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The socioeconomic vulnerability index: A pragmatic approach for assessing climate change led risks–A case study in the south-western coastal Bangladesh

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ABSTRACT

We develop a Socioeconomic Vulnerability Index (SeVI) for climate change affected communities in seven unions[1] of *Koyra* upazilla[2] in south-western coastal Bangladesh. We survey 60 households from each union to collect data on various vulnerability domains and socioeconomic indicators. The SeVI aggregate these collected data using a composite indicator index, where a relative weight is assigned to each indicator with a view of obtaining weighted average index scores for different vulnerability domains in different unions. Results suggest that southern and south-eastern unions are relatively more vulnerable, which are the most exposed to natural hazards and mostly surrounded by the mangrove forest *Sundarbans*. Furthermore, social, economic and disaster frequency are found as more influential indicators to adaptive capacity, sensitivity and exposure respectively in *Koyra*. This pragmatic approach is useful to figure out and monitor socioeconomic vulnerability and/or assess potential adaptation-policy effectiveness in data scarce regions by incorporating scenarios into the SeVI for baseline comparison.

1. Background

Over the last few years, the importance of vulnerability and adaptive capacity has been frequently cited in explaining the societal aspects of climate change [1]. Therefore, development of vulnerability research and consequent adaptation policy has become top priority [2]. Various climate change assessment studies explore the vulnerability status for the poor whose livelihood is natural resource dependent [3], which often leads to socioeconomic discrimination in the society [4,5]. However, some scholars opined that effects of environmental change might have catalysed the latent adaptive capacity of rural communities [6,7]. Therefore, policies addressing climate change adaptation put focus on coping capacity in convergence of increasing climatic catastrophes [8].

Since vulnerability possesses the site-specificity, many scholars urge for more local-level analyses for grabbing a better understanding of fundamental features underlying vulnerability along with appropriate targeting of adaptation policies for concerned agencies at local, national and international premises [9–11]. Vincent [12] and Hinkel [2] opined for development of vulnerability or adaptive capacity indices for narrowly defined systems where both deductive and inductive approaches could be endorsed for selecting and aggregating main variables. To show society-nature nexus while dealing with vulnerability, an inductive approach is preferred as it can be devised to suggest effective adaptive options for rural marginal poor [13–17]. For assessing vulnerability, Ostrom [18] and Wisner [19] also urged for an inductive approach where adaptive capacity and flexible governance structure were suggested to include.

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[1] Lowest tier of Local Government in Bangladesh.
[2] Sub-district.

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Starting from the fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC), there have been a good number of research endeavours targeting the vulnerability assessment and adaptive capacity of communities through the development of indices [20–24]. These studies are conducted at various spatial levels having main objectives as quantifying climate-change impacts and revealing who adapts, why and how. However, all these studies have encountered conceptual as well as data-related problems while selecting and aggregating concerned variables in respective indices.

Generally, an index deals with the aggregation of a series of observable contributing variables into a scalar variable [2]. Hence, the main aim of a vulnerability index is making a theoretical concept operational. Since vulnerability is a multidimensional phenomenon, the index generally consists of several subcomponents that aggregate the contributing variables [9]. Constructions of such index distinguish between two major ontological approaches: data-driven and theory-driven approaches [12]. The former approach deductively applies expert judgment and correlates with previous disaster records for the selection and aggregation of contributing indicators [25,26]. Whereas the latter approach applies insights from the literature to select and aggregate contributing indicators [12,27]. The weakness of the former approach revolves around the limited objectivity of experts and assessment of contributing indicators against a benchmark of vulnerability. For latter approach, the weakness is about the normative selection of contributing indicators those may be associated with uncertainty [9]. Considering the said limitations, a third group of scholars adopts both empirical and theoretical aspects to select and aggregate the contributing indicators for concerned index. Table 1 shows pros and cons of some of the recently developed vulnerability indices addressing different set of parameters, where a good number of indices encountered the question of weighing the contributing (sub)components. Furthermore, the conceptual work on vulnerability and its related theme has not resolved the methodological and terminological confusion until recently [2]. At the same time vulnerability conceptualisations are competing and vulnerability is place- and context- specific [33]. Therefore, developing a more focused vulnerability index, especially for coastal area, the IPCC Vulnerability Framework [34] and Coastal Specificities Framework [35] in terms of exposure, sensitivity and adaptive capacity [36] can be recommended. It is because such an index obtains aggregated as well as individual scores of various vulnerability dimensions at spatial context; and prescribes appropriate adaptation and coping options for coastal communities [37].

Considering the above-mentioned facets, in this study we propose an index-based vulnerability measurement which differs from previous methods since we explore vulnerability with a weighted quantitative assessment of observed events. Hence, the aim of this study is- to develop a Socioeconomic Vulnerability Index (SeVI) for coastal communities in Bangladesh, to assess the relative magnitude of domains (types) of vulnerability in different locations of study region and finally to assess the relative magnitude of contributing indicators within concerned vulnerability-dimension. Like some previous studies, we also adopt relative weight (Likert scale proposed by Wyatt and Meyers [38]) for our proposed vulnerability index. However, unlike those studies, we assign weight to each contributing indicator rather than to any of the domain/dimension as a whole. We assign weight to concerned indicators by utilising knowledge-base of local experts and scholars with an emphasis on inductive approach. Previous studies carried out on coastal Bangladesh mainly focused on hazard warning and evacuation system [39], health security due to disaster [40], physical injuries during cyclones [41]; and coastal hazards and community-coping method [42]. Thus, most of these studies dealt with the coastal coping and adaptation mechanisms. However, we hardly find any study that focused on index-based socioeconomic vulnerability measurement through any weighted index, especially in the South-western coastal Bangladesh. Therefore, applying the proposed methodological framework of determining socioeconomic vulnerability, we intend to bridge the gap between community necessity and priority at the micro level and policy variable at the meso level.

To realise the study objectives, we introduce theoretical framework in Section 2, study method including description of the study region and development of the socioeconomic vulnerability index in Section 3. The results are explored in Section 4 along with relevant discussions and usefulness of SeVI, and finally, we make concluding remarks in Section 5.

2. Theoretical conceptualisation

A comprehensive and varied theoretical-support exists on the vulnerability concept [43–52]. IPCC explores vulnerability through three core concepts: firstly, 'exposure magnitude' to which a system is physically in harm's way; secondly, 'sensitivity' of a system i.e. its likelihood to be affected by a shock; and thirdly, the 'adaptive capacity' of a system to cope or adjust with the negative impacts of a shock [53–55]. Again Adger [56] defines 'vulnerability' as exposure of a group or individual stress due to social and environmental change that disrupts livelihoods. He also defines *'Social Vulnerability'* as exposure of individual or group stress from exogenous risks, especially from climatic shocks [13,57]. For such shocks, Ibarraran et al. [58] shows that concerned community's vulnerability depends on its resilience capacity. This capacity of individual and social groups, during responding towards any external shocks is likely to affect their livelihood [59,60].

Since vulnerability is driven by a number of factors, Adger and Vincent [61] suggested a context-specific method for assessing and measuring vulnerability. Sustainable livelihood framework in terms of 'capital asset' is also suggested for measuring vulnerability [62–65]. A distinctive feature of vulnerability measuring concept is the level or scale of analysis which ends with an index construction. Variation in social and economic vulnerability to environmental risk, for instance, can be explained at individual household or community level. Sometimes biophysical indicators are incorporated in vulnerability index [32]. Such index is, furthermore, enriched by incorporating location, settlement pattern and land-use management [66].

Table 1
Comparison among different vulnerability indices.
Source: author's compilation based on literature survey.

Name of the index	Author(s) (Year)	Pros	Cons
Social vulnerability	Lee (2014) [28]	• Indicator based (in terms of capital) study • Zero-mean normalisation was applied to standardise the indicator values	• All indicators (variables) showed same (positive) direction to vulnerability • Considered only single hazard (flood)
Social vulnerability index (SVI)	Ge et al. (2013) [29]	• Application of Projection Pursuit Cluster (PPC) model • Hazard-loss assessment by using economic variables (GDP, PCI)	• Absence of exposure indicator(s) • No algebraic solution of PPC and hence no global optimal solution
Climate vulnerability index (CVI)	Pandey and Jha (2012) [24]	• Primary data based index • Useful tool for assessing spatio-temporal scale differences in vulnerability	• Suitable only for mountainous areas • Weightage of different (sub)components were data sensitive
Vulnerability index	Gbetibouo et al. (2010) [20]	• Large spatial base (9 provinces of South Africa) for data collection • Principal Component Analysis (PCA) for weighing indicators	• Likelihood of paradoxical weight assigning to indicators due to poor data structure
Livelihood effect index (LEI)	Urothody and Larsen (2010) [30]	• Primary data were used • Comparison between LVI and LEI	• Perception on climate change and assigning importance (weights) to contributing factors by the illiterate respondents might not be accurate
Household social vulnerability index (HSVI)	Vincent and Cull (2010) [31]	• Theory-driven index • Composite sub-indices	• Each of the five composite sub-indices was assigned equal weight whereas these might not affect vulnerability equally
Livelihood vulnerability index (LVI)	Hahn et al. (2009) [21]	• Good data set • Diversified components were considered for vulnerability	• Equal weights for all components
Social vulnerability index (SVI)	Vincent (2004) [32]	• Different weights were used for different sub-indices • Multi-country analysis	• For multi-country analysis the relative importance (weights) of sub-indices were likely to be different • Missing data problem due to usage of secondary data
Social vulnerability index (SoVI)	Cutter et al. (2003) [33]	• County-level socio-economic and demographic data were used • PCA was applied for data reduction	• Variables related to exposure to natural hazard were ignored • Likelihood of not considering important variable after extraction of principal components due to data structure

For theoretical framework of this study, we start with Pressure and Release (PAR) Model [67] for developing concept of Socioeconomic Vulnerability Index (SeVI) because this model is more relevant to disaster led vulnerability. We focus on the root causes and dynamic pressure of 'progression of vulnerability' part in the PAR model and select relevant contributing indicators for the study region. These contributing indicators are chosen in accordance with the concept of 'capital assets' developed by Chambers and Conway [62]. Five types of capital assets namely- human, natural, financial, social and physical; which are likely to affect the livelihood framework of people [68] are considered. Maintaining a synergy, we contrast and combine these variables with relevant part of vulnerability index proposed by Krishnamurthy et al. [36] and Community-based Risk Index developed by Bollin and Hidajat [69].

The Community-based Risk Index aims to identify and quantify the main risk factors like- exposure, vulnerability, management capacity etc. within a community [70]. The approaches used in this index can serve as an important tool to identify and highlight the areas where both risk and vulnerability reduction are needed. We adopt the 'Vulnerability' component from this index and modify it by incorporating relevant domains and dimensions complying with vulnerability concept by IPCC [34]. Therefore, in this study we develop the SeVI by combining Bollin and Hidajat's [69] Community-based Risk Index and Krishnamurthy et al.'s [36] Vulnerability index.

