Livelihood vulnerability of char land communities to climate change and natural hazards in Bangladesh: an application of livelihood vulnerability index

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Abstract
Bangladesh is one of the most vulnerable countries in the world to climate change. In general, Char land (Riverine Island) communities are frequently affected by floods, riverbank erosion, and other climatic hazards, including drought, cyclones, tornadoes, salinity intrusion, water logging, cold waves, etc., which cause many to lose their sources of livelihoods and properties and make them more vulnerable. Using survey data of 262 rural households, this study investigates the extent of livelihood vulnerability to climate change and natural hazards in the Char land communities by applying the climate change vulnerability index (CVI) (i.e., UN-IPCC vulnerability framework) and the livelihood vulnerability index (LVI) to develop context-specific interventions for building climate and livelihood resilience. The two approaches to vulnerability assessment were modified to incorporate local contexts and indigenous knowledge into 41 sub-components. The result shows that LVI and CVI values are different between Char land communities. The LVI index shows that households in Char Jotindro-Narayan (0.148) are more vulnerable than those in Char Kulaghat (0.139). The CVI values for Char Jotindro-Narayan (0.633) are slightly lower than for Char Kulaghat (0.639). The major vulnerability factors were access to food and water, social networks, natural disasters, and climatic variability. The study also indicates that flood, riverbank erosion, unemployment, and access to communication, market, and basic service opportunities are the major biophysical and socioeconomic factors determining livelihood vulnerability. Context-specific sustainable policies and development initiatives are required to improve the adaptive capacity of Char land communities across Bangladesh, thereby building their climate and livelihood resilience.

Keywords Char land · Climate change · Natural disaster · Livelihood vulnerability · Specific-context · Bangladesh

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1 Introduction

Bangladesh is the world’s most climate hotspot country due to its low-lying terrain, geographic condition, and climate change over time (Alam 2017; IPCC 2014). It is thought that climate change aggravates similar hazardous incidents, including floods, riverbank erosion, drought, cyclone, water logging, etc., which adversely affect socioeconomic improvement and living communities (Alam 2016; Alam et al. 2020; Simotwo et al. 2018; Panthi et al. 2016). In Bangladesh, these climatic hazards often occur on delta and riverine islands (huge sandbars that form in riverbeds as a result of silt and alluvium deposition) communities, specifically due to dynamic riverbank erosion and accumulation (Alam et al. 2017; Ahmed et al. 2019; Islam 2018). These areas are known as char areas, because they are familiar with numerous natural hazards and socio-economic vulnerabilities. The impacts will differ for people who work in various occupations, e.g., agriculture, fisheries, business, etc. Every year, frequent riverbank erosion loses a great amount of agricultural and usable land in char communities (Alam 2017). However, natural disasters wreak havoc on the communication structures of char land communities, denying char land residents equal access to the economic and social benefits enjoyed by mainland residents (Alam et al. 2017). These difficult scenarios are prevalent throughout Bangladesh’s various char areas, which represent around 5% of the country’s entire land (7200 sq. km) and population (6.5 million people) (Alam 2017; Alam et al. 2017; EGIS 2000). The most challenging fact for the char land people is their inability to relocate to the mainland to seek employment opportunities, which results in migrations within the char region (Alam et al. 2020). Approximately 25% of char households have migrated at least three times in the previous 10 years (CARE-Bangladesh 2002).

A climate change model projection for Bangladesh predicted that by the end of the century, the mean annual and seasonal temperatures would increase by 4.7 °C (Christensen et al. 2007). The precipitation in the wet season will experience an 11% increase, while the dry season will become significantly drier; the frequency and intensity of cyclones in the Bay of Bengal are also expected to increase, resulting in more intense rainfall in coastal regions, leading to widespread flooding and sea incursions (Christensen et al. 2007). Climate change, natural disasters, migration, and economic opportunities are threatening not only livelihoods but also the terrain that provides the foundation for effective agricultural activity, such as cropping patterns, crop yields, insect infestations, and water availability. Because of these challenges, the households of char communities are frequently losing their agricultural products (e.g., yields, poultry, and livestock), as well as the human and financial assets that are required to conserve their financial prosperity and overall persistence (Alam et al. 2018).

Climate change vulnerability has been described by the degree to which a system or civilization is susceptible to, or at risk of, and incapable of dealing with the deleterious impacts of climate change (Schneider 2007). Vulnerabilities of climate and their related consequences differ depending on the communities’ geographical, temporal, and socioeconomic characteristics, which make a community/system more vulnerable to the effects of climate hazards (Alam 2016; Alam et al. 2017; Ayanlade et al. 2018; Panthi et al. 2016). To reduce harmful livelihood effects, a location and context-specific strategy is required for assessing and monitoring vulnerability to assist in determining an optimal community’s adaptation strategies and policies at the regional, national, and global scale. (Alam 2017; Erdiaw-Kwasie et al. 2019; Zhang et al. 2018; Toufique and Islam 2014; Vignieri 2015). People in developing nations are vulnerable due to their reliance on farming and poor
earnings (UNDP 2008). These constraints can stimulate the investigation of resource-poor societies’ possible adaptive capabilities (Nelson 2007; Folke 2006). The degree to which humans are vulnerable to natural hazards in nearly all aspects of life, such as the human, social, financial, physical, and natural dimensions, has risen (Oo 2018; Ford 2010).

