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Agricultural vulnerability in Bangladesh to climate change induced sea level rise and options for adaptation: a study of a coastal Upazila

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Abstract: This paper examines the vulnerabilities of agriculture in coastal regions of Bangladesh to the different adverse effects of sea level rise induced hazards, and also identifies option for future agricultural adaptations. It reveals that due to sea level rise, agriculture of the study area has already experienced noticeable adverse impacts especially in terms of area of inundation, salinity intrusion and reduction in crop production. The study is conducted based on both primary and secondary data. A total 303 out of 1200 respondents from three coastal villages were randomly interviewed. Samples are drawn proportionately from three villages. Descriptive and inferential statistics and logistic regression have been done to analysis data. The study find that the agricultural land, production of crops, local crop varieties, income and employment facilities of the farmers is highly vulnerable to various SLR induced hazards. Selection of various adaptive options such as control of saline water intrusion into agricultural land, coastal afforestation, cultivation of saline tolerant crops, homestead and floating gardening, embankment cropping and increase of income through alternative livelihoods are emerging need for sustainable coastal agricultural development. Therefore, this paper argues that further development and implementation of such adaptive measures could help to minimize vulnerabilities of agriculture in the long run.

Keywords: SLR, vulnerability, agriculture, adaptation.

Introduction

Salinity intrusion due to SLR will decrease agricultural production by unavailability of fresh water and soil degradation. Out of 1.689 million hectares of coastal land about 1.056 million hectares are affected by soil salinity of various degrees (SRDI, 2009). Salinity also decreases the terminative energy and germination rate of some plants (Rashid *et al.*, 2004). Ali (2005) found that in a coastal village of Satkhira district the rice production in 2003 was 1,151 metric tons which is less than the year of 1985, and corresponding to a loss of 69 per cent. A World Bank (2000) study suggests that increased salinity alone from a 0.3 meter SLR will cause a net reduction of 0.5 million metric tons of rice production. Similarly, Miller (2004) stated that high projected rise in sea level of about 88 cm (35 inches) would inundate agricultural lowlands and deltaic parts of Bangladesh. Likewise, Islam *et al.* (1998) estimated that in Bangladesh alone 14,000 tons of grain production would be lost due to SLR in 2030, and 252,000 tons would be lost by 2075. GDP decrease in the range of 28 percent to 57 percent could result from a 1m SLR (Debove, 2003). In addition, Sarwar (2005) stated that SLR affects agriculture in three ways, such as salinity intrusion, flooding and increasing cyclone frequency. Aman suitable areas would decrease significantly and the ultimate result of reducing agricultural production will force Bangladesh to fail, obtaining the food security (CEGIS, 2006). Increase in SLR may cause migration of a lot of people and causing numerous socio-economic problems (Hussain, 2010).

Review of existing literatures unveils that adaptation to climate change is necessary in addition to mitigate and avoid unacceptable impacts of climate change induced SLR hazards. It is inferred from the available literature that crop production would be extremely vulnerable under climate change conditions, and as a result, food security of the country will be at risk (Mahatab, 1989; BCAS-RA Approtech, 1994; ADB, 1994; Warrick and Ahmad, 1996; Huq *et al.*, 1996; Karim *et al.*, 1998). Although the agricultural vulnerability will be very high and adaptation needs are paramount, very little efforts have so far been made to understand the potential of agricultural adaptation in Bangladesh. Few adaptation measures have also been promoted and subsequently applied in the south western region of Bangladesh such a bid to reduce vulnerability of communities to climate change by increasing people's coping capacity (RVCC, 2003; Schaerer and Ahmed, 2004); and application of some generic adaptation measures for the agriculture sector of Bangladesh (Ahmed, 2000; GOB-UNDP, 2005). Habibullah *et al.* (1998) provided insights into on-the-ground adaptation techniques that might be followed for reducing vulnerability of crops under moderate to high saline affected conditions. However, despite having highly vulnerability to sea level rise, the coastal agriculture may be sustained with the increasing of SLR by taking proper adaptive measures. Therefore, formulating adaptation policies are emerging needs to minimize SLR impacts and to mitigate or reduce the vulnerability of agricultural sector. The objective of this study is to explore the major vulnerabilities of coastal agriculture sector to various climate change induced SLR scenarios and identify adaptive options, and formulate policy guidelines to mitigate such agricultural vulnerabilities.

Materials and Methods

In order to conduct questionnaire survey Gabura, Munshiganj and Jhapa villages of Shyamnagar Upazilla are selected purposively considering their agricultural vulnerability to SLR. In these three village majority percentages of the households are either directly or indirectly dependent on agriculture for livelihoods. The Gabura and Jhapa villages are inundated by saline water every year as it is surrounded by river. On the other hand, Munshiganj village is not inundates each year, hence agricultural productivity is relatively higher than other two village. The methodology started systematically with problem identification and ended by explaining the impacts of SLR induced hazards on agriculture. The assumption of a 5 percent significance level resulted in an estimated sample size of 303 out of 1200 households, and samples from the three villages were in proportion (Yamane, 1967). The primary data were collected using structured questionnaire through face to face interview, direct observation and as well as via focus-group discussions with the respondents in the selected villages to know their adaptation measures under the given circumstances. Different types of collected data were analyzed using SPSS and M.S. EXCELL software. Descriptive statistics such as frequency, percentage, average and cross tabulation are also used to analyze socio-economic conditions of the vulnerable people, physical, socio-economic and environmental consequences of climate change in agriculture sector. Chi-square test is applied for gender, educational level, occupation, income, housing condition, amount of land, landuse, economic activities, adaptation options and some other relevant categorical data. To study the interrelationships among the variables the logistic regression are also considered. In addition, GIS based mapping techniques are applied to show the location of the study area using Arc GIS software.

