Evaluation of climate induced hazards risk for coastal Bangladesh: a participatory approach-based assessment

Md Faisal\textsuperscript{a}, Milton Kumar Saha\textsuperscript{b}, Md Abdus Sattar\textsuperscript{b}, A. K. M Abdul Ahad Biswas\textsuperscript{b} and Md Afjal Hossain\textsuperscript{b}

\textsuperscript{a}Department of Disaster Resilience and Engineering, Patuakhali Science and Technology University, Dumki, Patuakhali, Bangladesh; \textsuperscript{b}Department of Disaster Risk Management, Patuakhali Science and Technology University, Dumki, Patuakhali, Bangladesh

ABSTRACT
Bangladesh has been identified as one of the most susceptible countries to climate induced disasters. Geographical location of the country in the foothill of Himalayan system and in the mouth of north Bay of Bengal make it to experience frequent extreme environmental events such as flood, cyclone, draught, river erosion, sea level rise, salinity etc. The coastal region of Bangladesh is highly vulnerable to climate change and climate induced natural disasters. This study identifies the potential climate induced hazards, their vulnerability, capacity, associated risk and explores the potential strategies to reduce the disaster risk. This study was carried out in Uttar Bedkashi Union, Koyra Upazila under Khulna District in south west coastal region of Bangladesh. The information has been collected through individual level and key informant interview, focus group discussion, life history from local people to explore the context of the disaster risk and how they perceived it from their experiences. The study revealed that flooding as a result of high tide and salinity intrusion were the most prominent hazards followed by riverbank erosion and cyclone associated storm. Vulnerability assessment showed that cyclone associated storm surge was the major cause of vulnerabilities in the study area which followed by flooding and riverbank erosion. On the other hand, capacity assessment showed that community people have less capacity to deal with the multi-hazards risk. This study also revealed that riverbank erosion poses the highest risk in the study area followed by cyclone associated storm surge, flooding, and salinity intrusion. The study suggests some potential DRR strategy such as build disaster resilient house using indigenous and scientific knowledge, build or improve embankments, build or improve the communication roads, improve rain water harvesting system, provision of community-based health care center, create alternative and sustainable livelihood opportunity such as self-sustaining agriculture systems and further development of sustainable shrimp farming. The outcome of this study is expected to be useful for preparing an effective disaster risk mitigation plan by decision-makers. Further in-depth research on
potential risk reduction options will be analyzed to measure efficiency and effectiveness.

**Abbreviations:** BBS: Bangladesh Bureau of Statistics; CPP: Cyclone Preparedness Programme; DRR: Disaster Risk Reduction; FGD: Focus Group Discussion; JJS: Jagroto Juvo Sango; KII: Key Informant Interview; NGOs: Non-governmental Organizations; UNESCO: United Nations Educational, Scientific and Cultural Organization; UNO: Upazila Nirbahi Officer

1. Introduction

Climate change and its associated impacts are already being embraced through changing temperatures and precipitation, rising sea levels, changes in the frequency and severity of climate extremes, and the dynamics of hazardous conditions. Climate induced hazards affect millions of people every year around the world. Between 2005 and 2015, more than 1.5 billion people have been affected by various natural disasters with vulnerable groups such as children and women disproportionately (UNISDR 2015). Most of the climate induced hazard impact in the low-lying coastal belt of developing countries is often higher due to climate change impacts, frequently occurring cyclones, storm surges, etc. (Haque et al. 2020). The number of people and assets exposed to natural hazards in coastal areas have increased at a higher pace compared to the reduction in vulnerability (GFDRR 2016). Consequently, the potential disaster risk of communities has increased with significant socioeconomic, health, cultural, and environmental losses (UNISDR 2015; Mallick et al. 2017). It is, therefore, imperative to understand the potential disaster risk of coastal areas in order to mitigate the disaster impact on communities.

Bangladesh is regarded as one of the most disaster-prone countries in the world (Islam et al. 2013). Climate induced disaster is a common phenomenon in Bangladesh. Every year this country experiences different kinds of disasters like flood, tropical cyclones, tornadoes, tidal surges, droughts, and large scale river bank erosion (Roy et al. 2009; Mallick et al. 2017). Due to climate change, most of the coastal areas of the world are at risk of natural hazards and meteorological disturbances. The coastal areas of Bangladesh are not exception from it. As the Bay of Bengal is a perfect breeding ground for tropical cyclones, the coastal areas have been facing one or two severe events in each and every year (Perch-Nielsen et al. 2008; Mallick et al. 2017). For example, severe tropical cyclones and associated storm surges like SIDR and AILA can be mentioned. Cyclone, tidal surge, flood, river bank erosion are some of the worst types of hazards which have been badly affecting the livelihood of our citizens especially in the coastal zone (Islam and Hasan 2016; R. Kabir et al. 2016).

It is ironic that countries that are least responsible for or insignificant contributors to global climate change, are in fact, the most susceptible to its harmful impact. The long coastline of Bangladesh, faces potentially multi-hazard threat due to climatic change. The coastal zone of Bangladesh covers 32% of total land area and 30% of cultivable land, it supports a huge population of around 743 people per km² with diversified livelihood activities (Ahmad 2005). In 2001, coastal people of this country were
about 35.1 million which will be growing to about 57.9 million in 2050 (Islam 2004). Poor and marginalized people are more likely to depend heavily on natural resources (for example, agriculture, fishery) for their livelihoods (Helgeson et al. 2013). In coastal areas people at risk greatly depend on climate sensitive sectors, such as fishery, forestry, and tourism, for their livelihoods and very often need to adopt a number of strategies to cope with shocks inflicted by different climate hazards (Parvin et al. 2008).

Over the last two decades, people of coastal Bangladesh have been facing the rising degree of vulnerabilities due to multi hazard risk. This risk is the probability of a hazard turning into a disaster, with households or communities being affected badly. The lives and livelihoods of vulnerable communities are seriously disrupted beyond their capacity to cope or withstand using their own resources, with the result that affected population suffer serious, widespread human, material, economic or environmental losses (Wallman 2005; Ashraful Islam et al. 2016). The southwest coastal region of Bangladesh is unique for its environmental characteristics. It is extremely vulnerable to natural hazards such as floods, cyclones, tornadoes, tidal surges, storm surges, river bank and coastal erosion (Saha 2015; Roy 2018). Cyclone SIDR struck in the coastline of Bangladesh in 2007 and cyclone AILA hit the same region in 2009 with 13 feet high waters, damaged embankments and dykes in several places, washing away the lives and livelihoods of coastal communities (Saha 2015; Mallick et al. 2017). Khulna, in the south-western coastal belt was among the worst affected district.

