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Application of Livelihood Vulnerability Index in Assessing Local Vulnerabilities to Rapid Environment Change: A Case Study of South - Western Coastal Bangladesh

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Abstract: ***The south-western coastal zone of Bangladesh is one of the most vulnerable regions to recent environmental change of the world due to its geographical position, high population density and increasing poverty. This environmental change put stresses on ecosystem services and such ecosystem vulnerabilities exhibit varied impacts on the entire societal system. Though climate change impacts on environment and ecosystem services are rather well understood in broader range, micro scale research on analysis of the environmental stresses and their consequences on community livelihood vulnerabilities are scarce. This study developed a Livelihood Vulnerability Index (LVI) with an aim to assess community vulnerabilities due to rapid environmental changes in the study area. While developing the LVI, communities of 7 study sites from 3 study locations were selected as a comprehensive representation of the study area population of the south-western Bangladesh. The index is comprised of 31 subcomponents under 7 major components. Sarankhola was the most vulnerable location which was followed by Shyamnagar and Dacope in terms of vulnerability among study are. The developed LVI also revealed that the south-western coastal Bangladesh was most vulnerable in terms of food security, followed by health, social networks, livelihood strategies, natural disasters, water use & scarcity and socio-demographic condition in a descending order of vulnerability. Dependency ratio, agricultural livelihood diversification index, household with annually occurring diseases, household who didn't go to local leaders, household not having enough food throughout the year, household who used natural water sources and household who didn't receive warning of disasters contributed most to the major components of the LVI. This composite index also provided a quantified comparison of present vulnerability and potential vulnerability. Such intricate comparison helps determining the probable sector for capacity and resilience enhancement while divulging and signifying potential areas of development intervention.***

Keywords: Environmental changes, Vulnerability, Livelihood Vulnerability Index (LVI), South-western coastal Bangladesh

1. Introduction

Climate change is now a major global concern due to extreme weather events that are becoming unforeseeable [1]. Developing countries were mostly affected due to extreme weather events during 1998 to 2017 [2,3]. Bangladesh is considered as one of the most affected countries due to climate change [4]. It has been estimated that Bangladesh will be top in the list of most affected countries in South Asia with rapid environmental changes in the form of rising sea levels, frequent extreme heat waves and intense cyclones [5]. The geographical location, topography, high population density, socioeconomic condition and agricultural dependency are responsible for the high vulnerability of Bangladesh to climate change [6]. Food production, livelihoods, and infrastructure will be threatened due to the impact of these changes [5]. The loss of land due to sea level rise will be one of the highest in the world [7]. Agricultural production is mostly affected due to extreme temperature and variable rainfall and therefore, the earning opportunities of farmers are affected [7]. Moreover, saline water from the adjacent sea is reported to influence inland water of 100km or more during the dry season [7]. Climate change induced droughts are also responsible for the increased soil salinity [8]. Declining precipitation is also responsible for severe degradation of wetland ecosystems. The intensity of cyclone has increased though the number of cyclones originated in Bay of Bengal have been decreased since 1970 [7]. However, cyclone Sidr and Aila caused extensive damage to southwestern coastal area of Bangladesh. It was estimated a death toll of about 3400 by Cyclone Sidr along with over a million ton of rice destruction and loss and damages of over US$ 1.6 billion [5]. However, about 60% death in the world caused by cyclones in the last 20 years occurred in Bangladesh [9]. Bangladesh ranked ninth in the World Risk Index for natural disasters in 2017 [3].

The vulnerability of the coastal communities as a consequence of rapid environmental changes are complex and interlinked in southwestern Bangladesh. Climate change causes remarkable damage to the society and economy [10]. It was estimated that Bangladesh lost 5.9% of its GDP during 1998 to 2009 due to storms [11]. Seawater intrusion became a major problem for conventional agriculture. Agriculture employs 47% of the working population in Bangladesh and provides for 19% in the GDP [12]. In a low crop productivity scenario, Bangladesh is expected to experience a 15% increase of poverty [13]. Food security of the country will be at risk due to climate change [14]. Soil

salinity affects about 830,000 million hectares of arable land by varying degrees [15]. About 62% and 83% of the coastal land has an elevation of up to 3m and 5m above mean sea level respectively [16]. The World Bank study found that 1-meter rise in the sea level will displace about 15-17 million people [17]. Scientists believe that the worst impacts have already been experienced along the coasts of Bangladesh in terms of coastal inundation and erosion, saline intrusion, deforestation, loss of biodiversity and agriculture, and large-scale migration, the [18]. Besides these, health condition is also being affected. Hypertension has increased in pregnant women at the coasts compared to those of inland which is interlinked to saline intrusion [11].

