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Vulnerability of Livelihoods in the Coastal Districts of Bangladesh

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The paper uses the Livelihood Vulnerability Index (LVI) to measure the vulnerability of households living in the coastal region of Bangladesh. The results, based on the findings of a survey on 532 households from 12 coastal districts, indicate that rural households are more vulnerable than urban households, while households living in coastal districts are more vulnerable than those living in exterior districts. Finally, households affected primarily by cyclones are found to be more vulnerable than those affected by floods. The higher vulnerability of coastal households stems from poor access to health facilities, a weaker social network as well as from natural disasters and climate variability. The higher vulnerability of rural households is also explained by poor health factors such as lack of access to sanitary toilets. The rural households also have adverse social and demographic profile, weaker social networks and they are more vulnerable to natural disaster and climate variability.

Keywords: Vulnerability, Index, Climate Change, Adaptation, Coastal, Bangladesh
JEL Classification: Q54

I. INTRODUCTION

The coastal zone of Bangladesh has an area covering 47,211 km² facing the Bay of Bengal or having proximity to the Bay. It is prone to violent storms and tropical cyclones which originate in the Indian Ocean and track through the Bay of Bengal (Dasgupta *et al.* 2011). In the last 200 years at least 70 major cyclones hit the coastal belt of Bangladesh and during the last 35 years nearly 900,000 people died due to catastrophic cyclones (PDO-ICZMP 2004).

Bangladesh is widely recognised as one of the most climate vulnerable countries in the world (Harmeling 2010). It experiences frequent natural disasters

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that cause loss of life, damage to infrastructures and economic assets, and adversely impact on lives and livelihoods, especially of poor and marginal households.

Climate change will continue to exacerbate many of the current problems and natural hazards the country faces. It is expected to result in:

- increasingly frequent and severe tropical cyclones, with higher wind speeds and storm surges leading to more damage in the coastal region;

- heavier and more erratic rainfall in the Ganges-Brahmaputra-Meghna system, including Bangladesh, during the monsoon resulting in:

  - higher river flows, causing over-topping and breaching of embankments and widespread flooding in rural and urban areas,
  - river bank erosion, leading to loss of homes and agricultural land to the rivers;
  - increased sedimentation in riverbeds, leading to drainage congestion and water-logging;

- melting of the Himalayan glaciers, leading to higher river flows in the warmer months of the year, followed by lower river flows and increased saline intrusion after the glaciers have shrunk or disappeared;

- lower and more erratic rainfall, resulting in increasing droughts, especially in drier northern and western regions of the country;

- sea level rise, leading to submergence of low-lying coastal areas and saline water intrusion up along coastal rivers and into groundwater aquifers; reducing freshwater availability; damage to the Sundarbans mangrove forest, a World Heritage site with rich biodiversity; and drainage congestion inside coastal polders, which will adversely affect agriculture;

- warmer and more humid weather, leading to increased prevalence of disease.

These are wider impacts of climate change on resource systems and environment but the ultimate impact that matters most is on the livelihoods of the people. The crucial issue here is, how do they affect livelihoods? To address this and related concerns vulnerability assessment is required that can help understand the complex set of factors that contribute to adaptive capacity of the households. Vulnerability assessment describes a diverse set of methods used to systematically integrate and examine interactions between humans and their physical and social surroundings.

The field of climate vulnerability assessment has emerged to address the need to quantify how communities will adapt to changing environmental conditions. Many of these methods rely heavily on the IPCC working definition

of vulnerability as a function of exposure, sensitivity, and adaptive capacity (IPCC 2001). Hahn, Riederer and Foster (2009) have developed Livelihood Vulnerability Index (LVI) as a tool for vulnerability assessment.

The LVI uses multiple indicators to assess exposure to natural disasters and climate variability, social and economic characteristics of households that affect their adaptive capacity, and current health, food and water resource characteristics that determine their sensitivity to climate change impacts. This approach differs from previous methods in that it uses primary data from household surveys to construct the index.

The approach used by Hahn *et al.* (2009) has several advantages over past efforts. First, it uses primary data from household surveys to construct the index. This helps to avoid the pitfalls associated with using secondary data. Second, it presents a framework for grouping and aggregating indicators at the regional level. Third, it does not depend on climate models and misses livelihoods complexity at the local level.

However, Hahn *et al.* (2009) did not apply their index beyond broader regional levels, although they mentioned of vulnerability differences across several dimensions. Kasperson and Kasperson (2001) show that climate change stressors can disproportionately affect the poor, elderly or, otherwise, marginal households. The extent of poverty has also been found to be higher in the coastal region as compared to other parts of Bangladesh (PDO-ICZMP 2003). Besides, there is an additional burden of poverty and vulnerability on the households living in coastal areas of Bangladesh (Sen and Yunus 2011). Dependence on agriculture based livelihoods can increase vulnerability of the households who do not diversify (Fields 2005). This analysis can be easily extended to other dimensions. For example, within a region one may expect different vulnerabilities for those living in the urban areas and those in the rural areas.

We will use and extend the scope of this index to measure and explain the vulnerability of the households living in the coastal region of Bangladesh covering three dimensions: rural-urban vulnerability, coastal-interior vulnerability and disaster related vulnerability (flood and cyclones). By measuring the LVI, we will try to specifically answer the following questions:

- Are rural households more vulnerable to climate change as compared to the urban households?
- Are households living close to the coast more vulnerable than those living away from the coast?
- Are households more vulnerable to floods than to cyclones?

