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Adaptation Practices by the Farmers for Reduction of Salinisation Problem in the Paddy Fields of South-Eastern Coast of Bangladesh

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Abstract: Climate change has become the biggest risk to the nutritional and food security of the planet worldwide. Rising temperatures, uneven rainfall, cyclones and droughts are unfavourably impacting agricultural production, which, in turn, is creating an elevated vulnerability to the livelihood of Bangladesh's huge population. Bangladesh is an agrarian country and almost half of the population depends on agriculture activities as a profession. But the agriculture sector of the country is experiencing adverse impacts at various levels and ways because of climate change-induced natural hazards. The present study was done to explore the salinity intrusion problem, soil fertility and rice production in the study areas. Besides, the authors also discover some indigenous knowledge-based adaptation and coping practices of the farmers for reducing the impact of climate change in the study areas. The study disclosed that salinity intrusion into the surface water recorded at high values everywhere and the quality of the sediments was alarming. According to the experiences of the farmers, knowledge and resources, they looked for adaptation strategies to cope with the changing climatic situation. The study will help to demonstrate adaptation practices by the farmers for reducing the salinity level of the agriculture field which will be effective in the vulnerable areas of other parts of the country and worldwide while the area was affected by the salinisation problem.

Key words: Climate change, agriculture land, salinisation, adaptation practices.

Introduction

The coastal zone of Bangladesh is prone to severe natural disasters, such as cyclones, storm surges and floods in combination with other natural and man-made hazards, such as erosion, the high arsenic contents of groundwater, saline water intrusion, water logging, water and soil salinity. These disasters have made coastal dwellers very vulnerable and the whole coastal and marine environment threatened (Islam, 2004). Coastal areas constitute about 2.5 million hectares which amount to about 25% of the total cropland of the country, nearly 0.84 million hectares are affected by varying intensities of salinity, resulting in very poor land utilisation (Barua and Rahman, 2017; Barua et al., 2017).

Among the 181 climate-vulnerable countries in the world, Bangladesh is positioned at 165th place as well as the 30th vulnerable country to climate change (IDMC, 2021). Bangladesh is an agricultural country, but agriculture is highly susceptible to climate change. Soil salinity is one of the major land degradation

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problems in the agriculture sector of Bangladesh which adversely affects the productivity of agricultural land. Chittagong district located in the southeastern coastal area of Bangladesh is vulnerable to cyclones, tidal surges, flash flood, tidal and flash flood, earthquake and other natural calamities. From the year 1960 to 2018, 32 major cyclones hit the whole district. The most devastating cyclone of the last century hit Chittagong in 1991 and after that the last cyclone damaged the coastal area in July 2016 when *Ruano* hit the coastal area of Banshkhali, Anwara upazila (Sub-district) of Chittagong district. Saline water and salinisation are the primarily associated factors of calamity, as they source and process various disasters like cyclones, tidal surges, flash and tidal and flash flood and tidal fluctuation because a huge volume of saline water is received by the inundated coastal areas (Barua and Rahman, 2021).

Rice is the most significant and demanded agricultural crop to the requirement of feeding and surviving products for the growing population of the earth. Almost 60% population of the world completely depends on rice production. Rice is a fastener crop among all other products in developing countries like Bangladesh. Almost 75% of the total fertile land is used for rice production. Thus, any decline in rice production because of climate change would gravely spoil the food security matters of the nation. Therefore, measuring the influence of climate change on rice cultivation and evaluating agriculture farmers' coping capability to adapt to climate change is the theme of pressing research (Barua et al., 2019). Alam et al. (2020) suggests that increasing rates of salinity level in the sediment is about 0.90% per year. The paddy land becomes saline due to its contact with seawater and continued flooding during high tides and seawater ingress through the Sangu river and creeks. As a result, the soil fertility status is reduced, changing traditional or old agricultural practices, and discouraging farmers from cultivating their land. The prime objectives of the study were to determine soil and water salinity and current soil fertility status on paddy land and deliver some measures to reduce salinisation processes and improve fertility status in the study area.