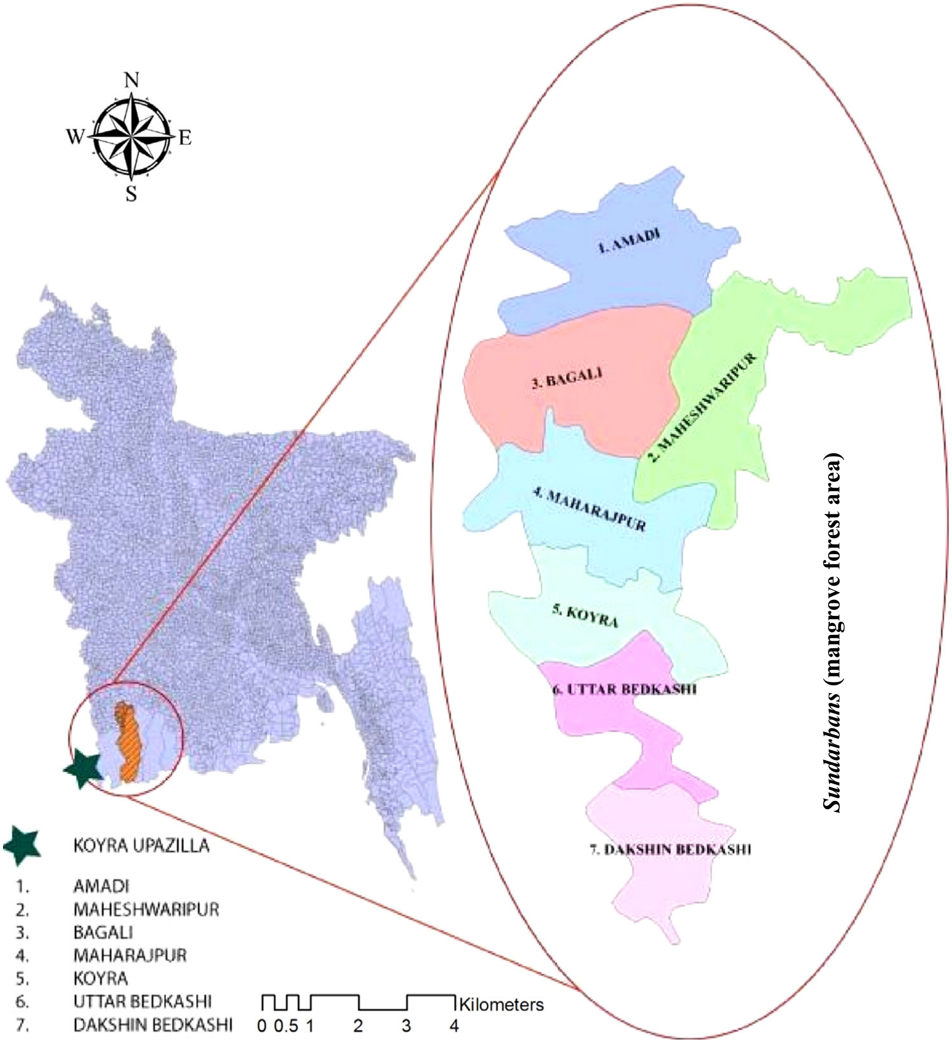

Fig. 1. Map of unions in *Koyra* upazilla.

3. Methods

3.1. Profile of the study region

With a view to assessing how vulnerability is propelled by local socioeconomic and biophysical factors, a case study approach is chosen. Hence, we put the spatial focus on *Koyra* upazilla (sub-district) under the Khulna district of Bangladesh. This upazilla is situated to the South-west part of Khulna district occupying an area of around 1800 km^2. *Koyra* was established as a *Thana* (a kind of sub-district) in 1980 and later was turned into an upazilla. This upazilla consists of seven union parishads,[3] seventy two mouzas[4] and one hundred and thirty one villages [71].

Koyra is about two metres above sea level at the northern edge and about one metre at the south [72]. This area comprises of flat land with natural ground slope surrounded by the *Sundarbans* (world's largest mangrove forest) and Bay of Bengal from the South-east and South directions respectively. This region belongs to immature deltaic slope where the long belt of land is hardly above the sea level.

The river *Koyra* is the main flow stream in this upazilla. Due to natural tidal action the rivers *Shibsa*, *Pasur* and *Dharla* have significant influence on both surface and groundwater quality [73]. Being with the coastal belt, the study region frequently faces different disasters like-cyclones, tidal surges, floods, heavy rainfall, river erosion, soil salinity and water logging. Recently the region was hit by two consecutive devastating cyclones – *Sidr* in 2007 and *Aila* in 2009. We carried out this study in all seven unions: *Amadi, Bagali, Koyra, Maharajpur, Maheshwarpur, Uttar Bedkashi and Dakshin Bedkashi*.

3.2. Data collection

In order to realise study objectives, we relied on both primary and secondary data. The qualitative approaches of

[3] Lowest tier of Local Government in Bangladesh.
[4] Clusters.

rapid rural appraisal (RRA) [74] in form of Focus Group Discussions (FGDs) were used to capture the insights into shaping socioeconomic vulnerability and to gain idea on contributing indicators of vulnerability in study region. One FGD was conducted in each union of *Koyra* sub-district. People from different occupations were invited as FGD participants. More than ninety per cent of the participants were the direct victims of climate led shocks during the time of FGDs. A panel of five members- one from local government, one from on behalf of local NGOs, one from Khulna University, one from local UNDP office and one of the authors facilitated the discussions in FGDs. By the dint of seven FGDs, we figured out 27 contributing indicators under five major IPCC-domains (for detail see Table 2). These FGDs were held in form of informal discussion with the local inhabitants to identify the contributing indicators those were responsible for exacerbating their socio-economic vulnerability due to climate change impacts. Fig. 2 shows different stages of data collection with concerned research method and data-type. These FGDs were held between November and December 2009. A quantitative household level survey was also conducted to collect data on contributing indicators of vulnerability. Relevant secondary data were also used for developing the vulnerability index. For household survey, a set of standard thumb-rules suggested by the United Nations Statistical Division [75] was followed. The questionnaire was prepared through an iterative process. Thus, empirical findings from relevant theories, information obtained from RRA and relevant parts from other questionnaires were incorporated while designing the first draft questionnaire, which was pretested and further modified. The survey collected information on demographic, social, economic, physical and exposure to natural-hazards aspects of vulnerability. For this survey, starting from the upazilla (sub-district) level, we narrowed down to the union level for sampling. For the upazilla level, simple random sampling was applied; and for union level stratified and cluster sampling were used. The former sampling type was adopted to conduct FGDs where stakeholders from all walks of life participated while the latter sampling type (both stratified and cluster) was for household questionnaire survey. Hence, a 'multi-stage random sampling' was conducted for data collection. From each union three villages, and from each village twenty households were randomly chosen. The socio-economic and biophysical characteristics of these selected villages were disaster-affected. Based on sample size determination [76,77] at 95% confidence interval, ±10% precision, 50% prevalence[5] with a design effect of 0.6 accounted for cluster sampling; 60 households in each union were surveyed.[6] Therefore, from seven unions of the study region, we selected a total of four hundred and twenty households for questionnaire survey. The questionnaire survey was conducted from December 2009 to January 2010, where 'random walk' [76] methodology was used. The surveyors were intensively trained through a week long workshop for the purpose of uniformity in surveying procedures before they were sent for data collection.

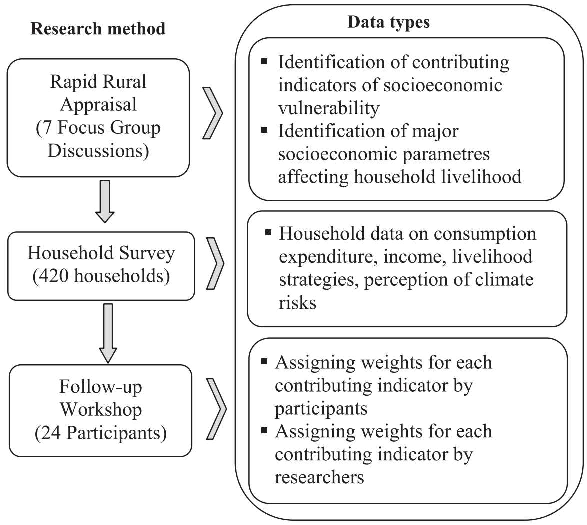

Fig. 2. Stages of data collection.

After data collection a follow-up workshop was arranged in local government administration office of *Koyra* on January 30th, 2010. The justification of this workshop was to settle down the weight for each of the contributing indicators identified during FGDs. We followed almost the same procedure while grouping the participants for obtaining weights for different indicators as did by Below et al. [9]. Like FGDs, the participants in this workshop were from heterogeneous occupations and societal groups. In addition, we invited the participants from local NGOs. A total of twenty four participants attended in the workshop whom we divided into three groups consisting of eight members in each group. Within group we assigned the lead role to either an educated farmer or agriculturist who had been a victim of natural hazard. This group leader was asked to assign weights for each contributing indicators after consultation with other group members. A five point Likert Scale (1 for least important, 5 for most important) was used to weigh the indicators following the method of Wyatt and Meyers [38]. Each group presented relative weight put for contributing indicators and then justified to other groups. This way all three groups finally settled down unique relative weights (1–5) for each of the 27 contributing indicators, which were exchanged through a plenary session. We, the researchers, also assigned weights (1–5) for the same indicators based on our observation during the survey and FGDs. Finally, we determined specific weight for each indicator by taking the average of weights assigned by the groups in the feedback workshop and by the researchers. We did such weighing for two reasons- first, to overcome the limitations of weighting process for indicators in some of the previous studies especially by Hahn et al. [21] and Gbetibouo et al. [20]; and second, to focus more on local phenomena (by considering local knowledge-base in terms of weights on different indicators) so that by replicating this study-method

[5] 50% prevalence indicates to point prevalence of indicators chosen for SeVI, which is a kind of default value for sample size determination when indicator prevalence is not known.

[6] Sample size formula: $n = DEFF \times [(z^2 \times p \times q)/e^2]$; where n=sample size, DEFF=0.6, z=1.96 (95% confidence interval), p=0.5, q=0.5, e=0.10.

Table 2
Major dimensions, domains and variables comprising for socioeconomic vulnerability index (SeVI) developed for *Koyra* sub-district.