The LVI will also help us to identify the factors that can explain the differences.

II. METHODOLOGY AND DATA

The original data was collected for making a coastal economic risk assessment of livelihoods brought about by tsunami/storm surge events. For this purpose, at the first stage, 12 coastal districts were selected. In the second stage, as many as 18 upazilas were selected from these districts (Table A.1 in the Appendix). These upazilas were selected on the basis of their proximity to the coast of the Bay of Bengal. In the third stage, as many as 36 union parishads/paurashavas were selected. As such, the selection process in the first and third stages was purposive. Finally, as many as 532 households were selected with average of 15 households from each union parishad/paurashava. The household questionnaire was designed in a manner to extract information about socioeconomic characteristics of a household, level of exposure to risks and the experience they had on the catastrophic impact of last disaster on their lives and livelihood and how they cope with the disaster. The data used in this paper was not specifically collected for the measurement of the LVI. However, the information contained in the questionnaire was used for measuring the LVI.

Based on available information in the dataset, we used several indicators to assess vulnerability. The following major components are used: *socio-demographic profile*, *livelihood strategies*, *social networks*, *health*, *food*, *water*, and *natural disasters and climate variability (*Table I). Each component has several sub-components. These sub-components are chosen on the basis of their relevance to each major component. Obviously, if we had more local information on some other aspects, the richness of the sub-components could have been easily improved. For example, we could not use rainfall and temperature data because we did not have these data at a disaggregate level. If we had this data we could have better capture more climate change effects. On the other hand, we used several indicators dealing with losses and damages incurred by the surveyed households from natural disasters. These information are not readily available from secondary sources and at a disaggregate level.

III. LIVELIHOODS VULNERABILITY INDEX (LVI)

Each of the seven major components of LVI comprises of several indicators or sub-components as shown in Table I. To calculate the LVI we used a balanced weighted average approach where each sub component contributes equally to the overall index though each major component is comprised of a different number of sub-components. As each sub-component was measured on a different scale, we first standardized each as an index using the following equation

$$Index_X = \frac{X - X_{\min}}{X_{\max} - X_{\min}} \tag{1}$$

X is the original sub-component, $X_{\min}$ and $X_{\max}$ are the minimum and maximum values, respectively, for each sub-component. For example, the value of the sub-component dependency ratio ranged from 1 to 5. These minimum and maximum values were then used to transform this indicator into a standardized index to integrate it into the major component Socio-Demographic Profile. For variables that measure frequencies such as the "percent of female headed households," the minimum value is set at 0 and the maximum at 100. Sub-components like "average agricultural livelihood diversity index" are created because an increase in the crude indicator, i.e. the number of agricultural livelihood activities undertaken by a household in this case, is assumed to decrease vulnerability. This means that a household who produces rice in the fields and culture fish in the ponds is less vulnerable than a household who only produces rice. We have taken an inverse of this number (1/ (1+1+1) =.33. Note that 1 is added to the denominator to avoid indeterminate ratios for households who do not pursue any agricultural livelihoods. The inversion generates a number that assigns higher values to households who pursue a lower number of agricultural livelihoods.

After each sub-component is standardized, they are averaged to calculate the value of each major component, as shown in equation 2:

$$M_z = \frac{\sum index_{s_z i}}{n} \tag{2}$$

where M_z is one of the seven major components [Socio-Demographic Profile (SDP), Livelihood Strategies (LS), Social Networks (SN), Health (H), Food (F), Water (W), or Natural Disaster and Climate Variability (NDC)] for zone z (say, coastal or interior), $index_{s_z i}$ represents the sub-components, indexed by i, that make up each major component, and n is the number of sub-components in each major component.

Once values for each of the seven major components were calculated, they were averaged using Eq. (3) to obtain the LVI:

$$LVI_z = \frac{\sum_{i=1}^{7} w_{M_i} M_{zi}}{\sum w_{M_i}} \tag{3}$$

It can also be expressed as:

$$LVI_z = \frac{WSDPSDP_z + WLSLS_z + WSNSN_z + WHH_z + WFF_z + WWW_z + WNDCNDC_z}{WSDP + WLS + WSN + WH + WF + Ww + WNDCNDC} \quad (4)$$

LVI_z is the Livelihood Vulnerability Index for zone z and equals the weighted average of the seven major components pertaining to that zone z. W_{mi}, or weights of each of the major components are determined by the number of sub-components that make up each major component. For example, SDP has four sub-components, so W_{SDP} will be 4. Weights are included so that all sub-components contribute equally to the overall LVI. In this paper, the LVI is scaled from 0 (least vulnerable) to 0.5 (most vulnerable).

One major limitation of this method is the use of equal weights. Not only the sub-components but also the major components are weighted equally. Eakin and Bojorquez-Tapia (2008) use a fuzzy logic method for deriving unequal weights on the factors. Vincent (2007), on the other hand, suggested use of expert opinions in determining the weights.

