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Natural Disaster Risk Assessment in the Coastal Area of Bangladesh: A Case Study on Cox's Bazar Paurashava

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Abstract: Bangladesh, which is known around the world as one of the most vulnerable countries to natural disasters, is still battling to benefit its entire population from present economic and social development. Issues like global warming and climate change are putting all the development works into a great challenge. To overcome these challenges, intensive research on disaster risk reduction programs are required. This paper works as a basis of such intensive research where combining the socio-economic factors and geographical factors, a combined risk index of a coastal area (Cox's Bazar Paurashava) has been identified. The study tried to establish some parameters regarding hazard, vulnerability and resiliency of the community in terms of the urban area of the coastal zone. In this way this study focused on the non-spatial pattern as well as spatial factors of the community like roads and cyclone shelters. In terms of non-spatial risk, it has been derived that weak socio-economic status plays the most dominant role for a family to become vulnerable to natural disaster along with poor infrastructure systems, less chance of access to information etc. which also intensify the vulnerability of the community. Information regarding natural disaster risk assessment of the study area was collected through a questionnaire survey and field observation. Numbers of academicians and professionals like professors and officials of the disaster management department were selected for key informants' interview to get some concepts, parameters, standards regarding preparing Natural Disaster Risk Assessment Index. In this study, all the factors have been considered together for quantifying the risk of the community. In this way, this research prepared different local maps on the basis of hazard, vulnerability, resiliency condition of the people. This study also prepared a spatial risk map, non-spatial risk map and final risk map. Thus, this study will certainly help to prioritize government and non-government interventions according to the risk category during emergencies.

Keywords: *Disaster; Hazard; Vulnerability; Resiliency; Spatial; Non-spatial.*

Introduction: Natural disasters are thought to have killed as many people as the two World Wars combined over the last century [1]. Between 1980 and 2016, around 10,500 natural catastrophes were documented, resulting in approximately 2.4 million deaths and $2.9 trillion in direct economic damage [2]. Approximately 350 natural catastrophes claimed the lives of close to 10,000 individuals in 2017, resulting in $317 billion in economic losses [3]. Recent empirical research reveals that those most affected by natural disasters are the poorest people on the planet [4]. Despite the geographical distribution of both frequency and intensity of dangers not being concentrated in these [5], developing countries have accounted for 93 percent of all-natural disaster deaths since 1980 [6].

The Ganges, Brahmaputra, and Meghna rivers constitute a low-lying deltaic region in South Asia known as Bangladesh [7]. Bangladesh sits at the confluence of two very different settings. To the north, the Himalayan foothills and Khasi-Jainta hills, while to the south, the Bay of Bengal and the Indian Ocean. The climate of the country is controlled, changed, and managed by these distinct parameters [8]. It is geologically part of the Bengal Basin, which was formed by sediments blown down from three sides of the mountains. It is bordered on the west, north, and east by India, and on the southeast by Myanmar [9]. Bangladesh's land border spans 4,246 kilometers, 93.9 percent of which is shared with India and the remainder with Myanmar [10]. There are 57 cross-border rivers, 54 of which are shared with India, while the lower riparian zone of all these trans-boundary rivers is shared with Myanmar and Bangladesh [11]. There are about 310 rivers and tributaries in this country, making it a riverine country [12]. The coastline area covers 47,201 km2, or roughly 32% of Bangladesh's entire land area. In terms of administration, 19 of the 64 districts are classified as coastal districts [13]. Approximately 10% of the country is 1 meter above sea level, and one-third is subject to tidal excursions [14]. The country has a 710-kilometer coastline along the Bay of Bengal [15]

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Background of the Research: Bangladesh is regarded as one of the most vulnerable countries to natural disasters and the effects of global warming and climate change around the world [16]. Almost every year, calamities such as tropical cyclones, storm surges, coastal erosion, floods, and droughts strike Bangladesh, causing huge loss of life and property and impeding development efforts [17]. "In 2019, according to global climate risk index (2021), German Watch ranked Bangladesh the number seven nation at risk for weather related damage" [19]. Bangladesh's climate has changed dramatically as a result of rapid global warming, and millions of people are suffering [20]. It is ,therefore, necessary to understand its hazard, vulnerability in terms of population and sectors at risk and its potential for adaptation to climate change [21].

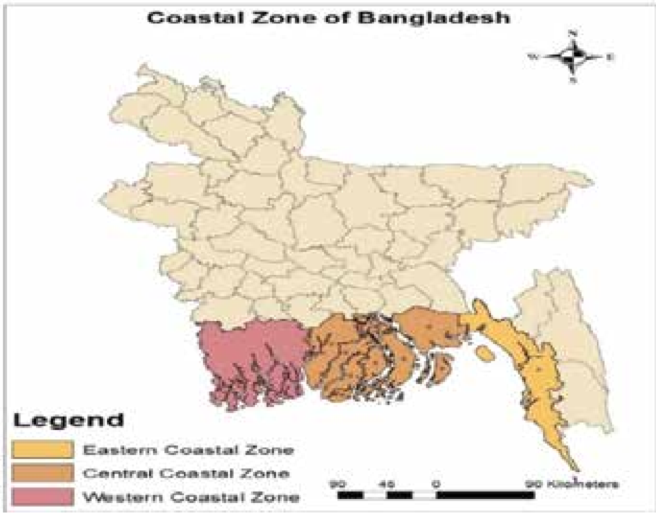

Fig.1: Map of Coastal Zone of Bangladesh. *(*Source: Disaster Management Bureau, 2019*).*

In recent times the coastal areas of Bangladeshi are sensitive to sea-level rise, changes in the frequency and intensity of storms increases in precipitation and Warmer Ocean temperatures. The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) projects a global sea-level rise in different RCP 's of 26 to 82 cm during the end of the 21st century [22] which would threaten the survival of coastal cities and entire island. Climate change, according to several famous scholars, is one of humanity's biggest issues in the twenty-first century. Climate change is evidenced by rising global temperatures, changing rainfall patterns, rising sea levels, and the prevalence of extreme weather events such as floods, cyclones, and droughts. [23]. In this regard, assessment of disaster risk should be prepared for reduction of the risk of natural disaster. So, this research tried to prepare a disaster risk assessment index based on hazard, vulnerability and resilience capacity of the people in the coastal area of Bangladesh.

