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Risk Perceptions and Vulnerability Assessment: Induced from Tropical Cyclone in the Southern Part of Coastal Bangladesh

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Abstract: The coastal area that borders Bangladesh is extremely vulnerable to natural disasters like tropical cyclones, which cause the majority of the damage and fatalities related to flooding. This study attempts to evaluate the susceptibility of coastal flooding induced by tropical cyclones in the South-Western coastal region of Bangladesh. It also identifies the relationship between the influencing factors and respondents' perceptions of risk in terms of socio-economic characteristics. Data was gathered by using a standardized interview schedule from coastal households of three districts named as South Khali (Bagerhat), Padma Pukur (Satkhira), and Rangopaldi (Patuakhali). The survey was taken through interview to assemble information on risk perception, also explores the impact of flood risk on agriculture, environment and livelihood sectors to describe the most specific vulnerable one of different regions that provides a robust insight of affected residents. Moreover, twenty-one predominant factors in terms of three components reveal a strong relationship with severity to flood risk. Results also indicate that, vulnerability indexes differ significantly (p value < 0.05) in the study areas (vulnerability index = 0.54 in South Khali, 0.77 in Padma Pukur, and 0.74 in Rangopaldi). In addition, disaster vulnerability index differs with different socio-economic and geographical factors which enhance the negative effect of flood for the coastal community. The study also reveals that, the selected area had no adequate dam and embankment, cyclone shelter as well as material support from the government and non-government organization which makes their life risky to flood. The research recommends that, generating different livelihood options, self-organization by different disaster preparedness training program to enhance their resilience, indigenous and disaster risk reduction strategies, build more coastal flood shelters and restore people's livelihoods by supplying agricultural seeds, livestock, poultry etc. significantly minimize the vulnerability of the affected community.

Keywords: Risk assessment; Tropical cyclone; Flood; Livelihood resilience; Coastal community.

INTRODUCTION

Bangladesh is situated between the border line of India and Myanmar where the Bay of Bengal covers the southern part of the country. This geographical setting makes the country most vulnerable to extreme climatic events where it is listed as the fifth most disaster-prone nation in the world (Becker *et al.* 2019; Mallick *et al.* 2017). It is mostly vulnerable to floods caused by cyclonic storm surge because of its placement in the path of tropical cyclones, the funneling shape with a wide and shallow continental shelf of the coast. Because of the thin continental shelf, the surge greatly intensifies as it gets closer to shore, resulting in destructive floods along the coast (Karim and Mimura 2008). Bangladesh's entire coastline is below 10 meters in elevation, and the land along the coast is sinking (Becker *et al.* 2019; Karim and Mimura 2008). Additionally, the country is densely inhabited, with an average of 1,240 people per km2 in 2018 (World Bank 2018; Fakruddin and Rahman 2014), with 40% people of the world's reside 100 km or less from a coast, making it primarily vulnerable to coastal flooding. One of nature's most destructive extreme events is tropical cyclones, which are characterized by powerful winds, copious amounts of rainfall, and enormous storm surges (Haque *et al.* 2018). When landfall occurred, a deadly storm surge with 3-4 meter height is appeared along the south-western coastlines of Bangladesh (Hossain *et al.* 2014). In large coastal locations, this storm surge may result in significant flooding that causes losses to the environment, economy, and society (Hsu et al. 2017). Bangladesh's Satkhira and Khulna districts, along with Laksmipur, Noakhali, Feni, Chittagong, Cox's Bazar, Bagerhat, Pirojpur, Barisal, Patuakhali, and Bhola, suffered the heaviest damage (Hossain *et al.* 2014).

Short term flood events as a consequence of tropical cyclone profoundly influence the life and welfare of many people in Bangladesh. Coastal flooding in 1987, 1988, 1991 and 2007 has affected 100 million peoples in Bangladesh and 60% of its territory surface changed dramatically (Werle *et al.* 2000). This situation kills people, damage their livestock and property, leaves many areas without crops, reduced fisherman and displaced many others drastically (Ahmed *et al.* 2016; Paul 2009). During the severe cyclone of (November 1970, April 1991, May 1997 and November 2007), associated storm surge was more than 4 m with gusts of wind exceeding 220 km/h (Karim and Mimura 2008). Furthermore, it is claimed that, the reason behind the appreciable rise in the frequency of natural disasters (floods, cyclones, etc.) is thought to climate change over the past several decades, especially in the Bangladesh's coastal regions (Karim and Mimura 2008; Paul and Hossain 2013).

Several studies (Alam *et al.* 2022; Sattar *et al.* 2020; Sattar and Cheung 2019; Abdullah *et al.* 2016) was involved to assess the risk of TC on people's livelihoods. According to (Haque *et al.* 2012) the death rate from cyclones has decreased in Bangladesh, though it is still challenging to evacuate before one. The economic effect of cyclone Aila is evaluated by (Abdullah *et al.* 2016) and they found that higher-income households were more vulnerable in Koyra (a sub-district of Khulna, Bangladesh) than the lower one. As the destitute people had fewer assets to lose something and could continue their livelihood by the forest resources. One of the studies of (Sattar and Cheung 2019) have focused on risk perception and risk reduction analysis of tropical cyclone for coastal part of Bangladesh, combining household and expert perspectives and concluded that risk perception assessment is a precondition for executing any plan or strategy for reducing risk. They also found that, there is a knowledge gap in reducing the risk of disasters and preparing for climate change mechanism among local people. Results also showed that, female participants are slightly at higher risk than the male one. However, (Sattar *et al.* 2020) have concentrated on the knowledge gaps that currently exist regarding humanitarian actions in Bangladesh's coastal areas, and they found that the health sector was the most vulnerable followed by the shelter settlement.