IPCC dimension	Domain	Variable/indicator	Explanation	Adapted source	Potential limitation
Adaptive capacity	Demographic	People per km^2	To identify the population density	Human capital [62]	Absence of updated census
		Percentage of old and children in sample	To understand the dependency pattern	Human capital [62]	Absence of birth registration document
		Male–female ratio in sample	To grab the gender gap pattern	Human capital [62]	Extended families; difficult to figure out exact number of families
		Population growth rate	To understand the pressure and potential impact on existing population size	Human capital [62]	Absence of updated census
		Percentage of migrated households in last 5 years in sample	To identify the migration pattern	Human capital [62]	Confusion on provided information when multiple families stay together
	Social	Percentage of illiterate households in sample	To identify the literacy condition. In this case a household's aggregated average schooling years is considered	Human capital [62]	Different understanding by respondents about defining literacy
		Percentage of households not having brick-built house in sample	To detect unsecured living condition	Physical capital [62]	Confusion on brick-built and mud-built among respondents
		Percentage of households participated in the last local-election in sample	To detect participation in decision-making process	Social capital [62]	Recall bias
		Percentage of households contributed free-labour to embankment construction or similar activity in sample	To grab the social responsibility as well as integration	Social capital [62]	Asymmetric information from respondents due to influence of local pressure groups
		Percentage of households enjoy group-credit facility in sample	To identify if there exists group-based credit facility	Financial capital [62]	Conditions for credit facility are heterogeneous in different areas
Sensitivity	Economic	Percentage of households depends on natural source for their income (fisheries, agriculture etc.) in sample	To identify the natural resource dependence for livelihood	Natural capital [62]	Likelihood of mixing up with income from non-agricultural source
		Percentage of consumption expenditure on food in sample	To identify food purchasing capacity	Financial capital [62]	Recall bias
		Percentage of unemployed households in sample	To find out employment pattern with nature-dependent sources	Human capital [62]	Extended families; difficult to figure out when multiple families stay together
		Percentage of households below poverty line in sample	To understand the poverty pattern (poverty line = US$ 202/capita/year in year 2008–09)	Financial capital [62]	Recall bias on consumption items
		Percentage of households lost land (homestead and/or other) in last 5 years due to disasters in sample	To figure out household's land-ownership pattern	Natural capital [62]	Land measuring unit (decimal) differs in areas
		Percentage of households suffered the damage or lost their capital goods (e.g. fishing boats, nets etc.) due to disasters in sample	To detect the asset condition of the household	Financial capital [62]	Subjective estimate of damage by respondents
	Physical	Percentage of households not getting electricity	To identify electricity connexion with household	Physical capital [62]	Confusion on electricity source (rural electricity board or solar energy)
		Percentage of households not having sanitary latrine	To grab the household health and sanitation status	Physical capital [62]	Definition of sanitary latrine differs due to structural method differential in areas
		Percentage of households using pond, river and well water for drinking and cooking		Physical capital [62]	Likelihood of bias response in case of using multi-source
		Percentage of households with family member with chronic illness		Human capital [62]	Subjective definition of 'chronic illness' by respondent
		Percentage of not-paved road in the area	To detect the transportation facility	Physical capital [62]	Absence of updated information from local government office

Table 2 (*continued*)

IPCC dimension	Domain	Variable/indicator	Explanation	Adapted source	Potential limitation
Exposure	Exposure to natural hazards	Percentage of households not willing to go to cyclone shelter	To identify if the households care more for their assets (e.g. cattle) than shifting even during disaster	Physical capital [62]	Difference in perceptions in different areas
		Percentage of households not having shelter in cyclone shelter or with neighbours	To assess the utility of cyclone shelter centres or neighbour's place	Social capital [62]	Recall bias
		Percentage of households do not understand National Warning System	To figure out if any adult member of the household can understand warning about disaster	Human capital [62]	Subjective definition of 'warning'
		Provision of local early warning system	To know if the signal system is easy enough to understand by the households	Physical capital [62]	Confusion on formal and informal warning system
		Number of cyclones in last five years	To detect the existence of disaster preparedness in the locality	Adapted from [81]	Reliability on short term average data
		Number of floods in last five years	To detect disaster frequency	Adapted from [81]	Reliability on short term average data

in other areas may provide efficient result for obtaining vulnerability.

3.3. *Development of the socioeconomic vulnerability index (SeVI)*

The SeVI was developed by using a Composite Indicator Framework method, which consists of three main dimensions: adaptive capacity, sensitivity and exposure [36,50]. These dimensions were further divided into five domains: demographic, social, economic, physical, and exposure to natural hazards. The domains were case-specific and qualitative in nature on a few occasions (for instance, free-labour contribution during any crisis), which were expressed quantitatively by using relevant proxies [78]. Under each domain there were a number of contributing indicators. These indicators altogether possessed certain characteristics, in terms of numerical value, of a specific domain in relation to climate variability and extremes and thus represented household's status in relation to these components [21]. Five domains comprised of 27 indicators (for details see Table 2) formed the SeVI. Since each of the indicator was measured on different scale, it was necessary to standardise each as index value. We used the following formula, adopted from a life expectancy index by UNDP [79], to obtain an index score of indicator for union 'i';

$$\text{Indicator index score}_i = \frac{x_i - x_{min}}{x_{max} - x_{min}} \tag{1}$$

where,

x_i=original value of indicator for the household/community.
x_{max}=the highest value of indicator for the household/community.
x_{min}=the lowest value of indicator for the household/community.

The indicator indices, therefore, produced numerical values showing concerned community's (obtained from aggregated response of households) relative status of vulnerability. For an indicator this numerical value ranges between zero to one. The maximum and minimum values were usually adjusted so as to avoid values of more than one. Any remaining values above one or below zero were fixed at one and zero, respectively.

Once the indicator index value was obtained; the relative weight obtained through follow-up workshop was multiplied with concerned indicator. This way a weighted score for an indicator as shown by Eq. (2) was determined.

$$\text{Weighted indicator score (WIS)}_k = (\text{Indicator index score})_k \times (\text{Average weight})_k \tag{2}$$

Once the weighted score was obtained for each contributing indicator, we proceeded to determining Domain Vulnerability Score by averaging the weighted scores of all indicators within the same domain (shown by Eq. (3)).

$$DO_i = \frac{\sum_{k=1}^{n} (WIS)_k}{\sum_{k=1}^{n} (Average\ weight)_k} \tag{3}$$

where DO_i denotes domain-scores of vulnerability index for union i, which is equal to weighted average of all indicators within the domain (here k indicates the number of indicators within the concerned domain mentioned in Table 2).

Having obtained the domain value of vulnerability; we proceeded for Dimension value of vulnerability. In this study we considered dimensions, suggested by IPCC, as Adaptive capacity, sensitivity and exposure to disasters. Eqs. (4)–(6) provides a clear idea on this-

$$DM_{Adaptive\ capacity_i} = \frac{\sum_{j=1}^{2} DO_j}{2} \tag{4}$$

$$DM_{Sensitivity_i} = \frac{\sum_{i=1}^{2} DO_i}{2} \tag{5}$$

$$DM_{Exposure_i} = \sum_{m=1} DO_m \tag{6}$$

Table 3
Summery statistics of socioeconomic characteristics of sample households in *Koyra* sub-district.
Source: Field survey, 2010

Respondent households' characteristics	Amadi	Bagali	D. Bedkashi	Maharajpur	Maheshwarpur	Koyra	U. Bedkashi
Percentage male respondents	80.9	78.9	86.2	81.3	85.5	89.2	81.4
Respondents' average age	46.2	39.7	41.3	38.2	36.3	42.1	43.2
Percentage of respondents' religion							
Muslim	83.7	92.1	79.7	89.3	91.1	93.2	89.1
Hindu	16.3	7.9	20.3	10.7	8.9	6.8	10.9
Percentage of literate households[a]	37.9	36.3	42.3	6.7	79.9	6.7	40.6
Percentage of respondents' occupation							
Self-employed farmer	22.0	23.1	16.8	18.4	18.4	24.7	21.3
Self-employed fisherman	12.6	15.2	19.3	16.8	13.4	12.7	11.3
Daily labour	27.1	23.4	14.7	18.1	21.2	25.7	21.6
Forest resource dependent	15.2	9.7	21.8	14.8	15.8	6.3	16.5
Others	11.8	15.2	9.6	17.1	18.7	21.2	18.1
Unemployed	17.8	13.4	11.3	14.8	12.5	11.2	9.4
Average number of family members (min–max)	5.6 (4–7)	5.2 (5–9)	4.6 (4–7)	4.2 (5–10)	5.1 (4–11)	5.1 (6–16)	4.2 (5–9)
Average household expenditure for basic needs [in US$/year] (st. dev.)	1000.4 (643.6)	799.1 (489.6)	505.3 (379.4)	1320.4 (1470.9)	952.1 (545.1)	466.7 (324.1)	351.7 (166.5)
Average per capita expenditure for basic needs [in US$/year] (st. dev.)	200.3 (102.1)	159.4 (89.1)	121.7 (77.2)	216.3 (163.5)	190.8 (81.9)	109.9 (80.5)	88.1 (36.0)
Percentage of households dependent on NRDI[b]	70.4	77.1	74.1	75.8	81.2	62.3	75.1
Percentage of households below poverty threshold[c]	71.6	75.6	78.1	82.2	83.4	72.1	87.2
Squared poverty gap	0.0503	0.0464	0.1028	0.1143	0.0323	0.0803	0.1328
Income inequality [Gini coefficient]	0.31	0.31	0.36	0.32	0.27	0.26	0.21
Percentage of households owing agricultural land	75.3	78.3	63.1	82.7	84.2	85.6	81.9
Average size (ha) land owned by households	0.29	0.31	0.23	0.32	0.36	0.41	0.37
Percentage of households having sanitary latrine	12.2	13.2	9.4	11.9	13.7	15.9	10.8
Percentage of households having tube-well (for drinking water)	6.7	6.1	3.5	7.7	8.2	9.8	6.3
Percentage of households having electricity connexion	17.8	20.7	10.2	20.2	22.6	28.3	15.6
Average annual disaster damage for household [in US$]	168	173	195	175	177	171	180

[a] A household is considered literate if its average aggregate academic schooling is at least 5 years.
[b] Natural Resource Dependent Income (NRDI) is considered as income obtaining from agriculture (crop cultivation), fishery and forest resource collection.
[c] The Bangladesh Bureau of Statistics calculates the Basic Need Cost as a poverty threshold value, which was US$ 202/capita/year in 2008–09.

where *j, l, m* denote number of domains under adaptive capacity, sensitivity and exposure to disasters respectively (see Table 2 for detail); and '*i*' denotes union. Finally the socio-economic vulnerability of a union '*i*' was obtained by Eq. (7)

$$SeVI_i = \frac{DM_{Adaptive\ capacity_i} + DM_{Sensitivity_i} + DM_{Exposure_i}}{3} \quad (7)$$

Hence, the Socioeconomic Vulnerability Index (SeVI) for union '*i*' equals the average of three Dimension-scores, where these dimensions possessed weighted scores. We assumed that interrelationship among three vulnerability dimensions was not specified and governed by concerned spatial attributes only. We, however, also assumed that SeVI possessed a direct relationship with system's exposure and sensitivity and inverse relationship with its adaptive capacity [80]. Hence, we used inverse (1 minus indicator score) value for adaptive capacity for index calculation.

In this study, the SeVI was scaled from 0 (least vulnerable) to 1 (most vulnerable). A detailed list of dimensions, domains, indicators/ contributing variables is given in Table 2 with the justification of choosing the indicators, adapted source for the indicator and potential limitations.