Conceptualization: A natural hazard is an event that occurs naturally and has a negative socioeconomic impact on humans. Natural risks are divided into three categories: atmospheric hazards caused by atmospheric processes, exogenic hazards generated by earth surface processes, and endogenic hazards caused by internal processes [24]. A natural hazard is a significant contributor to disaster occurrence. A disaster, on the other hand, will only occur when threats connect with vulnerable, exposed elements, resulting in humanitarian, economic, and ecological consequences. As a result, natural disasters are becoming more common. However, the final consequences will be determined by the elements at risk and their degree of vulnerability within a social structure. Thus, natural disaster risk can be said to be defined by three factors: hazard, elements at risk, and vulnerability [25]. According to IPCC (2012), the following criteria can be used to define a large disaster [26].

a) More than 100 casualties

b) Economic damage in excess of 1% gross national product (GNP)

c) More than 1% of an impacted country's population was harmed.

Research Design: This research was conducted by using qualitative and quantitative approach. Both qualitative and quantitative data are necessary for finding the final outcome of the research. The main focus of the research is to assess disaster risk of the people in the coastal areas of Bangladesh. So, it is necessary to have a clear idea about coastal areas. Qualitative part of this research helped to gain that idea. Quantitative approach was used to assess disaster risk. Literature review focuses on the issues of natural disaster and its impact, determinants of natural disaster, natural disaster risk assessment model-Crunch and release Model, hazard assessment, vulnerability assessment, capacity assessment, disaster risk assessment. An individual opinion survey was undertaken by means of a structured questionnaire. The questionnaire developed by the investigators contained six sections related to personal information, family related information, housing location and structure information, hazard condition, vulnerable condition and resilience condition. In this survey, an individual has been chosen as a sampling unit. 96 individuals are taken for collecting data. By using Rao software, sample size is fixed. Purposive sampling technique was used to collect data from individuals. Purposive sampling is a non-probability sampling method and it occurs when "elements selected for the sample are chosen by the judgment of the researcher. Researchers often believe that they can obtain a representative sample by using a sound judgment, which will result in saving time and money" [30]. There are 12 wards in Cox's Baazar Paurashava and eight respondents are surveyed for collecting data from each ward of the Paurashava. After collecting data, Key Informants Interview were carried out to capture more information about disaster risk and its assessment criteria. Officials and GIS specialist from the department of disaster management and academician from the specific field of disaster management were involved in this interview. These experts just give their opinion to fix the criteria, scale of disaster risk, level of disaster risk and provide different information about vulnerable people and their livings. From their opinion and conceptualization, the study was formulated a function which led to the assessment process. In this research, Risk has been categories into two segments as Non-Spatial Risk and Spatial Risk.

So, the mathematical expression of Non-Spatial Risk (NSR) is the following,

NSR = Hazard Score + Vulnerability Score – Capacity Score

On the other hand, Spatial Risk (SR) factors are those exclusively rely on the geographic location and spatial distribution of social elements over the community. Therefore, spatial risk has been calculated based on the proximate location of settlement from the road side and existing cyclone shelter.
Finally, these two risks have been combined giving equal weight and a final risk index has been prepared. The equation of combined risk is:

Combined Risk, (R) = (Non-Spatial Risk + Spatial Risk)/2

After identifying parameter and variable, the study was given weight of the value for measuring the disaster risk assessment. The weight of the value was given on the basis of some consideration. This idea was taken from the Disaster Crunch Model [27]. Waliuzzaman et al. (2016) considered assessment level after getting measurement calculation on the score from 1 to 5. They categorised three assessment level where 2.5-2.8 was considered as low, 2.81-3.35 was considered as medium and 3.36-3.75 as high [29]. After putting weightage, analyzing the collected information and data related to the research work had been begun. From the calculation of spatial risk index and non-spatial risk index, final risk score has been formulated for each ward of Cox's Bazar Paurashava using the following formula. Finally, wards having combined risk score 0-1.49 has been considered as lower risk areas; score 1.50-1.99 has been considered as low risk areas; score 2.00-2.99 has been considered as moderate risk areas; score 3.00-3.99 has been considered as high-risk areas and combined risk score 4.00-4.99 has been considered as severe risk prone areas for natural disaster.

Study Area: While the Cox's Bazar district is the worst affected district among the 19 coastal districts of country. Cox's Bazar is vulnerable to natural hazards and extreme weather and temperatures, which exacerbate factors that contribute to and create persistent pockets of poverty, particularly in the districts of Kutubdia and Maheshkhali, which have a coastline along the Bay of Bengal, flat deltaic plains, and sandy hills. During the monsoon and cyclone seasons, Cox's Bazar is vulnerable to landslides, river and seabed erosion, flash floods, and storm surges, although being less vulnerable to direct cyclone strikes than other sections of Bangladesh. In the district, increased deforestation has compounded the effects of natural disasters [28].

