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Adaptation Strategy with Climate Induced Salinity Disaster in the Coastal Area of Bangladesh

Md. Oliur Rahman[1*], Abul Kalam Mohammed Azad Rahman[2]

[1]Office of The Deputy Commissioner, Gaibandha, Bangladesh
[2]UNDP, Dhaka, Bangladesh
Email: *oliurrahman77@gmail.com

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Abstract

This study examined explanatory responses to saline-water intrusion in the coastal areas of Bangladesh which are renowned for providing ecological and livelihood services. The goal of this study is to look at the different adaption strategies which coastal people have been using to deal with the growing salty water incursion. To this end, the researchers conducted a survey on 100 (one hundred) coastal people (Female 37% & Male 63%) chosen at a random basis from two unions (the lowest tier of local government) namely Perikhali union of Rampal upazila under Bagerhat district and Banishanta union of Dacope upazila under Khulna District at the southwest coast of Bangladesh. Agriculture (30%) and fisheries (27%) were the main livelihoods of the respondents. While looking at their existing problems due to salinity, it is seen that around 65% people are to move 3 - 5 (three to five) kilometres to get water access, low yield from agriculture (47%) and conversion of agricultural land (25%), acute crisis of grazing land (50%), damaged housing of cattle (30%) and fisheries (92%) are being affected due to salinity. Along with the impact, locals also have adaptation like seasonal water storage (31%), desalination (30%) and rainwater harvesting (26%) for water related impact. For agriculture, farmers are rotating crops (32%), cultivating saline tolerant varieties and others have switched from rice cultivation to other crops (30%) and cultivating saline tolerant variety (32%). In livestock, farmers are using better management practices (39%) followed by complete shift of livestock rearing (20%) to other businesses. Shifting from freshwater fish to marine water fish and crab/prawn cultivation (38%) found the most adaptation practices by the communities. For long term resilience to salinity induced disaster, collection of safe water (93%), quality seed (57%), disease control (47%) in livestock and quality hatchlings are the main barriers identified by the communities. For strengthening

the current adaptation practices, rainwater harvesting (41%), household filtering of water (34%), ensuring of quality seeds (67%) and interest free loan to women through local NGOs have been stressed by the communities, local government officials as well as civil societies. Changes in land use patterns, use of contemporary technologies in agriculture, crop diversification, growing saline tolerant crops, income sources diversification, cultivating of saline tolerant fishes, utilization of savings, and rainwater harvesting are all prevalent adaptation strategies in the studied area. Moreover, to effectively address salinity in the coastal area of Bangladesh, the study also recommends increasing budget allocation for saline-water intrusion adaptation in the targeted institutions, staff capacity enhancement in water salinity monitoring, and provision of sophisticated equipment and technology.

Keywords

Adaptation, Climate Change, Salinity

1. Introduction

Changes in long-term trends in the average climate, such as changes in average temperature, are referred to as climate change. The effects of a gradual increase in temperature on ecosystems, growing seasons, animals, and their habitats are significant. The concentrations of greenhouse gases (carbon dioxide, methane, nitrate oxide, and chlorofluorocarbon) in the atmosphere have been changed because of human activity. Fossil fuel combustion now emits around 6.5 billion tonnes of CO_2 into the atmosphere each year. Concentrations of greenhouse gases have grown by 30% since the industrial revolution began in the 18th century. CO_2 levels in the atmosphere are currently 350 parts per million but are expected to rise to 500 - 700 parts per million by 2050 (IPCC, 1996). Sea level is rising by 0.8 $mm \cdot yr^{-1}$ because of rising global temperatures (University of Colorado at Boulder, 2006). If this trend continues, north-eastern China will become a desert, and Bangladesh, India, Malaysia and Indonesia will be drier than ever (UNEP, 1996). The concentration of salt in oceans, seas, and rivers has grown because of rising temperatures, which have a detrimental influence on aquatic species. As a result, the diversity and density of aquatic creatures, such as fish, has declined in many bodies of water. Although numerous rivers run through Bangladesh's south western region, it is a saline-prone terrain. The Gorai, Nabaganga, Bhairab, Chitra, Kapotakka, Shibsha, Pasur, Hariabhanga, Raimongol, Betna, Horihor, Ichhamoti, Kaliganga, Madhumita, Mukteshwari, and Teka are the principal rivers of the Southwestern area. These rivers are tributaries of the Ganges River. During the winter months, rivers in Southwestern Bangladesh do not receive enough water due to the Farakka Barrage on the Ganges. As a result, during high tide and full moon, all rivers get salinized (Rahman & Akhter, 2006). Saline water intrusion affects most waterbodies in the Southwestern country, in-

