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Risk Analysis of Climate Induced Disaster in Coastal Bangladesh: Study on Dashmina Upazila in Patuakhali District

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Abstract

The coastal region of Bangladesh is highly vulnerable to climate change and climate induced natural disasters. Almost every year the coastal people face different kinds of natural disasters like flood, tropical cyclones, tornadoes, tidal surges, droughts and large scale river erosion. The main aim of this study was to identify, analysis and prioritize the existing climate induced risks in study area. This study was carried out in Dashmina Upazila under Patuakhali District in southern coastal region of Bangladesh. The information has been collected through direct observations, key informant interview, focus group discussion and literature review. The study finds the ranking of various hazards based on their perceived level of impact and severity. Storm surge holds the highest ranking at number one, indicates significant devastation and danger. Following closely behind are cyclones, river bank erosion and floods, ranked at two, three, and four, respectively. Hazards such as storm winds and high tides hold moderate rankings at five and six, indicating their potential for damage but to a slightly lesser extent. Pest attacks, irregular rainfall, and hail storms fall in the mid-range of severity, ranked at seven, eight, and nine, respectively. Lastly, salinity is ranked at ten. The study suggests that the identified disaster risk should consider in time of decision making for planning any development project for disaster risk reduction and the study serves as a guide for prioritizing preparedness and mitigation strategies and allocates resources to tackle higher-ranked hazards that pose greater threats to the community or environment.

Keywords: Coastal region, disaster risk, risk analysis, risk reduction.

Introduction

Bangladesh is recognized as one of the most vulnerable countries globally to the impacts of climate change due to its geographical location and geomorphological conditions (Siddiqui, 2009; Islam et al., 2019). The nation frequently experiences a multitude of disastrous events such as cyclones, floods, saline water intrusion, waterlogging, heavy rainfall, river erosion, storm surges, tidal surges, tornadoes, and droughts, particularly in its coastal regions (Alam, 2005; Biswas et al., 2015; Islam and Hasan, 2016; Faisal et al., 2021). These events lead to significant loss of life, damage to property, environmental degradation, and severe disruptions to livelihoods, particularly affecting the citizens residing in coastal areas (Islam et al., 2019; Saha et al., 2019; Rokonzaman et al., 2023). Over the past two decades, the coastal communities of Bangladesh have faced increasing vulnerabilities due to the compounded risks of multiple hazards. Hazard events pose a risk of transforming into disasters, severely affecting households and communities beyond their coping capacities. This results in widespread human suffering, material losses, and economic and environmental damages (Ashraf Islam et al., 2016; Faisal et al., 2021).



The south-central coastal region of Bangladesh possesses unique environmental characteristics that render it highly susceptible to natural hazards such as floods, cyclones, tornadoes, tidal surges, storm surges, riverbank erosion, and coastal erosion (Saha, 2015; Majumder et al., 2017). Cyclones like SIDR in 2007 and AILA in 2009 have inflicted significant damage to the region, with high floodwaters breaching embankments and causing loss of lives and livelihoods (Saha, 2015; Mallick et al., 2017). Patuakhali, located in the south-central coastal belt, stands out as one of the worst-affected districts, regularly enduring floods, cyclones, storm surges, river erosion, and salinity intrusion almost every year (Biswas et al., 2015; Iva et al., 2017). Studies by Biswas et al. (2016) and Mukherjee et al. (2020) confirm the prevalence of natural hazards in coastal districts, including flooding, high tides, saline water intrusion, riverbank erosion, cyclones, storm surges, tidal surges, excessive rainfall, droughts, waterlogging, and extreme temperatures. Bauphal and Dashmina sub-districts within Patuakhali are particularly vulnerable, exposing various sectors and stakeholders in the coastal area to disaster risks (Biswas et al., 2015; Iva et al., 2017).

Given the imperative of public safety and the necessity to mitigate the adverse impacts of climate-induced disasters, conducting a thorough disaster risk analysis becomes paramount. Such analysis enables stakeholders to identify and prioritize risks, aiding in decision-making processes and facilitating the implementation of interventions. Therefore, it is essential to identify potential climate-induced disasters, assess their vulnerabilities, analyze associated risks, and explore strategies to reduce disaster risk for the safety of people and for development planning. The main aim of this research is to carry out a multi-hazards risk analysis for the coastal at-risk community in Bangladesh. The objectives of the study to identify, analysis and prioritize the existing climate induced risks of the study area by the people perception.

