Vulnerability assessment based on household views from the Dammar Char in Southeastern Bangladesh

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Abstract
Assessing vulnerability is vital for developing new strategies and improving the existing ones to fulfill contemporary demands toward achieving a disaster-resilient society. Dammar Char is situated in the southeastern (SE) coastal region of Bangladesh that has experienced frequent coastal hazards and disasters throughout the year. The present study has constructed a vulnerability index utilizing the quantitative and qualitative data based on household surveys to evaluate the vulnerability of the people and community of Dammar Char. Data were collected from 180 respondents during November–December 2018. The results demonstrate that, on average, the people living in the studied area have a high vulnerability (value of the vulnerability index 0.7015) to coastal hazards and disasters. The vulnerability level differs from individual to individual based on their gender, educational status, financial capacity, structural strength of houses, perception of the respective hazards and disasters, etc. Females have experienced more vulnerability than their adult male counterparts. The natural vulnerability was higher than socioeconomic and physical vulnerability due to the increase in unpredictable extreme climate-induced coastal events. To combat the adverse impacts of coastal hazards and disasters, the local Dammar Char inhabitants have adopted several adaptation measures. The adapted measures are homestead gardening, working in seasonal day labor, fish drying, rearing sheep, and ducks, constructing plinths for elevating the floor of the house, extensive banana cultivation, and storage of dry foods to reduce their vulnerability.

Keywords Climate change · Disaster · Vulnerability · Assessment · Coastal Bangladesh
1 Introduction

Climate change is the most challenging threat to world communities, evidenced by many devastating extreme climatic effects and their associated hazards and disasters. An analysis of the impact of climate extreme events and related socioeconomic data for the period 2000–2019 placed Bangladesh as the seventh most at risk country in the world (Eckstein et al. 2021). About 32% of this country’s area (47,201 km²) is found within the coastal region surrounded by the Bay of Bengal (Ahmad 2019). Of the 64 districts, 19 districts have been affected by several climate-induced coastal hazards and disasters such as cyclones, coastal erosion, storm surges, and salinity intrusion over the years, causing massive economic, social, and physical losses (Alam et al. 2018; Faisal et al. 2021; Mallick et al. 2022). Suitable and sustainable management strategies need to be implemented in these vulnerable areas to ensure that each society has the capacity to withstand these hazards and disasters with its resources (Warner and Van der Geest 2013). However, management capacity for adapting and reducing the risks of further hazards and disasters varies from one district to another district, one area to another area. The difference in management capacity relies on indicators such as socioeconomic status, structural strength, and intellectual ability. (Salam et al. 2021a). To ensure long-term sustainable coastal management against the devastating effects of hazards and disasters, an extensive study at the lower-level administrative unit of the coastal region is needed to assess the vulnerability. Vulnerability is a complex element of disaster risk reduction (DRR) strategy as well as climate change adaptation (CCA), reflecting the degree to which the environment tends to be harshly impacted by natural hazards (IPCC 2014; Rana and Routray 2018).

Vulnerability is an important element of disaster risk. Without the evaluation of vulnerability, it is impossible to get the correct scenarios of any place. Besides, the study of vulnerability assists the authorities to know the exact condition of the community and help them implement necessary strategies for reducing vulnerability which in turn lessens the level of overall disaster risk of the community. Several theoretical frameworks, conceptual models, and assessment techniques exist to conduct vulnerability assessments (Adger 2006; Cutter et al. 2000; Füssel 2007). Despite their differences, several common elements can be identified: (1) investigating vulnerability from a socioecological perspective; (2) understanding vulnerability from a locational perspective; (3) the cognition of vulnerability as a right-based approach (Sarewitz et al. 2003); and (4) the importance of vulnerability assessments to identify hazard zones (Brooks et al. 2005; Cutter et al. 2010; O’Brien et al. 2004). Some researchers have tried combining the factors that contribute to vulnerability. The most familiar conceptual model of vulnerability to hazards includes (1) pressure and release model by Wisner et al. (2004); (2) vulnerability/sustainability framework by Turner et al. (2003); and (3) hazards-of-place model of vulnerability (Cutter 1996). Most of the conceptual models and vulnerability assessment frameworks have emphasized assessing vulnerability at local unit level rather than macro- and meso-levels (Cutter 1996; Cutter et al. 2008; Dolan and Walker 2006). As such, for any given a targeted vulnerability assessment is crucial for determining the specific scenarios that would eventually assist the planners and stakeholders in planning correctly. The nature of vulnerability differs between closely located communities (Sowman and Raemaekers 2018).

