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Vulnerability Assessment of Coastal Wards of Chittagong City Corporation Due to Climate Change-Bangladesh

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Abstract: Coast of Chittagong City Corporation, Bangladesh is one of the populous regions of the world. As though, coast of Bangladesh is termed as hotspot for vulnerability to the impacts of climate change so coast of Chittagong City Corporation should be on focus as it is a port city and important for the economy of Bangladesh. This study was aimed to comprehend the vulnerability in several aspects due to climate change effects along the coastal wards of Chittagong City Corporation. Two different approaches of vulnerability to climate change namely as LVI (Livelihood Vulnerability Index) and IPCC-VI (Intergovernmental Panel on Climate Change vulnerability index), using 34 contributing factors were done to calculate the vulnerability of coast of Chittagong City Corporation, particularly in 4 wards: ward 11, ward 26, ward 39 and ward 41. Data were collected and integrated using questionnaire survey of households and secondary information about climate. However, same scale was used to evaluate the individual vulnerability indexes but the overall indicator scale was different between LVI (0 to 1) and IPCC-VI (-1 to 1). Results revealed high vulnerability in ward 11 (0.51) than the ward 26 (0.44), ward 39 (0.42) & ward 41 (0.41) according to LVI. On the other hand, ward 26 (0.05) and ward 41 (0.06) were more vulnerable than ward 11 (0.02) as well as ward 39 (0.02) according to IPCC-VI approach. This study provides land planners, policy makers and all other associated stakeholders a flexible pragmatic tool to assess the extent of level of vulnerability to climate change related impacts on coastal areas.

Keywords: Climate Change, Vulnerability, LVI, IPCC-VI, Chittagong City Corporation, Bangladesh

1. Introduction

Bangladesh is a resource rich country with its natural ingredients. But sometimes it is also cursed by various natural disasters. According to preliminary data from the South Asian country's sixth census published 27th of july 2022, Population and Housing Census 2022, Bangladesh now has a population of 165,158,616 which was 144,043,697 in 2021. This report shows that 83.35 million women and 81.71 million men. The number of people of the third gender stands currently at 12,629 [1]. Climate change is largely responsible for these different types of natural curses. Bangladesh seems to have little to no contributors to this climate issue, but it suffers a lot due to its global status and natural character. According to the Intergovernmental Panel on Climate Change, climate change will bring new environmental conditions due to changes in space and time, as well as the frequency and intensity of weather and climate processes [2]. Each of the past 30 years on Earth's surface has been warmer than any decade since 1850, according to the IPCC's Fifth Assessment Report (AR5). In the Northern Hemisphere, 1983-2012 could be the warmest 30 years in the past 1400 years [3]. IPCC based on its AR4 model also described the climatic modifications and their possible impacts on Bangladesh with high confidence.

Available evidence on climate change suggests that its effects will significantly increase the burden on populations already vulnerable to climate extremes and bearing the brunt of the projected (and increasingly observed) changes caused by global climate change [4]. Such changes often lead to severe weather events. These can have profound impacts on the poor and livelihoods. Each individual develops his or her way of being based on the natural environment and changes in the biotic and abiotic components of the environment. Communities adapt to these changes over the long term by modifying their socioeconomic components. This long-term incremental change ultimately changes the structure of society as a whole. However, due to socioeconomic conditions, each community failed to recover and restore capacity following a catastrophic event or natural disaster [5].

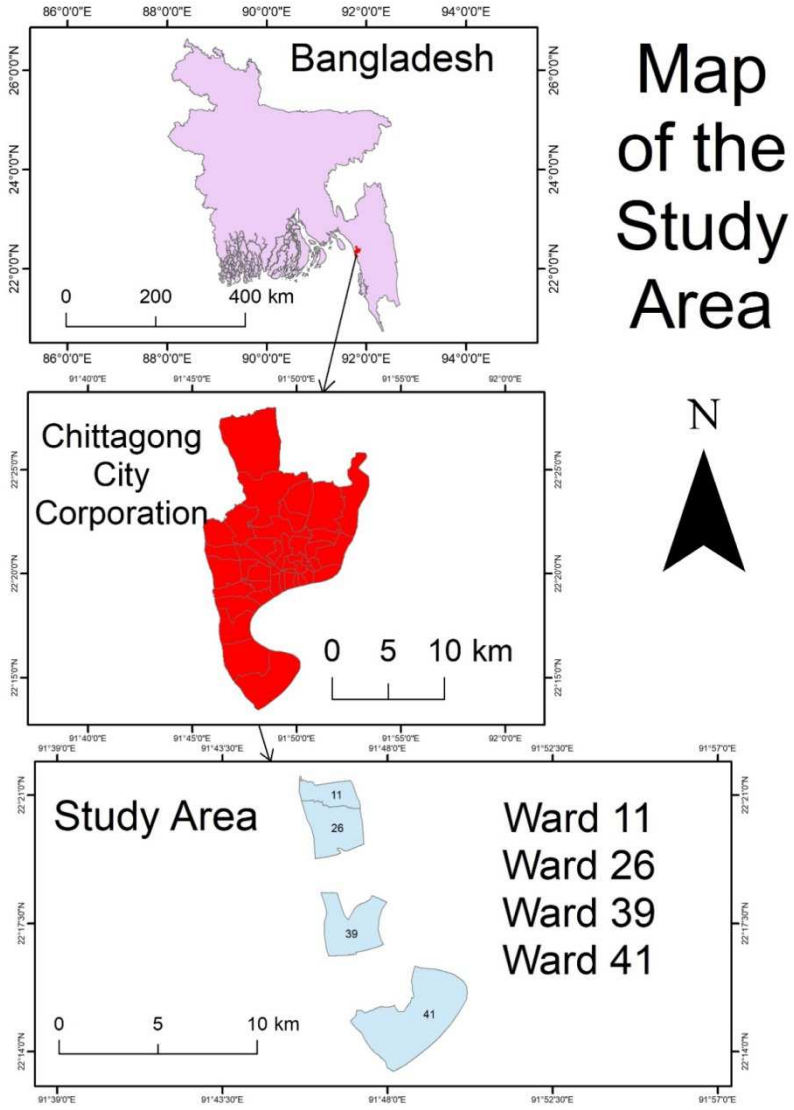


Figure 1. *Map Surveyed area, Chittagong, Bangladesh.*

Table 1. *Target Study Area Source [7].*

Location	Description
Ward-10 is namely as North Kattali	This ward is about 6.22 sq.km and a population of approximately 31401 in 9147 households.
Ward-11 is namely as South Kattali.	This ward is about 3.73 sq.km and a population of approximately 69134 in 20813 households
Ward-26 is namely as North Halishahar.	This ward is about 5.24 sq.km and a population of approximately 39792 in 10376 households.
Ward-37 is namely as North Mid Halishahar	This ward is about 4.1 sq.km and a population of approximately 33845 in 8841 households
Ward-38 is namely as South Mid Halishahar	This ward is about 6.14 sq.km and a population of approximately 50468 in 13741 households
Ward-39 is namely as South Halishahar	This ward is about 12.59 sq.km and a population of approximately 151556 in 24534 households.
Ward-40 is namely as North Patenga.	This ward is about 9.3 sq.km and a population of approximately 48230 in 21539 households
Ward-41 is namely as South Patenga	This ward is about 17.26 sq.km and a population of approximately 32218 in 8586 households.

2. Materials and Methods

2.1. Study Zone

Wards 10, 11, 26, 37, 38, 39, 40, and 41 were part of the Study zone along the Bay of Bengal coast. In Table 1, the ward's specifics are listed.

