Societal Dealings with Cyclone in Bangladesh–A Proposal of Vulnerability Atlas for Sustainable Disaster Risk Reduction

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Abstract

The factors of climate change, demographic patterns and the effects of economic globalization are increasing the risk exposure of almost all regions of the world. Coastal area of Bangladesh is a hotspot of cyclone hazards in the world. However, the perception and management practices of the cyclone events are spatially heterogeneous, so that comprehensive measures are in many cases neither socially acceptable nor economically sensible. It is therefore necessary to consider the actual heterogeneity of the factors of social vulnerability, in that they are collected and aggregated algorithms supported. It is essential that existing interactions between the factors that lead in most cases to an exponential amplification of social vulnerability and thus generate the socially devastating effects of natural disasters, be covered. The aim of this research was to develop methods of customized data collection and analysis and to determine the algorithms of the interactions between the factors of a cyclone induced vulnerable livelihood management. This is the basis of building plans and measures for the sustainable way of disaster risk reduction. The social acceptance of all consequent actions, including restrictions on use at the local level, can only be increased by the fact that the derivation of these limitations is transparent. All these are presented in this paper based on an empirical investigation with 1555 respondents those were victims of cyclone Sidr (2007) and cyclone Aila (2009) in southwest coastal villages in Bangladesh.

Introduction

The research community in the field of disaster prevention has gained broad experience in the registration and handling of climate-related hazards, for instance within the work of Intergovernmental Panel on Climate Change (IPCC) [1-3]. Global research on disaster management and notably individual groups increasingly focus on strengthening the resilience of local and regional structures to currently existing conditions as well as to future events due to climate change [4-6]. The concrete effects of climate change on a region depend on actual climatic conditions as well as on the predicted climate changes based on atmospheric scenarios by means of numeric models. Such changes in turn coincide with a socio-economic system bounded to adapt to the situation, even though its adaptability is being subjected to considerable variations. Thus, the effects of climate change also rely particularly on geographic, social, cultural, economic and political conditions [6], necessitating a variety of adaptation measures strongly depending on the local and regional circumstances [7]. Furthermore, the effects of climate change affect both different economic sectors as well as different spatial entities to a different extent.

Each incidence has different effects on a regional system shaped by natural, economic and social conditions. Compared to the technical and social standards of highly industrialized countries, social conditions such as knowledge, awareness, and relevant governmental responsibilities as well as to a certain extent also physical resources are often scarce in the developing countries of the South. Consequently, the death toll in case of comparably severe incidences blatantly differs between industrialized and developing countries: for instance, comparing the impacts of a cyclone in Bangladesh and the United States, the death toll is at a ratio of 1:1000 [8]. This discrepancy is rooted in the different reactions, action potentials and actions of the people concerned, depending on culture, politics, economic power,

etc. It reveals the necessity of developing adapted planning measures in coastal areas and raises the question of how coastal societies and their stakeholders in the affected countries – primarily developing countries – can respond to natural hazards, especially when it comes to prevention and coping with the hazard's impacts. In that context, it is important to not only determine the most functional measure, but also the one most appropriate in terms of economic and social adaptation and adaptability.

The question for particularly strongly affected areas directs the attention to the coastal regions. Even without the factors of climate change, these are zones in which problems accumulate and are partly aggravated by climate change. These problems include insufficient drinking water supply, salinization, insufficient transport facilities, subsidence, inshore and offshore garbage disposal leading to ocean and coastal contamination, depleted fishing resources, hazards caused by storm surges or abnormal precipitation. Coastal regions are mainly migration areas and the far above-average population growth leads to depletion of resources and increasing social conflicts. In these coastal regions, the conditions for a sustainable development are particularly impaired [9-12]. Therefore, there is an urgent need for action: national and local administrations need to collaborate with social and natural scientists, consolidating their interdisciplinary skills to tackle the

challenge of sustainable development of coastal regions with the required expertise [5,13,14].

Today, all levels of space-oriented public action including the national, regional and local level are asked to advocate disaster prevention measures and thus vulnerability reduction with the objective to systematically adapt spatial conditions to the challenges of climate change as well as to the demographic and economic change. Such measures involve coordinating interdisciplinary planning as well as of many technical plans which amongst others deal with the design and construction of infrastructures, also providing for their more resilient design.

This also implies an adaption to the respective spatially differentiated factors which, including their reciprocal effects, contribute to a region's overall vulnerability. To achieve this adaptation, the pre-requisites of data availability need to be established. As opposed to the high-technology countries of the northern hemisphere, no measures have been taken so far in the countries of the South to enhance the data availability. Furthermore, quality of the existing data is also poor. In most cases, the data lacks essential spatial differentiation and only features large-scale mean values concealing the actual hazardous extremes. Consequently, comprehensive preliminary studies as well as alternative methods data processing are necessary. The present contribution aims at elaborating a corresponding approach and to test the method on a particularly suitable region.

The research area is the southwestern coastal zone of Bangladesh, a global hotspot for social vulnerability. Regular cyclones from the Bay of Bengal with devastating effects, inundations caused by the large rivers of the North, increasing salinization of the groundwater and soils, the highest population density of any territorial state worldwide with upward trend, the problematic implications of the increasing international economic integration and thus dependency on the global market coincide in this southwest coast of Bangladesh. Yet, they have spatially heterogeneous effects, making nationwide interventions in many cases neither socially acceptable nor adequate. Therefore, the actual heterogeneity of vulnerability factors needs to be considered by recording and aggregating them. In doing so, the reciprocal effects between the vulnerability factors which in most cases trigger an exponential increase in vulnerability and causing the socially devastating effects of natural hazards need to be recorded, too. The challenge is to develop adapted methods for data collection and analysis and to determine the algorithms for reciprocal effects between the factors in order to provide a basis for further planning and interventions. The social acceptance of all measures deriving from this approach, including

limits of use on the local level, can only be increased by deducing these measures and constraints in a transparent way. Besides deducing the entire scope of social vulnerability by determining overall values such as vulnerability indices as well as the technical planning consequences which may affect for instance infrastructure planning, a comprehensive documentation is an essential task that also must be performed.
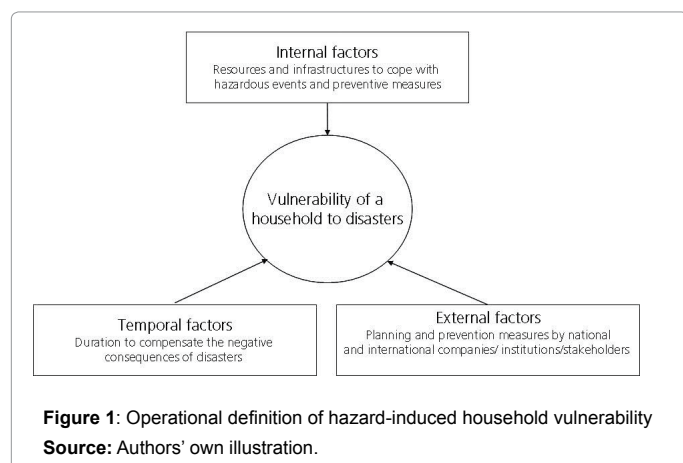
Current methodological approaches to vulnerability analysis

