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Climate Change Vulnerability Assessment: A Case Study of South West Coastal Community of Bangladesh

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Abstract: This study aimed at assessing the Livelihood Vulnerability Index (LVI) using the IPCC framework approach and a modified approach to estimate climate change vulnerability in south-west coastal area of Bangladesh. Nine Upazillas (sub-districts) in the south west coastal community were considered for this study. The major component indices of LVI such as socio-demographic profile, livelihood strategies, social network, health, food, water, natural disaster and climate variability were calculated based on the household survey data. The LVI based on the IPCC approach (LVI-IPCC) in nine upazillas in southwest coastal region of Bangladesh were found within a range of –0.02 to + 0.04 (on the scale of –1 to +1). In the modified approach, the LVI for the nine study areas was found within a wide range from 0.253 to 0.544 (on a scale of 0 to 1). For the LVI-IPCC approach, although the contributing factors (exposure, sensitivity and adaptive capacity) individually show variations in their indices from one to another, no significant variation is observed for the total livelihood index. However, the modified approach shows significant variation in LVI among the studied nine areas. It is concluded that the modified approach is suitable for community or district level assessment, whereas the LVI-IPCC may be suitable for regional level evaluation.

Key words: Vulnerability assessment, livelihood vulnerability index, coastal community, climate change, IPCC approach.

Introduction

Bangladesh is considered one of the most climate vulnerable countries in the world (Harmeling, 2010). Recurrent natural calamities that cause human casualties, damage to infrastructures and economic assets, and badly impact lives and livelihoods, especially of poor and marginal households, are very frequently observed in this country. The coastal zone of Bangladesh consists of 19 districts comprising 147 upazillas (sub-districts) covering an area of 47,201 km^2. The coastal districts of Bangladesh can be divided into three adjoining regions: south-west constituting Satkhira, Khulna and Bagerhat; south-central comprising Jashore, Patuakhali, Noakhali and Barisal; and south-east consisting of Chittagong and Cox's Bazar. The southern part of Bangladesh falls under the coastal zone that receives the discharge of numerous rivers, including the Ganges-Brahmaputra-Meghna (GBM) river system, creating one of the most productive ecosystems of the world. The month of April-May and September-November is known as 'Cyclone season', these natural and climate-related disasters have a significant and lasting impact on the lives and livelihoods of the extreme poor; particularly, in 12 districts including Khulna, Bagerhat and Satkhira. Cyclone Aila struck the South-West coast on the 25th of May of 2009 with a 13 ft. height of tidal surge and cyclone Sidr hit the coastal areas of Bangladesh on

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November 15 of 2007 with a surge height of 16 ft. During and after the disaster, the extremely poor people suffered the most because of their high dependency on natural resources for their livelihood. The vulnerable livelihood parameters are different for different regions. Moreover, the impact of the same hazard is not the same for all the areas. However, for the preparedness and protection against hazards as well as for the mitigation of post-hazard emergency needs, it is necessary to understand the demographic, socio-economic, public health and natural resources factors including regional vulnerable communities with spatial variations.

According to the IPCC (2007), vulnerability can be explained as a function of three contributing elements: exposure, sensitivity, and adaptive capacity. These three contributing factors of vulnerability have beem well explained in many previous studies (Ali and Syfullah, 2017; Herrick, 2021; Johnson and Marshall, 2007; Marshall et al., 2009). Sound knowledge of these elements can help to estimate the character and extent of the climate change hazard as well as perceive the key sources of vulnerability. Generally, in vulnerability assessment, the multidimensional issues are quantified using indicators (Bueno et al., 2021; Otto et al., 2017). Sometimes, the diverse variables are integrated into a composite index. In order to expansively assess the livelihood threats resulting from climate change, a novel approach for vulnerability assessment is needed that incorporates climate exposures and accounts for household adaptation practices (Sullivan et al., 2002). In this paper, the spatial variation of vulnerability indices and vulnerable livelihood parameters were presented for the south-west coastal belt of Bangladesh based on the calculated index. The objectives of this study are to determine the Livelihood Vulnerability Index (LVI) using two methods: (i) IPCC framework approach, where the LVI aggregates the major components into IPCC's three contributing factors to vulnerability-exposure, sensitivity, and adaptive capacity (IPCC, 2007) named here as LVI-IPCC and (ii) an alternative method for calculating the LVI is used that also incorporates the IPCC vulnerability definition but in a different orientation of contributing factors in the equation named here as YLVI developed by Yates (2010).