4. Results and discussion

We report the results of data analysis for socioeconomic vulnerability of the study region in two parts: domain wise and IPCC-dimension wise. We also discuss the possible reason(s) of different vulnerability patterns in different unions of the study region. Starting with Table 3, major demographic and socioeconomic characteristics of the respondent households are shown across the unions,

Table 4
Indicator index scores and overall SeVI scores of unions in *Koyra* sub-district (Average weight for concerned 'Domain' is in parenthesis).

Domain	Indicators	Amadi	Bagali	Dakshin Bedkashi	Koyra	Maharaj–pur	Maheshw-arpur	Uttar Bedkashi
Demographic (19.5)	People per km^2	0.94	1.00	0.27	0.96	0.86	0.86	0.00
	Percentage of old and child in the area	0.18	1.00	0.83	0.93	0.87	0.00	0.00
	Woman-man ratio	0.29	0.32	0.29	0.32	0.30	0.27	0.29
	Population growth rate	0.11	0.41	1.00	0.46	0.00	1.00	0.55
	Percentage of households migrated to this area in last 5 years	0.25	0.57	0.36	0.57	0.57	0.00	1.00
	Weighted average score (st. dev.)	**0.34 (0.34)**	**0.65 (0.32)**	**0.58 (0.34)**	**0.64 (0.29)**	**0.50 (0.37)**	**0.43 (0.47)**	**0.38 (0.42)**
Social (19.5)	Percentage of illiterate households	0.48	0.82	0.49	1.00	1.00	0.11	0.68
	Percentage households not having brick-built house	0.00	1.00	0.25	0.75	0.45	0.90	0.75
	Percentage of household participated in last national election	0.37	0.28	0.15	1.00	1.00	0.00	0.57
	Percentage of households contributing free labour to embankment construction or similar activity	0.00	0.75	0.31	0.19	0.19	0.71	0.22
	Percentage of households enjoying group-credit facility	0.81	0.84	0.00	1.00	0.90	0.10	0.30
	Weighted average score (st. dev.)	**0.34 (0.33)**	**0.73 (0.27)**	**0.38 (0.39)**	**0.77 (0.35)**	**0.69 (0.37)**	**0.36 (0.41)**	**0.48 (0.23)**
Economic (24)	Percentage of households depend on natural sources for income	0.42	0.08	0.27	0.32	0.77	1.00	0.00
	Percentage of unemployed households	1.00	0.66	0.08	0.11	0.55	0.54	0.00
	Percentage of consumption expenditure on food in sample	0.43	0.35	0.81	0.96	0.00	0.52	1.00
	Percentage of households below poverty line in sample	0.10	0.48	0.79	0.65	0.91	0.35	1.00
	Percentage of households lost land in last 5 years	0.28	0.56	0.72	0.64	0.64	1.00	0.58
	Percentage of households suffered disaster damage or lost capital asset	0.17	0.88	0.95	0.88	0.88	1.00	0.89
	Weighted average score (st. dev.)	**0.42 (0.32)**	**0.51 (0.27)**	**0.60 (0.35)**	**0.60 0.60 (0.33)**	**0.64 (0.37)**	**0.70 (0.27)**	**0.58 (0.47)**
Physical (20)	Percentage of households not getting electricity	0.44	0.46	0.87	0.45	0.40	0.00	1.00
	Percentage of households not having sanitary latrine	0.01	0.33	0.06	0.79	0.79	1.00	0.76
	Percentage of households use pond and well water for drinking	1.00	1.00	0.13	0.00	0.00	0.95	0.05
	Percentage of households with family member with chronic illness	0.70	0.64	1.00	0.00	0.95	0.98	0.55
	Percentage of not paved road in the area	0.44	0.80	0.98	0.00	1.00	0.75	0.52
	Weighted average score (st. dev.)	**0.55 0.55 (0.37)**	**0.66 (0.27)**	**0.61 (0.47)**	**0.23 (0.36)**	**0.61 (0.42)**	**0.74 (0.42)**	**0.56 (0.35)**
Exposure to natural hazard (25)	Percentage of households not willing to go to cyclone shelter	0.02	0.55	1.00	0.00	0.00	0.62	0.12
	Provision of local early warning system	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Percentage of households do not understand the National Warning System	0.00	1.00	0.45	0.28	0.49	0.07	0.38
	Percentage of households not having shelter in either cyclone centre or neighbours' place	0.00	0.47	0.51	0.38	0.52	1.00	0.18
	Number of cyclone in last five years	0.00	0.55	1.00	0.45	0.73	0.82	0.27
	Number of flood in last five years	0.00	0.70	0.90	0.30	0.80	1.00	0.50
	Weighted average score (st. dev.)	**0.18 (0.41)**	**0.73 (0.24)**	**0.81 (0.26)**	**0.42 (0.33)**	**0.61 (0.34)**	**0.73 (0.37)**	**0.43 (0.32)**
	Overall SeVI score (st. dev.)	**0.44**	**0.54**	**0.67**	**0.37**	**0.54**	**0.68**	**0.52**
	Overall SeVI score (st. dev.)		**(0.21)**	**(0.12)**	**(0.07)**	**(0.12)**	**(0.07)**	**(0.08)**

where on average 78.6 ± 5.9 percent households lived below poverty threshold (consumption of US$ 202/capita/year) and 73.7 ± 5.9 percent households were dependent on various natural sources for their livelihood. The average Gini coefficient was 0.29 ± 0.05 while the average poverty severity (squared poverty gap) was 0.05 ± 0.02 for the sample households in the study region. These indicate respondents in study region were likely to possess inconsistent income sources with either minimal or zero assets like land or capital goods. At the same time a good number of households suffered from lack of basic housing utilities like sanitary latrine, pure drinking water and electricity. We would now focus on discussion of major findings from domain (Fig. 3) and dimension (Fig. 4) –wise vulnerability.

4.1. Domain-wise vulnerability

4.1.1. Demographic vulnerability

Bagali was found as demographically the most vulnerable union with a weighted average score of 0.65 (± 0.32) whereas *Amadi* was found as the least vulnerable union with a score of 0.34 (± 0.32) (see detail in Table 4). Study findings indicated *Bagali* as the most densely populated union with 803 persons/km^2 and *Uttar Bedkashi* as the least densely populated union with 599 persons/km^2 (average percentage (in study region): 753.1 ± 130.6). The households reported the availability of income opportunity as the main reason behind such density variation across unions although the average percentage of unemployed household was 12.9 ± 2.8. *Bagali* again occupied the highest percentage (49.44) of elderly people and children (i.e. highest dependency ratio) while *Uttar Bedkashi* occupied the lowest percentage (45.82) (average percentage: 47.78 ± 1.66). *Koyra* and *Bagali* possessed highest male-female ratio of 1.05 whereas *Maheswarpur* possessed the lowest ratio of 0.95 (average ratio: 1.00 ± 0.03). *Dakshin Bedkashi*, despite the most natural hazard affected area, had the highest yearly population growth rate of 2.10 per cent versus *Maharajpur* occupied the lowest percentage of 1.17 (average percentage: 1.64 ± 0.36). In *Uttar Bedkashi* we found the highest percentage of migrant households (16.70) and the lowest (1.0) in *Maheshwarpur* (average percentage: 8.49 ± 4.93). The households reported the main factor behind such migration is degree of living expense.

4.1.2. Social vulnerability

We found *Koyra* as socially the most vulnerable union in the study region with an average score of 0.77 (± 0.35) and *Amadi* was identified as socially the least vulnerable with a score of 0.34 (± 0.33) (see detail in Table 4). Indicators of this domain showed that highest percentage (93.0) of illiterate households lived in *Koyra* and *Maharajpur*; whereas the lowest percentage (20.0) was found in *Maheshwarpur* union (average percentage (in study region): 64.23 ± 24.86). Households reported the lack of awareness on long-run benefit from education along with very poor infrastructure (such as- school building) was responsible for existing literacy status in study region. Considering shelter security, very few households were found living with brick-built places. This indicates most households resided in places made of weak materials like bamboo, mud and straw; and the maximum percentage (96.70) households found in this category lived in *Bagali* versus the minimum percentage (90.0) in *Amadi* (average percentage: 93.91 ± 2.43). Respondents reported the most influential determinant for above-mentioned phenomenon was inconsistent income source. We found an exceptionally positive response in case of households' voting-participation in national-level elections, where the lowest percentage of households (87.3) was found in *Bagali* and the maximum (100) was found in *Maheshwarpur* (average percentage: 93.03 ± 5.18). It was because the household-heads usually availed cash and non-cash incentives from the competing candidates during the election. We, however, found a poor response with greater deviation in case of free labour contribution, which was assumed to be a good proxy for social capital [82]. We found the highest percentage of households (96.70) in *Dakshin Bedkashi* to contribute free labour in common issue like damage construction of embankment, whereas the lowest percentage of households (43.30) in this case was in *Bagali* (average percentage: 66.56 ± 20.10). The magnitude of and return on such contribution was reported by households as main determinant for such result. Households were more likely to contribute their labour if they were to put small effort but with greater returns (both tangible and intangible benefits). Integration within society (i.e. social capital) was also an important factor in this regard as identified by the households. We found highest percentage of households (44.79) in *Koyra* versus lowest (23.11) in *Dakshin Bedkashi* who availed the group-credit facility from different NGOs (average percentage 35.32 ± 9.02). Households reported that main parameter of providing such credit had been the rate of recovery by the credit provider NGOs.

4.1.3. Economic vulnerability

Maheshwarpur was found economically the most vulnerable union (score: 0.70 (± 0.27)), and *Amadi* (score: 0.42 (± 0.32)) was found the least vulnerable union in this category. Indicators within this domain showed in *Maheshwarpur* the highest percentage (81.2) of households did depend on natural sources, especially on forest for their income; whereas, the lowest percentage was in *Koyra* (62.3) (average percentage (in study region): 48.13 ± 22.11). Households reported such nature-dependency was due to severe soil-salinity intrusion with arable lands. Again, highest percentage (17.8) of unemployed households[7] was found in *Amadi* whereas, the lowest (9.4) in *Uttar Bedkashi* (average percentage: 12.91 ± 2.76). Household-opinion on unemployment situation indicated that wage-paid jobs were scarce in all unions due to unfavourable economic infrastructure and frequent climatic catastrophes. Sample households in *Uttar Bedkashi* made the highest consumption expenditure (89.53%) on food only whereas households in *Maharajpur* spent the least (48.19%) for same purpose (average percentage: 72.19 ± 14.95). Survey findings indicated inhabitants in *Uttar Bedkashi* often struggled with managing foods from local sources and thus, they were to buy food items, which escalated their proportional

[7] Unemployed household refers to the ones where the household head does not have a paid or wage job.

spending on food. On the contrary, inhabitants in *Maharajpur* mostly managed their food items from existing natural sources and thus, they spent less on food; which seemed to be the reason of their highest consumption level (see Table 3). We found the highest percentage (87.2) of households living below the poverty[8] line in *Uttar Bedkashi* union and the lowest percentage was in *Amadi* (71.6) (average percentage: 57.48 ± 22.18). This scenario was governed by availability of wage-paid job opportunity as reported by the households. Considering the land loss issue, we found the highest percentage (51.70) households in *Maheshwarpur* had lost their land due to natural hazards in last five years whereas the lowest percentage (10.30) in this case was in *Bagali* (average percentage: 36.40 ± 8.83). Hence, degree of land and/or river erosion is inferred to be the maximum in *Maheshwarpur* and minimum in *Bagali*. From the perspective of disaster damage cost, highest percentage of households (96.70) had suffered such loss in *Maheshwarpur* union whereas the lowest percentage (25.0) in *Amadi* (average percentage: 82.91 ± 20.51).

