	25	46	6	12	7	16	26
Water logging	Severe	23	42	17	38	3	7	30
	High	9	16	7	15	4	9	14
	Moderate	8	15	7	15	3	7	13
	Low	5	9	7	15	21	49	23
	No Impact	10	18	8	17	12	28	20

4.5.3 Impacts of disasters on agricultural production, income and migration

Since the majority of people in the study area depend upon agricultural activities, probit regression analysis was used to test the impact of disasters on agricultural production (Table 4.8). The analysis showed that the probability of agricultural production decreased significantly (10% level) for agricultural farmers compared to other occupation. Further, the probability of agricultural production decreased significantly (1% level) due to cyclones and tidal flooding.

Table 4.8: Effect of disasters on agricultural production

Agricultural production (decreased 1, increased 0)	Coef.	Std. Err.	z	P>z
Age (years)	0.01	0.01	0.88	0.38
Gender (male 1, female 0)	-0.02	0.40	-0.06	0.95
Family size (number)	0.13	0.06	2.1	0.04
Occupation farmers (1 if agricultural farmer, otherwise 0)	0.64	0.37	1.76	0.08
Occupation service and business (1 if service and business, otherwise 0)	0.32	0.34	0.94	0.35
Cyclone(1 if have any negative impact, otherwise 0)	0.85	0.24	3.56	0.00
Tidal flood (1 if have any negative impact, otherwise 0)	0.86	0.32	2.65	0.01
Salinity (1 if have any negative impact, otherwise 0)	0.22	0.25	0.89	0.37
Constant	-2.63	0.73	-3.63	0.00

The probability of overall income of the respondents decreased significantly (10% level) for agricultural farmers compared to other occupation (Table 4.9). The probability of overall income has also decreased significantly because of cyclones and tidal surges at the 1 and 4 percent levels, respectively.

The probability of outward migration increased significantly (10% level) for farmers. Further, migration probability increased due to tidal floods significantly at a 5 percent level (Table 4.10).

Table 4.9: Effect of disasters on income of the respondents

Overall Income (decreased 1, increased 0)	Coef.	Std. Err.	z	P>z
Age (years)	0.01	0.01	1.32	0.19
Gender (male 1, female 0)	-0.72	0.40	-1.81	0.07
Family size (number)	-0.01	0.06	-0.26	0.79
Occupation Farmers (1 if agricultural farmer, otherwise 0)	0.65	0.36	1.8	0.07
Service and business (1 if service and business, otherwise 0)	0.37	0.34	1.07	0.28
Cyclone (1 if have any negative impact, otherwise 0)	0.68	0.23	2.89	0.00
Tidal flood (1 if have any negative impact, otherwise 0)	0.64	0.31	2.05	0.04
Salinity (1 if have any negative impact, otherwise 0)	0.25	0.24	1.03	0.30
Constant	-1.17	0.67	-1.76	0.08

Table 4.10: Effects of disasters on human outwards migration

Outward migration (yes 1, no 0)	Coef.	Std. Err.	z	P>|z
Age (years)	-0.01	0.01	-0.56	0.58
Gender (male 1, female 0)	-0.51	0.55	-0.94	0.35
Family size (number)	0.15	0.06	2.26	0.02
Occupation Farmers (1 if agricultural farmer, otherwise 0)	0.94	0.51	1.84	0.07
Service and business (1 if service and business, otherwise 0)	0.79	0.49	1.62	0.10
Cyclone (1 if have any negative impact, otherwise 0)	0.47	0.29	1.63	0.10
Tidal flood (1 if have any negative impact, otherwise 0)	0.99	0.50	2.00	0.04
Salinity (1 if have any negative impact, otherwise 0)	-0.18	0.28	-0.63	0.53
Constant	-2.76	0.82	-3.36	0.00

4.5.4 Consequential effects of disasters

Respondents from FGD's mentioned that both cyclone and tidal surges caused devastating effects, which ultimately led people to change their place of residence and their occupation. All other disasters, including drought, irregular rainfall, salinity and water logging have had similar effects and as a result, caused changes in the overall livelihood pattern (Table 4.11).