Study Area

The south-west coastal region of Bangladesh is the main focusing area of this study. It includes three districts namely Khulna, Bagerhat and Satkhira, which consist of 30 no. of upazillas. Among them, nine upazillas are selected for this study. In the selected areas, households' questionnaire survey was conducted. Based on this survey result, Livelihood Vulnerability Indices are calculated. Figure 1 shows the locations of the study area in south-west Coastal belt of Bangladesh.

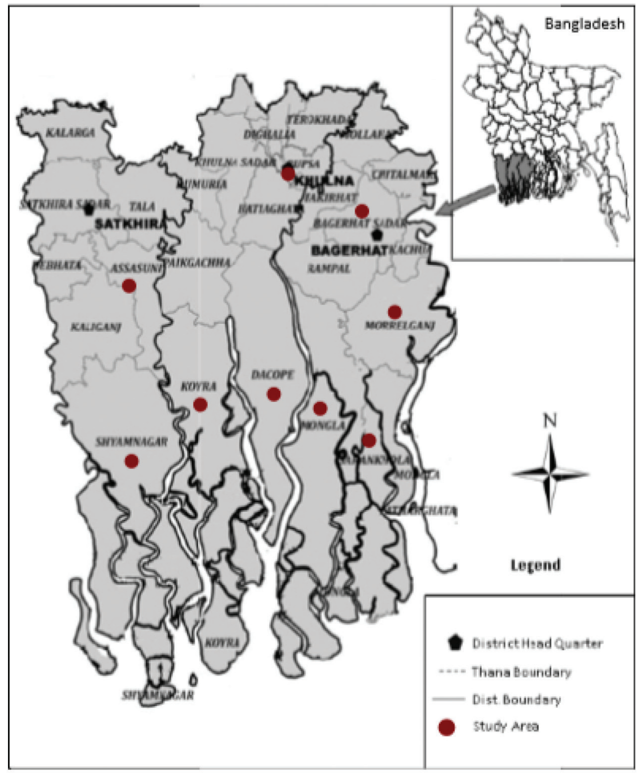

Figure 1: Location of study areas in south-west coastal belt of Bangladesh.

Methodology

Method 1: IPCC Framework Approach (LVI-IPCC)

The LVI includes seven major components: Socio-Demographic Profile (SDP), Livelihood Strategies (LS), Social Network (SN), Health (H), Food (F), Water (W), Natural Disasters and Climate Variability (NDCV). Each is consisting of several indicators or sub-components. In this study, the sub-components developed by Hann et al. (2009) were used with slight modification based on a review of the literature on each major component and considering the practicality of collecting the data through households' surveys and the area under study. The LVI uses a balance-weighted average approach (Hahn et al., 2009), where each sub-component is weighted equally to the overall index and each major component consists of a different number of sub-components.

Table 1: Categorisation of major components into IPCC's contributing factors of vulnerability

IPCC contributing factors to vulnerability	*Major components*
Exposure	Natural disasters and climate variability (NDCV)
Adaptive capacity	Socio-demographic profile (SDP)
	Livelihood strategies (LS)
	Social networks (SN)
Sensitivity	Health (HV)
	Food (FV)
	Water (WV)

Seven major components of LVI were categorised into IPCC's three contributing factors according to Table 1. The major components in a contributing factor are combined using the following equation:

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

where CF_d indicates the contributing factor exposure, sensitivity or adaptive capacity for the study site d; M_{di} are the major components for site d indexed by i; M_{di} is the weight of each major component in each contributing factor.

