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Climate Change Impacts and Vulnerability Assessment in Coastal Region of Bangladesh: A Case Study on Shyamnagar Upazila of Satkhira District

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Abstract: Coastal areas are more vulnerable to climate change and natural disasters. Due to increased weather extremes caused by climate change, the coastal communities fall at high risk of casualties and damages. According to DPSIR (Driver – Pressure – State – Impact –Response) framework, population, fisheries, aquaculture, agriculture and tourism are the main drivers of climate change at coastal Shyamnagar upazila which caused several social, financial, environmental and physical impacts. As most of the people are poor and living below the poverty line, the situation becomes worse during and after any climatic hazards. Natural capital, local economy, water and natural disaster etc. are more vulnerable components at the study area in terms of Livelihood Vulnerability Index (LVI) as people are dependent on natural resources from Sundarban for livelihood. IPCC framework of LVI was also determined for this study. The order of LVI for studied unions are: Gabura (0.027)>Padma Pukur (0.0264)>Munshiganj, Kaikhali, Kashimari (0.0242)>Buri Goalini (0.020)>Atulia (0.0172)>Bhurulia (0.0108)>Ishwaripur (0.0105)>Ramjannagar (0.0102)>Nurnagar and Shyamnagar (0.003). According to the index values, the situation is worse at Gabura and Padma Pukur unions. However, most of the unions are highly vulnerable to climate change impacts in terms of exposure and sensitive components which have also exceeded the adaptive capacity.

Keywords: Vulnerability index; DPSIR; Coastal region; Climate change; Bangladesh.

Introduction

Bangladesh is frequently cited as one of the most vulnerable countries to climate change (Huq and Ayers, 2007; UNDP, 2007; Rahman and Alam, 2003; Huq, 2001) because of its disadvantageous geographic location; flat and low-lying topography; high population density; high levels of poverty; reliance of many livelihoods on climate sensitive sectors, particularly agriculture, fisheries; and inefficient institutional aspects (Climate Change Cell, 2006). Many of the anticipated adverse effects of climate change, such as sea level rise, higher temperatures, enhanced monsoon precipitation, and an increase in cyclone intensity will aggravate the existing stresses that already impede development in Bangladesh, particularly by reducing water and food security and damaging essential infrastructure (MOEF, 2005). These impacts could be extremely detrimental to the economy, environment, national development and the people of Bangladesh (Reid and Sims, 2007). In the foreseeable future, Bangladesh is likely to be one of the most vulnerable countries of the world in the event of climate change. A number of studies on the impact

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of climate change in Bangladesh exist. Notable among them are those of Mahtab (1989), BCAS (1994), BUP (1994) and Bangladesh Climate Change Country Study Programme (1997).

Vulnerability to climate change and variability has been defined by various authors as the extent to which a system or society is prone, or at risk to, and unable to deal with the negative effects of climate change and variability (FAO, 2006, 2008; IPCC, 2007; Schneider et al., 2007; UNEP, 2009). Vulnerability to climate change depends on the rate of change of the climate and the extent to which a system is exposed, its sensitivity, and adaptation capacity (IPCC, 2007; FAO, 2009; UNEP, 2009). Sensitivity is the extent to which a system is either negatively or positively, directly or indirectly affected by climate change and variability (IPCC, 2007); and adaptation capacity is the ability of a system to reduce to moderate levels, the potential effects of climate change and variability by either taking advantage of existing opportunities or undertaking measures to deal with its consequences (IPCC, 2007; FAO, 2009). Most of the climate change impacts in Bangladesh are likely to come from the south that is, the Bay of Bengal and the adjoining North Indian Ocean. These ocean current are the sources of tropical cyclones, storm surges, coastal erosion, monsoon wind, evaporation for monsoon rainfall, floods and salinity intrusion. So, coastal areas of Bangladesh are more vulnerable to global climate change. For policy implementation and enhance capacity building with the impacts of climate change at national level, it is necessary to identify the vulnerable groups and areas. Considering these, the present study aims to assess climate change impacts and vulnerability in Shyamnagar upazila of Satkhira district, as it is the most impacted areas of recent devastating climatic events i.e., cyclone Sidr in 2007 and Aila in 2009.