Investigating and analyzing vulnerability requires a context-specific approach at all regional levels to develop effective policy and strategy and minimize harmful consequences to livelihoods (Adger 2005; Bevacqua 2018). In this study, we used a context-specific approach to describe and characterize the livelihood exposure to climatic vulnerability and identify the sensitivity of different capital resources such as human, natural, physical, financial, etc. for designing and delivering livelihood strategies (Tasnuva et al. 2021). The relationship between individuals and their social and biophysical environments is easily utilized to evaluate the development-policy framework using particular indicators (Eriksen 2007) and show perspective adaptation strategies (Gbetibouo 2010). It can compare and assess the level of vulnerability as it varies over time, location, and allocation of resources (Alam 2016; Preston 2011). The primary difficulty in vulnerability assessment is developing strong and reliable indicators (Alam 2016; Adger 2006).

This study focuses on the char land region in Bangladesh. Geologically, Bangladesh is recognized as one of the world’s biggest deltas, which comprises about 230 rivers, encompassing three major rivers known as Ganges–Brahmaputra–Meghna (GBM), which contains massive inland bodies of water (Islam and Bhuiyan 2016 2018; Monwar et al. 2018). Due to geographical context, Bangladesh’s coastline and riparian communities are extremely vulnerable to the effects of climate-induced hazards such as riverbank erosion, floods, cyclones, arsenic contamination, waterlogging, and salinity intrusion (Azad et al. 2013; Alam 2016; Alam et al. 2017; Islam and Uddin 2015; Islam 2013 2014; Salam et al. 2021). Aside from the isolation of char dwellers, the region is characterized by high precipitation rates, which have resulted in significant riverbank erosion (around 150,000 square km) over the last ten years (Alam 2017; Huq 2008; Mutton 2004). Over 20 of the 64 districts are vulnerable to severe riverbank erosion, resulting in the loss of 8700 hectares of land and the relocation of approximately 200,000 people per year (Alam 2016; Alam et al. 2017; Ahsan 2014; Barrett 2014; CEGIS 2012). Despite these threats and vulnerabilities, riverine people frequently choose char regions owing to increasing population pressure and cumulative stress on scarce land areas (BBS, 2014). The char land communities are recognized as among the poorest and most exposed groups to environmental dangers (Alam 2017; Islam and Hossain 2013). Adding to this, char residents are faced with inadequate communication networks, which excludes them from the services and advantages available to ‘mainland’ residents (Sarker et al. 2020; Thompson 2000).

For the government, NGOs, or/and foreign donor organizations to actively and successfully intervene in the current situations faced by the char residents, reliable information, and in-depth study findings are required (Alam 2016; Alam et al. 2017; Islam 2018). The policy action cannot occur unless the exact condition of char communities’ vulnerability is understood (Alam et al. 2017; Sarker et al. 2020; Islam et al. 2021). The Bangladeshi government views the vulnerability of char households as a critical issue that must be addressed (GOB 2011). This research intends to address this critical gap by implementing the IPCC vulnerability approach and building a livelihood vulnerability index (LVI) and a climatic vulnerability index (CVI). The study also seeks to investigate the extent to which char communities are vulnerable regarding livelihood and climate change situations within rural communities in the char area of Bangladesh.
2 Materials and methods

2.1 Study area

The study was conducted at Phulbari Upazila in Kurigram and Lalmonirhat Sadar Upazila in the Lalmonirhat district of northern Bangladesh. Geographically, this area is positioned between 25°52′0″N to 25°58′0″N latitude and 89°28′0″E to 89°33′0″E longitude (Fig. 1). These regions are among the most vulnerable to natural hazards and are considered geographically remote riverine areas. The Dharla River crosses the study region and poses a lot of challenges, including loss of livelihood assets, crops, and agricultural land, particularly in times of riverbank erosion. The regular flooding and erosion of riverbanks are a common phenomenon in the region that badly influences the char land communities (Mondal et al. 2020; Islam et al. 2019) (Fig. 2).

The study villages were purposefully chosen based on the extent of their natural hazards, especially flood and riverbank erosion, which have been reported in previous research papers, local expert views, policy documents, and newspapers. The respondents from these villages were elected randomly for the survey. The study determined two main constituencies: (i) the community which has relatively easy access to the mainland and (ii) the communities living in proximity to the Dharla River. Although both regions are frequently affected by natural hazards, they have their own uniqueness on the basis of communication systems, education, health services, and different livelihood assets.
The studied village in Phulbari Upazila was Char Jotindro-Narayan, and the distant villages in Lalmonirhat Sadar Upazila were Kulaghat char.

### 2.2 Sample size estimation

To estimate the sample size, the Cochran’s formula (1977) was applied (Eq. 1). According to the BBS (2011), these two selected villages from Phulbari and Lalmonirhat Sadar Upazila had a total of 823 households. The total sample size was 262 (131 for Char Jotindro-Narayan in Phulbari Upazila and 131 for Kulaghat char in Lalmonirhat Sadar Upazila). The confidence level was 95%, while the margin of error (confidence interval) was 5%, respectively (Cochrans 1977).
where \( n \) = sample size for the given population, \( n_0 \) = sample size of an infinitive population, \( N \) = population size.

### 2.3 Questionnaire and data collection

The survey was performed using a semi-structured questionnaire, focus group discussions (FGDs), and face-to-face interviews between January and February 2021. A total of 20 pre-test surveys were conducted to examine the transparency of the questionnaire, its appropriateness for contributors, the time required for per interview, and any potential impediments that could occur during the survey. After that, the questionnaire was finalized, consisting of three sections (i) adaptive capacity, (ii) exposure and, (iii) sensitivity, as well as eight major livelihood components: (i) socio-demographic profile, (ii) livelihood strategy, (iii) social network, (iv) health, (v) food, (vi) water, (vii) natural disasters, and (viii) climatic variability. The household head was the main targeted respondent. The survey was in the local language. A multi-stage sampling technique was used to identify respondent households. To begin, Phulbari and Lalmonirhat Sadar Upazila was chosen through purposive sampling due to the presence of vulnerability contexts. Secondly, the Char Jotindro-Narayan and Kulaghat char from Phulbari and Lalmonirhat Sadar Upazila were selected. Finally, 262 households were interviewed from these two char villages, with 131 participants from each village. Moreover, to the surveys, two focus group discussions (FGDs) were conducted in each village by groups of 10–12 family heads to collect perspectives on various climatic and socioeconomic variables. These thoughts were subsequently utilized to cross certify the survey results. Questions involved in the survey questionnaire are defined as the major components in "Appendix A". Analysis of livelihood vulnerability index (LVI) and climate vulnerability index (CVI) values was obtained utilizing Microsoft Excel and SPSS 24.