Results and Discussion

Different Vulnerabilities of Agriculture

Salinity Intrusion into Agricultural Land

SLR and other specific factors such as high intrusion of saline water into agricultural land, introduction of brackish water shrimp cultivation, faulty management of the sluice gates and polders, capillary rise of soluble salts, inundation of saline water into river due to SLR etc. are the main causes of increased soil salinity in the study area. The present study finds that highly saline affected area has increased significantly in the study area during 2000 to 2009 periods. Most of the respondents in the three villages have identified the salinity intrusion as a main problem related to SLR. In 2000 the level of salinity was about 23.93 dS/m and in 2009 it is about 28.64 dS/m in Shayamnagar Upazila (Figure 2).

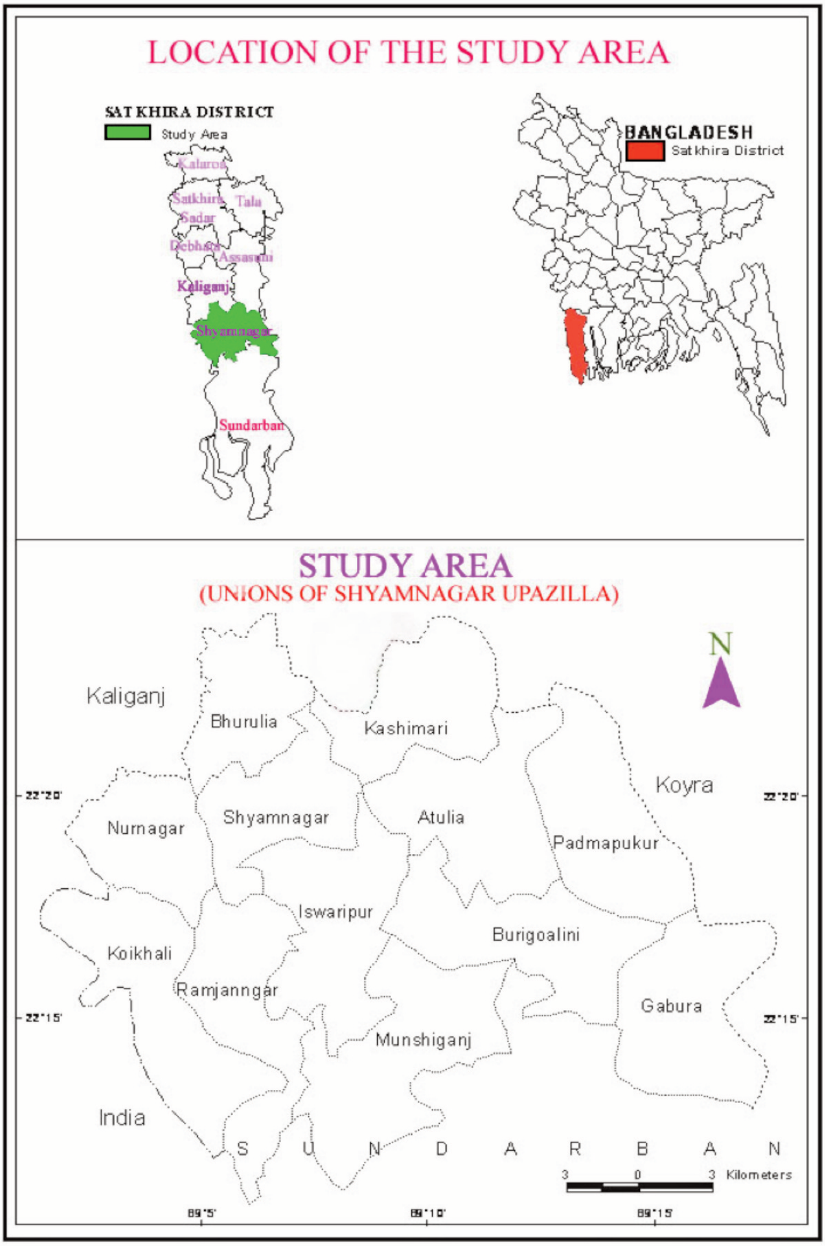

Figure 1 - Location of the study area.