Numerous studies on risk assessment (Mallick *et al.* 2017; Islam *et al.* 2016; Alam and Collins 2010) were carried out in the coastal region of Bangladesh's to ascertain which measures should be given top priority for implementation by policymakers. Numerous studies (Bernard *et al.* 2022; Hoque *et al.* 2019; Quader *et al.* 2017; Sahoo and Bhaskaran 2018) usually pay attention on flood risk and other patterns of social vulnerability to address cyclone flood vulnerability. However, several factors influence social vulnerability assessments including gender, level of education, income, livelihood opportunities, perceptions of hazards, scale and intensity of hazards, magnitude of the structural and economic damage, and resource availability (Sattar and Cheung 2019; Quader *et al.* 2017).

A review of the current research shows that, while several studies have examined various aspects of coastal flooding, cyclones, and storm surges in Bangladesh, there is still a deficiency in the systematic documentation of risk assessment and the identification of the various underlying factors that influence the vulnerability of the region to flooding caused by cyclones. So, the current study aims to investigate risk perceptions and vulnerability assessment in light of the cyclone-enforced floods in coastal Bangladesh. Additionally, an effort has been made to elucidate how various factors, including age, gender, education, occupation, dwelling location, and types, affect the degree of vulnerability as well as to explain the sector specific vulnerability based on agriculture, environment, livelihood and the composite index.

MATERIALS AND METHODS

Study Area

Prior to data collection, the investigated areas were identified based on the sampling procedure that required three steps to complete. Firstly, we chose 19 Bangladeshi coastline districts, namely Bagerhat, Satkhira and Patuakhali. In addition, there are nine Upazillas (sub-districts) in the Bagerhat district, compared to seven in Sathkhira and Patuakhali. In the second stage, we selected three Upazillas such as Sarankhola, Shyamnagar and Dashmina from Bagerhat, Satkhira and Patuakhali

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respectively. Finally, we identified three unions (the smallest local government and administrative rural unit in Bangladesh) such as South Khali, Padma Pukur, and Rangopaldi from each of the chosen Upazillas (Figure1). The first and foremost reason behind selecting these areas is that, they were badly affected by coastal flooding which originated from Cyclone Aila (2009) and Cyclone Fani (2019) (Sattar *et al.* 2020; Rawlani and Sovacool 2011). During cyclone Fani, it is apparent that, about 100 families were affected by coastal floods in Southkhali and Bagerhat (Hossain, 2019). In addition, a 150-meter embankment was damaged in this area during that time period. It was also reported that, more than 34,000 people became homeless in Gabura and Padma Pukur union in Satkhira district, and 10 people died in Padma Pukur during cyclone Aila (Subhani and Ahmad 2019).

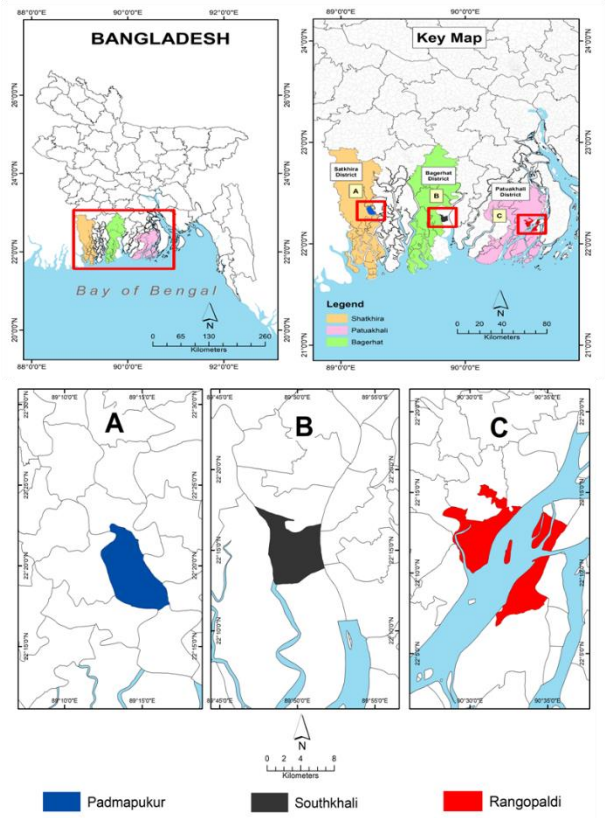

Figure 1. Study areas in Bangladesh: Padma Pukur (blue), South Khali (black), and Rangopaldi (red) unions from Satkhira, Bagerhat, and Patuakhali districts respectively

Data collection and sampling methods

For the determination of the sample size Equation (1) was utilized with a 95% confidence level, 0.5 variability, and 10% level of precision (Sattar and Cheung 2019; Sam *et al.*, 2017; Yamane 1973).

$$n = \frac{N}{1+N(e)^2} \qquad (1)$$

Where, n = Size of sample, N = Size of population (The total number of residences within the locations under study), and e = precision level.