Dammar Char is situated in the southeastern (SE) region of Bangladesh, which has frequently been affected by prevalent coastal hazards and disasters in Bangladesh. It is of paramount interest to assess the vulnerability scenarios of the people of Dammar Char to implement the timely and correct coastal management strategies for securing their lives,
livelihoods, and wealth from the destructive effects of extreme coastal hazard events. Several factors influence the level of vulnerability assessment perception such as gender, educational status, livelihood options, income, perception of the calamities, intensity and magnitude of the hazards, degree of economic and structural losses, availability of resources, etc. (Rana and Routray 2018; Sattar and Cheung 2019). Previous studies have assessed the vulnerability considering the whole coastal region or most of it using satellite data (Ahmed et al. 2021; Hoque et al. 2021). Vulnerability assessment using the data collected directly from the stakeholders provides more practical perspective of the respective area. Also, taking measures for tackling the adverse climatic events based on the results could bring more positive feedback. Some studies have also been conducted in the coastal region of Satkhira and Khulna (Hossain and Paul 2017; Nazir Hossain 2015) and Patuakhali districts (Saroor and Routray 2010) based on questionnaire surveys. Sattar and Cheung (2019) have appraised risk perception considering the views of primary stakeholders and the socio-economic status of Patuakhali, Satkhira, and Khulna districts situated in the southwestern region of Bangladesh. Tasnuva et al. (2021) have evaluated the social vulnerability, while Rakib et al. (2019) have investigated vulnerability to coastal hazards in the southwestern region of Bangladesh. To manage local-level vulnerability, it is essential to assess vulnerability at the local scale instead of constructing a generalized idea by considering an extended area. By searching the current literature in the discipline, it is to confirm that there are still scope to conduct vulnerability assessment at the local scale to coastal hazards and disasters. Thus, the present study is intended to fill this research gap using household survey data. Therefore, the principal aim of this study is to assess the overall vulnerability at the household level of the Dammar Char in the Noakhali districts of the SE region of Bangladesh to coastal hazards. More specifically, among four vulnerability categories (natural, financial, physical, and overall), the present study identified the most severe form of vulnerability that Dammar Char community experienced. Moreover, determining the educational status and gender-based differences in vulnerability is assessed. The outcome of this study will provide insights for disaster planners and policymakers to identify the class of the society which needs more attention during planning.

2 Material and methods

2.1 Study area

The district of Noakhali is the home to 3,127,393 people (BBS 2020), situated in the SE region of Bangladesh. This district is bounded by Cumilla, Feni, and Chattogram; Bhola and Lakhsmipur districts on its north, east, and west, respectively. The Bay of Bengal confines the southern part of this district. Noakhali extends from 22°07′ to 23°08′ N latitude and 90°53′ to 91°27′ E longitude, occupying an area of 3,685.87 km² (BBS 2017). Two main rivers flow over this district, namely the Meghna and Bamni. Average rainfall, maximum temperature, and minimum temperature are 3302 mm, 34.3 °C, and 14.4 °C, respectively (BBS, 2017). This district has been facing the effects of coastal flooding and erosion, river erosion, salinity intrusion, cyclones, and its associated storm surges for the long past. This study has selected Hatiya Upazila, from Noakhali districts as this Upazila has been facing all the above-mentioned hazards and disasters around the year (Fig. 1). From this Upazila, Dammar Char, an area constantly affected by severe flooding, erosion, and salinity, was selected to conduct household-level surveys. Nijum Dwip community was selected
from Hatiya Upazila. Mouza is the lowest administrative unit in Bangladesh. For the present study, Mouza is considered for collecting more precise data. Data were collected from the Sagar Tilla (Dammar Char) Mouza of the Nijum Dwip community.