Once exposure, sensitivity, and adaptive capacity were calculated, the three contributing factors were combined using Eq. (2) to obtain the LVI-IPCC:

$$LVI\ (IPCC_d) = (e_d - a_d) * s_d \quad (2)$$

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

Method 2: 12 approach (YLVI)

In this technique also, the LVI is calculated integrating the IPCC vulnerability definition but in the different orientation of contributing factors in the equation named here as YLVI developed by Yates (2010). Nahian et al. (2013) used this approach for the determination of vulnerability of water resources. The YLVI is determined as Equation (3), where the scale of YLVI varies from 0 (least vulnerable) to 1 (most vulnerable).

$$YLVI_d = \frac{(e_d) \times (s_d)}{a_d} \quad (3)$$

LVI of Major Components of Contributing Factors

The sub-components of LVI under each major component are presented in Table 2. Table 3 shows the calculated Overall LVI of seven major components, which are categorised into three contributing factors of IPCC. The results are explained below for each of the contributing factors separately.

Adaptive Capacity

Table 3 shows the LVI of major components of adaptive capacity for the nine study areas. Based on the surveyed results of major parameters (SDP, LS and SN), Rupsa, Bagerhat Sadar, Morrelganj and Mongla showed relatively less vulnerability to adaptive capacity than other areas. The vulnerability scores for adaptive capacity are found to vary from 0.365 (Saymnagar) to 0.325 (Bagerhat Sadar). Among its major components, the LS is found to be the most vulnerable sector (LVI varies from 0.444 to 0.348) compared to SDP (LVI varies from 0.361 to 0.266) and SN (LVI varies from 0.364 to 0.287).

To measure the extent to which households depend on family and friends for financial support and in-kind help, the ratios of borrowing money for lending and receiving assistance to give assistance were calculated. It is found that Rupsa and Assasuni households had a higher borrowed to lend ratio than households of other areas while Saronkhola households had higher receive to give ratios compared to other households. Morrelganj is found more vulnerable in terms of SN parameters because they do not get aid from local governments to compare with other areas.

Sensitivity

This factor helps in getting information on how household individuality contributes to the climate change vulnerability in each site. Accounting for the current health status as well as food and water security, Dacope is found to be more sensitive to climate change impacts than other regions. On the other hand, Bagerhat Sadar and Rupsa are quite less sensitive to water security and health component. The vulnerability scores for sensitivity are found to be varied from 0.449 (Dacope) to 0.302 (Bagerhat Sadar). Among its major components, the food vulnerability contributed the most (score varies from 0.518 to 0.597) and the health sector

Table 2: Indexed sub-component values of LVI for selected nine study areas

Major components	*Sub-component*
Socio-demographic Profile	Dependency ratio
	Percent of female-headed households
	Average age of household heads
	Percent of illiteracy
	Percent of households where head of household has not attended school
Livelihood Strategies	Percent of households works in different community
	Percent of households dependent solely on agriculture as a source of income
	Average Agricultural Livelihood Diversification Index
	Natural resource and Livestock index
Health	Average time to health facility
	Percent of households with family member with chronic illness
	Percent of households where a family member had to miss work or school in the last 2 weeks due to illness
	Access to sanitary latrine
Social Networks	Average Receive: Give ratio
	Average Borrow: Lend Money ratio
	Availability of amenities
	Percent of households that have not gone to their local government for assistance in the past 12 months
Food	Percent of households dependent on family farm for food
	Average number of months households struggle to find food
	Average Crop Diversity Index
	Percent of households that do not save crops
	Percent of households that do not save seeds
Water	Percent of households that utilize a natural water source
	Time to travel the source of natural water
	Percent of households that do not have a consistent water supply
	Inverse of the average number of liters of water stored per household
Natural Disasters and Climate Variability	Average number of floods, drought, and cyclone events in the past 6 years
	Percent of households that did not receive a warning about the pending natural disasters
	Percent of households with an injury or death as a result of the most severe natural disaster in the past 6 years
	Mean standard deviation of average maximum temperature
	Mean standard deviation of average minimum temperature
	Mean standard deviation of average precipitation

is found to be relatively less vulnerable (score varies from 0.103 to 0.335). The vulnerability score for the water component varies from 0.166 to 0.415.