2.2. Site Selection

Three adjacent regions can be made up of Bangladesh's coastal districts: the south-west, which includes Satkhira, Khulna, and Bagerhat; the south-central, which includes Jashore, Patuakhali, Noakhali, and Barisal; and the south-east, which includes Chittagong and Cox's Bazar [6]. There are 41 wards in Chittagong City Corporation. Among these 8 wards are near the coast of Bay of Bengal. These 8 wards are namely as North Kattali (10), South Kattali (11), North Halishahar (26), North Mid Halishahar (37), South Mid Halishahar (38), South Halishahar (39), North Patenga (40), South Patenga (41). These wards were selected to assess the vulnerability of the Chittagong City Corporation coast as these are facing towards sea and at a close distance from sea. A questionnaire survey was used to assess the vulnerability of livelihood sectors, the existing adaptation condition and possible required adaptation measures. In addition, secondary data about climate and sea level change was collected from Bangladesh Meteorological Department.

2.2.1. Sampling Design

There are 8 wards situated on the coast of Chittagong City Corporation. Simple Random Sampling was done for choosing the wards. 4 wards were chosen for this study. Then how many households were surveyed that had calculated through following equation:

$$n_{0=}\frac{z^2p(1-p)}{e^2}$$

$$\text{n}=\frac{n_{0N}}{n_0+N-1}*1.5$$

Here, N=total households (456644), z=1.96, e=0.05, p=0.10.

Through this equation approximate household number for survey was found around 210.

2.2.2. Calculating the LVI: Composite Index Approach

According to Hahn et al. (2009), the LVI employs a balance-weighted average technique, in which each sub-component contributes equally to the total index and each main component has a varied number of sub-components [8]. Climate change's impact on livelihoods may be effectively understood as a result of biophysical and social elements [9]. Depending on the local condition, available information from various sources and reconnaissance survey LVI in this study includes 7 categories:

1) Family status, Education & Occupation-FEA.
2) Asset, income & dependency-AID.
3) Treatment, training & cultivation-TTC.
4) Natural Resources (Land, Forest, Water)-NR.
5) Residence Condition & Energy-RCE.
6) Communication-C.
7) Climatic condition-CC.

These 7 categories were again subdivided by 34 components. These components are mentioned in the following pages along with their importance on vulnerability and calculation procedure.

LVI adopts balanced weighted average [10] where each major component has a variable number of sub-components, but each sub-component contributes equally to the overall index. The LVI formula takes the straightforward approach of giving each key component equal weights because we wanted to create an assessment tool usable by a wide range of users in settings with limited resources. Future users could modify this weighting system as necessary. It was first necessary to standardize each sub-component into an index because they are all assessed on various scales. The equation used to calculate the life expectancy index, which is the ratio of the difference between the actual life expectancy and a predefined minimum, and the range of the predetermined maximum and minimum life expectancy, was modified from that used in the Human Development Index [11].

$$\text{Index}S_{ward} = (S_{ward} - S_{min})/(S_{max} - S_{min})$$

Where, Sward is the original sub-component for any ward, and Smin and Smax are the minimum and maximum values, respectively, for each sub-component determined using data from each wards.

After each was standardized, the sub-components were averaged using Eq. (2) to calculate the value of each major component

$$C_{ward} = \frac{\sum_{i=1}^{n} indexS_{ward}}{n}$$

Where, C_ward = one of the six major components for any ward.

[(family status, Education & Occupation-FEA), (Asset, income & dependency-AID), (Treatment, training & cultivation-TTC), (Natural Resources-NR), (Residence Condition & Energy-RCE), (Communication-C), (Climatic condition-CC)], index S_ward represents the sub-components, indexed by i, that make up each major component, and n is the number of sub-components in each major component.

Once values for each of the seven major components for a ward were calculated, they were averaged using Eq. (3) to obtain the Ward-level LVI:

$$LVI_{ward} = \frac{\sum_{i=1}^{n} WC_i.C_{wardi}}{\sum_{i=1}^{n} \mathrm{WC_i}}$$

Which can also be expressed as

$$LVI_{ward} = \frac{W(FEO)FEO_{ward}+W(AID)AID_{ward}+W(TTC)TTC_{ward}+W(NR)NR_{ward}+W(RCE)RCE_{ward}+W(C)C_{ward}}{W(FEO)+W(AID)+W(TTC)+W(NR)+W(RCE)+W(C)}$$

Where, LVI_{ward}, the Livelihood Vulnerability Index for ward, equals the weighted average of the six major components. The weights of each major component are WC_i determined by the number of sub-components that make up each major component and are included to ensure that all sub-components contribute equally to the overall LVI [10]. In this study, the LVI is scaled from 0 (least vulnerable) to 0.5 (most vulnerable).

2.2.3. Calculating the IPCC-VI: IPCC-VI Framework Approach

In this approach the LVI will be = (Exposure – Adaptive Capacity) × Sensitivity.

In this technique, IPCC-VI scaled was as -1 (least vulnerable), 0 (highly vulnerable) and 1 (most vulnerable).

2.2.4. Major Components and Sub Components

Table 2. *Major components and sub-components according to 3 IPCC-VI contributing factors.*

Contributing Factors	Components	Sub-components
Adaptive Capacity	Family Status, Education & occupation	Family size
		Senior citizen (60+)
		Literacy rate
		Education
	Asset, income & dependency	Agricultural and non-agricultural land
		Having (Shop/boat/net)
		Domestic animal
		Family income
		Dependency occupation
	Communication	Time to reach nearest cyclone center/safe place
		Access of relief during disaster
		Road quality
		Having information by local govt. before disaster
	Residence condition & Energy	House type
		House ownership
		Homestead plantation
		Affected by water during high tide
		Electricity
		Solar power
		Use of candle or kerosene
Sensitivity	Natural resources	Productivity loss
		Land loss due to climate change
		Use of firewood
		Scarcity of firewood
		Salinity intrusion
		Availability of freshwater
		Availability of doctor
Exposure	Treatment, training & Cultivation	Vegetable cultivation
		Training about climate change or natural disaster management
		Percentage of people go to cyclone center/any safe place during disaster
	Climatic Condition	Average temperature
		Humidity
		Average rainfall
		Wind Speed

2.2.5. Data Calculation Procedure

Dependency ratio

It was assumed over 60 years' people will be more vulnerable during disaster to cope with.

Dependency ratio = Number of total people (over 60 years)/ Number of total people (population).

Average family member in a HHs

It was assumed that more family members, the more economic problems and during disasters it would be difficult to manage efficiently.

Average family members in a HHs = total population in the survey/Total HH surveyed for a ward.

Average of inverse land holding index

It was assumed that the less the land of people, the less the assets of them. So their economic status might be normal or below normal.

$$\text{Average of inverse land holding index} = \frac{\sum[1/landarea(ganda)repoted\ by\ a\ house\ hol+1)]}{total\ HH\ surveyed\ for\ a\ ward}$$

I was added because if some households have not their own land then it will be 0 and the inverse of 0 will be unreal, and the reason of inversing was that the more land a household had the less vulnerability would occur), e.g.,

A house hold that has 0.91 hector will have inverse of Average land holding index =1/ (0.91+1) =0.52

Percent of HHs who's have not their own shop/fishing boat/ other business

It was assumed that the households having their own shop/ fishing boat / other business will be less vulnerable than other because of their own asset and outsource income beside their other occupations

Percent of households who have not their own shop/fishing boat/other business = (total households who have not their own shop/fishing boat/other business X 100)/ Total HH surveyed for a ward.

Percent of HHs who's have not cattle/other types of domestic birds

It was assumed that the households having their own cattle /other types of domestic birds will be less vulnerable than other because it will help them for extra income.

Percent of HHs who's have not cattle/other types of domestic birds = (total households who have not their cattle/other types of domestic birds' X 100)/ Total HH surveyed for a ward.

Average of inverse monthly income index

It was assumed that the less the income of household the more the vulnerability of the people.

Average of inverse monthly income=∑ [1/monthly income class of house hold (thousand+1)]/Total HH surveyed for a ward

1 was added because if some households have no income, then it will be 0 and the inverse of 0 will be unreal, and the reason of inversing was that the more income a household had the less vulnerability would occur), e.g.

