Household's Agricultural Vulnerability to Climate Induced Disasters: A Case on South-west Coastal Bangladesh

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Abstract

The purpose of this study was to assess household's agricultural vulnerability to climate induced disasters and to identify the indicators of adaptive capacity that determine the vulnerability of south-western coastal household's in Bangladesh. The vulnerability was calculated by taking the Intergovernmental Panel on Climate Change (IPCC) concept through an Agricultural Vulnerability Index (AVI). Then the ordered logit model was employed in order to identify key determinants of agricultural vulnerability to climate induced disasters. A survey of 346 household's head from the two settlements (181 household's head from *Sutarkhali* and 165 household's head from *Nalian*) of *Sutarkhali* Union of *Dacope Upazila* under Khulna District was used in this study. Findings revealed that the mean score of *Sutarkhali* was 0.703 (high) in exposure, 0.724 (high) in sensitivity, 0.341 (low) in adaptive capacity and finally, the agricultural vulnerability index (AVI) was 0.695 (high). On the same fashion, *Nalian* was an average score of 0.697 (high) in exposure, 0.721 (high) in sensitivity, 0.386 (low) in adaptive capacity, and finally 0.677 (high) in agricultural vulnerability index (AVI). Annual savings, formal education, ownership of livestock, improved seeds supply, access to irrigation pump, improved crop diversification/ High Yielding Variety (HYV) crops, access to large farm size and access to farm credit were found to be statistically significant indicators of adaptive capacity that determine agricultural vulnerability of the both study sites. Finally it is recommended that the intervention required for coastal adaptation of agriculture should be initiated by respective authorities.

1. Introduction

A number of studies have been used to understand the concept of vulnerability to climate disasters in the different fields of the society. The aspect cannot be easily applied because of so many issues associated with its events and the effects ([Adger et al., 2005](#); [Cardona, 2013](#); [Nelson et al., 2010](#); [o'Brien et al., 2004](#)). Basically, there are two elements related to the vulnerability to climate disasters: consequence of incidence of an extreme event, which can be recognized as climatically-extreme sensitivity (e.g. crop failure, land fertility loss, salinity on land etc.) and the community's resilience to the event (e.g. physical and economic resources, adaptation mechanisms etc.) ([Luers et al., 2003](#); [Nelson et al., 2010](#)). However, the widespread impact of climatic disasters especially throughout the agricultural sector has become more and more severe over time. The disasters associated with climate variation such as- coastal flooding, cyclones, river erosions and tidal surge with increasing severity have an impact on the agricultural industry throughout the significant decrease of agriculture production, enhancing crop failure and increasing farmed animals overall survival ([Harvey et al., 2014](#); [Morton, 2007](#)). A wide range of natural and biological mechanisms which drive productivities in agricultural systems, land management and forestry are significantly impacted by inter-annual, monthly and regularly distribution of climate parameters e.g. temperature, radiation, precipitation, water-vapor pressure in the atmosphere and the wind ([Easterling et al., 2007](#)). The effects of this climatic variability on agriculture seem to be the most detrimental site. For instance, conventional extreme weather effects of climate change endanger the survival of the people who rely on agriculture ([Rosenzweig et al., 2014](#); [Zhai & Juzhong, 2009](#)). Due to

climate fluctuations, agricultural production and productivity adjustments are significantly segregated across the various areas of the globe (Lipper et al., 2014).

As agriculture is one of the most climate-infected area, attempts to highlight and evaluate overall level of agricultural vulnerability are taken by producing comparative variables focusing on the numerous parameter of vulnerability, the exposure, sensitivity and adaptive capacity of agro-ecological systems (Neset et al., 2019). In fact, several literature studies (Acheampong et al., 2014; Aleksandrova et al., 2016; Gbetibouo et al., 2010; Islam et al., 2014; Li et al., 2016; Li et al., 2015; Monterroso et al., 2014; Sujakhu et al., 2018; Wiréhn et al., 2015) took place across a multitude of dimensions covering various areas of agriculture, such as farming, livestock, fisheries, and forestry. These studies were mainly aimed at helping decision makers to detect 'access points' in prioritization of adaptation capital, raising awareness about climatic risk and uncertainty, monitoring the implications of adaptation strategies and understanding limitations of social and environmental scheme that contributes greatly to vulnerability. Overall, the majority of all these research indicates 'a brief look' on the vulnerability of agricultural systems by incorporation of some frequently used determinants.