As pointed out by Vincent (2007), the indicators (major and sub-components) oversimplify a complex reality and there is inherently no straightforward way to validate indices comprised of disparate indicators. Also, as the sub-components are averaged into one major component score, the indexing approach does not incorporate variance between study populations. The selection of sub-components and the assignment of directionality from less to more vulnerable involve normative judgment.

IV. MAJOR COMPONENTS AND SUB-COMPONENTS COMPRISING THE LIVELIHOOD VULNERABILITY INDEX (LVI)

In this study we have considered seven major components: social and demographic profile or SDP, livelihoods strategy or LS, social network or SN, health (H), food (F), water (W), and natural disaster and climate variability (NDCV). Each major component has several sub-components, as shown in Table I. The figure in parenthesis indicates the number of sub-components that belong to the respective major component. For example, the major component social and demographic profile or SDP has four sub-components and each of the sub-components is described in subsequent columns. We have provided explanation of the sub-component as well as the survey question associated with it. In the final column we have provided an explanation of the relationship of these sub-components to vulnerability.

TABLE I
MAJOR COMPONENTS AND SUB-COMPONENTS COMPRISING THE LIVELIHOOD VULNERABILITY INDEX (LVI)

Major Components	Sub-components	Explanation of Sub-components	Survey Question	Relationship/explanation
1. Social and Demographic Profile, SDP (4)	1.1. Dependency ratio	Ratio of the population under 15 and over 65 years of age to the population over 15 and below 65 years of age	Information collected from household roster on age of each member.	Positive (Higher dependency ratio increases vulnerability)
	1.2. Per cent of female members in households	Percentage of female members to total members in the household	Information collected from household roster on sex of each member.	Positive (Higher proportion of female members increases vulnerability)
	1.3. Average education of the head of the household	Percentage of households where the heads of household report that they have attended zero years of formal schooling	Information collected from household roster on the level of education of each member, including the head of the household.	Positive (More illiterate head of the households increase vulnerability)
	1.4. Average age of household heads	Average age of head of households	Household roster collected information on age of each member, including the head of the household.	Positive

(Contd. Table I)

Major Components	Sub-components	Explanation of Sub-components	Survey Question	Relationship/explanation
2. Livelihood Strategies, LS (5)	2.1. Agricultural livelihood diversification index	The inverse of the number of agricultural livelihood activities +1 reported by a household. For example, a household that cultivates rice, vegetables and has aquaculture in pond will have a livelihood diversification index = 1/ (3 + 1) = 0.25.	What are the crops that you cultivate? How much land do you devote in each crop and aquaculture?	Positive (More agricultural livelihoods reduce vulnerability but here an inverse is considered)
	2.2. Natural resource and livestock index	The inverse of the number of natural resource and livestock ownership+1 reported by a household. For example, a household that has livestock, poultry and tree will have a natural resource and livestock index = 1/ (3 + 1) = 0.25.	What are the different livestock or natural resources that you own? What are they? How many?	Positive (More natural and livestock resources reduce vulnerability but here an inverse is considered)
	2.3. Percentage of agricultural livelihoods	Percentage of agricultural livelihoods undertaken by a household compared to its total number of livelihoods	What is your occupation? What are the occupations of your family members?	Inverse (Non-agricultural livelihoods have higher incomes)
	2.4. Agricultural and fishing equipment value index	Inverse of value of total fishing and agricultural equipment owned by a household + 1.	The household stated the number of such equipment owned and their unit price.	Positive (More agricultural and fishing assets reduce vulnerability but here an inverse is considered)

(Contd. Table I)

Major Components	Sub-components	Explanation of Sub-components	Survey Question	Relationship/explanation
	2.5. Transportation assets value index	Inverse of the value of total transportation equipment of households+ 1. Transport equipment includes rickshaws, vans and so on.	The household stated the number of transport equipment owned and their unit price.	Positive (More transportation assets reduce vulnerability but here an inverse is considered)
3. Social Network, SN (3)	3.1. Availability of amenities	Inverse of the total number of types of amenity available. For example, if the village has primary school and primary health care centre, amenity= 1/ {1+ (1+1) =.33.	Do you have primary school, high/junior school, primary health care, doctor's chamber, cyclone shelter, general hospital, bazar, fire services in your village?	Positive (More amenities reduce vulnerability but here an inverse is considered)
	3.2. Sources of assistance received	Inverse of the sources of assistance that the household received from government agencies/NGOs/financial institutions+1	Did any of the following institutions help you after the natural disaster?	Positive (More sources of assistance reduce vulnerability but here an inverse is considered)
	3.3. Total assistance received	Inverse of the total number of type of assistance received plus 1.	This considers the loans received from NGOs, other assistance received from NGOs and so on.	Positive (More assistance reduce vulnerability but here an inverse is considered)

(Contd. Table I)