A household that has income 4 thousand will have inverse of Average land holding index =1/ (4+1) =0.20

Percent of HHs that do not have homestead vegetable cultivation

It was assumed that households that have homestead vegetable cultivation might use the vegetable in different times and it can be cultivated in homestead area instead of separate places also help economically

Percent of HHs that do not have homestead vegetable cultivation business = (total households who have homestead vegetable cultivation X 100)/ Total HH surveyed for a ward.

Average of inverse education index

It was assumed that people have qualification could know more than other about different aspects and also about nature and climate change, their causes and consequences. These might also influence family members and others to go to school and could also spread their knowledge to other people.

$$\text{Average of inverse education index} = \frac{\sum[1/\text{average educational qualification of a household (class)}+1)]}{\text{Total HH surveyed for a ward)}}$$

Here qualification is defined by number of classes. In case of average education of a household people were considered with age more than 6 years and religious school was also taken into consideration. 1 is added to avoid unreal number through dividing by 0 e.g.

If the highest educational qualification of a household is class 3.5 then inverse of education index = 1/ (3.5+1) = 0.22

Percent of HHs that are at a remote place where relief items cannot be served easily after disaster

It was assumed that households that are remote place where relief items cannot be served easily after disaster might be

deprived of relief items or lately served and this would act as barrier to recover quickly.

Percent of HHs that are a remote place where relief items cannot be served easily after disaster = (total households that are at a remote place where relief items cannot be served easily after disasters X 100)/ Total HH surveyed for a ward

Average time to reach nearest cyclone center/safe place

It was assumed that more time to reach the nearest cyclone centers/safe place would indicate people inability to reach there in time before cyclone. However, it might also indicate the absence of cyclone center nearby.

Average time to reach nearest cyclone center/safe place = Total time (min) to reach nearest cyclone center/safe place from every household/ Total HH surveyed for a ward

Percent of HHs who lack of candle/kerosene for lighting at night or other materials for energy

It was assumed that lack of candle/kerosene for lighting at night would indicate the unavailability of these things nearby and also might indicate the economic condition of the households.

Percent of HHs who lack of candle/kerosene for lighting at night = (total HHs who lack of candle/kerosene for lighting at night or other materials for energy × 100)/ Total HH surveyed for a ward

Percent of HHs who have no solar power

It was assumed that solar power would be an important alternate energy resource to get electricity.

Percent of HHs who have no solar power = (Total HHs who has no solar power× 100)$/Total\ HH\ surveyed\ for\ a\ ward$

Percent of HHs who have no electricity supply

It was assumed that HHs who have no electricity supply would not intend to buy TV and radio through which they can get information. Moreover, they might face trouble to recharge their mobile battery.

Percent of HHs who have no electricity supply = (Total HHs who have no electricity supply× 100)$/Total\ HH\ surveyed\ for\ a\ ward$

Percent of HHs that do not have Homestead plantation

It was assumed that HHs having homestead tree plantation are less vulnerable to cyclone, storm and strong wind.

Percent of HHs that do not have Homestead tree plantation= (total HHs that do not have Homestead tree plantation × 100)$/Total\ HH\ surveyed\ for\ a\ ward$

Percent of HHs that have kacha house pattern

It was assumed that HHs having Kacha house are vulnerable to cyclone, storm and strong wind.

Percent of HHs that have kacha house = (total HHs that have kacha house × 100)$/Total\ HH\ surveyed\ for\ a\ ward$

Percent of HHs that do not have daily availability of fresh water

It was assumed that daily unavailability of water would indicate the fresh water shortages as well as risk on health.

Percent of HHs that do not have daily availability of fresh water = (total HHs that do not have daily availability of fresh water× 100)$/Total\ HH\ surveyed\ for\ a\ ward$

Percent of HHs reporting that firewood is being scarce now in comparison to 30 years' back

It was assumed that scarcity of firewood comparison to 30 years back indicate the existing poor forest condition.

Percent of HHs reporting that firewood is being scarce now in comparison to 30 years back = (total HHs reporting that firewood is being scarce now in comparison to 30 years back× 100)$/Total\ HH\ surveyed\ for\ a\ ward$

Percent of HHs use firewood

It was assumed that using firewood destroy the existing forest gradually and also it would indicate the lack of adaptive capability in finding alternatives.

Percent of HHs use firewood = (Total HHs using only firewood × 100)$/\ Total\ HH\ surveyed\ for\ a\ ward$

Percent of HHs reporting land productivity loss

It was assumed that decreased land productivity with time might make th HHs vulnerable in near future.

Percent of HHs reporting land productivity losses= (total HHs reporting land productivity loss

$$\times 100)/Total\ HH\ surveyed\ for\ a\ ward$$

Average of inverse Road quality index
It was assumed that road quality could support the HHs resiliency economically.

$$\text{Average of inverse road quality index} = \sum[\frac{1}{road\ quality}]/Total\ HH\ surveyed\ for\ a\ ward$$

Average of inverse doctor availability index
It is assumed that doctor availability is very important in climate vulnerability.

$$\text{Average of inverse doctor availability index} = \sum[\frac{1}{doctor\ availability}]/Total\ HH\ surveyed\ for\ a\ ward$$

Here doctor availability index will be divided into 3 categories (Low=1, Moderate=2, Good=3).
Percent of people who report on Salinity intrusion
Salinity intrusion indicates the high vulnerability.

$$\text{Percent of people who report on salinity intrusion= (total people reporting on salinity intrusion} \times 100)/90$$

Average of inverse dependency on occupation
It is assumed that who are dependent on agriculture, Business near coast and fishing more vulnerable than others

$$\text{Average of inverse dependency on occupation} = \frac{\Sigma[\frac{1}{dependency\ on\ occupation}]}{Total\ HH\ surveyed\ for\ a\ ward}$$

Here dependency on occupation is divided into 3 categories (Agriculture=1, Business near coast=2, fishing=3).

2.2.6. Detail Results of the Sub-components

Table 3. *Family status & Education.*

Sub-components	Unit	Value of index					
		Ward 11	Ward 26	Ward 39	Ward 41	Max	Min
Average family size	Count	5.25	5.12	4.59	5.17	11	1
Dependency rate	Ratio	0.09[8]	0.12	0.06	0.12	0.17	0.05
Literacy rate	Percent	64.69	60.7	72.99	53.6	100	0
Average inverse education index of HHs	1/# average education	0.68	0.71	0.57	0.57	1	0.23

Table 4. *Asset, income & Dependency of work.*

Sub-components	Unit	Value of index					
		Ward 11	Ward 26	Ward 39	Ward 41	Max	Min
Land	1/landholding	0.53	0.58	0.86	0.54	1	0.09
Asset	Percent	15.5	25	32	51	100	0
Domestic animals	Percent	50	58.82	23.75	25	100	0
Family income	1/monthly income index	0.46	0.53	0.43	0.4	1	0.2
Dependency of Occupation	Percent	40	26	14	21	100	0

Table 5. *Treatment, training & cultivation.*

Sub-components	Unit	Value of index					
		Ward 11	Ward 26	Ward 39	Ward 41	Max	Min
Availability of doctor	1/availability of doctor class index	0.66	0.68	0.48	0.77	1	0.33
Vegetable cultivation	Percent	52.95	47.05	81.25	75	100	0
Training on climate change	Percent	91.18	97.06	85	78.57	100	0
How many people didn't go to cyclone center during disaster	Percent	39.71	20.59	2.5	17.86	100	0

Table 6. *Natural resources.*

Sub-components	Unit	Value of index					
		Ward 11	Ward 26	Ward 39	Ward 41	Max	Min
Productivity loss	Percent	57.35	14.71	30	14.28	100	0
Land loss	Percent	44.12	14.71	10	10.71	100	0
Use of firewood	Percent	64.71	8.82	20	32.14	100	0
Firewood scarcity	Percent	67.65	85.29	62.5	92.86	100	0
Salinity intrusion	Percent	52.94	97.05	42.5	32.14	100	0