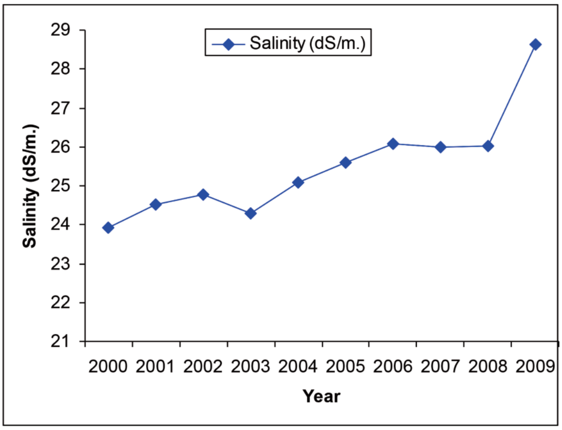

Figure 2 - Trends of soil salinity in Shyamnagar Upazila from 2000 to 2009.

Impact of SLR on Drainage Congestion and Flooding

Rising sea level increases water in the river and thereby accelerating risks of flood and water logging. SLR scenario of 32 cm and 88 cm were considered for assessing the impact of flood and drainage in the study area. The overall comparison of flooding area and land class shifting with 32 cm and 88 cm SLR against the flooding year 2000 is presented in the Table 1. It is reveals that free flood depth land area would be reduced, whereas the deeply flooded area will increase given the 32 cm and 88 cm SLRs respectively.

Impact on Coastal Fisheries and Aquaculture

Salinity intrusion in the freshwater zone of the coastal area has opened the door to cultivate tiger shrimp in the study area. Every year about 500 hectare area of land is converted to saline land. The increasing rate of newly saline affected area has a positive impact on the spreading of shrimp farm area in Shyamnagar Upazila. In 2001, the shrimp farm area was about 12500 hectare and in 2010 it is about 14659 hectare.

Table 1 - Inundated areas under different SLR scenarios by land class (Source: CEGIS, 2008).

Condition	Area of Land Class by Flood Depth (sqkm)					
	Dry	0 - 30 cm	30 - 90 cm	90 - 180 cm	180 - 300 cm	>300 cm
Yr 2000	1058	534	1009	515	200	1
SLR 32 cm	836	444	1007	710	318	2
SLR 88 cm	537	279	878	1011	541	71

Although, it is thought that the sea level rise is favorable to shrimp culture, but the maximum rise of sea level has a negative impact on shrimp culture as well. Hassan and Shah (2009) indicates that the 'suitable' area for shrimp culture will increase up to 37% with 32 cm SLR, but it will reduce from 32 cm to 88 cm SLR due to the increase of flood depth and salinity.(Table 2)

Table 2 - Suitability (% of area) for shrimp culture under different SLR scenarios. (Source: Hassan and Shah, 2009).

Scenario	Area (%)			
	S1 (Highly suitable)	S2 (Suitable)	S3 (Moderately suitable)	S4 (Not suitable)
Base	0	25	35	40
32 cm SLR	1	37	42	20
88 cm SLR	9	29	29	33

Socio-economic Impacts

The present study finds that the level of vulnerability to SLR is very high for the middle class people whose income is 1000-5000 and 6000-10000 BDT per month. The people who have no permanent source of income and the income level are below 1000 BDT per month are also relatively more vulnerable to SLR. Based on the findings of the present study it reveals that increasing income reduces the level of vulnerability to SLR, and socio-economic condition of the respondent is highly related to income level, where lower income groups are more vulnerable to SLR impacts than high and upper income groups (Table 3).

Vulnerability of Local Crop Varieties

The present study finds that a significant number of local rice varieties (kalojira, najirsail, boran etc.) have already been extinct from coastal area because of high salinity intrusion such. Majority of the respondents (34.7%) of the three study villages selected that the vulnerability of local rice varieties is very high due to sea level rise. Due to high increasing rate of salinity many local rice varieties have already been extinct. Extinction and vulnerability of these local rice varieties have negative impact on cultivation and production of the study area. Present study also finds that vulnerability of local rice varieties to SLR is almost similar irrespective of village locations (Table 4).

*Table 3 - Relationship between different socio-economic impacts of SLR and income level of the people (*Source: Household Survey, 2011).

Socio-economic Impacts of SLR	Respondent Income								Total	
	<1000		1000-5000		6000-10000		>10000			
	F	%	F	%	F	%	F	%	F	%
Increasing food insecurity and scarcity of drinking water	22	7.3	55	18.2	50	16.5	12	4	139	45.9
People loss their homestead and become climate refugees	9	3	14	4.6	13	4.3	9	3	45	14.9
People suffering from diseases and malnutrition	9	3	15	5	17	5.6	7	2.3	48	15.8
Unemployment in agriculture sector creates social conflicts	6	2	13	4.3	14	4.6	6	2	39	12.9
Flood and cyclone damages infrastructure & loss of life	5	1.7	13	4.3	9	3	5	1.7	32	10.7
Total	51	16.8	110	36.3	103	34	39	12.9	303	100

Chi-square Test: Sig. Value=0.459 with degree of freedom=12

Table 4 - Main vulnerable agricultural sectors of ShyamnagarUpazila (Source: Household survey, 2011).