Major Components	Sub-components	Explanation of Sub-components	Survey Question	Relationship/explanation
4. Health, H (2)	4.1 Access to sanitary latrine	Percentage of households without a sanitary latrine	What is the type of latrine you use? The response "no latrine" is reckoned here.	Positive (Higher the proportion of households without access to sanitary latrines, higher is the ulnerability)
	4.2. Total person days of injury in the households	Number of days someone in the household is injured	What is the duration of illness due to injury in days?	Positive (Higher the duration of illness due to injury/sickness, higher is the vulnerability)
5. Food, F (3)	5.1. Number of months with adequate food supply	Number of months a household had adequate food supply through production and purchase	How many months on average was it possible to provide sufficient food to family members?	Inverse (Higher food security results in lower vulnerability)
	5.2. Number of months with adequate food supply from own production	Number of months a household has adequate food supply through production only	How many months on average was it possible to provide sufficient food to family members from own production?	Inverse (Higher food security results in lower vulnerability)
	5.3. Extent of crop damage	Value of crops damaged due to natural disaster	What are the amounts of crop damaged? What are the prices per unit of the crops?	Positive (Higher the extent of crop damage, higher is the vulnerability)

(Contd. Table I)

Major Components	Sub-components	Explanation of Sub-components	Survey Question	Relationship/explanation
6.Water, W (4)	6.1. Unsafe source of drinking water	Whether the household has access to safe drinking water. Sources of water such as from pond, water-tank or river/canal/marshland, etc. are considered unsafe.	What is the source of your drinking water? Several choices are given which are classified as safe (tap, tube-well, etc.) and unsafe (pond, river, etc.)	Positive (So higher percentage of households drinking unsafe water implies higher vulnerability.)
	6.2. Distance to source of natural water	Self Explanatory	What is the distance (in km) of source of drinking water from your home?	Positive (Longer the distance, the higher is the vulnerability)
	6.3. Whether experienced scarcity of water	Self Explanatory	Is the water supply from the source you use adequate?	Inverse (More adequate source of water supply reduces vulnerability)
	6.4. Whether the household spent money to get water	Amount of money spent on getting water	Did you spend any money on drinking water in the last 12 months? If Yes, how much?	Positive Higher the amount of money spent on getting water, higher is the vulnerability.
7. Natural Disaster and Climate Variability, NDCV (9)	7.1. Number of natural disasters during the last 20 years	Natural disasters include, among others, flood, draught, cyclone, surge, etc.	How many natural disasters occurred in your village during the past 20 years?	Positive (Higher the incidence of natural disasters, higher is the vulnerability)

(Contd. Table I)

Major Components	Sub-components	Explanation of Sub-components	Survey Question	Relationship/explanation
	7.2. Number of times affected by disaster	Total number of times the household is affected by natural disasters in the past 20 years	In the past 20 years, how many times have you been affected by natural disasters?	Positive (A household more affected by disaster is more vulnerable)
	7.3. Value of crops damaged	Value of the crops damaged due to natural disaster	Was any crop damaged due to natural disasters?	Positive (Higher the value of crops damaged, more vulnerable is the household)
	7.4. Value of pond fish damaged	Value of the fishes in pond damaged due to natural disaster	Was there any damage of pond fishes due to natural disasters?	Positive (Higher the value of fishes in pond damaged, more vulnerable is the household)
	7.5. Value of livestock damaged	Value of the livestock damaged due to natural disaster	Was there any damage to livestock due to natural disasters?	Positive (Higher the value of heads of livestock damaged, more vulnerable is the household)
	7.6. Value for damaged agricultural equipment	Value of cultivation machineries and equipment damaged due to natural disaster	Was there any damage of equipment due to natural disasters?	Positive (Higher the value of cultivation machineries and equipment damaged, more vulnerable is the household)

(Contd. Table I)

Major Components	Sub-components	Explanation of Sub-components	Survey Question	Relationship/explanation
	7.7. Value for damaged fishing equipment	Value of fishing machineries and equipment damaged due to natural disaster	Was there any damage of equipment due to natural disasters? Amount of damage in numbers?	Positive (Higher the value of fishing machineries and equipment damaged, more vulnerable is the household)
	7.8. Value for damaged household items	Value of the household items damaged due to natural disaster	Was any household items damaged due to natural disasters? Amount of damage in numbers?	Positive (Higher the value of household items damaged, more vulnerable is the household)
	7.9. Indicator of vulnerable house	Indicates how vulnerable a house is to natural disasters. Inverse of (strong walls+ strong roof + strong floor+1). For example, if a house consists of strong walls, weak roof and strong floor, the value will be {1/ (1+0+1+1)} = 0.33.	What is the wall of your house made of? What is the roof of your house made of? What is the floor of your house made of?	Positive (A stronger house reduces vulnerability but here an inverse is considered)

V. RESULTS AND ANALYSIS

The main purpose of this paper is to measure LVI to see whether LVI varies by coastal and interior regions or by rural and urban locations or by the type of natural disasters (flood and cyclone). Estimates of the major components and the sub-components are provided in Table II.

5.1 Coastal and Interior Vulnerability

Are households living close to the coast more vulnerable than those living away from the coast? If so, why? What are the factors that may make a household living in the coastal areas more vulnerable to a household living in an interior area?

LVI estimates show that the households living more close to the coast are more vulnerable than those living away from the coast. The LVI for households living close to the coast is 0.348 as against 0.324 for those living in the interior.