2. Literature Review

Marshall et al. described vulnerability as an outcome of three different elements: sensitivity, exposure and adaptive capacity [19]. Vulnerability assessment examine the integrated interconnection of with human being with the physical environment and social surroundings. A tool for vulnerability assessment, the Livelihood Vulnerability Index (LVI), had been proposed by Hahn, Riederer and Foster [20]. Different sector-wise substitutes are taken into account as indicators of the state of the livelihood practices, livelihood support and stresses on them by the LVI. Multiple indicators are used in the LVI to determine the level of exposure to climate change and natural disasters, socioeconomic characteristics of households that influence their adaptive capacity, food, health and water resource characteristics [21]. Vulnerability has been measured in terms of natural hazard [22]. Moreover, different studies have conceptualized vulnerability from different angles [23] though many other studies defined it in a similar way [7, 24, 25]. Vulnerability differs with time and place with respect to different factors [24]. The degree and rate of climate change also governs the level of vulnerability [24]. The level of exposure, how sensitive and adaptive the system is, also respond to the climate change [7]. Location of an area also specifies the level of exposure and therefore, exposure is different for different climatic zone. Coastal area is exposed to cyclone. A decrease in rainfall will affect less in tropical ecosystem than desert ecosystem because of water flow from upstream in tropical ecosystem. Community depends on mining is also less sensitivity to changing precipitation than community depends on agriculture for livelihood activities [7].

Bangladesh has been rated as the third most vulnerable country in the in terms of number of people affected [26]. The poor, elderly or, otherwise, marginal households can be disproportionately affected by climate change stressors [27]. It has been found that the extent of poverty is higher in the coastal region as compared to other parts of Bangladesh [28]. Rural households were found to be more vulnerable in terms of source of drinking water. Vulnerabilities due to cyclones (LVI=.339) was higher than vulnerabilities due to floods (LVI= .320) [21]. High dependency of communities on natural resources i.e. agriculture and fishing were observed. Besides, the communities were less prepared to the adverse effects of climate change [29]. However, Haque (2019) found that Bhola, Patuakhali, and Lakshmipur districts were the hot spot of vulnerability distribution in Bangladesh [30]. Moreover, Hossen (2016) revealed that Sarankhola was more vulnerable in terms of water resources. On the other hand, Dacope was vulnerable in terms of health facility whereas Shyamnagar was vulnerable in terms of socio demographic profile and natural disaster [31]. Study also examined vulnerabilities due to climate change on fishermen communities [32]. Another research tried to compare livelihood vulnerabilities between urban and rural area [21]. However, recent study on vulnerability assessment using index was very scarce. Therefore, the study tried to find out the level of vulnerabilities of coastal communities to different environmental stresses of southwestern coastal Bangladesh. Moreover, the present study contributes to the livelihood vulnerability literature by assessing and comparing the local livelihood vulnerabilities by applying Livelihood Vulnerability Indexing (LVI) due to the entire environmental factors in southwestern coastal zone.

3. Materials and Methods

The study was conducted in southwestern coastal Bangladesh which is located in between 21°36´ and 22°40´ north latitudes and in between 89°00´ and 89°54´ east longitudes (Figure 01). Dacopeupazilla of Khulna district, Shyamnagarupazilla of Satkhira district and Sarankholaupazilla of Bagerhat district of the study area were selected as the study locations. The study was carried out in 7 sites under the 3 study locations.