4.1.4. Physical vulnerability

Results indicated *Maheshwarpur* as physically the most vulnerable union with a score of 0.74 (±0.42); whereas, *Koyra* was the least vulnerable with a score of 0.23 (±0.36). Indicators within this domain showed that the highest percentage (98.40) of households not getting electricity lived in *Uttar Bedkashi* union and the lowest percentage (76.70) in *Maheshwarpur* (average percentage (in study region): 87.90 ± 7.17). This result confirmed that majority of the people did not have electricity access due to frequent catastrophes and insufficient capacity of local Rural Electrification Board. Virtually none of the households in *Maheshwarpur* had any sanitary latrine; the lowest percentage of households (11.0) not using sanitary latrine was found in *Amadi* (average percentage: 58.47 ± 35.41). Households reported that due to lack of awareness about health- and sanitation- benefits along with high construction-cost refrained local inhabitants to avail such latrine. Almost all households in *Amadi* and *Bagali* used ponds and/or wells as sources of drinking water, the lowest percentage of households (8.30) in this case was found in *Koyra* (average percentage: 49.27 ± 46.09). It was because of too few deep tube wells across the unions except *Koyra* in the whole study region. In case of households' having family member(s) with chronic illness, the highest percentage (81.25) household was figured out in *Dakshin Bedkashi* versus the lowest (47.41%) in *Koyra* (average percentage: 70.87 ± 11.99). Respondents reported that household members were mainly suffered by water-borne diseases like diarrhoea, cholera and typhoid, which were the most common diseases in water-logged or/and inundated areas where pure drinking water became scarce. Considering the paved road network in the whole study region, *Maharajpur* possessed the lowest percentage (11.71) of paved road out of its total road network, and *Koyra* had the highest percentage (39.22) (average percentage: 21.57 ± 9.71). In this case *Koyra* enjoyed the advantages of being the administrative centre of local government and thus, higher budget allocation for road construction and repairing; however, in the other unions such allocations was relatively low.

[8] Basic need cost as a poverty line value, which is US$ 202/capita/year.

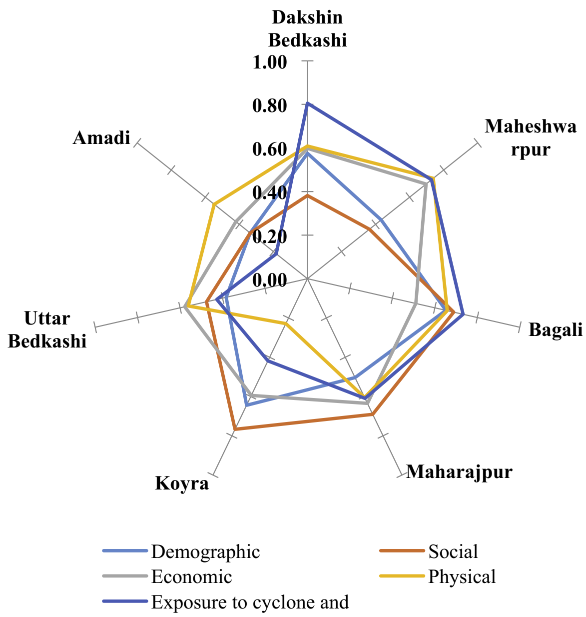

Fig. 3. Domain-wise vulnerability scores.

4.1.5. Exposure to natural hazards

Based on the weighted average scores, we found *Dakshin Bedkashi* (score: 0.81 (±0.26)) as the most vulnerable union due to natural hazards; and *Amadi* (score: 0.18 (±0.41)) as the least vulnerable. Indicators within this domain revealed that the highest percentage (73.30) of households not willing to evacuate and go to cyclone centre during any natural hazards was in *Dakshin Bedkashi*, whereas it was the lowest (6.70%) in *Koyra* (average percentage (in study region): 28.80 ± 26.33). We figured out households in *Dakshin Bedkashi* along with other hazard-prone unions did not want to lose their assets like cattle, poultry, fishing gears, precious household belongings etc. during catastrophes, and hence not interested to shift to cyclone centres. None of the unions had provision of early warning system to warn people in event of any upcoming catastrophe. Therefore, people had to rely on domestic radio for forecasting. For the understanding of National Warning System, we found a surprising result indicating almost half of the households (48.30%) in *Bagali* union did not understand the warning system whereas in *Amadi* almost all the households knew and understood such warning (average percentage: 18.36 ± 15.94). The reason behind such scenario might be lack of information-dissemination initiative by the concerned agencies as opined by the surveyors after consultation with respondent households. In addition, literacy rate of households might be another determinant for such scenario. During any crisis period (usually at time of natural hazard) the highest percentage (63.30) of households not getting shelter in either cyclone centre or neighbours' place was found in *Maheshwarpur* union, whereas it was the lowest (6.70%) in *Amadi* (average percentage: 31.43 ± 17.78). Households in *Maheshwarpur* possessed too little possession to help neighbours during natural hazards, which seemed to be the reason of not offering shelter to affected neighbours during crises. Dealing with disaster frequency in last five years, we found the highest number (17) of cyclones hit *Dakshin Bedkashi* whereas the lowest number (6) hit *Amadi* (average number: 12.0 ± 3.74). Geographical location was likely to be main factor in this case. Simultaneously, during the same time-period we identified the highest frequency (12) of flood in *Maheshwarpur* and the lowest frequency (2) in *Amadi* (average number: 8.0 ± 3.56). Elevation from sea-level, number of water-streams (canal/river) and their depths, and embankment-condition were likely the main factors behind flooding in study region.

4.2. Overall vulnerability score

Based on final weighted average score of SeVI, we identified *Maheshwarpur* (weighted average score: 0.68 ± 0.07) is socioeconomically the most vulnerable union, followed by *Dakshin Bedkashi* (0.67 ± 0.12), *Bagali* (0.54 ± 0.21), *Maharajpur* (0.54 ± 0.12), *Uttar Bedkashi* (0.52 ± 0.08). On the contrary, the least vulnerable union is *Koyra* (0.37 ± 0.07) followed by *Amadi* (0.44 ± 0.24) (see detail in Table 4). A supporting graph is also prepared (Fig. 5) to show the magnitude of concerned indicators (separately) across unions and within the specific dimension having a scale of 0 to 7 (closer to 7 indicates more vulnerable). We found the most vulnerable union (*Maheshwarpur*) is at the North-east of the study region which was surrounded by mangrove forest *Sundarbans* from three sides (see Fig. 1). Despite not being the most hazard affected union, *Maheshwarpur* had suffered the most from economic and physical vulnerability than rest of the unions in study region. Survey findings indicated this union as relatively income poor and highly dependent on resources from the adjacent mangrove forest *Sundarbans*. Therefore, during any event of natural hazard (e.g. cyclone) when the forest got severely hit; forest-dependent households from these unions were likely to face resource scarcity in the forest. This directly affected their earning of livelihood. In addition, maximum households (96.7% in our sample) in this union reported to incur damage to their assets and/or capital caused by natural hazards. Moreover, households in this union acutely suffered from shortage of basic utilities such as- pure drinking water supply, health facilities, physical infrastructure and basic sanitation support from local government. These obstacles altogether were likely to make *Maheshwarpur* socioeconomically the most vulnerable union in our study region, which is also reflected through Fig. 5.

In contrast, *Dakshin Bedkashi* being the most disaster affected in study region was a bit less vulnerable than *Maheswarpur*. Households of this union reported that being disaster affected area they (households) used to avail handsome quantity (although not evenly distributed) relief in form of dry food and/or cash from different national and international agencies. Such external assistance made them less dependent on natural source for livelihood and induced them to spend lion's share (more than 80%) of total consumption expenditure for purchasing of food. We identified a robust social capital among the households in *Dakshin Bedkashi* since social -reciprocity and –network were very strong here, especially during crises periods. In addition, most households suffered from water-borne contagious diseases throughout the year, which eventually resulted to death of family member(s). Most households reported the locational disadvantage (since it is the most exposed area to the Bay of Bengal) of this union was likely to be the pivotal factor for their socioeconomic vulnerability. Such phenomenon of *Dakshin Bedkashi* resembles to 'Backwash effect' [83,84] of natural hazards. Scores of contributing indicators (see Table 4 and Fig. 5) of *Dakshin Bedkashi* union justify such conclusion.

The geographical location of *Bagali* union is not that much disadvantageous as of *Dakshin Bedkashi* or *Maheshwarpur*. However, the high population density (803 persons/km^2) and highest percentage (49.4) of dependency ratio in whole study region made this union demographically the most vulnerable. This union possessed very high percentage of illiterate households (63.7%) which was well reflected in households' understanding of the national warning system. All the concerned contributing indicators constituted a higher score of social vulnerability in *Bagali*. A good number of natural hazards (12 cyclones and 9 floods) hit this union in last five years, which exacerbated the damage for households. Moreover, lack of pure drinking water source, sanitation facility, prevalence of chronic diseases and very poor physical infrastructure (especially, road network) escalated its overall socioeconomic vulnerability. Compared to *Maheswarpur* and *Dakshin Bedkashi*, *Bagali* was neither exposed to sea shore nor mostly surrounded by the *Sundarbans*; however, its overall vulnerability was governed by demographic and social vulnerability along with some indicators of economic, physical and disaster-exposure domains (see Fig. 5).

Both *Bagali* and *Maharajpur* possessed same level of socioeconomic vulnerability (score: 0.54) but influence pattern of its domains was different which was reflected through their respective standard deviations (see Table 4). *Maharajpur* is surrounded by the *Sundarbans* only from one side (see Fig. 1), but a significant percentage of households (75.8) in this union reported to be directly dependent on forest resources for their livelihood. In addition, poverty severity, highest (and most uneven) average household expenditure for basic need and disaster damage (see Table 3) made households of this union economically very vulnerable. Simultaneously adverse effects of concerned indicators exacerbated its physical vulnerability. Households in this union also reported that despite their high dependence on forest resource, they availed the locational advantage of being just beside of *Koyra*- the sub-district headquarters. In summary, it can be inferred that high degree of forest-resource dependency for livelihood, poverty, demographic pressure and prevalence of chronic diseases in *Maharajpur* were supposed to create higher degree of socioeconomic vulnerability; however, the spread wash effects [83] from the adjacent sub-district headquarters were likely to restrain the exacerbation of overall socioeconomic vulnerability of *Maharajpur*.