Materials and Methods

Study Area

Shyamnagar upazila is located between 21°36′ and 22°24′ north latitudes and between 89°00 and 89°19′ east longitudes (Figure 1). It has a population of 2,65,004 with an average literacy rate of 28.1% (BBS, 2011). It consists of 12 union parishads, 127 mouzas and 216 villages. The socio-economic condition of Shyamnagar is not so good, because the local economy depends on fishing, shrimp farming, agriculture and natural resources of Sundarban. Main occupation of the

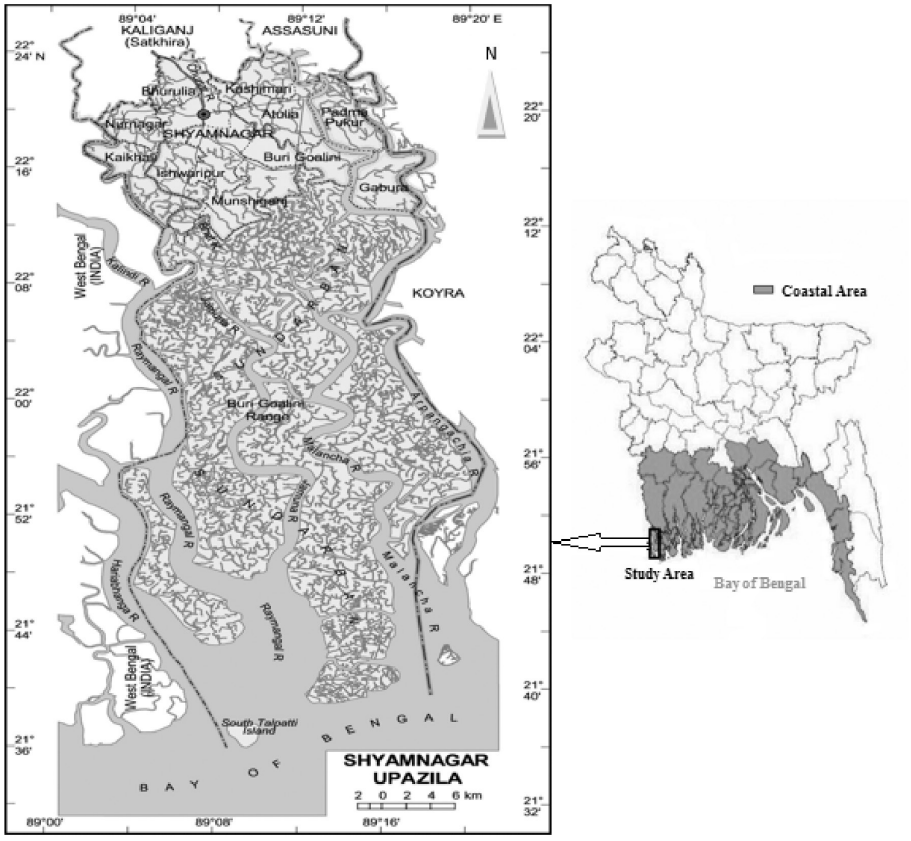

Figure. 1: Map of the study area.

study area is agriculture (32.93%), agricultural labour (25.81%), and wage labourer (6.21%), forestry (2.34%), fishing (5.5%), transport (1.61%), commerce (10.11%), service (3.38%) and others (12.11%) (BBS, 2011). Various types of natural disaster such as—cyclone, storm surge, flood, tidal wave and salinity intrusion are very common phenomenon in this region (Islam et al., 1998; Ahmed, 2006; Pender, 2008).

Impact Assessment Approach

DPSIR (Driver–Pressure–State–Impact–Response) is a conceptual framework to understand the connections among different indicators of environmental and social systems developed by the European Environmental Agency (EEA) in 1999 (EEA, 1999). The advantage of this framework is being able to clarify and analyze complex multi-sectoral inter-relationship for impact assessment. DPSIR framework was used after simple modification of its components for coastal Shyamnagar upazila.