cluding rivers, baors, beels, and Ghers. As a result, the diversity and productivity of fish species in rivers, baors, beels, and Ghers have been plummeted. Because of the salinity, large carps and catfish are uncommon in these rivers, baors, beels, and Ghers. Furthermore, the region's aquifer is polluted by salt and arsenic. Fish eggs require a favorable temperature and saline-free quality water for fertilization, hatching, and survival. Because of its geographical location and river network, people of the coastal region, agriculture, cattle, poultry, fish, and fisheries in the Southwestern region are highly sensitive to climate change impacts. Too much rain during the monsoon, too little rain during the dry season, floods, unexpected showers, riverbank erosion, drought, water table dropping, aquifer contamination, cold waves, and salt intrusion are all problems in the Southwest. With the foregoing in mind, this research is conducted to evaluate adaptation strategies for dealing with climate-related salinity intrusion disasters (Adger et al., 2005). Globally, there are enormous evidence and scientific consensus on adverse effects of climate change including rise of the sea level, warmth of the earth, variations in the seasons, increase of cyclones, floods and draughts and other climatic events (AR4, 2007). Undoubtedly, climate change related disasters are the global threat to human being. The coastal zone is especially vulnerable to climate change and different extreme events and their impacts on the salinity of soils and fresh water.

We see that adaptation to climate change is the significant one which helps to reduce the loss of lives and livelihoods. Thus, adaptation to climate change has become the core of climate change discussion (Bele et al., 2010). Thus, this study focuses on adaptation actions to climate change induced salinity of coastal communities in Bangladesh. Bangladesh is situated in South Asia with a geographic strategic location between Himalayan Mountain Range and the Bay of Bengal and geologically located at the intersection of the three interacting geo-tectonic plates (Alam et al., 2003). Notably, it is one of the largest, youngest and most active deltas in the world formed by the alluvial deposits of the Ganga-Brahmaputra-Meghna River system (Shafie, 2019). The country is a part of Bengal Basin with low lying riverine country along with a long coastline of 710 km. There are about 230 rivers and their tributaries and most of them pass through the coastline. Thus, the distinct vulnerabilities of the coastline of this country are highly riverine, low lying and marshy land. Due to climate change, most of the coastal areas of the world are at risk from natural disasters and meteorological disturbances. The coastal areas of Bangladesh are even in vulnerable situation of climate change. Climate change impacts are not gender-neutral and many of the consequences of climate-induced impacts are more severe for women and adolescent girls also. Women and girls have importantly lack of access to productive resources as well as decision making power, and this has impacts on their health, food security, and safety. About two third of the total area of the country is coastal land (Kantamaneni et al., 2018). Evidently, the coastal areas of Bangladesh have been facing high frequency of climate induced cyclones,

water logging, sea-level rise, intrusion of salinity etc. These adverse effects of climate change have a chain impact on live and livelihoods of the coastal people. Therefore, it is difficult to adapt the coastal people with the adverse impacts of climate change and these adverse impacts demand enhancing coping capacity for the coastal people. Thus, this study locates its rationale to identify suitable strategies for adaptation with climatic salinity in the coastal areas of Bangladesh.

