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Climate Change Vulnerability in Dacope Upazila, Bangladesh

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: This study was aimed to assess the climate change vulnerability of Dacope upazila of Bangladesh and analyze the factor behind the vulnerability components. Additionally, it was intended to visualize the relative vulnerability of different unions in GIS environment.

Place of Study: Dacope Upazila of Khulna district comprising an area of 991.57 km^2, bounded by Batiaghata upazila on the north, Pasur river on the south, Rampal and Mongla upazilas on the east, Paikgachha and Koyra upazilas on the west.

Methodology: Integrated assessment approach was used to determine the union level climate change vulnerability. 100 households from 9 unions of the study area were taken for survey. The vulnerability determined in this study was calculated from exposure, sensitivity and adaptive capacity. All the parameters were weighted with highest factor loadings from Principal Component Analysis.

Results: From analysis of all the identified indicators the study found Banishanta (0.97), Kamarkhola (0.97) and Sutarkhali (1.13) highly vulnerable due to their low adaptive capacity (0.31 for all). On the contrary, lower level of vulnerability is found in Dacope (0.52) and Chalna (0.37) unions with relatively higher adaptive capacity (0.50 and 0.67). Adaptive capacity was found the

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most influential (correlation coefficient of -0.723) components of vulnerability.
Conclusion: Unions of Dacope upazila are mostly vulnerable due to their low adaptive capacity. The vulnerability situation is even worse in southern unions like Sutarkhali. The present study can be useful in addressing proper measures to increase adaptation and mitigation of climate change in SW coastal Bangladesh.

Keywords: Climate change; vulnerability; exposure; sensitivity; adaptive capacity; Bangladesh.

1. INTRODUCTION

Least developed countries are readily at risk to the negative impacts of anticipated climate change where livelihoods are mostly natural resource dependent [1]. The society and its interaction with the climate affect the climate change impact along with the biophysical characteristics of a certain area. According to the Second Assessment Report, Socio-economic systems are more vulnerable in developing countries as the economic and institutional circumstances are not strong enough [2]. IPCC also describes that vulnerability is highest where sensitivity is high and adaptive capacity is low. Further in the Fourth Assessment Report, the IPCC defines the vulnerability as the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. The focus of the researches has been to mitigation and adaptation to climate change after the Fourth Assessment Report of IPCC, which brings in researches that have centered on analysis of human welfare in order to specify the vulnerability of an area [3].

Vulnerability can be defined as the ability or inability of individuals or social groupings to respond to, in the sense of cope with, recover from, or adapt to, any external stress placed on their livelihoods and well-being [4]. On the other hand, Barker, et al., defines vulnerability as a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity [5]. Understanding of vulnerability have been described both theoretically and practically through conceptual models, framework and assessment techniques [6]. Adger conceptualizes the vulnerability as a function of exposure, sensitivity and adaptive capacity as per the definition of IPCC [7].

Climate change vulnerability of household, community, region, or country is very much related to the social and economic development [8]. Moreover, the vulnerability to climate change varies from one place to another and depends on factors like exposure, sensitivity and adaptive capacity. The net effect of sensitivity and exposure on adaptive capacity in South Africa and shows that vulnerability is characterized by the combination of medium-level risk exposure and medium to high levels of social vulnerability [8]. In addition to this, O'Brien et al. stressed that institutional support can help in adapting to climate change [9]. Deressa, Hassan & Ringler analyzed the household vulnerability to climate change in the Nile basin of Ethiopia using econometric approach and shows that farmers' vulnerability is highly sensitive to their minimum per day income requirement (poverty line) and agro-ecological setting [10]. This emphasizes that there is need for identification and characterization of climate change impact from the perspective of vulnerability. Also, IPCC has stressed that priorities should be given for advancing understanding of potential consequences of climate change for human society and the natural world, as well as to support analyses of possible responses [11]. Further for increasing resilience and adapting to climate change, it is important to understand the nature of vulnerability and reflect it in various development strategies formulated at different levels [12].