Sub-components	Unit	Value of index					
		Ward 11	Ward 26	Ward 39	Ward 41	Max	Min
Availability of freshwater	Percent	57.35	35.29	16.25	25	100	0

Table 7. *Residence condition & energy.*

Sub-components	Unit	Value of index					
		Ward 11	Ward 26	Ward 39	Ward 41	Max	Min
House type	Percent	54.41	55.88	15	25	100	0
Ownership of house	Percent	42.65	41.18	81.25	57.14	100	0
Homestead plantation	Percent	48.53	55.88	66.25	42.86	100	0
Affected during high tide	Percent	61.74	41.18	61.25	60.71	100	0
HHs Having electricity	Percent	11.76	8.82	12.5	28.57	100	0
HHs who use solar power	Percent	89.71	91.18	92.5	57.14	100	0
Using alternative source of energy	Percent	36.76	17.65	12.5	17.86	100	0

Table 8. *Communication status.*

Sub-components	Unit	Value of index					
		Ward 11	Ward 26	Ward 39	Ward 41	Max	Min
Time to go to cyclone center	Minute	19.59	18.56	5.5	12.96	45	0
Percent HHs who get relief after the disaster	Percent	80.88	70.59	61.25	60.71	100	0
Road quality	1/#road quality	0.62	0.42	0.43	0.55	1	0.33
Don't get Early warning about upcoming disaster by local government	Percent	1.47	0	0	0	100	0

Table 9. *Climatic condition.*

Sub-components	Unit	Value of index					
		Ward 11	Ward 26	Ward 39	Ward 41	Max	Min
Wind speed (BMD, 2014a)	m/s	5.37	5.37	5.37	5.37	8.87	2.11
Humidity (BMD, 2014b)	Percent	78.58	78.58	78.58	78.58	85	70
Rainfall (BMD, 2014c)	Mm	243.26	243.26	243.26	243.26	727	5.6
Average temperature (BMD, 2014d)	Degree Celsius	25.62	25.62	25.62	25.62	32.6	13.2

2.2.7. Detailed Results of Contributing Factors

Table 10. *Contributing Factors of Vulnerability- Exposure.*

Sub-components	Vulnerability index			
	Ward 11	Ward 26	Ward 39	Ward 41
Availability of doctor	0.49	0.52	0.22	0.74
HHs who have vegetable cultivation	0.53	0.47	0.81	0.75
Percentage of people who have training about climate change or natural disasters	0.91	0.97	0.85	0.79
Percentage of People who didn't go to the cyclone center during the disasters	0.38	0.21	0.03	0.18
Average wind speed	0.48	0.48	0.48	0.48
Average humidity	0.57	0.57	0.57	0.57
Average rainfall	0.33	0.33	0.33	0.33
Average temperature	0.64	0.64	0.64	0.64

Table 11. *Contributing Factors of Vulnerability- Adaptive Capacity.*

Sub-components	Vulnerability index			
	Ward 11	Ward 26	Ward 39	Ward 41
Average family size	0.53	0.41	0.43	0.27
Dependency ratio	0.05	0.08	0.40	0.54
Literacy rate	0.64	0.60	0.72	0.54
Inverse Average education of HHs	0.57	0.58	0.46	0.44
Average of inverse landholding index	0.48	0.52	0.83	0.49
Percentage of HHs who have fishing boat, net or other business related to sea	0.16	0.25	0.32	0.51
Percentage of people who haven't domestic animals	0.5	0.59	0.24	0.25
Average of inverse family income	0.31	0.41	0.78	0.25
Percentage of people who mainly dependent on fishing or agriculture	0.4	0.26	0.14	0.21
Percentage of HH having Kacha House	0.54	0.56	0.15	0.25
Percentage of people who lives in own house	0.43	0.41	0.81	0.57
Percentage of HH who have homestead plantation	0.48	0.56	0.67	0.43
Percentage of HH who are affected during the high tide	0.62	0.41	0.61	0.61
Percentage of people who haven't electricity	0.12	0.88	0.13	0.29
Percentage of HH haven't solar power system	0.90	0.91	0.93	0.57

Sub-components	Vulnerability index			
	Ward 11	Ward 26	Ward 39	Ward 41
Percentage of HH haven't other energy sources	0.37	0.18	0.13	0.17
Average time (minute) to go to the cyclone center or any other safe place	0.44	0.61	0.12	0.13
Percent of HHs who didn't get relief after the disasters	0.81	0.71	0.61	0.61
Inverse road quality index	0.43	0.15	0.14	0.32
Percent of HHs who didn't get information before the upcoming disasters	0.01	0	0	0

Table 12. *Contributing Factors of Vulnerability- Sensitivity.*

Sub-components	Vulnerability index			
	Ward 11	Ward 26	Ward 39	Ward 41
Percent of People who face productivity loss problem	0.57	0.15	0.30	0.14
Percent of people who have facing land loss problem	0.44	0.15	0.10	0.11
Percent of who use firewood as fuel	0.65	0.09	0.20	0.32
Percentage of people who observed firewood scarcity	0.68	0.85	0.61	0.92
Percent of HHs who faced salinity intrusion problem	0.53	0.97	0.41	0.32
Percent of HHs who didn't get available freshwater	0.57	0.35	0.16	0.25

3. Result and Discussion

3.1. Adaptive Capacity

Adaptive planning for climate change can result in legislative interventions that result in lost opportunities, the foreclosing of private property, required structural alteration, and desertion on a large scale in communities, changes to occupations and professional activity, and disturbance of collective lifeway's [12].

3.2. Dependency Ratio

In case of dependency ratio ward 26 and ward 41 were more vulnerable (index- 0.122 and 0.115) than that of ward 11 and 39 (Figure 2). This might be because of more over aged people in the families of ward 26 and ward 41.

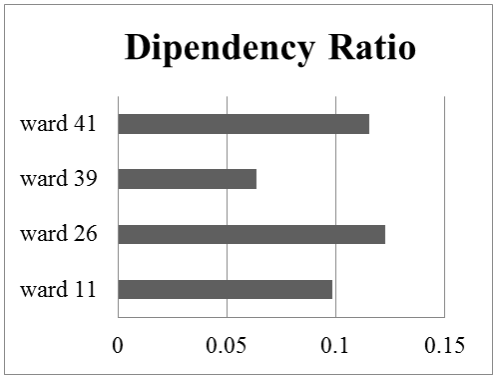


Figure 2. *Vulnerability index of dependency ratio among the wards.*

Similar type of ratio (0.374) was found in Bhutan (jakobsen, 2011) and 0.238, 0.229) in Lete and Kunjo, Nepal [13].

3.2.1. Education Index

In terms of education, demonstrate that average education was highly vulnerable (ward 11- '0.68', ward 26- '0.72', ward 39- '0.57' and ward 41- '0.57'). Here, ward 26 was mostly vulnerable.

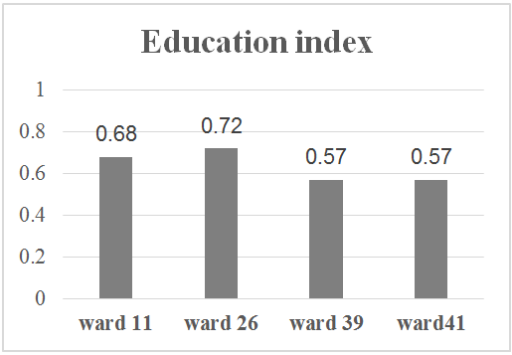


Figure 3. *Average education index of HHs.*

3.2.2. Having Domestic Animals

Some households of these wards had domestic animals. Among them around 50% and 58.82% households had domestic animals respectively in ward 11 and ward 26. These wards were less vulnerable than ward 39 as well as ward 41. On the other hand, they had to graze these animals in the field. Sometimes this was done by the children, which made the children vulnerable during disasters.