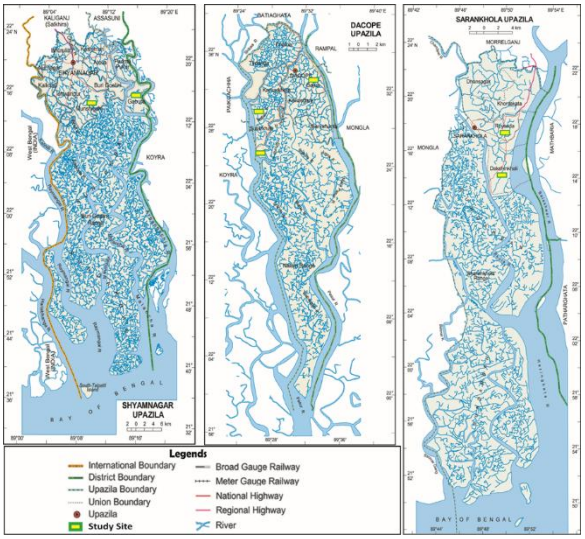


Figure 1: Map of the study locations and the corresponding study sites

Based on KIIs, FGDs and expert's opinion, Bajua, Sutarkhali and Kalabogi from Dacope, Munshiganj and Gabura from Shyamnagar and Royenda and Dakshinkhali from Sarankhola were chosen as the study sites. Exposure, sensitivity and adaptive capacity in terms of vulnerability of the communities were taken into account while selecting the study locations and sites for this study. Average literacy rate ranges between 40% to 56% whereas income from agriculture comes between 52% and 66% in the study locations. Shrimp cultivation was practiced by significant

number of people. More than half of the people owned land whereas the rest were landless. Upazila health complex, several health and family planning centers and private clinic were situated in each of the study locations. Tube wells and ponds were the main sources of drinking water and less than half of the dwellers had sanitary latrines [33].

One reconnaissance survey, several KIIs and FGDs were conducted in the study area prior to questionnaire designing. A few informal FGDs were also conducted within the communities to get an insight into the real situation. 50 samples for each of the study site with a total of 350 samples were selected randomly. The index included seven major components: Socio-demographic Profile (SDP), Livelihood Strategies (LS), Social Networks (SN), Health (H), Food Security (FS), Water Uses and Scarcity (WU&S) and Natural Disasters (ND). Each is comprised of several subcomponents as indicators, totaling at 31. The details subcomponents are mentioned in result section.

To calculate the LVI for study sites, a balanced weighted average approach was used where each subcomponent contributed equally to the overall index. As each subcomponent is measured on a different scale, first standardizing of each as an Index was done using the following equation:

$$\text{Index}_x = \frac{X - X_{min}}{X_{Max} - X_{min}} \quad (1)$$

Where, X is the original subcomponent value and X_{min} &X_{Max} are the minimum and maximum values respectively, for each subcomponent regarding the households of a particular study site. After all the subcomponents are standardized as index, the subcomponents had been averaged to calculate the value of each major component as shown in the following equation,

$$MC = \frac{\sum_{i=1}^{n} \text{Index}_x\, i}{n} \quad (2)$$

Where, MC is one of the seven major components for study site, Index_x i represents the subcomponents, indexed by i, that make up each major component and n is the number of subcomponents in each major component. Once values for each of the seven major components were calculated for each study site, they were averaged according to their weight using the following equation to obtain the LVI_{ss},

$$LVI_{ss} = \frac{\sum_{i=1}^{n} W_{mi} MC_i}{\sum_{i=1}^{n} M_i} \quad (3)$$

Where, LVI_{ss} is the Livelihood Vulnerability Index for a particular study site, equals the weighted average of the seven major components. The weights of each of the major components, W_{mi}, were determined by the number of subcomponents. Then, for calculating the LVI for study locations, LVI_{ss} values of the representative study sites for each of the study locations were averaged according to the following equation,

$$LVI_{sl} = \frac{\sum_{i=1}^{n} LVI_{ss}\ i}{n} \quad (4)$$

Where, LVI_{sl} is the Livelihood Vulnerability Index for a particular study location, LVI_{ss} i represents the study site LVIs, indexed by i, that make up each study location, and n is the number of study sites in each study locations. And finally, to obtain the LVI for the study area, LVIsl values of the representative study locations for the study area were averaged according to the following equation,

$$LVI_{sa} = \frac{\sum_{i=1}^{n} LVI_{sl}\ i}{n} \quad (5)$$

Where, LVI_{sa} is the Livelihood Vulnerability Index for the study area, LVI_{sl} i represents the study location LVIs, indexed by i, that make up the study area, and n is the number of study locations representative of the study area.