Main vulnerable agricultural sectors	Respondent village name						Total	
	Gabura		Munshiganj		Jhapa			
	F	%	F	%	F	%	F	%
Local rice varieties	54	17.8	30	9.9	21	6.9	105	34.7
Vegetation and fruit trees	45	14.9	26	8.6	17	5.6	88	29.0
Fresh water fisheries	39	12.9	24	7.9	12	4.0	75	24.8
Livestock	15	5.0	13	4.3	7	2.3	35	11.6
Total	153	50.5	93	30.7	57	18.8	303	100

Chi-square Test: Sig. value = 0.952 with degree of freedom = 6

Loss of Agricultural Land due to Salinity

The present study finds that in 2000, the net cropped area was 22,385 hectares, highly saline land was 3500 hectares, and increasing rate of saline land is 15.63% during the period of 2000 to 2004. In 2005, only 374 hectares of crop land is added to net cropped area and total net cropped area become 22,759 hectares. Highly saline land has increased from 3,500 hectares to 3,900 hectares and increasing rate is 17.13% during the period of 2005 to 2008. In 2009, net cropped area has increased only 2,131 hectares from 2005 and the total net cropped area become 24,890 hectares.

Vulnerability of Farmers

The loss of agricultural land and crop production due to SLR results in poor socio-economic condition of the farmers. The present study finds that due to the losses of agricultural land, majority of the farmers (47.9%) of the study area have become poor to poorer. The level of poverty increases and pushes farmers to migrate another place to compensate the losses by alternative sources of income. Likewise tendency to migrate another place among the landless farmer (34.7%) is also high. However, it is relatively lower among middle class farmers who have their own land than landless and marginal farmers (Table 5).

Table 5 - Peoples opinion on migrational types of farmers because of increasing poverty by agricultural loses (Source: Household Survey, 2011).

Types of farmers	Respondent village name						Total	
	Gabura		Munshiganj		Jhapa			
	F	%	F	%	F	%	F	%
Marginal farmer	72	23.8	45	14.9	28	9.2	145	47.9
Landless farmer	57	18.8	31	10.2	17	5.6	105	34.7
Middle class farmer	24	7.9	17	5.6	12	4.0	53	17.5
Total	153	50.5	93	30.7	57	18.8	303	100

Chi-square Test: Sig. value=0.026 with degree of freedom=4

Options for Agricultural Adaptations

Options to Mitigate Salinity Intrusion

The people of the study area have selected some adaptive measures to mitigate the saline water inundation into agricultural land in the context of different future sea level rise scenarios. The Gabura village is surrounded by a river; therefore about 16.2% people out of 50.5% have selected the construction of dam/dyke as a main adaptive measure to control saline water inundation. On the other hand, in the context of 14cm sea level rise in 2030, about 32.3% of the respondents have identified the removal of shrimp farms from agricultural land as a main adaptive measure to minimize saline water intrusion into agricultural land. Likewise, in the context of 32 cm sea level rise in 2050, about 34.7% of the respondents have identified the control of shrimp farm expansion as a main adaptive measure. About 47.9% respondents of the three study village have identified the measure construction of very high dam along river side as a main adaptive measure to control saline water inundation into agricultural land in the year of 2100 if sea level rises 88 cm. Besides, increasing the height of land from saline water level and taking proper saline water inundation into agricultural land in 2100 if sea level rises 88 cm.

Alternative Landuse Practices

It reveals that at present about 21.5% 0f the respondents use their land for the purpose of shrimp culture but if the sea level rises 88cm in 2100 it may become 42.9%. So there is a high possibility of increasing trend of using land for shrimp culture instead of agriculture. Although the use of land for the purpose of crop agriculture is decreasing gradually, but there are some alternative options for agriculture are coming into front such as embankment cropping, plantation of mangrove trees like golpata and kaora, cultivation of saline tolerant grass, mele (reed) cultivation and floating dhap cultivation etc. Present and future potential land use practices under different SLR scenarios are presented in Table 6.

Cultivation of Saline Tolerant Crops

At present about 36.3% of the respondents cultivate the high yielding varieties of crops such as BRRI dhan-28,30 and BR-10,11,22,23 and about 29.7% of the respondents cultivate different local rice varieties such as Purbachi, Jamaibabu, Canning Rice etc. It reveals that cultivation of HYV rice verities has gradually decreased due to the possible unavailability of saline tolerant HYV rice varieties. Besides, cultivation of local varieties will increase with the increase of SLR. In 2100, for the increase of salinity level in 25 dS/m, about 40.3% of the respondents have identified the local rice varieties such as Kajalshail, Hamai, Nonakachi, etc. will be suitable for cultivation. Such finding unveils that probably saline tolerant HYV may not properly match with gradually increasing level of soil salinity. Therefore, farmers become reluctant and go back for the selection of traditional local rice varieties. Hence, the present findings unveil that cropping pattern of the study villages may change according to various SLR scenarios (Table 7).

Measures for Increasing Farmers Participation in Agriculture

Due to the vulnerability of agriculture a significant number of farmers of Shyamnagar Upazila migrate to other places to work in brick field, industry and as a rickshaw-puller mainly in towns and cities. Table 8 shows that about 42.9% of the respondents of the three study villages identified that the controlling of salinity intrusion into agricultural land is the main measure to bring back the farmers in agriculture instead of migrating to cities and town for searching jobs. Nearly 24.1%

Table 6 - Agricultural landuse practices of the study area in the context of different SLR scenarios (Source: Household Survey, 2011).