The Koyra sub-district under Khulna is one of the worst vulnerable area to disasters that bring disaster risk to different sectors and actors in the coastal area of Bangladesh (Sadik et al. 2017). Salinity and water logging have already been considered major problems here after the cyclone AILA (Sadik et al. 2018). On the other hand, cyclone, coastal flooding, river bank erosion, health hazard etc. are also being severe. As a result, every year huge amount of crop, house damage with extreme economic losses. Life loss is a general event here in different disaster. Here before overcome the loss of one disaster, another disaster hit them and people gradually loss their disaster management capacity and gradually poverty to extreme poverty take place (Hossain 2015). This union is an area of high risk by coastal threats and therefore in need of assess the risk at a local level with understanding of community resilience and its socioeconomic conditions in order to improve the value of hazard prioritization and risk mapping and suitable risk reduction strategy. Community-based risk assessments are valuable measures to support the risk evaluation and mitigation process and to find appropriate risk reduction options such as land-use planning, early warning systems, preparedness, awareness-building activities, and suitable adaptation strategies (Renn 2004; Van Aalst et al. 2008). For example, daily experiences and local knowledge of people using resources in risk-prone areas, have proven to be detrimental for determining whether policies and measures will be accepted or not (Keskitalo 2013), in generating support for initiatives for mitigation and adaptation (Lujala et al. 2015), and in making vulnerability mapping more locally relevant and reliable (Rød et al. 2012; Barquet and Cumiskey 2018). Thus, involvement of community members and key actors through participatory methodologies are crucial for
integrating opinions in the formal decision-making process because the ability to reduce risk from hazards will depend to a large extent on the political, economic and technological capacities that actors involved in coastal management have at their disposal (Van Aalst et al. 2008; Keraita et al. 2008; Toufique and Yunus 2013; R. Kabir et al. 2016; Hoque et al. 2021; Pal and Karnjana 2021). It is still remained un-researched the underlying factors that are responsible for disaster risk and the management policy against these risks. Therefore, this research will assess disaster risk in different sectors and actors by identifying the risk factors and potential management policies of climate induced disaster risk. The main aim of this research is to carry out a multi-hazards risk assessment for the coastal at-risk community in Bangladesh and to recommend possible risk reduction strategies. The objectives of the study were to explore the people perception of hazard, vulnerabilities, capacities and risk; analysis the risk; and recommend potential disaster risk reduction strategies.

2. Methodology

2.1. Overview of the study area

The study was conducted in Koyra Upazilla (sub-district) of Khulna district located in the south-west Bangladesh and close to Bay of Bengal surrounded by the Sundarban (Fig. 1), the largest mangrove forest in the world and a UNESCO World
Heritage Site. Koyra upazilla is located between 22°55’N Latitude and 89°15’E Longitude with an altitude of 3.0-3.5 m from MSL (BBS 2015).

The administrative structure of Koyra consists of seven union parishads (lowest tier of local government in Bangladesh), 71 mouzas (village-clusters), and 133 villages (BBS 2015). Geo-morphologically, the Upazila is about two meters above sea level in its northern part and about 1 m in its southern part. Koyra is made up of flat land, with a natural ground slope to the southeast and south along the Sundarbans and near the Bay of Bengal (BBS 2015). Biophysically it is characterized by an immature deltaic slope with numerous biotic and abiotic factors and a substantial portion of land that is hardly above sea level. The tropical cyclone SIDR and AILA devastated the region in 2007 and 2009, causing substantial economic and noneconomic damage. According to the assessment of Ministry of Disaster Management and Relief, more than 152,496 people were affected by the cyclone AILA and most of them then become as climate refugee (Saha 2015).

The Uttar Bedkashi union (smallest administrative unit) was purposively selected for the study, as it is located to the proximity to the Bay of Bengal and frequently affected by hydro-meteorological hazards like cyclone and cyclone driven storm surges, river bank erosion, tidal flooding, saline water intrusion, etc. This area is situated on the bank of the Kapatakho and Shakbaria river. Agriculture, fisheries and day labour are the main occupation of that area’s people.

2.2. Data collection method

2.2.1. Determination of the sample size

Multi-stage and simple random sampling technique were used for the selection of sample size. Koyra Upazila is consisted of 7 unions (BBS 2015) out of which Uttar Bedkashi was selected randomly at the first stage. In the second stage, 7 (seven) villages out of 13 villages are randomly selected. The total number of households of these three villages is 1362 (BBS 2015). We have opted to cover most of the areas in our sample. For this, at a 95% confidence level with a precision of 10% the required sample size was 96 (Cochran 1963). Finally, this study considered 120 households as a sample size.

2.2.2. Structured questionnaire survey

A semi-structured questionnaire was designed by considering various indicators that used for collecting the household data. We mainly designed the household survey in the form of a close-ended questionnaire, with few open-ended options. The questionnaire was divided into four different sections, highlighting (i) the socio-economic characteristics of the respondents; (ii) perception, knowledge, and attitude related to hazards and vulnerability; (iii) household assets and livelihood strategies; and (iv) shocks, stresses, and coping strategies for adaptation. We developed the questionnaire in such a way that we could gather more than 80% of the answers through direct discussion with the family members, observation in reality, and watching the socio-economic conditions of the neighbours. Stratified random sampling method was used for household survey. For this study, a number of criteria were made to survey the
To fulfill the objectives of this study, qualitative data was collected through key informant interview (KII), focus group discussion (FGD), life history and transect walk. A semi-structured interview schedule was followed for KII. There are 13 (thirteen) KII were conducted from the school teachers, Upazila nirbahi officer (UNO) of Koyra Upazila, chairmen of Uttar Bedkashi union parishad, male and female members in this union, member of disaster management committees, volunteer of red crescent society, project manager of Islamic Relief Koyra Office, manager of Rupantar and Jagroto Juvo Sango. The study also followed a semi-structured interview schedule for in-depth focus group discussion (FGD). A total of 10 (ten) in-depth focus group discussion with village people were conducted in different village. The secondary data was collected through different reports, research articles, newspaper articles, journal papers were analyzed and integrated with primary data. Some unpublished data was collected from Islamic Relief project office, Jagroto Juvo Sango (JJS) and Rupantar, Koyra. During data collection, the authors tried to conduct the interview and all discussions using the local language.

2.3. Concept of disaster risk

A growing body of literature on climate change and natural disasters defines ‘disaster risk’ is the probability of harmful consequences, or expected loss of lives, people injured, property, livelihoods, economic activity disrupted (or environment damaged) resulting from interactions between natural or human induced hazards and vulnerable conditions (Granger et al. 1999; Brooks 2003; UNDP 2004; Wisner et al. 2004). Generally, disaster risk emerges when hazards interact with physical, social, economic and environmental vulnerabilities. Hazard is a phenomenon, an event, or occurrence (Gunn 1992; Haase 2013; Smith 2013) that has the potential for causing harm to life or damage to property or the environment (Raetzo et al. 2002)(Buckle 2001). Vulnerability refers to the limitation of a community to a hazard and the prevailing condition, including physical, socioeconomic, and political factors that adversely affect its ability to respond to hazards or disastrous events (Brouwer et al. 2007; Ginige et al. 2009; Chen et al. 2012). However, the community-based disaster risk refers to the combined susceptibility and vulnerability of the community to potential damage caused by a particular hazard within a specified future time period (Tobin 1997; Khan 2007; Islam et al. 2013). Risk is rooted in conditions of physical, socioeconomic, and environmental vulnerability that need to be assessed and managed on a continuous basis (Fekete et al. 2010; Wisner et al. 2014). Disaster risk measures involve the assessment and mapping of hazards, identification of the elements at risk (Menoni et al. 2012)(Morshed and Huda 2002), and their vulnerability to a specific hazard, and formulating risk-reducing measures, including risk mapping and hazard prioritization (Van Niekerk 2005; Füssel and Klein 2006; Tate 2012; Wamsler et al. 2012). So, the equation of disaster risk proposed by climate and disaster exponents can be revealed as ‘Risk = Hazard × Vulnerability’ (Brooks 2003; UNDP 2004; Wisner et al.
On the other hand, most of the studies calculated risk is a function of hazard, vulnerability, and capacity that is widely accepted (van Riet 2009; Rashid 2013). The following formula is often used to assess the disasters risk:

\[
\text{Risk} \ (R) = \frac{\text{Hazard} \ (H) \times \text{Vulnerability} \ (V)}{\text{Capacity} \ (C) \ \text{or Manageability} \ (M)}
\]
Here, Risk (R) = Likelihood of harmful consequences, arising from the interaction of hazards, vulnerable elements and the environment. Hazard (H) = Potentially, but not necessarily, damaging physical events, phenomena or human activities that may trigger loss of life or injury, damage to property, social and economic stress or environmental degradation. Vulnerability (V) = Inability to cope with, withstand and recover from hazards. Capacity (C)=The strengths and resources available within a community, society or organization that can reduce the level of risk or the effects of a hazard.