4. Results and Discussion

The results revealed that the vulnerability index of subcomponents ranged from 0.009 to 0.843 in different location of study area (Table 01). Dacope was most vulnerable in terms of dependency ratio (0.386) and female-headed household (0.023) whereas Shyamnagar and Sarankhola was most vulnerable in terms of household head who didn't attend school (0.346) and household with orphans (0.170) respectively. On the other hand, Sarankhola was found as most vulnerable for family members working outside the community (0.504), family income based only on agriculture (0.251) and agricultural livelihood diversification index (0.603). Distance to health facility (0.231), household with chronic illness (0.631), household with annually occurring diseases (0.742) and duration of annual diseases persistence (0.187) condition were worst in Sarankhola comparing to other locations. Dacope was most vulnerable in terms of member missing work or school for illness (0.490). Moreover, Sarankhola was most vulnerable in terms of help received and given ratio (0.173), borrowed and lent money ratio (0.567), household who didn't go to local leader (0.693), household who went but didn't get help from local leader (0.339). It was also found that Sarankhola was most vulnerable in terms of household mostly dependent on own farm for food (0.155), not having enough food round the year (0.843), number of months facing trouble to get enough food (0.262), growing single crop (0.324). However, Shyamnagar was found as most vulnerable for household who do not save crops (0.781) and seeds (0.760). The study revealed that Dacope and Shyamnagar were most vulnerable for household who use natural water source (0.733) and inversed stored water (0.053) respectively whereas Sarankhola was most vulnerable for reporting water conflicts (0.628), distance to water source (0.133) and not having available water everyday (0.375). Sarankhola was found to be mostly vulnerable for flood, drought, cyclone events in last decade (0.373) and injury from disasters (0.223). However, Dacope and Shyamnagar were most vulnerable in terms of people who didn't receive warning of disasters (0.820) and death from disasters (0.435) respectively. The study also revealed the vulnerability indexing of major components of the study locations. It was found that Sarankhola was most vulnerable, followed by Dacope and Shyamnagar in terms of socio-demographic profile (SDP), livelihood strategies (LS), health (H), social networks (SN), food security (FS), water uses and scarcity (WU&S). In Sarankhola, the household were more likely to have orphans than other locations. Household members of Sarankhola had to work outside the community and they

were more depended on agriculture than the other locations. Health facilities were comparatively distant in this location as well as people were suffering with different chronic illness. They were less likely to go to local leaders asking for help and they were more depended on their own farm for their food. Sarankhola also recorded a higher percentage of people not having enough food throughout the year and it was also disaster-prone in last decade comparatively to other locations. However, Shyamnagar was most vulnerable in terms of natural disasters (ND), followed by Sarankhola and Dacope. Death rate in disasters was significantly much higher in Shyamnagar than other locations.

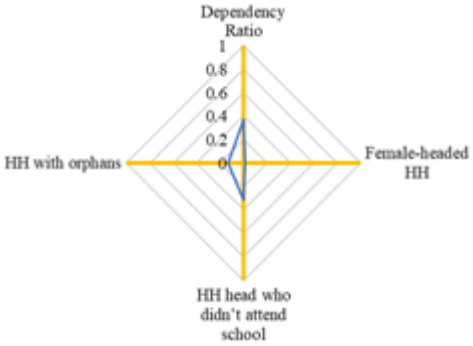
Table 1: Indexed subcomponents and major components of Livelihood Vulnerability Indexing (LVI) of the different study locations and study area of south-western coastal Bangladesh

