Vulnerability of Households and Decisions for Adaptation to Climate Change: An Empirical Study in Coastal Sunderban, West Bengal, India

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Abstract

Indian Sundarban is one of the most hazardous areas in the Indian subcontinent in respect of poverty, sea level rise and cyclonic storms. The present study analyzes degree and pattern of Vulnerability based on composite Vulnerability Index followed by Patnaik and Narayanan (2005) methodology to identify region specific adaptation strategies in the coastal belts of Indian Sunderban. Binary Probit Model is used to identify the factors responsible for such adaptation strategies. Primary data were collected on 202 households from two coastal villages of Sunderban, during 2014 with structured questionnaire and group discussions. The vulnerability index for the sample households in coastal Sunderban is found to be 0.6532. The result shows that majority (64.36%) of households belongs to moderate vulnerability whereas only quarter of sample households are highly vulnerable. Migration, diversification of livelihoods and livestock rearing are identified as the significant adaptation strategies adapted by the households as means of resilience. The socio-economic and climate variables explain the decisions for adaptation at household level. The paper has an important policy implication for the conservation of natural resources like fishing and crab collection and enhancement of sustainable livelihood security of the vulnerable coastal people.

Key words*: vulnerability, adaptation, Probit model, diversification of livelihoods, migration, livestock rearing.*

1. Introduction

Sundarban Delta is one of the Asian Mega Deltas with highest population density and identified as most vulnerable region (Nicholls et al. 2007). This region is characterized by tropical cyclones, storm surges, land subsidence, sea level rise, coastal erosion and coastal inundation (Dey et al. 2016). On the other hand the Sundarban region is one of the richest ecosystems regions in the world. It is the largest tidal mangrove forests in Asia. The sources of livelihood of the millions of people in Sundarban are fishing, crab collection and honey collection. There are 4.4 million of the most impoverished and vulnerable people and about half of this population lives below the poverty line (BPL), with poverty incidence highest in the blocks close to the vast mangrove forest(Phillips and Perez 2017). Nearly 60 percent of working population of Sundarban is dependent on agriculture (Rajshekar 2011). They are adversely affected by increases in salinity due to sea level rises, intensity of storms, cyclones, coastal inundation and land erosions (WWF 2010, Lwasa 2014). In the last ten years, the progress of literature on vulnerability assessment increased rapidly and is divided into three groups. First, some literature are related to conceptual and methodological issues of climate

risk, vulnerability and their assessment in general, as well as assessment implications for adaptation planning (Malone and Engle 2011, Funfgeld and McEvoy 2011, Hinkel 2011, Joakim et al 2015, Dilling et al. 2015, Preston et al. 2011). The second group is concerned with the studies, utilizing a number of different indicators based methodologies, with visual representations of results (Rod et al. 2015, KC et al. 2015, Wolf and McGregor 2013, Veerbeek and Husson 2013) or a ranking of regions or countries (Brooks et al. 2005, Haddad 2005). Third group of literature investigate the drivers and context of vulnerability (Morss et al. 2011, Luers 2005, and O'Brien et al. 2007). There are another set of literature emphasized on the resilience building strategies for national and regional planning for reducing vulnerability (Brooks et al. 2005; Fussel 2007; Hinkel 2011). There are few studies available for climate change analysis ranges from local or household level (Adger 1999) to the global level (Brooks et al. 2005; Deressa et al. 2008, IPCC 2014). The paper utilizes the measurement of vulnerability on the basis of Fourth Assessment Report of IPCC 2007. Here, vulnerability is a function exposure, sensitivity, and adaptive capacity (IPCC 2007). Exposure is treated as the direct danger and it affects climate variables like temperature, precipitation, extreme weather events etc. Sensitivity is the degree to which a system is affected by the climate change (Gallopin 2006); and the adaptive capacity is the ability of a system to cope or recover from the climate change (Smit and Wandel 2006). Given the above backdrop, the objectives of the paper are four fold. First is to measure vulnerability of coastal people in the Indian coastal Sunderban of West Bengal. Second is to find out the proportion of vulnerable households, moderate vulnerable households and high vulnerable households in the Indian coastal Sunderban. Third is to identify the adaptation options of the households and to estimate the factors responsible for the decisions of adaptation to climate change. Lastly the paper tries to examine the policies of the government of India to enhance climate resilience development.