2.4. Method for risk assessment

Hazard assessment was determined through scoring some criteria such as the probability of occurrence (Monirul Qader Mirza 2002), the severity of the damage (Afjal Hossain et al. 2012; Bhowmik et al. 2021), lean time of the effect (McGranahan et al. 2007), and predictability of the hazards (Zaman and Mondal 2020) and coded each criterion with the numeric number (Table 1). Firstly, the coded score was summed up and then divided the total score by the total number of the criteria. Similarly, the vulnerability assessment was done by using different criteria of vulnerabilities i.e., density of the population in the vulnerable (Minar et al. 2013; Quader et al. 2017), people live in potential vulnerable area (Afjal Hossain et al. 2012; Shameem et al. 2014), resiliency of the house (Nadiruzzaman and Paul 2013; Mohiuddin and Latif 2015; Al-Maruf et al. 2021), socio-economic condition of the people (Ericksen et al. 1996; Shameem et al. 2014), condition of the physical structure of the community (Mallick et al. 2011; Moniruzzaman et al. 2012; Amin et al. 2016; Wedawatta et al. 2016), and the condition of critical infrastructure (Chakraborty et al. 2016; Iqbal 2019; Zafri et al. 2021) (Table 1). Likewise, the capacity was assessed by using several criteria i.e., present status of local-level Govt. and NGOs structure for disaster management (Azad et al. 2019; Seddiky et al. 2020; Uddin et al. 2020), present status of disaster preparedness plan (Khan 2008; Huq 2016; Islam et al. 2021), sound and observed legislation about DRR and disaster preparedness (Banu 2015; Naser 2015; Shahjahan et al. 2016), status of diversity of livelihood options in the community (Kamal 2013; Roy and Basu 2020; Sarker et al. 2020), existing Govt. resource levels to minimize disaster risk (Khan and Rahman 2007; Afrin 2018), people knowledge level of different hazards (I. Kabir et al. 2016; Barua and Rahman 2017; Chowdhooree 2019) (Table 1). Finally, the risk analysis was done by using the Eq. (3).

2.5. Identification of potential risk reduction measures

The participatory approach was used to collect measures that community people perceived could minimize climate induced disaster risk. Adopting the cards technique, community people wrote feasible measures for risk reduction on large multi-coloured paper cards of different shapes and sizes large enough to be seen by the whole group. Community people who could not write were helped to do so by others in their midst but care was taken by facilitators to minimize influence. After displaying the cards, discussions started among community people for clarifications which led to the
identification of additional measures. These primary measures were entirely suggested and identified by the community people. The research team was not involved in the discussions. Afterwards, the research team gave inputs to community peoples’ discussions, which generated additional risk reduction measures, called secondary measures here.

2.6. Data analysis

At the end of data collection, risk of each hazard was calculated on the basis of the Equation (3). Statistical calculation like Pearson’s correlation calculation and different graphs and charts were prepared by SPSS-20 and Microsoft Office Excel program.

3. Results

3.1. Different climatic hazards perceived by the respondents

Nearly 60% of the respondent reported being exposed to different climatic hazards throughout the year. Table 1 shows that more than 90% of the respondents reported that flooding and high tide had become more frequent which followed by salinity intrusion, river bank erosion, and cyclone associated storm surges. On the other hand, excessive rainfall, drought, and pest attack were the medium categories that mentioned by 66%, 46%, and 45% HHs members respectively. The water logging, hailstorm, and extreme temperature have low categories hazards that mentioned by sampled HHs.

3.2. Different vulnerabilities perceived by the respondents

Table 2 shows the people perceived vulnerability aspects of the study area. Among the 27 vulnerabilities aspect, weak flood protection embankment was the most prominent that mentioned all of the sample respondents. In addition to, more than 90% of the respondents reported that the lack of saline free water for drinking purpose was another vulnerability aspect for this area. On the other hand, about 81-88% of respondents mentioned that inappropriate technology for water supply and sanitation, weak house structure, increase the hardship of women and adolescent girls, the uncertainty of income, unfertile land were the severe vulnerability aspects for this area. Similarly, about 71-78% of the respondents urged that weak road infrastructure, high nature dependency for income, inadequate cyclone shelter, and fluctuation/decline in wage rate were the high vulnerability aspects. The vulnerabilities of this area are highly related to increasing

| Climatic Hazards                  | %  | Rank | Degree |
|-----------------------------------|----|------|--------|
| Flooding and tidal surge          | 92 | 1    | High   |
| Salinity intrusion                | 89 | 2    | High   |
| Riverbank erosion                 | 85 | 3    | High   |
| Cyclone and storm surge           | 77 | 4    | High   |
| Excessive rainfall                | 66 | 5    | Medium |
| Drought                           | 46 | 6    | Medium |
| Pest attack                       | 45 | 7    | Medium |
| Water logging                     | 41 | 8    | Low    |
| Hailstorm                         | 35 | 9    | Low    |
| Extreme temperature               | 27 | 10   | Low    |
Table 3. People perceived vulnerability aspects in study area.

| Vulnerability aspects                                         | f   | %   |
|--------------------------------------------------------------|-----|-----|
| Weak flood protection embankment and insufficient repairment | 120 | 100 |
| Lack of saline free fresh water for drinking                 | 110 | 92  |
| Inappropriate technology for water supply and sanitation      | 105 | 88  |
| Weak house structure                                          | 102 | 85  |
| Increases hardships of women and adolescent girls             | 102 | 85  |
| Uncertainty of income                                         | 98  | 82  |
| Loss of crop production due to unfertile land                 | 97  | 81  |
| Weak road infrastructure                                      | 93  | 78  |
| High dependency on nature (e.g., River, Climate, Forest)      | 92  | 77  |
| Inadequate cyclone shelter (quantity, capacity, and facility)| 89  | 74  |
| Drinking water ponds are exposed to storm surge               | 88  | 73  |
| Fluctuation/decline in wage rate                              | 85  | 71  |
| Increase cost of agricultural production                      | 79  | 66  |
| Increase intension to take loan with high interest            | 79  | 66  |
| Increase number of non-fishing day                            | 76  | 63  |
| Lack of sanitation awareness                                  | 76  | 63  |
| Unsustainable growth of saline water shrimp farming inside the polders | 76 | 63 |
| Lack of disaster preparedness                                 | 74  | 62  |
| One-way communication with local government                   | 70  | 58  |
| Low access to medical facilities                              | 69  | 58  |
| Lack of ministerial hygiene facilities while staying in cyclone shelter | 67 | 56 |
| Prevalence of waterborne diseases                             | 67  | 56  |
| Lack of early dissemination of warning information            | 66  | 55  |
| Inadequate knowledge on multi-hazards                         | 60  | 50  |
| Seasonal shortage of fodder                                   | 55  | 46  |
| Degradation of pastureland                                   | 48  | 40  |
| Higher risk in offshore fishing                               | 40  | 33  |

intension to take the loan with high interest, increase the number of non-fishing days, lack of sanitation awareness, unsustainable growth of saline water shrimp farming inside the polders, and lack of disaster preparedness which mentioned by 62-66% respondents. Some other aspects of vulnerabilities are one-way communication with local government, low access to medical facilities, lack of ministerial hygiene facilities while staying in cyclone shelter, the prevalence of waterborne diseases, lack of early dissemination of warning information, inadequate knowledge on multi-hazards, seasonal shortage of fodder, degradation of pastureland and higher risk in offshore fishing that reported by 33-58% of the respondents.