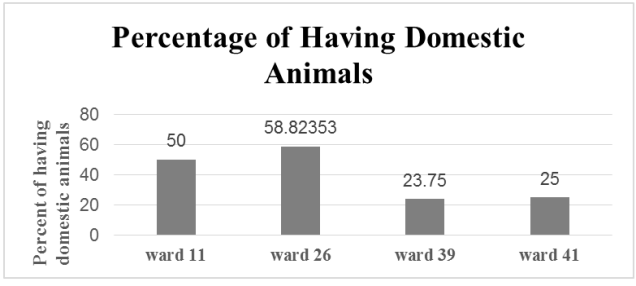


Figure 4. *Percentage of having domestic animals among the wards.*

3.2.3. Land Holding Index

The vulnerability in case of average land holding ward 39 (0.86) was much more than ward 11 (0.53), ward 26 (0.57) and ward 41 (0.54) according to Figure 5. It might be due to huge human pressure in small areas whether the actual land status could not be verified. In this case, ward 39 was more

vulnerable than others. On the other hand, other wards showed almost similar inverse land holding index.

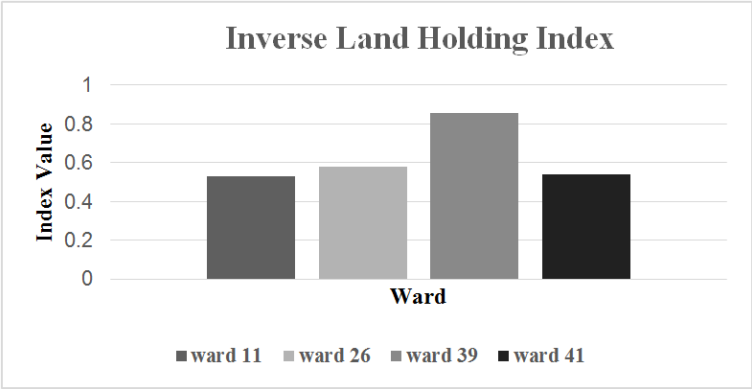


Figure 5. *Inverse land holding vulnerability index.*

3.2.4. House Type

From Figure 6, around 54.41%, 55.88%, 15% & 25% house of ward 11, 26, 39 & 41 was in Kacha formation. Here ward 11 & 26 are mostly vulnerable than the word 39 & and 41.

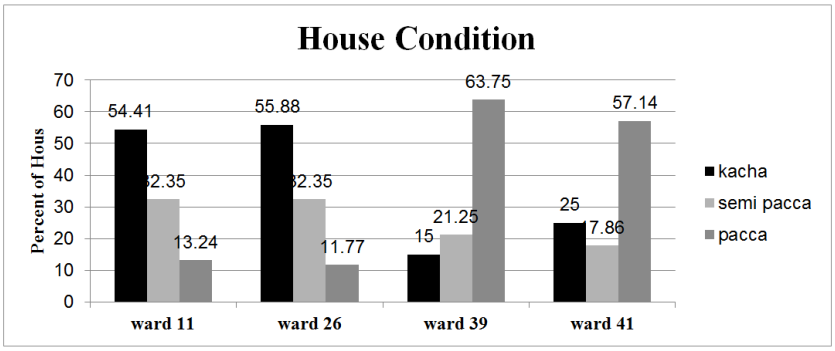


Figure 6. *House condition.*

3.2.5. Family Income

In this study, it was found that in range 1000-10000 taka/month for household income ward 26 got the highest position and ward 39 got the lowest position. Again, in the second range (11000-20000) ward 11 & 39 show higher than the ward 26 as well as ward 41. At 3rd range (21000-30000) all wards show almost the similar result, these are 29.41%, 32.35%, 32.5% and 28.57% respectively for ward 11, 26, 39 and 41. After that, at 31000 to 40000 range ward 41 got the highest pic than the others almost 35.71%. Then at range (41000 to 50000) show the poor result for every wards, in that position 7.14% family of ward 41 earn in this range. After that, only 1.47% & 2.5% family from ward 11 as well as ward 39 earn above 50000 taka per month and ward 26 & 39, 0% family found who earn in this range.

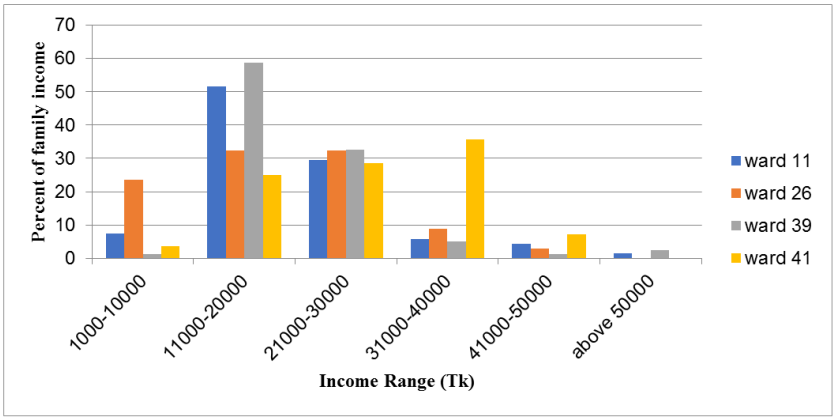


Figure 7. *Family income classification.*

3.2.6. Vegetable Cultivation

It was assumed that HHs that have homestead vegetable cultivation might use the vegetables in different times and it can be cultivated in homestead area instead of separate places and also help economically. From the Figure 8, it was seen that 47.05%, 52.94%, 18.75% & 25% HHs among ward 11, 26, 39 & 41 respectively. In that regard, ward 39 is more vulnerable than the other wards because a very few populations in this ward have homestead vegetable cultivation. Then ward 41 will be counted in these circumstances. As though people of ward 41 has huge bare land.

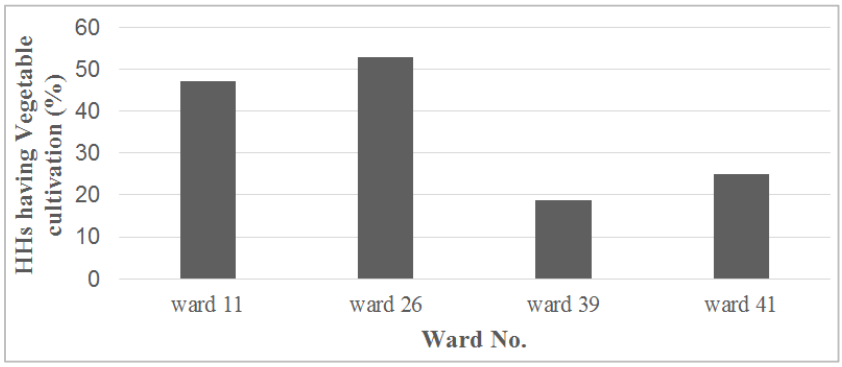


Figure 8. *HHs who's having homestead vegetable cultivation.*

3.2.7. Homestead Plantation, Tidal Effect and Electricity

HHs of ward 11, 26, 39 & 39 has around 66.18%, 44.12%, 33.75% and 57.14% homestead plantation. It was assumed that high quantity of homestead plantation means low vulnerability of a community. Here, ward 39 got the lowest rank and this ward is mostly vulnerable than the other wards. Again, 61.76%, 41.17%, 61.25% and 39.29% HHs of ward 11, 26, 39 & 41 were affected during high tide respectively. In that situation, ward 11 & 39 are more vulnerable than ward 26 as well as ward 41. According to the Figure 9, there has good electricity supply in every ward. After the HH survey around 88.24%, 91.17%, 87.5% and 71.43% HHs have electricity among ward 11, 26, 39 & 41 respectively. Here ward 41 is in the lowest rank.