In Bangladesh there have been very few studies done regarding climate change vulnerability. However, in those studies expert judgment has been implemented to weight variables. The use of expert judgment to give the weights may not properly determine the climate change vulnerability as using the expert judgment may have biases due to cognitive limitations [13]. Vulnerability analysis will be clearer and sound if both socio-economic and biophysical indicators are used [14]. While it is difficult for policymaker to indicate vulnerability according to area by taking large number of discrete indicators, there is significant value to capture multiple aspects of climate change vulnerability in smaller number of aggregate indices by spatially-explicit measures [15]. So, this paper identifies district wise climate change vulnerability of Nepal using both socioeconomic and biophysical indicators. Further, it uses Principal Component Analysis (PCA) to give weights to the indicators of climate change vulnerability to lessen the biases that may arise due to cognitive limitations.

2. MATERIALS AND METHODS

There are basically three conceptual approaches for assessment of vulnerability [10],

- Socio-economic approach: The socio-economic approach mainly focusses on socioeconomic and political variations within the society, but not environmental factors, so it basically tries to identify the adaptive capacity of the individual and communities based on their characteristics [10].
- Biophysical approach: The biophysical approach basically tries to capture the damage done by environmental factors on the social and biological systems and mainly focuses on the physical damages like change in yield, income, etc. [10].
- Integrated assessment approach: The integrated assessment approach combines both the approaches, socioeconomic and biophysical approaches [10].

Though the integrated approach tries to correct the limitations of the other two approaches, it has its own weakness as there is no standard process of combining socioeconomic and environmental indicators, and also this approach does not account for dynamism in vulnerability. This study aims to assess the vulnerability of the unions of Dacope Upazila with integrated assessment approach using indicator. According to IPCC Fourth Assessment Report vulnerability may be formulated as:

Vulnerability = Exposure + Sensitivity – Adaptive Capacity

A higher adaptive capacity is associated with the lower vulnerability while a higher exposure and sensitivity is associated with higher vulnerability. To make the vulnerability indicators comparable they were standardized [16]. The values of each variable are normalized to the range of values in the data set by applying the following general formula:

$$index\ Value = \frac{(Actual\ Value - Minimum\ Value)}{Maximum\ Value - Minimum\ value}$$

After standardizing, weight is attached to the vulnerability indicators (Table 1) using PCA. PCA is a technique used to extract few orthogonal linear combinations of variables which most successfully capture information from a set of variables [8].

The objectives of the study are as follows,

- To assess union level climate change vulnerability of Dacope upazila of Bangladesh;
- To visualize relative vulnerability of different unions in GIS maps; and
- To identify factors behind components of vulnerability of Dacope upazila;

Table 1. Indicators of climate change vulnerability, identified for the study area

Vulnerability Components	Determinants of Vulnerability	Description of indicators	Unit of measurement
Adaptive Capacity	Social	Literacy	Number
		Dependency Ratio	Percentage
	Infrastructure	Health Institute	Number
		School	Number
		Road	Kilometer
		Cyclone shelter	Number
		Irrigation	Area
		Electricity	Number
		Drinking water	Number
	Wealth	House	Number
		Away population	Number
	Information	Radio	Number
		TV	Number

Sensitivity	Human	Disable population	Number
		Population density	Number
		Female household head	Number
	Ecological	Use of fuel wood	Number
	Shocks due to natural hazards	Death	Number
		Injured	Number
		Houses damaged/ destroyed	Number
		Crop damaged	Hectare
		Damage to fisheries	Hectare
Exposure	Climatic Variables	Change in temperature	Coefficient
		Change in rainfall	Coefficient
	Natural hazards	Frequency of natural hazards	Number

This study adopts the integrated assessment approach and uses the indicator method to assess the vulnerability of Dacope Upazila of Bangladesh, the study area. Dacope Upazila of Khulna district comprising an area of 991.57 sq km, located in between 22°24' and 22°40' north latitudes and in between 89°24' and 89°35' east longitudes (Fig. 1). It is bounded by Batiaghata Upazila on the north, Pasur river on the south, Rampal and Mongla upazilas on the east, Paikgachha and Koyra upazilas on the west.