Approaches to Measure Vulnerability

Econometric and indicator approaches are two techniques commonly employed to measure vulnerability to climate change (Deressa et al., 2009). The econometric technique employs the use of econometric methods such as regression analysis. The challenge of this approach is the problem of testing various econometric assumptions regarding standard errors, hypotheses and confidence intervals as well as imputing causality without making stringent assumptions. This study therefore adopts the indicator approach in measuring the vulnerability to climate change. Vulnerability indicators provide a potentially useful means of monitoring vulnerability over time and space, identifying the processes that contribute to vulnerability, prioritizing strategies for reducing vulnerability, and evaluating the effectiveness of these strategies in different social and ecological settings (Adger et al., 2009). This study uses the Livelihood Vulnerability Index (LVI) developed by Hahn et al. (2009). Several variables are used to capture the level of exposure to natural disasters and climate variability, adaptation capacity of households and their sensitivity to climate change impacts (Hahn et al., 2009). This index is easier to compute because with the exception of precipitation and temperature data, it uses primary data from households.

Livelihood Vulnerability Index (LVI)

According to Hahn et al. (2009), LVI contains seven major components i.e., Socio-Demographic Profile (SDP), Livelihood Strategies (LS), Social Networks (SN), Health (H), Food (F), Water (W) and Natural Disaster (ND). The above index was revised by adding Natural Capital (NC) in view of the prevailing conditions of the sample households, obtained from the Bihar Statistical Handbook (Bihar Department of Planning and Development, 2011). In this study combinations of all components were used to assess vulnerability of 12 unions of the study area. UNDP (1990) also used similar components to vulnerability assessment. Each comprised several sub-components or indicators as shown in Table 1. These indicators directly as well as indirectly represented household's capacity to cope with climate change impacts. The dimensions of vulnerability were assessed on a scale of 0 to 1 with equal weight to all associated indicators, similar to Pandey and Jha (2012). To calculate the vulnerability index, they used a balanced weighted average approach where each indicator contributes equally to the overall index though each component comprised a different number of indicators. As each indicator was measured on a different scale, at first standardized each as an index using the following equation:

$$\text{Index } X_{ij} = (X_{ij} - \text{Min } X_i)/ (\text{Max } X_i - \text{Min } X_i)$$

where Index X_{ij} is the index value (i.e. 0 to 1) of the sub-component or indicators for union j, X_{ij} represents the value of the i^{th} indicator for each union, and Max X_i and Min X_i manifest the maximum and minimum value of the i^{th} indicator among all the unions. After all the indicators are indexed, the indicators had been averaged to calculate the value of each major components using:

$$M_j = \Sigma_{i=1}^{n} \text{Index } X_{ij} / n$$

where M_j is the components (SDP, LS, SN, NC, H, F, W and ND) of vulnerability. Index X_{ij} is the index value of the i^{th} indicators for union j and n is the number of indicators in each major component. Finally each of the eight major components was calculated using following equation.

$$\text{Livelihood Vulnerability Index (LVI}_j) = \frac{\sum_{i=1}^{n} W_{mi} M_j}{\sum_{i=1}^{n} W_{mi}}$$

It can also be expressed as:

$$\text{LVI}_j = \frac{W_{SDP}SDP_j + W_{LS}LS_j + W_{SN}SN_j + W_{NRE}NRE_j + W_H H_j + W_F F_j + W_{ND}ND_j}{W_{SDP} + W_{LS} + W_{SN} + W_{NRE} + W_H + W_F + W_{ND}}$$

Vulnerability index equals the weighted average of all the components. W_{mi}, or weights of each of

Table 1: Description of IPCC (2001) contributing factor, major components and indicators of vulnerability