Material and Methods

Chittagong is a coastal district situated on the southern-eastern coast of Bangladesh and a natural combination of hill and sea. The study was carried out in the Banshkhali Upazila (sub-district) which is under Chittagong District in the Division of Chittagong. Among the 14 unions of Banshkhali Upazila (sub-districts), the study majorly concentrated on the two climate change-affected area named Khankhanabad and Baharchara unions. The authors followed a mixed-method approach to answer the research questions. For the information collection, the authors conducted Focus Group Discussions, Key Informant Interviews, community consultation and a questionnaire survey with the agriculture farmers. The study villages of two unions were selected based on a pre-survey field visit and in consultation with local government institutes and vulnerable communities. The villages selected were those most affected in the study sub-district.

Spot method and random sampling techniques were used for sample collection in the agricultural fields. Soil and water samples were collected at a depth of 10 cm on agricultural fields and total of 11 samples were collected for determination of soil fertility status and surface water salinity from the 4 villages of 2 unions. The study was conducted for 1 year round from January 2018 to December 2018. For soil samples, transparent polythene bags were used to preserve the samples and each bag was labeled. The labeled samples were analysed in the environmental lab of the Bangladesh Council for Scientific and Industrial Research, Chittagong, Bangladesh. The samples were kept in an oven at 105°C for 24 hours; then cooled in desiccators and weighed again and soil texture was determined using the hydrometer method. Table 1 indicated the parameters of sediments and water quality samples, and analytical and unit techniques were used for soil and water quality analysis in the study areas.

Results and Discussion

Soil and Water Quality Parameters Analysis

Table 2 summarises the selected parameters of the surface water salinity and soil quality and fertility status on paddy fields.

Production of food grains in the coastal zones of Bangladesh is thought to be severely limited by the salinity level of the soil (Haque, 2004). In this study, it was discovered that the lowest, maximum, mean, and standard deviation among the climatic variables, salinity in water and sediments and fertility status are significantly correlated. The authors found the lowest salinity level (0.42%) in site 4 and highest salinity level (45.10%) in site 5. The mean salinity was 24.83% and the standard deviation was 14.65%. The lowest temperature recorded at site 2 and highest 35 °C at site 6, with the mean temperature being 31.81 °C and the standard deviation being 2.60 °C. The authors found

Table 1: Sediments and water quality parameters analytical methods

Parameters	*Units*	*Analytical methods*
Temperature	°C	Thermometer
Bulk Density	g/cm^3	
Soil pH	–	pH meter (HANNA HI 8424 pH meter) (made in Romania)
Electrical conductivity (EC)	$\mu S\ cm^{-1}$	Combo meter, Model HI 98129 (HANNA Instruments, Inc., Woonsocket, RI)
Soil and water salinity	%	Combo meter, Model HI 98129 (HANNA Instruments, Inc., Woonsocket, RI)
Phosphorus	NTU	phospho-vanadomolybdate method (Hanson 1950).
Potassium (K), Calcium (Ca) and Magnessium (Mg)	$mg\ L^{-1}$	after digestion with nitric acid-perchloric acid (Olsen and Sommers 1982)
Salinity	$mg\ L^{-1}$	Chloride Concentration and Salinity
Total Nitrogen		Micro-Kjeldahl digestion method
Ammonia (as nitrogen) (NH^-_3)	$mg\ L^{-1}$	Direct Nesslerization Method, Reference 1
Organic carbon		Wet-Oxidation method
Organic matter		Van bemmelen method, factor of 1.73

Table 2: Summary of surface water salinity and soil quality and fertility status

Water quality					
Parameters	*No. of sample*	*Minimum*	*Maximum*	*Mean*	*Std. deviation*
Salinity (%)	11	0.42	45.10	24.8291	14.65116
Soil quality					
pH	11	1.80	3.60	2.8955	0.54150
Colour	11	Reddish	Blackish		
Temperature (°C)	11	26.00	35.00	31.8182	2.60070
Salinity (%)	11	1.00	30.50	19.1727	12.01491
Soil fertility status					
Structure & textural class	11	Sandy	Sandy loam		
Bulk Density (g/cm^3)	11	1.51	1.66	1.5809	0.04949
OC (%)	11	0.13	0.77	0.4473	0.18347
OM (%)	11	0.22	1.32	0.7718	0.31654

that surface water salinity in the study areas were high or extremely strong for rice production as surrounding water bodies were ingested by salinity intrusion problem. Sangu River and enormous tidal creeks were too much active with saline water fluctuating activities. On the other hand, only two sites (3 and 4) were found low saline or very slight salinity because 3 and 4 sites were situated alongside a hill or high land and also these sites were covered by high land in the study area (Figure 2). The result of correlations among the studied physico-chemical properties of agriculture and field soils of the study area has been given in Table 3. Limits of correlation coefficient among parameters take values from -1 to +1. i.e. $-1 \leq r_{xy} \leq 1$. The table indicated that Pearson correlations, among other parameters including correlation, are significant at the 0.01 level, and the correlation is significant at the 0.05 level (2-tailed).