Like *Maharajpur*, *Uttar Bedkashi* union also availed same locational advantage from *Koyra* sub-district headquarters.

An interesting feature in this regard could be the most disaster-affected union is at the downstream of *Uttar Bedkashi* and sub-district headquarters is at its upstream. On the whole, overall vulnerability was relatively less in *Uttar Bedkashi* despite having the lowest average per capita for basic needs and maximum poverty severity (see Table 3). It might be because of least dependency on nature for households' income and lowest percentage (9.4) of unemployment-rate although a few of the contributing indicators in economic and physical domains had mentionable adverse effects on its overall socioeconomic vulnerability. Hence, only economic and physical domains were dominating towards socioeconomic vulnerability for this union. On the contrary, the rest of domains did act positively for *Uttar Bedkashi* perhaps due to possible spread wash effects from sub-district headquarters.

We identified *Amadi* as second least vulnerable union. Although highest number of households (17.8%) in the sample reported to be unemployed here, this union was economically least vulnerable (score: 0.42) in the study region. Besides, households in this union experienced the least number of natural hazards (6 cyclones and 2 flash floods) in last five years and therefore, disaster damage was relatively low here. The geographic location of this union is behind the most hazard prone areas and thus, fewer catastrophes hit this area. However, this area suffered from lack of pure drinking water source, sanitation and prevalence of chronic diseases for households. These exacerbated its physical vulnerability. However, the other vulnerability domains did not affect its overall vulnerability at greater extent. Hence, the overall SeVI score for *Amadi* was relatively less than most unions in study region.

We found *Koyra* as socioeconomically the least vulnerable union in the whole study region. Despite having higher population density (796 persons/km^2) and dependency ratio (49.4), this union enjoyed direct and indirect economic benefit for being the headquarters of sub-district. Moreover, impact and intensity of natural hazards here were relatively low along with better communication and transportation with other district headquarters. All these indicators boosted up the economic condition of households in this union. This was reflected in relatively lower percentage of unemployed households (See Table 3). This union, indeed, availed the spillover benefits of agglomeration economies. All these phenomena were likely to promote multifarious opportunities here for the households. For example, highest number of households (44.79%) reported to enjoy the group-credit facility in *Koyra*. Hence, most of important contributing indicators altogether were likely to make this union the least vulnerable in the study region.

4.3. IPCC-dimension wise vulnerability and magnitude of contributing indicators within dimensions

While obtaining 'IPCC-dimension wise' vulnerability scores, we made necessary adjustments to align among different dimensions. Our results show that in study region both 'sensitivity' and 'exposure' were more dominant dimensions than 'adaptive capacity' (see Fig. 4). In this study we considered a dimension having average weighted score of either equal or above 0.60 had contributed significantly towards socioeconomic vulnerability of the concerned area, and hence, we focused only on dimensions having above stated score. We found the average highest sensitivity score for *Maheshwarpur* union (0.72 ± 0.33), followed by *Maharajpur* (0.62 ± 0.37), *Dakshin Bedkashi* (0.60 ± 0.39), *Uttar Bedkashi* (0.58 ± 0.27) and *Bagali* (0.57 ± 0.40); while the lowest scores were found for *Koyra* (0.41 ± 0.37) and *Amadi* (0.48 ± 0.33). Dependency highly on nature for livelihood-earning, losing land (both cultivable and homestead), incurring damage and/or capital asset loss due to natural hazards and breaking out of multifarious diseases due to lack of sanitation altogether were dominant to make *Maheshwarpur*, *Maharajpur* and *Dakshin Bedkashi* sensitive to climate change impacts (See Table 3). In addition, very poor road network and communication facility of *Maheshwarpur*, higher percentage of households below poverty line and the highest (and most uneven) average expenditure for basic need in *Maharajpur*, and higher percentage of consumption expenditure making for food only in *Dakshin Bedkashi* also contributed to their specific sensitivity (See Tables 3 and 4).

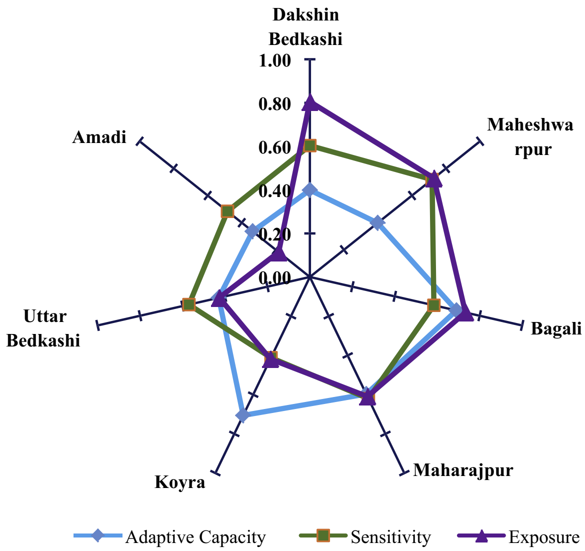

Fig. 4. IPCC-dimension-wise vulnerability scores.

Considering 'exposure' dimension- we found *Dakhsin Bedkashi* union with the average highest score (0.81 ± 0.26) followed by *Maheshwarpur* (0.73 ± 0.37), *Bagali* (0.73 ± 0.24) and *Maharajpur* (0.61 ± 0.34). On the contrary, we found the average lowest score for *Amadi* (0.18 ± 0.41) followed by *Koyra* (0.42 ± 0.33) and *Uttar Bedkashi* (0.43 ± 0.32). Geographically *Dakshin Bedkashi* is surrounded by the *Sundarbans* from three sides and this union was frequently hit by either cyclone or flood or storm-surge. In addition, highest percentage (73.30) of households not interested to evacuate and shift to cyclone centre during hazards, absence of formal early warning system and increasing number of catastrophes in last five years made this union acutely exposed to natural disasters. Despite possessing same score (0.73) for 'exposure' dimension, we figured out interesting responses of contributing

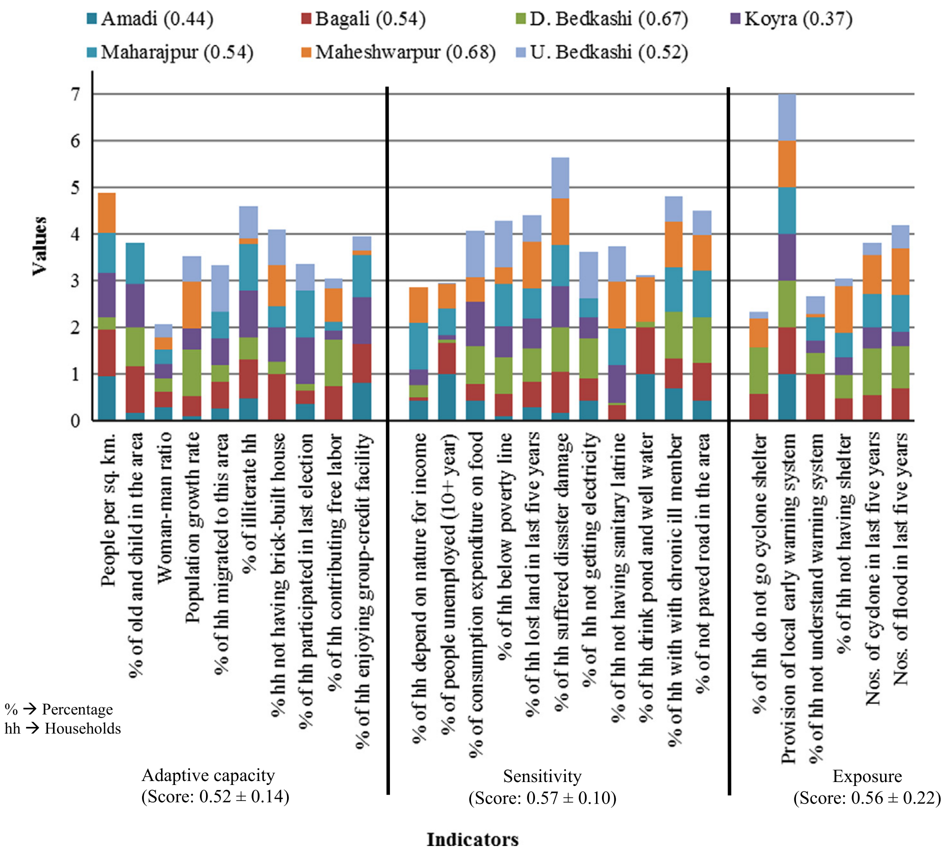

Fig. 5. Magnitude of indicators within IPCC-dimensions across unions.

indicators of exposure in *Maheshwarpur* and *Bagali* union, which is reflected in difference in standard deviations of average scores for exposure. Almost half of total households (48.3%) in *Bagali* did not understand the national warning system whereas only 3.3 percent households reported the same in *Maheshwarpur*. Interestingly these percentages are reflected through literacy rates reported in Table 3. Considering shelter availability during hazards, 66.7 per cent households in *Bagali* and 36.7 per cent in *Maheshwarpur* could avail it. The above-mentioned three unions suffered at least 12 cyclones (out of 17) and 9 flash floods (out of 12) in last five years.

Finally, for adaptive capacity scores, we found *Koyra* to have the average highest score (0.71 ± 0.31) followed by *Bagali* (0.69 ± 0.28) and *Maharajpur* (0.60 ± 0.36). In contrast, we found the lowest score for adaptive capacity with *Amadi* (0.34 ± 0.32), followed by *Maheshwarpur* (0.40 ± 0.42), *Uttar Bedkashi* (0.43 ± 0.33) and *Dakshin Bedkashi* (0.48 ± 0.36). *Koyra* is the headquarters of local government among the seven unions and hence, it was well connected with the district headquarters. *Koyra* possessed highest adaptive capacity (score: 0.71 ± 0.31) by the dint of lower population growth rate (1.60% per annum), higher participation rate (88.3% households) in national election, moderate level of migration (10% households) in last five years and highest percentage (44.79) of households' availing group-credit facility. Moreover, geographically its position is behind the most hazard prone coastal unions and hence, it had suffered relatively less from impact of climatic shocks. Lower number of illiterate households along with better social capital made *Bagali* more adaptive. For *Maharjpur*, lowest population growth rate and social capital contributed significantly to its adaptive capacity.

4.4. Benefits of SeVI approach

The SeVI can be applied to assess the effectiveness and/or impact(s) of a programme or policy by reproducing the index values of contributing indicators and therefore, new scores for SeVI. For example, if the objective of disaster risk management intervention is to increase the knowledge level of households about understanding of early warning system, the number of disaster management workshops held in concerned area over a stipulated time period could be incorporated and hence, a new SeVI score can be obtained. Then the new SeVI could be contrasted with baseline SeVI to assess the intervention's effect on households' socioeconomic vulnerability.