The methodological approaches to vulnerability analysis applied so far include a demographic, taxonomic, cross-cutting as well as contextual and pro-active approach [14]. Existing methods for vulnerability analysis develop indices for quantitative registration [15]. In addition to the description of geophysical hazards and risk probabilities [16,17], a social vulnerability analysis for future spatial mitigation and prevention in the coastal areas including these partial aspects is needed. For this purpose, both social groups as well as regions need to be considered in view of vulnerability factors and chances of mitigation through different actors. Bohle et al. [18] determined three dimensions of vulnerability that lead to a complex and comprehensive typology of vulnerability and its essential actors. Their model developed socio-institutional factors such as economic, political and ecological dimensions of vulnerability. Yet, their approach was rather based on theory and can hardly be transferred onto action-oriented concepts. Kasperson et al. [19] and Hufschmidt [20] presented a comprehensive understanding of the development of conceptual approaches on vulnerability.

Generally, there are two classical approaches of vulnerability research, namely the risk-hazard approach [17,21,22], and the political economy approach [23,24]. Based on these approaches, Füssel [25] mentioned further strategies, namely the 'Pressure-and-Release (PAR)' model by Wisner et al. [14], the ,integrated approaches' i.e. ,hazard-of-place' model by Cutter et al. [26], as well as the, resilience approaches'.

The Risk-hazard Approach (RHA) is used by engineers, economists and epidemiologists [27]. However, it is difficult to apply this model on humans as their exposure to hazards largely depends on their behavior which is determined by socio-economic and individual factors [25]. The RHA distinguishes between "hazard" and "vulnerability". Accordingly, the RHA concept of vulnerability is characterized by the exposition to hazards. In case of the Political Economy Approach (PEA), the analysis focuses on humans, asking who are the most vulnerable and which social conditions, notably distribution of power, are most influential [25].

Currently, the most discussed model, the PAR model, deals with the risk-hazard framework. It defines the concept of "hazard" as a result of threat and vulnerability. The PAR model includes global agents, regional factors and local risk-susceptible conditions without explicitly defining

Figure 1: Operational definition of hazard-induced household vulnerability
Source: Authors' own illustration.

Analysis dimension	Concretization in the present research context	Example
System	southwestern coast of Bangladesh	households and local communities
Attribute	socioeconomic and geographic attributes	livelihood indicators, respondents' situation
Hazard	Cyclone	cyclone *Sidr* in 2007 and cyclone *Aila* in 2009
temporal reference	Period needed to compensate negative impacts of the cyclone	Period needed to resume everyday life

Table 1: Nomenclature of vulnerability in the context of this research according to Füssel [25]
Source: Authors' own illustration.

the notion of "vulnerability". In the course of time, the RHA and the PEA have been combined and extended based on different Integrated Approaches (IA), especially the "Hazard of Place (HOP)" model, the coupled human-environment system, and the BBC framework, [26,28-30].

One of the most important features is the combination of internal factors of a vulnerable system with its exposition to external hazards. Traditionally, integrated approaches have focused on physical stressors such as natural hazards or climate change. In this tradition, the Community-based Disaster Risk Index (CBDRI) by Bollin and Hidajat [31] has been developed to assess the local scale risks. The CBDRI aims at providing a basis to decide whether a hazard results from the exposition to a threat, from particular helplessness or a deficient capacity to adapt. Cutter et al. [26] developed a new framework, the 'Disaster resilience of place (DROP)' model, in order to improve a comparative assessment of resilience on local or community level, rather concentrating on resilience than on vulnerability. Hahn et al. [32] developed the Livelihood Vulnerability Index (LVI) in order to quantify vulnerability caused by climate change and tested this index in the two districts of Mabote and Moma in Mozambique. The empirical inquiry included data on socio-demographic characteristics, securing livelihood, social networks, health, food and water, security, natural disasters and climate fluctuations. Such an index-based pragmatic approach can be used to monitor vulnerability changes and their underlying societal processes. In the conceptual work of Bogardi and Birkmann [29] and Cardona [30], is considered as a basis for the BBC Framework and linked to it. This approach includes the "capacity to cope" as a concept of vulnerability and illustrates the correlation between human and environmental conditions [13].

Previously, the Resilience Approach (RA) was rooted in ecology. Currently, this approach plays a less important role in the global research on environmental change [33]. O'Brien et al. [34] conceived the "Outcome Vulnerability" and the "Contextual Vulnerability" which are linked to different scenarios of political involvement in climate change. According to their concluding remarks, "vulnerability" is a linear result of prognosticated effects of climate change on a given exposition unit (i.e. biophysical or social). Contextual vulnerability refers to the

multidimensional perspective on the reciprocal effects between society and physical environmental conditions which recursively interact in the context of political, social, institutional and economic changes.
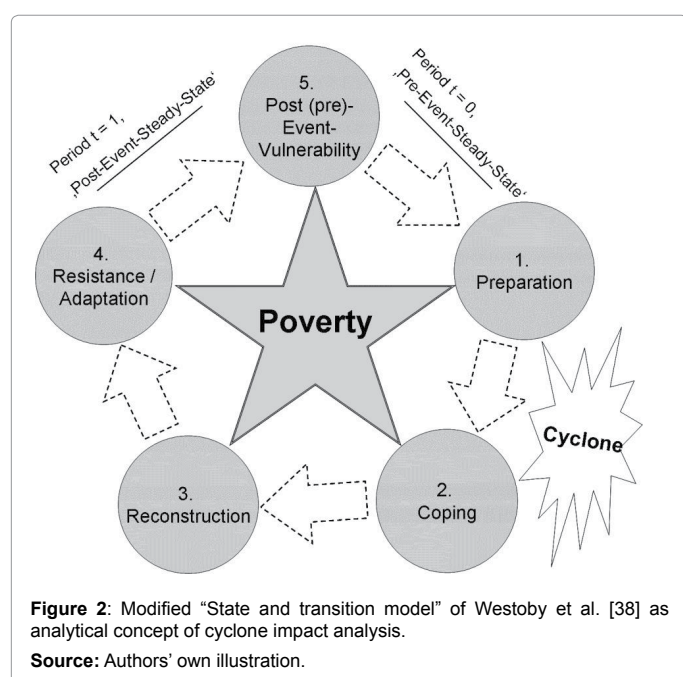
Hufschmidt [20] dressed up a comparative analysis of six models of vulnerability and identifies the differences and commonalities between different approaches to understand the quantification of vulnerability. This analysis should enhance the dialogue between different approaches to vulnerability and resilience research, fathoming a multitude of partially highly different processes relying on different methods and on different spatial scales. In this work, a detailed discussion of the interdependency of these processes on different spatial and temporal scales is dispensable. Instead, the vulnerability model is applied on a household and group level, as the implementation of adaptation measures depend on the accessibility of resources that tend to be either at the command of individuals, households or a community.