### 2.4 Context-specific framework approach

Climate vulnerability refers to the extent to which environmental, geophysical, and socioeconomic conditions are susceptible and incapable to deal with the negative effects of climate change (IPCC 2007). Climate vulnerability is a composite and sophisticated legislative issue, engaging with social, economic, political, and environmental elements at global, nationwide, and local levels (Adger 2005, 2006). Climate vulnerabilities and their related impacts differ across sectors and contexts depending on the geographical, temporal, and socioeconomic characteristics (Alam 2016; Ayanlade et al. 2018; Jurgilevich 2017). The context-specific approach responds with knowledge of the complicated historical and contemporary context in which any action is being performed, as well as the potential influence and engagement that any activity may have on that context. Therefore, to characterize a specific context of a study area, it needs to evaluate the interactions between temporal, geographical, social, financial, political, and resource or livelihood capital factors. Climate change effects will modify the biophysical features of the context and influence the interplay between multiple aspects that regulate the dynamics of climate vulnerability (O’Brien 2007; Thornton 2014). While it is needed to realize how to identify a context, it is also needed to fix what context must be recognized for developing adaptation policies at various
levels (e.g., nationwide, sub-national, or local) (Leichenko 2014; Erdiaw-Kwasie et al. 2019). In our study, we followed the context-specific approach (Fig. 3). Context identification is a great tool to specify and characterize the context. In our study, after the context is identified, we specify the livelihoods exposure to the climatic vulnerability on a context and consequence basis. This phase involves determining the sensitivity of livelihood activities while considering the accessibility and usage of various capital resources for developing and spreading livelihood strategies. There are some steps to accessing adaptive capacity which include government, NGOs institutional planning for fixing the virtue and connectivity to capital assets. For the LVI framework in the study, we identified 8 major components comprising 41 sub-components under the 5 livelihoods capitals: human, natural social, physical, and financial. These consist of food, water, health, socio-demographic profile, livelihood strategies, social network, natural disasters, and climatic variability. This context-specific LVI technique adopted will investigate the actual circumstances of livelihood vulnerability. The ultimate phase of the approach is an evaluation of adaptation plans to reduce context-specific vulnerability, and prevent unfavorable outcomes.

Fig. 3 A context-specific framework approach for livelihood vulnerability
2.5 Vulnerability analysis

Vulnerability refers to the status of a personal or group to stresses caused by alterations in socio-economic and environmental factors that disrupt livelihoods (Adger 1999). Vulnerability estimation identifies vulnerable people and sensitive factors to climatic hazards and reveals the results of communal systems and materials within the framework (Adger 2006; Ford et al. 2010; Tavares et al. 2015). In terms of livelihood vulnerability, both char lands communities face a number of natural hazards, such as flood, riverbank erosion, drought, cyclone, and salinity, that damage their agricultural land, livestock, and sources of livelihoods and make them more susceptible (Alam 2016; Alam et al. 2020; Sarker et al. 2020). Char lands communities adopt a variety of coping strategies, such as homestead gardening, high-yielding varieties, opening a savings account, receiving government and organizational training, to mitigate the impact of these types of issues on their livelihoods (Alam et al. 2017; 2020; Sarker et al. 2020). Vulnerability is determined by the function of three primary dimensions, which are sensitivity, exposure, and adaptive capacity (IPCC 2007) by Eq. (2)

\[
\text{Vulnerability} = f(\text{Exposure, sensitivity, adaptive capacity})
\]

In general, vulnerability is a positive function to sensitivity and exposure of the system and a negative function to adaptive capability (Ford et al. 2010; Ford and Smit 2004; Alam 2017). Community views of social identity influence outlining climate risk opinion and resulting adaptive capacity (Frank et al. 2011). For this study, we used LVI (Alam 2017; Hahn et al. 2009; Alam et al. 2017) and CVI (Pandey and Jha 2012; Alam 2016 2017) to measuring livelihood vulnerability of char land communities and evaluate the comparative degree of the major participating parameters under the comprehensive IPCC framework.

The IPCC livelihood framework approach measures vulnerability using three key functions: sensitivity, exposure, and adaptive capacity. Numbers of scholars have utilized this similar technique (Alam 2016; Alam et al. 2017; Sarker et al. 2019; Gerlitz et al. 2017; Orencio et al. 2013). The LVI method attentions on assessing the strong suit of present livelihood status, health, food, and water reserve features, as well as households’ ability to modify these approaches in reply to exposures that are related with climate change (Hahn et al. 2009). The weighted balanced and comprehensive strategy based on LVI and CVI was used, with local and traditional knowledge factored into the indicator selection. In our study, LVI comprises eight major components, comprising livelihood strategies, social network, socio-demographic profile, accessibility to water, food, and health, and the negative effects of climatic variability and natural disaster described further into 41 sub-components together ("Appendix A"). These components were built on the review of literature, local condition, and local expert views on each major component, and owing to the simplicity of the technique, further significant indicators are encompassed for this study. The outcomes are comparative and are determined on a scale of 0 (least vulnerable) to 1 (most vulnerable). To assess the least and most vulnerable groups, an intra- and inter-group cross-comparison is performed.