Table 4.11: Disasters and their consequential effect on the study area

Disasters	Occurrences in last 20 years		Effects		Adaptation strategies	Remark
Cyclone\Tidal flood	2 times	Destruction of house and properties	Destruction of paddy and other agricultural crops	Cattle and fish decrease	Taking loan from bank or microcredit NGO's and migration to other places	From 2009 to 2011 there was no production of crops in the field, most of the people were involve in cutting soil
Drought	From 2001 to present, every year in summer	Scarcity of irrigation and drinking water	Damages of crops	Death of shrimp fry and growth of shrimp reduced	Nothing	Nothing
Irregular rainfall	1 time excessive rainfall	Damage of crops for excessive rainfall	Water logging	-	Nothing	Nothing
Salinity	Increasing from the year 2000	Crop production reduced	Shrimp growth hampered	Reduction of native tree species	New verities (Hybrid) crop cultivation	Nothing
Water logging	Occurring occasionally from the year 2000	Damage to the agricultural crops	Death of cattle and destruction of trees	Loss in fish culture	Nothing	Due to drainage congestion

4.5.5 Diseases outbreak after disasters

Respondents mentioned about various disease outbreaks after the latest cyclone Aila in 2009. Most of the respondents (91 and 95 percent) were affected by diarrhea and headache, and 92 percent of the respondents were affected by dysentery, pneumonia and jaundice. Skin diseases, typhoid fever and viral diseases of the eye have been experienced by almost 67, 57 and 44 percent respondents, respectively (Table 4.12).

Table 4.12: Diseases outbreak after latest disaster (Cyclone Aila 2009)

Diseases After (Aila)	Frequency	Percent (Multiple Value)
Diarrhea	132	91
Cholera	12	8
Skin Diseases	98	68
Chicken pox	18	12
Typhoid /Fever	83	57
Headache	138	95
Viral diseases of eye	64	44
Dysentery, Jaundice and Pneumonia	133	92

4.6 Migration in the study area and their causes

About 21 percent of the respondents mentioned they had migrated within the last 13 years. In Shyamnagar union, 96 percent of the respondents mentioned that there was no outward migration from 1999 to 2012 (Table 4.13). The principal causes behind outward migration (Table 4.14) are job and income, as mentioned by almost 16 and 13 percent of the respondents, respectively.

Table 4.13: Outward migration in study area

Area	Shyamnagr Union		Koikhali Union		Nildumur Union		All
Outward migration	N	%	N	%	N	%	%
Yes	2	4	8	17	19	44	21
No	53	96	38	83	24	56	79

Table 4.14: Causes of outward migration in study area

Causes of Migration	Frequency	Percent (Multiple Value)
Job	23	15.9
Income	19	13.1
Natural Disasters	15	10.3
Others (River Bank Erosion, Better Life and Education)	17	11.7
No Migration	92	63.4

4.7 Changes in tree and fish species

Most respondents (93 and 92 percent) from the household survey mentioned that tree and fresh water fish species decreased between1999 and 2012 (Table 4.15). The main reason behind these changes was salinity intrusion and occurrences of cyclone, as mentioned by respondents from the FGD.

Fish species became extinct from the study area within last 13 years are Rui (*Labeo rohita*), Katla (*Catla catla*), Climbing perch (*Anabas testudineus)*, Snakehead murrel (*Channastriata*), Walking catfish (*Clarias batrachus*), Puntio barb (*Puntius puntio)*, Spotted snakehead (*Channa punctata)*, Wallago (*Wallagoattu*), Tengra (*Batasio batasio*).

Type of tree species became extinct from the study area are Mango (*Mangiferaindica*), Lime (*Cytrusaurantifolia*), Jackfruit (*Artocarpus heterophyllus*), Coconut (*Cocos nucifera*), Papaya (*Carica papaya*), Guava (*Psidiumguajava*), Betel nut (*Areca catechu*), Palmira palm (*Borassus flabellifer*), Sapota (*Manilkara achras*), Tamarind (*Tamarindus indica*), Babla (*Acacia nilotica*), Jamun (*Syzygium cumini*), Indian lilac (*Azadirachta indica*), Mahogany (*Swietenia macrophylla*), and most of the flower trees.

Table 4.15: Changes in tree and fish species from 1999 to 2012 (according to respondents) in study area

Category	Tree species (%)	Fish species (%)
Increased	3	4
Decreased	93	92
No change	4	4

5. DISCUSSION

5.1 Changes in land-use and land-cover in the study area from 1999 to 2012

Changes area prominent feature in the land-use and land-cover of any social-ecological system. It is not possible to keep any social-ecological system constantly unchanged. Humans are changing the land-cover continuously to cope with the changing environment. Land-use has been changed rapidly and drastically all over the world over the last few decades (Xing et al. 2006). From the satellite image analysis, it is also evident that very significant land-cover change (positive and negative) has occurred in the study area within the last thirteen years. Increases have occurred in the water bodies category because shrimp culture ponds have increased. Increases have also occurred in the built-up and bare land category. Built up areas increased due to an increase in population, but this does not explain increases in the bare land category. Bare land might increase due to the secondary effects of various disasters. For example, water logging occurs in the study area due to tidal surges and floods. Because it is surrounded by coastal embankments, the natural drainage system is blocked due to dams or polders, land grabbing, siltation and decreases in upstream water flow and, as a result, salinity intrusion occurs in agricultural land and other areas. Thus, most of the lands of the area have become unproductive for any use due to long-term inundation by saline water resulting in increases in the bare land category. UN-HABITAT reported that because of high intensity disasters, large parts of an area may become uninhabitable due to long-term inundation (UN-HABITAT 2010).