Methods

3.1 Ecology of the Study Area

This study was conducted at Dashmina upazila in Patuakhali District, Bangladesh. The upazila occupies an area of 351.87 square km. It is located between 22°02' and 22°18' north latitudes and between 90°29' and 90°40' east longitudes (Figure 1). The upazila is bounded on the north by Bauphal upazila, on the east by Char Fasson upazila of Bhola zila, on the south by Galachipa upazila and on the west by Galachipa upazila of Patuakhali District (BBS, Jun 2012). Total population in Dashmina Upazila is 123388, population density 351 [sq. km], total households 28490, average size of household 4.3 (BBS, Jun 2012). where male 49%, female 51%, Muslim 93%, Hindu 7%, average literacy 29.6% (BBS, Jun 2012).

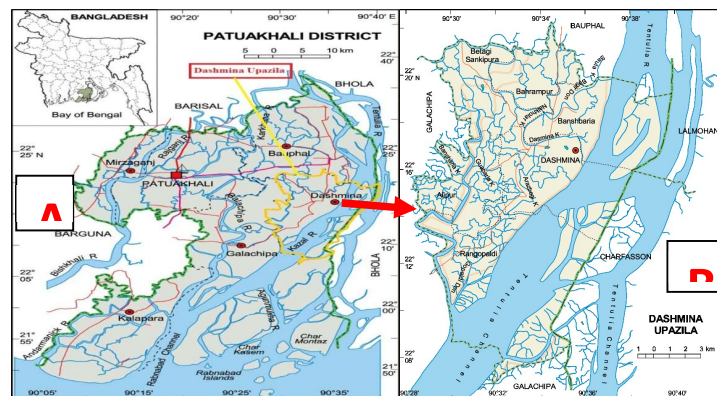
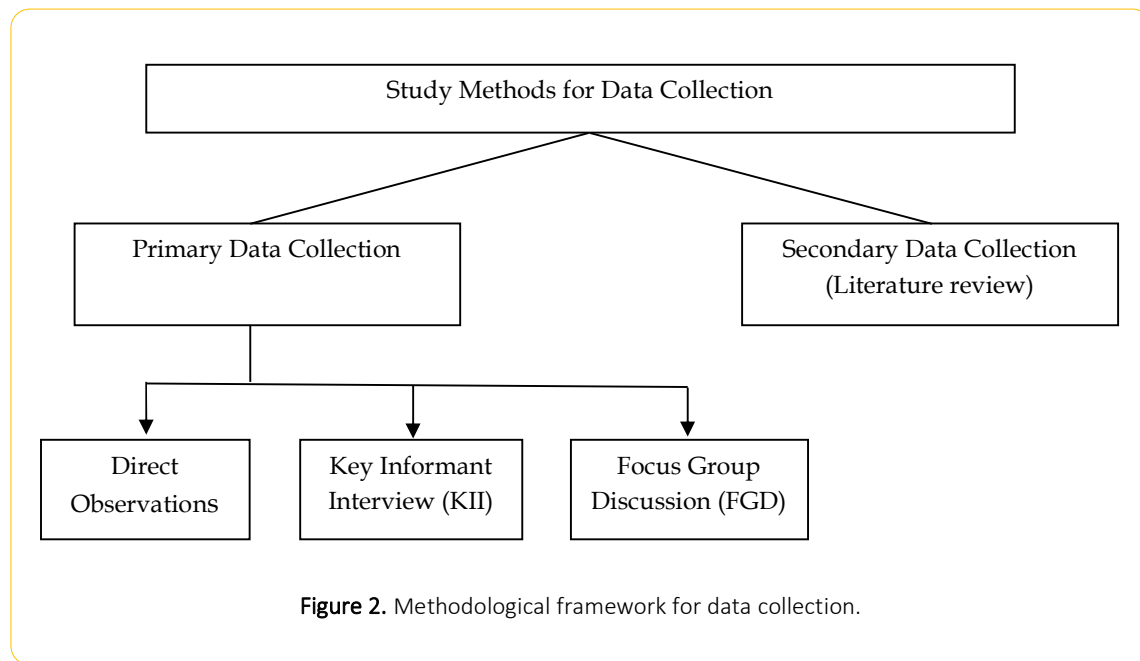


Figure 1. Study area map (A) shows Patuakhali District, the position of it in Bangladesh and position of Dashmina Upazilla in Patuakhali District; map (B) shows the Dashmina Upazila. (Map source: Bangala pedia map).