Vulnerability analysis in this research context

The relation between science and risk is largely characterized by a parallel method of approach, steered by a technical natural science concept which needs to be complemented by studies on risk perception and risk communication [35]. The underlying scientific concept is geared to the idea of a non-evaluative study of physical and social reactions to human interventions in the physical and/or social sphere. This idea is problematic [36,37]. According to the nomenclature of Füssel [25] and the, Vulnerability Model' of Hufschmidt [20], the present study develops a provisional definition of vulnerability as outlined in Figure 1. This definition attempts to characterize vulnerability in regard to three different aspects of livelihood. The first aspect refers to the internal sources of a household, for instance workforce available, household income, expenditures, assets and usable land. The second aspect includes external resources such as political relations, infrastructural support, charity organizations; and the third aspect focuses on the temporal impact of a given hazardous incidence, i.e. the time affected households need to recover from the damages and losses and to be able to return to a safe initial situation or a corresponding situation.

The above-mentioned provisional definition of vulnerability is devised in Table 1 according to the nomenclature of Füssel [25]. In this work, the system of analysis is geographic regions such as the southwestern coast of Bangladesh. Humans and their socioeconomic profiles are the attributes that need to be considered. In the framework of this research, cyclones are considered as threatening factors and the time needed to compensate for their negative impacts is considered as temporal frame of reference. Accordingly, the nomenclature of this research is interpreted as "threat of livelihood loss at the southwestern coast of Bangladesh during a cyclone".

The nomenclature of vulnerability developed in this study is helpful to pass on to the next level which deals with evaluating the most suited methods to conduct a vulnerability analysis. The provisional definition focuses on spatial and temporal aspects that turn humans vulnerable on a local level and at a certain point of time. Especially from a development aid policy point of view, interaction of social, economic, political and geographic indicators in combination with living conditions must be understood as a key to vulnerability. This perspective is also true from a regional science point of view, as the key approach of regional science is to include the contextual circumstances. This holistic approach distinguishes regional science from engineering sciences which for instance analyze the construction of embankments but for example leave aside their social impacts in the impact analysis and follow-up prognosis.

Figure 2: Modified "State and transition model" of Westoby et al. [38] as analytical concept of cyclone impact analysis.

Source: Authors' own illustration.

Methodology

Analytical model

As there is no comprehensive model including the entire spectrum of a disasters' functional chain, in the present work, a risk research model on "state and transition" is adapted to assess the vulnerability of households (Figure 2).

In applied ecology, the "state and transition" model serves to understand and quantify ecosystem reactions on natural and anthropogenic interventions which are mostly understood as disturbances [38]. The extreme values of any possible state in space and time are called "threshold". As soon as the threshold is exceeded due to environmental conditions or anthropogenic interventions, the situation loses its ecologic balance (i.e. its resiliency, the ecologic capacity of self-healing). This triggers a process of transition to a new state marked by other ecologic characteristics [39].

In the present study, a modified version of this model is applied in order to recognize the households' response to cyclones. It is assumed that at a point of time t=0 ("pre-event steady state"), households are in a stable residential state. The households' capacity (e.g. tangible assets and intangible property assets, workforce) to react to external disruptions is defined as threshold of this condition. Exogenous shocks (such as cyclones or floods) trigger off coping actions, for instance reconstruction measures or actions to replace goods. However, by the kind and extent of damages exogenous shocks provoke, they may exceed the household's capacity to preserve their original state, provoking the households to switch over from one stable condition to another. This transition can be compared to the flight path between two points. The restrictive conditions of poverty link-up the single phases of this temporal sequence. In the frame of the authors' research, this model describes the societal handling of cyclones (Figure 2).

Assuming that humans act on rational motives is a simplification. Disruptions may also provoke shocks and triggers of panic-driven irrational reactions that cannot be described by the introduced model. Next to material and physical conditions, the actors' mental conditions even sometimes play a decisive role. To include this condition is a desideratum of research. The present concept offers points of contact to achieve this objective.

Empiricism

The determination of regional vulnerabilities calls for a data volume that can only be provided by official statistics of the countries of the north, whereas in the south the data is either lacking or not reliable. Therefore, vulnerability research is dependent on empirically collected data. Data collection is based on random sample based social science methods that are applied to spatial research questions. Generally, this is a deductive process called "tri-angulations". In this process, the research area is concretized into three dimensions referring to spatial, technical and temporal aspects. The spatial concretization refers to the three districts hit by the cyclones Sidr and Aila. The spatial concretization results from the research question on the factors of regional vulnerability and the temporal concretization refers to the incidences before, during and after the two cyclones in 2007 and 2009.
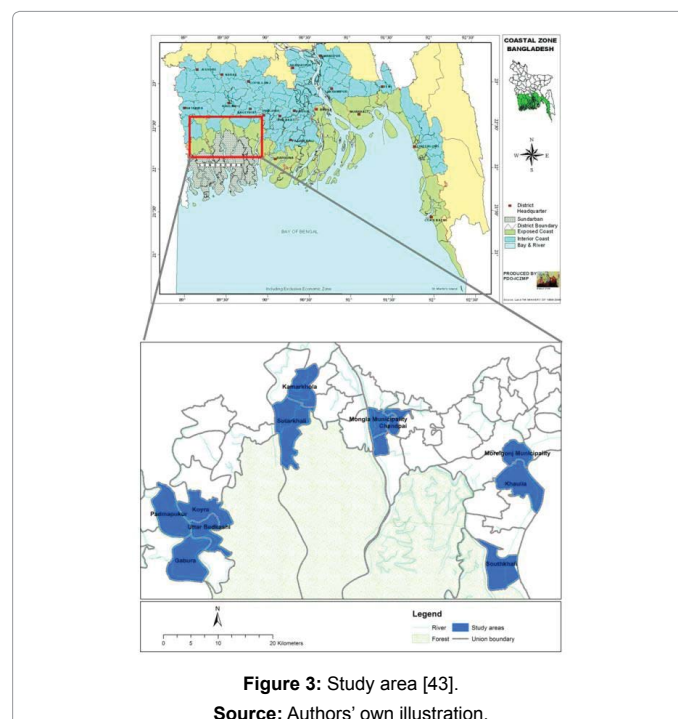
The study deals with the actions of all parties involved, including public representatives. On one hand, the study analyzes measures of disaster prevention such as the construction of embankments or shelters are analyzed. On the other hand, communication and technical infrastructure are surveyed, which generally improves the living standard. However, the field of communication and technical infrastructure is also vulnerable to disastrous events. At the same time, it causes dependencies which in turn may increase the regional vulnerability. Therefore, planning and consequent actions may both aggravate and mitigate local vulnerability. Finally, the technical localization focuses on the risk of conditional vulnerability ("hazard-dependent vulnerability") of the respondents together with the vulnerability to storm surges and infrastructural development and planning aspects of coastal regions. Temporally, the present study concentrates on two disastrous events, cyclone Aila in 2009 and cyclone Sidr in 2007. Although these two cyclones strongly differed in terms of speed, strength and damage, the social effects of both cyclones were similar. Consequently, the present study considers both disasters in equal measure and analyzes them by means of the same questions.