Bangladesh is an agrarian-economy dependent growing nation (Nasim et al., 2019) where agricultural households, specifically in the coastal region (Chen & Mueller, 2018; Chowdhury et al., 2012; Hoque et al., 2019; MoA, 2013; Shamsuddoha & Chowdhury, 2007; Yunus, 2017; Yunus & Kabir, 2018), has become increasingly vulnerable with increasing climatic fluctuations and severe weather occurrences (coastal flooding, tidal storm, cyclone etc.), alongside agricultural devastation (salinization, water shortage, and soil degradation), throughout the timespan (Hoque et al., 2019; Khanom, 2016). For instance, the very last two massive-cyclone occasions, namely, *Sidr* and *Aila*, took place in 2007 and 2009, triggering a great number of human deaths. They have led to failure in the agricultural sector, livestock farming and resources. They also have a deterioration in economic and environmental functions (Shamsuddoha & Chowdhury, 2007; Yunus, 2017). In the meantime, approximately 63% of the coastal arable land territory is hampered by varying levels of soil salinity due to these climate disasters (Hoque et al., 2019; MoA, 2013). Nevertheless, adjusting to an increasing rate of climate induced disasters have become the greatest problem, contributing to a growing demand for better expanded mitigation options, in order to protect coastal people's agricultural properties and resources, and to extrapolate more changing climate in the long term (Brown et al., 2018; Quader et al., 2017; Yunus & Kabir, 2018). Therefore, it is extremely important that agricultural vulnerability to climate disasters is assessed to develop and apply intended adaptation policies as well as to characterize major concern sections for agricultural improvement.

Until now, household's agricultural vulnerability analysis studies, particularly in the south-west coastal region of Bangladesh, have not been extensively or adequately characterized. Though there is a substantial number of vulnerability studies (Ahsan & Warner, 2014; Bhuiyan et al., 2017; Hoque et al., 2019; Islam et al., 2014; Islam et al., 2013; Mullick et al., 2019; Rabby et al., 2019; Rakib et al., 2019; Uddin et al., 2019; Yunus, 2017; Yunus & Kabir, 2018) have found but there is hardly a single study to assess the agricultural vulnerability of household's to climate induced disasters in the south-western coastal Bangladesh. Therefore, this study was focused on assessing agricultural vulnerability to climate induced

disasters of south-west coastal Bangladesh using agricultural vulnerability indicators under the umbrella of climate induced disasters vulnerability components of exposure, sensitivity and adaptive capacity which have been widely used and recognized by Intergovernmental Panel on Climate Change (IPCC) and recent studies on climate change. This study has also identified key determinants of agricultural vulnerability. Further, this analysis has made it easier to understand the agricultural vulnerability of the household's regionally in the south-western coastal Bangladesh.

2. Conceptual Framework

The basic principle of vulnerability contains a series of concepts aligned with the various phases in which the assessment of the agricultural vulnerability to climate disasters had allowed to take (Hoque et al., 2019). (Li et al., 2016) mentioned that vulnerability was connected to or linked with abstract ideas such as perseverance, sensitivity, ability to adapt, destructiveness and potential danger. (Füssel, 2007) made it clear that there had been no common vulnerability theoretical underpinnings in the same situation. This study incorporated the basic idea of vulnerability assessment using both the Intergovernmental Panel on Climate Change (IPCC) and United Nations Development Program (UNDP) Human Development Index. Vulnerability is defined as "the extent to which agricultural system of a household is vulnerable or unable to comply with the consequences of climate disasters" (Parry et al., 2007). We therefore used a range of 0 to 1 for developing the agricultural vulnerability index. The assessment for the agricultural vulnerability to climate induced disasters may be summarized through three indicators: (a) exposure (the extent of climatic stressful events); (b) sensitivity (agriculture system that has been negatively affected or is susceptible to climatic stimuli); and (c) adaptive capacity (efficiency of households to adapt with climate disasters, address the impacts and seize opportunities).