Overall, WV scores for Bagerhat Sadar (0.166) and Rupsa (0.186) are low, and that of Saronkhola (0.415) and Dacope (0.411) are high. It is found that the local governments of Rupsa installed deep tube-well in different places, and in Bagerhat Sadar almost every household has its own tube-well. This reduces the time that people of Bagerhat Sadar and Rupsa households take in travelling to a water source. These practices have reduced the vulnerability in the water sector in Bagerhat

Table 3: LVI of major components of IPCC contributing factors

LVI of Major component	*Morrelganj*	*Mongla*	*Saronkhola*	*Dacope*	*Koyra*	*Assasuni*	*Shyamnagor*	*Bagerhat Sadar*	*Rupsa*
Major Components of Adaptive *Capacity*									
Social Demographic Profile	0.266	0.297	0.317	0.339	0.330	0.318	0.361	0.301	0.355
Livelihood Strategies	0.352	0.349	0.370	0.415	0.401	0.444	0.404	0.348	0.371
Social networks	0.364	0.346	0.345	0.306	0.316	0.294	0.329	0.335	0.287
Major Components of *Sensitivity*									
Health	0.235	0.198	0.248	0.335	0.224	0.310	0.332	0.103	0.153
Food	0.584	0.597	0.518	0.570	0.594	0.576	0.576	0.568	0.553
Water	0.364	0.379	0.415	0.411	0.360	0.337	0.332	0.166	0.186
Major Components of *Exposure*									
Natural disasters and climate variability	0.273	0.287	0.345	0.375	0.309	0.373	0.427	0.273	0.299

Sadar along with Rupsa and are reflected in its low water vulnerability score despite drought conditions. High dependency on natural water sources causes the higher vulnerability index of other sites. All the sub-component indices of water are found relatively higher for Saronkhola and Dacope compared to other sites.

The overall food vulnerability (FV) scores for Mongla (0.597) and Koyra (0.594) are found relatively higher. The Koyra and Dacope households reported that they are struggling the most to find adequate food for their families (more than 3 months/year); on the other hand, Bagerhat Sadar and Rupsa households reported struggling to find food for less than a month per year. The majority of households of Bagerhat Sadar and Rupsa do not depend solely on family firm food and a smaller proportion reported engaging in seed storage and other food management practices. The Bagerhat Sadar and Rupsa households did not report the same level of food insecurity as other households do but still it had a high vulnerability score. This suggests that inspiration for food production, education on storage, crop diversification, and seed preservation might constitute an appropriate intervention for the Bagerhat Sadar and Rupsa households in spite of their existing safe food status relative to other sites.

The households of Shyamnagor reported a longer average time to health facilities and a higher prevalence of chronic illness. Dacope households reported that the highest proportion of households do not have proper sanitising arrangements for people. Since past 2 weeks people in this area were so sick that they had to miss work and the percentage of such people was found to be higher compared to other studied areas. In spite of being two health indicators highest in Shyamnagor (indices are: average time to a health facility is 0.747 and access to sanitary latrine is 0.42), the overall health vulnerability (HV) was found highest for Dacope (0.335) and Shyamnagor (0.332) compared to the score of other areas with the lowest at Bagerhat Sadar (0.103). Considering the estimated result, required sanitary latrine installation and a periodic health check-up to find out the diseases causing people to miss work might be desirable for Dacope. The location and quality of health facilities in Shyamnagor may be the other reasons, why Shyamnagor households reported long travelling times to look for health care.