Decreases occurred in the agricultural land category due to an increase in shrimp culture ponds in the area. The FGDs showed that agricultural land has been converted to shrimp culture ponds for economic, social and political reasons. Decreases have also occurred in the vegetation category, including trees and mangrove forest. This may be due to occurrences of both natural disasters and other anthropogenic activities. Respondents from the household survey also mentioned that tree species have decreased as a result of cyclones. Salinity intrusion due to shrimp farms is another reason for destruction of trees, as the forest is cleared to cultivate shrimp (Haque et al. 2008).

Respondents from the FGDs mentioned other land-use changes in the study area, including increased urbanization and land degradation. Urbanization increased due to population pressure, while land fertility and plant production yields both decreased due to increased salinity levels.

Natural drainage systems, dams and polders decreased due to congestion in the canals, land grabbing, river bank erosion and storm surges.

5.2 Effects of land-use changes

Ecosystems provide various services, including biodiversity and other resources such as food, fiber and water for human society. Land-use change modifies the capability of the ecosystem to provide those services in the future. Unsustainable land-use directly affects biodiversity and contributes to global climate change (Chase et al. 2000). If ecosystem services and livelihood systems are altered by land-use change, this may cause land degradation and thus impact the social-ecological system. Unsustainable shrimp culture can negatively affect the resilience of the social-ecological system. Destruction of habitat and biodiversity of fish species by shrimp fry collectors catching fry from rivers adjacent to Sundarban is an activity which affects the ecosystem (Islam & Ahmed 2001). Construction of shrimp ponds and infrastructure for shrimp farms is the main reason behind the intrusion of saline water in the study area. Within four decades, the salinity of the study area has increased by 3.02 percent (Miah 2010). Soil degradation has occurred as the salinity has increased in the soil and water body which in turn leads to deforestation (Islam et al. 2004). Respondents from the FGDs mentioned that the rice fields associated with the shrimp farms became infertile due to salinity intrusion. Large shrimp farmers purchase those infertile lands for little money and leave the poor farmers landless, creating social conflict (Tutu 2004). This salinity intrusion has made the people dependent on rice imports from other parts of the country and subject to food insecurity and malnutrition (Islam & Ahmed 2001). Shrimp culture has also accelerated the process of eutrophication and pollution in the surrounding area from run-off or seepage of nutrients, release of sewage, the use of veterinary products and from feed added to the ponds. Various water-borne diseases have occurred as this pollution reaches the fresh water reservoirs.

Some forest areas in the study area have also disappeared due to shrimp farms, as the image analysis and household survey suggest. Most of the local tree species have become extinct, affected by other land-use change outcomes such as water logging and salinity intrusion. Also, most of the fresh water fish species have become extinct as the salinity level of surface and ground water has increased.

5.3 Drivers behind major land-use changes

Respondents from the FGDs mentioned four types of driver (social, economic, political and natural) behind the major land-use changes which have occurred in the study area. Respondents identified economic drivers as the primary reason because shrimp culture is more profitable than paddy culture. Shrimp has a high value in the international market, and the local economy is increasingly connected to the international shrimp product chain. Social drivers are the second reason identified by the respondents because, due to social conflict, many farmers have been forced to initiate shrimp culture in the first place. Upazila Sub Assistant Agriculture Officer (SAAO), Md Modaasor Billah, also mentioned this during a personal interview:

> "*Most of the areas of Shyamnagar were used for paddy cultivation before but, after the introduction of shrimp culture in this region, some farmers started to cultivate shrimp in their paddy field as it is more profitable than paddy culture. Other farmers were forced to start shrimp culture on their paddy fields as the salinity level increased in the surrounding areas of shrimp ponds. As a result, agricultural land decreased over time and shrimp culture ponds increased*."

Political drivers are the third category suggested by local people. Some powerful people with political shelter have forced the small farmers to lease their lands, and in some cases even land grabbing has occurred. Natural drivers are the last reason identified by the respondents. They reported that cyclone and tidal floods have destroyed the paddy fields by increasing salinity, thus making them suitable only for shrimp culture. Also, natural drivers have caused the destruction of trees which has led to changes in land-cover. From the analysis, it is evident that the bare lands category has increased due to natural drivers.