Land inundated by saline water causes the seepage of saline water into the adjacent paddy fields, causing problems in rice production. Plane land soil is more fertile (Table 4) than hill soil because the above table shows that a portion of silt loam particles was high on the plane soil on the other hand portion of sandy loam and sand participles were high on the hill soil.

The dry weight of a unit volume of soil inclusions pore spaces is called bulk density. The average density of soil in bulk is 1.5 gm/cc. Soil bulk density was moderate for paddy cultivation in the study areas (Table 5), showing that the valley area's soil bulk density was poor, however, it was good in-plane land soils.

Table 3: Pearson correlations among parameters for the study area

Parameters	*Soil pH*	*Soil salinity*	*Soil temperature*	*Bulk density*	*% O.C*	*% O.M*	*Water salinity*
Soil pH	1	.437	-.107	.215	-.574	-.577	.539
Soil salinity(%)	.437	1	.498	.103	-.051	-.050	.857**
Soil temperature (°C)	-.107	.498	1	-.177	.231	.241	.193
Bulk density (g/cm^3)	.215	.103	-.177	1	-.593	-.593	.006
% O.C	-.574	-.051	.231	-.593	1	1.000**	.013
% O.M	-.577	-.050	.241	-.593	1.000**	1	.006
Water salinity	.539	.857**	.193	.006	.013	.006	1

** Correlation is significant at the 0.01 level (2-tailed); *Correlation is significant at the 0.05 level (2-tailed).

Table 4: Finding of soil structure and texture in the study areas

S.N.	*Soil structure or separation*				*Soil texture*	
	% Sand	*% Silt*	*% Clay*	*Fertility status**	*Textural class*	*Fertility status**
Site 1	92.9	2.5	4.6	Poor	Sandy	Poor
Site 2	62.9	30	7.1	Poor	Sandy loam	Medium Good
Site 3	37.9	52.5	9.6	Good	Silt loam	Good
Site 4	57.9	35	7.1	Medium good	Sandy loam	Medium good
Site 5	60.4	35	4.6	Poor	Sandy loam	Medium good
Site 6	75.4	17.5	7.1	Poor	Sandy loam	Medium good
Site 7	75.4	17.5	7.1	Poor	Sandy loam	Medium good
Site 8	50.4	40	9.6	Good	Loam	Very Good
Site 9	32.9	60	7.1	Very good	Silt loam	Very Good
Site 10	35.4	57.5	7.1	Very good	Silt loam	Very Good
Site 11	45.4	45	9.6	Very good	Loam	Very Good

*Fertility status determined by the help of the above literature reviews

Table 5: Finding of soil bulk density in the study areas

Sample location	*Bulk density (g/cm^3)*	*Fertility status*
Site 1	1.66	Poor
Site 2	1.60	Poor
Site 3	1.51	Good
Site 4	1.59	Poor
Site 5	1.61	Poor
Site 6	1.63	Poor
Site7	1.63	Poor
Site 8	1.53	Good
Site 9	1.55	Good
Site 10	1.55	Good
Site 11	1.53	Good

*Fertility status determined by the help of the above literature reviews.

The paddy field's soil pH was rather acidic (Table 6). The mean pH was found to be 2.8955, with a maximum of 3.60 and a minimum of 1.80, and a standard deviation of 0.54150.

Salinity causes unfavourable environments and hydrological situations that restrict normal crop production throughout the cultivation period. Table 6 shows that the level of organic matter, organic content, electrical conductivity were very low in the study areas.