3.2 Data Collection

In order to meet the research objectives, primary data was gathered from the local community using methods such as Direct Observations, Key Informant Interviews (KIIs), and Focus Group Discussions (FGDs). Secondary data, on the other hand, was sourced from various scientific reports and research articles. The data collected had a quantitative nature. The target demographic for data collection included members of the general public, Community Based Organization (CBO) members, representatives from Union Parishads (the smallest rural administrative and local government units in Bangladesh), social leaders, NGO workers, school teachers, religious leaders, officials from Upazila Parishads, individual households, and the elderly.



Direct Observations

To gain an understanding of climate-induced risks in the study area, direct observations were conducted. This involved conducting transect walks through areas of interest to observe, listen, and identify various levels of risk. The observations focused on answering questions such as: What risks are present? When do these risks occur? Where are they located? Who is affected by them? Why do they occur? How do they manifest? Direct observation validates the information found in Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs).

Focus Group Discussion (FGD)

Following the approach proposed by Hawkins (2009), a smaller group of 6-10 individuals was carefully selected based on their specialized knowledge or perspectives on the issue at hand. In this research, emphasis was placed on engaging experienced villagers who had encountered various natural disasters, including both men and women.

The primary method employed for collecting in-depth descriptive data from the respondents was Focus Group Discussions (FGDs), facilitated by a pre-designed discussion guideline. The questions in the guideline covered various aspects, such as the probability of occurrence, severity of damage, duration of effects, and predictability of hazards. Additionally, discussions encompassed topics like population density in vulnerable areas, presence of high-risk populations in potential danger zones, resilience of housing structures, socio-economic conditions of residents, physical condition of community infrastructure, status of critical services like water and electricity, effectiveness of local government and NGO structures for disaster management, readiness of disaster

preparedness plans, legislation regarding disaster risk reduction (DRR) and preparedness, diversity of livelihood options in the community, availability of government resources for mitigating disaster risks, and community knowledge of different hazards.

A total of 15 Focus Group Discussions were conducted for disaster risk assessment. During these sessions, discussions were recorded using mobile phones and written down in exercise books for further analysis.

Key Informant Interview (KII)

To gather qualitative information, interviews were conducted with individuals possessing sufficient experience relevant to the study objectives, representing various interest groups and perspectives, following the methodology outlined by Hawkins (2009). Key Informant Interviews (KIIs) were conducted with social leaders, school teachers, Community Based Organization (CBO) members, religious leaders, and respective officials of the Upazila Parishad.

A pre-designed interview questionnaire was utilized to facilitate these sessions, focusing on major disasters in the area and validating the data collected from Focus Group Discussions (FGDs). The discussions were recorded in exercise books. A total of 5 key informant interviews were conducted for disaster risk assessment.

Secondary Data Review

The secondary data review involved examining a variety of relevant sources, including reports, books, articles, maps, journals, research papers, websites, thesis papers, and baseline reports from different non-governmental organizations (NGOs).

3.3 Risk Analysis Methods

For the risk analysis most of the studies calculated risk is a function of hazard, vulnerability, and capacity that is widely accepted (Faisal et al. 2021). The following formula (Blaikie et al., 2014; Wamsler et al., 2012) is often used to assess the disasters risk:

$$R = (H \times V)/C \quad (1)'$$

Where, R=Risk; H=Hazard; V=Vulnerability and C= Capacity

At the end of data collection, risk of each disaster was calculated by using the equation (1).

3.4 Data analysis Methods

Hazard assessment involved scoring criteria such as the probability of occurrence, severity of damage, duration of the effect, and predictability of hazards, as described by Zaman and Mondal (2020) and Bhowmik et al. (2021). This assessment was conducted by formulating a series of questions addressing each criterion. For instance, questions included assessing the likelihood of a disaster occurring in the near future, estimating the potential severity of the disaster, predicting its duration, and identifying any pre-warning signs. Numeric scores were assigned to these questions based on respondents' assessments. The total score was calculated by summing up the coded scores for all questions and dividing by the total number of questions, as outlined by Faisal et al. (2021).