Exposure

According to the index, it is observed that Shyamnagor is the most vulnerable area, where Dacope, Assasuni and Saronkhola are relatively and moderately vulnerable and Koyra, Morrelganj, Mongla, Bagerhat Sadar and Rupsa are less vulnerable in terms of NDCV induced exposure. Although the households of Shyamnagor, Dacope and Assasuni pointed out a higher total number of natural disasters over the past 6 years, the inconsistency in the monthly average precipitation has been greater in Morrelganj, Mongla, Saronkhola and Bagerhat Sadar. Furthermore, the variability in the monthly average minimum and maximum daily temperature has been greater in Assasuni and Shyamnagor along with not receiving a warning about the pending natural disasters and more injury or death as a result of recent natural disasters resulting in a higher natural disaster and climate variability (NDCV) score for Shyamnagor and Assasuni.

LVI of Contributing Factors for Different Study Areas

The individual indices for LVI contributing factors are presented in Table 4. A vulnerability spider diagram of the contributing factors of LVI-IPC for nine study areas is shown in Figure 2. The figure illustrates that Shyamnagor may be more exposed (0.427) to climate change than Dacope (0.375), Assasuni (0.373), Saronkhola (0.345), Koyra (0.309), Mongla (0.287), Bagerhat Sadar (0.281), Morrelganj (0.273) and Rupsa (0.273). Considering the current health status and food and water security, Dacope is found to be more sensitive (0.449) to climate change impacts than Shyamnagor, Assasuni, Morrelganj, Koyra, Mongla, Saronkhola, Rupsa and Bagerhat Sadar (0.426, 0.421, 0.409, 0.408, 0.407, 0.403, 0.317 and 0.302, respectively). Based on demographics, livelihoods, and social networks, Dacope (0.356) and Assasuni (0.354) showed higher vulnerability to adaptive capacity than Koyra (0.350), Saronkhola (0.342), Rupsa (0.342), Morrelganj (0.321), Mongla (0.332), Shyamnagor (0.334), and Bagerhat Sadar (0.325).

The overall LVI–IPCC and YLVI scores indicate that Shyamnagor households are more vulnerable than Assasuni, Saronkhola, Koyra, Mongla, Morrelganj, Rupsa and Bagerhat Sadar households. Due to the low estimated adaptive capacity of Shyamnagor households compared to Saronkhola, Dacope and Rupsa households, which was resulting from demographic imbalance and adaptation strategies such as livelihood diversification and food, natural disaster and storage of water increased Shyamnagor's overall LVI–IPCC score. Although Morrelganj, Mongla, Saronkhola, Dacope, Koyra, Assasuni, Bagerhat Sadar and Rupsa households did not mention comparable adaptation capacity, they also did

Table 4: Estimated LVI-IPCC and YLVI for different study areas

IPCC contributing factors	*Bagerhat Sadar*	*Morrelganj*	*Mongla*	*Saronkhola*	*Rupsa*	*Koyra*	*Dacope*	*Assasuni*	*Shyamnagor*
Adaptive capacity	0.326	0.322	0.333	0.342	0.339	0.348	0.352	0.349	0.365
Sensitivity	0.302	0.409	0.407	0.403	0.317	0.408	0.449	0.421	0.426
Exposure	0.273	0.273	0.287	0.345	0.295	0.309	0.375	0.373	0.427
LVI-IPCC	-0.016	-0.020	-0.018	0.001	-0.015	-0.017	0.009	0.008	0.040
YLVI	0.253	0.348	0.351	0.406	0.274	0.361	0.473	0.444	0.544