Present land use practices	Respondent village name						Total	
	Gabura		Munshiganj		Jhapa			
	F	%	F	%	F	%	F	%
Cultivation of local rice varieties	45	14.9	31	10.2	19	6.3	95	31.4
Vegetable and fruit cultivation	40	13.2	19	6.3	13	4.3	72	23.8
Shrimp culture	33	10.9	19	6.3	13	4.3	65	21.5
Fresh water fisheries	16	5.3	12	4.0	4	1.3	32	10.6
Homestead forestry	10	3.3	10	3.3	6	2.0	26	8.6
Grazing Land	9	3.0	2	0.7	2	0.7	13	4.3
Total	153	50.5	93	30.7	57	18.8	303	100
Chi-square Test: Sig. value = 0.821 with df = 10								
Probable land use practices in 2030 if Sea Level Rises 14 cm								
Cultivation of saline tolerant crops varieties	50	16.5	30	9.9	18	5.9	98	32.3
Convert fresh water fisheries to shrimp farm	41	13.5	27	8.9	19	6.3	87	28.7
Vegetable cultivation in homestead	29	9.6	16	5.3	10	3.3	55	18.2
Homestead forestry with saline tolerant tree	24	7.9	16	5.3	8	2.6	48	15.8
Cultivation of saline tolerant grass	9	3.0	4	1.3	2	0.7	15	5.0
Total	153	50.5	93	30.7	57	18.8	303	100
Chi-square Test: Sig. value = 0.092 with df = 8								
Pobable land use practices in 2050 if Sea Level Rises 32 cm								
Cultivation of highly saline tolerant crops	52	17.2	31	10.2	12	4.0	95	31.4
Shrimp culture in maximum land	36	11.9	28	9.2	19	6.3	83	27.4
Embankment cropping	37	12.2	18	5.9	12	4.0	67	22.1
Plantation of mangrove trees	21	6.9	11	3.6	8	2.6	40	13.2
Fallow land	7	2.3	5	1.7	6	2.0	18	5.9
Total	153	50.5	93	30.7	57	18.8	303	100
Chi-square Test: Sig. value = 0.092 with df = 8								
Probable land use practices in 2100 if Sea Level Rises 88 cm								
Shrimp culture in whole land	68	22.4	40	13.2	22	7.3	130	42.9
Plantation of Golpata and Kaora	34	11.2	19	6.3	13	4.3	66	21.8
Floating dhap cultivation	21	6.9	16	5.3	11	3.6	48	15.8
Mele(reed) cultivation	15	5.0	12	4.0	6	2.0	33	10.9
Fallow land	15	5.0	6	2.0	5	1.7	26	8.6
Total	153	50.5	93	30.7	57	18.8	303	100
Chi-square Test: Sig. value = 0.092 with df = 8								

respondents of the three study village have identified the availability of saline tolerant crop varieties as another important option for farmer's adaptation to stop migration to other places. Other relevant factors associated with migration are reducing the impacts of natural hazards, increasing employment in agriculture and providing Government and NGOs' credit facilities.

Options for Sustainable Agricultural Development

In 2030, in the context of SLR 14 cm, about 33.7% of the respondents of the three study villages have identified the measure of controlling saline water intrusion for

Table 7 - Name of the suitable crops for cultivation in the context of salinity intrusion (Source: Household Survey, 2011).

PRESENT CULTIVATED CROPS	RESPONDENT VILLAGE NAME						TOTAL	
	GABURA		MUNSHIGANJ		JHAPA			
	F	%	F	%	F	%	F	%
BR-10,11,22,23: BRRI dhan-28,30	56	1	32	10.6	22	7.3	110	36.3
Purbachi, Jamaibabu, C.R.(Canning Rice)	45	1	27	8.9	18	5.9	90	29.7
Water melon(Glory), Mustard(Tori-7)	32	1	23	7.6	13	4.3	68	22.4
BARI Mug-2: BARI Till-3	20	6.	11	3.6	4	1.3	35	11.6
Total	153	5	93	30.7	57	18.8	303	100
Chi-square Test: Sig. value = 0.022 with df = 6								
NAME OF POSSIBLE CULTIVABLE CROPS IN 2030 (IF SALINITY LEVEL INCREASE IN 18 dS/m)								
BRRI dhan-41,49	55	1	33	10.9	20	6.6	108	35.6
Lal teer, Kajallata, China(Shaitta) dhan	49	1	29	9.6	18	5.9	96	31.7
BARI Mug-5,Water Melon	27	8.	19	6.3	11	3.6	57	18.8
Need to invent tolerable varieties	22	7.	12	4.0	8	2.6	42	13.9
TOTAL	153	5	93	30.7	57	18.8	303	100
Chi-square Test: Sig. value = 0.099 with df = 6								
NAME OF POSSIBLE CULTIVABLE CROPS IN 2050 (IF SALINITY LEVEL INCREASE IN 20 dS/m)								
BARI dhan-40,47	50	1	30	9.9	18	5.9	98	32.3
Hybrid Hira, Shaebkachi, Malageti, Sadagotal	42	1	28	9.2	17	5.6	87	28.7
BINA dhan-7,8,9	31	1	20	6.6	12	4.0	63	20.8
Need to invent tolerable varieties	30	9.	15	5.0	10	3.3	55	18.2
TOTAL	153	5	93	30.7	57	18.8	303	100
Chi-square Test: Sig. value = 0.996 with df = 6								
NAME OF POSSIBLE CULTIVABLE CROPS IN 2100(IF SALINITY LEVEL INCREASE IN 25 dS/m)								
Kajalshail, Hamai, Nonakachi, Durgabhog	69	2	30	9.9	23	7.6	122	40.3
Tolerable local varieties	37	1	40	13..2	16	5.3	93	30.7
Need to invent tolerable varieties	32	1	18	5.9	15	5.0	65	21.5
No comment	15	5.	5	1.7	3	1.0	23	7.6
TOTAL	153	5	93	30.7	57	18.8	303	100
Chi-square Test: Sig. value = 0.061 with df = 6								