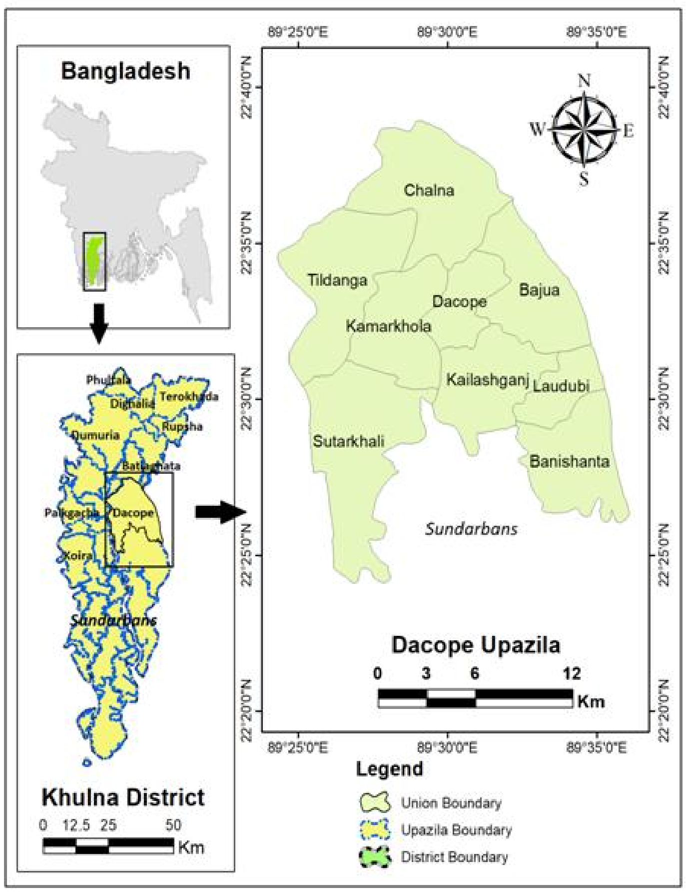

Fig. 1. Map of the study area

3. RESULTS AND DISCUSSION

3.1 Climate Trend of Bangladesh

Rashid (1991) classified Bangladesh into 7 climatic sub-regions, Southeastern zone, Northeastern zone, Northern part of the northern region, Northwestern zone, Western zone, Southwestern zone and Central zone (Fig. 2) [17]. The study area falls in the Southcentral zone. Though the maximum temperature of the Southcentral zone showed very little change (0.19°C), the minimum temperature increased 0.61°C in 30 years which is clearly a climatic stress (Fig. 3). The changes in rainfall pattern are important climate change phenomena, which are likely to be observed all over the land. The southcentral zone showed a decrease in rainfall during winter and pre-monsoon while monsoon and post-monsoon rainfall increases. The odd thing is that monsoon rainfall in southcentral zone is not increasing in a manner as do in other regions (Fig. 4).

3.2 Climate Change Vulnerability

The weight of variables for adaptive capacity, sensitivity and exposure are measured from Principal Component Analysis (PCA). PCA shows eight components having Eigen value greater than 1 and accounting for 77.5% of total variance (Fig. 5). The first principal component (F1) has the highest variance around 24% (Fig. 5).

The heaviest factor loading from PCA is used as weight for the variables. It is seen that adaptive capacity can be categorized as income and infrastructure, education, road and agricultural facilities. Similarly, sensitivity can be categorized as casualties, physical damage, environmental and social. While exposure can be categorized as climate extremes due to rainfall, increasing temperature and natural hazards.