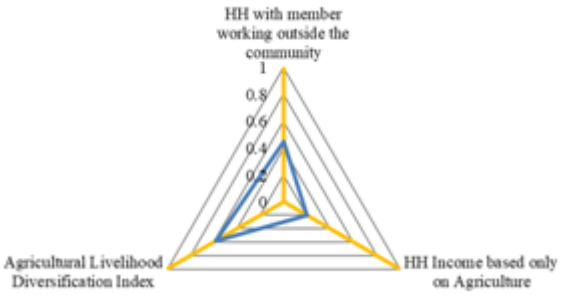
Indexed Subcomponents for Households (HH)	Study Locations			Study Area
	Dacope	Shyamnagar	Sarankhola	South-western Bangladesh
Socio-demographic Profile				
Dependency Ratio	0.386	0.354	0.369	0.370
Female-headed HH	0.023	0.012	0.015	0.016
HH head who didn't attend school	0.290	0.346	0.297	0.311
HH with orphans	0.130	0.103	0.170	0.134
Average SDP	0.207	0.204	0.213	0.208
Livelihood Strategies				
HH with member working outside the community	0.425	0.409	0.504	0.446
HH Income based only on agriculture	0.206	0.153	0.251	0.203
Agricultural Livelihood Diversification Index	0.545	0.590	0.603	0.579
Average LS	0.392	0.384	0.453	0.409
Health				
Distance to Health Facility	0.177	0.169	0.231	0.192
HH with chronic illness	0.603	0.600	0.631	0.611
HH with member missing work/school for illness	0.490	0.407	0.456	0.451
HH with annually occurring diseases	0.700	0.720	0.742	0.721
The duration annual diseases persist for	0.143	0.152	0.187	0.160
Average H	0.423	0.410	0.449	0.427
Social Networks				
Help Received: Given ratio	0.151	0.142	0.173	0.155
Borrowed: Lent Money ratio	0.545	0.510	0.567	0.541
HH who didn't go to local leader	0.602	0.673	0.693	0.656
HH who went & didn't get help from local leader	0.287	0.242	0.339	0.289
Average SN	0.396	0.392	0.443	0.410
Food Security				
HH mostly dependent on own farm for food	0.120	0.123	0.155	0.132
HH not having enough food round the year	0.813	0.742	0.843	0.799
Months HH have trouble getting enough food	0.249	0.180	0.262	0.230
HH growing single crop	0.290	0.212	0.324	0.275
HH who do not save crops	0.686	0.781	0.751	0.739
HH who do not save seeds	0.712	0.760	0.741	0.737
Average FS	0.478	0.466	0.513	0.485
Water Uses and Scarcity				
HH reporting water conflicts	0.602	0.601	0.628	0.610
HH who use natural water source	0.733	0.592	0.689	0.671
Distance to water source	0.089	0.100	0.133	0.107
HH not having available water everyday	0.228	0.317	0.375	0.306
Inversed stored water by HH	0.038	0.053	0.042	0.044
Average WU&S	0.338	0.333	0.373	0.348
Natural Disasters				
Flood, drought, cyclone events in last decade	0.339	0.345	0.373	0.352
HH who didn't receive warning of disasters	0.820	0.813	0.635	0.756
HH with Injury from disasters	0.097	0.141	0.223	0.154
HH with death from disasters	0.009	0.435	0.182	0.209
Average ND	0.316	0.434	0.353	0.368
Overall LVI	0.372	0.380	0.406	0.386

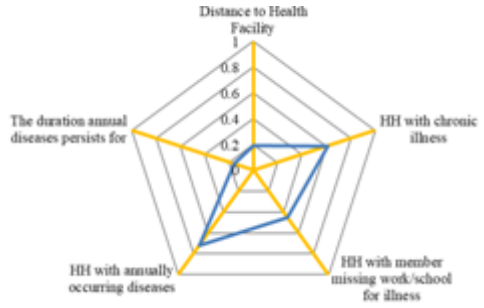
The results also revealed that south-western Bangladesh was the most vulnerable in terms of dependency ratio within socio-demographic profile (0.370); in terms of agricultural livelihood diversification index (0.579) within livelihood strategies; in terms of household with annually occurring diseases (0.721) within health; in terms of household who didn't go to local leader (0.693) within social network; in terms of household not having enough food round the year (0.799) within food security; in terms of household who use natural water source (0.671) within water use and scarcity;