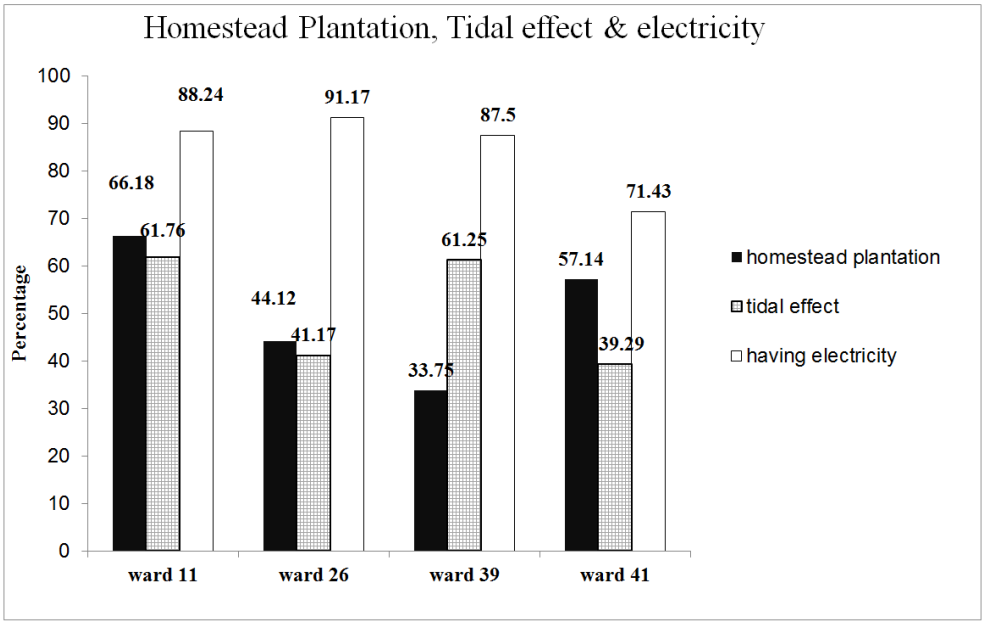


Figure 9. *Percentage of HHs having homestead plantation, tidal effect due to high tide and electricity.*

3.2.8. Sensitivity

Natural Resources

According to Figure 10, 57.35%, 14.7%, 30% and 14.29% HHs of ward 11, 26, 39 and 41 showed about the productivity loss of soil due to climate change. This Figure showed that ward 11 got the highest rank in productivity loss and this ward was mostly vulnerable. On the other hand, ward 41 was low vulnerable. Again, land loss bar diagram form ward 11, 26, 39 & 41 showed 44.12%, 8.82%, 10% & 10.71% percent people reported about the land loss. In this regard ward 11 is mostly vulnerable. Again 58.82%, 85.29%, 20% & 32.14%

HHs from ward 11, 26, 39 & 41 used firewood as fuel respectively. From that sequence ward 20 is mostly vulnerable. Therefor, 97.05%, 97.05% 62.5% & 92.85% people of ward 11, 26, 39 & 41 respectively noticed that firewood scarcity is going on rapidly. Salinity intrusion is also a very common effect of climate change. Around 54.41%, 35.29%, 42.5% and 32.14% people from ward 11, 26, 39 and 41 respectively suffer from salinity intrusion. Among them ward 11 is mostly vulnerable due to the climate change activities. From that Figure 10, it was assumed that 57.35%, 76.47%, 80% and 75% HHs of ward 11, 26, 39 and 41 got available freshwater respectively. Here ward 11 is mostly vulnerable than the other words.

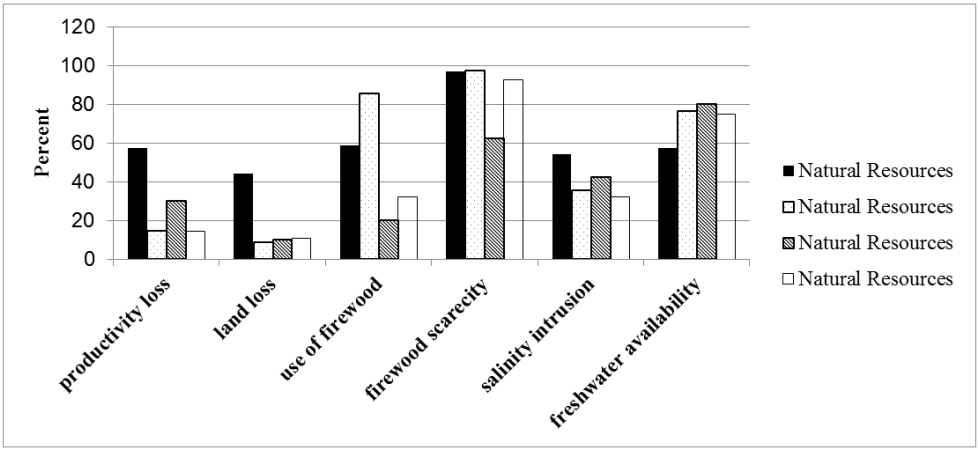


Figure 10. *Natural resources status with a view to climatic effect.*

3.2.9. Exposure

Availability of Doctor

From the Figure 11 for ward 11 it was seen that 35.29% HHs got low medical support or available doctor facility, 54.41% HHs got medium doctor facility & 10.29% HHs got high available facility of doctor. At ward 26 it was seen that 41.17% HHs got low medical support or available doctor facility, 41.17% HHs got medium doctor facility & 17.65% HHs got high available facility of doctor. On the other hand, at ward 39 it was seen that 5% HHs got low medical support or available doctor facility, 67.5% HHs got medium doctor facility & 27.5% HHs got high available facility of doctor. Again, at ward 41 it was seen that 53.57% HHs got low medical support or available doctor facility, 46.43% HHs got medium doctor facility & 0% HHs got high available facility of doctor. From that, it could be said after the HH survey ward 41 is more vulnerable than the other wards due to availability of doctor.

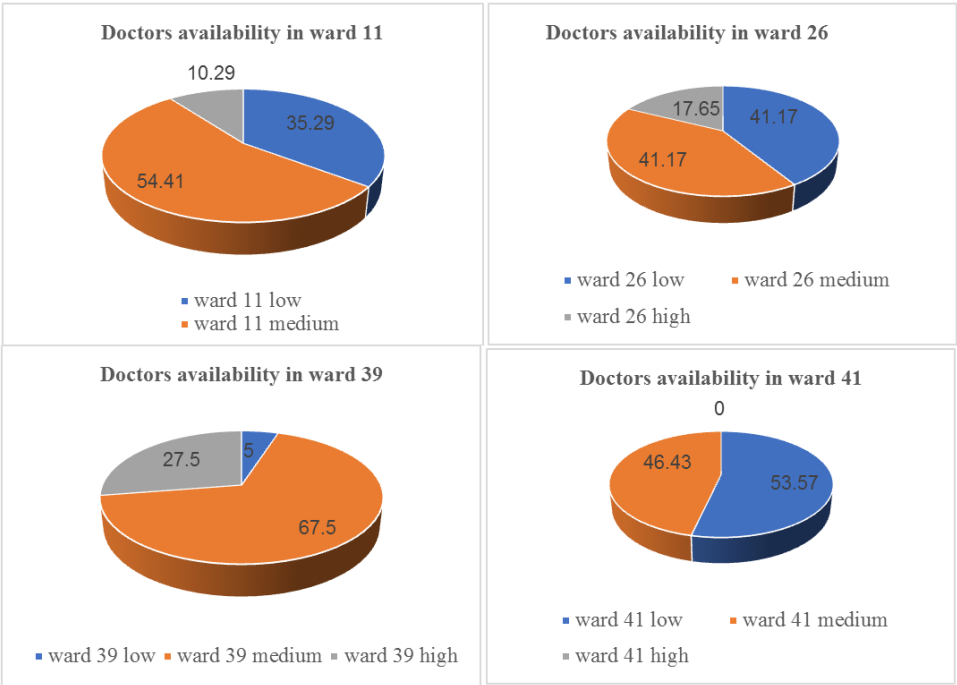


Figure 11. *Availabilty of doctor.*

3.2.10. Training

It was assumed that people who haven't training about the climate change and its effect or other perspective related to climate change are more vulnerable. Figure 12 shows that 8.82%, 2.94%, 15% and 21.43% people from ward 11, 26, 39 & 41 got training about the climate change related perspective or activities. In that regard every ward is vulnerable but among them ward 26 is mostly vulnerable than the other 3 wards.