3.3. Different capacities perceived by the respondents

Table 3 shows the people perceived capacity aspects of the study area. Among the 13 capacity aspects, the most important aspect is cyclone hazards early warning message dissemination. More than 90% of the respondents mentioned that CPP is functional to disseminate cyclone related information and about 82% of them mentioned that people have better knowledge on using cyclone shelter. In addition to, about 74% sample respondents mentioned that this area has adequate number of cyclone shelter, about 73% mentioned have better knowledge on using water purification tablet, and about 72% reported that they have cultivated vegetable on homestead yard for reduce the food insecurity. On the other hand, about 65% respondent mentioned that people of this area were migrated to cities or other area in order to better income opportunities. Raised the homestead plinth is one of the most prominent way to avoid the risk
of the flood and tidal surge which mentioned by 65% respondents. About 63% of the sample respondents mentioned that the poultry farming is one of the better options for alternative livelihood source. Additionally, 54% of the respondents urged that people of this area harvesting rainwater through hanging canvas. On the other side, about 47% of the respondents mentioned people of this area cultivated vegetable on the bank of the homestead fish pond. The respondents perceived relatively medium level capacity of this area were homestead gardening, active NGOs, and good relation with Union Parishad (Table 4).

3.4. Hazards, vulnerability, and capacity assessment

Fig. 2 shows the results of the hazards, vulnerability, and capacity assessment. Overall, it was observed that flooding as a result of high tide and salinity intrusion were the most prominent hazards followed by riverbank erosion and cyclone associated storm surge. On the other hand, excessive rainfall and drought were the medium priorities hazards whereas pest attack, waterlogging, hailstorm, extreme temperature were the lowest priorities hazards. From vulnerability assessment, we can see that cyclone associated storm surge was the major cause of vulnerabilities in the study area which followed by flooding and riverbank erosion. Similarly, salinity intrusion was another cause of the vulnerabilities. On the other hand, drought, pest attack, water logging, hailstorm, and extreme temperature have obtained lowest level of vulnerabilities score. From the capacity assessment, we can see that community has a moderate level of capacities against the flooding and high tide and hailstorm event that followed by excessive rainfall, drought, extreme temperature, and salinity intrusion. On the other hand, community people have less capacity to deal with riverbank erosion, cyclone associated storm surge, waterlogging, and pest attack.

3.5. Risk analysis

From risk analysis, we can see that riverbank erosion poses the highest risk in the study area followed by cyclone associated storm surge, flooding, and salinity intrusion (Fig. 2). On the other hand, there is a moderate level of risk due to waterlogging and drought followed by excessive rainfall, pest attack, extreme temperature, and hailstorm.
3.6. Analysis of correlation of hazard, vulnerability, capacity and risk

Statistical analysis has been performed to understand the relationship between hazard, vulnerability, capacity and risk in all-natural hazards perspective in the study area. Fig. 3 shows the good relation among the variables. This figure proved that when vulnerability is increased simultaneously risk also increased because of the lack manageability of hazard event and vice-versa. Again, when capacity is increased simultaneously risk decreased. In some rare cases risk is increased with capacity increased because of the high community vulnerability and vice-versa.

4. Discussion

The geographic location of Bangladesh and its topographic characteristics have made the country easily vulnerable to natural disasters such as tropical cyclones and accompanying storm surges, floods, river bank and coastal erosion and climate change. The hazards of the study area were assesses based on the participants life context and rational perception of hazard characteristics such as likelihood, speed of onset, intensity, duration, predictability, familiarity, consequences and risk. Usually, southwestern coastal residents are living in the low-lying region and very familiar with a number of hydro-meteorological hazards such as flood, inundation, tropical cyclone, storm surge, wind storms and sea-level rise. As the Uttar Bedkashi is very close to the Sundarbans and the Bay of Bengal, the residents are highly vulnerable and very sensitive to be affected by natural hazards. Biswas et al. (2015) noted that flooding, high
tide, riverbank erosion, cyclone, salinity, storm surge, tidal surge, excessive rainfall, drought, water logging and extreme temperature are frequently occurred in Koyra Upazila.

Finding showed that flooding and tidal surge got the highest priority hazard occurring in this area. Due to the flooding every year a great damage of livelihood; crop-livestock-fisheries production; change in lifestyles; disruption of immobile infrastructure, communication and livelihood system and loss of life. Similar result also found in the study of Hossain (2015).

Salinity was the second most priority hazard in the study area. Due to the salinity intrusion the difficulty of potable water was increased because most of the tube wells in this area were found to be saline affected. Poor people especially face acute salinity problems in drinking water. For suppling safe drinking water, women and adolescent girls were usually responsible for collecting drinking water from distant sources. In some areas, neighbourhood water sources were all affected by high salinity, so they must travel long distances on foot every day to find and procure drinking water. Women and girls also have trouble finding enough time to carry out other household duties such as cooking, bathing, washing clothes, and taking care of elders. These results supported the study of Abedin and Shaw (2012), Rahman and Islam (2019). The increased unavailability of freshwater also forces people to drink contaminated water, which can lead to diarrhea and water-borne diseases such as cholera. Moreover, high salinity not only causes destruction of infrastructure, including educational institutes, but also increases the high rate of drop outs of school. Study also

Figure 3. Correlation among hazards, vulnerability, capacity, and risk.
showed that salinity was a major problem in agriculture because soil salinity decreased soil fertility that hampered productivity. Similar result revealed in a study of Akhi et al. (2019). It was found that in some places, shrimp farmers cut embankments to enter salt water into their farms, in some places they entered water into farms through making holes in embankments as a result the salinity problem increased day by day. These results are similar to other studies by Datta et al. (2010), Saha (2017).

Study revealed that riverbank erosion negatively effects on people and their livelihood with their economic, social and psychological distress increasing over the time. Most of the people were vulnerable and their economic condition were fragile in the study area. Riverbank erosion breaks down the embankment as a result flooding and salinity intrusion problem was acute in this area. Results from this research resonate the study of Rahman and Gain (2020). The embankments play a vital role in protecting coastal people and their properties and assets during a cyclone (Dasgupta et al. 2014; Ataur Rahman and Rahman 2015). The height of the embankments with their sluice gates in the Uttar Bedkashi union are not strong enough to combat a storm surge. On the other hand, more than 30 km embankment was vulnerable for riverbank erosion. The embankment breaks down in several point in every rainy season and water enter into the locality as a result damage the agricultural crops, fisheries due to inundation.

The frequency of the cyclone event in the study area has been increased noticeably. Due to the cyclone hazards the vulnerability of this area has been increased day by day. Most of the people depends on fishing and agriculture farming for their primary livelihood options. Production of agricultural products in these lands reduced remarkably after the cyclone hit the area. The financial suffering of these farmers was increased remarkably. These findings are in keeping with other studies such as Ahsan et al. (2020), Kabir et al. (2016), Sadik et al. (2018). Study revealed that people in this area infected different diseases after the disaster. A lack of pure drinking water aggravated the spread of waterborne diseases in the affected areas. According to the respondents of this research, the main diseases were diarrhea, dysentery, fever, typhoid, pneumonia, cholera, hepatitis, stock, skin diseases etc. but in this union had no hospital as a result they take their treatment from village doctor. The analysis shows that mental health problems are also a major growing concern for the cyclone affected population. According to the respondents in this study, the post-SIDR and post-Aila the number of people with mental health problems has increased dramatically. Due to the cyclone children and women were more vulnerable because of their physical formation. Women were more at risk because they stayed behind to save or search for their children, while others escaped. Study also found that children and the elderly were found most vulnerable during the cyclone. They are vulnerable due to health and physical vulnerabilities and because of their inability to run fast. These results are similar to other studies by Kabir et al. (2016), Saha (2015).