IPCC contributing factors of vulnerability	*Major components*	*Indicators*
Adaptive capacity	Socio-demographic profile (SDP)	Dependency ratio (% of population below 15 and over 65 years of age).
		Percentage of female headed household (If a male head is away from home >3 months per year).
		Percentage of households where head of the household had not attended school.
		Percentage of households where members had any formal or informal skill.
		Average family member in a household
	Livelihood strategies (LS)	Percent of households dependent solely on agriculture as income source.
		Percent of households dependent on other occupations.
		Average number of households who have burden of loan.
	Social network (SN)	Average time to reach nearest vehicle station.
		Percent of HHs have communicative devices (TV, radio, mobile etc.) at home.
		Percent of HHs where a family member is affiliated with any organization
	Food (F)	Percent of households dependent solely on family farm for food.
		Percentage of households struggle to find food to support whole year.
		Percentage of households that do not save seeds.
		Percentage of households with primary irrigation source
Sensitivity	Natural Capital (NC)	Household income per month.
		Percentage of people using natural resource for livelihood.
		Percentage of households with fertile land
	Water (W)	Percentage of households that utilise natural water source
		Percentage of households reported to have water availability problem.
	Health (H)	Average time to nearest health centre.
		Percent of households with family member with chronic illness.
		Percentage of households receiving treatment from government or private hospitals.
Exposure	Natural disasters, warning and impact (ND)	Average number of floods, droughts and cyclones in past six years
		Percentage of households that did not receive warning about natural disasters.

the components are determined by the number of sub-components that make up each component. For example, if SDP has four indicators, W_{SDP} will be 4. In this study, the LVI is scaled from 0 (least vulnerable) to 0.5 (most vulnerable).

IPCC Framework for Calculating LVI

IPCC-LVI is another framework which was used for calculating indices to identify the vulnerable areas. Intergovernmental Panel on Climate Change (IPCC, 2001) defines vulnerability as a function of three contributing factors: adaptive capacity, sensitivity and exposure.

Vulnerability = f (Exposure, Sensitivity, Adaptive capacity)

The alternative method for calculating LVI incorporated the IPCC vulnerability definition by grouping the eight components under exposure, adaptive capacity and sensitivity (Table 1). Components of the vulnerability index contributing to vulnerability – exposure; adaptive capacity and sensitivity etc. – are combined using following equation (Hahn et al., 2009).

$$CF_j = \frac{\sum_{i=1}^{n} W_{mi} M_{ij}}{\sum_{i=1}^{n} W_{mi}}$$

where CF_j is the contributing factor (exposure, sensitivity or adaptive capacity) for the union j, W_{mi}, determined by the number of components that make up each component and M_{ij} is the major components for j union indexed by i. After calculating exposure, sensitivity and adaptive capacity, IPCC-LVI was calculated using the following formula pertaining to the IPCC's definition of vulnerability.

$$\text{IPCC-LVI} = (\text{EI} - \text{AI}) \times \text{SI}$$

where EI is exposure index, AI is adaptive capacity index and SI is the sensitivity index. Range of IPCC-LVI varies from –1 to +1, where –1 denotes least vulnerable (adaptive capacity is more than exposure), 0 denotes moderately vulnerable (exposure and adaptive capacity are equal) and 1 denotes extremely vulnerable (exposure is higher than adaptive capacity).

Data Sources and Sampling Procedure

The study was conducted at November 2014 based on both primary and secondary data. To collect primary data different methods had been adopted which were informal interview, pre-formulated questionnaire survey and Focused Group Discussion (FGD). For questionnaire survey, sample quantity was n = 260 and it was done through random sampling techniques. Informal interview and focus group discussions were also conducted in the study area. There are 25 interviews and 1 FGD was carried out in every union. For interview and FGD both male and female but not more than 15 people have been chosen; the age of the people was between 25-65 years. The occupations of the correspondents were farmer, day labour, businessman, service holder, housewife, fishermen, teacher etc. Secondary data has been collected from different journals, reports, research papers, websites, and different government and non-government organizations i.e., Satkhira zila parishad, Shyamnagar upazila parishad, Disaster management bureau, food, agriculture, family planning, hospital authorities, the Bangladesh Bureau of Statistics (BBS, Census Wing) and local NGO's etc.

Results and Discussions

Climate Change Impacts Assessment Using DPSIR

Coastal threat seems to be exacerbated due to climate change. Climate change is reality and its impacts have been experienced in many parts of the world, such as increased disaster magnitude and uncertainty, fresh water shortage due to increased salt intrusion and tidal inundation. According to the modified DPSIR framework socioeconomic stressors are identified as the main **drivers** namely: rapid population growth, aquaculture, fisheries, agriculture and tourism. Although agriculture does not bring much income for local farmers, it is a traditional livelihood to engage large rural population. It is rather important activity to maintain the food security. From field survey, it was observed that recently farmers had been experiencing low crop production because of increasing salinity. But being different from agriculture, fisheries and aquaculture activities have been extended rapidly from the past few years as alternative of crop production.