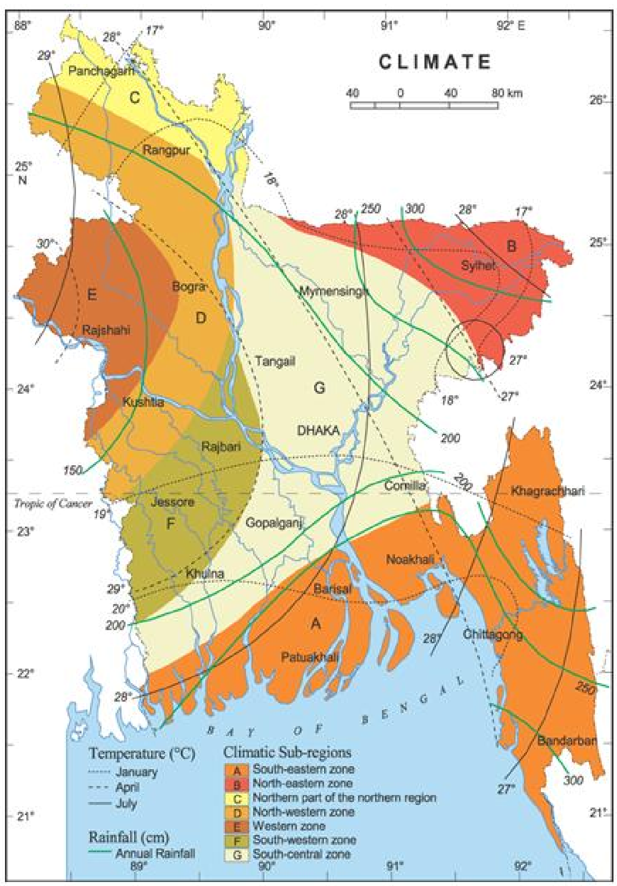

Fig. 2. Climatic sub regions of Bangladesh (Rashid, 1991)

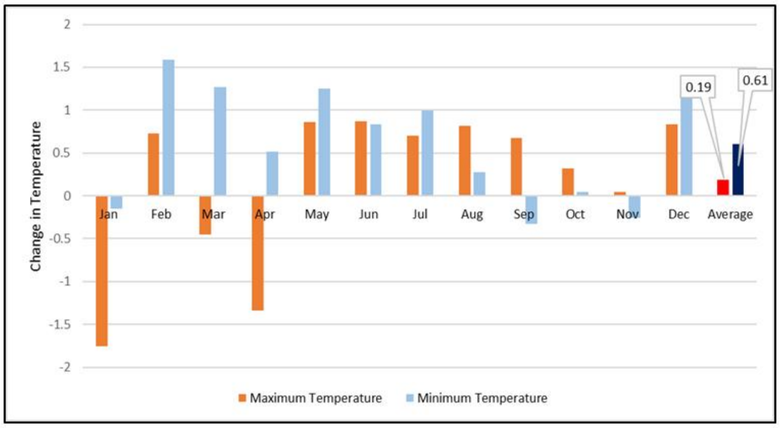

Fig. 3. Changes in temperature in south central climatic zone of Bangladesh in last 30 years