2. Materials and Methods

2.1 Study area

The Indian Sundarban comprises 19 community development blocks -13 under South 24 Parganas and 6 under North 24 Parganas district of West Bengal with a total population of 4.1 million. At least 5 of the 13 Sundarban blocks are entirely or mostly constituted by islands which do not have a direct road link with the mainland. These are Gosaba, Basanti, Kultali, Patharpratima and Sagar. The people in Sunderban comprise scheduled caste and tribe (44%), 85% people are dependent on agriculture.

The State is sharing borders with countries of Bangladesh, Nepal and Bhutan and other Indian states of Odisha, Jharkhand, Bihar, Sikkim and Assam. West Bengal is the only state of India that extends from the Himalaya in the north to Bay of Bengal in South (State of Environment Report, West Bengal 2016). In South 24 Parganas, annual average maximum temperature is 35^0C and minimum temperature is 18.5^0C during 2010-12 (Figures 1 and 2). Average humidity is about 82% which remains more or less constant due the region's proximity to the sea. Average annual rainfall is 109 cm in 2010 out of which 75% is received during June to September. In South 24 Parganas, a trend in rainfall is decreasing since 1990s (Figure 3).

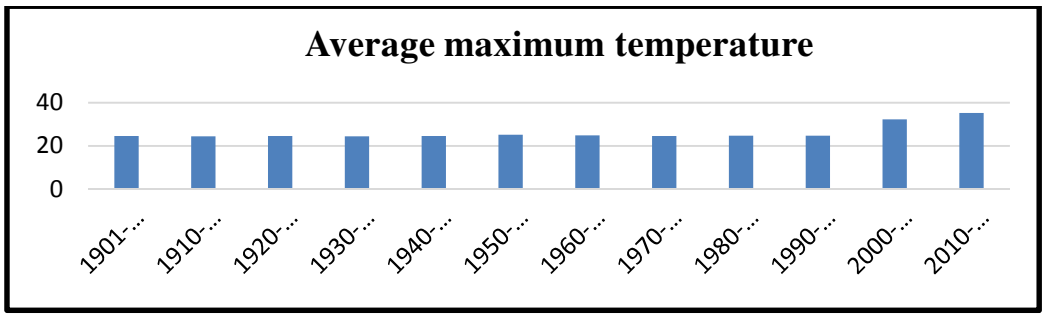

Figure 1 Yearly average maximum temperature in South 24 Parganas, West Bengal

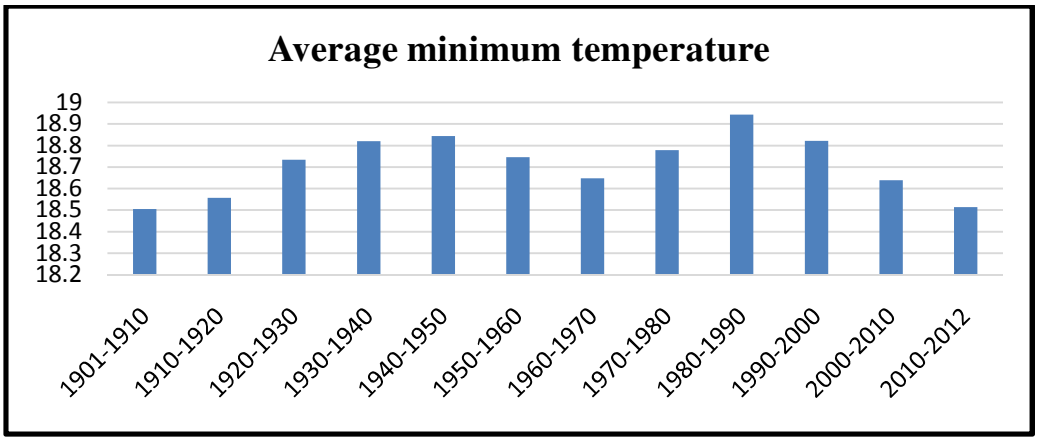

Figure 2 Yearly average minimum temperatures in South 24 Parganas, West Bengal

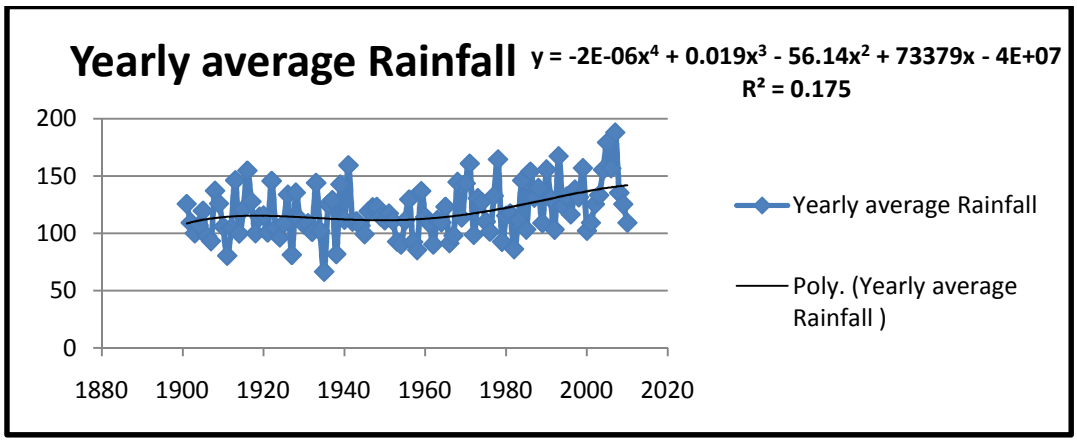

Figure 3 Yearly average rainfalls in South 24 parganas, West Bengal

2.2 Method of data collection

Data were collected by conducting field survey in the Indian coastal Sunderban, South 24 Parganas in West Bengal, India in 2014. The field work combined interviews and discussions with the local people and interviews with local experts and school teachers and other knowledgeable elders in the village. This study was conducted in two villages- of Gossaba block in coastal Sunderban, West Bengal, namely Jamespur and Chargheri . The study selects

30% households randomly from each village. Total number of sample households in coastal Sunderban was 202. A total of 202 structured household interviews were conducted.

2.3 Data