The LVI was calculated using the balanced weighted technique (Hahn et al. 2009; Alam et al. 2017; Pandey and Jha 2012). Each sub-component participates equally to the total index, even though each main component has a varying numeral of sub-component. Since each sub-component was calculated at a distinct scale, these were standardized as follows (Eq. 3)
where $S_d = \text{original sub-component for the study area}$ and $S_{\text{min}}$ and $S_{\text{max}}$ denote the minimum value and maximum value of each sub-component correspondingly. These minimum values and maximum values were used to develop the standardized index. The percentage of different components was determined using a scale ranging from 0 to 100. After collecting the sub-components values, the average of each sub-components was computed applying Eq. 4, which produces the major components value.

$$M_d = \frac{\sum_{i=1}^{n} \text{index}_{S_d}}{n}$$  \hspace{1cm} (4)$$

where $M_d$ = one of the major components for the study site, $\text{index}_{S_d}$ = sub-components, and $n$ = numbers of sub-components of each major component.

When each value of the eight major components for the study area was computed, they were then averaged by Eq. 5 to get the study area LVI.

$$LVI_d = \frac{\sum_{i=1}^{8} w_{Mi} M_{di}}{\sum_{i=1}^{8} w_{Mi}}$$  \hspace{1cm} (5)$$

which can also be expressed as-

$$LVI_d = \frac{w_{\text{SDP}} S_{\text{D}} + w_{\text{LS}} S_{\text{L}} + w_{\text{SN}} S_{\text{N}} + w_{\text{H}} S_{\text{H}} + w_{\text{F}} S_{\text{F}} + w_{\text{W}} S_{\text{W}} + w_{\text{ND}} S_{\text{ND}} + w_{\text{CV}} S_{\text{CV}}}{w_{\text{SDP}} + w_{\text{LS}} + w_{\text{SN}} + w_{\text{H}} + w_{\text{F}} + w_{\text{W}} + w_{\text{ND}} + w_{\text{CV}}}$$  \hspace{1cm} (6)$$

where $LVI_d$ = livelihood vulnerability of the study site that equals the eight major components weighted average. Each weight of the major components, $w_{mi}$, is obtained by the numbers of sub-components which constitute each major component. The weights were involved so that each sub-components participated equally in the overall LVI.

The exposure (Exp) index contained climate variability (CV) and natural disasters (ND) and was computed using Eq. 7.

$$\text{Exp} = \frac{W_{\text{exp1}} \text{ND} + W_{\text{exp2}} \text{CV}}{W_{\text{exp1}} + W_{\text{exp2}}}$$  \hspace{1cm} (7)$$

where $W_{\text{exp1}}$ and $W_{\text{exp2}}$ express the weight of natural disasters and climate vulnerability correspondingly.

The index of sensitivity (Sen) includes food (F), health (H), and water (W), and was calculated using Eq. 8.

$$\text{Sen} = \frac{W_{\text{sen1}} H + W_{\text{sen2}} F + W_{\text{sen3}} W}{W_{\text{exp1}} + W_{\text{exp2}} + W_{\text{exp3}}}$$  \hspace{1cm} (8)$$

where $W_{\text{exp1}}$, $W_{\text{exp2}}$ and $W_{\text{exp3}}$ were expressed the weights of three major components health, food, and water correspondingly.

The adaptive capacity (AdaCap) index was computed using Eq. 9.
Where $W_{ad1}$, $W_{ad2}$ and $W_{ad3}$ were expressed as the weights of three major components socio-demographic profile, livelihood strategies, and social networks correspondingly.

The index value of the IPCC three-dimension functions sensitivity, exposure, and adaptive capacity was applied to calculate the weighted average of the climate vulnerability index (CVI) as follows:

$$CVI = 1 - \left\{ \frac{N1Exp - N2Ada.cap}{(N1 + N2)} \right\} \ast \left\{ \frac{1}{Sen} \right\}$$  \(10\)

where $N_i$ = numbers of major components in the $i$th vulnerability dimension. The value of each dimension varied to a minimum of 0 and a maximum of 1.

2.6 IPCC Framework Approach

The IPCC framework combines the eight major components into three dimensions: sensitivity, exposure, and adaptive capacity. These three participating factors are integrated using Eq. 11.

$$LVI - IPCC_d = (Exp - Ada.cap) \ast Sen$$  \(11\)

where $LVI - IPCC_d$ = LVI for the community, $d$, denotes the IPCC vulnerability framework. LVI-IPCC index value ranged to $-1$ (least vulnerable) and the maximum to 1 (most vulnerable).

The selection of meaningful and robust parameters particular to regional communities is a key issue connected with vulnerability analysis (Adger 2006; Alam 2016; Alam et al. 2017; Etwire et al. 2013; Salvati and Carlucci 2014). However, this limitation is overcome by an exhaustive literature study, firsthand observations, and expert views to get representative and complete results. The adopted approach may be used to estimate and compare the susceptibility of other rural populations because of the method’s flexibility, which allows for adjustments in indicators based on the conditions of a particular state of an area, sector, or community.

3 Results and discussion

In this segment, the outcomes of LVI and CVI are summarized from the survey. The LVI outcome values are shown in Table 1.