As the efforts of an investigation which covers the entire coastline of Bangladesh is not justifiable, a suitable subarea is chosen. Due to its current vulnerability and concern, it reflects the diversity of socioeconomic conditions of the whole region. At the same time, the subarea should feature the characteristics of an actual concernment by at least one such like event. The research focuses on the region hit by cyclone Sidr and cyclone Aila (Figure 3), namely the districts of Khulna, Bagerhat and Satkhira, the so-called western littoral of Bangladesh [40-42]. Altogether, during the field studies, 1555 households were questioned by means of standardized questionnaires. In addition, qualitative and expert interviews as well as other methods had to be applied.

Social supremacy index (SSI)

Which factors do actually determine the resilience of households to disruptions? On one hand, there are measurable attributes of wealth. Yet on the other hand there is social supremacy and access to networks which are more difficult to determine. Based on the link between income, land ownership and investments into dwelling construction a "Social supremacy Index" (SSI) has been developed. The SSI represents an expansion of the work of Mallick and Vogt [44]. First, income is

Figure 3: Study area [43].
Source: Authors' own illustration.

Social level	Indicator	Remarks
decision maker/,"social supremacy"	monthly income: more than US$ 120 (3) building costs of residence: more than US$ 750 (3) land tenure: more than 0.6 hectare (3)	Education level is negligible, as without wealth and well-constructed houses, education has no decision making power in rural Bangladesh; Occupation level important, i.e. whether they are in business or a job
socially underprivileged groups (or average income group)	monthly income of US$ 30 -120 (2) building costs of residence: US$ 250 to 750 (2) land tenure: 0.2 to 0.6 hectare (2)	
privileged class (fringe groups of local community)	monthly income: less than US$ 30 (1) building costs of residence: less than US$ 250 (1) land tenure: less than 0.2 hectare (1)	

Table 2: Social Supremacy Index (SSI).
**Source:** Authors' own illustration.

a generally accepted indicator of an individual's material wealth and accordingly their capacity to react to disruptions. Secondly, the residential building is a key attribute of social prestige. The residence's quality is a sign of social supremacy as well as social status. Accordingly, those who have or strive for a supreme social status invest capital in house construction [44]. Thirdly, the extent of land ownership of the individual households is included as large amounts of land tenure are also an indicator of power in the rural society of Bangladesh [44]. Subsequently, these three chosen indicators are weighted according to the index value as illustrated in Table 2. The surveyed households were weighted according to these index values. Consequently, households with an index value of 9 are considered as "social supreme" in this context. Their options to react to disruptions are better than those of households with inferior index values.

Likewise, households with an index value between 5 and 8 are classified as "socially under-privileged" as those groups are only rarely considered in development programs. Benefitting most from development programs, households with an index value between 3 and 4 are marked as "privileged classes".

Construction of the social vulnerability index linked to disasters (SOVI)

Albeit there are two approaches to define the vulnerability of an individual or a household - either hazard independent or hazard dependent [13,29] - the present work does only focus on the hazard-dependent vulnerability, tagging it as "household's dynamic". That is, each household or each system is based on its internally and externally conditioned capacities, and each process has a temporal continuity. These three aspects ("internal", "external", "temporal") of the individual system or household define the susceptibility to vulnerability (negative dimension) or resilience (positive dimension). The chosen variables are analyzed by means of the principal component analysis (PCA). First, the input variables were standardized in order to avoid the problems that may occur through the application of variables in the PCA. The input variables were thus transformed into the Z value with zero average value and variability. The Z values for each of the 21 variables were used in the PCA in order to compress the variables to a smaller group of components. The components resulting from this process, i.e. 7 components from 21 variables have been derived and are linear combinations from correlated variables. This results in a broader scale to assess how individual components contribute to vulnerability.

According to Cutter et al. [45], the SOVI has been used as Kaiser Criterion (eigen-value exceeding 1.0) in order to use the set of factors which are selected by the index construct. Once the components had been chosen, the result was rotated with a varimax rotation in order to facilitate the interpretation of results. The varimax rotation includes uncorrelated components. Following Cutter et al. [45], the authors assumed that components between -0.5 and +0.5 are reasonable. The algebraic sign of the calculated component shows the tendency of vulnerability fluctuation.
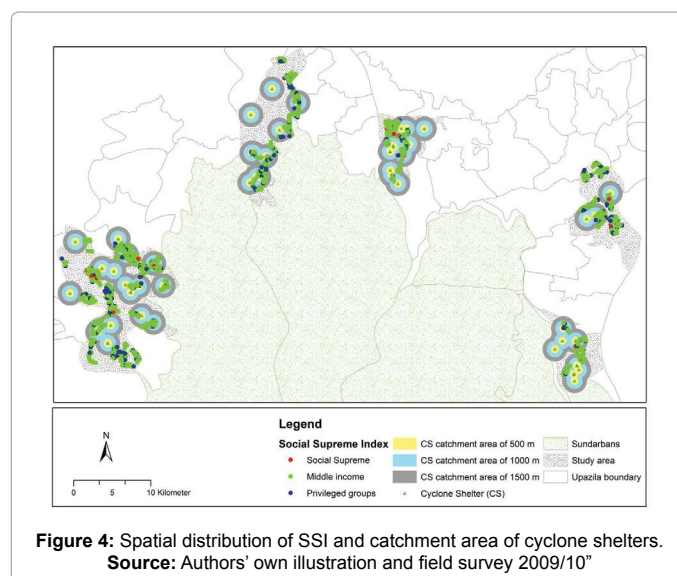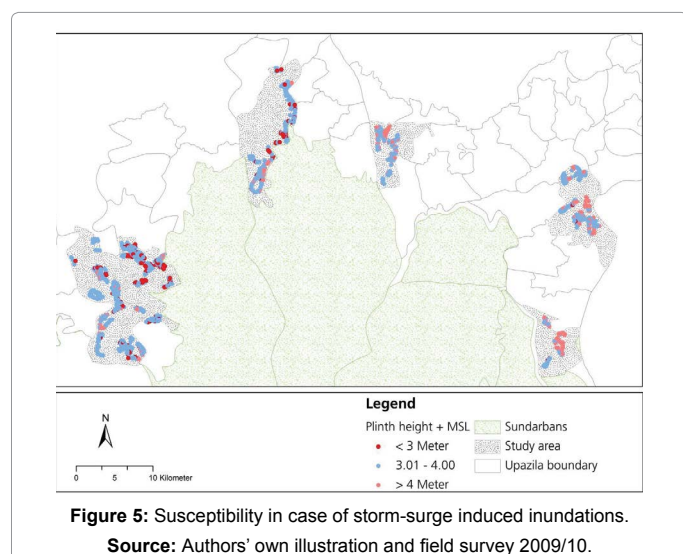
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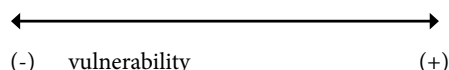
(-)   vulnerability   (+)

"(+)" is attributed to the components increase vulnerability, e.g. income poverty [15]; and "(-)" is attributed to components that reduce vulnerability, such as the condition of the own house [15]. There upon, an additive model is applied to all components, whereas each component is equally weighted. The same weighting approach is adopted in the original application of the SOVI [45] and is adopted in later applications of the index.