Data on socio-economic variables, like age, sex, education, land holdings, sources of credit, physical assets, livestock assets, income from various sources, poverty, food sufficiency , fishing & crab collection; honey collection, self-help group, borrowing, etc and data on climate perceptions like sea level rise, warmer summer, less cool winter, overlapping seasons have been collected from the field survey.

2.4 Analytical Methods

2.4.1 Vulnerability Index

In calculating the vulnerability index, we have followed an indicator based model. First we convert indicators' values into normalized form which are free from unit and standardized values lie between zero and unity. Before doing this we identify the functional relationship between indicators and vulnerability. There are two types of functional relationships; one is positive and another is negative.

Step 1: For the variables having positive functional relationship with vulnerability the normalized value (X) of the kth indicator for mth households has been calculated using the following formula:

$$X_{ij} = \frac{Xij - Min(Xij)}{Max(Xij) - Min(Xij)} \text{ ----------(1)}$$

For the variables having opposite functional relationship with vulnerability the normalized value (X) of the kth indicator for mth households has been calculated using the following formula:

$$X_{ij} = \frac{Max(Xij) - Xij}{Max(Xij) - Min(Xij)} \text{ ----------(2)}$$

Step 2: After normalization calculate an average index for each of the sources of vulnerability. This is done by taking a simple average of the indicators in each category with equal weights.

Average Vulnerability Index (AIi)= [Indicator 1 +……. + Indicator J] / J

Step 3: The composite or overall vulnerability index (Patnaik and Narayanan 2005) is computed by employing the following formula:

$$VI = [\sum_{i=1}^{n} (AIi)^{\alpha}]^{\frac{1}{\alpha}}/n \text{ ---------- (3)}$$

Where *n* is the number of sources of vulnerability and $\alpha = n$.

2.4.2 Probit model for adaptation decisions

Probit model is used to determine the factors responsible for the decisions of adaptation to climate change. A Probit model is a type of regression where the dependent variable can take only two binary values, viz. 0 and 1. Y=1 means adaptation takes place and "0" means no adaptation occurs.

The model is given by the form of

$Pr(Y = 1| X) = \Phi (X\beta)$

Where Pr denotes probability and Φ shows Cumulative Distribution Function (CDF). The parameters βs are estimated by the method of maximum likelihood.