5.4 Effects of disasters on the study area

Disasters are common in the study area, as discussed in the literature review. An overview of occurrences is given in the Appendix (8.3). These disasters are the outcome of both natural and anthropogenic activities. The social-ecological resilience of the study area has also been affected due to disasters. For example after the latest disaster, cyclone Aila in 2009, most of the fresh water sources were contaminated due to salinity intrusion by sea water and water logging (Kumar et al. 2010). Respondents to the household survey mentioned that many people are still drinking saline water. Some of them have access to potable water, but they have to walk 8 to 10 kilometers from their home to collect water. They also mentioned that most suffered from several types of diseases after that event, and that the duration of diseases was more prolonged than before. Previous studies suggested that extreme disaster events like cyclone, drought, rainfall and major floods could cause the spread of diseases (Epstein 1999; Milly et al. 2002). There was no crop production in the year 2010, due to salinity intrusion (Kumar et al. 2010), and subsequently in 2011 the crop production was also lower. The majority of the respondents to the household survey mentioned the destruction of all their household trees due to the disaster. Most native fresh water fish species also became extinct due to saline water intrusion in the surrounding water bodies. Many poor people are still living on the embankment or on the land provided by the government. Some respondents mentioned that they had shrimp culture ponds before the cyclone, but all the ponds were flooded by the tidal flood. They failed to start the culture again because they do not have sufficient money. In the study area, about 70 percent of families depend on agriculture, including cropping, livestock, fishing and forestry (BBS 2001). The analysis proves that, due to various disasters the probability of overall income and agricultural production significantly decreases for those families who are dependent on agriculture. This is due to the fact those families who are extremely poor cannot adapt to the immediate after-effect of disasters. Also, there is no agricultural insurance system in Bangladesh like that in developed countries. Thus, they are forced to change their occupation and, as a result, overall income decreases.

5.5 Causes of migration in the study area

Almost 21 percent of people from the household survey observed outward migration in the study area. Most of the outward migration was observed in the Nildumur union because it was more badly affected by the disasters than the other two unions. Outward migration means movement from one area to another. Respondents also mentioned the causes of migration; the majority of people mentioned job and income as the primary reasons behind migration. Almost 11 percent of respondents to the household survey mentioned natural disasters as a reason behind migration. Also, the analysis shows that the probability of migration increased significantly for farmers. This is due to conversion of agricultural land to shrimp culture; marginal farmers are more affected because shrimp culture requires less employment. Respondents from the FGDs also mentioned that, due to land-use change, most poor farmers have been forced to quit their occupation and have migrated to other places to find a job. Some migration has also occurred due to disasters. Tidal flood has significant effects on migration because it causes water logging and salinity intrusion and thus destruction of houses, properties, agricultural crops and shrimp ponds. As a result, people have been forced to migrate to other safer places for a better job and income.

5.6 Resilience and vulnerabilities of the study area

5.6.1 Social-ecological resilience and thresholds

It is difficult to identify the level of resilience in the social-ecological system of the study area because of the complexity and uncertainties in these regime dynamics. Indicators of social and ecological resilience include habitat fragmentation, the number of endangered species, reduction in soil biological activity, lack of alternative water resources, international isolation, forced outward migration, loss of traditional knowledge and lack of institutional memory (Renaud et al. 2010). It is not possible to identify all these indicators of the social-ecological system in the findings of this study. Only a few of these indicators can be explained. For example, habitat fragmentation, extinction of fish and tree species, land degradation, drinking water scarcity and outward migration all occurred in the study area, as the findings suggest. These changes in the study area and their causes can be looked upon as disturbances of the social-ecological system. Disturbances may be external and internal, where external disturbances are disasters and land-use changes caused by natural factors, and internal disturbances are those changes in land-use due to social, political and economic factors. These changes adversely affect not only social-ecological resilience but also the people and their livelihoods. All the findings indicate that the social system is fairly flexible in managing resilience. It can therefore be said that the area’s social-ecological resilience was severely affected by disasters and land-use changes.