2.2 Sample size, questionnaire design, and data collection

Field visits were executed in the study area to collect basic and underlying vulnerability factors. The total population of the Nijum Dwip union and Dammar Char is 20,022 and 2,367, respectively (BBS 2017). The formula proposed by Cochran (1977) was used to calculate the sample size. According to Cochran’s formula, the calculated sample size \( p < 0.05 \) and error value at \( \pm 7\% \) was 182. The present study used a sample size of 180 (male 134 and female 46) for Dammar Char. In October 2018, a pretesting survey was held for getting information about the rationality and appropriateness of the questions included in the structured
questionnaire. After the pretesting survey, all the irrelevant questions were excluded from the structured questionnaire and finalized. Both male and female household heads were considered for collecting data. The household heads (respondents) were randomly selected. Face-to-face interviews were utilized for collecting data—between November and December 2018. At first, the survey data collectors informed respondents about the purpose of the survey. If any respondent declined to provide the required information for this study, then the surveyors proceeded to the next one. The data found from close-ended questionnaire was then coded and interpreted by using Statistical Package for Social Sciences (SPSS v.23). This study has verified the outcomes, revealed by statistical analysis, and the qualitative data presented in the results and discussion section.

2.3 Indicators and weights

After an extensive review of the existing literature, 16 indicators under three classes of vulnerability were chosen to assess the study area’s vulnerability. The three classes are (i) natural, (ii) socioeconomic, and (iii) physical. The justification and details of the selected indicators are presented in Table 1. Range values (0 to 1) are used in assigning the weights of the indicators. Two classes are assigned by 1 and 0; 1, 0.67, 0.33, and 0.00 are allocated for four classes; 0.20, 0.40, 0.60, 0.80, and 1.00 are allocated for five classes. Consequently, the values of vulnerability level exist on the scale from 0 and 1. The used weights are allocated based on the existing literature conducted by scholars from home and abroad (Khan 2012; Rakib et al. 2019; Salam et al. 2021b).

2.4 Calculation of vulnerability

The present study has used the weighted mean method for developing the vulnerability index. This method is convenient as it is easy to use for showing relation with the appropriate participants and improves transparency (Sorg et al. 2018). Considering the respective weights of all the indicators, the original datasets have been utilized to make the composite index by using Eq. (1), as modelled by scholars who have undertaken similar works (Abbas and Routray, 2014; Sattar and Cheung, 2019).

\[
CI = \frac{W_1 + W_2 + W_3 + \ldots + W_n}{n} = \sum_{i=1}^{n} \frac{W_i}{n}
\]

where

\[CI\] indicates the composite index,

\[W_1\] to \[W_n\] are the respective weights allocated to the respective indicators, and \[n\] denotes the total number of indicators.

The vulnerability index was developed based on Eq. 1. The original statistical form of the vulnerability index is:

\[
\text{Vulnerability Index} = \sum_{i=1}^{n} \frac{W_i}{n}
\]
| Sl. no. | Indicators                        | Classes | Weights | Explanations                                                                 | Source                          |
|--------|----------------------------------|---------|---------|-----------------------------------------------------------------------------|---------------------------------|
| 1      | Perception of the coastal natural calamities | Yes     | 0       | Respondents who have a good knowledge of the coastal calamities will be less impacted as they know about avoiding damage and losses | Salam et al. (2021b)            |
|        |                                  | No      | 1       |                                                                              |                                 |
| 2      | The intensity of coastal natural calamities | Very low | 0.20    | Higher intensity means much severity and resultant damage                     | Saha (2015)                     |
|        |                                  | Low     | 0.40    |                                                                              |                                 |
|        |                                  | Moderate| 0.60    |                                                                              |                                 |
|        |                                  | High    | 0.80    |                                                                              |                                 |
|        |                                  | Very High| 1.00    |                                                                              |                                 |
| 3      | The magnitude of the calamities   | Very low| 0.20    | The magnitude of the onset the amount of loss and damage will increase        | Hufschmidt (2011)               |
|        |                                  | Low     | 0.40    |                                                                              |                                 |
|        |                                  | Moderate| 0.60    |                                                                              |                                 |
|        |                                  | High    | 0.80    |                                                                              |                                 |
|        |                                  | Very High| 1.00    |                                                                              |                                 |
| 4      | Increase the calamities related illness | Yes     | 1.00    | Different hazards and disasters assist in the outbreak of some mental, food-borne, and waterborne illness | Paul et al. (2011)              |
|        |                                  | No      | 0.00    |                                                                              |                                 |
| 5      | Loss of livestock                 | Very low| 0.20    | The death of livestock resources makes a family less capable of fighting hazards and disasters | Jamshed et al. (2017)           |
|        |                                  | Low     | 0.40    |                                                                              |                                 |
|        |                                  | Moderate| 0.60    |                                                                              |                                 |
|        |                                  | High    | 0.80    |                                                                              |                                 |
|        |                                  | Very High| 1.00    |                                                                              |                                 |
| 6      | Loss of soil fertility            | Very low| 0.20    | Coastal hazards increase the susceptibility to the loss of soil fertility which leads to the decrease in crops production | Rakib et al. (2019)            |
|        |                                  | Low     | 0.40    |                                                                              |                                 |
|        |                                  | Moderate| 0.60    |                                                                              |                                 |
|        |                                  | High    | 0.80    |                                                                              |                                 |
|        |                                  | Very High| 1.00    |                                                                              |                                 |
| 7      | Loss of crop production          | Very low| 0.20    | Loss of crop production leads to unstable economic conditions, increasing the vulnerability to hazard occurrence | Sattar and Cheung (2019)        |
|        |                                  | Low     | 0.40    |                                                                              |                                 |
|        |                                  | Moderate| 0.60    |                                                                              |                                 |
|        |                                  | High    | 0.80    |                                                                              |                                 |
|        |                                  | Very High| 1.00    |                                                                              |                                 |
| Sl. no. | Indicators               | Classes          | Weights | Explanations                                                                 | Source                          |
|--------|--------------------------|------------------|---------|-----------------------------------------------------------------------------|---------------------------------|
| 8      | Loss of agricultural land| Very low         | 0.20    | A higher rate of loss of agricultural land increases the susceptibility      | Sattar and Cheung (2019)        |
|        |                           | Low              | 0.40    | of hazard occurrence                                                        |                                 |
|        |                           | Moderate         | 0.60    |                                                                             |                                 |
|        |                           | High             | 0.80    |                                                                             |                                 |
|        |                           | Very High        | 1.00    |                                                                             |                                 |
| 9      | Occupation of household’s head | Unemployed       | 1       | Unemployed and lower-income generating people have less capability to fight | Cutter et al. (2003)            |
|        |                           | Daily laborer    | 0.80    | against hazards                                                            |                                 |
|        |                           | Farming          | 0.60    |                                                                             |                                 |
|        |                           | Business         | 0.40    |                                                                             |                                 |
|        |                           | Govt./other services | 0.20   |                                                                             |                                 |
| 10     | Average monthly household’s income (Taka) | < 5000       | 1       | Lower-income households have less capability to take appropriate and timely | Khan (2012)                     |
|        |                           | 5000–10,000      | 0.80    | actions for combating the impacts of hazards                                |                                 |
|        |                           | 10,000–15,000    | 0.60    |                                                                             |                                 |
|        |                           | 15,000–20,000    | 0.40    |                                                                             |                                 |
|        |                           | > 20,000         | 0.20    |                                                                             |                                 |
| 11     | Food shortages           | Very Low         | 0.20    | Food availability decreases the risk of vulnerability, and food shortage    | Kulatunga et al. (2014)         |
|        |                           | Low              | 0.40    | increases the risk of vulnerability                                         |                                 |
|        |                           | Moderate         | 0.60    |                                                                             |                                 |
|        |                           | High             | 0.80    |                                                                             |                                 |
|        |                           | Very High        | 1.00    |                                                                             |                                 |
| 12     | Increase the price of the land | Yes              | 1.00    | Coastal flooding and erosion decrease the cultivable land and the land for | Fedeski and Gwilliam (2007)     |
|        |                           | No               | 0.00    | human habitat, which eventually increases the land price in the disaster-prone |                                 |
|        |                           |                  |         | areas                                                                       |                                 |
| 13     | household pattern        | Jupri            | 1       | Kucha housing type is more vulnerable than pucca in terms of any disaster   | Fedeski and Gwilliam (2007)     |
|        |                           | Kucha            | 0.67    |                                                                             |                                 |
|        |                           | Semi-pacca       | 0.33    |                                                                             |                                 |
|        |                           | Pucca            | 0.00    |                                                                             |                                 |
| Sl. no. | Indicators                      | Classes        | Weights | Explanations                                                      | Source                      |
|--------|--------------------------------|----------------|---------|------------------------------------------------------------------|-----------------------------|
| 14     | Sanitation facilities          | Very Low       | 0.20    | Improved sanitation facilities decrease the risk of vulnerability | Kulatunga et al. (2014)    |
|        |                                | Low            | 0.40    |                                                                  |                             |
|        |                                | Moderate       | 0.60    |                                                                  |                             |
|        |                                | High           | 0.80    |                                                                  |                             |
|        |                                | Very High      | 1.00    |                                                                  |                             |
| 15     | Availability of pure drinking water | Yes            | 0.00    | Availability of pure drinking water decreases vulnerability    | Cutter et al. (2010)        |
|        |                                | No             | 1.00    | as the people do not need to pay for it                         |                             |
| 16     | Household’s received a warning | Yes            | 0.00    | Early warning opportunities undoubtedly increase the capacity of a locality | Gain et al. (2015)         |
|        |                                | No             | 1.00    |                                                                  |                             |
2.5 Adaptive strategies