Determination of Soil Fertility Status on Paddy Fields

Land inundated by saline water is causing the seepage of saline water into the adjacent paddy fields, causing problems in rice production. Potassium (K) uptake is also impaired by salinity, and experiments have shown that the application of additional K in highly saline soils is not effective in improving the K uptake. According to SRDI (2010), naturally, saline water contains various dissolved solids composed mainly of carbonates, bicarbonates, chlorides, sulphates, phosphates, silica,

Table 6: Finding of soil parameters of the sample sites of the study areas

Sample No.	*pH*	*Salinity*	*EC mS/cm*	*% O.C*	*% O.M*	*Total % N*	*Total % P*	*Total % K*	*Total % Ca*	*Total % Mg*
1	3.0	22.3	0.08	0.13	00.22	0.06	0.3075	0.20	0.0037	0.110
2	3.5	1	0.05	0.31	00.53	1.00	0.28	0.54	0.0009	0.434
3	1.8	1	0.01	0.62	10.07	1.02	1.135	1.04	0.0000	0.532
4	2.3	1	0.05	0.49	00.85	0.98	0.69	0.56	0.0002	0.160
5	2.8	30.5	0.10	0.53	00.91	1.04	1.0225	0.51	0.0003	0.115
6	3.0	25.5	0.09	0.27	00.47	0.73	1.03	0.33	0.0001	0.061
7	3.0	23.2	0.08	0.47	00.82	0.78	0.7875	0.26	0.0006	0.078
8	2.8	29.4	0.15	0.58	00.01	1.00	1.51	0.64	0.0001	0.313
9	2.6	22	0.12	0.77	00.32	1.23	0.3425	1.05	0.0003	0.584
10	3.5	29.4	0.05	0.46	00.79	0.88	0.7975	0.78	0.0003	0.614
11	3.6	25.6	0.01	0.29	00.50	0.31	0.8325	0.70	0.0001	0.029

Ca, Mg, Na and K. From the finding of Table 6, it was revealed that the level of N, K, Ca, Mg in the agriculture field is a very low amount and for that soil fertility status become good for agriculture production and productivity become low at present time.

Community Perception of Salinity Levels in Rice Fields

Islam (2004) states that many coastal districts, including Chittagong, are facing increased levels of salinity in agricultural fields. A recent report shows that more than 1 million hectare of arable land in Bangladesh are affected by salinity intrusion caused by slow- and rapid-onset events (SRDI, 2010). According to the BBS, the net cultivated area in Chittagong decreased by about 7% from 1996 to 2015 (BBS, 2016). Focus group participants and questionnaire survey, farmers claim that salinity intrusion has increased sharply over the last decade and particularly over the past five years (Figure 1).

Currently, high salinity in the rice fields is caused to a large extent by cyclone *Mahasen*, which hit the area in 2013. In 2020, when the fieldwork took place, about 65% of farming households experienced high salinity in rice fields (Figure 2).

Farmers in the study areas, mainly cultivate rice varieties, which grow between April and August. In the past 20 years, the pattern of T. Aman production at Khankhanabad Union has been quite irregular. The data show that total T. Aman production was more than 10,000 tonnes between 2000 and 2005, but was less than 7,500 tonnes from 2006 to 2011. In 2012, the production of Aman was about 6,800 tonnes. Since then, it has decreased substantially by 25% and 15% in 2013 and 2014 respectively in the study area (UAO, 2015). There were different responses regarding the changes in rice production over the last 20 years. About 76% of farmers in the study villages believe that rice production has decreased over the years (Figure 3).

According to Figure 4, it is found that most respondents (98%) identified salinity intrusion as the main cause of declining rice production, followed by lack of rainfall (65%). Other factors mentioned included excessive rainfall in short periods of time (called 'sky

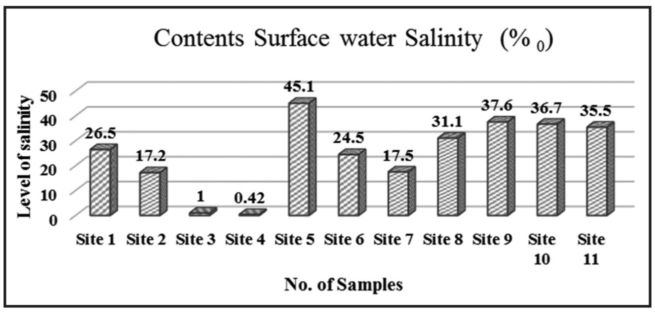

Figure 1: Content of surface water salinity in paddy fields.