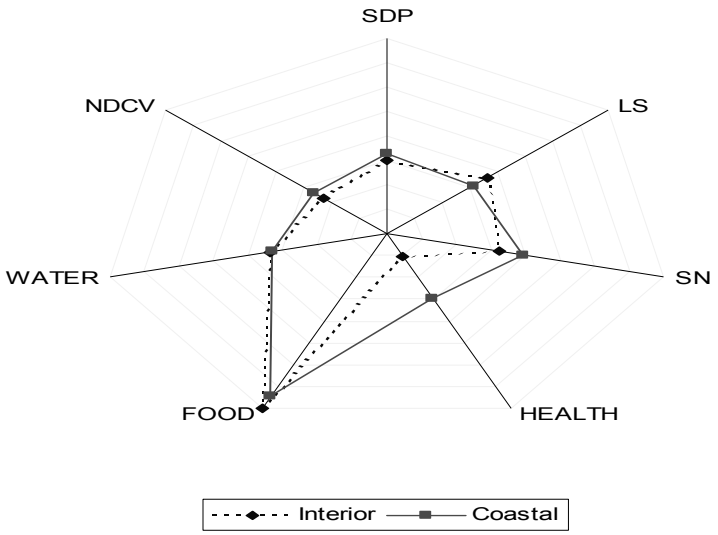
The crucial issue here is the health factors. It is the lack of access to sanitary latrines that makes the households more vulnerable in the coastal areas. Note that the households living in the interior are slightly more vulnerable to injury but it is the sanitary condition of the toilets that makes health conditions worse in the coastal region.

The households in the coastal areas also have weaker social networks. These are reflected in the number of amenities such as the number of primary, junior and high schools, primary health care facilities, doctor's chambers, cyclone shelters, general hospitals, bazaars, fire services, etc. available to the households. These amenities are less available in the coastal region as compared to the interior. The coastal households also received assistance from fewer sources. Government organisations, NGOs or the banks did not provide enough assistance to them.

The households in the coastal areas are also found to be more vulnerable to natural disasters and climate variability factors. For example, they faced more disasters in the last 20 years, they were more affected by these disasters, and the extent of damage to crops was higher. The extent of damage to livestock, household items were also high. On the other hand, they live in more vulnerable houses.

The relative contribution of the major components to overall vulnerability is shown in the spider diagram (see Figure 1). The diagram, in this context, provides a visual aid to identify the major components that are responsible in determining vulnerability. Figure 1 depicts differential vulnerability between the households living in interior and coastal regions.

Figure 1: Vulnerability Spider Diagram of the LVI for Interior and Coastal Regions



5.2 Rural and Urban Vulnerability

Are rural households more vulnerable to climate change as compared to the urban households? What factors explain the difference?

The LVI for the rural households has been estimated at .337 as compared to .324 for the households living in urban areas. Thus our estimates of LVIs suggest that a household living in the rural areas is more vulnerable than a household living in urban areas. We will now analyse the factors that explain this difference.

The key factor here is the health services available to urban and rural households. The rural households are more vulnerable than the urban households due to higher prevalence of unhygienic toilets. Also, the members of rural households have more injuries from natural disasters.

The rural households have been found to have a weaker social network. This is explained by relative remoteness in the rural areas of the coastal regions of Bangladesh. Although the rural households are better positioned in terms of the number of sources of assistance received and also in terms of total assistance received, they are worse off in terms of availability of amenities such as the number of schools, health care, etc. These amenities are available more to the households living in the urban areas.

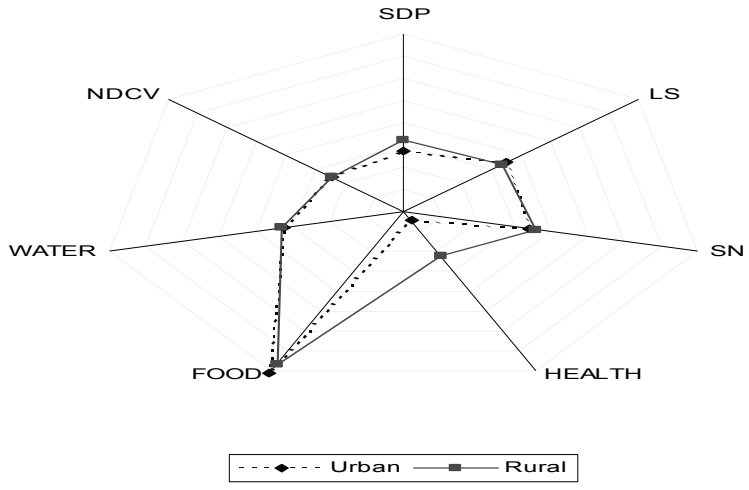
The rural households are also vulnerable because of adverse social and demographic profile. The rural households have more female members in the households, dependency ratio is also higher. More rural household heads have not ever been to formal school (zero years of schooling). The average age of the head of the household in the rural areas is larger than the age of the head of the household living in the urban area.

The rural households are more vulnerable than their urban counterparts from natural disaster and climate variability. While in some respects the urban households are more vulnerable (number of disasters, damaged household assets and fishes in ponds), in others it is the other way round (crops, livestock, fishing equipment damaged). The crucial factor here is the weaker housing structures in the rural areas. The houses are not as strong as urban houses and this increases vulnerability of rural households.

Rural households are more vulnerable in terms of source of drinking water. A larger percentage of households in the rural areas reported that they depend on unsafe source of drinking water such as ponds or river. Rural households have some advantages because they do not have to pay for water as much as urban households have to pay for it. Also, source of water is close to the rural households.