The present study has articulated the most practiced adaptive strategies by the Char inhabitants to reduce their losses. The feedback coming from the survey is processed by using statistics to get rank-based adaptive strategies. As well, this articulation assists to know the level of their capacity and vulnerability.

2.6 Data homogeneity

The collected data were tested to assess the validity for further analysis using SPSS. One-way ANOVA test revealed that all the collected data were significant at 95% ($p < 0.05$) further analysis.

3 Results and discussion

3.1 Socioeconomic description of the respondents

The socioeconomic status of the respondents is presented in Table 2. The majority of participants were over 30 years old, with only 10 participants graduating from a university level education. Fifty-one participants had no education and were illiterate randomly 10 participants were unemployed.

Agriculture, fishing, and business are the most common occupations of the respondents. Twelve respondents work for the government and other organizations commensurate with the educational status. Monthly income varies from person to person. The highest numbers of the respondents get their monthly wages at the range from 5000 to 8000 Taka (currency unit in Bangladesh). Only two participants earn more than 15,000 Taka, which depicts the financial picture of the households of the study area ($1 US = 85 Taka$). The majority of the respondents live beside the coast, and the rest live next to the cultivable land. There are four classes of owners of the houses found. Of the 180 households, only 50 people own their own home. The majority of participants live in kutcha dwellings houses, making them susceptible to vulnerability. Five different natural disasters are frequent in the study area: cyclones, storm surges, tidal flooding, coastal erosions, and salinity intrusions.

3.2 Vulnerability assessment of the study area

Figure 2 demonstrates the degree of overall vulnerability of the respondents of the study area. The level of vulnerability varies from person to person. The reasons for the difference in individual vulnerability and risk are gender, educational attainment, occupation, and income (Salam et al. 2021a; Sattar and Cheung 2019; Younus and Kabir 2018). Vulnerability decreases with the increase of participants socioeconomic status (Salam et al. 2021a). The mean individual vulnerability level Dammar Char is high (0.7015). A very low and high level of vulnerability value 0.2625 and 0.9418 was reported for the male participants, respectively. A very high and low vulnerability value of 0.941875 and 0.3125 was reported for female participants, respectively. Hoque et al. (2021) obtained similar results that the people of the SE region of Bangladesh are highly vulnerable to coastal hazards. Ahmed
Table 2  Socioeconomic status of the respondents