The early warning system was very poor in the study area. Only cyclone early warning system was strong here. The CPP volunteer is functional to disseminate cyclone related information About 50% of respondents got cyclone warning before 1-6 hours that was very little time for prepared them against a large cyclone. In case of
other disasters like flood, high tide, excessive rainfall, drought, riverbank erosion etc. had no warning signal disseminate system here which make them more vulnerable for those hazards. More than 50% of the people were not going to the cyclone shelter because of insufficient space and facilities. Study found that woman faced different problem in cyclone shelter like sexual harassment, water and sanitation, food etc. (Ayeb-Karlsson 2020). The study found that there were nine non-governmental organizations (NGOs) and local government agencies working on disaster risk reduction. Their activities were increasing the capacity of the peoples to reduce the

| Sl. no. | Area of risk       | Effects                                      | Successful initiative                                                                                                                                 |
|---------|--------------------|----------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|
| 01      | Physical           | Embankment will break down                   | Build or improve embankments                                                                                                                           |
|         |                    | Roads will damage                            | Increase the height of the embankment                                                                                                                   |
|         |                    | House will damage                            | Setup block in the slope of the embankment                                                                                                             |
|         |                    | Water logging/flooding                      | Repairing the roads and raising the roads elevation                                                                                                |
|         |                    | Limited number of cyclone shelter           | Raising the height of the house basement and build the disaster-resilient house                                                                            |
|         |                    | compare to the population                   | Construct/repair sluice gate and culvert                                                                                                                |
|         |                    | School connectivity roads will break down    | Build more cyclone shelters                                                                                                                              |
|         |                    | Trees number will reduce                    | Ensure safety and security in the cyclone shelters                                                                                                     |
| 02      | Food security      | Disrupt the agricultural activities and      | Salt tolerant trees plantation                                                                                                                             |
|         |                    | reduce the crop production                  | Ensure fresh water for crop production                                                                                                                 |
|         |                    | High expensive agricultural equipment’s      | Available the saline tolerant rice varieties for the farmers                                                                                           |
|         |                    | Reduce the land fertility                    | Ensure the availability of agricultural equipment’s                                                                                                      |
|         |                    | Reduce the fish production                   | Increase the soil fertility by using organic fertilizer                                                                                                 |
|         |                    | Inundation of Ponds and ghers               | Increase the supply of high yield fish variety                                                                                                         |
|         | Fresh water scarcity| Ground water table will decrease             | Increase the height of the bank of ponds and ghers                                                                                                      |
| 03      |                    | The platform of deep tube well will be       | Community based rain water harvesting system and tank will be constructed for store the rain water                                                                 |
|         |                    | inundated                                   | Install Pond Sand Filters (PSF) to ensure pure drinking water for all                                                                                  |
|         |                    | The pond will be inundated                   | Raising the platform of tube well upper the high flood level and make them disaster resilient                                                            |
|         |                    | Scarcity of safe water                       | Raising the bank of the pond                                                                                                                             |
|         |                    |                                            | Excavate the new pond and increase the depth of the existing pond                                                                                       |
| 04      | Sanitation         | Inundate the basement of the toilet         | Community based rain water harvesting system and tank will be constructed for store the rain water                                                                 |
|         |                    | Reduce the habit of hand wash               | Increase the height of the basement                                                                                                                        |
|         |                    | Water borne disease will be spread out      | Awareness raising about the practice of hand wash and sanitation                                                                                          |
| 05      | Livelihood         | Reduce the livelihood options               | Awareness raising about different diseases                                                                                                               |
|         |                    | Lack of savings                             | Provision of community-based health care center                                                                                                          |
|         |                    | Lack of opportunities for vocational        | Create alternative livelihood options                                                                                                                    |
|         |                    | knowledge and training                      | Provide financial support to poor people and those who have lost everything                                                                            |
|         |                    |                                             | Ensure the micro credit system                                                                                                                           |
|         |                    |                                             | Arrange the sector basis training system for establish the self-employment.                                                                             |

Source: Focus Group Discussion (FGD) and Questioner Survey
vulnerabilities and disaster risk. Study revealed that 92.86% people take the disaster management training directly and indirectly.

5. Potential disaster risk reduce strategy

In this study, we proposed some potential disaster risk reduction strategies, which is presented in Table 5. Findings from the focus group discussions revealed that structure mitigation measures such as cyclone shelter, embankment, sluice gate etc. are crucial for reducing community level disaster risk. Embankments play a vital role in protecting coastal people and their properties and assets during cyclone associated storm surge. We observed that the height and structure of the embankments with their sluice gates in the study union is not resilient to protect the community to storm surge. As a result, many hectares of croplands were damaged in this area. Much of the discussions in focus group interviews centred around these measures, suggesting the reliance of vulnerable communities on these measures and the significance attached to these by the communities. Significant reliance of communities on community-level structural protection measures is linked to the financial status of the residents, these mostly being financially deprived communities. Lack of financial resources has significantly hindered their ability to better prepare; e.g., by moving out of highly vulnerable areas and making their homes safe, despite their willingness to do so. The communities recognized the need for improving their financial status, if they are to better prepare. Financial incentives can therefore be identified as an effective measure that will enable preparedness. At a more fundamental level, this highlights the importance of empowering vulnerable communities financially by means such as vocational training, self-employment and micro business opportunities, etc.

Furthermore, we observed severe pure drinking water scarcity in the study area. Also, we noticed that only pond sand filter is an option for pure drinking water, which simply was not enough for the community. It is obvious to point out that many communities are facing many problems regarding the availability and supply of safe drinking water.

Due to the fragile embankment and high intrusion of saline water, the food production in the study area has significantly reduced. During the focus group discussions with the community leader, they highlighted the drawbacks of existing measures, and more importantly, how they can be improved. It also has to be noted that many initiatives, including structural measures as well as other measures, were found to be in place to reduce disaster vulnerability in the region. Initiatives where community concerns are addressed or are planned to be address were mentioned in discussions with the local policy makers. Where new initiatives are required, these were acknowledged by the local policy makers.

6. Conclusion

Reducing vulnerability to climate-induced disasters and subsequently reduce the risk of those disasters requires to know the perceive multiple hazards risk and the capacity to act accordingly. Though climate induced disasters are widespread in the developing world and are likely to become more prevalent in the wake of climate change, there are
few studies that simultaneously examine the overlapping risks in a multi-hazard. In this study, face-to-face questionnaire survey and site observation methods were employed to reach the research objectives. Our analysis found that coastal flooding, salinity intrusion, riverbank erosion, and cyclone were the most priorities hazards in the study area. Results also showed that cyclone associated storm surge, riverbank erosion, and salinity intrusion were the major cause of vulnerabilities in the study area. Capacity assessment indicates that community people have less capacity to deal with riverbank erosion, cyclone associated storm surge, waterlogging events. Many good practices are in place at both the government and household levels, but they are not enough. The most important DRR measures are to: build more cyclone shelters; build the disaster-resilient house; build or improve embankments; build or improve the communication roads; improve rain water harvesting system; provision of community-based health care center; create alternative livelihood options, and arrange the sector basis training system for establish the self-employment. Following this research, further study can be done in depth analysis of each hazards in coastal areas, which will help understand the different scenarios in detail for formulating effective disaster risk reduction strategy.