The **pressures** exerted by these booming economic activities are subsequently transformed in a variety of natural processes that may result in changes in the **state** of both physical and biological environment. This causal-effect relationship is analysed in modified DPSIR framework (Figure 2) by following Nga et al. (2013). Moreover, this area is vulnerable to increase of all types of coastal hazards, i.e. cyclone and storm surge, tidal flooding, water-logging and salinity intrusion. Except degradation of water quality, all other changes of state would accelerate the vulnerability of natural hazards to local communities. Figure 2 also presents four groups

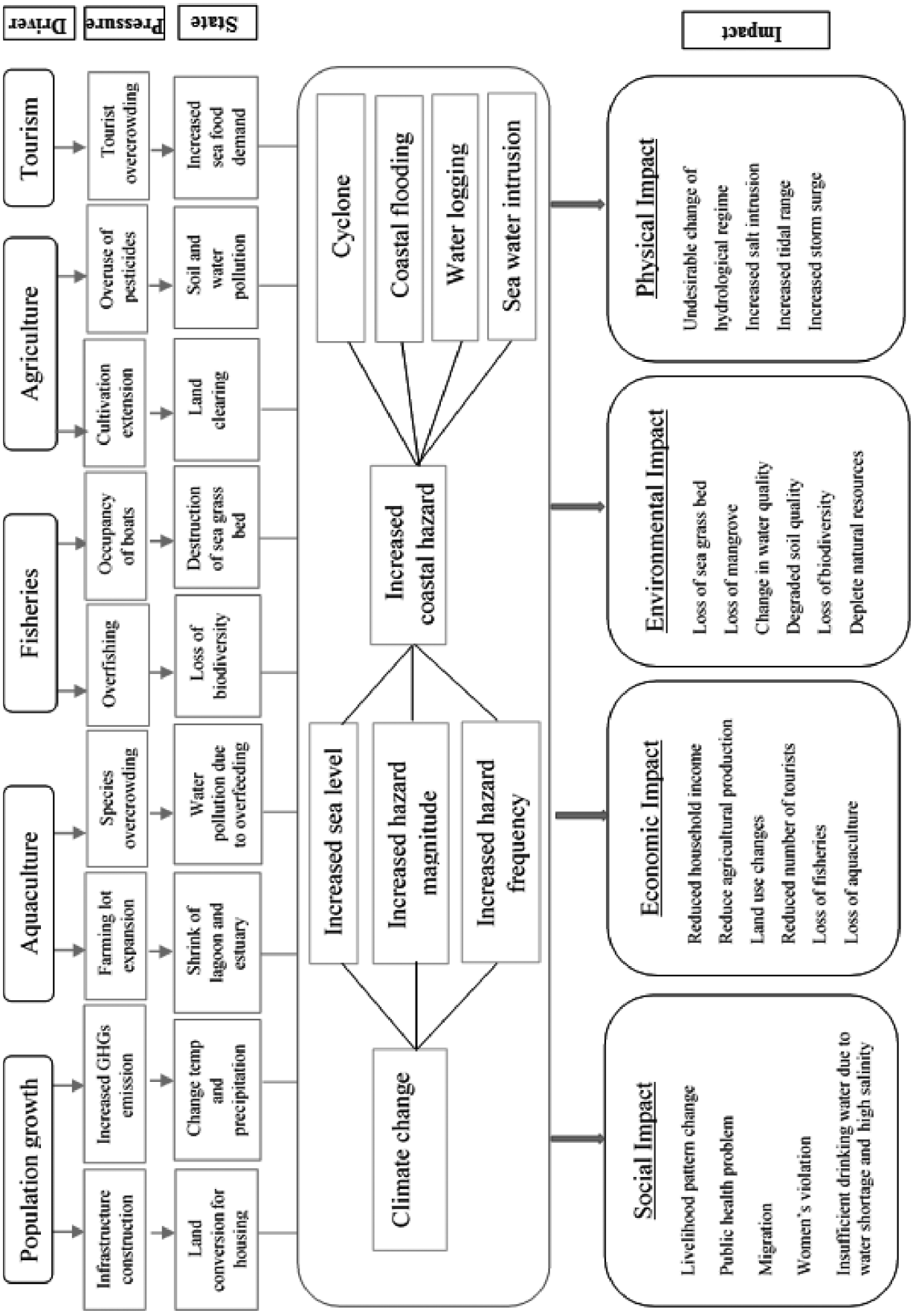

Figure 2: Modified DPSIR framework for climate change impact assessment in study area (after Nga et al., 2013).