The relative contribution of the major components to total vulnerability is shown in the spider diagram (see Figure 2). The contrast in vulnerabilities amongst households living in urban and rural regions is also depicted.

Figure 2: Vulnerability Spider Diagram of the LVI for Urban and Rural Regions



5.3 Vulnerability from Floods and Cyclones

Are households more vulnerable to floods than to cyclones? If so, what key factors explain these differential vulnerabilities? Even though the sample households are located along the coast lines, some of the households may be more susceptible to flooding than cyclone. The respondents were thus asked to characterise their location against these two attributes. Thus this categorization along flood-prone vis-à-vis cyclone-prone is based on the perception of respondents.

LVI calculated for cyclones (.339) is found to be higher than the LVI calculated for floods (.320).

Social networks do not work well during cyclones as compared to floods. Vulnerabilities from all the sub-components of the major component social network are found to be higher for cyclones as compared to floods.

Water is also a crucial factor. Safe source of drinking water becomes more problematic during cyclones as compared to floods. Besides, there is more scarcity of drinking water during cyclones. More households have to pay for water during cyclones as compared to floods.

Cyclones make food situation more vulnerable than what floods do. The findings suggest that those who identified cyclones as a major concern have lesser number of months of adequate food supply. They also face a higher extent of crop damage from cyclones. In terms of health factors, regions identified as more flood-prone are found to be more vulnerable.

The relative contribution of the major components to vulnerability brought about by floods and cyclones is shown in the spider diagram (see Figure 3). It shows the major components that explain the difference in vulnerability of the households under flood and cyclone conditions.

Figure 3: Vulnerability Spider Diagram of LVI from Flood and Cyclone

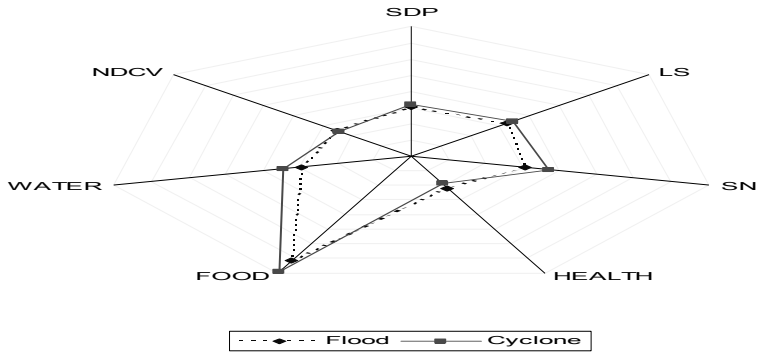


TABLE II

INDEXED SUB-COMPONENTS, MAJOR COMPONENTS, AND OVERALL LVI FOR THE REGIONS INTERIOR, COASTAL, URBAN, RURAL, FLOOD PRONE AND CYCLONE PRONE.

Major Components	SL	Sub-components	Units	Interior	Coastal	Urban	Rural	Flood	Cyclone	Overall
Livelihood Vulnerability Index, LVI				*0.324*	*0.348*	*0.324*	*0.337*	*0.320*	*0.339*	*0.335*
	1.1	Dependency ratio	Average	0.498	0.498	0.487	0.500	0.514	0.493	0.498
	1.2	Per cent of female members in households	Per cent	0.159	0.176	0.096	0.181	0.153	0.170	0.167
	1.3	Average education of the head of the household	Average	0.149	0.215	0.109	0.194	0.172	0.182	0.180
	1.4	Average age of household heads	Average	0.398	0.434	0.407	0.416	0.382	0.423	0.415
1. Social and Demographic Profile, SDP (4)				0.301	0.330	0.275	0.323	0.305	0.317	0.315
	2.1	Agricultural livelihood diversification index	Ratio	0.731	0.641	0.758	0.675	0.748	0.673	0.689
	2.2	Natural resource and livestock index	Ratio	0.308	0.218	0.280	0.263	0.169	0.291	0.266
	2.3	Percentage of agricultural livelihoods	Per cent	0.046	0.071	0.016	0.066	0.050	0.059	0.057
	2.4	Agricultural and fishing equipment value index	Ratio	0.709	0.664	0.852	0.656	0.661	0.695	0.688
	2.5	Transportation assets value index	Ratio	0.933	0.936	0.955	0.930	0.881	0.948	0.934
2. Livelihood Strategies, LS (5)				0.545	0.506	0.572	0.518	0.502	0.533	0.527
	3.1	Availability of amenities	Ratio	0.163	0.241	0.031	0.233	0.179	0.205	0.200
	3.2	Sources of assistance received	Ratio	0.484	0.593	0.644	0.514	0.483	0.549	0.536
	3.3	Total assistance received	Ratio	0.316	0.352	0.351	0.329	0.248	0.355	0.333
3. Social Network, SN (3)				0.321	0.395	0.342	0.359	0.304	0.370	0.356
	4.1	Access to sanitary latrine	Percent	0.191	0.580	0.080	0.432	0.422	0.362	0.374
	4.2	Total person days of injury in the households	Average	0.019	0.010	0.014	0.015	0.020	0.014	0.015
4. Health, H (2)				0.105	0.295	0.047	0.224	0.221	0.188	0.194
	5.1	Number of months with adequate food supply	Average	0.656	0.577	0.680	0.607	0.430	0.668	0.619
	5.2	Number of months with adequate food supply from own production	Average	0.879	0.879	0.902	0.875	0.917	0.869	0.879