Vulnerability to storm-surges

The analysis aimed at identifying deprived communities in selected coastal districts, upazilas, unions and also villages through the spatial distribution of the Social Vulnerability Index (SOVI). The definition of social groups, their spatial distribution and specific risks were further steps in this analysis. Here, at first in a simplified way, social vulnerability is related to hazards caused by nature (parameterization: height of sea level). Therefore it is essential to find out whether socially vulnerable villages are hit by storm surge impacts or face a disproportional high level of costs and time efforts in order to react appropriately to such threats caused by cyclones/storm surges.

In the landfill regions within the area of interest, the susceptibility to storm tides essentially relies on the dwelling's absolute height above sea level. By means of a Digital Elevation Model (DEM), the absolute topographic heights of selected villages were determined. The relative ground level of the dwelling was gathered during the household surveys, which was then added to the respective house's height in order to obtain the absolute height above sea level of the surveyed households' dwellings. Based on this data, the potential impacts of a storm surge at

Figure 4: Spatial distribution of SSI and catchment area of cyclone shelters.
Source: Authors' own illustration and field survey 2009/10"

Figure 5: Susceptibility in case of storm-surge induced inundations.
Source: Authors' own illustration and field survey 2009/10.

different levels of the surveyed households were analyzed by means of ArcGIS, a spatial analysis tool.

First results

Societal perception of cyclones: Applying the analytical model (Figure 2), results of the empirical researches are carried out. First, the "pre-event steady state" is introduced by means of an exemplary result on the "Cyclone Shelter" (CS). Cyclone shelters are an important instrument of cyclone provision in the coastal region of Bangladesh. Therefore it is essential to determine the shelters' socio-spatial location. For this purpose, a GIS based spatial analysis was conducted (Figure 4).

Figure 5 shows a graphic illustration of the result. The circles represent the catchment areas of the single cyclone shelter within a radius from 500 to 1500 meters (smaller to bigger). Red dots represent the group of "social supreme", blue dots the group of "privileged" and light blue dots the group of "socially disadvantaged (underprivileged)" inhabitants. It turns out that only rarely, the members of the social supreme group are residing outside the catchment area. Considering a radius of 1.5 kilometers, in general, 90 percent of all households including the three above-mentioned groups are close to a cyclone shelter; considering a catchment area of 1 kilometer, 65 percent of the above-mentioned groups are close to a cyclone shelter; yet, only 25 percent of the surveyed households live within a distance of 500 meter from the cyclone shelter. Above, there are households which are even located outside of the defined catchment areas of cyclone shelters.

In the next step, the dwellings' elevation was included into the analysis. In case of the crevasses that often occur during storm surges, the landfill cells are flooded. The average height of a storm flood is between 3 to 4 meters above mean sea level [46]. Therefore, the floor of the dwellings which are usually blocked during the storm surge must be built at least 4 meters above sea level. The higher a dwelling's elevation, the less its inhabitants are affected by the impacts of a flood. By means of the digital height model and the dwellings' height above ground it was found out that the average elevation of the dwellings is only 3.5 meters above sea level (Figure 5). If the banks break or are overtopped, living space is highly imperiled to be inundated by flood waves above 3.5 meters. Except for the embankments' dike peaks; there are only few areas that are situated higher than 4 meters above sea level. Considering the spatial distribution it is now possible to deduce the probabilities of a dwelling's destruction including the whole sequence of effects.

Exemplarily, the next step of the analytical concept integrates a cyclone preparation measure. The reception of early warnings is pre-requisite for the inhabitants to take preparatory actions in case of an imminent disastrous incident. The survey reveals that approximately 75 percent of all respondents had received the early warning, whereas only 30 percent took action. Among this group, for instance, 53 percent tied up their houses' roofs to trees, whereas others removed their food to a safe place.

Why have so few respondents been able to prepare themselves for the cyclone? Two explications were most often mentioned: the respondents either indicated not to have had enough time or to have felt helpless. The biographical interviews reveal that many inhabitants had been surprised by the onset of the cyclone. Shahabuddin, a 70-year old man from the village of Sharankhola reported: "It came all of sudden, we felt paralyzed". The second example was provided by a 38-year old woman, Karuna Bala Dashi from the village of Koyra. She said: "When cyclone Aila hit, the water rose hip-high within 20 to 30 minutes. All of us got on our boats and reached for the few things we could rescue." In the framework of this study it is essential to know where the persons concerned stayed during the cyclone, where they have searched for and found a safe place, and which have been the shelters in the research area. As mentioned earlier, cyclone shelters are important refuges and are the basis for the country's prevention concept. Why the concerned tried to reach a cyclone shelter? The group discussions and household surveys gave information on this question (Figure 6). The group has collectively discussed and appreciated the distance to the shelters and how often they had been used. The result was illustrated graphically. The surface represents the shelters' intake capacity as perceived by the concerned people. The length of the arrow indicates the distance to the shelter and the width stands for number of refugees. This collective assessment is reproduced here because it has a much stronger influence on an individual's actions than the objective distance as shown in Figure 6. In this context, it is important to note that only a minority of inhabitants sought refuge in the cyclone shelters, although they offered sufficient intake capacity. The results of a principal component analysis offer explications why the minority of inhabitants did not use the shelters: the reception of the early warning plays the most important role, followed by the individual household's preparedness. Surely, state of the respondents' dwelling plays a key role in their decision-taking. People assume that they can still take measures even on the flood-waves arrival if they perceive a concrete endangerment of their property. However, this is not possible from a distant shelter as the social status is decisive, too, for instance farmers or day-laborers. Eventually, due to cultural reasons, women take less often refuge in cyclone shelters than men. Individual positive experience with cyclones however encourages people to search for refuge in a cyclone shelter.

When a cyclone has passed the region, the concerned must overcome the consequences, traumata and damages in order to be able to live on. It is not always possible for them to cope with these challenges on their own as resources are either inexistent or have been destroyed as well. Humanitarian organizations and, as most important factor, government should support the concerned lot in this situation. Sometimes, also private initiatives offer emergency relief. However, in the research area, these measures of emergency assistance are unevenly distributed in terms of space, which can only partly be explained by differing accessibility. Political and social assessment and the distribution of power play a major role. Emergency relief projects are first and foremost implemented at places where they can be geared towards the media that is close to minimizing traffic connections or hotel, guest houses. In such preferential areas, donors compete while the peripheral regions hardly benefit from any emergency assistance.