Bangladesh is one of the most vulnerable countries due to climate change especially, the coastal areas which have been affected by recent devastating cyclones namely SIDR (2007), Aila (2009), Mohasen (2013), Bulbul (2019), Amphan (2020), Yaas (2021). These disasters are happened mainly due to geographical location of the study area. The effects of climate change in the coastal area are enormous like inundation, water logging which are the factors for intrusion of salinity etc. Among the different disasters, frequently happening climate change-induced salinity is of so serious, wide spread and has immediate effect in the coastal areas of Bangladesh. As a result, adaptation with salinity in the coastal areas of Bangladesh has attracted the scientists, policy makers, development partners and NGO representatives of Bangladesh (Abedin et al., 2014). Sea level rise, frequent cyclones, tidal surges, cultivation pattern and unplanned infrastructural development spread out climate change-induced salinity intrusion into water and soil of the coastal area. Several researches have been conducted on the causes and consequences of climate change in Bangladesh. However, research on identifying adaptive strategies towards the climate change induced salinity in the coastal areas of Bangladesh is remained unexplored. Since the government and donors prioritized actions on adaptation to climate change, a number of legal documents and organizations have been established and focused on adaptation strategy. As a result, government agencies like Ministry of Disaster Management and Relief (MoDR), Ministry of Environment, Forest and Climate Change (MoEFCC) are rendering different activities related to adaptation with climate change. Moreover, Bangladesh government formulated Bangladesh Climate Change Strategy and Action Plan (BCCSAP)-2009 to adapt with the adverse effects of climate change. Bangladesh Climate Change Trust Fund (BCCTF) was also founded in 2010 to fight against the adverse effects of climate change. The government has also published National Environment Policy 2018, Disaster Management Act 2012, Disaster Management Policy 2015, National Adaptation program 2005, Standing order on Disaster (SoD) 2019 to enhance the adaptation strategies with climate change and to improve the environmental management. Moreover, the government is also committed to implement the 3 (three) goals (goal no 13 to 15) of SDG (Sustainable Development Goals). Therefore, it is, now, obviously important to study the process of adaptation to the climate change as well as salinity in the coastal areas of Bangladesh.

In past few years, research has given emphasis on adaptation to climate change which is a strong basis for policy making those includes institutional networks, planning, anticipatory adaptation potential to reduce vulnerability and response

towards vulnerabilities and hazards of climate change. Government of Bangladesh has identified the adverse effects of climate change variability and the adaptation strategies related to climate-induced salinity which are: 1) providing drinking water to coastal communities to combat enhanced salinity due to sea-level rise. 2) Promoting adaptation to coastal crop agriculture to combat increased salinity. 3) Promoting adaptation to coastal fisheries through culture of salt tolerant fish special in coastal areas of Bangladesh. 4) Promotion of research on drought, flood and saline tolerant varieties of crops to facilitate adaptation in future (Nda, 2005). Some adaptation strategies with saline water can be possible through establishing shallow shrouded tube wells, pond and filters, household filters, infiltration wells or galleries, rain water harvesting, solar desalination and surface water treatment plants. Adaptation strategies can also be strengthened through implementing community-based management strategy, building community enterprise and ensuring household demand-based strategy. Moreover, adaptation strategies with salinity includes water harvest, seasonal storage, desalinization (drinking), sediment management, controlled aquaculture (shrimp based), salt tolerant rice, construct sluice gates, land use zoning, diverse cropping systems/cultivate crops on embankments (especially agroforestry, mangrove fuel wood), dredging, barrage for freshwater flow, storm surge barrier, increase high embankments, combat erosion, and smart polders to capture or manage sediment (Hossain & Zaman, 2018).

The main purpose of the study is to understand the adaptation strategies with climate induced salinity disaster in a selected coastal area of Bangladesh which might help researchers, policy makers, politicians, planners, development partners and administrators to formulate guidelines for combating impacts of salinity intrusion in the southern parts of Bangladesh. Within this main objective, the specific objectives are: 1) to visit existing problems of salinity and its impact on coastal people; 2) to understand the existing adaptation capacity with salinity of the coastal people in Bangladesh; 3) to know the barriers of existing adaptation strategies for the coastal people; 4) to explain how the existing adaptation strategies can be strengthened through building an inclusive strategic framework. It can be mentioned that there are a good number of studies regarding the adaptation strategies relating to climate-induced salinity in the coastal-Bangladesh. However, this study tries to explore how those organizations and stakeholders could identify the local knowledge, skills, resources and technologies to build up a smart-strategic-framework for the coastal community to adapt with the climate-induced salinity. In line with the research problem statement and the research objectives, some research questions have been identified which are: 1) what are the existing adaptation strategies of the coastal people with salinity in Bangladesh? 2) What are the barriers of existing adaptation strategies for the coastal people? 3) How do the existing adaptation strategies with salinity can be strengthened through building an inclusive strategic framework?