Suppose there exists an auxiliary random variable,

$Y=X\beta + \varepsilon$…… (4)

Where $\varepsilon \sim N(0, 1)$. Then Y can be viewed as an indicator for whether this latent variable is positive:

$$Y* = \begin{cases} 1, & Y > 0 \\ 0, & otherwise \end{cases} = \begin{cases} 1, & -\varepsilon < X\beta \\ 0, & otherwise \end{cases}$$

3. Results and Discussions

3.1 Vulnerability indices

The description of variables is presented in Table 1. The environmental variables are wormer summer, less cool winter, overlapping of seasons, overall low rainfall, increase in storms and these variables are treated as proxy to the exposure component of vulnerability. On the other hand, the variables like decrease in mangrove forest density, decrease in fish collection and decrease in honey collection are taken into consideration as sensitivity analysis. The mangrove forest density decreasing means that there is an indication of degradation and deforestation of mangrove forest. As mangrove forest declines vulnerability has gone up. The decrease in fish collection and honey collection mean there has been a fall in income derived from such occupation which leads to increase in vulnerability. Under adaptive capacity component of vulnerability we have taken per capita wealth, literate households, own land holdings, social capital like member of Self-help group (SHG) and borrowing loan from money lender. Physical wealth consists of fishing net, boat, agricultural inputs axe, cycle, radio and mobile etc.

Table 1: Description of the variables for measuring Vulnerability indices in coastal Sunderban

Variable	Description	Unit	% of People perceived	Hypothesized Relationship with vulnerability *
Warmer summer	Whether the household observe warmer summer or not	Yes = 1, No = 0	98.02	(+)
Less cool winter	Whether the household observe less cool summer or not	Yes = 1, No = 0	85	(+)
Over lapping of seasons	Whether the household observe season overlapping or not	Yes = 1, No = 0	43.56	(+)
Over all low rainfall	Whether the household observe overall low rainfall or not	Yes = 1, No = 0	83.66	(-)
Increase stormy events	Whether the household observe increasing stormy events or not	Yes = 1, No = 0	97.54	(+)
Mangrove forest density decreasing	Whether the household observe lower density of mangrove forest or not	Yes = 1, No = 0	77.21	(-)
Fish collection	Whether the household observe	Yes = 1,	99.95	(-)

decreasing	decreasing fish collection or not	No = 0		
Honey collection decreasing	Whether the household observe decreasing honey collection or not	Yes = 1, No = 0	46.53	(-)
Per Capita Wealth	Per capita value of the physical asset of the household	Rupees	1819.82	(-)
Education of head of the households	Years of schooling of head	Years	69.31	(-)
Own land holding	Area of own land holding of the household	Acre	32.67	(-)
Member of SHG	Whether the household is a member of self-help group or not	Yes = 1, No = 0	84.16	(-)
Borrowing loan from money lenders	Whether the household borrow money from money lender or not	Yes = 1, No = 0	99.01	(-)

Source: Author's Calculation

The results of the vulnerability indices are given in Table 2. It is observed from Table 2 that the exposure index is 0.75, the sensitivity index is found to 0.70957 and adaptive capacity index is 0.52263. The overall vulnerability index is given by 0.653220. The moderate value of overall vulnerability is due to low adaptive capacity and high exposure and sensitivity.

Table 2: Vulnerability Indices of the coastal people in Coastal Sunderban of West Bengal, India

Indicator	Variable	Index
Exposure	Warmer summer	0.9480
	Less cool winter	0.8119
	Overlapping seasons	0.3564
	Overall low rainfall	0.5743
	Increase in stormy events	0.8762
Exposure Index		0.7500
Sensitivity	Mangrove forest density decreasing	0.8020
	Fish collection decreasing	0.9678
	Honey collection decreasing	0.3589
Sensitivity Index		0.7096
Adaptive Capacity	Per capita wealth (Rs)	0.7948
	Years of schooling of head	0.7274
	Own land holding	0.9226
	Member of Self help groups	0.1584
	Borrowing loan from money lenders	0.0099
Adaptive Capacity Index		0.5226
Overall Vulnerability Index		0.6532

Source: Author's Calculation

The households are classified into three categories of vulnerabilities like less vulnerable, moderate vulnerable and high vulnerable based on the values of vulnerability index (Table 3). Less vulnerable households are those who fall in the vulnerability index values less than equal to 0.55(≤ 0.55). Moderate vulnerable households are those who are in the range of 0.56 to 0.71 vulnerability index and the high vulnerable households have index values above 0.71. It is revealed from Table 3 that majority of the households fall within the moderate vulnerable categories with 64.36% households. The less vulnerable households constitute 11%, while the highly vulnerable households are 25% of total sample households. This result shows that the high and moderate vulnerable households pre-dominate the coastal Sunderban.