Table 1 outlines the factors that contribute toward vulnerability for each region. The differences in LVI and CVI values between the study area show that the vulnerability of Char Jotindro-Narayan and Kulaghat char households differ overall and regarding the specific components and sub-components mentioned below.
Table 1  Indexed value of the major components and sub-components consist of livelihood vulnerability index (where HHs = households). Source: Field Survey, 2021

| Major components          | Indexed value of each component | Sub-components or indicators                                                                 | Indexed value of each sub-component (indicator) |
|---------------------------|---------------------------------|-----------------------------------------------------------------------------------------------|-----------------------------------------------|
|                           | Char Jotindro-Narayan | Kulaghat char |                                                                                               | Char Jotindro-Narayan | Kulaghat char |
| Socio-demographic profile | 0.289                          | 0.284          | Dependency ratio                                                                                 | 0.045                          | 0.041          |
|                           |                                 |                | % of HHs where the head of the HH has not attended school                                      | 0.53                          | 0.523          |
|                           |                                 |                | Average number of family members in the HHs                                                   | 0.292                          | 0.287          |
| Livelihood strategy       | 0.225                          | 0.327          | % of households dependent only on agriculture as a main income source                          | 0.265                          | 0.424          |
|                           |                                 |                | % of the HHs taking traditional control measures to reduce the adverse impacts?              | 0.273                          | 0.333          |
|                           |                                 |                | % of HHs have saving account                                                                  | 0.098                          | 0.129          |
|                           |                                 |                | % of HHs have rent out farming land                                                            | 0.136                          | 0.106          |
|                           |                                 |                | % of HHs who do not attempt homestead gardening                                                | 0.129                          | 0.227          |
|                           |                                 |                | % of HHs that has no farming approaches to survive with erosion                                | 0.553                          | 0.689          |
|                           |                                 |                | % of HHs that have no place for relocation if erosion or disaster occur                        | 0.098                          | 0.492          |
|                           |                                 |                | % of HHs who have burden of loan                                                              | 0.25                           | 0.22           |
| Social network            | 0.350                          | 0.315          | % of HHs who have not gone to their local government for help in the previous 12 months      | 0.75                           | 0.811          |
|                           |                                 |                | % of HHs received help from relatives, neighbors                                              | 0.553                          | 0.538          |
|                           |                                 |                | % of HH received government and organizational support                                         | 0.379                          | 0.311          |
|                           |                                 |                | % of household getting credit facilities                                                       | 0.371                          | 0.212          |
|                           |                                 |                | % of HHs involved in non-farm activities?                                                     | 0.386                          | 0.356          |
|                           |                                 |                | % of HHs involved in cooperative society or any organization?                                | 0.159                          | 0.189          |
|                           |                                 |                | % of HHs getting any training from government organizations?                                | 0.159                          | 0.068          |
|                           |                                 |                | % of HHs getting any training from a non-government organization?                           | 0.22                           | 0.182          |
|                           |                                 |                | % of HHs getting any information on new technology or varieties from agri. Extension officer? | 0.174                          | 0.174          |
| Major components   | Indexed value of each component | Sub-components or indicators                                                                 | Indexed value of each sub-component (indicator) |
|--------------------|---------------------------------|------------------------------------------------------------------------------------------------|-----------------------------------------------|
|                    | Char Jotindro-Narayan | Kulaghat char |                                                                                                   | Char Jotindro-Narayan | Kulaghat char |
| Health             | 0.315                          | 0.323         | % of HHs with experience any waterborne disease                                                      | 0.538                          | 0.394         |
|                    |                                 |               | % of HHs those family members suffering from chronic disease                                          | 0.182                          | 0.159         |
|                    |                                 |               | % of HHs who do not attend a local doctor through illness                                             | 0.038                          | 0.159         |
|                    |                                 |               | % of HHs receiving treatment in government hospitals                                                 | 0.697                          | 0.879         |
|                    |                                 |               | % of HHs in which a family member skipped work due to disease in the previous two weeks            | 0.174                          | 0.144         |
|                    |                                 |               | % of HHs having sanitary latrines                                                                  | 0.265                          | 0.205         |
| Food               | 0.588                          | 0.512         | Average number of months HHs work to find food                                                       | 0.745                          | 0.799         |
|                    |                                 |               | % of HHs who do not save crops                                                                      | 0.258                          | 0.326         |
|                    |                                 |               | % of HHs missing their farming land                                                                  | 0.879                          | 0.523         |
|                    |                                 |               | % of HHs facing food insecurity and malnutrition are increasing in the previous 10 years?          | 0.47                           | 0.402         |
| Water              | 0.020                          | 0.04          | % of HHs reporting water conflicts                                                                 | 0.023                          | 0.045         |
|                    |                                 |               | % of HHs using unsafe drinking water (pond, river, water hole, arsenic-contaminated water)         | 0.038                          | 0.045         |
|                    |                                 |               | % of HHs receiving water from a distant (more than 0.5 km) water source (tube well)                | 0                              | 0.03          |
| Natural disasters  | 0.781                          | 0.781         | % of households affected by floods and riverbank erosion during last 10 years?                      | 0.962                          | 0.955         |
|                    |                                 |               | % of agricultural land affected by erosion                                                          | 0.955                          | 0.856         |
|                    |                                 |               | Average number of other natural calamities during previous 10 years                                  | 0.628                          | 0.716         |
|                    |                                 |               | % of HHs faced movement in previous 10 years                                                        | 0.811                          | 0.871         |
|                    |                                 |               | % of HHs loss livestock due to natural disaster during previous 10 years?                           | 0.553                          | 0.508         |
### Table 1 (continued)

| Major components | Indexed value of each component | Sub-components or indicators | Indexed value of each sub-component (indicator) |
|------------------|--------------------------------|------------------------------|-----------------------------------------------|
|                  | Char Jotindro-Narayan | Kulaghat char | Char Jotindro-Narayan | Kulaghat char |
| Climatic variability | 0.671 | 0.717 | Facing progressively increasing temperature from previous 10 years | 0.932 | 0.955 |
|                    |                  |               | Facing gradually decreasing rainfall from previous 10 years | 0.689 | 0.871 |
|                    |                  |               | Facing progressively growing riverbank erosion from previous 10 year | 0.394 | 0.326 |