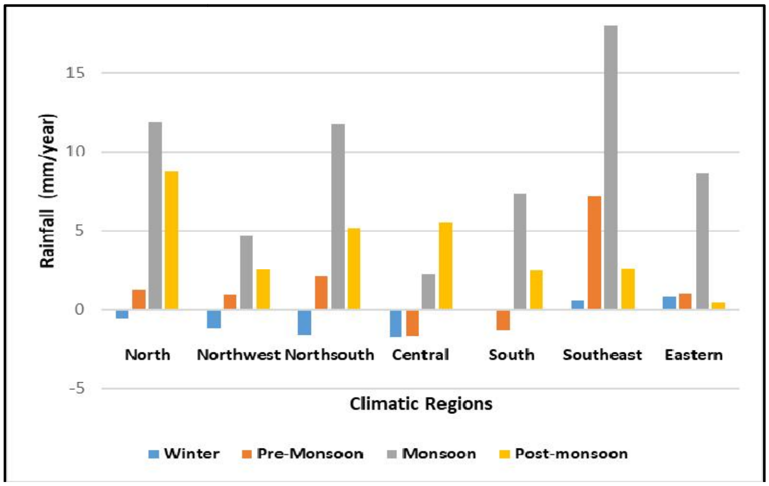

Fig. 4. Changes in amount of rainfall in four seasons in last 30 years

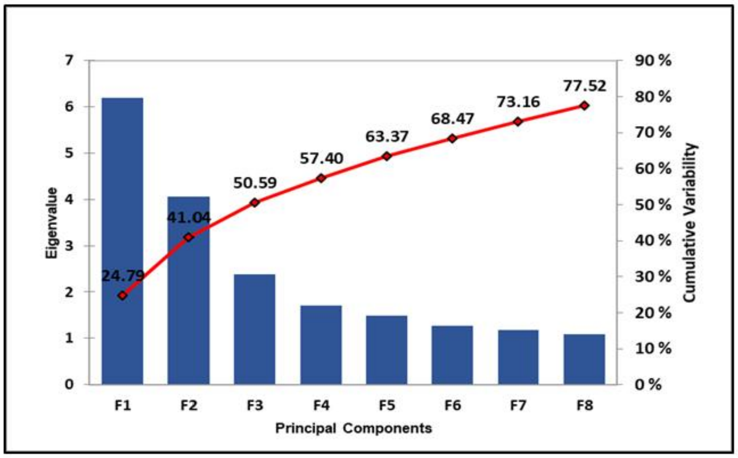

Fig. 5. Principal components having higher Eigenvalue

Table 2. Determined exposure, sensitivity and adaptive capacity for different unions of Dacope Upazila

Union	Exposure	Sensitivity	Adaptive capacity	Vulnerability
Bajua	0.59	0.54	0.51	0.63
Banishanta	0.57	0.72	0.31	0.97
Chalna	0.54	0.49	0.67	0.37
Dacope	0.55	0.46	0.50	0.52
Kailashganj	0.63	0.54	0.43	0.74
Kamarkhola	0.63	0.64	0.31	0.97
Laudubi	0.58	0.56	0.48	0.66
Sutarkhali	0.75	0.69	0.31	1.13
Tildanga	0.51	0.53	0.47	0.57

Table 3. Categorized unions of Dacope Upazila according to their levels of exposure, sensitivity and adaptive capacity

Level	Exposure (mean 0.60)	Sensitivity (mean 0.57)	Adaptive Capacity (mean 0.44)	Vulnerability (mean 0.73)
Low	(below 0.59) Banishanta, Chalna, Dacope, Tildanga	(below 0.55) Bajua, Chalna, Dacope, Kailashganj, Tildanga	(below 0.43) Banishanta, Kamarkhola, Sutarkhali	(below 0.62) Chalna, Dacope, Tildanga
Moderate	(0.59 - 0.67) Bajua, Kailashganj, Kamarkhola, Laudubi	(0.55 - 0.64) Kamarkhola, Laudubi	(0.43 - 0.55) Bajua, Dacope, Kailashganj, Laudubi, Tildanga	(0.62 - 0.87) Bajua, Kailashganj, Laudubi
High	(above 0.67) Sutarkhali	(above 0.64) Banishanta, Sutarkhali	(above 0.55) Chalna	(above 0.87) Banishanta, Kamarkhola, Sutarkhali

3.2.1 Exposure

Exposure is highest in Sutarkhali union with score of 0.75 while is lowest in Tildanga with score of 0.51 (Table 2). Chalna being the only Paurashova of Dacope upazila is lower in exposure. Tildanga and Dacope unions are also lower in exposer while Sutarkhali is highly exposed to climate change stress due their remoteness and they are in the frontline to face disasters like Cyclones and Storm surges. Bajua, Kailashganj, Kamarkhola and Laudubi holds a moderate position (Fig. 6) with score between 0.59 – 0.67 (Table 3). The factors that controls the exposure of the highest level are Cyclone, Storm surges and Salinity in soil and water. Among the physical factors Road networks and Health services are significant.