of **impacts** namely: social, economic, environmental and physical impacts of the study area.

Climate Change Vulnerability Assessment Using LVI

The concept of vulnerability is a descriptor of the status of a society or community with respect to an imposed hazard or threat. Vulnerability to impacts is a multi-dimensional concept, encompassing bio-geophysical, economic, institutional and socio-cultural factors. It is usually considered as a function of a system's ability to cope with stress and shock (Smith, 1992). The resultant values of each component of LVI for the study area are given in Table 2.

Empirically, the vulnerability indices of the major components ranged from 0.23-0.47 as shown in Table 2. The indices being relative values are compared across 12 unions of the study area. The vulnerability of socio-demographic profile is highest in Padma Pukur (0.43) and lowest in Nurnagar (0.25). SDP depends on formal and informal skill, education, dependency ratio, average family member etc. (Table 1). Furthermore, the areas where the level of education was low, formal and informal skill levels were also low and mostly it controls the socio-demographic score of the study area. The livelihood strategies of the households were diverse because of their knowledge and experience of disaster exposure. Among the study sites livelihood index are better at Nurnagar (0.27) and Shyamnagar sadar unions (0.28) compared to the other unions. Aid is usually in the form of money, care during indisposition, and marketing among others. High-quality social networking mostly lessens the impact of climatic stresses on individual households. However, social network is relatively better in Nurnagar (0.21) union than Gabura (0.41), Padma Pukur (0.42) and Atulia (0.43) unions. Food-stuff is another important item for adaptation with any disaster or climatic impacts which is much better in Nurnagar (0.31) than other unions of the study area.

Natural resources, water and public health are the most essential and sensitive issues to any hazard. Regarding these aspects the index values are more vulnerable at Gabura and Padma Pukur unions. Most of the people of Shyamnagar upazila are dependent on Sundarbans' resources and coastal aquaculture for their livelihood. The highest values of indices are shown in Gabura (0.47) and the lowest in Nurnagar and Shyamnagar sadar (0.31) unions. The vulnerability index for the water component of the LVI shows that Gabura is the most vulnerable (0.48) union, where highest percentage of households reporting conflicts for water resources, which negatively affect the social integration. Most of the household's respondent in this region use water from ponds or relief water. The average time spent for water is found maximum at Gabura and Padma Pukur unions (almost 2-3 hours a day). Water is usually collected by women and girls. Hence distant water sources increases the time burden of household chores and affects time for house-caring women and school-going children. Three indicators are influenced to make up the health major component (Table 1). When

Table 2: Livelihood Vulnerability Index (LVI) for different unions of Shyamnagar upazila

IPCC contributing factor	*Components*	*Atulia*	*Bhurulia*	*Buri Goalini*	*Gabura*	*Ishwaripur*	*Kaikhali*	*Kashimari*	*Munshiganj*	*Nurnagar*	*Padma Pukur*	*Ramjan Nagar*	*Shyamnagar*
Adaptive strategies	Socio-demographic profile	0.41	0.26	0.28	0.42	0.36	0.27	0.41	0.39	0.25	0.43	0.27	0.26
	Livelihood strategies	0.39	0.25	0.27	0.43	0.35	0.28	0.38	0.38	0.23	0.41	0.26	0.23
	Social network	0.43	0.23	0.27	0.41	0.25	0.27	0.40	0.37	0.21	0.42	0.26	0.23
	Food	0.41	0.39	0.33	0.41	0.37	0.32	0.39	0.36	0.31	0.40	0.32	0.33
Sensitivity	Natural Capital	0.43	0.36	0.41	0.47	0.41	0.42	0.41	0.41	0.31	0.46	0.34	0.31
	Water	0.46	0.36	0.38	0.48	0.41	0.38	0.43	0.40	0.33	0.47	0.37	0.33
	Health	0.41	0.38	0.40	0.41	0.26	0.41	0.42	0.41	0.28	0.41	0.34	0.28
Exposure	Natural disasters, warning and impact	0.45	0.32	0.34	0.47	0.42	0.34	0.43	0.35	0.27	0.47	0.31	0.27
LVI	-	0.42	0.32	0.34	0.43	0.37	0.34	0.41	0.39	0.27	0.43	0.31	0.28
Rank		2	7	6	1	5	6	3	4	10	1	8	9