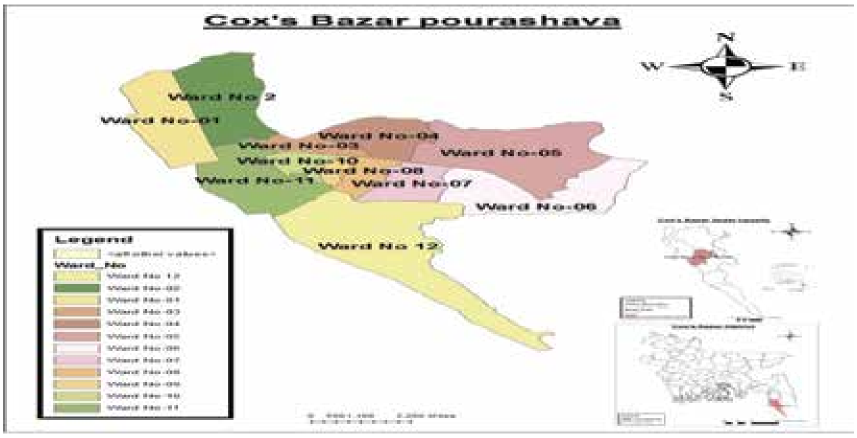

Fig. 2: Map of Study Area. (Source: Prepared by Authors, 2021).

Natural Disaster Risk Assessment Analysis: This analysis focuses on the socio-economic condition of the study area and the hazard, vulnerability and resiliency assessment in the context of natural hazard like cyclone and flooding. The detailed analysis of different variables regarding Natural Disaster Risk Assessment Index are given below:

Socio-Economic Condition: In the study, it is found that the respondents of Cox's Bazar Paurashava are middle aged where almost 50% respondents are within 30-60 aged and 50% people have graduation degree. So it might be told that Cox's Bazar Purashava has large educated people.

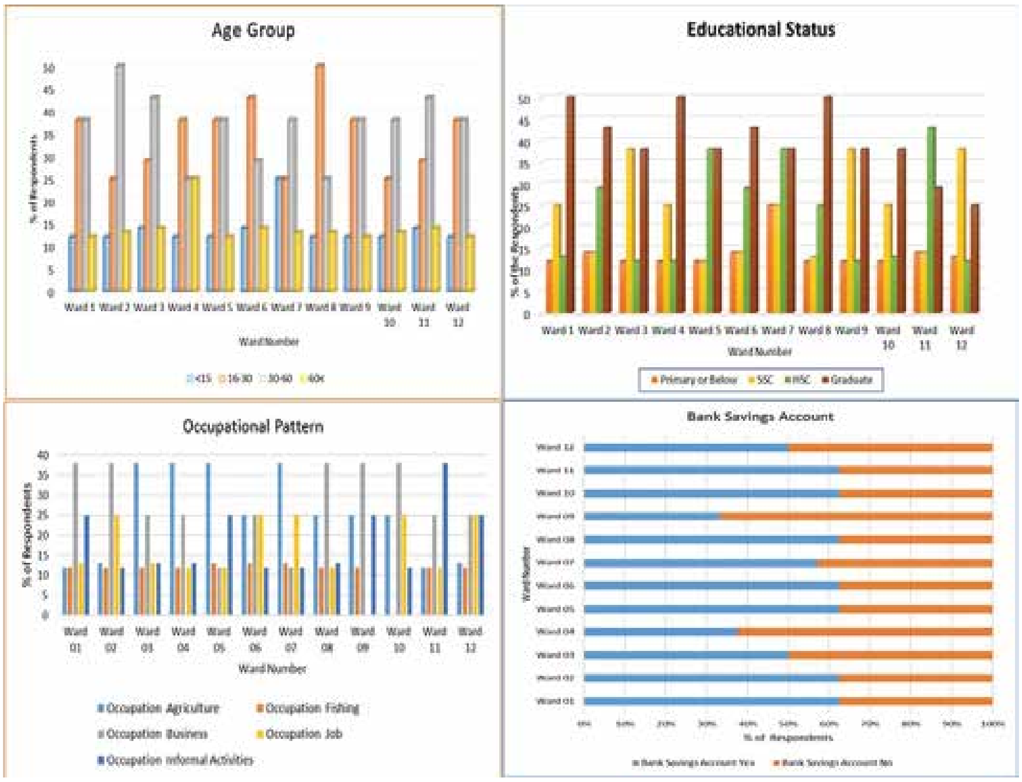

Fig.3: Socio-Economic Condition. (Source: Field Survey, 2019).

It is also found that agriculture (40%) and business (30%) sector are dominant occupations in Cox's Bazar Paurashava. It is noticed that maximum people have bank savings account. As a tourist area, people makes lots of transaction through banking channel.

Hazard Condition: Hazard condition can be easily measured through the criteria of cyclone frequency, intensity and magnitude of loss and damage of the people.

Hazard Score: In order to calculate the hazard score, relevant hazard assessment criteria have been set up according to the frequency of the hazard, intensity of the hazard and magnitude of the hazard.

Table 1: Hazard Score. (Source: Field Survey, 2019; Prepared by Authors, 2021).

Criteria	**Scale of Scoring (1 to 5)**	**Hazard Score for each wards of Cox's Bazar Paurashava**											
		1	2	3	4	5	6	7	8	9	10	11	12
Frequency	Both Cyclone and Flood/Tidal Surge Occurs in Every Year = 5 Cyclone or Flood/Tidal Surge Occurs in Every Year = 4 Cyclone or Flood/Tidal Surge occurs in 1 Year Gap = 3 Cyclone or Flood/Tidal Surge occurs in 2-3 Years Gap = 2 Cyclone or Flood/Tidal Surge occurs in over 5 years Gap = 1	3	3	3	3	3	3	3	3	3	3	3	3
Intensity	10 feet tidal surge and 200 km wind speed = 5 10 feet tidal surge or 200 km wind speed = 4 5 feet tidal surge or 150 km wind speed = 3 Below 5 feet tidal surge or 100 km wind speed = 2 Little Flooding or below 100 km wind speed = 1	5	5	3	3	3	3	3	3	3	3	5	5
Magnitude	Loss of Human life and Property value BDT 20,000 = 5 Human life injured and loss of Property value BDT 20,000 = 4 Loss of Human/animal life or Property Value BDT 20,000 = 3 Loss of Firms and Agro Industry = 2 Minimum Destruction = 1	2	1	3	3	3	3	2	3	3	3	3	4
Average		3.3	3	3	3	3	3	2.6	3	3	3	3.6	4

According to the table above, respondents from all wards of the Paurashava experienced a natural disaster on average once every year. Maximum responders of wards 3, 4, 5, 6, 7, 8, 9, 10 in Cox's Bazar Paurashava suffered 5 feet tidal surge or 150 km wind speed, while wards 1, 2, 11, 12 in Cox's Bazar Paurashava faced light flooding or 100 km wind speed. In terms of magnitude of natural hazard, maximum respondents of wards – 1 and 7 lost their livestock mostly, maximum respondents of wards – 3, 4, 5, 6, 8, 9, 10, 11 lost human/animal life or property values of BDT 20,000 and more.