(Contd. Table II)

Major Components	SL	Sub-components	Units	Interior	Coastal	Urban	Rural	Flood	Cyclone	Overall
	5.3	Extent of crop damage	Average	0.857	0.778	0.848	0.814	0.799	0.825	0.820
5. Food, F (3)				0.798	0.745	0.810	0.765	0.715	0.787	0.773
	6.1	Unsafe source of drinking water	Per cent	0.319	0.016	0.057	0.200	0.046	0.210	0.177
	6.2	Distance to source of natural water	Average	0.872	0.932	1.000	0.881	0.991	0.877	0.900
	6.3	Whether experienced scarcity of water?	Per cent	0.142	0.368	0.227	0.252	0.119	0.281	0.248
	6.4	Whether the household spent money to get water?	Average	0.015	0.010	0.038	0.007	0.010	0.013	0.012
6.Water, W (4)				0.337	0.332	0.330	0.335	0.291	0.345	0.334
	7.1	Number of natural disasters during last 20 years	Average	0.123	0.297	0.238	0.198	0.353	0.166	0.205
	7.2	Number of times affected by disaster	Average	0.191	0.320	0.292	0.243	0.435	0.204	0.251
	7.3	Value of crops damaged	Average	0.015	0.029	0.019	0.022	0.020	0.023	0.022
	7.4	Value of pond fish damaged	Average	0.020	0.018	0.029	0.017	0.023	0.018	0.019
	7.5	Value of livestock damaged	Average	0.035	0.053	0.030	0.046	0.029	0.047	0.043
	7.6	Value for damaged agricultural equipment	Average	0.004	0.000	0.000	0.002	0.000	0.002	0.002
	7.7	Value for damaged fishing equipment	Average	0.026	0.018	0.016	0.024	0.020	0.023	0.022
	7.8	Value for damaged household items	Average	0.011	0.015	0.039	0.008	0.004	0.015	0.013
	7.9	Indicator of vulnerable house	Ratio	0.436	0.511	0.218	0.522	0.322	0.510	0.471
7. Natural Disaster and Climate Variability, NDCV (9)				**0.096**	**0.140**	**0.098**	**0.120**	**0.134**	**0.112**	**0.117**

VI. POLICY IMPLICATIONS

Social networks play an important role in determining vulnerabilities in the coastal districts in Bangladesh. In order to improve the social networks of people living in the coastal regions more amenities have to be made available there. Such assistance includes cyclone shelters, markets, fire services, health care facilities, schools, and so on. On the other hand, the government should increase various assistances given to the coastal households and the NGOs should also be motivated to increase their support. Improving these amenities, particularly during the aftermath of natural disasters, will reduce vulnerability of the households living in the coastal regions.

Health related factors also play an important role. Access to safe drinking water, particularly during natural disaster, is crucial for reducing vulnerabilities of the households. Improving the quality of drinking water will reduce rural vulnerability. The government and the NGOs can install more tub-wells in the rural areas or distribute water purifying tablets during natural disasters.

The issue of sanitary services has been identified as an important factor contributing to vulnerability in this paper. The government should improve the sanitary conditions in the coastal regions and raise consciousness on sanitary issues through awareness programmes. Also, more clinics and hospitals could be built in the coastal regions, particularly in the rural areas, so that days lost in injuries can be reduced.

The government should invest in disaster preparedness, early warning and increase the number of cyclone shelters in the coastal region. Investment in education in the rural areas in the coastal regions will also reduce vulnerability. We have also found that stronger houses reduce vulnerability. The government should make stronger houses during rehabilitation or provide incentive to the rural households for making stronger houses.

VII. LIMITATIONS OF THE STUDY

A balanced weighted average approach was used in the construction of the LVI where each sub-component contributed equally to the overall index. If these weights were derived from other methods such as discussion with the stakeholders, this would have improved the reliability of the index.

We could not use rainfall and temperature data as these are not available at the sub-district levels. It was also not possible to classify the coastal regions included in the study in a meaningful way so that the rainfall and temperature data could be incorporated.

Finally, although we used primary data, it was not collected for measuring vulnerability as such. As information was available that could be used to measure LVI, we have taken advantage of this opportunity. However, this resulted in the absence of more detail explanation of the factors that could better explain differential vulnerabilities. The sub-components were not determined by making field level qualitative exercises but, to our judgement, they do reflect different dimensions of vulnerability in the coastal region of Bangladesh. We have provided our judgement on the sub-components and their relationship to vulnerability in Table I but no supporting opinions were obtained from the surveyed households. It is generally intuitive that the coastal households are more vulnerable than the households in the interior or that the rural households are more vulnerable than the urban households respectively. This has been proven to be correct from our estimates of LVIs, which, in turn, justifies that the interpretation of the sub-components has been in line with reality. For example, a recent survey of 100 fishers from Mongla under the coastal district of Bagerhat by Ahmed, Occhipinti-Ambrogi and Muir (2013) has found that the surveyed fishers identified inadequate food and nutrition (25 per cent), poor housing (18 per cent), health problems (15 per cent), and drinking water crisis (7 per cent) as the key impact of climate change. The study found that the fishing households faced severe health problems with no medical facilities. Most households of fishers (87 per cent) suffered from chronic drinking water shortages, because of groundwater salinity and inadequate tube-well facilities. The problem of drinking water in the coastal districts has been studied by others (Farhana 2011, Khan *et al.* 2011). These factors have been found to play an important role in determining vulnerability of the surveyed households (see Table I).