Overall livelihood vulnerability index:
Char Jotindro-Narayan: 0.391, Kulaghat char: 0.402
3.1 Livelihood vulnerability index

The value of LVI in Kulaghat char (0.402) was more than Char Jotindro-Narayan under Lalmonirhat Sadar and Phulbari Upazila, respectively (Table 1). These LVI values denote that the households of Kulaghat char and Char Jotindro-Narayan had a distinct level of vulnerability. Kulaghat char households were faced with more problems than Char Jotindro-Narayan, owing to lack of accessibility to financial resources, and health care and educational opportunities, as well as intense exposure to climatic vulnerability (Table 1). The study shows that the two household groups had similar socio-demographic profile, natural disasters, but lot of differences in several sub-component such as social network, livelihood strategies, food, and climatic variability. The dependency ratio of household head is higher in Char Jotindro-Narayan than in Kulaghat char. The value of livelihoods strategy is lower in Char Jotindro-Narayan (0.22525) while higher in Kulaghat char (0.3275) (Table 1). The social network indexing value varied slightly among the study areas. The social network and food index values were higher in Char Jotindro-Narayan with the value of (0.350111) and (0.588) correspondingly as compared to (0.588) and (0.512542) in Kulaghat char households; these findings are explained more in detail below.

The outcomes of the major components are displayed in the spider diagram (Fig. 4). The climatic variability value in Char Jotindro-Narayan is lower with the value of (0.671), while in Kulaghat char, it was (0.717). The value of natural disasters in both char communities was similar because of their low-lying geography and extreme vulnerability for flood disasters with enormous riverbank erosion.

![Spider diagram of major components of LVI for both study areas. Source: Field survey, 2021](image-url)
The outcomes of climate vulnerability index (CVI) for the study area are presented in Table 2. The CVI values denote there was almost no distinction between the two char communities, but the values in Kulaghat char (0.639) are slightly higher than Char Jotindro-Narayan (0.633).

Figure 5 reveals the vulnerability triangle; this exhibits the score participating elements for the sensitivity, exposure, and adaptive capacity. The result shows that the households of Char Jotindro-Narayan have higher sensitivity in the basis of access to food, health, and water with a value of (0.331), while it shows lower in Kulaghat char with the value of (0.316). The study reveals that the char land communities of Kulaghat char are slightly exposed than Char Jotindro-Narayan. However, both study regions are equally affected by flood and riverbank erosion per year and are most vulnerable.

**Table 2** Indexed dimensions of climate vulnerability of Char Jotindro-Narayan and Kulaghat char. Source: Field Survey, 2021

| Contributing elements to vulnerability                                      | Char Jotindro-Narayan | Kulaghat char |
|---------------------------------------------------------------------------|-----------------------|---------------|
| Adaptive capacity (socio-demographic, livelihood strategies and social network) | 0.291                 | 0.315         |
| Sensitivity (health, food, water)                                         | 0.331                 | 0.316         |
| Exposure (natural disasters and climatic variability)                     | 0.74                  | 0.757         |
| Climate vulnerability index (CVI)                                         | 0.633                 | 0.639         |
| LVI-IPCC                                                                  | 0.148                 | 0.139         |

**Fig. 5** The vulnerability triangle diagram of the dimensions of the climate vulnerability index. Source: Field Survey, 2021

### 3.2 Climate vulnerability index

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LVI-IPCC vulnerability index outcomes represent that the Char Jotindro-Narayan households are most vulnerable than the char Kulaghat households with the index value of (0.148) and (0.139) correspondingly (Table 2).

### 3.3 Livelihood vulnerability

The outcomes show that the livelihood vulnerability condition in Kulaghat char was higher than the Char Jotindro-Narayan households. The most significant contributing components values of livelihood strategy (0.327), health (0.323), water (0.04), and climate variability (0.717 were higher in Kulaghat char than Char Jotindro-Narayan, which were 0.225; 0.315; 0.020, and 0.671, respectively (Table 1). The livelihood strategy component contribution in Kulaghat char represents that these community households mainly depend on farming for their main earnings and food safety. Riverbank erosion and floods regularly damage their agricultural land, crops, etc. where households have no farming strategies to cope with these situations, and the few households that practice homestead gardening to fight against high natural hazards and climatic variability. Climatic disaster, such as drought, flood, riverbank erosion, and cyclone, damages the livelihoods of char lands communities, and the agriculture-based livelihoods can leave households in a more vulnerable position if they lack the option to diversify their livelihood plans (Alam et al. 2017; Alam 2016; Mirza 2003; Islam et al. 2021). In the Kulaghat char region, the water component had an even greater impact on vulnerability. In this region, households used unsafe drinking water from the pond, river, water hole/tube wells, and majority of these have been reported to be infected by arsenic. In conversations, it was noticeable that households were conscious of the hazards of imbibing arsenic-contaminated water, and then alternatives are frequently inaccessible; water conflict is also a problem among communities, with disputes frequently arising over water accessibility and property rights, such as ownership. In Kulaghat char, majority of the households are affected by different health-related issues like communicable diseases like tuberculosis and diarrhea. People in rural locations drive a greater distance to attend health-care facilities, and the availability of veterinary competence is also inadequate due to poor communication systems. The findings revealed that the number of waterborne diseases, such as cholera, diarrhea, dysentery, hepatitis A, and chronically ill people in Char Jotindro-Narayan was higher than in the Kulaghat char. These affected people are regularly denied normal government care owing to limited accessibility. The study found that the Kulaghat char household’s perceived temperature and rainfall fluctuation rates over the last 10 years are higher than the Char Jotindro-Narayan.