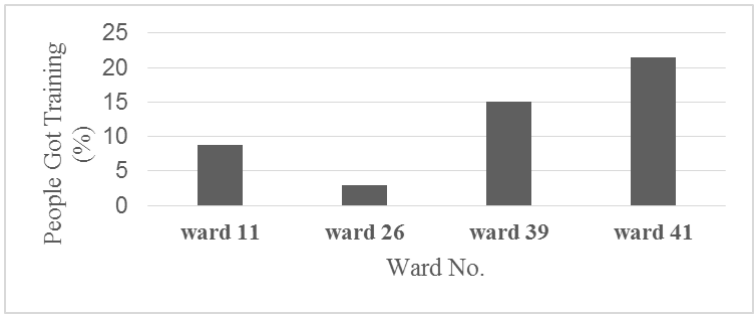


Figure 12. *Percent of people who have training on climate change.*

3.3. Cyclone Center and Safety

Around 60.29%, 79.41%, 97.5% and 82.14% HHs from ward 11, 2, 39 & 41 went to the cyclone center during the disaster.

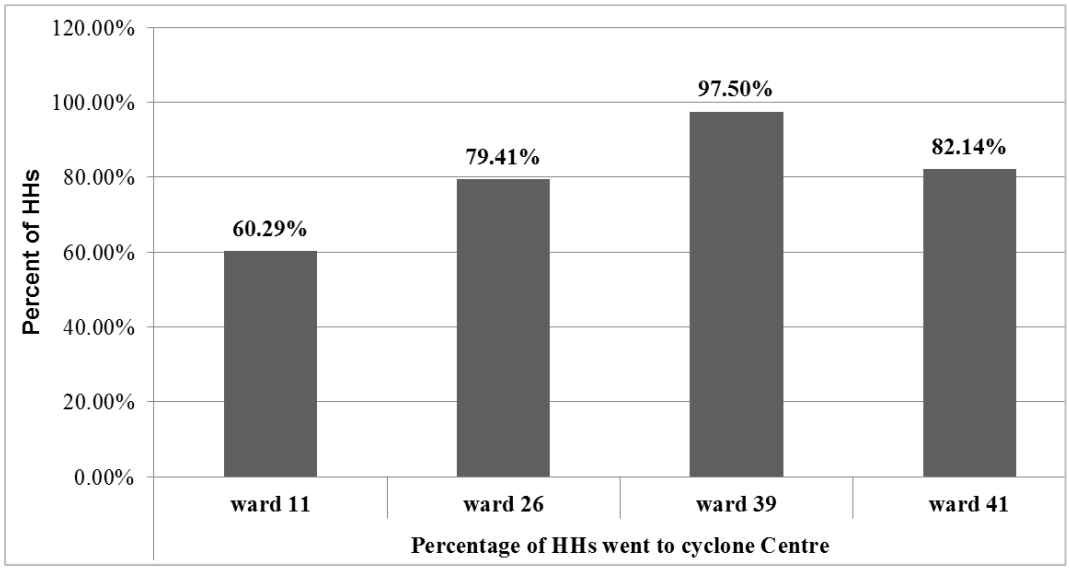


Figure 13. *Percent of people who went to cyclone center.*

3.3.1. Time to Go to the Nearest Cyclone Center or Any Safe Place

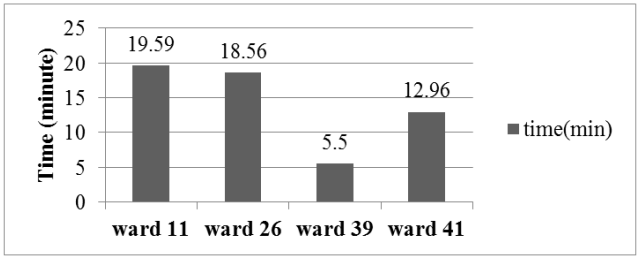


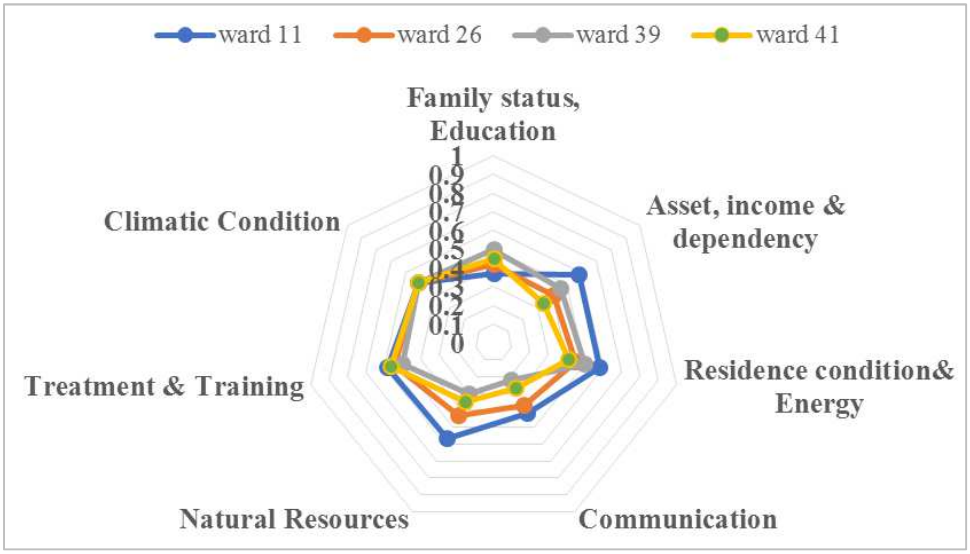
Figure 14. *Average time (minute) to go to the nearest cyclone center or any other safe place.*

Cyclone centers are very important to cope up with the natural disasters. From Figure 14, average 19.59min, 18.56min, 5.5min & 12.96min was needed to go to cyclone center or any other safe place of the people of ward 11. 26. 39 & 41 during the natural disasters. From that study people of ward 11 needed more time than the other wards to go to cyclone center. So ward 11 was mostly vulnerable than the other wards.

3.3.2. Major Components

Index values for all major components of the contributing factors are shown in Figure 15. In case of 'Family status and Education' ward 39 (0.50) was mostly vulnerable than other wards. In case of 'Asset, income and dependency' ward 11 (0.58) was mostly vulnerable than others and ward 41 (0.34) showed the low vulnerability. In the major component 'Residence condition and Energy' ward 11 (0.58) was mostly vulnerable because most of the people were poor and lives in 'kacha' house and ward 41 (0.41) showed the low

vulnerability. In 'Communication' phase ward 11 (0.42) was again mostly vulnerable and ward 39 (0.22) showed the low vulnerability than others. In case of 'Natural Resources' ward 11 (0.57) showed the high vulnerability and ward 39 (0.30) showed the low vulnerability. In case of 'Training and treatment' ward 11 (0.58) and ward 41 (0.56) showed almost similar result and these are highly vulnerable. On the other hand, in 'Climatic Condition' all wards showed the same result (0.51) because of same geographical location.



Note: - 0 = least vulnerable / most adaptive capacity; 1 = most vulnerable /least adaptive.