Similarly, vulnerability assessment was conducted using various criteria, including population density in vulnerable areas, presence of high-risk populations, resilience of housing structures, socio-economic conditions, and status of critical services, following the approach of Afjal Hossain et al. (2012) and Al-Maruf et al. (2021). Questions were formulated based on these criteria and assigned numerical values. The cumulative score was calculated similarly to the hazard assessment.

Capacity evaluation involved assessing criteria such as the state of local government and NGO structures, status of disaster preparedness plans, effectiveness of legislation, diversity of livelihood options, availability of resources, and community knowledge, as described by Islam et al. (2021), Seddiky et al. (2020), and Uddin et al. (2021).

Questions were formulated to evaluate each criterion and assigned numerical codes. Scores were calculated by summing up the coded responses and dividing by the total number of questions.

Finally, the risk of each hazard was calculated based on equation (1). Data analysis and representation were performed using Microsoft Excel 2010, with quantitative data presented in tabular and graphical formats. The research was concluded after thorough data rechecking and presentation. Microsoft Office Word 2010 was utilized for report preparation.

Results

4.1 Disaster Risk Assessment of Study Area

4.1.1 Potential Climate Induced Disaster in the study area

Through key informant interviews (KII) and life histories, potential climate-induced disasters in Dashmina Upazila were identified. During these sessions, respondents were queried about major disasters prevalent in the area. The findings revealed that 100% of the respondent's reported exposure to various climatic hazards year-round. Cyclones, storm surges, floods, riverbank erosion, storm winds, irregular rainfall, hailstorms, high tides, salinity, and pest attacks were cited as frequent occurrences by all respondents. Additionally, waterlogging, droughts, thunderstorms, and nor'westers were categorized as medium hazards by 80% of the respondents, while cold waves, fog, and earthquakes were perceived as low hazards by 20%.

These findings align with previous studies conducted in Patuakhali district, which indicate recurrent natural hazards such as floods, cyclones, storm surges, river erosion, and salinity intrusion (Biswas et al., 2015; Iva et al., 2017). Similar results were observed in studies by Biswas et al. (2016) and Mukherjee et al. (2020), emphasizing the prevalence of flooding, high tides, saline water intrusion, riverbank erosion, cyclones, storm surges, tidal surges, excessive rainfall, droughts, waterlogging, and extreme temperatures in coastal districts. For the risk analysis, hazards frequently mentioned by 100% of the respondents were selected (Table 1).

4.1.2 Hazard Scoring

The results of the hazard scoring framework revealed valuable insights into the relative severity and potential impact of various hazards in the study area. River Bank Erosion emerges as the most critical hazard, with a high score of 7.42 (Figure 3), indicating its substantial threat to communities, infrastructure, and ecosystems. This finding underscores the urgent need for measures to address and mitigate the effects of river bank erosion, which can lead to significant land loss, property damage, and population displacement.

Following closely behind are Storm Surge and Storm Wind, with scores of 6.35 and 6.14, respectively (Figure 3). These hazards pose significant risks, particularly in coastal regions, where they can cause extensive damage to infrastructure and pose threats to human lives. Similarly, Cyclones and Pest Attacks rank high, with scores of 6.33 and 6.51, highlighting their significant impacts on agricultural sectors and human settlements. While hazards like Salinity, Irregular Rainfall, and High Tide have comparatively lower scores ranging between 3.25 and 4.94, they still present substantial challenges to agricultural productivity, water resources, and coastal areas. Additionally, even though Hail Storms have a relatively low score of 3.35, they can still cause localized damage, warranting attention in disaster preparedness and mitigation efforts.

Overall, the hazard scoring framework provides a comprehensive understanding of the varying degrees of hazards in the study area, allowing for prioritization of resource allocation, disaster preparedness, and resilience building strategies. These findings can inform policymakers, disaster management agencies, and communities in developing tailored strategies to address the specific risks posed by each hazard, thus contributing to effective risk mitigation and sustainable development efforts.