The results show that both char land households are vulnerable, but Char Jotindro-Narayan households are more vulnerable than Kulaghat char due to its residents living far away from the mainland. This is most likely owing to services given by government and non-governmental groups, improved social networks and communication, educational amenities, and comfortable relocation through natural catastrophes (Alam et al. 2017; Sarker et al. 2019; Mukta et al. 2022). Char Jotindro-Narayan households generally have a poorer range of education and a greater prevalence of malnutrition.
Traditional views (especially surrounding local remedies for health difficulties) and a lack of education generate community obstacles that influence family vulnerability and adaptive capability (Alam et al. 2016; Jones and Boyd 2011; Tasnuva et al. 2021).

Riverbank erosion is a general problem in char regions, and these study locations experience it frequently. The degree of riverbank erosion within Char Jotindro-Narayan is greater than in Kulaghat char. The overall LVI and CVI index had high index values in Kulaghat char. The Char Jotindro-Narayan households are mainly struggling more than Kulaghat char households with natural disasters, social networking, and food security due to the proximity of the river Dharla. Similar outcomes are obtained in a few research (Alam 2016; Sarker et al. 2019). The CVI (Table 2) shows vulnerability to climate-driven hazards by providing index values of sensitivity, adaptive capacity, and exposure to climate change. The results in Table 2 show that by IPCC-LVI index, Char Jotindro-Narayan is the most vulnerable area with less adaptive capability than households of Kulaghat char. Char Jotindro-Narayan households have lower income sources, a higher reliance on agriculture, a higher dependence ratio, and a better education level.

3.4 Policy implications and lesion learning

A context-specific intervention program for char communities is required. To promote societal resilience, reduce the sensitivity of habitat conditions, and increase individual stability to solve livelihood issues, particularly for female-headed households. The participation of different GO and NGO safety net programs is insufficient in some areas; it should be greatly enlarged. Moreover, on a long-term basis, the development of a communication network, transportation system, basic service accessibility, and market facilities for other livelihood plans is also crucial. Access to financing for poor farmers should be promoted to help improve their access to resources and technology, which is critical for their adaptability. Although the char households’ livelihood depends mainly on agriculture, agricultural institutions should be encouraged to generate new crop varieties and promote technology-transfer mechanisms. This would improve the resilience of vulnerable households in the char land communities, Bangladesh.

The intensity of livelihood vulnerability of a community depends mainly on their assets and natural resources. The context-specific views represent the vulnerability intensity on a distinct scale, which also varies by the terms of geographic location, perceptual responses, and temporal/seasonal stress or critical issues with community livelihoods capitals. In a devolving country like Bangladesh, climate change effects, including floods and riverbank erosion, especially affect the (bar land) char land communities, which damages natural resources and their saving that resulting in their being more vulnerable. A large number of farmland and crops are damaged due to floods and riverbank erosion, reducing the financial growth of the community. The study reveals that, peoples in the community who are aware and adopt different measures to stand against the floods, riverbank erosion, critical issues or other stresses, are the least vulnerable. Therefore, to decrease the sensitivity of livelihood vulnerability in such char communities’ policymakers could amplify these above offers of training and additional services, especially for basic needs, information, and communication technologies.
4 Conclusion

This study was carried out to investigate the level of vulnerability of communities to climatic hazards in char land (bar land) of the Dharla River, situated at Phulbari Upazila in Kurigram and Lalmonirhat Sadar Upazila in the Lalmonirhat district of northern Bangladesh. Using the context-specific livelihood vulnerability index (LVI) approach and the IPCC-vulnerability index (IPCC-LVI), we quantified the vulnerability of livelihoods of the communities. The outcomes show that the study regions are the most vulnerable to climate change and natural disasters, where sensitivity and exposure levels exceed adaptive capacity. The char areas are commonly impacted by environmental hazards, including floods, riverbank erosion, heatwaves, and drought, which greatly reduce their livelihood assets. The study reveals that, the most important livelihood vulnerability driving factors for the Jotindro-Narayan and Kulaghat chars are climate variability (0.617; 0.717), natural disasters (0.781; 0.781), and food (0.588; 0.512). The social network, water, and health facilities of the char dwellers are very low, that makes them more vulnerable to any hazards. The LVI and CVI outcomes represent that both char communities are vulnerable to natural disasters and climate variability. However, disparities in sub-component values among char communities suggest that climate change vulnerability varies even within units of individuals undertaking the same livelihood activities. Therefore, particular care is necessary for these vulnerable char land communities. The study indicates that a long-term sustainable development strategy that includes road construction, tree plantation, employment opportunities, and capacity building will be beneficial in building resilience among households in such vulnerable regions in Bangladesh.