Hazard Category: After getting score for individual ward, the study identified different wards as different level hazardous situation. These are given below:

Table 2: Hazard Category. (Source: Field Survey, 2019; Prepared by Authors, 2021).

Ward Number	Hazard Score	Hazard Category
Ward - 01	3.3	High Hazardous
Ward – 02	3	High Hazardous
Ward – 03	3	High Hazardous
Ward – 04	3	High Hazardous
Ward – 05	3	High Hazardous
Ward – 06	3	High Hazardous
Ward – 07	2.6	Moderate Hazardous
Ward – 08	3	High Hazardous
Ward – 09	3	High Hazardous
Ward – 10	3	High Hazardous
Ward – 11	3.6	High Hazardous
Ward - 12	4	Severe Hazardous

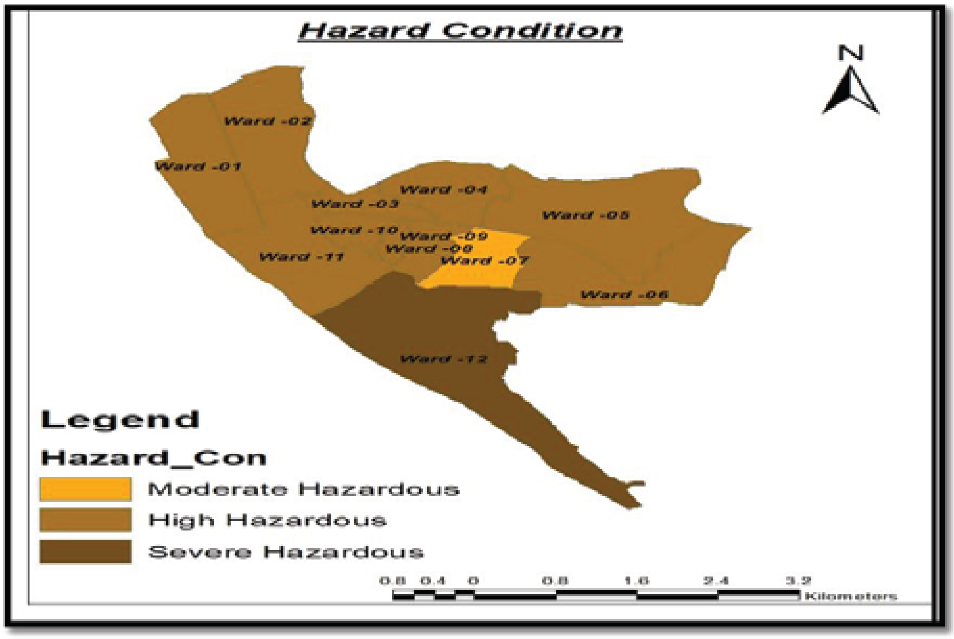

Fig. 4: Map of Hazard Condition of Different wards. (Source: Prepared by Authors, 202).

From the Above calculation of hazard Score, this study found three types of hazardous condition out of five hazardous condition. Ward – 1, 2, 3, 4, 5, 6, 8, 9, 10 and 11 are high hazardous prone area where Ward – 12 is severe hazardous prone area. Ward – 7 is comparatively less hazardous area than others. According to the level of scale, it is moderate hazardous prone area in this study

Vulnerability Score: Similar method has been used to calculate the vulnerability score. Following criteria has been considered to calculate the vulnerability score. The scoring scale for vulnerability assessment is created in the following manner. [27]

Table 3: Vulnerability Score. (*Source: Field Survey, 2019; Prepared by Authors, 2021).*

Criteria	**Scale of Scoring (1 to 5)**	**Vulnerability Score for each wards of Cox's Bazar Paurashava**											
		1	2	3	4	5	6	7	8	9	10	11	12
House location within 1 km. sea or river	More than 80% house = 5 From 60%-80% = 4 From 40% - 60% = 3 From 20-40% = 2 Below 20% = 1	5	4	4	3	3	3	2	2	1	2	5	5
Income Source	Agriculture = 5 Fishing = 4 Business = 3 Informal Job = 2 Public and Private Job = 1 (The ward with the highest percentage of respondents received the highest score)	3	3	5	5	5	3	5	3	3	3	2	3
Structure of House	Mud/Bambo = 5 Tin = 4 Tin and Brick = 3 Brick = 2 Others = 1 (The ward with the highest percentage of respondents received the highest score)	3	4	4	4	3	4	3	4	4	2	2	2
Access to local Government	More than 80% = 1 From 60%-80% = 2 From 40% - 60% = 3 From 20-40% = 4 Below 20% = 5	4	3	2	4	3	3	3	2	1	3	3	3
Early Awareness	More than 80% = 1 From 60%-80% = 2 From 40% - 60% = 3 From 20-40% = 4 Below 20% = 5	2	3	1	2	3	2	2	1	3	2	2	1
Children and Disabled Person	More than 80% house = 5 From 60%-80% = 4 From 40% - 60% = 3 From 20-40% = 2 Below 20% = 1	3	4	4	4	3	4	5	4	4	5	3	4
Efficient Infrastructure	More than 80% = 1 From 60%-80% = 2 From 40% - 60% = 3 From 20-40% = 4 Below 20% = 5	2	1	2	3	2	2	2	3	4	4	3	2
Age	Above 70 = 5 Below 10 = 4 10 - 15 = 3 16 - 30 = 2 30 - 60 = 1 (The ward with the highest percentage of respondents received the highest score)	1	1	1	2	1	1	1	2	1	1	2	1
Education	More than Graduate = 1 HSC = 2 SSC = 3 Below SSC = 4 Illiterate = 5 (The ward with the highest percentage of respondents received the highest score)	1	1	3	1	2	1	2	1	3	1	2	3
More than One Earning Member	More than 80% house = 1 From 60%-80% = 2 From 40% - 60% = 3 From 20-40% = 4 Below 20% = 5	3	5	3	4	4	3	3	3	4	5	3	3
Safe Drinking water	More than 80% house = 1 From 60%-80% = 2 From 40% - 60% = 3 From 20-40% = 4 Below 20% = 5	4	4	3	2	3	2	3	2	3	2	4	2
Average		2.8	3	2.9	3.1	2.9	2.6	3.1	2.4	2.8	2.7	2.8	2.6