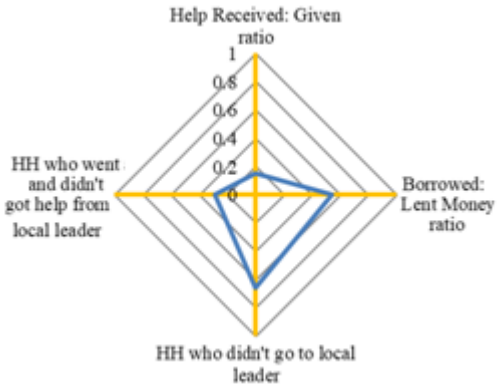
in terms of HH who didn't receive warning of disasters (0.756) within natural disasters. The results also revealed that the descending order of vulnerability of southwestern Bangladesh in terms of major components was FS> H> SN> LS> ND> WU&S> SDP. However, Sarankhola was the most vulnerable in terms of Livelihood Vulnerability Index (LVI), followed by Shyamnagar and Dacope among the study locations. Alternatively, it can also be said that Dacope was in good state of livelihood capacity in terms of Livelihood Vulnerability Index (LVI) among the locations followed by Shyamnagar and Sarankhola. Moreover, the Livelihood Vulnerability Index for the south-western Bangladesh corresponded by all study locations was found as 0.386.

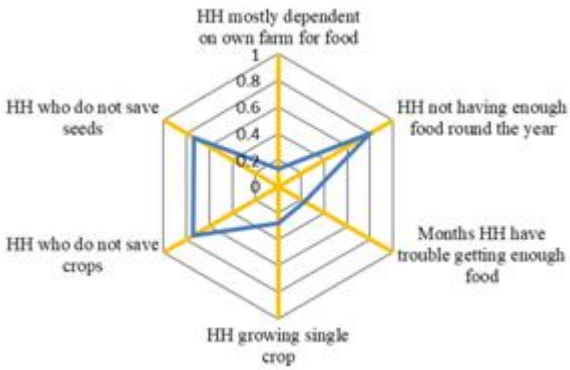
The present and potential vulnerabilities of south-western Bangladesh are discussed in terms of various major components used as sector-wise indicators. The higher the index value for these subcomponents is the higher the vulnerability of the study area regarding to the major component. Present vulnerability of the major components are the enclosed area colored blue and the potential vulnerabilities are as enclosed by the plot area in the following figures (Figure 01a-g). It was found that dependency ratio contributed the most to social-demographic vulnerability, followed by household who didn't attend school, household with orphans and female-headed household (Figure 1a). On the other hand, agricultural livelihood diversification index contributed the most to livelihood strategies vulnerability, followed by household with member working outside the community and household income based only on agriculture (Figure 1b). However, household with annually occurring diseases contributed the most to health vulnerability, followed by household with chronic illness, household with member missing work or school for illness, distance to health facility, the duration annual diseases persists for with descending contributions (Figure 1c). Moreover, household who didn't go to local leaders contributed the most to social networking vulnerability, followed by ratio of borrowed and lent money, household who went but didn't get help from local leaders and ratio of help received and given from society (Figure 1d). On the other hand, household not having enough food throughout the year contributed the most to food security vulnerability, followed by household who didn't save crops, save seeds, growing single crop, number of months facing trouble in getting enough food and household mostly dependent on own farm for food (Figure 1e). However, household who used natural water source contributed the most to WU&S vulnerability, followed by household reporting water conflicts, household not having available water every day, distance to water source and inversed stored water (Figure 1f). Lastly, household who didn't receive warning of disasters contributed the most to natural disaster vulnerability, followed by flood, drought and cyclone events in last decade, household with death and injury from disasters (Figure 1g). The major component-wise vulnerability in comparison to the potential vulnerability also divulges and signifies potential areas of intervention, regarding the subcomponents of respective major components for the south-western Bangladesh.