3. Materials And Methods

3.1 Study Sites

A quantitative approach was taken to ascertain how local socio-economic factors and bio-physical influences of climate induced disasters are responsible for agricultural vulnerability. Multi-stage sampling technique was used to identify the study sites. Hence, we placed the spatial emphasis on *Dacope Upazila* (sub-district) under Khulna district (South-west coastal region) of Bangladesh. Locating on the South-eastern part of *Khulna* district, this *Upazila* covers an area of around 991 km² including forestry conservation area of 494.69 km². In 1906 *Dacope* had been established as a *Thana* (a kind of sub-district), which later became an *Upazila* in 1983. This *Upazila* is comprised of one *paurashava*, nine wards, fifteen *mahallas*, nine unions, twenty six inhabited *mauzas* and ninety-seven villages (Statistics, 2013).

This region contains a flat land with a natural land slope bounded by the Sundarbans (world's largest mangrove forest) and the Bay of Bengal from the south-west and the south directions accordingly. This is an unripe deltaic slope where the length of the belt rarely reaches above the height of the sea level. The

rivers in this *Upazila* are the basic flow stream. Therefore, the rivers e.g. *Pasur, Shibsa, Manki, Bhadra* have a substantial influence on both surface and groundwater quality due to natural tidal movement (Parishad, 2005). Being with the coastal belt, the study region frequently faces different disasters like cyclones, tidal surges, heavy rainfall, river erosion etc. Two back to back destructive cyclones: *Sidr* in 2007 and *Aila* in 2009 have subsequently impacted the area. This research had been conducted in two settlements: *Sutarkhali* and *Nalian* under the *Sutarkhali* union of the *Upazila*.

3.2 Vulnerability Indicators

Exposure, sensitivity and adaptive capacity are the key elements to determine agricultural vulnerability to climate induced disasters of the households through climate variation and change (Parry et al., 2007). In this study, exposure refers to the occurrences, intensities and magnitudes of climate induced disasters and positions of the agricultural land from hazard area to which agriculture based households systems are susceptible (McCarthy et al., 2001). Exposure indicators selected for the two study sites characterize the position of agricultural land and occurrences, intensities and magnitude of climate induced hazards and standard deviation of past 15 years temperature and precipitation in Khulna district.

Sensitivity is the extent to which the agricultural system of households is negatively affected or immune to climate stimuli (Parry et al., 2007). In this study, sensitivity indicators included reduction of irrigation water availability, salinity severity on arable land, irrigation potential of cultivable land, agricultural properties loss, agricultural production trend, cropping intensity, income from agriculture, and food security loss to climate-related hazards over the last 15 years.

We define adaptive capacity as the household’s capability or potential to respond to climate induced catastrophe, to cope with its consequences and to seize opportunities (McCarthy et al., 2001). Adaptive capacity of a household was taken as annual savings, formal education, high household size, non-farm employment, ownership of livestock, agrochemical/fertilizer supply, improved seeds supply, access to irrigation pump, gardening with mangrove trees improved crop diversification/High Yielding Variety (HYV) crops, access to large farm size, access to farm credit, membership in Non-government Organizations (NGOs)/Community Based Organizations (CBOs) and share of embankments/dams.

Table 1: Major vulnerability indicators, sub-components and hypothesized functional relationship comprising for agricultural vulnerability index (AVI) developed for *Dacope* sub-district.

Vulnerability Indicators	Sub-components	Adapted source	Hypothesized Relationship
Exposure	Position of agricultural land	(Sujakhu et al., 2018)	Higher value reflects higher exposure.
	Standard deviation of annual rainfall	(Sujakhu et al., 2018)	Higher exposure = Higher Agricultural Vulnerability
	Standard deviation of annual temperature	(Sujakhu et al., 2018)	
	Intensity of cyclone	(Hoque et al., 2019)	
	Occurrences of river erosion	(Hoque et al., 2019)	
	Intensity of tidal surge	(Hoque et al., 2019)	
Sensitivity	Reduction of irrigation water availability	(Pandey et al., 2015)	Higher value reflects higher sensitivity.
	Salinity severity on arable land	(Hoque et al., 2019)	Higher sensitivity = Higher Agricultural Vulnerability
	Irrigation potential of cultivable land	(Tessema & Simane, 2019)	
	Agricultural properties loss	(Pandey et al., 2015)	
	Agricultural production trend	(Tessema & Simane, 2019)	
	Cropping intensity	(Hoque et al., 2019)	
	Income from agriculture	(Tessema & Simane, 2019)	
	Food security loss	(Pandey et al., 2015)	
Adaptive Capacity	Annual savings	(Tessema & Simane, 2019)	Lower value reflects lower adaptive capacity.
	Formal education	(Tessema & Simane, 2019)	Lower adaptive capacity = Higher Agricultural Vulnerability
	High household size	(Hoque et al., 2019)	
	Non-farm employment	(Tessema & Simane, 2019)	
	Ownership of livestock	(Tessema & Simane, 2019)	
	Agrochemical/Fertilizer supply	(Tessema & Simane, 2019)	