The total number of households in South Khali, Padma Pukur and Rangopaldi unions are 6179, 5495 and 5112, respectively (Bangladesh Bureau of Statistics 2015). By applying equation 1, the sizes of the sample for the three unions were selected as 98.407, 98.212, and 98.081 consecutively. As a result, we took into account 300 households in total from three districts, where each study area consisted of 100 household samples. The households were chosen according to their geographical locations, including their proximity to rivers and dams, their distance from cyclone shelters, and away from rivers and dams. Moreover, previous studies (Sattar *et al.* 2020; Mills *et al.* 2016; Wachinger *et al.* 2013; Kellens *et al.* 2011; Peacock *et al.* 2005) have reported that some socio-economic factors such as gender, age, income, housing type, house location, occupation, education, and past cyclone experience can influence respondents' risk perceptions and actions (Table 1). Our research team took help from local people/leaders to choose the participants so that, we can easily identify suitable victims and communicate them. However, the lack of a local leader allowed for the collection of the data because it may have influenced participants' opinions from various angles. The Covid-19 period coincided with the field survey's execution in December 2020, and the Kobo Toolbox (https://www.kobotoolbox.org/) was used to gather data for this purpose. This toolbox is simple, robust and powerful for data collection.

In order to assess the consequences of the flood and to improve the validity and reliability of the information, we created a detailed and structured questionnaire and conduct face-to-face verbal interaction with the participant. The generated questionnaire was finalized following expert consultation and pre-testing in the field. To ensure a diverse range of individuals, the samples were selected at random with consideration to evolving gender viewpoints and socio-economic conditions. Further details have been observed during conversations with several groups of people within the designated region. After collecting qualitative data based on questionnaires, a conversion of the quantitative format was required to calculate the indices. Finally, we provided a description of the indicators and their relative weights in the subsequent section, which were created using pre-defined indicators.

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Indicators and impact assessment

Previous studies revealed that, some factors such as, social bonding, social income, occupation, duration and the intensity of precipitation, flood frequency and location of the house etc. influence the components of risk. To assess the risk and impact of coastal flooding on people's livelihood, we constructed 21 indicators: 6 for the agriculture component of disaster risk, 3 for the environment component of disaster risk, and 12 for the livelihood component of disaster risk (Table 2). Detailed descriptions of these indications are added in the supplementary material, which were related to the participants' previous experience with coastal flooding. We considered the following factors when the questionnaires were constructed (see the supplementary material):

a) Socio-economic**:** Income, education, occupation, insurance, house-rent, access to the tube- well for the

purposes of drinking water, access to electricity, availability to an improved toilet, shortages of food and preservation of arid foods.
b) Environmental: Frequency, duration and the severity of flooding.
c) Physical**:** Type of dwelling, construction materials and infrastructure.
d) Geographical: The house location, location of agricultural land and how far it is from the closest medical institution.
e) Psychological: Chronic disease, pregnancy, disability, or mental illness.
f) Demographics: Gender, population, and family structure.
We determined scores ranging from 0 to 1 based on the various indicator classes in this study. The maximum weight value is 1, while the lower class is less than 1. We allocated weights of 1 or 0 to the Yes or No classes. Therefore, all values of the composite indices are between 0 and 1. The lower weight of indicators indicates the safer condition of affected areas (e.g., 0.2 indicate very low/very good) and the higher weight of indicators presents the insecure condition (e.g., 1 indicates Very High/Very Bad). Again 0 indicates a secure situation whereas 1 means an insecure condition.

$$CVI = \frac{W+W_2+W_3+\ldots W_n}{n} = \sum_{i=1}^{n} \frac{W_i}{n} \quad (2)$$

Where, CVI is the combination of vulnerability index, W_1 to W_n are the respective weights assigned to indicators, and n is the number of indicators used to estimate the CVI.

$$\textit{Agricultural Index (AI)} = \frac{\sum_{i=1}^{6} AW_i}{n} \quad (3)$$

$$\textit{Environmental Index (EI)} = \frac{\sum_{i=1}^{3} EW_i}{n} \quad (4)$$

$$\textit{Livelihood Index (LI)} = \frac{\sum_{i=1}^{12} LW_i}{n} \quad (5)$$

Following sector-specific index computation, CVI was calculated by using the equation (2). Several recent research have employed a similar methodology (Islam *et al.* 2020; Sattar *et al.* 2020; Sattar and Cheung 2019; Rana and Routray 2016; Gain *et al.* 2015).

Data analysis

We employed statistical methods to test the significance level of the survey results. Significant numerical values were assigned with different indicator classes (Table 2) for assessing the disaster vulnerability index. IBM SPSS Statistics 25 was used to do a one-way analysis of variance (ANOVA). We used the paired t-test and the standard Student's t-test to determine sample size and it was notified that the difference in results between the t-test and ANOVA was negligible. So, the ANOVA test and descriptive statistics in terms of frequency is reported in the following study.

Research ethics and demographic information of the respondents

The participants were chosen at random, and they voluntarily provided their responses to the questions during field survey. The questionnaires were pre-examined before to final data collection in order to make them factual with regard to local catastrophe susceptibility issues and mitigation techniques. Before beginning the survey, participants were given an explanation of the research aims, and the surveys were carried out at a convenient time. As the participants joined spontaneously, no financial support was provided to them. Funding organizations had no influence over the process of gathering data, analyzing it, creating reports, or preparing manuscripts.