sustainable agricultural development. About 23.1% of the respondents have identified the measure of cultivation of saline tolerant crops. Other possible measures are increasing fresh water irrigation facilities and reducing disaster induced vulnerabilities of farmers', and such findings are statistically significant (Table 9). In 2050, in the context of 32 cm sea level rise about 35.6% respondents have identified the controlling prolonged inundation of saline water as a main option for sustainable agricultural development. Other possible measures are levelling ground and harvesting rainwater, removing saline water from land, cultivation through Sarjan method and fertilisation of crops etc. However, such findings are not significantly different among the study villages (Table 9). In 2100, in the context of 88 cm sea level rise about 28.4% of the respondents have mentioned the preservation of land rights of marginal farmers as an important measure. Similarly, protective dam and provision of sluice gate is another

Table 8 - Measures to come back the farmers in agriculture in lieu of migration (Source: Household Survey, 2011).

Measures in lieu of migration	Respondent village name						Total	
	Gabura		Munshiganj		Jhapa			
	F	%	F	%	F	%	F	%
Control salinity intrusion in agricultural land	64	21.1	41	13.5	25	8.3	130	42.9
Providing saline tolerant crop varieties	39	12.9	19	6.3	15	5.0	73	24.1
Reducing the impacts of natural hazard	23	7.6	12	4.0	7	2.3	42	13.9
Increasing employment in agriculture	17	5.6	11	3.6	5	1.7	33	10.9
Providing Govt. and NGO. facilities	10	3.3	10	3.3	5	1.7	25	8.3
Total	153	50.5	93	30.7	57	18.8	303	100

Chi-square Test: Sig. value = 0.049 with degree of freedom = 8

Table 9 - Possible measures for sustainable agricultural development in the context of different sea level rise scenarios (Source: Household Survey, 2011).

Probable measures for sustainable agricultural development in 2030 if SLR 14 cm	Respondent Village Name						Total	
	Gabura		Munshiganj		Jhapa			
	F	%	F	%	F	%	F	%
Control saline water intrusion	53	17.5	29	9.6	20	6.6	102	33.7
Cultivation of saline tolerant HYV crops	37	12.2	21	6.9	12	4.0	70	23.1
Selection of appropriate cropping pattern	23	7.6	22	7.3	11	3.6	56	18.5
Increase of fresh water irrigation facilities	28	9.2	15	5.0	9	3.0	52	17.2
Reducing disaster vulnerabilities	12	4.0	6	2.0	5	1.7	23	7.6
Total	153	50.5	93	30.7	57	18.8	303	100
Chi-square Test: Sig. value = 0.014 with df = 8								
Probable measures for sustainable agricultural development in 2050 if SLR 32 cm								
Control prolonged inundation of saline water	52	17.2	31	10.2	25	8.3	108	35.6
Leveling of land and storing rain water	41	13.5	27	8.9	14	4.6	82	27.1
Remove saline water logging from land	30	9.9	18	5.9	10	3.3	58	19.1
Cultivation in Sarjan method	17	5.6	12	4.0	6	2.0	35	11.6
Fertilization of crops	13	4.3	5	1.7	2	0.7	20	6.6
Total	153	50.5	93	30.7	57	18.8	303	100
Chi-square Test: Sig. value = 0.875 with df = 8								
Probable measures for sustainable agricultural development in 2100 if SLR 88 cm								
Preserve land rights of marginal farmers	49	16.2	23	7.6	14	4.6	86	28.4
Protective dam and provision of sluice gate	43	14.2	21	6.9	16	5.3	80	26.4
Improvement of floating dhap cultivation	19	6.3	23	7.6	12	4.0	54	17.8
Need adaptive research and policy	22	7.3	14	4.6	9	3.0	45	14.9
Providing Government and NGO facilities	20	6.6	12	4.0	6	2.0	38	12.5
Total	153	50.5	93	30.7	57	18.8	303	100
Chi-square Test: Sig. value = 0.052 with df= 8								

adaptive option in the case of 88 cm SLR. In addition, Government and NGOs' credit facilities are also identified as a common adaptive measure in case of 88 cm SLR. Floating Dhap cultivation and cultivation by Sarjan method are also the two other important measures for agricultural adaptation.