Improved seeds supply	(Tessema & Simane, 2019)
Access to irrigation pump	(Hoque et al., 2019)
Gardening with mangrove trees	(Hoque et al., 2019)
Improved crop diversification/HYV crops	(Hoque et al., 2019)
Access to large farm size	(Tessema & Simane, 2019)
Access to farm credit	(Tessema & Simane, 2019)
Membership in NGOs/CBOs	(Tessema & Simane, 2019)
Share of embankments/dams	(Hoque et al., 2019)

3.3 Data Collection and Sample Size Determination

Both primary and secondary data was used in this study. Primary data collected through a structured interview schedule from the households at both study sites in the period between January and May, 2019. Households were selected using systematic random sampling with an interval of every 10th household from the starting point. We had used the corresponding widely used formula for determining the sample size (Naing et al., 2006):

$$n = \frac{Z^2 P (1 - P)}{d^2}$$

$$n' = \frac{NZ^2 P (1 - P)}{d^2 (N - 1) + Z^2 P (1 - P)}$$

Where n = Sample size; n^c = Sample size with finite population correction; Z = The standard normal deviate, corresponding to a significance criterion of 0.05 (95%) = 1.96; d = Margin of error, we will tolerate which is ±0.05; P = Incidence rate or proportion predicted, corresponding to a significance criterion of 0.5 (50%) or and N = Total population, we had included total 3451 households from including 1810 households from *Sutarkhali* and 1641 households from *Nalian* (Statistics, 2013).

$$n = \frac{(1.96)^2 \times 0.5 (1 - 0.5)}{(0.05)^2} = 384.2$$

$$n' = \frac{3451 \times (1.96)^2 \times 0.5 (1 - 0.5)}{(0.05)^2 (3451 - 1) + (1.96)^2 \times 0.5 (1 - 0.5)} = 345.8 \approx 346$$

Thus, we had enrolled 346 households head from the two settlements of *Sutarkahli* union. To reduce the variance, we had used stratified sampling for data collection including 181 households head from *Sutarkhali* and 165 households head from *Nalian*. Secondary data was used in this study for calculating the standard deviation of last 15 years temperature and precipitation in Khulna district. We extracted this data from Bangladesh Meteorological Department (BMD) of Khulna.

3.4 Integrated Agricultural Vulnerability Index

An integrated vulnerability index had been used to determine exposure, sensitivity and adaptive capacity. This method calculates a vulnerability index for a set of indicators using an aggregated mean. This helps to identify factors or determinants for evaluating involvements and tracking systems. Each indicator was standardized (This value ranges from 0 to 1 for an indicator. Maximum and minimum values have generally been set to avoid more than one value. Any residual values greater than one or lower zero have been calculated at one and zero respectively (Ahsan & Warner, 2014).):

$$Index_{si} = \frac{S_i - S_{min}}{S_{max} - S_{min}} \dots \dots \dots (1)$$

Where, $index_{si}$ is a standardized value of an indicator for a household (HH); S_i is the actual value of the same indicator, and S_{min} and S_{max} are the minimum and maximum values, respectively, of the same indicator. Average standardized values were used to deliver the three sub-indices for exposure, sensitivity and adaptive capacity.

After the calculation of the “Exposure”, “Sensitivity” and “Adaptive Capacity” values that are derived from the variables average of each item, Equation (2) has been used to calculate the vulnerability index as like as (Inostroza et al., 2016).

$$V = \frac{E + S + (1-AC)}{3} \dots \dots \dots (2)$$

Where V, E, S and AC represent the vulnerability, exposure, sensitivity and adaptive capacity of the household, respectively.