Figure 6: Mobility diagram.
Source: Authors' own illustration and field survey 2009/10.
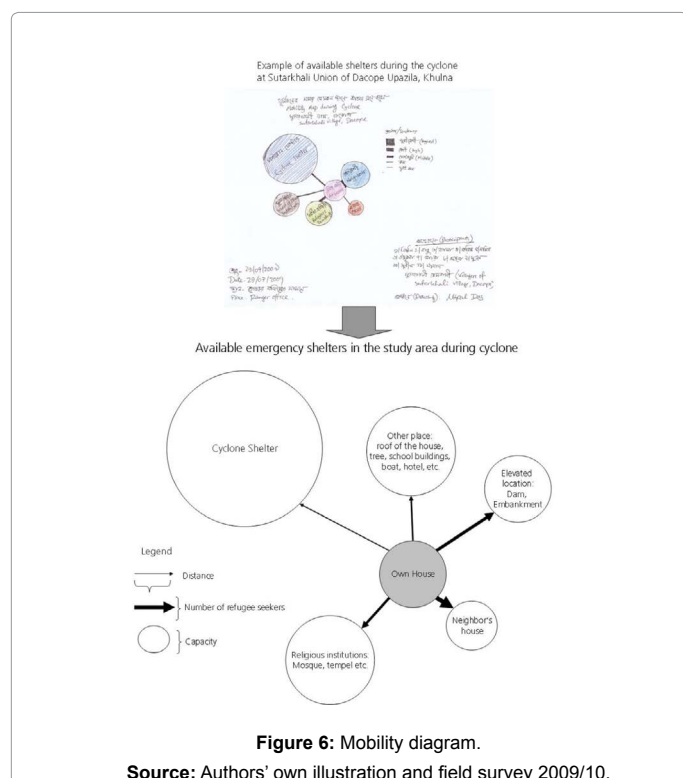
Independent from the objectives of the donor organizations, supporting measures always result from religious, social and political loyalty. They also serve as an instrument to at least preserve the local disparity of power, possibly also to increase their own influence. This has an effect on the distribution of emergency relief measures which cannot be explained without considering this social background. Over the years, the Bangladeshi governments and other development partners (i.e. UNDP, JICA, GIZ, EU and others) have invested about 1.4 Billion USD to support the affected communities' recovery from damages caused by the cyclones Sidr and Aila. Analyses shows that within the frame of reconstruction and emergency programs, affected people are treated differently, some of them obviously due to political, religious or family reasons. This is backed up by the victims' assessment. For instance, the survey revealed that 57 percent of the respondents believed that local politicians had taken advantage of their power during emergency relief distributions. Group discussions and biographical interviews yielded the same results. Therefore, discrimination during emergency assistance can be proved to exist where those in power take advantage of their position to increase their personal profit. In addition, the social structures in the villages are characterized by close networks of patron-client relationships, with different dependency-based networks competing against each other. During this conflict, disasters represent a chance to strengthen such networks by exploiting external aid programs, to establish new dependencies and to gain advantages in different fields of action this way, for instance when it comes to the distribution of emergency measures during the next disaster, whenever it will strike. Therefore, these relief programs entail an increased risk of dependency. They may also lead to lethargy. If people repeatedly receive support from others they become incapable to evaluate a risk, to respond to it, to mitigate it or to handle risks in any other way. Above all, it is problematic if the social hierarchy is changed through the emergency measures. If there is the chance to do so, the affected people try to emulate their role models at local and regional level and profit

either in a social or in an economic way. They have great expectations as to the long-term effects of this strategy and adopt it as best action strategy. This assumption was summarized in a biographical interview. The respondent, Mr Alam Mia from the village of Majherchar in the Southkhali Union, said: "Why should I reconstruct my damaged house? After the cyclone Sidr, many NGOs came to reconstruct my house. Back then, I made a mistake by accepting the help of the relief organization Caritas Bangladesh. If I had accepted the help of the organization Muslim-Aid, I would have a very solid house today. This time, I will wait until Muslim-Aid comes to me or I will go to them myself."

This statement shows that there is an increasing attitude of expectation among people affected which guides their actions.

However, even if the emergency relief organizations stop their programs, people must live on and secure their livelihood. How do the people affected react on this situation? They could sell their own resources, for instance, 17 percent of the respondents have sold their crops, cattle or jewelry. 14 percent of the interviewees have changed their employment due to the extent of damages, their dependency on the exploitation of the Sundarbans and the limited opportunities to participate in reconstruction works. In most cases, the farmers have worked as fishermen, as in the wake of the cyclone Aila, farmlands were inundated and could not be longer be cultivated. Yet not all the affected could follow this strategy and therefore took out a loan, which became the main source of income to secure their livelihood. About 80 percent of the questioned households have taken out loans from different mortgagees such as NGOs, banks or local money lenders. Some of them have borrowed money because an emergency relief organization has asked them to do so. Actually, aid organizations have often created microcredit programs after the end of the emergency relief, which became one of the most important sources of income helping the impoverished inhabitants to survive. Some of the inhabitants have left the village. Those who had received only little help and had borrowed substantial amounts of money have most often migrated to nearby towns. 34 percent of the questioned households reported that at least one family member had left the village. This situation which recurs after every similar incident explains for the rapid growth of cities and also leads to a gradual change of the affected society.

Socio-spatial disparity of vulnerability: From the factors that influence the population's security during a cyclone, first, their "adaptability" to a disaster impact needs to be determined. It was asserted that only 13.5 percent of the respondents had successfully implemented their own plans. Considering their socioeconomic and risk-dependent characteristics, 16 variables were used in the principal component analysis and divided into five categories: (i) preparation to the post cyclone situation; (ii) reception of the early warning and prevention plan; (iii) state of the dwellings; (iv) access to medical care and drinking water; and (v) access to cyclone shelter. These components explain (KMO = 0.833, Chi-Quadrat = 14927.59, df = 120, p <0,000) that preparation for the cyclone is an important explanatory factor to the social impacts of a natural disaster. Thus, the adaptability of the individual households mainly relies on the residents' strategy to take measures against a cyclone.

The question is what kind of socioeconomic factors determine or influence the residents' ability to guard against natural disasters. Does this ability depend on age, religion, income or profession? These questions are aimed at aspects of the respondents' vulnerability and resilience and will be analyzed closely below. The questions have been conceived to determine vulnerability by means of measurable indicators in order to build adequate strategies on them. The actual

damages affected parties suffer depend on the size of their country, their individual resources, and their cattle stock before the cyclone and also on the investments made into their dwellings. It has been mentioned before that 22.5 percent of all respondents reported on injured family members. Far less often, they reported on casualties within their family. Taking into account the situation of these respondents, the following results were specified.