Government and NGOs roles for agricultural adaptation

At present about 36.3% respondents of the three study villages have identified the control of the expansion of new shrimp farms as a necessary measure to combat SLR impacts, and Government and NGOs should come forward to assist for such agricultural adaptation. In the context of 14 cm rise of sea level in 2030 about 31.4% respondents expected that it is necessary to ensure the availability of saline tolerant seed for agricultural adaptation. On the other hand, large land ownership is a threat for agricultural activities of the marginal farmer because it creates discrimination between the marginal farmers and the landlords. In the context of 32 cm SLR in 2050, about 23.8% respondents expect that Government and NGOs should take proper steps for providing the support to store seed and food. Besides proper sluice gate management, increase in national allotment and implementation of Integrated Coastal Zone Management Programme (ICZMP) are also the others expected adaptive measures from Government and NGO's side for agricultural adaptation to combat SLR impacts. Likewise, in the context of 88 cm rise of sea level in 2100 about 29.6% respondents expected that the Government and NGOs should take necessary steps to ensure the supply of fresh water for the irrigation purpose. Infrastructural development and providing subsidies for alternative livelihoods are other expected measures from Government and NGO's side for agricultural development of the study area in the context of 88 cm SLR in 2100.

Regression analysis for identifying factor influence adaptation

The relationship between the different socio-economic factors such as education, occupation, income etc. of the respondents and the selected adaptive measures for agriculture in the study area in the context of different projected sea level rise scenarios is presented by using multinomial logistic regression. The covariates of different present adaptive measures (Table 10) to agriculture reveals that there have a overall influences on the selection of different adaptive measures to combat the vulnerabilities of agriculture in the context of present sea level rise induced hazards.

From the analysis of the covariates of different adaptive measures (Table 11) to agriculture it reveals that there have a overall influences on the selection of different adaptive measures to combat the vulnerabilities of agriculture in the context of 14 cm sea level rise in 2030.

Similarly, form the analysis of the covariates for 2050, if SLR 32 cm (Table 12), the types of occupation of the respondents has significant influences to adopt different adaptive measures to combat the possible vulnerabilities of agriculture. The education level of the respondents has also significant influence to adopt the measure for the development of drainage system as a measure for adaptation and it is 2 times more

Table 10 - Multinomial logistic regression analysis of covariates for different present adaptive measures of agriculture.

Present adaptive measures*	Independent variables	B	Std. Error	Wald	df	Sig.	Exp (B)	95% Confidence Interval for Exp(B)	
								Lower Bound	Upper Bound
Construction of dam/dyke around agricultural land	Education	.085	.319	.070	1	.791	1.088	.582	2.034
	Occupation	-.152	.160	.911	1	.340	.859	.628	1.174
	Income	.321	.396	.655	1	.418	1.378	.634	2.994
Increasing storing capacity of rain water in land	Education	-.074	.334	.050	1	.823	.928	.483	1.785
	Occupation	-.166	.168	.974	1	.324	.847	.609	1.178
	Income	.084	.422	.039	1	.843	1.087	.475	2.487
Irrigation by fresh water	Education	-.443	.348	1.628	1	.202	.642	.325	1.268
	Occupation	-.139	.175	.636	1	.425	.870	.618	1.225
	Income	.637	.434	2.153	1	.142	1.890	.808	4.425
Cultivation of all over the years	Education	.279	.701	.159	1	.690	1.322	.335	5.219
	Occupation	.242	.342	.500	1	.480	1.273	.652	2.489
	Income	.333	.663	.253	1	.615	1.396	.381	5.116

* The reference category is: Proper drainage to remove saline water.

Model Fitting Information

Model	Model Fitting Criteria	Likelihood Ratio Tests			Pseudo R-Square (Cox and Snell)
	-2 Log Likelihood	Chi-Square	df	Sig.	
Intercept Only	273.094				
Final	252.362	20.733	12	.054	.066

Table 11 - Multinomial logistic regression analysis of covariates for adaptive measures of agriculture in 2030 if SLR 14 cm.

Adaptive measures in 2030*	Independent variables	B	Std. Error	Wald	df	Sig.	Exp (B)	95% Confidence Interval for Exp(B)	
								Lower Bound	Upper Bound
Construct high dam around agricultural land	Education	-.373	.706	.279	1	.597	.689	.173	2.745
	Occupation	-.158	.346	.209	1	.647	.854	.433	1.681
	Income	-.204	.660	.096	1	.757	.815	.224	2.972
Dig deep canal around agricultural land	Education	-.184	.639	.083	1	.774	.832	.238	2.913
	Occupation	-.399	.308	1.674	1	.196	.671	.367	1.228
	Income	-.024	.550	.002	1	.965	.976	.332	2.870
Protect river bank erosion	Education	-.362	.647	.314	1	.575	.696	.196	2.474
	Occupation	-.410	.313	1.716	1	.190	.663	.359	1.226
	Income	-.235	.571	.170	1	.681	.790	.258	2.422
Reduce the evaporation from agricultural land	Education	-.709	.656	1.170	1	.279	.492	.136	1.778
	Occupation	-.375	.317	1.398	1	.237	.688	.370	1.279
	Income	.285	.580	.242	1	.623	1.330	.427	4.145

*The reference category is: Remove shrimp farm from in sight of agricultural land.