Table 3: Classification of proportion of households according to the ranges of vulnerability index

Vulnerability Index	Assigned attributes	No. of Households	% of Households
≤ 0.5500	Less Vulnerable	22	10.89
0.5600 - 0.7100	Moderate Vulnerable	130	64.36
>0.7100	High Vulnerable	50	24.75

Source: Author's Calculation

3.2 Adaptation options and Decisions

Our study identifies adaptation options which include accessing borrowing loan, livestock rearing, and formation of Self Help Groups (SHGs), migration, fishing and crab collection and diversification of livelihood. These adaptation options are shown in Table 4.

The first option is borrowing loan from money lender**.** Households access loan for the needs of emergency purposes during cyclone and floods from money lenders. About 85% households borrowed money from money lenders (Table 4).

The second option is livestock rearing**.** Livestock rearing is an important option for income generation of the poor. About 75% households reported that they rear live stock asset like cow, goat, hen, sheep and pigs for additional income generation (Table 4).

The third option is formation of Self-help groups (SHGs)**.** In the study area the household's women members have formed SHGs under microfinance program. The formation of SHGs is one of the climate risk reduction measures. Increased income from SHGs helps them to mitigate climate risk. About 84% households have formed SHG (Table 4).

The fourth option is migration. The study finds seasonal migration occurs for alternate source of income during the lien period (between the two cropping seasons and between cropping and harvesting period). Table 4 shows that 79% household reported that they migrate nearby district to earn more money when local availability of work becomes limited.

The fourth option is fishing and crab collection. The major livelihood of Sunadarban people is fishing and crab collection. In our study it is found that most of the households are poor and they depend on fishing and crab collection for subsistence. About 97% households are engaged in fishing and crab collection (Table 4).

The last option is diversification of livelihood. In the study area there is conversion of livelihood from fishing to wage labour. The main causes behind this conversion include a decrease in both the fish stocks, which are aggravated by climatic changes and increased cyclone. About 87% households reported that they prefer to daily wage labour work for their livelihoods (Table 4).

Table 4: Percentage of households has adaptation options in the coastal Sunderbans

Adaptation strategies	Number of Households(N=202)	% of households
Borrow money from money lenders	172	85.14
Formation of SHGs	170	84.15
Migration	160	79.20
Fish and crab collection	196	97.02
Diversification of livelihood	176	87.12
Livestock rearing	151	74.75

Source: Field Survey

In order to estimate the factors responsible for adaptation strategies of a household we apply Probit model. The descriptions of dependent variables and independent variables are shown in Table 5. The results of Probit model estimation are presented in Table 6. It is observed from Table 6 that migration, diversification of livelihoods and livestock rearing are the significant adaptation strategies of the households. The goodness of fit in the binary dependent variable model is measured by McFadden's Pseudo-R^2. For the purpose of examining the overall significance of Probit model we use Likelihood Ratio- statistic (LR statistic) which is Chi-square with degrees of freedom. The degree of freedom is equal to the number of explanatory variables. On the basis of the values of LR Chi-square the selected dichotomous dependent variables are migration, diversification of livelihoods and livestock rearing (Table 6). Thus we have chosen these three dependent variables which have followed overall significance. It is observed from the Table 6 migration and livelihood diversification is highly significant at 1 percent level whereas livestock rearing is significant at 5% level. The McFadden's Pseudo-R^2 s is 0.1582, 0.2443 and 0.2095 for migration, livelihood diversification and livestock rearing respectively.

Now we turn back to look upon the factors that explain the behavior of a particular adaptive strategies. At first we consider the probit model where migration is the dichotomous dependent variable. Among the explanatory variables, share of wage income to total income, share of forestry income to total income, share of fishery income to total income and climate change perception index explains the migration significantly at a high level (1% level) whereas physical asset value is significant at 5 % level. The coefficient of physical asset value shows that with the household that posses more physical asset, it has to migrate less to cope with the climate change. Percentage share of wage income to total income is also negatively related to migration. The Probit model of the study shows that those households who earn more wage income; the household migrate less as adaptive strategies to climate variability. One point increase in wage income of a household leads to 5 % decrease in chance to migrate. Percentage share of fishery income also shows an inverse relation with the migration as an adaptive strategy. The result of binary probit model indicate that if a household earn more and more income from fishing, the probability of that household to migrate in search of alternate livelihood is less and less. With the increase in one percentage point in fishery income the probability to migrate is less by 4.45%.