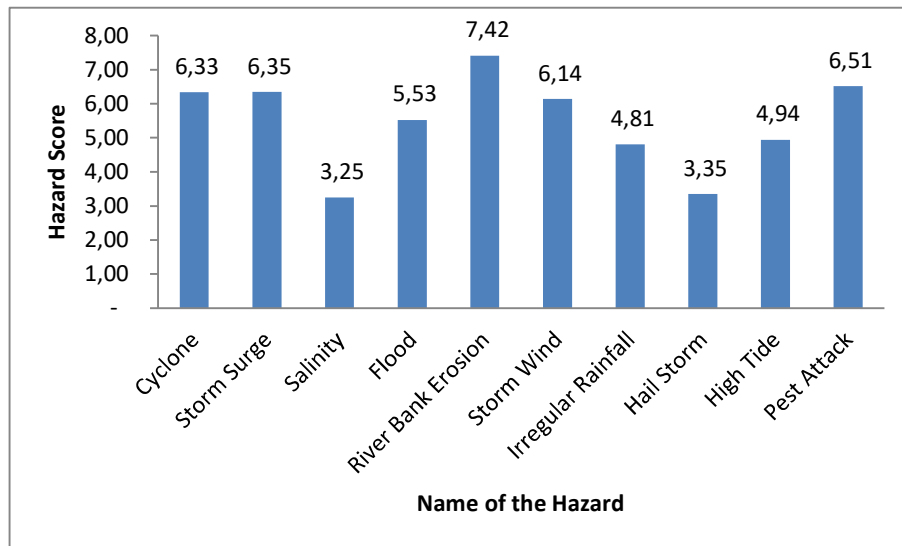


Figure 3. Hazard Scoring.

4.1.3 Vulnerability Scoring

The vulnerability score revealed that Storm Surge and Cyclones emerge as the most severe threats, with scores of 8.25 and 8.34 respectively (Figure 4). These high scores indicate the increased vulnerability of areas or populations to these specific threats, highlighting their capacity to cause extensive damage due to high wind speeds and accompanying flooding. River Bank Erosion and Floods follow closely behind, with scores of 7.23 and 7.11 respectively, signifying their ability to disrupt habitats and infrastructure through gradual erosion or sudden inundation. Storm Winds present a considerable threat as well, scoring 6.05 due to their destructive force. High Tide, while impactful, scores lower at 4.88, likely because its effects are more predictable and localized. The lower scores assigned to threats like Pest Attacks, Irregular Rainfall, Hail Storms, and Salinity (ranging from 3.11 to 2.69) indicate their comparatively lesser but still notable potential for agricultural or localized damages.

Overall, the vulnerability scoring framework provides valuable insights into the relative susceptibility of the region or community to various hazards. These findings can inform decision-makers and stakeholders in developing targeted strategies for disaster preparedness, mitigation, and resilience building efforts. By understanding the specific vulnerabilities associated with each hazard, effective measures can be implemented to reduce the potential impacts and enhance the overall resilience of the region or community.

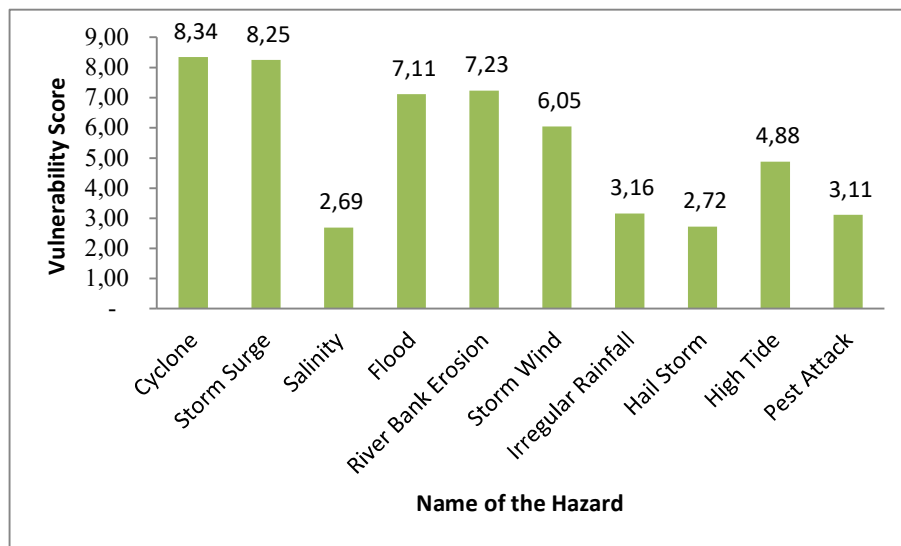


Figure 4. Vulnerability Scoring.