3.2.2 Sensitivity

Sensitivity is very high in Sutarkhali and Banishanta with score of 0.69 and 0.72 respectively. On the other hand, Chalna and Dacope are low in sensitivity with score of 0.49 and 0.46 respectively. As both Chalna and Dacope are relatively developed and urbanized with respect to other unions of the Upazila, their level of sensitivity is lower than others. Kamarkhola and Laudubi, are in moderate (Fig. 7) sensitivity zone (Table 3). Natural resource availability and Socio economic conditions make the community of Dacope upazila sensitive to Climate change impacts. In house characteristics like disability also controls the level of sensitivity at household level.

3.2.3 Adaptive capacity

Banishanta, Kamarkhola and Sutarkhali, previously being the most sensitive unions, are very low in adaptive capacity with score 0.31 for all. The main controlling factors for adaptive capacity are incidences of frequent natural disasters and infrastructural development like road networks, availability of health services etc. However, Chalna has the highest level of Adaptive Capacity. As mentioned earlier that

Chalna being urbanized and the only pourashava in Dacope Upazila is readily more adaptive and less sensitive and exposed to Climate Change. Bajua, Dacope, Kailashganj, Laudubi and Tildanga on the other hand shows moderate level (Fig. 8) of adaptation capability with the score from 0.43 – 0.55 (Table 3).

3.2.4 Vulnerability

Vulnerability to climate change is found to be the highest in southern part of the upazila. Banishanta, Kamarkhola and Sutarkhali are highly vulnerable to Climate change with score of 0.97, 0.97 and 1.13 (Table 2). Chalna, Dacope and Tildanga have low (Fig. 9) vulnerability with score of 0.37, 0.52 and .57 respectively (Table 2).

From the analysis it is clear that Unions of the southern Dacope are more vulnerable to climate change impacts. The relatively developed and urbanized Pourashava Chalna and Union Dacope are less vulnerable because of their higher adaptive capacity with respect to their exposure and sensitivity (Fig. 10). The higher the level of adaptive capacity from the level of exposure and sensitivity the lower the level of vulnerability. Therefore, sutarkhali has the highest vulnerability. Chalna, though has higher exposure and sensitivity than TIldanga, poses less vulnerability than Tildanga because of higher level of Adaptive Capacity (Fig. 10).

3.3 Identifying Controlling Factors of Vulnerability Components

Though vulnerability is the function of exposure, sensitivity and adaptive capacity in this case adaptive capacity has the highest negative influence (correlation coefficient of -0.72338) on vulnerability (Table 4). The factor analysis of the indicators of exposure showed river erosion, salinity intrusion and deforestation to be influential on the vulnerability component exposure (Table 5). While disability is the indicator that makes a household most sensitive to climate stresses, previous impacts of disasters like injury, household destruction, crop damage and damage to fisheries are almost equally influential to sensitivity of the study area (Table 6). Adaptive capacity is highly influenced by health service, electricity, drinking water availability, house structure, clone shelter, etc. but mostly controlled by the availability of safe drinking water (correlation coefficient 0.721611) (Table 7).