Diversification of livelihood is other important strategies that adopted by the communities in Sundarban as a resilient measure to frequent climate change. It takes as dependent variable with two values 0 and 1. Among the explanatory variables the amount of operational holding possess by households significantly explains the diversification of livelihoods as an adoptive strategies at 10% level. The probit model of the study shows those households which posses more operational holdings, have less urgency to diversify their sources of income. One point increase in operational holding of a household leads to 65% less probability to change their occupation in alternate earning.

Livestock rearing is one of the important sources of livelihood among the people of coastal region of Sunderban. The study takes livestock rearing as the dependent variable as adaptive strategy to prevent the shock of climate related hazard. When a household gives positive answer that they rear livestock the study takes the response as 1, other wise 0. Hence dependent variable becomes binary. The result of the probit model shows that wage income , fishery income are highly significant at 1 % level to explain the probability of livestock rearing, while age of household head, education level of head of the household and amount of operational holding possess by the household significantly explains the livestock rearing at 5 % level.

Percentage share of wage income to total income is also negatively related with livestock. The probit model of the study shows that those if there is chance of a household to earn more from wage income there is a less chance of that household to adopt livestock rearing as adaptive strategies to climate variability. One point increase in wage income of a household leads to 5.1 % decrease in chance for livestock rearing. Percentage share of fishery income also shows an inversely related with the livestock rearing as an adaptive strategy. The result of binary probit model indicate that if an household earn more and more income from fishing, the probability of that household to rearing livestock is less and less. With increase in one point in fishery income the probability to rearing livestock is less by 10.61%.

The study finds that age of the household is positively related with the livestock rearing. The result of the probit model reveals that there is a more chance to rearing livestock with the increase in age of the head of household. One point increase in age of a household leads to 1.97 % more chance to rearing livestock.

Education is one of the important indicators that directly related with the livestock rearing behaviour of households. Result of probit model shows that with the increase in education there is more likely to a family to adopt livestock rearing. One point increase in education of a household leads to 5.94% more chance to rearing livestock. Normally it is believe that with the increase in education probability of rearing livestock is decreasing. But educated person mostly adopted scientific methods of rearing hybrid type of species and find alternate livelihoods in hazard prone region.

Again another important variable that explains livestock rearing is operational holdings. The probit model of the study shows that the household with more land posses more livestock. One point increase in possession of operational holdings indicates that there is 96.63 % chance to rear live stock.

Table 5: Description of the variables affecting adaptation to climate change in Coastal Sunderban

Independent variables	Description	Unit	Expected relation with Adaptation
Household Size	Total family member of the household	Person	+
Age	Age of head of the family	Years	−
Education of Head of the Households	Years of schooling	Years	+
Adult male in the family	Total number of adult male in the household	Person	+
Operational Holding	Land cultivated by the household except the leased in or leased out land	Acre	+
Physical Asset Value	Total value of the physical assets of the household	Rupees	+
Wage Income	Percentage share of total income	Rupees	+
+Forestry Income	Percentage share of total income	Rupees	+
Fishery Income	Percentage share of total income	Rupees	+
Perception Index	Average of normalized score of the climate related variables like longer duration of summer, shorter winter etc.		+

Dependent Variables			
Borrowing money from money lenders	Whether households borrowed money from money lenders?	Yes=1, No= 0 (Dummy)	
Formation of SHGs	Whether households formed SHGs?	Yes=1, No= 0(Dummy)	
Migration	Whether households migrate or not?	Yes=1, No= 0 (Dummy)	
Accessibility of fishing and crab collection	Whether the households have access of fishing and crab collection?	Yes=1, No= 0 (Dummy)	
Diversification of livelihood	Is there any diversification of agriculture to wage labour for livelihood?	Yes=1, No= 0 (Dummy)	
Livestock rearing	Are households' rear livestock?	Yes=1, No= 0 (Dummy)	