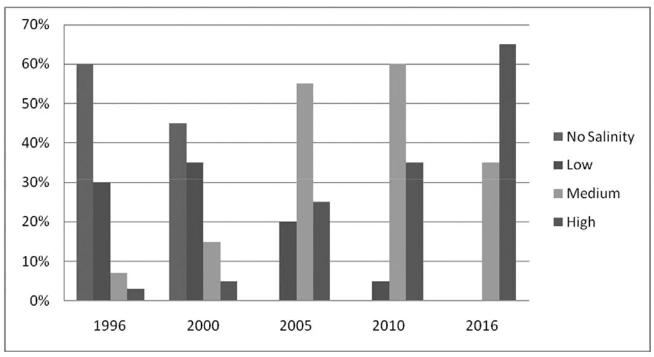

Figure 2: Respondents' perceptions of the trend of salinity during the last 20 years in the study area.

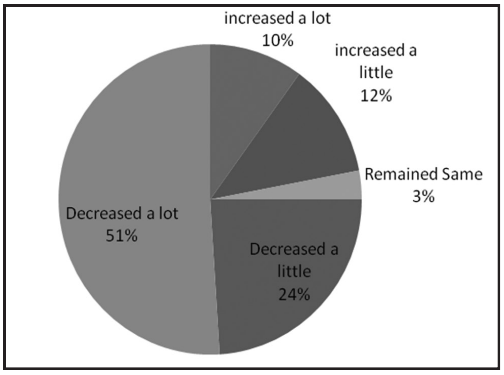

Figure 3: Change in rice production in the study areas over the last 20 years.

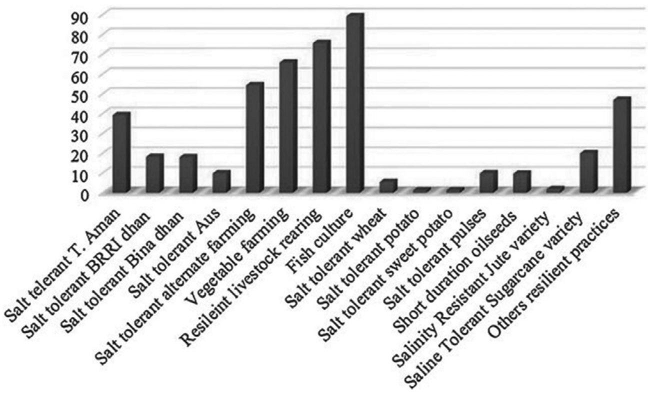

Figure 4: Percentage of respondents on causes of reduction in rice production.

floods' locally), pest attacks, no provision of fertiliser at the right time, water logging, high cost of cultivation, and lack of irrigation water. All the farmers strongly believed that salinity intrusion in soil and water is the main challenge to rice farming in the study areas.

Adaptation Practices by the Farmers to Reduce the Salinisation Problem

Farmers in the study areas experienced that climate change and variability directly affected the agriculture sector, especially crop, fisheries and livestock production. The farmers of the study area reported that the concept of pre-emptive adaptation is foreign. They don't plan ahead – they will wait till it happens, and then they will adapt. Besides, to cope with climate change-induced natural disasters in the study areas, farmers applied alternative land use practices like shrimp farming instead of crop production, embankment cropping, plantation of mangrove trees, cultivation of saline-tolerant grass, using flood- and saline-tolerant rice, etc. Farmers of the study areas apply some climate-resilient agro-based practices which are indicated in Table 7. With the support of the district agriculture office of Chittagong, Bangladesh local farmers of the Banskhali sub-districts of Chittagong district practice agriculture under different salinites, flood-tolerant rice varieties; cage fishing, mele (reed) cultivation, floating dhap cultivation, shifting planting time, short- duration rice varieties, integrated farming, crab patenting, semi-scavenger housing for goat, duck, and hen rearing, net fishing, dyke farming, salt-tolerant wheat, salt-