According to the table above, Wards 01, 11, and 12 are located near the sea, making them more vulnerable to natural disasters. In other wards, the housing structure is likewise in poor condition. Wards 2, 3, 4, 6, 8 and 9 have a considerable number of residences built in tin shed housing. The table revealed that individuals in Cox's Bazar Paurashava do not have enough access to local government bodies. Connecting individuals with local government authorities is critical for lowering catastrophe risk. Cox's Bazar Pourashva has a well-developed early warning system for many natural disasters. According to the interviewees, the study area's infrastructure is in good shape. More than 60% of respondents are pleased with the state of their infrastructure. People of the Cox's Bazar Paurashava do not have a very well water supply system.

Vulnerability Category: After getting score for individual ward, the study categorized different wards as different vulnerable levels. These are given below:

Table 4: Vulnerable Category. (Source: Field Survey, 2019; Prepared by Authors, 2021).

Ward Number	Vulnerability Score	Vulnerable Category
Ward - 01	2.8	Moderate Vulnerable
Ward – 02	3	Highly Vulnerable
Ward – 03	2.9	Moderate Vulnerable
Ward – 04	3.1	Highly Vulnerable
Ward – 05	2.9	Moderate Vulnerable
Ward – 06	2.6	Moderate Vulnerable
Ward – 07	3.1	Highly Vulnerable
Ward – 08	2.4	Moderate Vulnerable
Ward – 09	2.8	Moderate Vulnerable
Ward – 10	2.7	Moderate Vulnerable
Ward – 11	2.8	Moderate Vulnerable
Ward - 12	2.6	Moderate Vulnerable

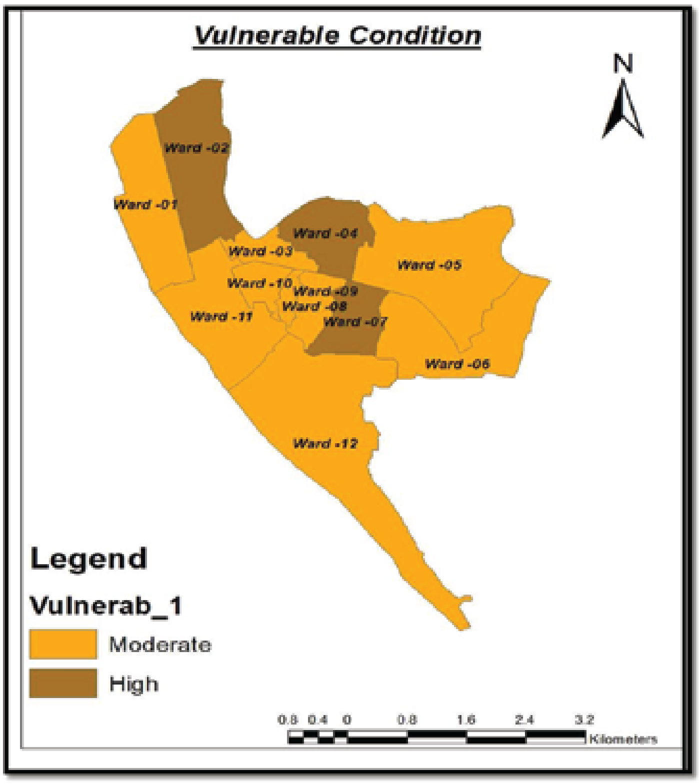

Figure 5: Map of Vulnerable Condition of Different Wards. (*Source: Prepared by Authors, 2021).*

In the calculation of Vulnerability scale, this study identified that two types of vulnerable condition are found in the study area. Three Wards of the Cox's Bazar Paurashava (Ward – 2, 4 and 7) are more vulnerable to natural hazard. Their socio-economic conditions are weak than other wards. On the other hand, other Nine Wards (Ward – 1, 3, 5, 6, 8, 9, 10, 11 and 12) are comparatively less vulnerable to natural hazard

Resilience Assessment

The capacity of the community refers to the resilience factors causing the risk of natural disaster to be reduced. For the current study, the availability of protection system into the community, access to information and savings have been considered in order to calculate the capacity score [27].

Table 5: Capacity Assessment Index.

Criteria	Scale of Scoring (1 to 5)	Capacity Assessment Score for each wards of Cox's Bazar Paurashava											
		1	2	3	4	5	6	7	8	9	10	11	12
Physical Protection System	More than 80% house = 1 From 60%-80% = 2 From 40% - 60% = 3 From 20-40% = 4 Below 20% = 5	4	4	4	5	4	5	4	4	3	3	4	4
Savings and Assets	More than 80% = 1 From 60%-80% = 2 From 40% - 60% = 3 From 20-40% = 4 Below 20% = 5	2	2	3	4	2	2	3	2	4	2	2	3
Access to Information	More than 80% house = 1 From 60%-80% = 2 From 40% - 60% = 3 From 20-40% = 4 Below 20% = 5	2	1	1	1	2	1	1	1	2	1	1	1
Average		2.6	2.3	2.6	3.3	2.6	2.6	2.6	2.3	3	2	2.3	2.6

Source: Field Survey, 2019; Prepared by Authors, 2021.