To determine the severity of cyclone effects, the socio-economic aspect is crucial. Variation in age and gender is important in this situation. Because of their greater physical strength and financial considerations, men are less vulnerable than women. As a result, the frequency of age and gender variance in sampling has received particular attention. Important indicators are the number of family members and the earner in the household. Higher dependency rates indicate a higher danger because dependents are less mobile than adults and will need special help.Beside this, the relationship between vulnerability and kind of income source/job bears a significant importance. It also changes depending on whether a given occupation's sources of revenue are unstable or stable (Kulatunga *et al.* 2014**).** Agricultural fields and homes are more susceptible to hazards as they get closer to rivers and uplands, which affect how exposed they are to dangers (Cutter *et al.* 2000**).** The greater literacy boosts people's access to information and resources, which improves the ability of households. For this focus has taken on Household's education level (Zhou *et al.* 2015). Building/house construction materials can affect cyclone exposure and vulnerability that's why types of houses have taken in special consideration (Fedeski and Gwilliam 2007**).**

Table 1. The participant's socio-economic profiles of at the household level

Socio-economic characteristics		Bagerhat		Satkhira		Patuakhali	
		Frequency	%	Frequency	%	Frequency	%
Age	<=30	30	10	31	10.33	42	14
	31-45	47	15.67	27	9	25	8.33
	46-60	17	5.67	27	9	24	8
	>60	6	2	15	5	9	3
Gender	Male	67	22.33	42	14	62	20.67
	Female	33	11	58	19.33	38	12.67

	Other	0	0	0	0	0	0
Number of family members	<4	14	4.67	27	9	15	5
	4--5	52	17.33	48	16	45	15
	6--7	25	8.33	14	4.67	25	8.33
	>7	9	3	11	3.67	15	5
Earning members in a family	0	1	0.33	1	0.33	1	0.33
	1	76	25.33	77	25.67	70	23.33
	2	17	5.67	17	5.67	18	6
	3	6	2	2	0.67	7	2.33
	>4	0	0	3	1	4	1.33
Occupation of the household's head	Government job	0	0	0	0	1	0.33
	Agriculture	6	2	13	4.33	17	5.67
	Fishing	48	16	26	8.67	11	3.67
	Day-Labour/Others	46	15.33	61	20.33	71	23.67
Types of house	Pacca	1	0.33	17	5.67	7	2.33
	Tin-shaded	81	27	15	5	31	10.33
	Kaccha	18	6	68	22.67	60	20
	Homeless	0	0	0	0	2	0.67
Location the of house	Highland	1	0.33	2	0.67	7	2.33
	Floodplain	68	22.67	0	0	16	5.33
	Adjacent to river	18	6	50	16.67	33	11
	Lowland	13	4.33	48	16	44	14.67
Most agricultural field location	Highland	0	0	2	0.67	3	1
	Floodplain	37	12.33	1	0.33	14	4.67
	Adjacent to river	11	3.67	34	11.33	43	14.33
	Lowland	14	4.67	38	12.67	36	12
	No agricultural land	38	12.67	25	8.33	4	1.33
Household head's educational level	Masters	0	0	2	0.67	1	0.33
	Bachelor	4	1.33	6	2	7	2.33
	Secondary/ Higher Secondary	30	10	14	4.67	32	10.67
	Primary	50	16.67	36	12	29	9.67
	Illiterate	16	5.33	42	14	31	10.33

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Table 2. An overview of a few chosen indicators for the assessment of disaster risk and impact

Sl No.	Indicators	Units	Classes	Weights	Explanations	Sources
Agricultural Component of Disaster Risk						
01.	Most agricultural field location	Text	Highland Floodplain Lowland Adjacent to river	0.25 0.50 0.75 1.00	The vulnerability of agricultural fields increases from highland and close to rivers, hence the hazards they face are altered accordingly	(Hummell *et al.* 2016)
02.	The degree of the damage and crop production loss	Text	Very Low Low Moderate High Very High	0.20 0.40 0.60 0.80 1.00	Focus group discussions (FGDs)	(Sattar *et al.* 2019)
03.	The magnitude of the damage and loss of livestock	Text	Very Low Low Moderate High Very High	0.20 0.40 0.60 0.80 1.00	(FGDs)b	(Sattar *et al.* 2019)
04.	The highest extent of damages and losses of the destruction of farmland	Text	Very Low Low Moderate High Very High	0.20 0.40 0.60 0.80 1.00	(FGDs)b	(Sattar *et al.* 2019)
05.	The magnitude of impact on the agricultural land	Text	Very Low Low Moderate High Very High	0.20 0.40 0.60 0.80 1.00	(FGDs)b	(Sattar *et al.* 2019)
06.	The magnitude of damage and loss of poultry		Very Low Low Moderate High Very High	0.20 0.40 0.60 0.80 1.00	(FGDs)b	
Environmental Component of Disaster Risk						
01.	Creation of erosion	Text	Very Low Low Moderate High Very High	0.20 0.40 0.60 0.80 1.00	(FGDs)b	FGDs
02.	Wash away soil nutrients	Text	Very Low Low Moderate High Very High	0.20 0.40 0.60 0.80 1.00	(FGDs)b	FGDs
03.	Pollution of water bodies	Text	Very Low Low Moderate	0.20 0.40 0.60	(FGDs)b	FGDs