Figure 15. *Vulnerability spider diagram for major components.*

Capacity Index values for the major components of the contributing factors are shown in Figure 15.

Index values for the contributing factors and the same for LVI-IPCC is shown in Table 13. Index values for the contributing factors and the same for LVI-IPCC was shown in table for ward 11, 26, 39 and 41 according to 3 IPCC-VI contributing factors namely as adaptive capacity, sensitivity and exposure. And 7 categories/major components were introduced in these 3 contributing factors. Here index values of these 7 major components were shown in the following table. And their number of sub-components also mentioned. After that contributing factor values of ward 11 were 0.51 for adaptive capacity, 0.57 for sensitivity and 0.54 for exposure. Contributing factor values of ward 26 were 0.41 for adaptive capacity, 0.43 for sensitivity and 0.52 for exposure. And contributing factor values of ward 39 were 0.42 for adaptive capacity, 0.30 for sensitivity and 0.50 for exposure. After that contributing factor values of ward 41 were 0.37 for adaptive capacity, 0.35 for sensitivity and 0.54 for exposure. In this context, in adaptive capacity ward 11 was mostly vulnerable and ward 41 was low vulnerable than others. Then in the scenario of sensitivity ward 11 was mostly vulnerable and ward 39 showed the lowest vulnerability than other wards. After that in case of exposure ward 11 and ward 41 were mostly vulnerable than other 2 wards and ward 39 showed low vulnerability. On the other hand, in IPCC-VI value for ward 11, 26, 39 & 41 were 0.02, 0.05, 0.02 & 0.06. In this case ward 26 and ward 41 were more vulnerable than others. Several measures taken by NGOs may increase the adaptive capacity which made them to defense exposures.

Table 13. *Index values for the contributing factors and for LVI-IPCC.*

	Contributing Factors	Major Components	Value	No. of sub-components	Contributing Factor Value	LVI-IPCC
Ward 11	Adaptive capacity	Family status & education	0.37	4	0.51	0.02
		Asset, income & dependency	0.58	5		
		Residence condition and energy	0.58	7		
		Communication	0.42	4		
	Sensitivity	Natural resources	0.57	6	0.57	
	Exposure	Treatment & training	0.58	4	0.54	
		Climatic condition	0.51	4		
	Contributing Factors	Major Components	Value	No. of sub-components	Contributing Factor Value	LVI-IPCC
Ward 26	Adaptive capacity	Family status & education	0.42	4	0.41	0.05
		Asset, income & dependency	0.41	5		
		Residence condition and energy	0.45	7		
		Communication	0.37	4		
	Sensitivity	Natural resources	0.43	6	0.43	
	Exposure	Treatment & training	0.54	4	0.52	
		Climatic condition	0.51	4		

	Contributing Factors	Major Components	Value	No. of sub-components	Contributing Factor Value	LVI-IPCC
Ward 39	Adaptive capacity	Family status & education	0.50	4	0.42	0.02
		Asset, income & dependency	0.46	5		
		Residence condition and energy	0.50	7		
		Communication	0.22	4		
	Sensitivity	Natural resources	0.30	6	0.30	
	Exposure	Treatment & training	0.50	4	0.50	
		Climatic condition	0.51	4		
	Contributing Factors	Major Components	Value	No. of sub-components	Contributing Factor Value	LVI-IPCC
Ward 41	Adaptive capacity	Family status & education	0.45	4	0.37	0.06
		Asset, income & dependency	0.34	5		
		Residence condition and energy	0.41	7		
		Communication	0.27	4		
	Sensitivity	Natural resources	0.35	6	0.35	
	Exposure	Treatment & training	0.56	4	0.54	
		Climatic condition	0.51	4		

3.3.3. IPCC's Contributing Factors of Comparison

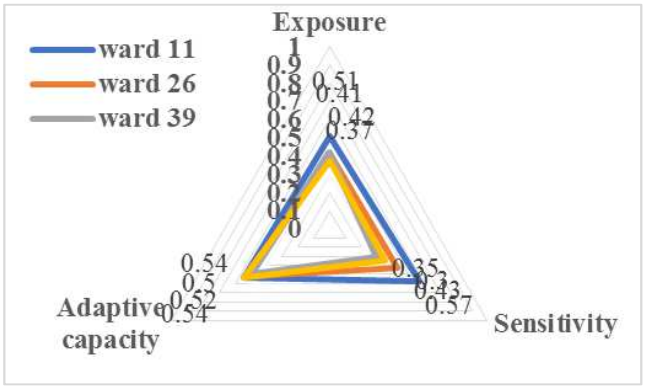


Figure 16. *Different IPCC-VI contributing factors condition and comparison among the wards.*

According to Figure 16, ward 11 was more vulnerable than others in every sector namely as adaptive capacity (0.54), Exposure (0.57) & Sensitivity (0.51). On the other hand, ward 39 shows low vulnerable in sensitivity & adaptive capacity. Again, ward 41 is low vulnerable from other wards in exposure (0.37) phase. On the other hand, ward 26 & 41 is medium vulnerable overall.

3.3.4. LVI and IPCC-VI

According to the questionnaire survey, Livelihood Vulnerability Index (LVI) was high in ward 11 (0.56) than ward 26 (0.44), ward 39 (0.42) and ward 41 (0.41). On the other hand, in IPCC-VI value for ward 11, 26, 39 & 41 were 0.02, 0.05, 0.02 & 0.06. in this case ward 26 and ward 41 were more vulnerable than others. Several measures taken by NGOs may increase the adaptive capacity which made them to defense exposures.

Table 14. *Overall vulnerability indexes (LVI and IPCC-VI).*

Overall index	Ward 11	Ward 26	Ward 39	Ward 41
LVI (livelihood vulnerability index)	0.51	0.44	0.42	0.41
IPCC-VI value	0.02	0.05	0.02	0.06

A study done [14] revealed that in case of Environmental vulnerability index, Bangladesh possessed medium vulnerability. In another study [8] found that in terms of climate vulnerability index Bangladesh was under high vulnerability (54.7) situation in 2000 and 2030 it will be under more high (58.3) vulnerable situation. The survey findings also revealed similar type of result for coastal wards of Chittagong City Corporation. However it was more vulnerable situation in ward 11 compared with overall LVI: Moma (0.316) and Mabote (0.326) and LVI-IPCC: Moma (-0.074) and Mabote (0.005) according to the research findings of [8].

4. Conclusion

The ability to prepare for, deal with, withstand, and recover from the effects of natural catastrophes is known as vulnerability [15]. The LVI and IPCC-VI measured the vulnerability of ward 11 (South Kattali), ward 26 (North Halishahar), ward 39 (South Halishahar), ward 41 (South Patenga) in Chittagong City Corporation in different ways. In LVI ward 11 was most highly vulnerable than other wards. Ward 26 was the 2nd highly vulnerable ward. After that ward 39 and ward 41 got the 3rd and 4th position in vulnerable scale. The IPCC-VI index showed that similar types of result. Ward 11 and ward 39 is highly vulnerable in IPCC-VI scale. On the other hand, as though ward 26 and ward 41 were showed less vulnerable than ward 11 and ward 39 but these are also in highly risk position.

5. Recommendation

1) Urgent intervention is necessary from the local and governmental level. The people who are in low housing condition should be given loan for their better settlement from the governmental level with a very low interest.
2) Community based organizations should act more effectively in terms of helping people the local people controlling the impacts of climate change.
3) Promotion of informal and non-informal education and training about climate change and disaster management

via NGOs or government is effective way in making people aware in problem they are facing due to climate change.

4) Local health center should be more effective provided with sufficient practitioners, nurses, equipment and medicines. Therefor mobile hospital can be launched.
5) Community afforestation and reforestation especially coastal afforestation program must urgently be launched in every wards under the supervision of Forest Department.

Acknowledgements

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