Table 7: Agro-based resilient practices in the study areas

Resilient sector	*Options*
Salt-tolerant T. Aman	BR-22 and BR-23, Bina shail
Salt-tolerant BRRI dhan	33, 56, 57, and 62 BRRI dhan 40, 41, 53, 54
Salt-tolerant Bina dhan	7 and 16 Bina dhan-8 and 10
Salt-tolerant Aus	BRRI dhan 65
Salt-tolerant alternate farming	Mele (reed) cultivation, salt-tolerant grass farming
Vegetable farming	Floating dhap cultivation, dyke farming, homestead farming
Resilient livestock rearing	Semi-scavenger housing for goat, semi-scavenger housing for duck, semi-scavenger housing for hen, semi-scavenger housing for sheep
Fish culture	Net fishing, cage fishing
Salt-tolerant wheat	Bijoy, BARI Gom-25, BAU-1059
Salt-tolerant potato	BARI Alo-22, CIP Clone -88,163
Salt-tolerant sweet potato	BARI Mishti Alo-8,9
Salt-tolerant pulses	BARI Mug- 2,3,4,5,6, BM-01, BM-08 BARI Falon- 1, BARI Sola-9
Short-duration oilseeds	BARI Sharisha-14,15 BARI China badam-9, BINA China badam-1, BINA China badam-2, BARI Soyabean-6 BARI Til-2,3,4
Salinity-resistant jute variety	HC-2, HC 95, CVL 1
Saline-tolerant sugarcane variety	ISWARDI-40
Others resilient practices	Land use changing practice, integrated farming, crab patenting, shifting plantation timing

tolerant potato, salt-tolerant sweet potato, salt- and heat-tolerant pulses: short- duration and salt-tolerant oilseeds, salt-resistant jute varieties and salt-tolerant sugarcane varieties for coping with salinity intrusion in the agriculture field (Table 7).

According to Figure 5, the authors explore the farmers' responses to cultivation methods in response to reducing the salinity level and increasing crop production in their areas. Besides, 54.3% of farmers used alternate cropping including mele (reed) cultivation and salt-tolerant grass farming in the study area (Figure 5). Fish culture is the common practice of coastal Bangladesh, but due to sea level rise, tidal inundation, storm surges, and flood, this practice is being restricted for the recent time.

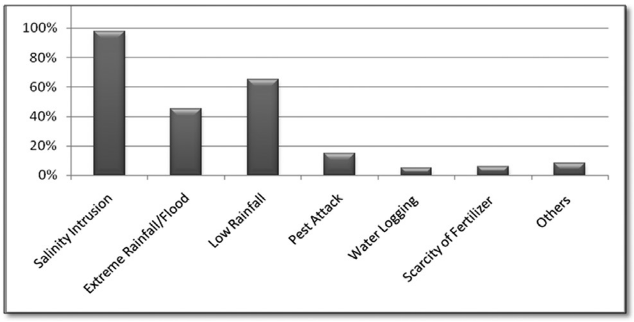

Figure 5: Climate-resilient agro-based practices in the study areas.

Conclusion and Recommendation

Due to the effects of climate change, crop production in Bangladesh's coastal region now depends significantly on the salinization process and the fertility of the soil. In general, coastal area of Bangladesh are low lying topography, enormous tidal creeks and quite low in soil fertility. Soil salinity is a worldwide problem and Bangladesh is no exception to it. In Bangladesh, salinisation is one of the major natural hazards that disrupt crop production mainly rabi season crops (wheat, barley, maize, boro, mustard and vegetables) are affected due to different degrees of salinity. The salinisation process not only changes the paddy crop rotation but also discourages farmers for cultivated crops in the study of South-Eastern coast of Bangladesh. The level of poverty, low level of resilience, and lack of alternative livelihoods together with such climate-induced hazards cause huge losses for not only study communities but also the people of the whole coast. Increasingly, people are moving from the coast, mainly because of the loss of livelihood opportunities. Bangladesh urgently needs support in developing a climate-resilient agriculture if its people are to survive and prosper in the long term. Climate change is affecting the country in many ways. For instance, rising sea levels are causing some agricultural land in coastal areas to become more saline, reducing both the quality and quantity of the products available. The impact of climate change on agriculture is undeniable and will most certainly worsen if climate-resilient farming practices are not adopted. In southern districts, where land is only a few centimeters higher than the brackish estuarine water, large swathes of agricultural land are becoming arid. Crop yields are shrinking because of increased salinity due to rising water levels in the Bay of Bengal. Despite all these climatic stressors, people are trying to cope with the adverse situation, both through their traditional knowledge of agrarian adaptation and newly emerged technologies in the agricultural sector. These adaptation options vary with geographic location, extent and type of climatic impacts, etc. The people of Bangladesh are applying such practices since they are well-known adaptation options for those climate-induced disasters and extreme events. They are trying their level best to build their resilience in combating climate change impacts in the agricultural domain. These efforts need to be more organised and developed, based on improved technologies existing in the world.

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