3.5 Vulnerability Analysis

We had calculated vulnerability index for each study site. The analysis was conducted by using Statistical Package for Social Sciences (SPSS 20.0) and Microsoft Excel (Version 2013).

Finally, we had used a ordered logit model (Tsue et al., 2014) with a view to identifying the indicators of adaptive capacity that determine the agricultural vulnerability for both study sites. It is a regression model with ordinal dependent variables that are "low", "medium," and "high" and used to see how the responses to other questions can predict or determine the ordinal outcomes (Fullerton, 2009). Here, with the categorized dependent variable, the model had been stated as:

$$\Pr(Y \leq j) = \ln \left(\frac{\exp(Y \leq j|X)}{1 - \exp(Y \leq j|X)} \right) = \alpha_j + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_{14} X_{14} \dots \dots \dots (3)$$

Where, Y = Agricultural vulnerability to climate induced disasters (which is categorized into 3: low = 0, medium = 1 and high = 2); α = threshold; β_1 - β_{14} = estimated parameters; X_i are the sub-components of adaptive capacity. Agricultural vulnerability classes were regressed as outcome variables, and sub-indicators of adaptive capacity as explanatory variables. The analysis was performed on STATA (Version 13.0).

4. Results And Discussion

The analysis of agricultural vulnerability are disclosed in two segments for both areas. The first segment is concerned with determining the different vulnerability measurements with estimates of Agricultural Vulnerability Index (AVI) through the respective sub-components (Table 2) and the second deals with estimating different determinants of agricultural vulnerability to climate induced disasters through ordered logistic regression (Table 3).

4.1 Exposure

Households differ from exposure (Coulibaly et al., 2015; Pachauri et al., 2014; Sujakhu et al., 2018), but due to a lack of absolute data, the inclusion of climate variability data is very difficult. We extracted data for rainfall and temperature during last 15 years from Bangladesh Meteorological Department of Khulna. However, for each household or cluster of households near the area, we obtained data for distance of agricultural land from hazard areas and intensity and occurrences of climate induced hazards as exposure. In total six parameters were used to evaluate the households' "exposure" position. The parameters of exposure included position of agricultural land, standard deviation of rainfall, standard deviation of temperature, intensity of cyclone and tidal surge and occurrences of river erosion. The substantial hazards in the surveyed site had been found cyclone, river erosion, and tidal surge with varying intensities, magnitudes and impacts on agricultural production (Table 2).

The analysis found that the overall mean exposure for *Sutarkhali* and *Nalian* was 0.703 and 0.679 respectively, which had been considered to have increased agricultural vulnerability exposure for both study sites (Mean Score> 0.61). Households disclosed the necessity of pre-monsoon precipitation to ascertain the season of harvesting. Most households' farm land was based on the harvesting rain water during the monsoon season, and the significantly reduced precipitation rate could affect households by impacting agriculture more (Sujakhu et al., 2016; Sujakhu et al., 2018). Extreme cyclone strength with a tidal wave induces large-scale flooding (Islam et al., 2015) and damages crops and land in large areas (Hoque et al., 2019; Rahman, 2010), leading to saline intrusion (Hoque et al., 2019) and water shortages (Sujakhu et al., 2018) that are regarded as a major problem as an irrigation system. Extreme cyclone magnitude was identified in 2007 and 2009 with higher tidal surge and coastal flooding in the coastal region of Bangladesh (Islam et al., 2015; Shahid, 2012). The threat of cyclone and tidal surge was strongly felt by agriculture farmers. Besides with the position of agricultural land within or nearby the

hazard area or river and frequently occurrences of riverbank erosion exposed a higher threat to livelihood (Hoque et al., 2019) as well as the agriculture sectors in the study area. Taken broadly (Table 2), it should be noted that location and distance of farmland from hazardous areas, climatic hazards, and climate variability for all households are more or less common in the both area which ultimately leads to a higher or lower vulnerability. Climate-induced events had exacerbated the exposure and vulnerability of the areas to water shortages, saline severity, dropping irrigation potential, crop production loss, properties loss, and food scarcity. More unpredictable climatic hazards with climate variation might worsen the current agricultural risks.