Research depending on secondary data often suffers with limited or no information on measurement error. In such case(s), there is no way to detect potential biases while interpreting the results. The SeVI used household level primary data for measuring index-scores of chosen indicators. Hence, this approach was free from limitations of secondary data driven approaches. In addition, our household survey method for SeVI was least affected by measurement-source error and self-reported data error. Furthermore, we were able to conform reliable household-survey data collection with the few missing response frequencies. This is how the SeVI approach could be useful to address the missing data problem.

The method of selecting the contributing indicators of SeVI and weighing them were more scientific in the sense that local knowledge as well as expertise were utilised and hence, the framework of SeVI became appropriate for the concerned locality or region. Considering weights, SeVI provided location specific vulnerability scores across a region. Hence, application of SeVI paved the avenue for determining location-specific vulnerability. In this context, the usefulness of Fig. 5 can be mentioned. This figure represents SeVI at micro- and meso- levels in identifying the magnitudes of contributing indicators within concerned domain and dimension. Fig. 5 also postulates the relatively robust indicators propagating vulnerability which were resembled to root causes and dynamic pressure of vulnerability in Pressure and Release (PAR) model by Blaikie et al. [67]. For example, Fig. 5 shows that within 'Exposure' dimension- the score for provision of local early warning system is the highest, which indicates that all of the unions in the study region were likely to be highly exposed to hazard-risk (and hence, vulnerable) due to absence of early warning system. Thus, the concerned agency may urge for installing warning system from the government in *Koyra* region. Again, for example, for exposure dimension the average score of both *Maheshwarpur* and *Bagali* was found same (0.73); however, the standard deviations of this average score were different which indicates that the same set of contributing indicators influenced 'exposure' differently in the mentioned unions. In such case Fig. 5 provides the concerned scenario of each contributing indicator of SeVI across the unions and thus, conveys important message for policy makers. Furthermore, by manipulating some of the contributing factor-scores within different dimensions (e.g. literacy level, poverty level, unemployment level etc.); a kind of sensitivity analysis is also possible to be calibrated with SeVI within and between areas across a region. Even some spillover effects (e.g. increasing consumption expenditure in terms of purchasing capacity) on other contributing factors can also be calibrated within SeVI considering spatial variation. From such calibration the policy makers may presume their optimal approach in policy intervention for future adaptation-related risk reduction. In addition, the effect of multi-hazards (in future) on vulnerability can also be obtained through SeVI by adjusting number of cyclone, flood, drought and so on within 'exposure' domain. Furthermore, standard deviations of domain- and dimension- scores provide the spread-pattern of influencing-indicators within concerned domain/dimension which are likely to be very important information for policy makers. Finally, methodology of contributing indicator selection along with weighing procedure of SeVI can be adapted to address the needs of a specific community or final-user where other assessments reviewed here have incorporated these indicators (or/and domains) as fixed within their concerned frameworks of assessment [12,63,85]. In this way SeVI can be a simple but effective tool for obtaining and comparing socioeconomic vulnerability in hazard prone regions.

4.5. Defining an appropriate scale for socioeconomic vulnerability assessment

A question may remain challenging the appropriateness of a scale at which to conduct socioeconomic vulnerability assessment. Different multinational agencies (e.g. CARE) develop household-based livelihood or security index by utilising qualitative data that affect household's livelihood or security. Various methods like- focus group discussion, anthropometric surveys and community informal discussion apart from household survey are used by those agencies for data collection for concerned index [86]. For instance, different studies considered different spatial aspects (e.g. local, national) while assessing vulnerability [12,87]. In this study, we computed SeVI at the union (lowest tier of local government) level. Hence, we do not suggest SeVI for vulnerability assessment at household level. It is because the contributing indicators are time variant – both in short-term and long-term.

A study by Eakin and Bojorquez-Tapia [87] figured out same values of many indicators across vulnerability categories, and suggested that household livelihood profiles should be considered from social and economic perspectives of concerned region. A good number of contributing indicators of our SeVI such as- population density, dependency ratio, dependency on nature for livelihood, sanitation status and medical facilities were same among respondent-households within a specific union (area). In the same way- natural hazard frequency, early warning system and cyclone centre locations also occurred at a local rather than regional scale. Hence, the nexus between regional characteristics and climate variability should be taken into consideration while fixing appropriate scale for socioeconomic vulnerability assessment.

Finally, determination of appropriate scale also depends on aim of the vulnerability assessment. We developed SeVI to figure out specific vulnerability at local level in order to assist the policy-makers and different development organisations. With a view to capitalising the scale-economies, the concerned organisations may opt for vulnerability assessment interventions at community or sub-district rather than household level. Instances in this context may incorporate disaster management plans, agricultural insurance, developing medical facilities or instituting health education programmes.

5. Concluding remarks

Throughout this study we have explored and assessed the vulnerability status of coastal communities with the help of longitudinal analysis on coastal households' response towards climate change impacts. The objectives of this study were to develop an index (SeVI) that measures socioeconomic vulnerability in coastal Bangladesh and to assess the relative magnitude of vulnerability -domains and -dimensions in different locations. The results of our study show that the newly developed SeVI is a simple but promising approach to capture the vulnerability scenario of coastal communities considering spatial variation. Due to impact of *Sidr* (in 2007) and *Aila* (in 2009) in *Koyra*, the economic opportunities for people became very narrow. Hence, they could hardly secure their daily livelihood. This fact was reflected in this study through SeVI. The index values of contributing indicators in SeVI indicated which specific factors were responsible for emerging the vulnerability and hence, where to emphasise in policy adoption for households to make them less vulnerable in future. The uniqueness of this SeVI is two folds: firstly- for constructing the index both primary and secondary data were used; and secondly- a weighted average was used in order to triangulate perceptions of local people, local experts and ours (researchers) for each of the index indicators. From this perspective, our approach is expected to reduce the high risk of wrongly specified weights found in previous approaches [20] due to three main reasons: (1) we carefully chose surveyors for data collection from the local university, experts from NGOs and local stakeholders and thoroughly trained them with necessary information on climate change and vulnerability; (2) we used relevant contributing indicators closely associated with local vulnerability and were easily accessible for surveyors and local experts; (3) we obtained the weights of index indicators through an iterative stepwise approach, adopting the established technique of a five-point 'Likert scale' proposed by Wyatt and Meyers [38]. There are no substantial restrictions to apply SeVI to other research premises. However, the selection of the variables needs a rational assessment since climate led vulnerability is correlated with local biophysical and socioeconomic features. In addition, a good deal of data is necessary to have proper reflection of socioeconomic vulnerability through SeVI.

Quantitative assessment of vulnerability-determinants can be conducted by applying SeVI, which is likely to provide important location-specific messages for policy makers. To do so, three main criteria must be maintained: firstly, determinants of vulnerability require to have a sound theoretical foundation; secondly, the contributing indicators must be measured as accurately as possible since random searching in vast quantity of data for significant correlation may not be justified; and thirdly, vulnerability determination in either binary or multi-level response is relatively coarse and hence, the weights of the contributing indicators must be obtained through a justified procedure. However, we must acknowledge that in spite of maintaining all synergic methodological procedures, the likelihood of logical subjective element is always reflected through weighing variables [9]. The background assumption while computing SeVI indicates that responses collected from sample households were fair and unbiased. This assumption is not uncontroversial. Hence, household responses were cross-checked with the outcomes from FGDs. This study also assumed that vulnerability in the coastal region was governed by different determinants and thus, vulnerability dimension-behaviour differed within and between areas. It is also important to note that we standardised the indicator index score by adopting maximum and minimum values of our study sample households. Hence, our SeVI estimates may not compatible with future studies unless these follow our study methods. Again, studies like climate projection models are not compatible with SeVI method. Shortcomings of overall SeVI approach may indicate the application of indicators and indices, that these indices oversimplify a complicated reality and apparently no straightforward way to validate these indices made up of dissimilar indicators [12]. Moreover, the selection of indicators and assigning weights for each indicator from less to more important involves normative judgement. In this SeVI, two variables (participation in national election and free labour contribution) under the 'social' domain were quasi-institutional in nature. Hence, incorporation of pure institutional indicators in future studies may provide better reflection of institutional status in the concerned SeVI. Nonetheless, the methodology of SeVI can be a useful tool for policy makers in terms of prioritising investments and formulating adaptation strategies. Furthermore, the SeVI method offers an unbiased procedure to assign relative weights to the concerned indicators which are likely to produce transparent results on vulnerability. Hence, priority-fixing based on these results would also be transparent, which is inevitably a highly political process. Therefore, the proposed SeVI method may help the policy-makers to steer climate change adaptation policy with a focus on disaster risk management in a more sustainable direction.

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References

[1] Füssel HM, Klein RJT. Climate change vulnerability assessments: an evolution of conceptual thinking. Clim Change 2006;75:301–29.
[2] Hinkel J. Indicators of vulnerability and adaptive capacity: towards a clarification of the science-policy interface. Glob Environ Change 2011;21:198–208.
[3] Mearns R, Norton A. Social dimensions of climate change: equity and vulnerability in a warming world. World Bank Publications, Washington, DC; 2010.
[4] Ahmed SA, Diffenbaugh NS, Hertel TW. Climate volatility deepens poverty vulnerability in developing countries. Environ Res Lett 2009;4(3). 〈10.1088/1748-9326/4/3/034004〉.
[5] Kasperson RE, Kasperson JX. Climate change, vulnerability, and social justice. Stockholm: Stockholm Environment Institute; 2001.
[6] Nelson DR. Adaptation and resilience: responding to a changing climate. Wiley Interdiscip Rev: Clim Change 2011;2:113–20.
[7] Pelling M, High C. Understanding adaptation: what can social capital offer assessments of adaptive capacity? Glob Environ Change 2005;15:308–19.
[8] Paavola J, Adger WN. Fair adaptation to climate change. Ecol Econ 2006;56:594–609.
[9] Below TB, Mutabazi KD, Kirschke D, Franke C, Sieber S, Siebert R, et al. Can farmers' adaptation to climate change be explained by socio-economic household-level variables? Glob Environ Change 2012;22:223–35.
[10] Garcia C, Fearnley CJ. Evaluating critical links in early warning systems for natural hazards. Environ Hazards 2012;11:123–37.