Model Fitting Information

Model	Model Fitting Criteria	Likelihood Ratio Tests			Pseudo R-Square (Cox and Snell)
	-2 Log Likelihood	Chi-Square	df	Sig.	
Intercept Only	271.873				
Final	251.074	20.799	12	.053	.066

Table 12 - Multinomial logistic regression analysis of covariates for adaptive measures of agriculture in 2050 if SLR 32 cm.

Adaptive measures in 2050*	Independent variables	B	Std. Error	Wald	df	Sig.	Exp (B)	95% Confidence Interval for Exp(B)	
								Lower Bound	Upper Bound
Development of drainage system	Education	.787	.356	4.876	1	.027	2.196	1.092	4.413
	Occupation	-	.400	7.595	1	.006	.332	.152	.727
	Income	-.266	.388	.469	1	.493	.767	.358	1.640
Rain water harvesting for irrigation	Education	-.233	.449	.270	1	.603	.792	.328	1.910
	Occupation	-	.436	7.133	1	.008	.312	.133	.734
	Income	-.836	.404	4.287	1	.138	.433	.196	.956
Ensuring the reservation of fresh water	Education	.507	.436	1.354	1	.245	1.660	.707	3.899
	Occupation	-.896	.479	3.507	1	.051	.408	.160	1.043
	Income	-.258	.465	.307	1	.580	.773	.310	1.924
Development of sluice gate system	Education	.295	.885	.111	1	.739	1.343	.237	7.608
	Occupation	-	.822	4.417	1	.036	.178	.035	.890
	Income	-.697	.928	.564	1	.453	.498	.081	3.070

*The reference category is: Control the aggression of new shrimp farm.

Model Fitting Information

Model	Model Fitting Criteria	Likelihood Ratio Tests			Pseudo R-Square
	-2 Log Likelihood	Chi-Square	df	Sig.	(Cox and Snell)
Intercept Only	106.950				
Final	84.015	22.935	12	.028	.073

Table 13 - Multinomial logistic regression analysis of covariates for adaptive measures of agriculture in 2100 if SLR 88 cm.

Adaptive measures in 2100*	Independent variables	B	Std. Error	Wald	df	Sig.	Exp (B)	95%Confidence Interval for Exp(B)	
								Lower Bound	Upper Bound
Intense afforestation in river side	Education	.025	.361	.005	1	.944	1.026	.506	2.081
	Occupation	.329	.364	.817	1	.366	1.389	.681	2.834
	Income	-.558	.438	1.627	1	.002	.572	.243	1.349
To high land from saline water level	Education	-.917	.482	3.611	1	.067	.400	.155	1.029
	Occupation	.831	.499	2.770	1	.096	2.296	.863	6.111
	Income	-1.370	.457	8.989	1	.003	.254	.104	.622
Increasing the upstream flow of river	Education	-.216	.434	.248	1	.619	.806	.344	1.885
	Occupation	1.051	.529	3.939	1	.047	2.859	1.013	8.068
	Income	-.982	.467	4.418	1	.036	.375	.150	.936
Taking proper saline management programme	Education	-.767	.637	1.449	1	.229	.464	.133	1.619
	Occupation	.588	.678	.751	1	.386	1.800	.476	6.805
	Income	-1.536	.577	7.081	1	.008	.215	.069	.667

*The reference category is: Construction of very high dam.

Model Fitting Information

Model	Model Fitting Criteria	Likelihood Ratio Tests			Pseudo R-Square
	-2 Log Likelihood	Chi-Square	df	Sig.	(Cox and Snell)
Intercept Only	118.952				
Final	92.985	25.967	12	.011	.082

likely (odd ratio = 2.196) to be selected than the measure of controlling the aggression of new shrimp farms by the education level of the respondents.

In addition, from the analysis of the covariates for 2100, if SLR 88 cm (Table 13), the income level of the respondents has significant influences to adopt various adaptive measures to combat the possible vulnerabilities of agriculture. The types of occupation of the respondents also have significant influence to adopt the measure of the increasing the height of land from saline water level as a measure for adaptation and it is 2 times more likely (odd ratio = 2.859) to be selected than the measure of the construction of very high dam by the types of occupations of the respondents.

Conclusion

The present study finds that high salinity intrusion, tidal inundation, flooding and drainage congestion, saline water logging on agricultural land lack of irrigation facilities, decrease in cultivable land, loss of crop production, extinction of local crop varieties, lack of saline tolerant crop varieties, and unemployment in agriculture are the major impact areas of sea level rise on agriculture. Due to such impacts on coastal agriculture the farmers of the study area remains highly vulnerable and they become poor to poorer. The farmers of the study villages have identified some alternative measures for agricultural adaptation such as cultivation by sarjan method, embankment cropping, rice-fish mixed farming, floating agriculture, crab fattening and plantation of different mangrove trees like golpata and kaora. As the coastal agriculture is highly vulnerable to various sea level rise induced hazards, formulation of various adaptive measures is very necessary for coastal agricultural adaptation. It is also necessary to take some effective adaptive measures to minimize the sea level rise impacts on agriculture. Development and implementation of selected adaptive measures have emerging need for sustainable agricultural development of the study area.

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