85.5 percent of the respondents received the early warning on the cyclone on average 3.51 hours before its arrival. This led to the situation that 53.6 percent were not prepared for it in time, and that another 20 percent did not manage to reach a shelter within the time left. 70 percent of the respondents also reported that their efforts to take preventive measures failed. At the same time, it was also noted that those who did not have any preventive plan at all were more prone to the cyclone's hazards. In addition prior to the cyclone, 96.9 percent of the people who reported casualties had owned brick-earth dwellings with an average height of 1.2 meters above the ground. According to their statements, their average building costs had been US$ 270 (BDT 15900). Above, normally, only 5.1 percent of the respondents could earn their annual livelihood for at least six month by yielding crop. A quarter of the interviewees also worked as peons and did not have any regular source of income. Their monthly average income ranged from US$ 25 to US$ 69, suggesting that income is an important vulnerability factor. Furthermore, education is an important factor, as more than half of the respondents (52.7 percent) even did not finish primary school. Only 10 percent of the interviewees could rapidly reach a cyclone shelter (within 10 minutes). This situation reflects the income poverty level and the accessibility of shelters.

A few days after the cyclone, 76.6 percent of the respondents did not have any possibility to cook, which is a threatening situation in view of hygienic circumstances. 83.2 percent also did not have access to clean drinking water, although 91.2 percent had received their food from emergency aid organizations. In addition, despite the numerous reconstruction programs in the area, 59.5 percent of them did not have any possibility to earn money and 18.2 percent of the interviewees participated in reconstruction projects such as the rebuilding of banks. Consequently, 73.8 percent of these people have changed their source of income after the cyclone, of which however only 2.6 percent reported that their economic situation has improved due to occupational changes. Moreover, 84.3 percent took on micro credits, and 34.5 percent reported that male family members had migrated in the wake of the cyclone, primarily to the urban centers. In the research area, the interplay between micro credits and catastrophes is a permanent research objective.

Consequently, there are different socioeconomic indicators that are relevant in order to determine the factors of vulnerability. By means of PCA, components of the social vulnerability index (SOVI) were identified. The SOVI parameterizes the risk level during a cyclone in the researched communities (Table 3). On the one hand, the index describes the risk of being threatened by cyclones and also shows the ability to resist a cyclone, i.e. to be resilient. The SOVI varies between -1 to +1, whereas a negative value indicates the predominance of endangerment and a positive value rather indicates the ability to withstand a cyclone. This shows that most of the respondents have to be attributed to the negative scale of the SOVI. In turn, this also means that a vast majority of interviewees share the tendency to "vulnerability".

All these factors in combined account for 82.7 percent of the overall variance (KMO = 0.768, p<0.001). The first two components, for instance emergency aid and support on community level, are
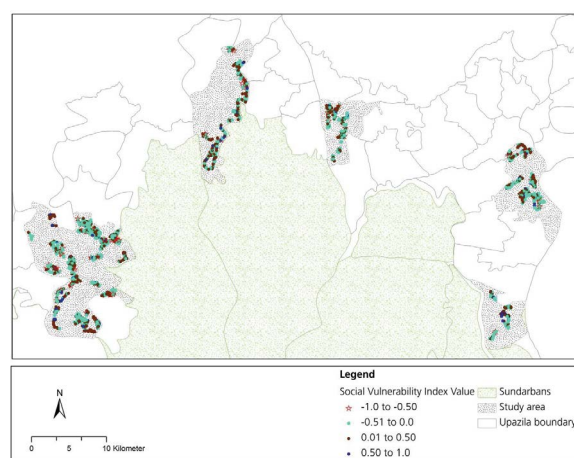
Figure 7: Repartition of the SOVI
Source: Authors' own illustration and field survey 2009/10.
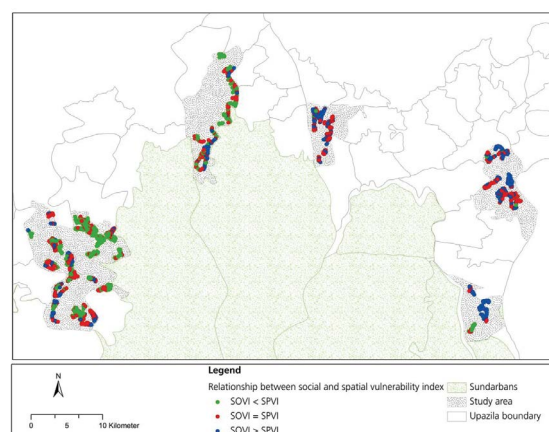
Figure 8: Connection between SOVI and SPVI
Source: Authors' own illustration and field survey 2009/10.

caused by external factors. Altogether, they comprise 44.9 percent of the total explained variance. The efficiency of household resources has a variance share of 9.4 percent. Age and individual experience on site include the fourth component, while the income level and the estate's size are summarized into the fifth component. Here, the access to the cyclone shelter is defined as a temporal factor as the temporal aspect of accessibility outbalances the availability of shelters in the village. Here, too, the state of dwelling was defined as an internal factor for determining SOVI.

The SOVI analysis shows that "resilience" can be seen as a part of the "coping capacity" during cyclones and that the individual abilities and capacities represent the extent of vulnerability after the cyclone. The illustration of extremely "vulnerable" and extremely 'resilient' values with regard to the SOVI. The extremely vulnerable partition (-1.0 <SOVI> -0.50) covers 4.4 percent of all respondents, out of which 6.6 percent are located in the resilient partition (0.50 <SOVI>1.00) (Table 3). This interpretation is based on only one index that has been deduced according to the statistic "multilevel" analysis. Therefore,

Categories of SPVI			Categories of SOVI		
Value of SPVI	Frequency	Percent	Value of SOVI	Frequency	Percent
Less than 3.0 meters (extremely vulnerable)	229	14.7	-1.0 to -0.50 (extremely vulnerable)	69	4.4
3.0 to 3.5 metres (extremely vulnerable)	542	34.9	-0,51 bis 0,00 (vulnerable)	745	47.9
3.0 to 4.0 metres (vulnerable)	525	33.8	0.01-0.50 (less resilient)	639	41.1
more than 4.0 meters (less vulnerable)	259	16.7	0.51-1.00 (resilient)	102	6.6
Total	1555	100.0	Total	1555	100.0

Table 3: Categories of SOVI and SPVI

Source: Authors' own illustration.
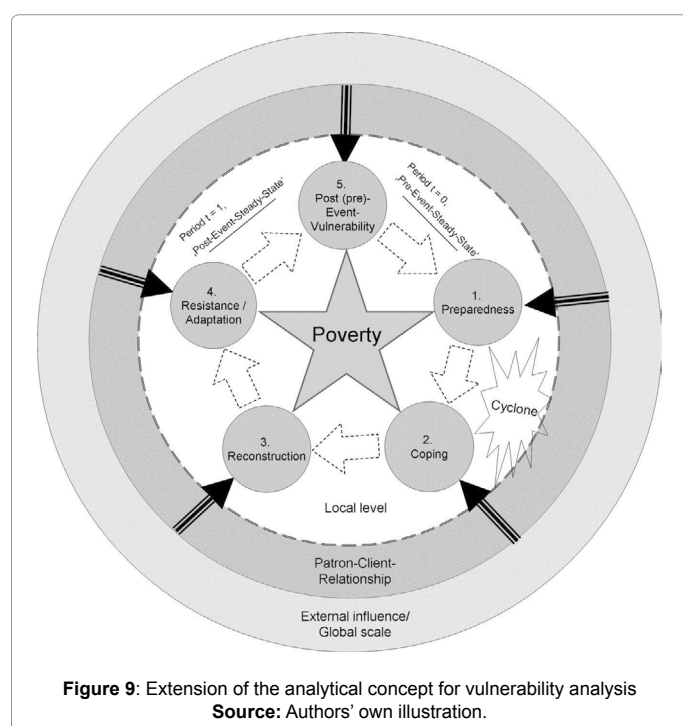
Figure 9: Extension of the analytical concept for vulnerability analysis

Source: Authors' own illustration.

the observations in reality and in the context of another threat will differ from this result. However, the findings from the SOVI analysis can reveal and support empirically non-trivial connections between "vulnerability", "adaptability" and "resilience".