The thresholds of social-ecological systems are complex to determine when considering the multi-scale interactions (Renaud et al. 2010). According to Resilience Alliance (RA), thresholds characterize the shift of a social-ecological system from one state to another alternate state (Quinlan 2007). The state of the social-ecological thresholds of the study area can be explained by the effects of both unsustainable land-use and disasters. Various shifts in the social-ecological system of the study area also occurred, including salinity intrusion, land degradation, decreasing vegetation, extinction of native tree and fish species, decreasing numbers of cattle, scarcity of drinking water and the lowering of ground water aquifers. In addition, overall income and agricultural production decreased significantly and outward migration occurred in the study area, while respondents from the FGD's and the household survey mentioned that production of paddy has increased this year compared to the previous two years. To cope with the rising salinity problem, farmers are now using new varieties of crops (BR28, BR60) known as high yielding variety (HYV) crops. Most people who migrated to other areas to look for a job and work have recently come back. Therefore, it can be said that the specific social-ecological system considered here has not passed the thresholds (the breaking point of an ecosystem), as regeneration of the social-ecological system is occurring, although some components of the system have been severely affected. For example, after the 2004 tsunami in Sri Lanka, there was a serious effect on the social-ecological system, even though the local people continued their livelihoods despite the rising salinity problem (Renaud et al. 2010).

5.6.2 Vulnerabilities of social-ecological system

Vulnerabilities occur when communities or people in a social system are exposed to stress and unable to cope effectively with the stress (Adger 2006). As discussed earlier, vulnerabilities depend not only on resilience but also on sensitivity and exposure to disasters. From the findings, it is not possible to explain whether sensitivity and exposure are high or low but rather an overview of their condition was obtained. Sensitivity depends on income, occupation, household structure, infrastructures and the condition of the coastal vegetation. From the findings, the income and agricultural production of the study area have decreased significantly within the last 13 years. About 90 percent of house structures comprise mud, wood, bamboo and tin (BBS 2001). Most roads are constructed from mud and are damaged very easily during cyclones and tidal surges. The area was abundant with wetlands and various trees a few years back but these have now all decreased, as the image analysis confirmed. On the other hand, exposure depends on the location of the area (the impact zone of coastal disasters) and the extent to which the area is affected by disasters. The study area is situated in a high risk zone of cyclone and tidal surges, as the area is close to the Bay of Bengal (Appendix 8.4). From the findings and analysis, it is evident that land-use changes coupled with extreme disasters have increased the vulnerability of the social and ecological system. Figure 5.1 represents the outcome vulnerability of the study area due to exposure to various events, where both human and natural causes affect the social-ecological system.