these indicators are aggregated, Kashimari was found to be the most (0.42) vulnerable to health. The average time taken to reach nearest health centre is highest here due to poor communication system. Inadequate access to health services results in decrease of the public health status of community people, thereby increasing their vulnerability to extreme climatic events.

The seventh major component of this conceptual framework is the natural disasters and climate variability which is comprised of two indicators (Table 1). Gabura and Padma Pukur unions were found to be the most vulnerable (0.47) and Nurnagar and Shyamnagar unions were quite safe (0.27) in terms of natural disasters and climate variability. Table 2 shows that natural capital, water and natural disaster etc. are more vulnerable components in all the unions of study area. The results of overall vulnerability index show that the score is higher in Gabura and Padma Pukur (0.43) compared to other unions. Table 3 also represents the vulnerability scores with ranking according to IPCC-LVI for all the unions of study area. It shows the similar result with Gabura (0.027) whilst Nurnagar and Shyamnagar sadar are comparatively lowest vulnerable (0.003) area.

All the unions are highly vulnerable with high risk in climatic hazard showing high exposure and sensitivity compared to adaptive capacity. However, people still depend on natural capital for maintaining their livelihood. It means that the livelihood of households living below the poverty line is controlled and regulated by the whims of nature. Infertility and dispossession of land as well as dependency on primary irrigation facilities have made the situation worse. Unskilled labourers are left with no employment opportunities, consequently migrate to other areas. Social ties facilitate the process of migration (Deshingkaret et al., 2006) but for the marginal people it is difficult to migrate without any network or support (De Haan, 2002). They survive in worse situation by struggling with various climatic events and natural calamities.

Conclusions

Climate change is a reality but the impacts of climate change are severing in coastal regions. Like other coastal areas of Bangladesh, the people of Shyamnagar upazila suffer from the negative impacts of climate change where most of the people live below the poverty line. From the approaches of Livelihood Vulnerability Index and IPCC-LVI, it is shown that the situation is much worse in Gabura and Padma Pukur unions where natural capital, water and natural disasters are more vulnerable issues. Exposure factors and sensitive components index are higher than adaptive capacities in the study area. However, increased adaptive capacity to cope with climatic hazard can minimize the impacts. If the identified potential impacts and vulnerable areas get special priorities with enhancing the awareness of local communities about their vulnerability (social, economic, environmental and physical) to climate change, it can strengthen their resilience in the long term and will help to cope with the challenges posed by climate change.

Table 3: Vulnerability index (IPCC-LVI) for different unions of the study area

Name of union	*Adaptive capacity Index (AI)*	*Sensitivity Index (SI)*	*Exposure Index (EI)*	*IPCC-VI*	*Rank*
Atulia	0.41	0.43	0.45	0.0172	5
Bhurulia	0.29	0.36	0.32	0.0108	6
Buri Goalini	0.29	0.40	0.34	0.020	4
Gabura	0.41	0.45	0.47	0.027	1
Ishwaripur	0.34	0.35	0.37	0.0105	7
Kaikhali	0.28	0.40	0.34	0.024	3
Kashimari	0.37	0.40	0.43	0.024	3
Munshiganj	0.29	0.40	0.35	0.024	3
Nurnagar	0.26	0.30	0.27	0.003	9
Padma Pukur	0.41	0.44	0.47	0.0264	2
Ramjan Nagar	0.28	0.34	0.31	0.0102	8
Shyamnagar	0.26	0.30	0.27	0.003	9

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