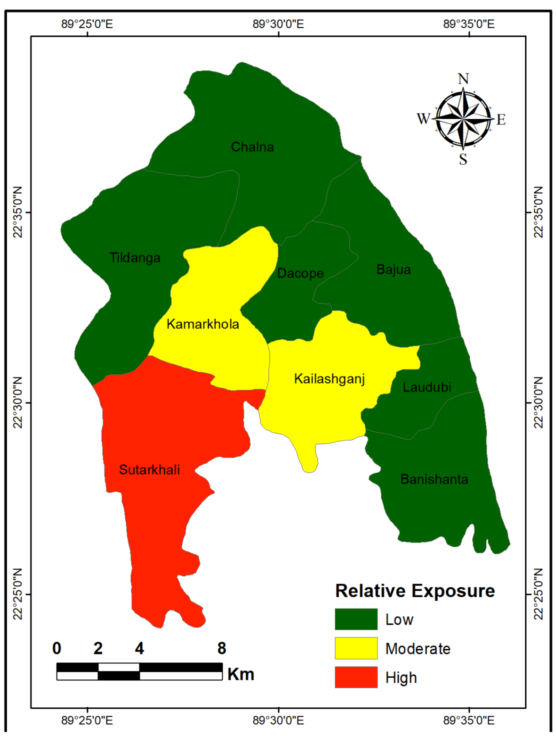

Fig. 6. Relative exposure of unions of Dacope upazila, Bangladesh

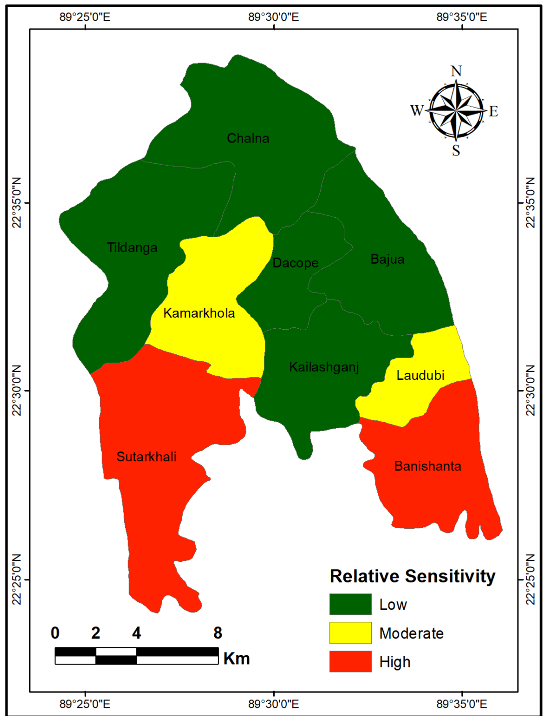

Fig. 7. Relative sensitivity of unions of Dacope upazila, Bangladesh

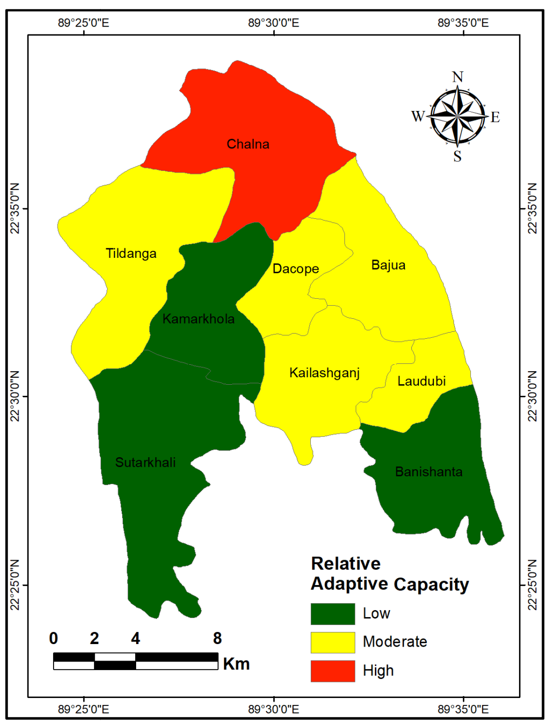

Fig. 8. Relative adaptive capacity of unions of Dacope upazila, Bangladesh

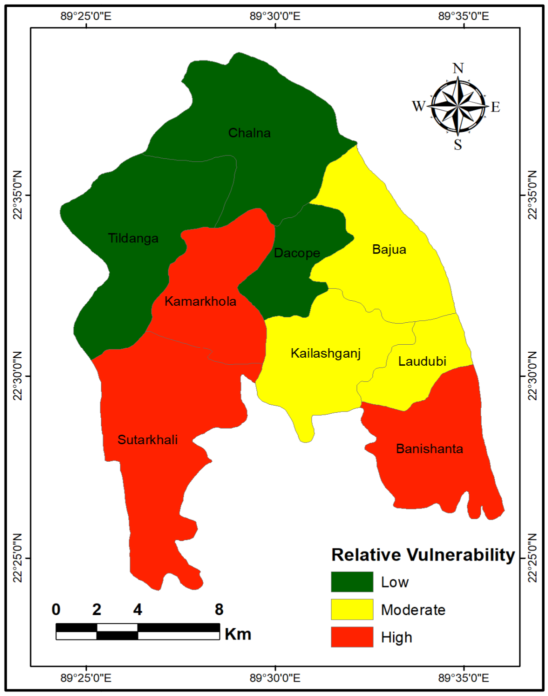

Fig. 9. Relative vulnerability of unions of Dacope upazila, Bangladesh

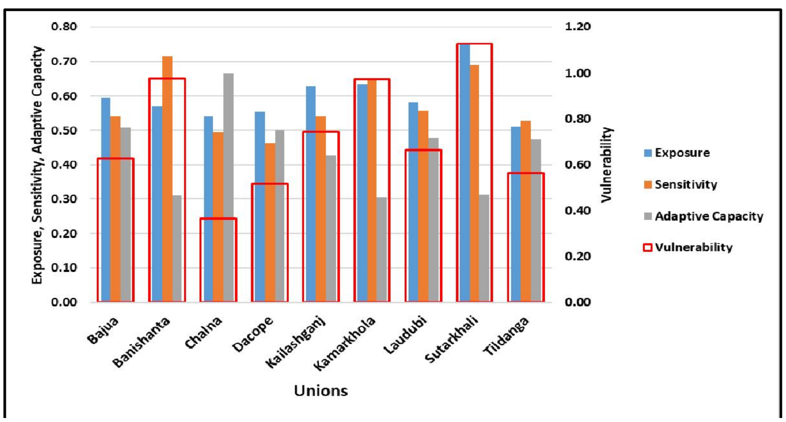

Fig. 10. Exposure, sensitivity and adaptive capacity of different unions of Dacope Upazila

Table 4. Correlation of vulnerability with different components

Vulnerability	Correlation coefficient
Exposure	0.709246
Sensitivity	0.678294
Adaptive capacity	-0.72338

Table 5. Indicators of exposure having moderate to high correlation

Exposure	Correlation coefficient
River erosion	0.455365
Salinity	0.605038
Deforestation	0.602801

Table 6. Indicators of sensitivity having moderate to high correlation

Sensitivity	Correlation coefficient
Disability	0.634164
Injured in past	0.458603
Household Destroyed	0.54374
Crop Damaged	0.541218
Fish Damaged	0.482916

Table 7. Indicators of adaptive capacity having moderate to high correlation

Adaptive capacity	Correlation coefficient
Health service center	0.590499
Drinking water	0.721611
Electricity	0.65208
Radio/TV	0.608956
House structure	0.4191
School/Madrasa	0.537894
Cyclone Shelter	0.403589

4. CONCLUSION

As Bangladesh holds highest risk to be affected by effects of climate change, understanding of vulnerability to climate change needs to be implicitly introduced before any development and adaptation intervention. Since the local authorities play important role in the implementation of strategies for adapting to climate change, this study analyses union wise climate change vulnerability in Dacope upazila of Bangladesh. The present study shows that climate change vulnerability in Dacope upazila depends mainly on adaptive capacity. It is also seen that natural hazards increase the overall vulnerability. It is observed that southern unions are more vulnerable because of low adaptive capacity and higher natural hazards. Especially, unions like Banishanta, Kamarkhola and Sutarkhali have the high climate change vulnerability mainly due to low adaptive capacity as well as occurrence of natural hazards. So, in order to enhance resilience to climate change in Dacope upazila, it is necessary to prioritize measures which increases adaptive capacity but mitigates natural hazards. For that, it is necessary to map vulnerability using more robust indicators denoting land-use change and topography. It is also imperative to understand the disparity of climate change vulnerability even within a union in order to identify social groups, communities, and households who are prone to adverse impact of climate change.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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