Given these limitations, the study has shown the usefulness of survey data in measuring LVI. In particular, we have shown that information on many aspects is available in many data that are not generated to measure vulnerability. The paper has also shown that LVI can also be used to explain differences in vulnerability beyond region and capture dimensions of location (coastal and interior, urban or rural) or even types of disasters (flood and cyclones).

VIII. SUMMARY AND CONCLUSIONS

Climate change is explained by changes in temperature and rainfall and its variability and unpredictability. These make the livelihood of those affected vulnerable. While massive changes are brought about, often slowly over a longer period, to resource systems and ecology, the final impact is on people. The pathways to this impact come from a wide range of factors not yet well

understood. In this paper we have identified seven broader factors that affect vulnerability. These are social and demographic factors, livelihood strategies undertaken by the households, social networks, health, food, water and natural disasters.

These broader level factors (major components of livelihoods vulnerability) are affected by smaller components (sub-components) that constitute them. These factors are identified, quantified and added to develop a composite index which has been termed as Livelihood Vulnerability Index.

In this paper we have measured the LVI from a survey of 532 households living in 12 coastal districts of Bangladesh. The LVIs have been constructed to test whether households living in the interior areas of the coastal region of Bangladesh are more vulnerable than households living in the exterior areas. We have tried to check if, within the coastal belt, households living in the rural areas are more vulnerable than those living in the urban areas. Finally, we have compared vulnerabilities arising from floods and cyclones in the coastal region.

We have found that households living in interior region are more vulnerable than those living in the exterior region, those living in the rural areas are more vulnerable than those living in the urban areas. We have also found that vulnerability from cyclones is higher than vulnerability from floods in the coastal region. This paper has identified the factors that explain the vulnerability. The key factors affecting vulnerability in this study are summarised in appendix Table A.2.

Social networks play a key role in all the three dimensions of vulnerability we have studied. Social network is captured by factors such as availability of amenities like schools, hospitals, cyclone shelters, markets and so on. It covers active presence of government and NGO institutional networks and how this network responds to the need of the households confronted by climate change stresses and shocks. The second major factor is associated with health. Health factors are captured by sanitary conditions and by institutional capacity to minimise the time lost and human suffering from injury. Policies have been suggested to address these issues. The third major factor is water. We have considered the degree to which water available to the households is safe, its availability and costs.

It goes without saying that vulnerability is too complex a term to be indexed by a number, as done in this paper. There are also other determinants of vulnerability not included in this measure. Active presence and support from government and other institutions such as the NGOs, better health facilities and

safe and accessible water can help households living in the coastal region of Bangladesh to cope with and adapt to climate change.

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APPENDIX

TABLE A.1
SPATIAL DISTRIBUTION OF THE SAMPLE HOUSEHOLDS

Districts	Upazila	Union Parishad/Paurashava
Bagerhat	Sharankhola	Dakshinkhali (15)
		Royenda (15)
Barguna	Amtali	Amtali Sadar (15)
		Haldia (13)
	Patharghata	Patharghata Sadar (15)
		Kalmegha (15)
	Char Fashion	Char Kalmi (15)
Bhola		Char Manika (14)
	Tazumuddin	Chandpur (15)
		Chanchra (15)
Chittagong	Banshkhali	Katharia (15)
		Saral (14)
	Port Thana	Paurashava (Two Wards) (29)
	Sitakunda	Barabkunda (15)
		Muradpur (15)
Cox's Bazar	Cox's Bazar Sadar	Khurushkul (15)
		Chaufaldandi (15)
	Maheshkhali	Dhalghata (14)
		Kutubjhum (15)
	Sonagazi	Sonagazi Sadar (14)
Feni		Char Chandia (15)
	Dakope	Banishanta (15)
Khulna		Sutarkhali (15)
	Ramgati	Char Ramiz (15)
Laxhmipur		Char Alexander (15)
	Companyganj	Char Fakira (15)
Noakhali		Char Kakra (15)
Patuakhali	Dashmina	Dashmina (15)
		Banshbaria (15)
	Kala Para	Khaprabhanga (15)
		Lata Chapli (15)
Pirojpur	Mathbaria	Tushkhali (15)
		Bara Machhua (15)
Satkhira	Shyamnagar	Buri Goalini (14)
		Atulia (15)
Total		**432**

Note: Size of the sample in each union parishad/paurashava is in the parentheses.

TABLE A.2
THE KEY FACTORS EXPLAINING VULNERABILITY

Major components	Coastal more vulnerable than interior	Rural more vulnerable than urban	Cyclones more vulnerable than floods
Social Networks	Yes	Yes	Yes
Health	Yes	Yes	-
Water	-	Yes	Yes
Natural disasters and climate variability	Yes	-	-
Social and demographic profile	-	Yes	-
Food	-	-	Yes