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			High	0.80		
			Very High	1.00		
Livelihood Component of Disaster Risk						
01.	Households members were injured and took medical support	Number	0	0.00	Households with injuries in the previous cyclone show vulnerability	(Hahn *et al.* 2009)
			1	0.33		
			2	0.67		
			>2	1.00		
02.	Households members caused the death	Number	0	0.00	Households with deaths in the previous cyclone show vulnerability	(Hahn *et al.* 2009)
			1	0.33		
			2	0.67		
			>2	1.00		
03.	Problem on electricity supply	Text	Yes	0.00	Lack of access to the electricity increases the vulnerability	(Ahsan *et al.* 2014)
			No	1.00		
04.	Access to improved toilet	Text	Yes	0.00	Having access to an improved toilet decreases the health risk	(Ahsan *et al.* 2014)
			No	1.00		
05.	Difficulties on the transportation system during and post coastal flooding	Text	Yes	0.00	Having difficulties with on well-transportation system increases the risk	(Ahsan *et al.* 2014; Flanagan *et al.* 2020)
			No	1.00		
06.	Food shortages during the extreme coastal flooding	Text	Yes	0.00	Having a food shortage increases the vulnerability and risk	(Kulatunga *et al.* 2014)
			No	1.00		
07	Kind of economic situation after flooding	Text	Very Good	0.20	The economic situation indicates the severity of damage	FGDs
			Good	0.40		
			Moderate	0.60		
			Bad	0.80		
			Very Bad	1.00		
08.	Impact on education	Text	Very Low	0.20	A greater literacy rate increases people's easier access to information and resources	FGDs
			Low	0.40		
			Moderate	.0.60		
			High	0.80		
			Very High	1.00		
09.	Impact on health	Text	Very Low	0.20	Better health service decreases the health risk	FGDs
			Low	0.40		
			Moderate	0.60		
			High	0.80		
			Very High	1.00		
10.	Impact on the road network	Text	Very Low	0.20	Having access to a good road network indicates less risk	FGDs
			Low	0.40		
			Moderate	0.60		
			High	0.80		
			Very High	1.00		
11.	Impact on safe water/deep tube-well	Text	Very Low	0.20	Having access to a deep tube well decreases the health risk	FGDs
			Low	0.40		
			Moderate	0.60		
			High	0.80		
			Very High	1.00		
12.	Impact on income	Text	Very Low	0.20	Vulnerability differs from income level	FGDs
			Low	0.40		
			Moderate	0.60		
			High	0.80		
			Very High	1.00		

Source: authors.

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RESULTS AND DISCUSSION

Impact of disaster at the household level

For identifying the most affected area, we calculated the Composite vulnerability Index (CI) based on household opinion of the three sectors: agriculture, environment and livelihood. Results clearly indicate that, Padma Pukur has the greatest CVI score (0.78), followed by Rangopaldi (0.74), whereas the lowest value (0.54) was calculated for the South Khali union (Figure 2). There are statistically significant differences in vulnerability indexes (p value <0.05), which implies individual households has varying degrees of vulnerability. The three sectors' respective contributions to the vulnerability were examined following the analysis of catastrophe vulnerability after the disaster vulnerability analysis. Findings show that, environment (0.88) is the most vulnerable sector followed by livelihood (0.75) and agriculture (0.70) in all three study sites. This result also reveals that, the environment sector in Padma Pukur union is extremely susceptible to natural calamities and therefore, it's necessary to pay more attention on this sector. Moreover, the results also indicate the economic condition of the affected people after coastal flooding (Table 3) where it is apparent that, most of the households of the coastal areas go through economic instability as a result of flooding condition.

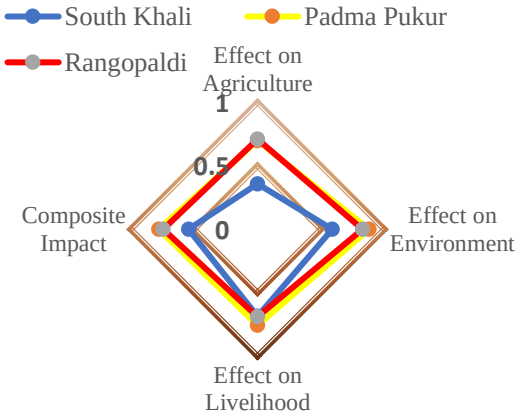

Figure 2. Sector-specific susceptibility index among three unions in the selected region. **Source:** authors.

Table 3. Economic situation after coastal flooding

Financial Situation	Frequency	Percentage	Valid percentage	Cumulative percentage
Poor	82	27.3	27.3	27.7
Extremely poor	172	57.3	57.3	98.7
Moderate	38	12.7	12.7	41.3
Excellent	3	1.0	1.0	28.7
Extremely excellent	4	1.3	1.3	100.0
Valid	1	0.3	0.3	0.3

Source: authors.

Factors affecting disaster vulnerability

This study examined how different categories of people's disaster vulnerability varied with age, gender, occupation, education level, house location, house type and results are shown in Figure 3. The findings show that vulnerability differs substantially ($p < 0.05$) among the variables such as age, education, house type, housing-location and occupation (Figure 3b, 3c, 3d, 3e, 3f) while there was no statistically significant difference in gender (Figure 3a). From gender perspectives (Figure 3a), females are slightly more vulnerable than the male group which is similar to (Sattar and Cheung 2019). This may be due to the less priority of the females in family decision making or less work opportunity during the hazard. In respect of age, old people (age > 59) are highly vulnerable compared to other groups (Figure 3b), while middle aged (between 30 and 39) is the least vulnerable group.