[11] Mano R, Nhemachena C. Assessment of the economic impacts of climate change on agriculture in Zimbabwe: a Ricardian approach. Washington, DC: The World Bank; 2007.
[12] Vincent K. Uncertainty in adaptive capacity and the importance of scale. Glob Environ Change 2007;17:12–24.
[13] Adger WN. Vulnerability. Glob Environ Change 2006;16:268–81.
[14] Füssel HM. Adaptation planning for climate change: Concepts, assessment approaches, and key lessons. Sustain Sci 2007;2:265–75.
[15] Füssel HM. Vulnerability: a generally applicable conceptual framework for climate change research. Glob Environ Change 2007;17: 155–67.
[16] Huq S, Grubb M. Mitigation and adaptation strategies for global change: preface. Mitig Adapt Strateg Glob Change 2007;12:645–9.
[17] Lemos MC, Boyd E, Tompkins EL, Osbahr H, Liverman D. Developing adaptation and adapting development. Ecol Soc 2007;12:26.
[18] Ostrom E. A diagnostic approach for going beyond panaceas. Proc. Natl. Acad. Sci. U.S.A. 2007;104:15181–7.
[19] Wisner B. Climate change and cultural diversity. Int. Soc. Sci. J. 2010;61:131–40.
[20] Gbetibouo GA, Ringler C, Hassan R. Vulnerability of the South African farming sector to climate change and variability: an indicator approach. Nat. Resour. Forum 2010;34:175–87.
[21] Hahn MB, Riederer AM, Foster SO. The livelihood vulnerability index: a pragmatic approach to assessing risks from climate variability and change-a case study in Mozambique. Glob Environ Change 2009;19:74–88.
[22] Iglesias A, Quiroga S, Diz A. Looking into the future of agriculture in a changing climate. Eur Rev Agric Econ 2011;38:427–47.
[23] Malone EL, Brenkert AL. Uncertainty in resilience to climate change in India and Indian states. Clim. Change 2008;91:451–76.
[24] Pandey R, Jha S. Climate vulnerability index – measure of climate change vulnerability to communities: a case of rural lower Himalaya, India. Mitig Adapt Strateg Glob Change 2012;17:487–506.
[25] Alberini A, Chiabai A, Muehlenbachs L. Using expert judgment to assess adaptive capacity to climate change: evidence from a conjoint choice survey. Glob Environ Change 2006;16:123–44.
[26] Brooks N, Adger WN, Kelly PM. The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. Glob Environ Change 2005;15:151–63.
[27] Briguglio L. Small island developing states and their economic vulnerabilities. World Dev 1995;23:1615–32.
[28] Lee YJ. Social vulnerability indicators as a sustainable planning tool. Environ Impact Assess Rev. 2014;44:31–42.
[29] Ge Y, Dou W, Gu Z, Qian X, Wang J, Xu W, et al. Assessment of social vulnerability to natural hazards in the Yangtze River Delta, China. Stoch Environ Res Risk Assess 2013;27:1899–908.
[30] Urothody A, Larsen HO. Measuring climate change vulnerability: a comparison of two indexes. Banko Janakari 2010;20:9–16.
[31] Vincent K, Cull T. A household social vulnerability index (hsvi) for evaluating adaptation projects in developing countries. In: Proceedings of PEGNet conference 2010: policies to foster and sustain equitable development in times of crises. Midrand; 2010.
[32] Vincent K. Creating an index of social vulnerability to climate change for Africa. Tyndall Center for Climate Change Research. Working paper 56; 2004. p. 41.
[33] Cutter SL, Boruff BJ, Shirley WL. Social vulnerability to environmental hazards. Soc Sci Q 2003;84:242–61.
[34] IPCC. Assessing key vulnerabilities and the risk from climate change. Fourth assessment report. Geneva; 2007.
[35] Bjarnadottir S, Li Y, Stewart MG. Social vulnerability index for coastal communities at risk to hurricane hazard and a changing climate. Nat Hazards 2011:1–21.
[36] Krishnamurthy PK, Choularton RJ, Betts R, Lewis K. Assessing the impacts of climate risk on food security through a vulnerability index. In: Proceedings of GI Forum 2011. Salzburg; 2011.
[37] Smit B, Wandel J. Adaptation, adaptive capacity and vulnerability. Glob Environ Change 2006;16:282–92.
[38] Wyatt RC, Meyers LS. Psychometric properties of four 5-point Likert type response scales. Educ Psychol Meas 1987;47:27–35.
[39] Paul BK, Dutt S. Hazard warnings and responses to evacuation orders: the case of Bangladesh's cyclone *Sidr*. Geogr Rev 2010;100: 336–55.
[40] Ray-Bennett NS, Collins A, Bhuiya A, Edgeworth R, Nahar P, Alamgir F. Exploring the meaning of health security for disaster resilience through people's perspectives in Bangladesh. Health Place 2010;16:581–9.
[41] Paul BK. Human injuries caused by Bangladesh's cyclone *Sidr*: an empirical study. Nat Hazards 2010;54:483–95.
[42] Parvin GA, Takahashi F, Shaw R. Coastal hazards and community-coping methods in Bangladesh. J Coast Conserv 2008;12:181–93.
[43] Burton I, White GF. The environment as hazard. New York: The Guilford Press; 1993.
[44] Cannon T. Vulnerability analysis and the explanation of 'natural' disasters. Disasters, Dev Environ 1994:13–30.
[45] Cannon T, Twigg J, Rowell J. Social vulnerability, sustainable livelihoods and disasters. Londres: DFID; 2003.
[46] Dercon S. Assessing vulnerability to poverty. UK Department for International Development; 2001.
[47] Dercon S. Income risk, coping strategies and safety nets. World Bank Res Obs 2002;17:141–66.
[48] Dercon S. Vulnerability: a micro perspective. Secur Develop Unstable World 2006:117–46.
[49] IPCC. Second assessment report (SAR). Economic and social dimension of climate change. Intergovernmental panel on climate change. Cambridge, United Kingdom and New York; 1995.
[50] IPCC. Contribution of working group II to the fourth assessment report of IPCC on climate change. Impacts, adaptations and vulnerability. Cambridge University Press; 2007.
[51] Moser CON. The asset vulnerability framework: Reassessing urban poverty reduction strategies. World Dev 1998;26:1–19.
[52] Pelling M. The vulnerability of cities: natural disasters and social resilience. London: Routledge; 2003.
[53] Barnett J, Adger WN. Climate change, human security and violent conflict. Polit Geogr 2007;26:639–55.
[54] McCarthy JJ. Climate change 2001: impacts, adaptation, and vulnerability: contribution of working group II to the third assessment report of the intergovernmental panel on climate change. Cambridge University Press; 2001.
[55] Smit B, Pilifosova O. Adaptation to climate change in the context of sustainable development and equity. Sustain Dev 2003;8:9.
[56] Adger WN. Social vulnerability to climate change and extremes in coastal Vietnam. World Dev 1999;27:249–69.
[57] Adger, WN. Approaches to vulnerability to climate change. Working paper – Centre for Social and Economic Research on the Global Environment GEC 96-05; 1996.
[58] Ibarrarán ME, Malone EL, Brenkert AL. Climate change vulnerability and resilience: current status and trends for Mexico. Environ, Dev Sustain 2010;12:365–88.
[59] Adger WN, Kelly PM. Social vulnerability to climate change and the architecture of entitlements. Mitig Adapt Strategies Glob Change 1999;4:253–66.
[60] Rose A. Economic resilience to natural and man-made disasters: multidisciplinary origins and contextual dimensions. Environ Hazards 2007;7:383–98.
[61] Adger WN, Vincent K. Uncertainty in adaptive capacity. C R – Geosci 2005;337:399–410.
[62] Chambers R, Conway G. Sustainable rural livelihoods: practical concepts for the 21st century. IDS, Brighton report no. 296; 1992.
[63] O'Brien K, Leichenko R, Kelkar U, Venema H, Aandahl G, Tompkins H, et al. Mapping vulnerability to multiple stressors: climate change and globalization in India. Glob Environ Change Part A 2004;14: 303–13.
[64] Reid P, Vogel C. Living and responding to multiple stressors in South Africa–Glimpses from KwaZulu-Natal. Glob Environ Change 2006;16: 195–206.
[65] Yohe G, Tol RSJ. Indicators for social and economic coping capacity–moving toward a working definition of adaptive capacity. Glob Environ Change 2002;12:25–40.
[66] Alam E, Collins AE. Cyclone disaster vulnerability and response experiences in coastal Bangladesh. Disasters 2010;34:931–54.
[67] Blaikie P, Cannon T, Davis I, Wisner B. Disaster pressure and release model, at risk: natural hazards, people''s vulnerability and disasters. London: Routledge; 21–45 [etc.].
[68] Scoones I. Sustainable rural livelihoods: a framework for analysis. Working paper no. 72. Institute of Development Studies Brighton; 1998.
[69] Bollin C, Hidajat R. Community-based disaster risk index: pilot implementation in Indonesia. In: Brikmann J, editor. Measuring vulnerability to natural hazards- towards disaster resilient societies. Tokyo, New York, Paris: UNU-Press; 2006. p. 271–89.
[70] Birkmann J. Risk and vulnerability indicators at different scales: Applicability, usefulness and policy implications. Environ Hazards 2007;7:20–31.
[71] BBS, Bangladesh Population Census 2001. In: Planning MO (editor). Government of the People's Republic of Bangladesh, Dhaka; 2007. p. 41–4.
[72] Banglapedia. Koyra Upazilla, Banglapedia – the National Encyclopedia of Bangladesh. Dhaka: Asiatic Soiety; 2006.

[73] PDO-ICZMP. Delineation of the Coastal Zone. Working paper. Government of Bangladesh; 2003. p. 119–27.
[74] Chambers R. The origins and practice of participatory rural appraisal. World Dev 1994;22:953–69.
[75] U.N.S. Division. Designing household survey samples: practical guidelines. United Nations, New York; 2008.
[76] WHO. Assessing tuberculosis prevalence through population-based surveys. Geneva: World Health Organization; 2007.
[77] WHO. Tuberculosis prevalence surveys: a handbook. World Health Organization; 2011.
[78] Deems H. Vulnerability of rural communities in the Mediterranean region to climate change and water scarcity: the case of Cyprus. Spain: Universitat Autònoma de Barcelona; 2010 (M.Sc. thesis).
[79] UNDP. Human development reports 2007/8. Fighting climate change: human solidarity in a divided world; 2007.
[80] Ford JD, Smit B. A framework for assessing the vulnerability of communities in the Canadian Arctic to risks associated with climate change. Arctic 2004:389–400.
[81] W.E. Management. Household natural hazards prepardness questionnaire. Peninsula Hazard Mitigation Planning Committee. Williamsburg, VA; 2004.
[82] Ahsan NM. Climate change and socioeconomic vulnerability: experiences and lessons from south-western coastal Bangladesh, Development Economics Group and Disaster Studies Chair. Wageningen: Wageningen University Library; 2010.
[83] Myrdal G. Economic Theory and Undeveloped Regions. London: Methuen & Co.; 1957.
[84] Gaile GL. The spread-backwash concept. Reg Stud 1980;14:15–25.
[85] Thornton P, Jones P, Owiyo T, Kruska R, Herero M, Kristjanson P, et al. Mapping climate vulnerability and poverty in africa. Report to the Department for International Development. Nairobi: ILRI; 2006.
[86] Lindenberg M. Measuring household livelihood security at the family and community level in the developing world. World Dev 2002;30:301–18.
[87] Eakin H, Bojorquez-Tapia LA. Insights into the composition of household vulnerability from multicriteria decision analysis. Glob Environ Change 2008;18:112–27.