This research opts to develop a nexus between hazard, vulnerability, capacity, and risk. The results demonstrate that plenty of scopes are in place to make communities more resilient to climate-related stress in the coastal areas. The research also suggests that assets are differential amongst coastal community dwellers, which often make the disparity of the coping capacity of the households to bounce back from the negative effects of climate-induced hazards. Because of the differential coping capacity amongst the coastal households, some are sliding into the vulnerable outlier category, and some have the capacity to bounce back from climate-induced shocks and stresses. This research provides a clear indication of the seemingly overlapping relationship between vulnerability and way to reduce disaster risk. The findings of this research will widely use to assess the disaster risk in the coastal area of developing countries and find out possible risk reduction options. In future research, potential risk reduction options will be analyzed to measure efficiency and effectiveness. The assessment process helps to develop any new policies at national level or start a new project for the local community. However, the general concept and calculations of risk assessment process may not be possible to demonstrate the situation at local context especially for developing countries like Bangladesh. There are various complex processes for assessing the disaster risk and for that reason, there should be flexible and cost-effective risk assessment approach that suits the local conditions of Bangladesh.

**Acknowledgement**

The kind assistance of the government officials of Koyra sub-district and the Uttar Bedkashi Union during field work is highly appreciated. Authors are thankful to Key Informant persons for their help during data collection.

**Ethical declaration**

We performed the study in accordance with the ethical standards. Informed consent was obtained from all individual participants involved in the study. Consent to participate in the
research has been given freely and without coercion. Consent of the research subject has not been influenced by financial inducement, improper pressure or any form of misrepresentation.

**Disclosure statement**

On behalf of all the authors of the paper titled 'Risk Analysis of Climate Induced Disasters in Coastal Bangladesh: A Study on Koyra Sub-district in Bangladesh', I would like to declare that we have no conflict of interest among us and with others.

**Authors’ contributions**

All authors contributed to this work equally.

**Data availability**

The data that support the findings of this study are available but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. However, data are available from the corresponding author upon reasonable request.

**References**

Abedin MA, Shaw R. 2012. Safe water adaptability for salinity, arsenic and drought risks in Southwestern Bangladesh. Proc 4th Int Disaster Risk Conf Integr Risk Manag Chang World Pathways to Resilient Soc IDRC Davos. 4(2):11–14.

Afjal Hossain M, Imran Reza M, Rahman S, Kayes I. 2012. Climate change and its impacts on the livelihoods of the vulnerable people in the southwestern coastal zone in Bangladesh. In: Leal Filho W, editor. Climate change and the sustainable use of water resources. Climate change management. Berlin, Heidelberg: Springer Berlin Heidelberg; p. 237–259.

Afrin S. 2018. The role of local government in managing disaster induced risk: A sociological study in Munshigonj.

Ahmad M. 2005. Living in the coast: people and livelihoods. US: Program Development Office, Integrated Coastal Zone Management Plan.

Ahsan MN, Khatun A, Islam MS, Vink K, Ohara M, Fakhruddin BSHM. 2020. Preferences for improved early warning services among coastal communities at risk in cyclone prone southwest region of Bangladesh. Prog Disaster Sci. 5:100065.

Akhi TH, Khan MH, Bashar R, Jimmy AN, Khan NA. 2019. Land-use conversion, shrimp culture and salinity intrusion at the south-western regions of Bangladesh: the cases of Koyra and Shymnagar. J Environ. Prote. Sustain. Dev. 5(4):132–137.

Al-Maruf A, Jenkins JC, Bernzen A, Braun B. 2021. Measuring household resilience to cyclone disasters in coastal Bangladesh. Climate. 9(6):97.

Amin MN, Shil SC, Hasan M. 2016. Status of cyclone shelter facilities in south central Bangladesh. J Environ Sci Nat Resour. 9(1):75–79.

Ashraful Islam M, Mitra D, Dewan A, Akhter SH. 2016. Coastal multi-hazard vulnerability assessment along the Ganges deltaic coast of Bangladesh-A geospatial approach. Ocean Coast Manag. 127:1–15.

Ataur Rahman M, Rahman S. 2015. Natural and traditional defense mechanisms to reduce climate risks in coastal zones of Bangladesh. Weather Clim Extrem. 7:84–95.

Ayeb-Karlsson S. 2020. I do not like her going to the shelter: Stories on gendered disaster (im)mobility and wellbeing loss in coastal Bangladesh. Int J Disaster Risk Reduct. 50(im):101904.
Azad MAK, Uddin MS, Zaman S, Ashraf MA. 2019. Community-based disaster management and its salient features: a policy approach to people-centred risk reduction in Bangladesh. Asia Pac J Rural Dev. 29(2):135–160.

Banu N. 2015. Disaster management in the five-year plans of Bangladesh: an assessment. In: Strateg Disaster Risk Manag Asia. Berlin: Springer; p. 15–28.

Barquet K, Cumiskey L. 2018. Using participatory multi-criteria assessments for assessing disaster risk reduction measures. Coast Eng. 134(August):93–102. http://dx.doi.org/10.1016/j.coastaleng.2017.08.006.

Barua P, Rahman SH. 2017. Indigenous knowledge practices for climate change adaptation in the southern coast of Bangladesh. IUP J Knowl Manag. 15(1): 1-21.

BBS 2015. Bangladesh population and housing census 2011, Community Report: Khulna. Dhaka, Bangladesh.

Bhowmik J, Irfanullah HM, Selim SA. 2021. Empirical evidence from Bangladesh of assessing climate hazard-related loss and damage and state of adaptive capacity to address them. Clim Risk Manag. 31:100273.

Biswas AAA, Islam T, Sattar A, Mili SN, Jahan T. 2015. Community based risk assessment of agriculture sector in Sreerampur Union of Bangladesh. J Food Secur. 3(5):125–136.

Brooks N. 2003. Vulnerability, risk and adaptation: a conceptual framework. Tyndall Cent Clim Chang Res Work Pap. 38(November):1–16. papers2://publication/uuid/D2016620-F4DE-4C0A-BE4B-78E8F2701438%5Cnhttp://www.tyndall.ac.uk/sites/default/files/wp38.pdf%5Cnhttp://files/1067/Brooks_VulnerabilityRisk&AdaptationToCC.pdf%5Cnhttp://files/424/Vulnerability,riskandanadaptation-Aconceptual.

Brooks N, Neil Adger W, Mick Kelly P. 2005. The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. Glob Environ Chang. 15(2):151–163. https://linkinghub.elsevier.com/retrieve/pii/S0959378004000913.

Brouwer R, Akter S, Brander L, Haque E. 2007. Socioeconomic vulnerability and adaptation to environmental risk: a case study of climate change and flooding in Bangladesh. Risk Anal. 27(2):313–326.

Buckle P. 2001. Community based management: a new approach to managing disasters. Draft August.

Chakraborty TK, Kabir A, Ghosh GC. 2016. Impact and adaptation to cyclone AILA: focus on water supply, sanitation and health of rural coastal community in the south west coastal region of Bangladesh. J Heal Environ Res. 2(3):13–19.

Chen C-W, Tseng C-P, Hsu W-K, Chiang W-L. 2012. A novel strategy to determine the insurance and risk control plan for natural disaster risk management. Nat Hazards. 64(2):1391–1403.

Chowdhooree I. 2019. Indigenous knowledge for enhancing community resilience: an experience from the south-western coastal region of Bangladesh. Int J Disaster Risk Reduct. 40: 101259.

Cochran WG. 1963. Sampling techniques. 2nd ed, New York: John Wiley and Sons Inc.