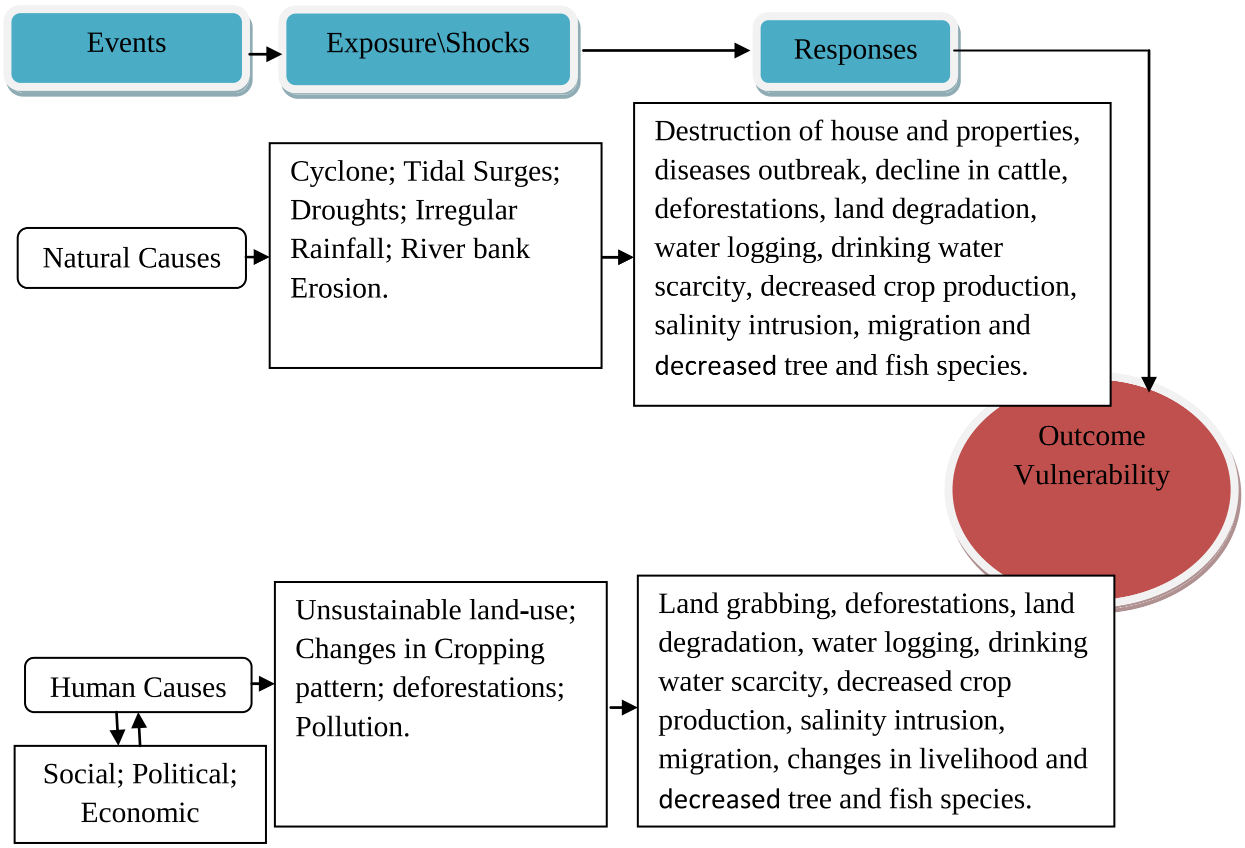

Figure 5.1: How disasters and LULCC increasing Vulnerability (Adapted from O'Brien et al. 2007)

6. CONCLUSIONS

This study found that Shyamnagar is prone to various land-use changes, which are sometimes exacerbated by various effects of disasters. The drivers behind those land-use changes are both natural and anthropogenic. From the findings, it can be said that significant changes occurred in land-use on Shyamnagar and its surrounding areas, of these the major change included conversion of agricultural land to shrimp culture ponds. Forest resources were also converted to shrimp culture ponds and agricultural lands. Outward migration also occurred. These were all due to combinations of various social, economic and political factors in addition to natural disasters.

The study showed that the social-ecological system of Shyamnagar became vulnerable due to unsustainable land-use, especially in the face of natural disasters. By changing the land-use, local land users exposed the social-ecological system to various hazards, such as salinity intrusion, changes in livelihood, drinking water scarcity, deforestation, land degradation, and decline in native fish species and cattle. The evidence from the study suggests that if people continue to destroy the buffer zones and increase those activities rendering the system vulnerable, then the system might exceed its critical thresholds; and if the social-ecological system is struck again by high intensity natural calamities in the future, then it might collapse entirely.

The findings of this study enhance the understanding of resilience and vulnerability studies by considering both disasters and land-use changes. The findings might also be relevant to all the south-west coastal areas of Bangladesh. Since most of the coastal areas of south-west are vulnerable to disasters, whereby changes in land-use are prominent and similar throughout the coastal ecosystem.

Since the vulnerability of the social-ecological system has increased, it would appear to be necessary to enhance the resilience of the system for maintaining its functions properly. This study's findings do not support any conclusive remarks as to how resilience should be enhanced, but emphasize that there are challenges involved in managing and building resilience. Further research is required to investigate how to manage and enhance resilience for sustainability and also increase the adaptive capacity of the area's social-ecological systems.

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8. Appendices

8.1 Appendix 8: Household questionnaire

8.1.1: General background information

Date of interview	
Start time	
Name of interviewee	
Age	
Gender	
Occupation	
GPS measure (coordinate)	N……………… E…..………………
Address	
Total number of family members	F............... M............
Members able to read and write	

Category of family:

	Single	Joint	Others	Causes of changes the category of family
1995				
2005				
2012				

**Causes of changes

1= Due to natural disasters the family members go away for better place to live or opportunity 2= Due to conflict among the family members 3= Due to marriage of their daughter/ sister 4= Searching for better and higher income jobs 5= Due to higher education or occupation place 6= Others (please specify)

8.1.2: Information on Migration

Have anyone migrated from here or to here?

a. Yes b. No

If Yes, then

Name (If known)	From where	Year	Reason	To where

1= Insufficient job facility, 2= Monthly income is very low, 3= Natural disasters damaging houses and property, 4= Lack of social security, 5= Land fertility has declined, 6= Loss of property specially land 7= Cultivation has been disrupted due to Natural disasters 8= Higher education 9= Others (please specify)

Household level effect due to climatic refugee

	Before In Migration/ Out Migration	After In Migration/ Out Migration
Space per person		
Income		
Expenditure		
Savings		

8.1.3: Information on Property

.... (Bigha).............Ha

(a) Ownership pattern of the household head:

1. Owner	☐	2. Tenant	☐	3. Gift	☐	4. Govt.	☐

If the owner, then answer the following questions

(b) Amount of land and their present value

Year / Purpose	Amount of land (Katha/Bigha/Ha			Present value per unite of land (K/B/H)
	1995	2005	2012	
1. Homestead				
2. Agricultural land (In terms of Quantity)				
3. Croping intensity of Agricultural land				
3. Commercial land				
4. Shrimp pond				
5. Vegetation				
6. Water body				
7. Other				
Total:				

(c) Do you have any shrimp culture land (Ghare)? Yes /No, If yes then,

(d) Total amount of land for this purpose___

Year / Ownership	1995		2005		2012	
	(√/×)	Bigha (Ha)	(√/×)	Bigha (Ha)	(√/×)	Bigha (Ha)
1. Owned land						
2. Lease in land						
3. Lease out land						
Total land						

(e) How this land was being used before shrimp culture?

1. Forest land 2. Paddy land 3.Vegetation land 4. Other crop land 5. Grazing land 6. Fishing

7. Other?

8.1.4: Information about Effects of Natural Disasters

Occurrences of Natural Disaster previous 10 years

What types of disaster mostly affect this area?

No	Type	Rating (1-9)
1	Cyclone	
2	Storm surge	
3	Arsenic pollution	
4	Salinity intrusion	
5	Flood	
6	Earthquake	
7	Drought	
8	Sea-level rise	
9	Water logging	

Some questions to detect impact of natural disaster

- Has income increased/decreased in the last 15 years?
- Has overall agricultural production increased/ decreased in the last 15 years?
- Is your physical/economical condition improved or declined in the last 15 years?
- Opportunity to work, especially for women, has increased/decreased in the last 15 years?
- Economic condition of the farmers in the last 15 years has changed positively/negatively?
- Have tree species increased or decreased in the last 15 years? Which one is the most affected (please specify and rate)
- Have fish resources increased or decreased during last 15 years? Which one is the most affected (please specify and rate)

- What is the present situation of agro-forest and social forest?

Slight affected b) severely affected c) affected not at all?

- Which type is agricultural crops is mostly affected (please specify)
- What kind of farming system are you practicing to combat with Disasters?
- What was your step for recovering your agricultural loss? (If you have any)
- Do you think there is any impact of natural disaster on your current farming system?
- Has salinity been increasing in this area? (Yes/no)
- If yes then what is the main reason behind increasing salinity (please specify)

Types of diseases outbreak after disasters and intensity of sufferings:

Year / Nameofdiseases	√/×	Duration Day
1. Diarrhea		
2. Cholera		
3. SkinDiseases		
4. Chickenpox		
5. Typhoid /Fever		
6. Headache		
7. Viraldiseasesofeye		
8. Other		

Have your family been affected by any kind of disasters? (which type)

a. Yes   b. No

If yes, then answer the questions:

Losses (Units)	Numbers			Spending Money for the recovery		
	1995	2005	2012	1995	2005	2012
1. Death people (Number)						
2. Casualties (Number)						
3. Houses destroy (Floor space)						
4. Furniture (Tk.)						
5. Livestock (Number)						
6. Trees (Numbers)						
7. Agricultural sector (Tk.)						
8. Shrimp cultural (Tk.)						
9. Fisheries sector (Tk.)						
10. Local road repair (m..)						
11. Others						

8.2 Appendix 2: FGD Questionnaire

8.2.1 Information on Land-use and Land cover change

8.2.1.1 Changes in practices and their causes (1999, 2005, 2012)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cropping pattern												
Cropping intensity												
Changes in Gher												
Others												

**Causes: 1. Disasters, 2.Economic, 3.Demographic, 4.Political 5.Others

8.2.1.2 What major type of land use occurred in this area in the last 20 years? **(please describe; +, - & No change)**

Shrimp pond (Gher)	
Cropping pattern	
Deforestation	
Agriculture development	
Drainage	
Dam (polders)	
Urbanization	
Road construction	
Land Degradation	
Salt Cultivation	
Others	

8.2.1.3 What are the major factors that are causing land-use change in order of importance (please explain)

Political	
Natural	
Economical	
Demographic	
Institutional	
Others	
Social Conflict	

8.2.1.4 What are the major changes in land use in present time (area + quantity)

Land Use Change Typology	Social	Economical	Political	Disaster	Demographic
Agri-Gher					
Forest-Agri					
Shrimp-Crab/salt					
Agri-Marshy					

Indicator: √; to find out the level of magnitude, frequency of symbol will be increased eventually. And where there is no correlation number of symbol will be zero in terms of counting.