2. Methodology

2.1. Site Selection

Bangladesh is very prone to climate change effects especially intrusion of saline water in the south and south western part. The Southern bank of the river Padma including the greater districts like Kushtia, Jashore and Khulna are the main affected areas of saline water intrusion. Therefore, this part of Bangladesh was selected for this study. Accordingly, the study was conducted in the selected areas of Rampal upazila under Bagerhat district and Dacope upazila of Khulna district. There are 10 (ten) unions in Rampal upazila and 09 (nine) unions in Dacope upazila. Among the 19 (nineteen) unions two unions namely Perikhali of Rampal upazila under Bagerhat district and Banishanta of Dacope upazila under Khulna district were purposively selected which were severely affected by salinity (Figure 1).

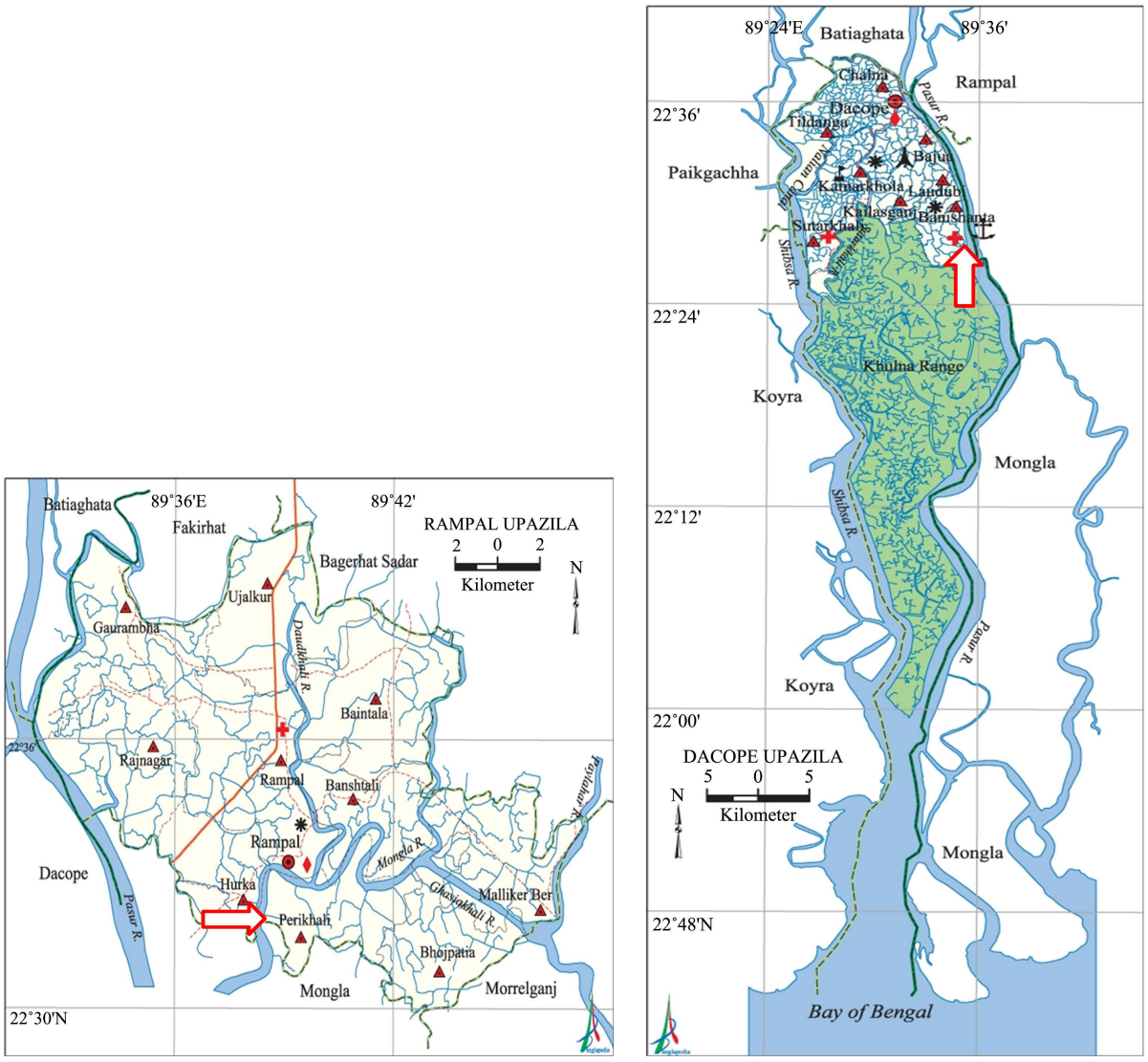

Figure 1. Map of the study area.