From educational aspect (Figure 3c), those who have completed a master's degree have a lower vulnerability risk compared to a higher vulnerability risk for the bachelor one. The reason for the minimum vulnerability of the master's degree group is that they are not present in the vulnerable place for working purposes.

The sample size may also be a factor, since just 0.33% of the sample has master's degree holders. Figure 3d illustrates that, dwellings on high terrain are less vulnerable than those next to rivers, which are more fragile and the reason is that, the highland is less likely to be flooded rather than the adjacent land to the river. In addition, the homeless are at low vulnerability risk as they have no houses to be damaged by coastal floods. In case of occupation (Figure 3e), farmers are higher vulnerable than the government jobholders and the other groups and the household group mean differences are statistically significant. The main cause of this vulnerability is that, some farmers experience agricultural crop loss while others do not. Besides this, those who have concrete houses are less vulnerable as they have a stable framework of housing system (Figure 3f).

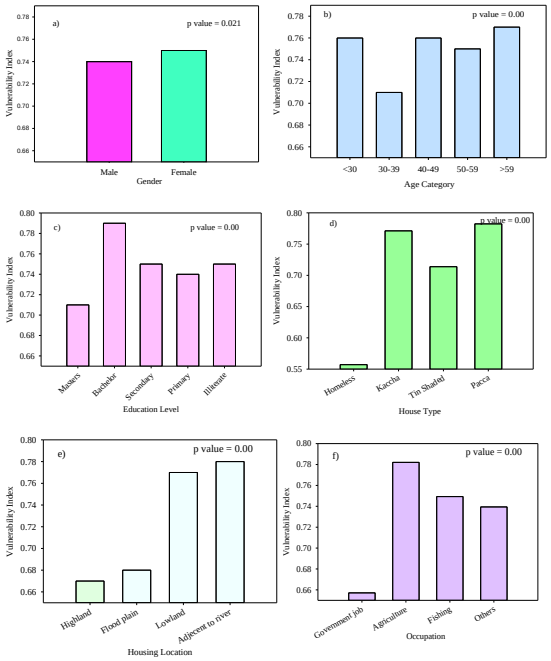

Figure 3. Variations of disaster vulnerability indices based on people's socio-economic profiles. (**Source:** authors)

People's perception of disaster response, preparedness and management

Early information is essential for reducing the intensity of damages caused by disaster. By obtaining disaster early warning information properly, everyone will get enough time to travel to the cyclone shelter and can save their life and valuable properties (Sattar *et al.* 2020). We analyze the perception of the respondents about some non-structural measures, including cyclone early warning system (EWS), first-aid, the necessity of insurance at household level and cyclone preparedness program (CPP) (Figure. 4a) where the satisfaction level was 88% with the EWS. Moreover, 57% of the participants were not familiar with fast-aid, while 42% of them were known about it. A noticeable feature is that, the majority of respondents (88%) were interested in taking part in the CPP training program though 83% of them were not interested in insurance at the household level.

In addition, embankments and dams are crucial for safeguarding coastal inhabitants' possessions during storms (Sattar and Cheung 2019; Dasgupta *et al.* 2014). People's experiences on the sufficiency of embankments and dams are shown in Figure 4b where a major portion of them were dissatisfied with the embankment sufficiency. We also assessed that, the govt. authority should construct more embankments and dams to reduce the damage of assets. On top of that, food shortage is one of the factors that make general people more vulnerable during coastal flooding. The real scenario of food sufficiency during coastal flooding is represented in (Table 4) and almost 93% people have experienced food shortage during the critical time period.

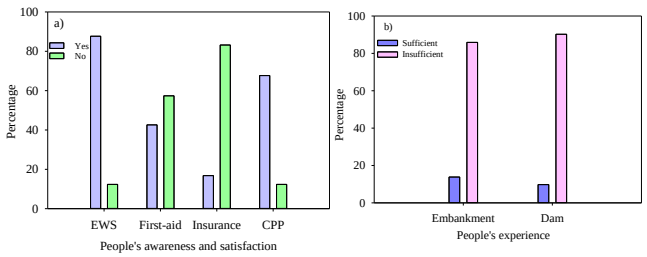

Figure4. People's perception in disaster response, preparedness and management: a) people's awareness and satisfaction regarding disaster preparedness and b) people's experiences regarding the sufficiency of embankment. (**Source:** authors)

Table 4. People's experiences regarding the food sufficiency during coastal flooding

Food shortages	Frequency	Percentage	Valid percentage	Cumulative percentage
Yes	279	93.00	93.00	100.0
No	21	7.00	7.00	7.00
Total	300	100.0	100.0	

Source: authors.

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People's expectations on healthcare, relief and financial help

The relief materials help to mitigate disaster impact after any natural disasters (Sattar *et al.* 2020). Relief expectations of the sufferer from the government during and post coastal flooding are shown in (Figure 5 & 6). Around 63% people expect to get relief, medical supports and other facilities from the government followed by relief and medical support (about 17%) during this period (Figure 5). On the other hand, during post coastal flooding, expectation level also is higher to get financial help, relief and other facilities from the government (Figure 6). In contrast, there are some people (19-21%) those has less interest on getting financial help and relief from the government in this period.