8.2.1.5 Describe land lost or additional land gained during the last 20 years and associated factors?

Time Frame	Land Lost	Land Gain	Land cover change	Reasons	Factors
1995-2000					
2000-2005					
2005-2012					

8.2.1.6 Describe new practices & policies that influence land management in your locality at different points in time and their impact?

Last 5 years:

Between 5 and 10 years ago:

Between 10 and 20 years ago:

8.2 Information on Disasters:

Disasters	Occurrences in last 20 years	Effects			Adaptation Strategies/ Link to land-use change (if any)
		1	2	3	
Storm Surge					
Cyclone					
Drought					
Irregular Rainfall					
Salinity					
Increasing temperature					
Water logging					
Others					

8.3 Appendix 3: List of occurrences of natural disasters on last 13 years

Table 8.3.1: Occurrences of natural disasters on the coastal areas of Bangladesh and their impacts

Year	Disasters	Affected District	Upazila	People	Crops damaged Fully(Acre)	Crops damage (Partially) (Acre)	No. of House damage Fully	No. of House Damage (Partially)	No. of Dead People	No. of Dead Livestock, cattle's and goats	Road Damage Fully (Km)
2007	Cyclone (SIDR)	30	200	8923259	743322	1730317	564967	957110	3363	1778507	12723
2009	Cyclonic storm (Aila)	11	64	3928238	77486	245968	243191	370587	190	150131	4588

Source: Disaster Management Bureau (2012)

8.4 Appendix 4: Cyclone and tidal surge risk areas of Bangladesh

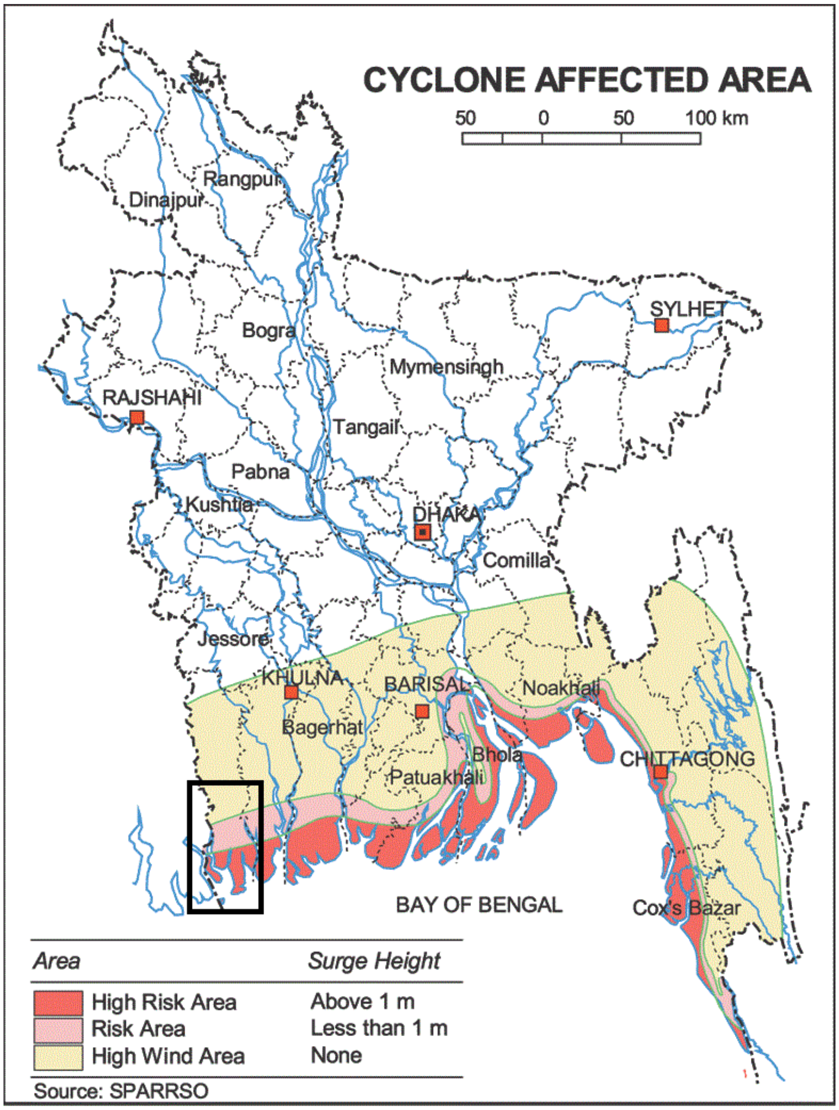

Figure: Cyclone and storm surge risk areas of Bangladesh. Black box represents Shyamnagar Upzila (BDKN 2009).