Resilience category

After getting score for individual ward, the study categorized different wards at different resilience level. These are given below:

Table 6: Capacity Category.

Ward Number	Capacity Score	Capacity Category
Ward - 01	2.6	Moderate Capacity
Ward – 02	2.3	Moderate Capacity
Ward – 03	2.6	Moderate Capacity
Ward – 04	2.3	Moderate Capacity
Ward – 05	2.6	Moderate Capacity
Ward – 06	2.6	Moderate Capacity
Ward – 07	2.6	Moderate Capacity
Ward – 08	2.3	Moderate Capacity
Ward – 09	3	High Capacity
Ward – 10	2	Moderate Capacity
Ward – 11	2.3	Moderate Capacity
Ward - 12	2.6	Moderate Capacity

Source: Field Survey, 2019; Prepared by Authors, 2021.

In terms of resiliency, Ward – 9 has most resilient condition to natural hazard. All of wards except nine are moderate resilient condition to natural disaster.

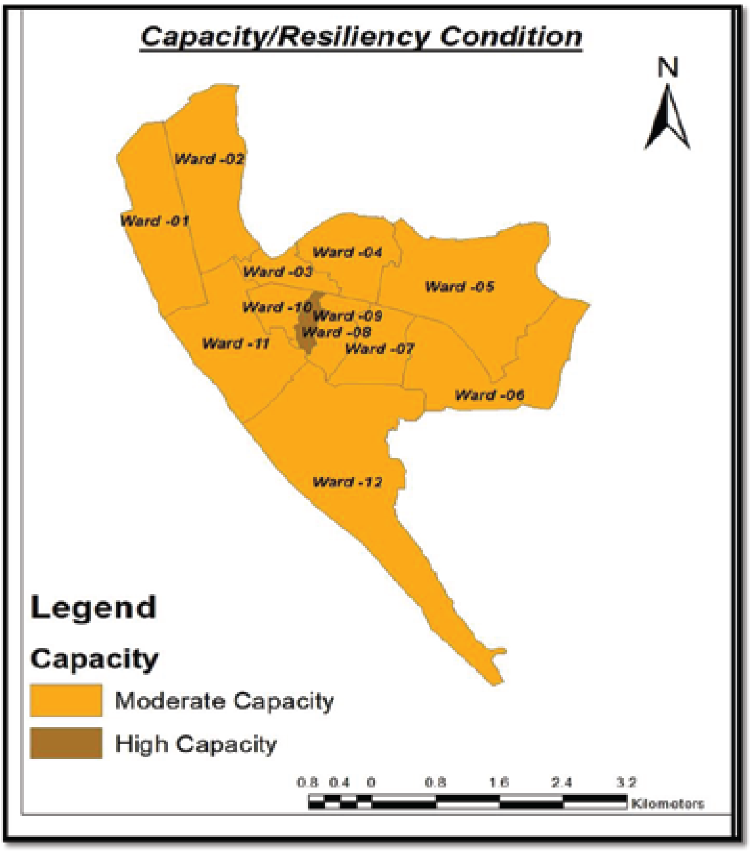

Figure 6: Resilience Condition. (*Source: Prepared by Authors, 2021*).

Non-Spatial Risk Assessment Index (NSRAI)

Based on the previous calculation of Hazard Score, Vulnerability Score and Capacity Score, total Non-Spatial Risk have been calculated by the following equation, NSR = (Hazard Score + Vulnerability Score – Capacity Score)

Table 7: Non-Spatial Risk Assessment Index (NSRAI).

Ward	Hazard (H)	Vulnerability (V)	Capacity (C)	H+V-C	Risk Category
Ward - 01	3.3	2.8	2.6	3.5	High Risk
Ward – 02	3	3	2.3	3.7	High Risk
Ward – 03	3	2.9	2.6	3.3	High Risk
Ward – 04	3	3.1	3.3	2.8	Moderate Risk
Ward – 05	3	2.9	2.6	3.3	High Risk
Ward – 06	3	2.6	2.6	3	High Risk
Ward – 07	2.6	3.1	2.6	3.1	High Risk
Ward – 08	3	2.4	2.3	3.1	High Risk
Ward – 09	3	2.8	3	2.8	Moderate Risk
Ward – 10	3	2.7	2	3.7	High Risk
Ward – 11	3.6	2.8	2.3	4.1	Severe Risk
Ward - 12	4	2.6	2.6	4	Severe Risk

Source: Field Survey, 2019; Prepared by Authors, 2021.