4.2 Sensitivity

Agricultural sensitivity refers to the probability of impacts of climate induced disasters on the agricultural sector (Hoque et al., 2019). Findings (Table 2) revealed that eight variables were used to analyze the “sensitivity” of the households for both areas. This analysis revealed that relative sensitivity in both regions was 0.724 in *Sutarkhali* and 0.721 in *Nalian*, and that agricultural sensitivity to climate induced disasters would considered high in both regions (Mean Score > 0.61). In both regions, the greater agricultural vulnerability of vulnerable households was caused by higher salinity and decreasing crop production trend and cropping intensity. In the last 15 years due to cyclone *Sidr* and *Aila* and other climate related hazards, salinity intrusion through tidal surge, coastal flooding due to cyclone and tidal surge with sea level rise and river erosion were reported by respondents of both areas which decreased the irrigation water availability, irrigation potential, crop production, and cropping intensity in the both areas. Moreover, land owned by households that were highly vulnerable could be the subject to salinity intrusion and other risks from climate induced disasters. Most were not irrigated and face greater risks of saline water, irrigation water scarcity, and loss of crop production, cropping intensity, agricultural income due to climate induced disasters (Islam et al., 2015; Pandey & Jha, 2012; Sujakhu et al., 2018).

Household respondents from the both area also stated that due to their crucial climate dependence, agricultural systems were faced considerable challenges due to the notable growth in the frequency and intensity of events linked to climate during the last decades. Climate induced disasters could affect crop growth, food safety, farming and fish farming and severely damage the forestry sector. Besides, the livelihoods and food safety of small-scale farmers were threatened from disasters and the number of people in need of food assistance was increased after disasters, especially when vulnerable populations are affected (Conforti et al., 2018; Islam et al., 2015).

4.3 Adaptive Capacity

A total of fourteen variables (Table 2) were used to evaluate 'adaptive capacity' status. The results found that the average index was 0.341 in *Sutarkhali* and 0.386 in *Nalian*, which suggested that adaptive capacity of agricultural households to climate-induced disasters were low in both regions (Mean Score < 0.51). In order to overcome unprecedented climate hazards such as the destructive cyclone *Sidr* and *Aila* with tidal surge and coastal flooding in Bangladesh in 2007 and 2009 (Islam et al., 2015) which had affected the whole of the south-west coastal region of Bangladesh, including the *Sutarkhali* and *Nalian*,

higher annual savings (Piya et al., 2016) of the coastal household's are required. Results indicated that most households with lower annual savings in the two study regions could not raise their agricultural and subsistence investments with greater vulnerability. The cultivation and selling of mangrove trees in both areas helped to increase annual savings. However, the increasing intensity and magnitude of climate hazards nevertheless exhausted their savings.

Households with less-educated head and small size were at higher risk, indicating that education and lower household size had decreased their capacity to deal with the climate risks. The literature shows that households with illiterate heads and lower size with less economically active members are more fragile and less resilient than households with literate heads (Nadeem et al., 2009; Opiyo et al., 2014). Result suggested that absence of households' head education had increased the vulnerability of the household to agricultures by limiting its capacity to deal with extreme events and access to agricultural resources and mechanisms in both study areas whereas *Sutarkhali* was highly vulnerable for the absence of high household size with less economically active members in the households. Households with a greater proportion of non-farming total income were less vulnerable to climate-driven disasters in agriculture. In general, the highest percentage of non-agriculture income was achieved in most of the households in both study sites as like as (Sujakhu et al., 2016).

Agrochemical/fertilizer supply, improved seeds supply with crop diversification or high yielding variety (HYV) crops, access to irrigation pump were identified major sub-indicators of adaptive capacity (Tsue et al., 2014; Wiréhn et al., 2015): with the lower supply improved seeds with crop diversification or saline tolerant HYV crops and lower access of irrigation pump, agriculture sectors were highly vulnerable although agrochemical/fertilizer supply were available in both areas. Social engagement with strong institutional power and improved infrastructure sharing improved the adaptive capacity (Pandey & Jha, 2012; Smit & Wandel, 2006). The results demonstrated that households with lower access to large farm size, farm credit and membership in community based organizations (CBOs) and non-government organizations (NGOs) were agriculturally vulnerable to climate induced disasters in both study sites.