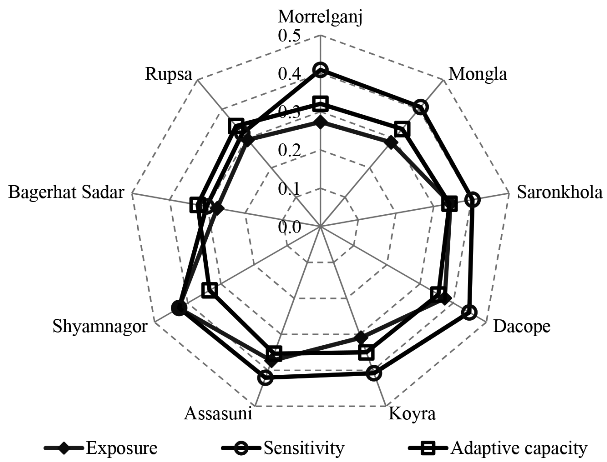

Figure 2: Vulnerability spider diagram of the contributing factors of the LVI-IPCC for different sites.

not mention the identical demographic stresses or same rates of school attendance prevalent like Shyamnagor.

Many researchers have tried to evaluate the livelihood vulnerability indices in various places in the world. Many of them rely on the composite index approach while many of them rely heavily on IPCC's working definition of vulnerability as a function of exposure, sensitivity, and adaptive capacity. Hahn et al. (2009) calculated the livelihood vulnerability indices in the Mabote and Moma Districts of Mozambique based on both the composite index approach and the LVI-IPCC approach. They obtained the indices based on the LVI-IPCC approach as -0.074 and +0.005 for Moma and Mabote, respectively. Shah et al. (2013) evaluated the livelihood vulnerability index in Trinidad and Tobago, a country that is expected to bear some of the most severe impacts of climate change. They evaluated the livelihood vulnerability indices using the LVI-IPCC approach at Nariva and Caroni communities in Trinidad and Tobago as –0.03 and +0.02, respectively. Madhuri et al. (2014) calculated the livelihood vulnerability indices in the context of Bihar at Narayanpur, Bihpur, Rangra Chowk, Gopalpur, Ismailpur, Naugachia and Kharik. The obtained indices based on LVI-IPCC are Narayanpur (0.07), Bihpur (+0.06), Rangra Chowk (+0.08), Gopalpur (+0.012), Ismailpur (+0.06), Naugachia (-0.07) and Kharik (+0.06).

In the present study, the Livelihood Vulnerability Index (LVI) based on the LVI-IPCC approach in nine upazillas (sub-districts) in the southwest coastal region of Bangladesh are found to be varied within a range of -0.02 to + 0.04. The results suggest that all the study sites shared a very similar degree of vulnerability that can be described as 'mid range' on the -1 to +1 scale (Shah et al., 2013). Therefore, although the contributing factors (exposure, sensitivity and adaptive capacity) individually show variations in their indices from one area to another, the calculated LVI-IPCC index for different study sites varies by very little amount compared to its -1 to +1 scale. Therefore, based on this index, it is difficult to categorise the different study sites to prepare any priority list for decision making towards managing sources of vulnerability or to guide the development of adaptation policies.

Using the Yates approach (YLVI), the indices for the nine study areas vary within a wide range from 0.253 to 0.544 on a scale of 0 to +1. Therefore, in this method, the vulnerability of different study sites can be compared and categorised more comfortably using this method.

Conclusion

The major components of LVI were calculated for nine Upazillas (sub-districts) in the south west coastal belt of Bangladesh based on survey data. The vulnerability indicators (sub-components) provided by this study are important for decision making towards managing sources of vulnerability and can be used to guide the development of adaptation policies. The Livelihood

Vulnerability Index based on the IPCC approach (LVI-IPCC) in nine upazillas were found within a range of -0.02 to + 0.04 (on the scale of -1 to +1). In the modified approach (YLVI), the LVI for the nine study areas was found within a wide range from 0.253 to 0.544 (on a scale of 0 to 1). For the LVI-IPCC approach, although the contributing factors (exposure, sensitivity and adaptive capacity) individually show variations in their indices from one upazilla to another, no major variation is observed for the total livelihood index. However, the modified approach shows significant variation in LVI among the studied nine villages and hence the vulnerability study sites can be compared and categorised more comfortably using this method. Therefore, it can be concluded that the modified approach is suitable for community or district level assessment, whereas the LVI-IPCC may be suitable for regional level evaluation.

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