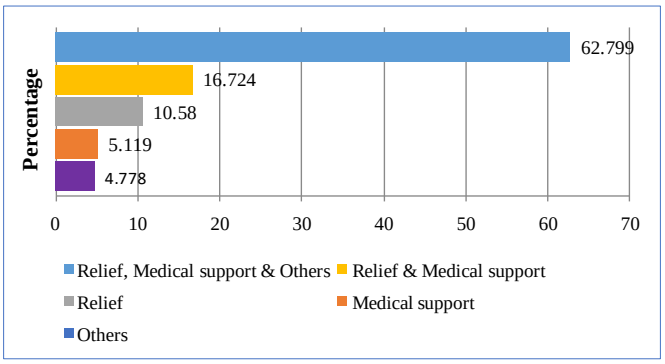

Figure 5. People's expectations on healthcare and relief from the government during coastal flooding.

People require supports from the government after a cyclone to recover from their damages. We also identified the relief required during post-flooding where about 19.244% respondents required both financial and relief support. Moreover, 21.6495% and 2.0619% begged for financial help and relief individually where only 3.7801% respondents expected other support from the government. A maximum portion of them (53.2646%) pay for all types of support including financial, relief as well as other from the government in post disaster recovery.

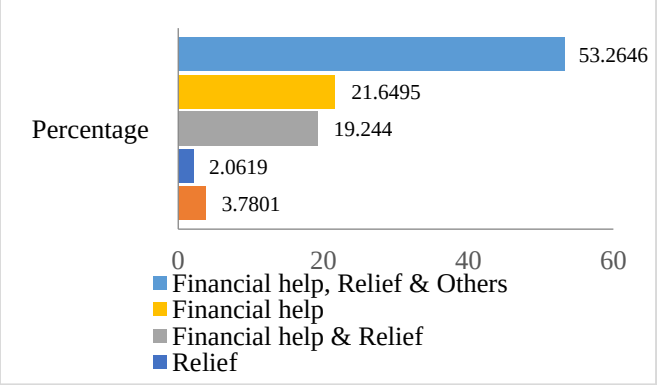

Figure 6. People's expectation from the government in post-coastal flooding**.**

Knowledge gaps concerning the impacted community's mitigating strategies

A few more important details regarding knowledge gaps about mitigation techniques was notified throughout the data collection process from households that increased their vulnerability level during and after coastal flooding. Fanaticism, illiteracy, and reluctance to go to the cyclone shelter are the prime gaps that increase their vulnerability and promote not to reduce the mitigation measures at the community level. The majority of the older members of the community are not interested in moving to cyclone shelters leaving behind their houses, possessions, and livestock. Consequently, cyclones and coastal floods can pose serious threats to their lives. In addition, religious, cultural, and social factors are also major barriers to women's responses to mitigation strategies for leaving their own houses, leading their lives in vulnerable situations and highly affecting their livelihood. Moreover, the underdeveloped communication system, lack of dam and early warning, as well as the distance to the cyclone shelter make lives more vulnerable to the community people. According to another study, the reason why the locals drink water from unsanitary sources is ignorance (Sattar *et al.* 2020; Rabbani *et al.* 2018; Akter and Ali 2014) and they are affected by various types of diseases including diarrhea, cholera, skin disease, typhoid and dysentery. Our study also found that, children especially women are more susceptible as they are less likely than men to seek refuge during a hurricane, without the permission of the male members of their family. They even have apathy to take medical care if the doctors are male, which makes this group more vulnerable. Therefore, this study recommends increasing awareness through various knowledge-based programs in the affected area, and appropriate attention should be given to the aforementioned knowledge gaps to make a coastal flooding resilient community in Bangladesh. In addition, to reduce these knowledge gaps related to mitigation measures the affected community needs more structural and non-structural measures, where structural measures mean physical constructions or modifications such as building cyclone shelters, and cyclone-resistant houses, constructing dams, and improving drainage systems. On the other hand, non-structural measures including education and training, early warning systems, planning, policies, and awareness campaigns, help the community members how to respond before, during, and after a cyclone and other disasters. Furthermore, the community also employs natural measures such as mangrove restoration, maintaining coral reefs, and conserving wetlands to reduce the impacts of tropical cyclones as well as storm surges. Consequently, the respondents in the community can address their vulnerability and take the initiative to mitigate it, while also enhancing their coping strategies against tropical cyclones.

Discussion

Bangladesh's low-lying coastal communities are experiencing more floods and faster sea level rise as a result of tropical cyclones brought on by climate change (Edmonds *et al.* 2020; Rao *et al.* 2020). To the author's greatest concern

there are no other studies which analyzed the level of vulnerability based on flooding on the livelihood, environment and agricultural perspective. In this study, we conducted a survey where 6 indicators with weights and frequencies were used for statistical analysis and found that more than 59 aged people are more vulnerable than the other one. Besides education act as the key component that helps to reduce vulnerability. In this case, illiterate and primary educated people are mostly vulnerable that consists major part of the study area and female participants perceive higher risk than male which is similar to (Sattar *et al.* 2019). This is because various issues work behind this including bigoted, less or no knowledge about the impact etc. On top of that, in developing nations, women are more susceptible due to the power dynamics of gender (the current disparity between men and women) and their marginalization in the social, economic, political, and cultural domains (Fakhruddin and Rahman 2014). Those people live in low land, flood plain or adjacent to river are mostly vulnerable because those areas are severely affected and causing devastating distraction on property, livelihood etc. and this aligns with the research on Mallick *et al.* 2017.