Table 2: Indexed dimensions of vulnerability and sub-components for assessing agricultural vulnerability

Vulnerability Components	Sub-components	Sub-components Score		Vulnerability Components Score	
		Sutarkhali	Nalian	Sutarkhali	Nalian
Exposure	Position of agricultural land	0.61	0.62	0.703	0.697
	Standard deviation of annual rainfall	1.00	1.00		
	Standard deviation of annual temperature	0.43	0.43		
	Intensity of cyclone	0.78	0.79		
	Occurrences of river erosion	0.75	0.71		
	Intensity of tidal surge	0.65	0.63		
Sensitivity	Reduction of irrigation water availability	0.73	0.73	0.724	0.721
	Salinity severity on arable land	0.78	0.78		
	Irrigation potential of cultivable land	0.80	0.81		
	Agricultural properties loss	0.62	0.62		
	Agricultural production trend	0.81	0.82		
	Cropping intensity	0.91	0.90		
	Income from agriculture	0.69	0.64		
	Food security loss	0.45	0.47		
Adaptive Capacity	Annual savings	0.35	0.37	0.341	0.386
	Formal education	0.30	0.37		
	High household size	0.31	0.57		
	Non-farm employment	0.64	0.57		
	Ownership of livestock	0.16	0.12		
	Agrochemical/Fertilizer supply	0.28	0.43		
	Improved seeds supply	0.30	0.25		
	Access to irrigation pump	0.15	0.17		
	Gardening with mangrove trees	0.60	0.65		
	Improved crop diversification/HYV crops	0.22	0.23		
	Access to large farm size	0.22	0.19		
	Access to farm credit	0.30	0.39		
	Membership in NGOs/CBOs	0.36	0.42		
	Share of embankments/dams	0.59	0.67		
Agricultural Vulnerability Index (AVI)				0.695	0.677
$V = (E + S + (1 - AC))/3$					

Mean Score < 0.51 = Low

Mean Score 0.51 - 0.61 = Medium

Mean Score > 0.61 = High

Source: Field Survey, 2019

4.4 Vulnerability

Overall agricultural vulnerability index was 0.695 for *Sutarkhali* and 0.677 for *Nalian* (Table-3) indicating that the farm households were highly vulnerable to climate disasters (Mean Score > 0.61). Result of ordered logistic regression (Table 4) showed that various sub-components of adaptive capacity were used to assess the prevalence of agricultural vulnerability to climate-induced disasters at both sites of the study. In total, eight indicators were statistically significant ($p < 0.01$ to $p < 0.1$) for both study regions. The ordered regression analysis showed that no access to farm credit for the two study sites was extremely significant ($p < 0.01$). At the same time, no annual savings, no ownership of livestock and no access to large farm size were statistically significant ($p < 0.01$ to 0.05) for both study areas. Similarly, no access to irrigation pump was statistically significant ($p < 0.01$ to 0.1) for both study areas. Seemingly, no formal education and no improved seeds supply were statistically significant ($p < 0.05$ to 0.1) for both study areas. Lastly, no improved crop diversification/HYV crops was statistically significant ($p < 0.05$) for both study sites. For determining the agricultural vulnerability of the households, these eight sub-indicators of adaptive capacity had played the important role in both sites.

The adaptive capacity of the households at our study sites was constrained by the lack of annual savings which is consistent with the results of studies by (Islam et al., 2014; Sujakhu et al., 2018). In addition to the key considerations of vulnerability on the south-west coast of Bangladesh, the formal educational attainment of the household head in Asian Highlands was meaningful (Sujakhu et al., 2018). (Nkondze et al., 2014) traced that livestock forces the households by switching to moderate vulnerability or high vulnerability from low vulnerability. The incorporation of livestock raising into crops minimized the vulnerability of smallholder farmers in *Dhading*, Nepal (Panthi et al., 2016). Ownership of livestock is quite relevant for such incorporation in this study. In comparison to conventional varieties crops, cultivated high yield varieties are related to the improved crop variety class (Evenson & Gollin, 2002). The adoption of no high yield crop diversity and no access to irrigation pumps had been described as the critical factors of low adaptive capacity to assess agricultural livelihood vulnerability to climate change in coastal Bangladesh. Variation of improved crop variety and irrigation pumps had influenced the adaptive capacity and resulted differential level of vulnerability to climate change (Hoque et al., 2019). Reported observations are similar to our study results for both study sites on access irrigation pump and improved crop diversification or HYV crops. (Tsue et al., 2014) used a logistic regression model to illustrate the major determinants of the vulnerability of farming households to environmental degradation in Nigeria including access to credit, land fragmentation and land tenure security. Such results are close to our findings concerning access to large farm and farm credit in both study sites.