4.1.4 Capacity Scoring

The capacity score showed that Storm Surge and Cyclones, rated at 3.44 and 3.47 respectively, indicate lower managing capacities, making them more severe threats compared to other hazards. River bank erosion and floods, scoring 4.71 and 4.19 respectively (Figure 5), suggest a lower managing capacity, increasing the potential for extensive damage to habitats and infrastructure. Storm wind and high tides, scoring 5.07 and 5.83, denote heightened danger due to their ability to cause widespread destruction. Moving up the scale, pest attacks and irregular rainfall, scoring 6.48 and 6.60, highlight the substantial impact on agriculture and livelihoods. At the upper end, hail storms and salinity, scoring 6.97 and 7.95, demonstrate severe implications for crops and ecosystems.

These scores serve as crucial indicators of potential hazards, guiding proactive measures and resource allocation to mitigate their detrimental effects on communities and environments. The assessments likely consider various elements such as historical data, potential damage, frequency, and geographical impact to determine the overall capacity and preparedness required to mitigate the risks associated with each hazard.

The lower scores imply a greater need for proactive measures, resource allocation, and community resilience strategies to effectively address potent threats like river bank erosion, floods, storm wind, and high tides, which present considerable challenges and impacts on affected regions or communities.

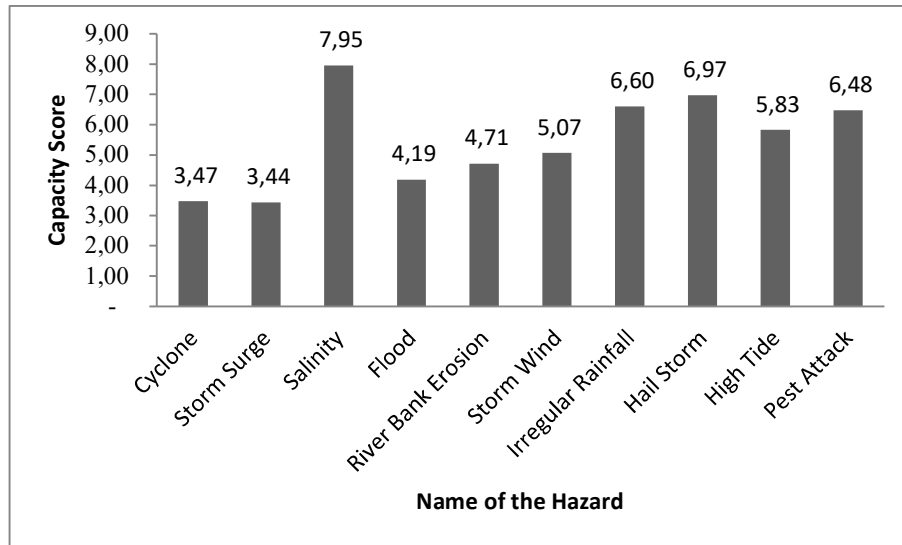


Figure 5. Capacity Scoring.

4.1.5 Risk Analysis

After analyzing the Hazard (H), Vulnerability (V) and Capacity (C) their score was calculated. The table 1 presents Risk (R) score, calculated using the formula $R = (H \times V) / C$, determines the overall risk level posed by each hazard. A higher R score implies a greater risk, taking into account both the hazard's severity and the vulnerability of the affected area while considering its capacity to manage the hazard. The Hazard (H) score represents the inherent danger or intensity of each hazard, where higher scores indicate more severe threats. Vulnerability (V) scores measure the susceptibility of a region or system to these hazards, with higher scores indicating higher susceptibility. Capacity (C) scores reflect the ability of a community or infrastructure to cope with or mitigate the impact of these hazards, where higher scores denote better preparedness and resilience. The rankings, based on the Risk scores, showcase the prioritization of hazards concerning their potential impact and the level of preparedness required to mitigate their effects.

Among the hazards listed, Storm Surge holds the highest risk (Ranking 1) with a Risk (R) value of 15.24, closely followed by Cyclone at a Risk (R) value of 15.22, securing the second position. This ranking indicates that Storm Surge and Cyclone are the most threatening hazards in this assessment due to their relatively high Hazard (H) and Vulnerability (V) scores in contrast to their Capacity (C) scores. On the other hand, hazards like Salinity, Irregular Rainfall, and Hail Storm have comparatively lower Risk (R) values, positioning them toward the lower end of the ranking. These hazards exhibit lower Hazard (H) and Vulnerability (V) scores or higher Capacity (C) scores, indicating they might pose a lesser risk compared to the top-ranked hazards. River Bank Erosion, Flood, and Pest Attack fall in the mid-range of the ranking, indicating a moderate level of risk concerning their impact, as they possess moderately balanced scores across the Hazard (H), Vulnerability (V), and Capacity (C) parameters.