| Socioeconomic characteristics | Description | Frequency | Socioeconomic characteristics | Description | Frequency |
|-------------------------------|-------------|-----------|-------------------------------|-------------|-----------|
| Age                           | < 30        | 40        | Location of the house        | Beside coast| 118       |
|                               | 31–45       | 45        |                               | Beside cultivable land | 62        |
|                               | 46–60       | 60        |                               |              |           |
|                               | > 60        | 35        |                               |              |           |
| Sex                           | Male        | 134       | Ownership nature of the house | Inherited   | 108       |
|                               | Female      | 46        |                               | Rental      | 9         |
|                               |             |           |                               | Lease       | 13        |
|                               |             |           |                               | Own         | 50        |
| Educational status            | Illiterate  | 51        | Housing pattern               | Jhupri      | 17        |
|                               | Primary     | 90        |                               | Kutcha      | 137       |
|                               | Secondary   | 14        |                               | Semi-pucca  | 23        |
|                               | Higher Secondary | 15   |                               | Pucca       | 3         |
|                               | Graduate    | 10        |                               |             |           |
| Occupation                    | Unemployed  | 10        | Natural disasters             | Cyclone     | 180       |
|                               | Agriculture | 64        |                               | Storm surge | 150       |
|                               | Business    | 10        |                               | Tidal flooding | 142     |
|                               | Fisherman   | 64        |                               | Coastal erosion | 118   |
|                               | Govt./other services | 12 |                               | Salinity intrusion | 180    |
| Monthly income                | < 5000      | 59        |                               |             |           |
|                               | 5000–8000   | 84        |                               |             |           |
|                               | 9000–12,000 | 11        |                               |             |           |
|                               | 13,000–15,000 | 5      |                               |             |           |
|                               | > 15,000    | 2         |                               |             |           |
stated that 11% and 24% of the SE region of Bangladesh is prone to a very high and high vulnerability, respectively, toward the coastal hazard. A male respondent (85 years old) described:

“at the age of 23, I came to this island from Hatiya due to riverbank erosion. From then to now many people come here who have been displaced due to extreme climate events, especially as a result of cyclones. Every year many people are displaced from here. Nowadays, this displacement is increasing, as extreme climatic events are increasing”.

Figure 3 represents the four classes of vulnerability status for Dammar Char: natural, socioeconomic, physical, and overall vulnerability. Comparing the four classes, the natural vulnerability was found as the most significant (0.737) followed by socioeconomic (0.723), overall (0.7015), and physical (0.624) vulnerability. Except for physical (moderate) vulnerability, the mean level of the other three classes indicates a high level of vulnerability. The findings suggest that Dammar Char has a high level of vulnerability for coastal hazards and disasters.

A 54-year-old male school teacher who has been residing in Dammar Char for more than 30 years stated:

“The people of this area are facing several types of impacts of natural hazards and disasters. Most of them do not have good knowledge about disasters. For this reason, they do not know how to protect their belongings from being lost due to disasters. Besides, nowadays disasters occur frequently.”

Fig. 3 The four classes of vulnerability level of Dammar Char
Lack of socioeconomic stability and capacity for combating the effects of climate-induced natural hazards and disasters has accelerated the level of overall vulnerability. The respondents lack adequate pure drinking water and quality sanitation facilities. Many of them possess Kuccha houses that are not resilient to hazard and disaster due to their structural weakness. The lack of structural integrity of Dammar Char homes has led to the increase of physical vulnerability for the population. The level of physical vulnerability is proportional to the level of socioeconomic and a high level of socioeconomic vulnerability also increases the risk of a respondent’s physical vulnerability (Salam et al. 2021a). Despite their willingness to take appropriate preparedness and mitigation strategies for reducing their vulnerability, lack of adequate socioeconomic strengths resists them from taking necessary measures on time. The increased risk from natural vulnerability coupled with socioeconomic and physical vulnerability has led to a high level of overall vulnerability for Dammar Char. Jamshed et al. (2017) and Alam et al. (2018) have found similar outcomes as the present study that vulnerability is also dependent on the economic strength which is the principal key to taking measures before and after the occurrence of any disaster.