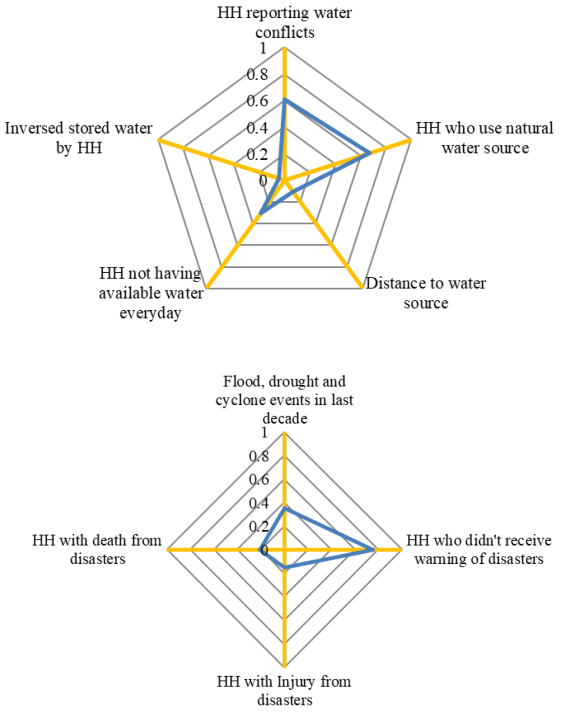


Figure 2: Major component-wise present and potential vulnerability spectrum (a-g) for the south-western coastal Bangladesh

The LVI used multiple subcomponents as indicators to assess exposure (with Natural disasters), sensitivity (with Health, Food security and Water Uses & Scarcity) and adaptive capacity (with Socio-demographic profile, Livelihood Strategies and Social Networks) of the communities under the circumstances of rapid environmental change in the south-western Bangladesh. The factors that governed the livelihood stresses of the south-western coastal population were identified as food security, health, social networks, livelihood strategies, natural disasters, water use & scarcity and socio-demographic profile. Each of these with their specific denomination along with the LVI denoted vulnerabilities of the south-western coastal population. An appraisal into these explores the state of resilience of the probable present and future adaptation and mitigation spectrum. For example, the south-western Bangladesh was most vulnerable in terms of food security, according to the LVI developed in this study, which can be interpreted in the light of the indicative subcomponents comprising the food security sector. As the LVI results on food security suggest, the communities of the study area didn't have the assurance of having food for the whole year with an LVI denomination of 0.799. This affected their livelihood capacity and resilience (with a reverse LVI denomination of 0.201), in terms of food security, the most. It was evident that livelihood capacity has a higher value than livelihood vulnerability and so the study area population was still resilient enough and knowing of the fact that their capacity might deteriorate at the wake of another extreme weather event or environmental disaster. Hence the probability of adaptation and mitigation pathway of the study area population would be ensuring attainment of food for the whole year. This can be facilitated by saving crops (LVI 0.739), saving seeds (LVI 0.737), practicing multi-crop agriculture (LVI 0.275) Months HH have trouble getting enough food (LVI 0.23) and HH mostly dependent on own farm for food (LVI 0.132) by improving the resilience (with reverse LVI 0.261, 0.263, 0.725, 0.77 and 0.868, respectively) in their respective terms. While improving the resilience and capacity, the communities of the study area will instinctively adopt different adaptive measures and mitigation approaches in line with the proper socio-economic perspectives.

Moreover, as the LVI approach focuses on quantifying the strength of current vulnerabilities and capacities of the communities, it also draws probable pathways towards a more resilient coastal Bangladesh. Denominating the lapses and lags of the present community response strategies, both in short and longer time frame, lets the community itself to alter these strategies in response to various environmental exposures. With facilitation from the scientists, policy makers, development organizations and other concerned bodies, this LVI can be used as a practical tool to comprehend adjustments made by the communities in their adaptation strategies. Therefore, such a composite index is very helpful in determining the sensitivity to environmental exposure and the range of adaptive capacity of particular communities, all of which will help enhance the capacity and resilience of the south-western coastal population. Also, the sector-wise flexibility of the LVI, in terms of various subcomponents and major components, divulges and signifies potential areas of intervention.

5. Conclusion

The study examined the livelihood vulnerabilities to environmental change of southwestern coastal Bangladesh by applying the Livelihood Vulnerability Index (LVI). The primary data were collected from 350 households of 7 study sites under 3 study location of this area. The applied LVI represented a utilitarian method for assessing and quantifying relative vulnerability of communities to various proxies induced by rapid environmental changes. The study indicated thatthe communities of the south-western coastal area of Bangladesh were most vulnerable within the jurisdiction of food security. It also depicted that the study area was the least vulnerable within the jurisdiction of socio-demographic profile. Ultimately the final LVI for the communities of the south-western coastal Bangladesh was determined to be 0.386 on a scale of 0-1. This can alternatively be interpreted as a designation of the potential vulnerability or a measure of the livelihood capacity and resilience. The study recommended that the food security and health facilities should be ensured to reduce the vulnerability by the government and NGOs.

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