This research evaluated disaster vulnerabilities and sector-specific risk analysis of three major coastal areas, such as agriculture, livelihoods, the environment and the similar vulnerability indices has been evolved in socio-economics, land use, and ecological environment due to tropical cyclone (Gao *et al.* 2014). The effects of flood and cyclone on housing and habitat, crop production, cattle, soil erosion, productivity, income, and employment opportunities loss has been evaluated in (Jisan *et al.* 2015). Research of Sahoo and Bhaskaran's 2018, also looked into the effects of tropical cyclones on coastal vulnerability from a physical, environmental, social, and economic standpoint. People in vulnerable physical environments, with lower incomes and educational attainments, have less access to resources for disaster preparation, weather forecasting, and dealing with possible future threats like storm surges and cyclones (Hossain 2015). Risk level of the tropical cyclone also varied, based on income, farm size, occupation, gender and geographical location of the affected people (Sattar *et al.* 2019). The people's infrastructure and socioeconomic standing have an impact on the susceptibility level as well (Shaji 2021).

Figure 7. Some ideal pictures showing the vulnerable and fragile structures (a,b,c) vulnerable houses (d) earthen and fragile embankment and (e, f) houses adjacent to the river system. **Source:** authors.

As we know, embankment play a vital role as a safeguard for protecting the coastal communities and their valuable assets from the cyclone and flood (Adnan *et al.* 2019; Sattar and Cheung 2019; Rahman *et al.* 2015; Dasgupta *et al.* 2014; Nowreen*et al.* 2014). But the associated study evolved that, there is no embankment or dam in Ranogopaldi union and the condition of the embankment in Padmapukur union was very fragile. The majority of respondents (86% and 90%) felt that, the existing embankment and dam is inadequate for saving them from any hazard. A serious scarcity of safe drinking water was observed in both the Padmapukur and Southkhali unions. We draw attention to the fact that, a lot of communities struggle to find and maintain a source of clean drinking water. We also note that, certain water purification systems were running to filter stored pond water.

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Furthermore, we observed that, the study area lacked sufficient cyclone shelters to house large numbers of people. Most of the residents of Southkhali union in Bagerhat district built their houses near adjacent to the river and embankment and most of the houses could not withstand during the cyclone. The cyclone affected victims require medical support, financial support, relief, etc. for their survival (Figure 5 & 6) where most of the respondents (93%) experienced food shortages during the cyclone (Table 4). In addition, a previous study has shown a lack of proper coordination between various government and non-governmental organizations (Jisan *et al.* 2015) during the emergency period.

There is no provision of disaster preparedness training program (CPP) for rural people though it was found that most respondents were inserted for CPP (Figure 4a). Nonetheless, the study's conclusions relied on how the subjects responded. In short, this study provides important information about the vulnerability and impact of natural disasters and current risk scenarios for responding to those disasters.

CONCLUSION

As far as we are aware, this is the first research where the influence of coastal flooding in Bangladesh is addressed. People who live along Bangladesh's coast are constantly impacted by flooding brought on by tropical cyclones. The study focused on how coastal flooding affects the ecosystem and people's way of life across three selected coastal regions in Bangladesh. With the aid of Kobo Toolbox, in-person verbal conversations and site observation techniques were utilized to meet the study's objectives. Our findings reveal that, the catastrophe vulnerability index varies depending on a number of socio-economic and geographic characteristics. (e.g., age, gender, education, occupation, house-location and types), which finally enhance disaster impact in the coastal region. Results also found that, the highly affected area was Padma Pukur in compare to Southkhali and Rangopaldi where people have experienced severe problems during and post coastal flooding as food shortage, insufficient relief, financial help and medical support etc. General people have less experience on cyclone early warning system while the majority of them are not satisfied with embankment sufficiency during coastal flooding. Nonetheless, before putting any plan or strategy for risk reduction into action, risk assessment is a crucial requirement. Therefore, the government and policy makers can utilize the study's findings to evaluate risk perception and risk-reduction tactics before putting those methods into practice and lowering the likelihood of the danger. For building a coastal community that is flood resilient in Bangladesh, we would like to prescribe some disaster risk reduction measures before, during and after flooding condition as build more embankments, sluice gates, and polders, build more coastal flood shelters, awareness raising and training programs, secure timely health services, preserve dry foods, increase the number of life-saving supplies, for example, life jackets, first aid kits, and boats, while enhance or rebuild people's livelihoods by providing livestock, poultry, and other farm products. Furthermore, the periphery and indicators of the study site can be enlarged to increase the future research opportunity and reveal the findings

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Data availability statement

All the information and resources used to support the findings and analyses presented in this paper are available upon request.

Conflict of Interest

The authors state that none of their known financial conflicts or interpersonal connections might have had an impact on the work presented in this paper.

Author Contributions

A number of authors contributed to the project. Sanjida Aktar contributed to the creation of the project's idea and fieldwork schedules, analysis and writing the manuscript. Md. Tauhid Hossain, Naiem Sheikh and Fahim Redwan were responsible of preparing the materials, gathering and analyzing the data, and creating the manuscript. Md. Masum Billah and Shahjahan Sheikh were involved in conceptualization, data collection and writing the manuscript. Ayesha Siddequa was the initial author to organize the manuscript which was finally edited by all co-authors. Md. Habibur Rahman and Kamrun Nahar were involved in visualization and editing the work, oversaw the fieldwork activities and performed as the project manager. Most. Nusrat Binte Nur was mainly responsible for revised the manuscript. All authors reviewed and approved the final manuscript.

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