The sub-indicators of adaptive capacity are also linked to each other's, e.g. lack of education, lower access to large farm and farm credit limits assignment in alternative irrigation approaches and the

potential for increased farm incomes. Financial status are constrained by lower revenue and annual savings. Farmers cannot afford fertilizers and improved seed varieties for cultivation or diversify the improved crops or saline tolerant high yielding variety crops due to lowered their financial status. We have also found that the most agricultural disadvantaged households are poor, in line with the findings of studies by (Bryan et al., 2013; Sujakhu et al., 2018).

Table 3: Determinants of vulnerability classes in the households (Highlighted variables were significant at both study sites)

Explanatory Variables	Sutarkhali			Nalian		
	Coeff.	z	P>z	Coeff.	z	P>z
Annual savings	-2.556	-3.88	<0.001***	-1.425	-2.13	0.034**
Formal education	-1.114	-1.85	0.065*	-1.569	-2.21	0.027**
High household size	-1.745	-2.81	0.005***	-0.948	-1.49	0.135
Non-farm employment	-2.299	-3.54	<0.001***	-0.628	-0.90	0.367
Ownership of livestock	-2.623	-2.87	0.004***	-2.323	-2.18	0.029**
Agrochemical/Fertilizer supply	-0.801	-1.04	0.300	-2.638	-3.17	0.002***
Improved seeds supply	-1.527	-2.09	0.036**	-1.656	-1.92	0.055*
Access to irrigation pump	-2.353	-1.76	0.078*	-3.252	-3.10	0.002***
Planting mangrove trees	-1.383	-2.15	0.032**	-0.973	-1.34	0.181
Improved crop diversification/HYV crops	-1.645	-1.79	0.074*	-1.504	-1.81	0.070*
Access to large farm size	-2.994	-2.94	0.003***	-2.198	-2.56	0.011**
Access to farm credit	-3.593	-3.57	<0.001***	-2.286	-3.28	0.001***
Membership in NGOs/CBOs	-0.996	-1.29	0.197	-2.822	-3.54	<0.001***
Share of embankments/dams	-1.469	-2.33	0.020**	-0.509	0.70	0.487
Cut1	-16.391			-15.505		
Cut2	-7.764			-7.467		
Number of observations	181			165		
LR chi ² (14)	254.30			237.17		
Prob> chi ²	<0.001			<0.001		
Pseudo R ²	0.72			0.73		
Log likelihood	-48.56			-42.84		

Link: Ordered Logistic Regression (*** p<0.01, ** p<0.05, * p<0.1)

Source: Field Survey, 2019

5. Conclusion And Recommendations

The agricultural vulnerability of household's to climate-induced disasters has been assessed through the use of an integrated index and quantitative methodologies. Particularly contextual and location suitable exposure, sensitivity, and adaptive capacity has been used. In both study sites, numerous adaptive capacity parameters affect household's agricultural vulnerability. Annual savings, formal education, ownership of livestock, improved seeds supply, access to irrigation pump, improved crop diversification/HYV crops, access to large farm size and access to farm credit were the main predictors of vulnerability especially in light of socioeconomic and spatial disparities. Throughout the two localities and perhaps in

other coastal regions, continuing to improve the determinants outlined in this research might assist to decrease the household's agricultural vulnerability to climate induced disasters in south-western coastal Bangladesh.

Depending on research results and respondents demand, we recommend that the administration interference should be strengthened:

Intensive handling of irrigation water. In order to support farmers' access to irrigations water for crop production facilities, the respective authority should prioritizes adequate water management and access to irrigation pump.

Improved seed supply, crop diversification and saline tolerant high yielding variety crops. To increase cultivation output and cropping intensity, the concerned entities should concentrate on cultivation diversification through the introduction and production of improved seeds and high-yielding saline tolerant crops.

Declarations

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Conflict of interest

No.

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Ethical considerations

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