2.2. Population

The researchers with the help of Upazila Nirbahi Officer (UNO), Upazila Fishery Officer, Upazila Agriculture Officer, Upazila Livestock Officer, Sub-Assistant Engineer, Public Health, Union Parishad Chairman, members, entrepreneurs of Union Digital Centre (UDC) collected the updated lists of fermers, fishers, gher-businessmen, farm owners, farm laborers of the selected unions (Perikhali of Rampal Upazila & Banishanta of Dacope Upazila) of Bagerhat and Khulna district. The total number of family heads was selected from farmers, fishers, farm-owners, gher-businessmen; village people of the study area and the number were 850 which was considered as population of this research.

2.3. Sample

The sample was then selected from 2 (two) unions by considering proportionate random sampling procedure. A reserve list of 15 family heads (15% of the sample) has been kept purposively if any respondent was unavailable at the time of data collection. The distribution of population and sample has been shown in the following Table 1.

Table 1. Population and sample.

District	Upazila	Union	Village	Number of family head (N)	Sample size (n)	Reserved family head
Bagerhat	Rampal	Perikhali	South Perikhali	260	32	5
			Shikir Danga	240	30	4
Khulna	Dacope	Banishant	Banishanta	200	25	4
			East Dengmari	150	13	2
		Total		**850**	**100**	**15**

2.4. Statistical Technique

After data processing, appropriate statistical technique was adopted. Standard deviation was applied to see the variation of different sectors.

2.5. Adaptation Level and Score

In this research, adaptation level of four sectors (agriculture, fisheries, livestock and safe water) is the dependent variable. The different variables were assigned into different scores (Peal et al., 2020). Thus, adaptation level is categorized into three categories (high adaptation, medium adaptation, low adaptation). The assigned score of adaptation level is given below (Table 2).

Table 2. Adaptation level score.

Level of adaptation	Score
High adaptation	3
Medium adaptation	2
Low adaptation	1

3. Result & Discussion

3.1. Demographic Information

Among all of the respondents, 63% of the respondents were male and 37% respondents were female (Figure 2). In this study, all of these respondents expressed their problems and issues that they were facing different problems created from climate induced salinity disaster while living in the coastal zones of Bangladesh which has implications on their livelihood, lifestyle, agriculture, fisheries, livestock, adaptation to climate and health aspect etc.

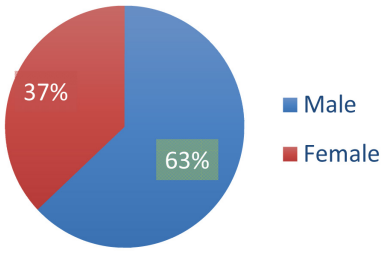

Figure 2. Gender distribution of the respondents.

Among the respondents, 30% of the respondents were from Agriculture, 27% are fishermen and 15% respondents were housewife, 5% were related to livestock, 5% were related with fishing gher, 4% were businessman, 4% were khamari, 1% were from service (Figure 3).

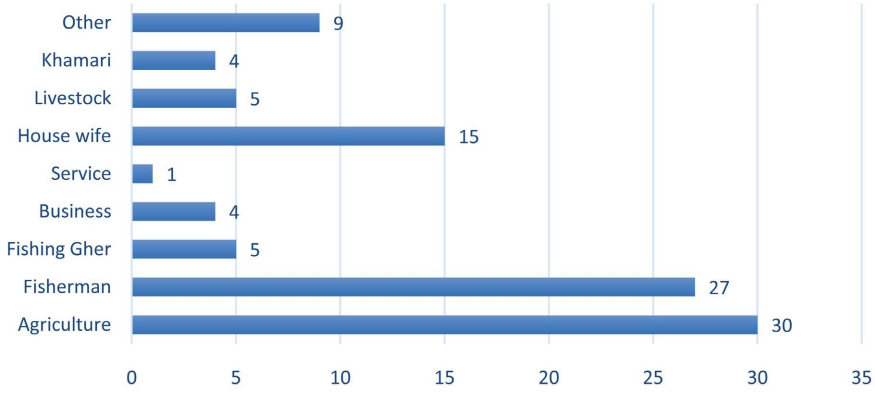

Figure 3. Livelihood distribution of the respondents.