Appendix 1

See Table 3.
| Major components       | Sub-components or indicator                                                                 | Units    | Score/values                                      | Sources                                      |
|------------------------|-----------------------------------------------------------------------------------------------|----------|---------------------------------------------------|----------------------------------------------|
| Adaptive capacity      | Dependency ratio                                                                           | Ratio    | If 1:3, then score = 1, if more = 0               | Alam (2017)                                  |
|                        | Percent of HHs were the head of the HH has not joined school                                 | %        | Yes = 1, No = 0                                   | Hahn et al. (2009), and Alam (2017)          |
|                        | Average number of family members in the HHs                                                  | count    |                                                   | Hahn et al. (2009) and Alam (2017)           |
| Livelihood strategy    | Percent of households dependent only on agriculture as a main income source                  | %        | Yes = 1, No = 0                                   | Alam et al. (2017)                           |
|                        | Percent of the HHs taking traditional control measures to reduce the adverse impacts?        | %        | Yes = 1, No = 0                                   | Developed for this study                     |
|                        | Percent of HHs have saving account                                                           | %        | Yes = 1, No = 0                                   | Developed for this study                     |
|                        | Percent of HHs have rent out farming land                                                     | %        | Yes = 1, No = 0                                   | Developed for this study                     |
|                        | Percent of HHs who do not attempt homestead gardening                                         | %        | Yes = 1, No = 0                                   | Alam et al. (2017)                           |
|                        | Percent of HHs that has no farming approaches to survive with erosion                         | %        | Yes = 1, No = 0                                   |                                               |
|                        | Percent of HHs that have no place for relocation if erosion or disaster occur                 | %        | Yes = 1, No = 0                                   |                                               |
|                        | Percent of HHs who have burden of loan                                                        | %        | Yes = 1, No = 0                                   |                                               |
| Social network         | Percent of HHs who have not gone to their local government for help in the previous 12 months | %        | Yes = 1, No = 0                                   | Jakariya et al. (2020) and Alam (2017)       |
|                        | Percent of HHs received help from relatives, neighbors                                         | %        | Yes = 1, No = 0                                   |                                               |
|                        | Percent of HH received government and organizational support                                  | %        | Yes = 1, No = 0                                   | Alam (2017)                                  |
| Major components                                    | Sub-components or indicator                                           | Units | Score/values | Sources                                      |
|----------------------------------------------------|-----------------------------------------------------------------------|-------|--------------|----------------------------------------------|
|                                                    | Percent of household getting credit facilities                       | %     | Yes = 1, No = 0 |                                              |
|                                                    | Percent of HHs involved in non-farm activities?                       | %     | Yes = 1, No = 0 | Alam (2017) and Panthi et al. (2016)         |
|                                                    | Percent of HHs involved in cooperative society or any organization?  | %     | Yes = 1, No = 0 | Alam et al. (2017) and Hahn et al. (2009)    |
|                                                    | Percent of HHs getting any training from government organizations?   | %     | Yes = 1, No = 0 | Developed for this study                     |
|                                                    | Percent of HHs getting any training from a non-government organization? | %     | Yes = 1, No = 0 | Developed for this study                     |
|                                                    | Percent of HHs getting any information on new technology or varieties from agri. Extension officer? | %     | Yes = 1, No = 0 | Alam et al. (2017)                           |
| Sensitivity                                        | Health                                                               |       |              |                                              |
|                                                    | Percent of HHs with experience any waterborne disease                | %     | Developed for this study | Alma et al. (2017) and Hahn et al. (2009) and Oo (2018) |
|                                                    | Percent of HHs those family members suffering from chronic disease   | %     | Yes = 1, No = 0 | Alam (2017), Ford (2014) and Fraser (2011)   |
|                                                    | Percent of HHs who do not attend a local doctor through illness      | %     | Yes = 1, No = 0 |                                              |
|                                                    | Percent of HHs receiving treatment in government hospitals           | %     | Yes = 1, No = 0 |                                              |
|                                                    | Percent of HHs in which a family member skipped work due to disease in the previous two weeks | %     | Yes = 1, No = 0 | Alam (2017) and Ahsan (2014)                 |
|                                                    | Percent of HHs having sanitary latrines                              | %     | Yes = 1, No = 0 | Alam et al. (2017), Gbetibouo (2010) and Preston (2011) |
| Major components | Sub-components or indicator | Units | Score/values | Sources |
|------------------|-----------------------------|-------|--------------|---------|
| **Food**         | Average number of months HHs work to find food | Count |              | Alam (2017) and Hahn et al. (2009) |
|                  | Percent of HHs who do not save crops | %     | Yes = 1, No = 0 | Hahn et al. (2009) |
|                  | Percent of HHs missing their farming land | %     | Yes = 1, No = 0 | Alam (2017) |
|                  | Percent of HHs facing food insecurity and malnutrition are increasing in the previous 10 years? | %     | Yes = 1, No = 0 | Developed for the purposes of this study |
| **Water**        | Percent of HHs reporting water conflicts | %     | Yes = 1, No = 0 | Sujakhu (2019) and Alam (2017) |
|                  | Percent of HHs using unsafe drinking water (pond, river, water hole, arsenic-contaminated water) | %     | Yes = 1, No = 0 | Alam et al. (2017) |
|                  | Percent of HHs receiving water from a distant (more than 0.5 km) water source (tube well) | %     | Yes = 1, No = 0 | Alam 2016; Jacobson, 2018 |
| **Exposure**     | Natural disasters | %     | Yes = 1, No = 0 |              |
|                  | Percent of households affected by floods and riverbank erosion during last 10 years? | %     | Yes = 1, No = 0 |              |
|                  | Percent of agricultural land affected by erosion | Count | Yes = 1, No = 0 | Alam (2016) |
|                  | Average number of other natural calamities during previous 10 years | %     |              |              |
|                  | Percent of HHs faced movement in previous 10 years | %     | Yes = 1, No = 0 | Alam (2017) |
|                  | Percent of HHs loss livestock due to natural disaster during previous 10 years? | %     | Yes = 1, No = 0 | Alam (2017) |
| Major components          | Sub-components or indicator                                      | Units | Score/values         | Sources                                      |
|--------------------------|------------------------------------------------------------------|-------|----------------------|----------------------------------------------|
| Climatic variability     | Facing progressively increasing temperature from previous 10 years | %     | Yes = 1, No = 0      | Hahn et al. (2009) and Alam et al. (2017)    |
|                          | Facing gradually decreasing rainfall from previous 10 years       | %     | Yes = 1, No = 0      | Developed for the purposes of this study     |
|                          | Facing progressively growing river-bank erosion from previous 10 year | %     | Yes = 1, No = 0      | Alam (2017) and Alam et al. (2017)           |
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Declarations

Conflict of interest  None.

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