The connection between SOVI and SPVI is important for future spatial planning. Table 3 shows the repartition of the SPVI and the SOVI. These statistics do not allow determining whether there is a strong positive correlation between SPVI and SOVI. It is therefore necessary to determine those groups that show a similar level with regard to their SOVI and SPVI. A result of this analysis is presented in Figures 7 and 8.

The analysis classifies as follows: (i) the respondents show a minor extent of social vulnerability as opposed to their vulnerability caused by their location (SOVI < SPVI), (ii) the respondents show a similar extent of social vulnerability and of vulnerability caused by their location (SOVI = SPVI), and (iii) the respondents show a higher social vulnerability compared to the vulnerability caused by their location (SOVI > SPVI). The results approximately spread in equal shares to the following three groups: 34.3 percent of the respondents have a minimal SOVI, but a comparatively higher SPVI; 36.8 percent have a similar

level of SOVI and SPVI and the remaining have a higher SOVI than SPVI value. There is no correlation between these two values, possibly due to the SPVI as the SPVI is calculated from a geographical value and a social indicator such as a dwelling's ground level.

The absolute ground level of the dwelling in turn depends on other socio-demographic characteristics of the respondents, such as monthly income ($r = 0.193$, $p<0.001$), landownership ($r = 0.191$, $p<0.001$) and building costs ($r = 0.506$, $p<0.011$). These values suggest that it is more important for future planning measures to consider the SOVI rather than ground level. If the respondents were socioeconomically resilient, they were comparatively more capable of managing the difficulties in the wake of a hazardous event. This may for instance be deduced from the regional disparities of the SOVI and SPVI in view of the whole sample. The samples show that only a minority of respondents in the districts of Satkhira and Khulna had built their houses higher than 3 meters above mean sea level, although they had a negative SOVI. In the district of Bagerhat, only few respondents lived in a location higher than 4 meters above mean sea level, although they have a negative SOVI. Considering further characteristics of the respondents, it can be noted that this group of respondents had to be localized in the upazilas of Sharankhola and Morelgonj where they received reconstruction support for their dwellings in the wake of cyclone Sidr. Indeed, with external support, these respondents managed to increase the distance between their houses' ground level and the underground. However, they could neither improve their income situation nor their opportunities to earn money. This clarifies the problem of using such indicators in a social context, which is influenced by external support.

A vast majority of the respondents has been affected by the cyclone Aila and has been asked in the framework of the present study immediately after the cyclone. Two years later, the study of Mondal [47] already reports an increased ground level of the dwellings in the upazila Koyra of the Khulna district. Given that the situation in 2011 had changed compared to 2009, the relation between SOVI and SPVI has also equally changed. In order to be able to draw the conclusion based on corresponding indicators that vulnerability due to location plays an important role in social vulnerability, another spatial analysis on other parts of the littoral is necessary.

In the future, based on the compiled data, it will be possible to monitor and measure more precisely temporal changes between the disastrous events and determine from these results the actions that need to be taken. This becomes more and clearer with increasing temporal distance to the disastrous event. In this way, it should be determined which adaptations to vulnerability are being abandoned and which ones have long-term effects.

Discussion

The results in selected communities of the study area after two cyclonic disaster-related events show that socio-economic conditions of the households surveyed are the most important factors in coping with the effects of cyclones. Thus, households with higher incomes have higher quality homes and were less susceptible to cyclones and tidal waves. The extent of damage and losses due to a cyclone was defined by the extent of loss of homes, crops, livestock, and number of casualties and the extent of the injuries of family members. On one hand, the extent of the damage shows adaptability to cyclones and on the other, it contributes to the explanation of vulnerability. The relationship between SOVI and SPVI shows the importance of addressing social aspects rather than the exclusive consideration of the physical aspects of vulnerability. This means that if the households in the communities are technically, socially and economically strong enough, they can resist with adverse consequences cyclone. Then their location-related vulnerability is less significant compared to their social vulnerability. In a global context, for example, the coastal communities of the global North are more resistant than the communities in the south. This is because the socio-economic standard in the south is far below the standard of the countries in the North [14]. This could also be confirmed in this study as those who achieved a positive SOVI, had lower damages, losses and injuries and were able to rebuild their homes on average within 20 days after the cyclone. Considering changes in the society, the analytical model of the catastrophe-related vulnerability analysis (Figure 2) provides all the previous results. Enlargement of the original analytical model is also shown in Figure 9.

If a society is changing, there will be consequences. Disaster relief efforts are exploited by those in power and controlled the whole process of emergency relief distribution in this sense. It means those in power or those considered as "social supreme" have a very big influence on the local decision making process. Only the wealthy and powerful groups have the opportunity to participate in policy decisions about social aid and disaster preparedness and planning. They support their dependent groups and reinforce this. This leads to social marginalization as a result of a disaster and also to strengthening of "patron-client-dependency" in the society. The current state of the coastal society is also a result of social processes during the frequent devastating cyclones or other natural events. In addition, the social power of different actors has a strong spatial pattern, corresponding to affects resulting from the reaction of those affected and mitigated. These spatial patterns are an important key to understanding the effects of cyclones and floods, as well as the subsequent relief and prevention measures. Therefore, for disaster preparedness planning and a holistic approach to the vulnerability and the local knowledge of a concept, it is important to assess disasters in their cultural, socio-economic, political and environmental context. The analysis presented should be a helpful guide for the development of concepts and strategies for future risk management.

Proposal of "Vulnerability Atlas" as a guideline for disaster risk reduction planning

The conditions for vulnerability are therefore dependent on spatially differentiated natural environment and social factors. Accordingly, spatially varying effects in large-scale differentiation arise and measures to prevent the disastrous effects of cyclones and floods must be built to be effective and optimize the investment targeted at best. The results of the research project demonstrate the need for such a spatially differentiated analysis and planning, including a vulnerability atlas in the sense of a comprehensive database, are the most useful measure for analysis and development of plans and measures. For a vulnerability atlas, which will be the basis of planning and implementation of preventive measures, the vulnerability will account for more variables to determine their effects and can be differentiated socially and professionally. The list of variables will be expanded beyond those currently investigated and include, for example, medical variables, and give thought to quantify the influence of social power relations. It will also be an instrument that shows temporal monitoring of the effects of disasters and relief and thus can also be used to evaluate policies for external interventions.

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