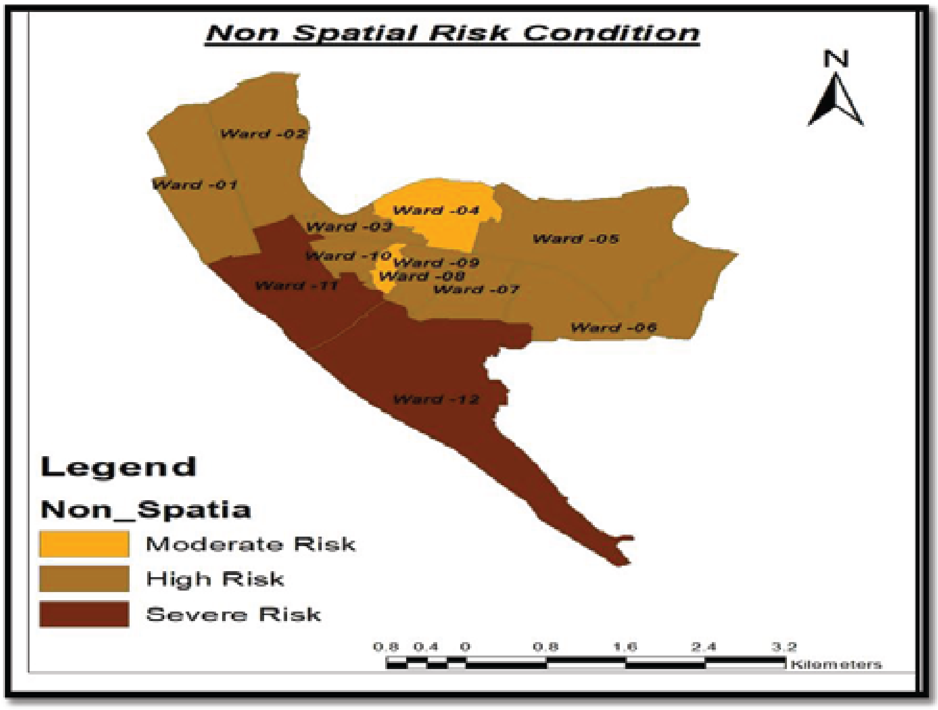

Fig.7: Map of Non-Spatial Risk. (Source: Prepared by Authors, 2021).

After getting hazard, vulnerability and resiliency score, this study can calculate Non-Spatial Risk condition on the basis of hazard, vulnerability and resiliency. From the Non-Spatial Risk calculation, this study found three types of disaster risk. Ward – 11 and 12 are severe risk prone area. Ward – 1, 2, 3, 5, 6, 7, 8 and 10 are high risk prone area in terms of Non-Spatial Risk. Ward – 4 and 9 are considered as moderate risk prone area.

Spatial Risk Assessment Index (SRAI): Spatial Risk Index for each ward has been calculated based on two major criteria which are distance from pucca road and distance from cyclone shelter.

Table 8: Spatial Risk Assessment Index (SRAI). (*Source: Field Survey, 2019; Prepared by Authors, 2021.*)

Criteria	**Scale of Scoring (1 to 5)**	**Spatial Risk Assessment Score for each wards of Cox's Bazar Paurashava**											
		1	2	3	4	5	6	7	8	9	10	11	12
Distance from Pucca road	More than 3 km. from house = 5 From 2-3 km. = 4 From 1-2– 1 km. = 3 From .5 -1 km.= 2 Below .5 km. = 1	3	1	1	2	2	2	3	2	2	1	2	1
Distance from cyclone shelter	More than 3 km. from house = 5 From 2-3 km. = 4 From 1-2– 1 km. = 3 From .5 -1 km.= 2 Below .5 km. = 1	3	3	3	2	3	2	3	2	3	3	2	2
Average		3	2	2	2	2.5	2	3	2	2.5	2	2	1.5

Spatial Risk Category: The calculation of spatial risk score has been provided in the following table. On the basis of this calculation, the risk ward can be identified.

Table 9: Spatial Risk Category. *(Source: Field Survey, 2019; Prepared by Authors, 2021).*

Ward Number	Spatial Risk Score	Spatial Risk
Ward - 01	3	High Risk
Ward – 02	2	Moderate Risk
Ward – 03	2	Moderate Risk
Ward – 04	2	Moderate Risk
Ward – 05	2.5	Moderate Risk
Ward – 06	2	Moderate Risk
Ward – 07	3	High Risk
Ward – 08	2	Moderate Risk
Ward – 09	2.5	Moderate Risk
Ward – 10	2	Moderate Risk
Ward – 11	2	Moderate Risk
Ward - 12	1.5	Low Risk

Spatial Risk Assessment Index is also prepared after finding non-spatial risk. Basically, Spatial Risk Index is prepared based distance from *pucca* road and distance from cyclone shelter. In this way, this study found three types of risk. Ward – 1 and 7 are high risk prone area. Ward – 12 is less risk prone area. Ward – 2, 3, 4, 5, 6, 8, 9, 10 and 11 are moderate risk areas in terms of spatial condition.

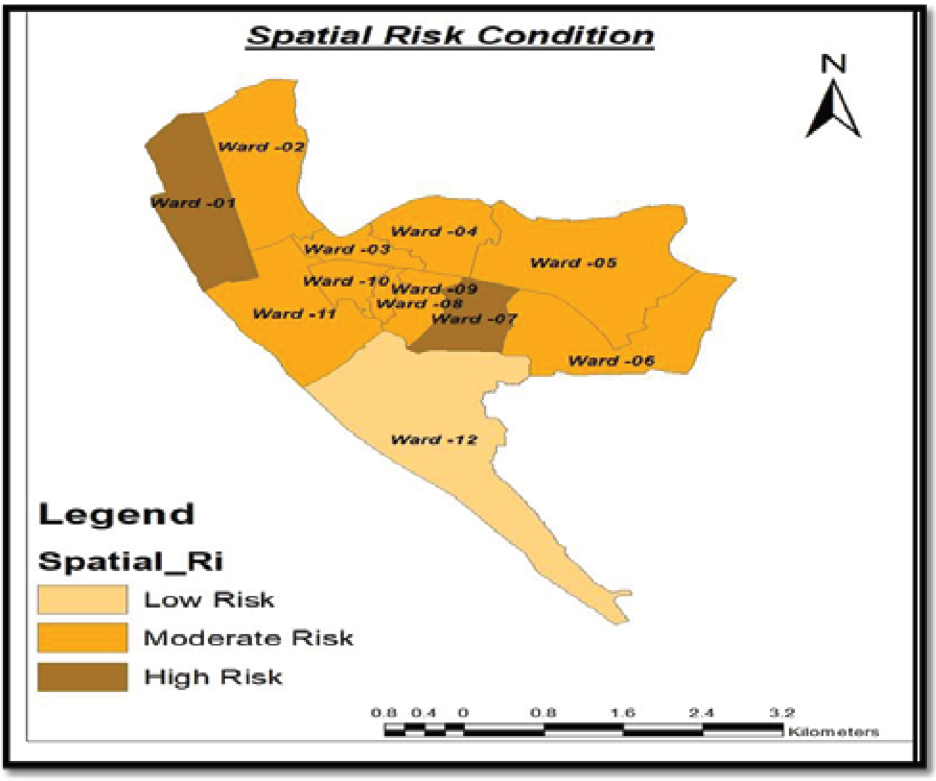

Fig. 8: Map of Spatial Risk of Different Wards. (*Source: Prepared by Authors, 2021).*

Final Risk Index: From the calculation of Non-Spatial Risk Index and Spatial Risk Index, a combined final risk score has been calculated for each ward using the following formula.