Table 6: Estimation of adaptation decision of the coastal people by Probit Model

Independent Variable	Adaptation Strategies					
	Borrow money from money lenders		Formation of SHGs		Migration	
	Coefficient	P- Value	Coefficient	P-Value	Coefficient	P-Value
Household Size	-0.0454	0.658	0.0151	0.866	-0.0392	0.658
Age of the Household	-0.0028	0.778	-0.003	0.746	0.0008	0.930
Education of head of household	0.0077	0.826	0.0191	0.587	0.0571	0.105
Adult male in family	-0.1374	0.465	0.1080	0.557	0.0315	0.86
Operational Holding	-0.7337	0.016**	-0.1628	0.615	0.2049	0.558
Physical Asset Value	-0.00003	0.064**	0.00004	0.072***	-0.00006	0.006***
Percentage share of wage income to total income	-0.0513	0.000*	0.0685	0.000*	-0.0562	0.000*
Percentage share of forestry income to total income			0.0568	0.089*	0.0514	0.114
Percentage share fishery income to total income	-0.0446	0.000*	0.0662	0.000*	-0.0524	0.000*
Climate change perception index	0.7765	0.489	-1.4721	0.187	-4.6017	0.000*
Constant	6.1092		-4.8887		-1.4090	
No. of Observation	202		202		202	
LR Chi-square	16.62		11.53		32.60	
Probability	0.1550		0.3180		0.0003*	
Pseudo Chi-square	0.0128		0.0654		0.1582	
Log likelihood	-32.532		-82.344		-86.727	

Independent Variable	Adaptation Strategies					
	Accessibility to Fishing & crab collection		Diversification of Livelihood		Livestock rearing	
	Coefficient	P-Value	Coefficient	P-Value	Coefficient	P- Value

Household Size	-0.0471	0.802	0.0583	0.590	0.0678	0.423
Age	0.0118	0.553	-0.0059	0.591	0.0197	0.029**
Education of head	-0.0091	0.891	0.0234	0.581	0.0594	0.071***
Adult male in family	0.1483	0.678	0.0331	0.880	0.0961	0.573
Operational Holding	0.0082	0.989	-0.6504	0.059**	0.9636	0.038**
Physical Asset Value	0.000009	0.792	0.00003	0.206	-0.000002	0.895
Wage Income	-0.0288	0.999	0.0766	0.998	-0.0516	0.000*
Forestry Income	-0.0865	0.996	0.0651	0.998	0.1061	0.306
Fishery Income	-0.0214	0.999	0.0539	0.999	-0.0538	0.000*
Perception Index	2.9244	0.105	-0.7301	0.561	-0.9158	0.374
Constant	1.7790	0.999	-4.6086	0.999	4.9773	
No. of Observation	201		201		201	
LR Chi-square	6.41		36.88		21.76	
Probability	0.7793		0.0001*		0.0164**	
Pseudo Chi-square	0.1189		0.2443		0.2095	
Log likelihood	-23.771		-57.047		-102.963	
Note: * = 1% level of significance, ** = 5% level of significance, *** = 10% level of significance						

Source: Author's Calculation

3.2.1 Discussions

The formation of SHGs through microfinance program is one of the important adaptation strategies revealed from this analysis. The micro-finance works in providing finance to the poor after organizing them into homogenous groups, commonly known as Self-help groups (SHGs), especially, among poor rural women (Sharma 2001). The Self-help group (SHG) - bank linkage model is one of the world's largest microfinance initiatives in terms of outreach (Kropp & Suran 2002). Microfinance services can enhance the livelihood asset base through direct income effects, indirect income effects (from education and training), and non-pecuniary effects (i.e. stronger social networks and increased confidence) (Hammill et al.2008). Microfinance service has the potential to help the world's poor and most vulnerable population adapt to climate change by providing them with a means of accumulating and managing the assets and capabilities (Ellis 2000). Some studies focused on positive relation between education of the head of the household and application of technology and adaptation to climate change (Igoden et al. 1990; Lin 1991 and Madison 2006). Livestock keeping is a safety valve for smallholder farmers in Africa during their crop failure due to drought (Sidahmed 2008). Livestock has the potential to support the adaptation efforts of the poor. In general, livestock is more resistant to climate change than crops because of its mobility and access to feed (IFAD 2009). A model has been developed to study the sensitivity of African animal husbandry decisions to climate (Seo and Mendelsohn (2006). According to them 5,000 livestock farmers in ten countries shows that the selection of species, the net income per animal, and the number of animals on a farm are all highly dependent on climate. As climate warms, net income from beef cattle falls. The fall in relative income causes a shift away from beef cattle towards sheep and goats. The results support the previous findings of Deressa et al. (2008) in similar ecosystems. Migration in response to climate change is another form of adaptation. Though most migration is driven by economic and security needs, migration can be influenced by weather and climate. Panel

studies suggest people respond in the short run to floods, droughts, tropical cyclones, and even heat waves by moving (Bohra-Mishra et al. 2014; Gray and Mueller 2012; Kelley et al. 2015; Marchiori et al. 2012; Mueller et al. 2014). Cross-section studies reveal that some long-run migration decisions by farmers can also be climate sensitive (Cattaneo and Massetti 2015). Deheza and Mora (2013) find that rural to urban migration is highest from the least productive climates in Mexico whereas Barrios et al. (2006) find that rural-city migration depends on rainfall in Africa. Our finding on migration as adaptation strategy supports the findings of other literature in Sundarbans likes (Mukherjee 2014; Ghosh et.al. 2014; Ghosh 2014). It is also projected that at least one million people would be migrated from the most vulnerable blocks of Sundarbans due to increasing hazards of climate change from 2030 onward (Danda et.al. 2011).