Dasgupta S, Huq M, Khan ZH, Ahmed MMZ, Mukherjee N, Khan MF, Pandey K. 2014. Cyclones in a changing climate: the case of Bangladesh. Clim Dev. 6(2):96–110.

Datta DK, Roy K, Hassan N. 2010. Shrimp culture: trend, consequences and sustainability in the south-western coastal region of Bangladesh. In Management and Sustainable Development of Coastal Zone Environments.Dordrecht: Springer, p. 227–244.

Erickson NJ, Ahmad QK, Chowdhury AR. 1996. Socio-economic implications of climate change for Bangladesh. In: Implic Clim sea–Level Chang Bangladesh. Berlin: Springer; p. 205–287.

Fekete A, Damm M, Birkmann J. 2010. Scales as a challenge for vulnerability assessment. Nat Hazards. 55(3):729–747.

Füssel HM, Klein RJT. 2006. Climate change vulnerability assessments: an evolution of conceptual thinking. Clim Change. 75(3):301–329.

GFDRR 2016. The making of a riskier future: how our decisions are shaping future disaster risk. Washington DC: Global Facility for Disaster Reduction and Recovery (GFDRR).
Ginige K, Amaratunga D, Haigh R. 2009. Mainstreaming gender in disaster reduction: why and how? Disaster Prev Manag an Int J. 18(1):23–34.
Granger K, Jones TG, Leiba M, Scott G. 1999. Community risk in Cairns: a multi-hazard risk assessment. Aust J Emerg Manag. 14(2):25.
Gunn SWA. 1992. The scientific basis of disaster management. Disaster Prev Manag an Int J. 1(3):16–21.
Haase D. 2013. Participatory modelling of vulnerability and adaptive capacity in flood risk management. Nat Hazards. 67(1):77–97.
Haque DME, Mimi A, Mazumder RK, Salman AM. 2020. Evaluation of natural hazard risk for coastal districts of Bangladesh using the INFORM approach. Int J Disaster Risk Reduct. 48(August 2019):101569.
Helgeson JF, Dietz S, Hochrainer-Stigler S. 2013. Vulnerability to weather disasters: the choice of coping strategies in rural Uganda. Ecol Soc. 18(2):1–14.
Hoque MA-A, Pradhan B, Ahmed N, Ahmed B, Alamri AM. 2021. Cyclone vulnerability assessment of the western coast of Bangladesh. Geomatics, Nat Hazards Risk. 12(1):198–221.
Hossain MN. 2015. Analysis of human vulnerability to cyclones and storm surges based on influencing physical and socioeconomic factors: evidences from coastal Bangladesh. Int J Disaster Risk Reduct. 13:66–75. http://dx.doi.org/10.1016/j.ijdrr.2015.04.003.
Huq SMS. 2016. Community based disaster management strategy in Bangladesh: present status, future prospects and challenges. Eur J Res Soc Sci. 4(2):22–35.
Iqbal MH. 2019. Disparities of health service for the poor in the coastal area: does Universal health coverage reduce disparities? J Mark Access Health Policy. 7(1):1575683.
Islam MR. 2004. Where land meets the sea: a profile of the coastal zone of Bangladesh. Cambridge: University Press.
Islam MT, Charlesworth M, Aurangojeb M, Hemstock S, Sikder SK, Hassan MS, Dev PK, Hossain MZ. 2021. Revisiting disaster preparedness in coastal communities since 1970s in Bangladesh with an emphasis on the case of tropical cyclone Amphan in May 2020. Int J Disaster Risk Reduct. 58:102175.
Islam MR, Hasan M. 2016. Climate-induced human displacement: a case study of Cyclone Aila in the south-west coastal region of Bangladesh. Nat Hazards. 81(2):1051–1071.
Islam MN, Malak MA, Islam MN. 2013. Community-based disaster risk and vulnerability models of a coastal municipality in Bangladesh. Nat Hazards. 69(3):2083–2103.
Kabir R, Khan HTA, Ball E, Caldwell K. 2016. Climate change impact: the experience of the coastal areas of Bangladesh affected by cyclones Sidr and Aila. J Environ Public Health. 2016:9654753.
Kabir I, Rahman B, Smith W, Afreen M, Lusha F, Azim S, Milton AH. 2016. Knowledge and perception about climate change and human health: findings from a baseline survey among vulnerable communities in Bangladesh. BMC Public Health. 16(1):1–10.
Kamal AM. 2013. Livelihood coping and recovery from disaster: the case of coastal Bangladesh. Curr Res J Soc Sci. 5(1):35–44.
Keraita B, Drechsel P, Konradsen F. 2008. Perceptions of farmers on health risks and risk reduction measures in wastewater-irrigated urban vegetable farming in Ghana. J Risk Res. 11(8):1047–1061.
Keskitalo ECH. 2013. Climate change and flood risk management: adaptation and extreme events at the local level. UK : Edward Elgar Publishing.
Khan B. 2007. Methodology for community based hazards vulnerability risk assessment in Gilgit District (Gilgit-Baltistan). UNDP Reg Clim Risk Reduct Proj Himalayas (Pakistan), World Wide Fund Nat Pakistan.
Khan MSA. 2008. Disaster preparedness for sustainable development in Bangladesh. Disaster Prev Manag an Int J. 17(5):662–671.
Khan MR, Rahman MA. 2007. Partnership approach to disaster management in Bangladesh: a critical policy assessment. Nat Hazards. 41(2):359–378.
Lujala P, Lein H, Rød JK. 2015. Climate change, natural hazards, and risk perception: The role of proximity and personal experience. Local Environ. 20(4):489–509.
Mallick B, Ahmed B, Vogt J. 2017. Living with the risks of cyclone disasters in the South-Western coastal region of Bangladesh. Environ - MDPI. 4(1):1–17.

Mallick B, Rahaman KR, Vogt J. 2011. Coastal livelihood and physical infrastructure in Bangladesh after cyclone Aila. Mitig Adapt Strateg Glob Change. 16(6):629–648.

McGranahan G, Balk D, Anderson B. 2007. The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones. Environ Urban. 19(1):17–37.

Menoni S, Molinari D, Parker D, Ballio F, Tapsell S. 2012. Assessing multifaceted vulnerability and resilience in order to design risk-mitigation strategies. Nat Hazards. 64(3):2057–2082.

Minar MH, Hossain MBB, Shamsuddin MD. 2013. Climate change and coastal zone of Bangladesh: Vulnerability, resilience and adaptability. Middle East J Sci Res. 13(1):114–120. http://www.scopus.com/inward/record.url?eid=2-s2.0-84874132449&partnerID=40&md5=adb714e955f1b379e6125de88148024a.

Mohiuddin M, Latif M. 2015. Housing condition of coastal area in Bangladesh: a case study of Kutubdia, Cox’s bazaar. J Environ Sci & Natural Resources. 6(1):15–20.

Monirul Qader Mirza M. 2002. Global warming and changes in the probability of occurrence of floods in Bangladesh and implications. Glob Environ Chang. 12(2):127–138.

Moniruzzaman M, Rahman MA, Hossain MS. 2012. Assessing the physical condition and management system of pond sand filter (PSF) of a coastal community of Bangladesh. J Bangladesh Natl Geogr Assoc. 40(1&2):59–68.

Morshed M, Huda N. 2002. Capacity building to community volunteers under Bangladesh urban disaster mitigation project (BUDMP). In: Reg Work Best Pract Disser Mitig Bali, Indonesia; p. 190–192.

Nadiruzzaman M, Paul BK. 2013. Post-Sidr public housing assistance in Bangladesh: a case study. Environ Hazards. 12(2):166–179.