Figure 4 illustrates the vulnerability index based on gender and educational status. On average, the female participants reported a high (0.7497) vulnerability level compared to their adult male (0.6851) counterparts (Fig. 4a). Perception of vulnerability varies between adult male and female. Rahman (2013) conducted research in Bangladesh to explore gender-based vulnerability to natural disasters and found that females perceived and experienced more vulnerability than their adult male counterparts. Discriminate distribution of

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**Fig. 4** Vulnerability level based on **a** gender and **b** educational status (Note: 1 = Graduate, 2 = Higher secondary, 3 = Secondary, 4 = Primary, and 5 = Illiterate)
resources and lack of leadership make women more vulnerable than men (Gaillard et al. 2015).

A 35-year-old female respondent uttered:

“During Cyclone Alia, I was pregnant. I was unable to enjoy my pregnancy period due to the climatic extremity. My vulnerability for the risks of the cyclone became proportionally increased as I was pregnant. Everyone left me and my two children at home during the onset, and I was unable to reach the evacuation shelter due to being heavily pregnant with two children. So, we all had to stay at home. The cyclone washed away all the stored foods in my house, and the scarcity of drinking water was severe. All of these impacts negatively affected my physical strength and I had to go through a very difficult time which was not faced by the adult male members of my family and community.”

This is not an isolated event, many women reported impacts on their ability to protect themselves and their children from the risk of coastal hazards and disasters.

There is a direct correlation between vulnerability and the level of educational attainment (4b). The illiterate respondents reported a high vulnerability compared to the occupational group. Among the literate people, the graduates have been facing low to moderate levels of vulnerability. The respondents who have a primary and secondary level of education have been experiencing a similar mean level of vulnerability (high), whereas people with higher educational qualifications experience a lower level of vulnerability. Individual’s educational qualification affects the livelihood choices which eventually controls the levels of both socioeconomic and physical and overall vulnerability level (Satter and Cheung 2019; Salam et al. 2021a, 2021b). An educated person possesses more knowledge about the mitigation and adaptation strategies against natural hazards and disasters and can implement a correct concept to deal with the devastating natural phenomena, making them capable of becoming more resilient (Lucas and Pabuayon, 2011; Roco et al. 2015; Ullah et al. 2015).

For reducing the risks originating from climate-induced hazards and disasters, the people residing in the study area have adopted several options as their means of adaptation. The most practiced options of the respondents are homestead gardening (71%), working in seasonal day labor (60%), fish drying (44%), ship and duck rearing (41%), constructing plinths for elevating the floor of the house (39%), extensive banana cultivation (28%), and storing dry foods (puffed rice and pressed rice) for rainy days (27%). Some snapshots of the communities’ adaptive measures are presented in Fig. 5.

4 Conclusions

The present study has assessed the level of vulnerability at the local level induced by the natural coastal hazards and disasters in the Dammar Char of Noakhali District in Bangladesh. The results show the high vulnerability status of the respondents. Natural vulnerability is higher among the Dammar Char residents than socioeconomic and physical vulnerability. Due to the increase of unpredictable coastal natural hazards, the people of Dammar Char have high vulnerability levels. Women, illiterate, and less educated respondents are more vulnerable than their other counterparts. The inhabitants take some adaptive measures to reduce the impacts of climate-induced extreme events. The findings of this study would assist the stakeholders, including policymakers, to take appropriate long-term
sustainable measures to make the area less vulnerable to coastal hazards and disasters. Future studies should consider expert views and intra-household perceptions for assessing the vulnerability of the present study area.

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Author contribution EA developed a conceptual framework, supervised the research work, and finalized contributions from all co-authors. MSK conducted fieldwork, performed data analysis, and initiated a draft of the manuscript. RS conducted the final data analysis and improved the manuscript.

Data availability Data are available within the tables of the manuscript.

Declarations

Conflict of interests The authors declare that they have no conflict of interest.

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