4. Conclusions and Policy Prescription

From the above analysis the following conclusions have been emerged; First, the vulnerability indices are calculated on the basis of three components like exposure, sensitivity and adaptive capacity of IPCC. It is observed that the exposure, sensitivity and adaptive capacity indices are found to be 0.75, 0.70957 and 0.52263 respectively. The overall vulnerability index for the households in coastal Sunderban is 0.653220. It indicates moderate vulnerability which is due to high exposure (0.75) and high sensitivity (0.7096) and low adaptive capacity (0.5226). Second, the result shows that majority (64.36%) of households belongs to moderate vulnerability whereas only quarter of sample households are highly vulnerable. That is the high and moderate vulnerable households pre-dominate the coastal Sunderban. Third, the paper has identified different adaptation options like migration; formation of Self-help Group (SHGs), accessibility of fishing and crab collection, borrowing of loan from money lenders, diversification of livelihood and livestock rearing. It is revealed that migration, diversification of livelihoods and livestock rearing are the significant adaptation strategies of the households based on the values of LR Chi-square in the Probit model. The determinants of adaptation are socio-economic variables like age, education, land holdings, wage income, fishing income, forestry income, and physical asset value and climatic variable. India launched National Adaptation Policy for Climate Change (NAPCC) in 2008 as a signatory of UNFCCC to address the issues of climate change like adaptation and mitigation with the aim of ensuring sustainable development and high economic growth rates. This policy has identified eight National Missions such as National Solar Mission, National Mission for Enhanced Energy Efficiency, National Mission on Sustainable Habitat, National Water Mission, National Mission for Sustainable Agriculture, National Mission for Sustaining Himalayan Ecosystems, National Mission for green India and National Mission on Strategic Knowledge for Climate Change. Later four National Missions were included in 2014 viz. Wind Energy, Health, Coastal Areas and Waste to Energy (Dey et al. 2016). In view of the above guidelines of NAPCC, every State of India directed to formulate State Action Plan on Climate Change to address climate change concern. The State of West Bengal launched its Climate Change Action Plan in 2011 and 2012. Their plan and policies on climate change adaptation incorporated the climate related sectors like Disaster Management, Agriculture, Water Resources, Forestry, Coastal Zone Management, Rural Development, Fisheries, Health, Energy, Rural Electrification, Poverty Alleviation, and Women Empowerment in the River Delta. West Bengal State Action Plan on Climate Change, WBSAPCC (2012) reported that the traditional farmers used indigenous varieties of seeds of agricultural crops which are climate tolerant and fight against climate change. At the same time, the farmers followed Integrated Farming System with the combination of crops, fisheries and livestock to ensure self-sustainability and alternative livelihoods. The State of

West Bengal gave an important priority on the construction of embankments and dykes under Flood Control/Management activities and took initiatives for raising irrigation coverage, encouragement of rain water harvesting for portable water and construction of portable tank water to avoid contamination. The State of West Bengal has taken various initiatives for expanding the Crop Insurance packages for small and marginal farmer's security against crop loss during flood or cyclone in the state (WBSAPCC, 2012). The state has also arranged Early Warning System (EWS) in the coastal Sunderban to combat the stress of cyclones and storm surges under Disaster Risk Reduction (WBSAPCC, 2012). The plantation and regeneration of mangrove forests on the degraded mud flats are on the top priority in Coastal Sunderban. This gives rise to ensure natural protection of island from cyclone and storms. There are several programs of the central and state governments working in coastal Sunderban like National Rural water and Sanitation Program, National Elementary Education Program (Sarva Shiksa Abhiyan), Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA), the housing scheme, Indira Awas Yojana, the Food for Work Programme, and the rural road building scheme, Pradhan Mantri Grameen Sadak Yojana. These programs are important for rural development and vulnerability reduction measures. The paper has an important policy implication for the reduction of vulnerability and conservation as well as maintaining sustainable livelihood security of the vulnerable coastal people.

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