Nasreen M. 2015. Climate change and migration: Law and policy perspectives in Bangladesh. AsianJLS. 2(1):35–53.

Nirupama N. 2012. Risk and vulnerability assessment: a comprehensive approach. Int J of Dis Res in the Bu Env. 3(2):103–114. https://www.emerald.com/insight/content/doi/10.1108/17595901211245189/full/html.

Pal I, Karnjana J. 2021. Factoring multi-hazard risk perception in risk assessment and reduction measures in landslide and flash flood prone areas—a case study of Sichon District, Nakhon Si Thammarat Province, Thailand. JDR. 16(4):571–578.

Parvin GA, Takahashi F, Shaw R. 2008. Coastal hazards and community-coping methods in Bangladesh. J Coast Conserv. 12(4):181–193.

Perch-Nielsen SL, B. Bättig M, Imboden D. 2008. Exploring the link between climate change and migration. Clim Change [Internet]. 91(3-4):375–393.

Quader MA, Khan AU, Kervyn M. 2017. Assessing risks from cyclones for human lives and livelihoods in the coastal region of Bangladesh. Int J Environ Res Public Health. 14(8):1-26.

Raez H, Lateltin O, Bollinger D, Tripet J. 2002. Hazard assessment in Switzerland—codes of practice for mass movements. Bull Eng Geol Environ. 61(3):263–268.

Rahman MS, Gain A. 2020. Adaptation to river bank erosion induced displacement in Koyra Upazila of Bangladesh. Prog Disaster Sci. 5:100055.

Rahman M, Islam M. 2019. Scarcity of safe drinking water in the south-west coastal Bangladesh. J Environ Sci & Natural Resources. 11(1-2):17–25.

Rashid AKMM. 2013. Understanding vulnerability and risks. In: Disaster risk reduction approaches in Bangladesh. Japan: Springer; p. 23–43.

Renn O. 2004. Perception of risks. Toxicol Lett. 149(1-3):405–413.

Rød JK, Berthling I, Lein H, Lujala P, Vatne G, Bye LM. 2012. Integrated vulnerability mapping for wards in Mid-Norway. Local Environ. 17(6-7):695–716.

Roy A, Basu S. 2020. Determinants of livelihood diversification under environmental change in coastal community of Bangladesh. Asia Pac J Rural Dev. 30(1-2):7–26.

Roy K, Kumar U, Mehed H, Sultana T, Ershad DM. 2009. Initial damage assessment report of cyclone AILA with focus on Khulna district. Khulna, Bangladesh: Unnayan Onneshan-Humanity Watch Kori; p. 31.
Roy T. 2018. Disaster risk reduction interventions in Bangladesh: a case study on selected villages of southwest region.
Sadik MS, Nakagawa H, Rahman R, Shaw R, Kawaike K, Fujita K. 2018. A study on cyclone aila recovery in Koyra, Bangladesh: evaluating the inclusiveness of recovery with respect to predisaster vulnerability reduction. Int J Disaster Risk Sci. 9(1):28–43.
Sadik MS, Nakagawa H, Rahman MR, Shaw R, Kawaike K, Fujita K, Islam SMT. 2017. Systematic study of cyclone Aila recovery efforts in Koyra, Bangladesh highlighting the possible contribution to vulnerability reduction. J Japan Soc Nat Disaster Sci. 36(Special): 107–119. [http://jsnds.org/ssk/ssk_36_s_109.pdf]
Saha CK. 2015. Dynamics of disaster risk in southwestern coastal Bangladesh: an analysis on tropical Cyclone Aila 2009. Nat Hazards. 75(1):727–754.
Saha SK. 2017. Socio-economic and environmental impacts of shrimp farming in the southwestern coastal region of Bangladesh Sebak. Int J Res Land-Use Sustain. (March). 3: 128–137.
Sarker MNI, Wu M, Alam GMM, Shouse RC. 2020. Livelihood diversification in rural Bangladesh: Patterns and determinants in disaster prone riverine islands. Land Use Policy. 96:104720.
Seddiky MA, Giggins H, Gajendran T. 2020. International principles of disaster risk reduction informing NGOs strategies for community based DRR mainstreaming: The Bangladesh context. Int J Disaster Risk Reduct. 48:101580.
Shahjahan M, Bhattacharjee V, Barua P, Molla MH. 2016. Addressing Disability Inclusive Climate Change and Disaster Management in Bangladesh: A review of existing laws, Policies and Strategies. Young Power Soc Action. 55
Shameem MIM, Mottaz S, Rauscher R. 2014. Vulnerability of rural livelihoods to multiple stressors: A case study from the southwest coastal region of Bangladesh. Ocean Coast Manag. 102(PA):79–87. [http://dx.doi.org/10.1016/j.ocecoaman.2014.09.002].
Smith K. 2013. Environmental hazards: assessing risk and reducing disaster. UK: Routledge.
Tate E. 2012. Social vulnerability indices: a comparative assessment using uncertainty and sensitivity analysis. Nat Hazards. 63(2):325–347.
Tobin GA. 1997. Natural hazards: explanation and integration. New York City: Guilford Press.
Toufique K, Yunus M. 2013. Vulnerability of livelihoods in the coastal districts of Bangladesh. Bangladesh Dev Stud. 36(1):95–120.
Uddin MS, Haque CE, Khan MN. 2020. Good governance and local level policy implementation for disaster-risk-reduction: actual, perceptual and contested perspectives in coastal communities in Bangladesh. Disaster Prev Manag an Int J. 30(2):94–111.
UNDP 2004. Reducing Disaster Risk: a Challenge for Development-a Global Report. [http://www.ifrc.org/en/what-we-do/disaster-management/preparing-for-disaster/risk-reduction/reducing-disaster-risk/].
UNISDR 2015. Sendai framework for disaster risk reduction 2015–2030. In: Proc 3rd United Nations World Conf DRR. Sendai, Japan.
Van Aalst MK, Cannon T, Burton I. 2008. Community level adaptation to climate change: The potential role of participatory community risk assessment. Glob Environ Chang. 18(1): 165–179.
Van Niekerk D. 2005. A comprehensive framework for multi-sphere disaster risk reduction in South Africa.
van Riet G. 2009. Disaster risk assessment in South Africa: Some current challenges. South African Rev Sociol. 40(2):194–208. [http://www.tandfonline.com/doi/abs/10.1080/21528586.2009.10425108].
Wallman P. 2005. Impacts of sea level rise on the coastal zone of Bangladesh. Lund: Lund University.
Wamsler C, Brink E, Rentala O. 2012. Climate change, adaptation, and formal education: the role of schooling for increasing societies’ adaptive capacities in El Salvador and Brazil. Ecol Soc. 17(2): 1–19.
Wedawatta G, Kulatunga U, Amaratunga D, Parvez A. 2016. Disaster risk reduction infrastructure requirements for South-Western Bangladesh: perspectives of local communities. Built Environ Proj Asset Manag. 6(4):379–390.

Wisner B, Blaikie PM, Blaikie P, Cannon T, Davis I. 2004. At risk: natural hazards, people’s vulnerability and disasters. London: Psychology Press.

Wisner B, Blaikie P, Cannon T, Davis I. 2014. At risk: natural hazards, people’s vulnerability and disasters. UK: Routledge.

Zafri NM, Nurullah M, Neema MN, Waliullah M. 2021. Spatial accessibility to healthcare facilities in coastal region of Bangladesh. Int J Health Plann Manage. 36(3):643–655.

Zaman S, Mondal MS. 2020. Risk-based determination of polder height against storm surge hazard in the south-west coastal area of Bangladesh. Prog Disaster Sci. 8:100131.