Table 1. Risk Analysis.

Hazard	Hazard (H) Score	Vulnerability (V) Score	Capacity (C) Score	Risk (R) $R=(H \times V)/C$	Ranking
Cyclone	6.33	8.34	3.47	15.22	2
Storm Surge	6.35	8.25	3.44	15.24	1
Salinity	3.25	2.69	7.95	1.10	10
Flood	5.53	7.11	4.19	9.39	4
River Bank Erosion	7.42	7.23	4.71	11.38	3
Storm Wind	6.14	6.05	5.07	7.32	5
Irregular Rainfall	4.81	3.16	6.60	2.30	8
Hail Storm	3.35	2.72	6.97	1.30	9
High Tide	4.94	4.88	5.83	4.14	6
Pest Attack	6.51	3.11	6.48	3.13	7

Source: Focus Group Discussion (FGD).

In summary, this table offers a comprehensive evaluation of various hazards, enabling a comparative analysis of their potential risks based on their individual characteristics of hazard severity, vulnerability and capacity, aiding in informed decision-making for risk management and mitigation strategies.

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 (Faisal et al. 2021). The study presents a risk analysis involving various natural phenomena or events, quantifying their risk based on a formula incorporating three factors: the hazard (H), vulnerability (V), and coping capacity (C). The risk (R) is calculated using the formula $R = (H \times V)/C$ (Blaikie et al., 2014; Wamsler et al., 2012). Each hazard is assigned a numerical risk value, and they are ranked accordingly. Figure 6 shows Storm Surge is identified as the most severe risk (Ranking 1) with a high score of 15.24, indicating its potential to cause significant damage due to its combination of hazard intensity, vulnerability of the affected area or population, and limited coping capacity. Faisal et al. (2021) noted that tidal surge got the highest priority hazard occurring in coastal area of Bangladesh. Similar result also found in the study of Hossain (2015) and Islam et al. (2019). Similarly, Cyclone follows closely behind with a score of 15.22 (Ranking 2). These findings are in keeping with other studies such as Faisal et al. (2021), Ahsan et al. (2020), Kabir et al. (2016), Sadik et al. (2018). Studies revealed that the frequency of the cyclone event in the coastal area of Bangladesh has been increased noticeably (Murshed et al., 2022; Sarkar et al., 2024). 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 coastal area. River Bank Erosion (ranking 3) also highlights its significant risk level. Similar result also found in the study of Hasan et al. (2018); Roy et al. (2021); Faisal et al. (2021) and Murshed et al. (2021). Hazards like irregular rainfall hailstorms and salinity pose relatively lower risks (Rankings 8, 9, and 10) due to their comparatively lower severity, vulnerability, or the region's better coping mechanisms. Storm Surge is identified as the most critical threat, likely due to its potential to cause significant coastal flooding and damage. Floods, Storm Winds, and High Tides follow closely behind, reflecting their substantial capacity to cause destruction and disruption. Lower in the

ranking, hazards like Salinity, Irregular Rainfall, Hail Storms, Pest Attacks, and Critically Irregular Rainfall are considered relatively less severe but are still recognized as potential risks, with Salinity and Pest Attacks holding the lowest rankings (10 and 7, respectively). Sometimes vulnerabilities not indicate the high risk. For an example from the Table 1 we find that the cyclone got the highest vulnerability score but after completing the total disaster risk analysis process it is seen that storm surge got the ranking 1 (one), that means Storm surge is the most devastating disaster in study area. The main reason of that case is the high capacity to manage the cyclone disaster and low capacity to manage the storm surge disaster.

Vulnerability scoring reaffirms the susceptibility of the region to hazards like Storm Surge and Cyclones, emphasizing the urgent need to bolster community resilience and enhance early warning systems. Capacity scoring highlights existing challenges in managing hazards such as Storm Surge, Cyclones, River Bank Erosion, and Floods, emphasizing the importance of investing in infrastructure, institutional capacity, and community preparedness to reduce overall risk.