Final Risk Index, R = (Non-Spatial Risk Index + Spatial Risk Index)/2

Table 10: Final Risk Index. (Source: Field Survey, 2019; Prepared by Authors, 2021*)*.

Ward	Non-Spatial Risk Index (NSRI)	Spatial Risk Index (SRI)	Final Risk Index = (NSR+SR)/2	Risk category
Ward - 01	3.5	3	3.25	High Risk
Ward – 02	3.7	2	2.85	Moderate Risk
Ward – 03	3.3	2	2.65	Moderate Risk
Ward – 04	2.8	2	2.4	Moderate Risk
Ward – 05	3.3	2.5	2.9	Moderate Risk
Ward – 06	3	2	2.5	Moderate Risk
Ward – 07	3.1	3	3.05	High Risk
Ward – 08	3.1	2	2.55	Moderate Risk
Ward – 09	2.8	2.5	2.65	Moderate Risk
Ward – 10	3.7	2	2.5	Moderate Risk
Ward – 11	4.1	2	3.05	High Risk
Ward - 12	4	1.5	2.75	Moderate Risk

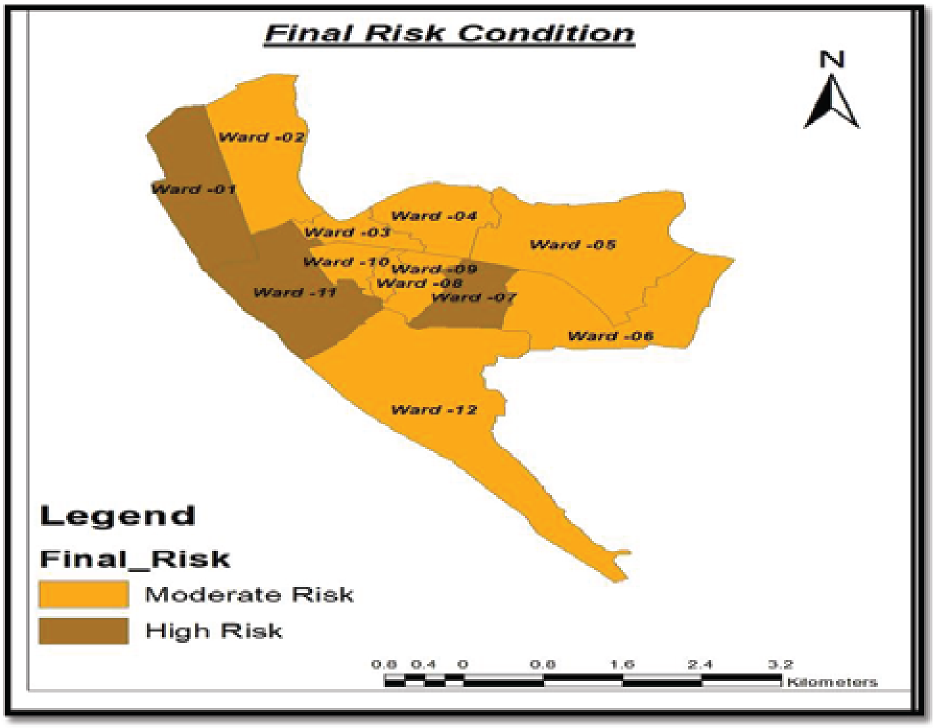

Fig. 9: Map of Final Risk Condition of Different Wards. (Source: Prepared by Authors, 2021).

So According to the Above calculation, Final Risk Index is formulated combining Non-Spatial Risk and Spatial Risk Index. In this regard, this study identified two types of risk at last. Three wards (ward – 1, 7 and 11) out of twelve of Cox's Bazar Paurashava have been resulted as a high risk area of natural disaster like cyclone, flood, storm surge, Tsunami whereas nine Wards (Ward- 2, 3, 4, 5, 6, 8, 9, 10 and 12) of the Paurashava have been categorized as moderate risk area.

Conclusion: Natural disaster risk of coastal communities of Bangladesh is basically a function of their vulnerability in terms of weak socio-economic structure and existing poor infrastructure development. Along with the lack of consciousness and haphazard development, the present form of institutional structure within coastal communities and lack of access of the people in the development process are also the cause of high degree of vulnerability.

The methodology used in this study is very effective to identify the socio-economic and spatial factors. Different types of indicators and parameters are formulated in terms of hazard, vulnerability, resiliency of the people and spatial factors in respect of their settlement. Final Risk Assessment Index (FRAI) is developed from different indicators which are related with hazard, vulnerability, resiliency etc. This index shows different levels of risk on the basis of categorizing the risk level. This study shows that three wards out of twelve wards of the paurashava are in a high-risk category because of their socio-economic and geographical location.

The methodology can be used in the other coastal district or country based on the context and considering different relevant factors such as local area characteristics, selection of necessary vulnerability indicators, resiliency indicators, availability of data, study objectives, study area etc. It is also recommended that appropriate hazard, vulnerability, capacity indicators should be identified for risk assessment in the other areas of the country.

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