The risk analysis offers valuable insights for policymakers, disaster management agencies, and local communities, guiding prioritization of resources and interventions. With Storm Surge and Cyclones emerging as the most menacing hazards, concerted efforts are required to address these threats effectively. The study's findings can inform targeted mitigation and preparedness strategies tailored to the specific risks faced by affected regions, ultimately contributing to enhanced resilience and reduced disaster impacts.

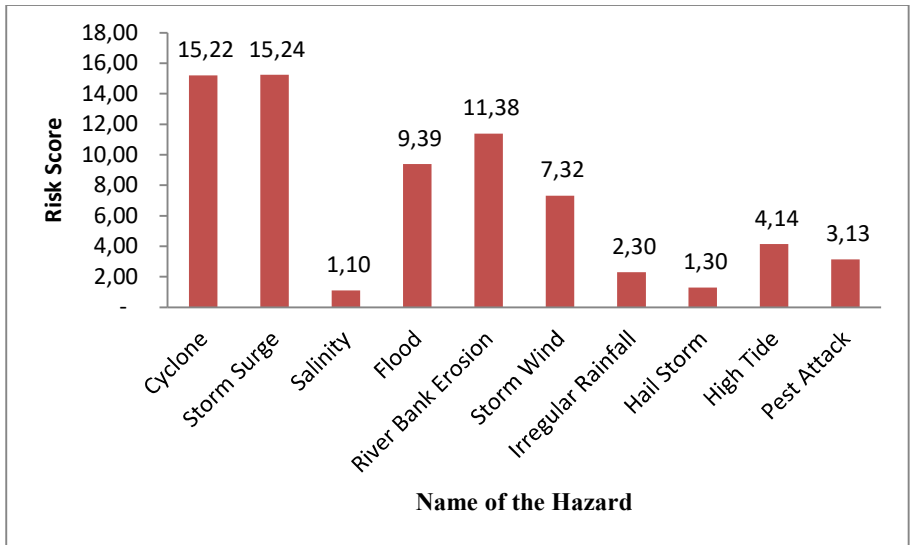


Figure 6. Risk Analysis.

Institutional collaboration, economic safety, good governance, a proper budget, crisis management framework and sustainable environmental management which will reduce the vulnerability and increase the capacity to manage different disasters in coastal Bangladesh (Mukherjee et al., 2020; Sammonds et al., 2021; Khan et al., 2022). This study can serve as a guideline for prioritizing resource allocation, preparedness strategies, and mitigation efforts based on the perceived severity of each hazard in the context of their potential impact on the affected region or community.

Conclusions

The vulnerability of people in Bangladesh to disasters and climate change is a pressing concern, with the coastal region particularly susceptible to climate-induced natural disasters. Through a comprehensive hazard ranking system, this study sheds light on the varying levels of risk posed by different hazards, offering valuable insights for prioritizing mitigation and preparedness efforts. The study presents a ranking of various hazards, each assigned a numerical value from 1 to 10 based on their perceived level of threat or risk. Storm Surge holds the highest risk level with a ranking of 1, indicating its significant potential for causing damage. Following closely behind are Cyclones at 2 and River Bank Erosion at 3, both presenting considerable threats. Floods, Storm Winds, and High Tides fall within the mid-range rankings of 4, 5, and 6, respectively, showcasing their moderate yet impactful risks. The hazards deemed less severe include Irregular Rainfall at 8, Pest Attacks at 7, Hail Storms at 9, and Salinity at 10, suggesting they are seen as comparatively lower threats, though they can still pose challenges or disruptions. Overall, the study highlights the critical importance of addressing vulnerabilities exacerbated by river bank erosion, particularly in areas lacking embankments such as Bashbaris, Dashmina, and Rong Gopaldi. Repairing and fortifying embankments using a combination of indigenous and scientific knowledge is recommended to mitigate the risk of various hazards, including storm surge, cyclones, river bank erosion, and monsoon floods. By prioritizing interventions based on the severity of hazards and leveraging both traditional and modern approaches, communities and policymakers can enhance resilience and reduce the impact of disasters on vulnerable populations in Bangladesh. This integrated approach is crucial for building sustainable and adaptive systems capable of withstanding the growing challenges posed by climate change and natural disasters.

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