3.2. Examining the Existing Problems of Climate Induced Salinity

The existing problems of climate induced salinity to water, agriculture, livestock and fisheries are shown in Tables 3-7.

Table 3. Distance of drinking water from home.

Distance of drinking water	Number	Percentage (%)	Mean	Standard deviation
One kilometre	2	2	4.58	0.658
Two kilometre	3	3		

Continued

Three kilometre	30	30
Three to Five kilometre	65	65
Total	100	100

Table 4. The Effects of salinity on agriculture.

Category	Number	Percentage	Mean
Agricultural land converted into shrimp culture	25	25	
Rice/vegetable productivity reduced	47	47	
Agriculture is now completely going to be eliminated	19	19	2.12
Land submerged by saline water	9	9	
Total	100	100	

Table 5. The effects of salinity on livestock and poultry.

Category	Number	Percentage	Mean	Standard Deviation
Livestock houses destroyed due to storm surge	30	30		
Grazing land and fodder are not available	50	50	1.97	0.846
Disease infestation increase	13	13		
Others	7	7		
Total	100	100		

Table 6. The effects of salinity on fisheries.

Category	Number	Percentage	Mean	Standard deviation
Yes	92	92		
No	8	8	1.08	0.273
Total	100	100		

Table 7. Existing problems of climate-induced salinity and its impact.

Category	Mean	Standard deviation
Safe drinking water	**4.58**	0.658
Agriculture	2.12	0.891
Livestock	1.97	0.846
Fisheries	1.08	0.273

Scarcity of safe drinking water is crucial in the study area. It is a serious problem for the people of that area. It is found that most of the respondents collect safe drinking water far away from their home. Collectors especially, women of the community, are suffering from collecting safe drinking water for a distance ranging from 3 to 5 km. Time, energy and money are lost due to increased salinity. Scarcity of safe drinking water of the people of study area are impacted negatively on the health as they take low amount of water than health standard as prescribed by WHO. Consequently, local people especially women and children suffer from kidney-related diseases, constipation and skin diseases (Table 3).

It is found from Table 4, 25% agricultural land converted into shrimp culture, 47% rice/vegetable productivity reduced, 19% agriculture is now completely eliminated, and 9% land submerged by saline water. According to the statements of local people of the study area, increased salinity has destroyed the local variety of agriculture, vegetable, paddy and other crops. Characteristics and quality of top soil has been changed due to increased salinity. Accordingly, diversity, density and production of paddy, vegetable and other crops have been decreased considerably. Decreased production of paddy, vegetable and other crops reduced the income of the local people that impacted negatively on their livelihood, health and social status. Income source and amount of local people have become limited due to low production.

From Table 5, it is seen that livestock are affected mostly by salinity. About 30% livestock houses are destroyed due to storm surge, 50% grazing land and fodder are destroyed, and 13% disease infestations are increased due to salinity. The agriculture land, livestock cultivation, aquaculture are negatively affected by saline water (Lam, Winch, Nizame, Broaddus-Shea, & Harun, 2022). Local farm- owners have reported that livestock and poultry production in the southwestern region have been decreased critically due to increased salinity in rivers, beels and ghers. They also said that grazing land and drinking water became limited both for the livestock especially cattle, goat and poultry birds farming. Moreover, death of livestock and poultry birds are a common phenomenon due to different sorts of diseases like kidney failure, skin disease and indigestion. Decreased production of livestock and poultry birds created serious problem to the local people as their income has decreased greatly which impacted negatively on their income, health, nutrition, education, livelihood and social status.

It is found from Table 6 that 92% fisheries are affected due to salinity and only 8% fisheries are exempted from the effect of salinity. Increased climate induced salinity changed the quality and properties of water that impacted negatively on the aquatic Ichthyo diversity of rivers, beels, and ghers of Southwestern area of Bangladesh. Community fishermen and people living in this area said that diversity, density, and production of freshwater fishes have been decreased greatly due to increased salinity. Maturity, reproductive physiology and natural breeding phenomenon of fishes have been changed due to increased level of salinity. Consequently, natural recruitment of fishes has been stopped. Phytop-

lankton, zooplankton, benthos and other food organisms have also been decreased critically that augment the reduction of fish production and diversity. Accordingly, income of fishers, farmers and hatchery operators have been decreased greatly which impacted negatively on their health, nutrition, education, and social status etc.

People of coastal area are facing major problems in collecting safe drinking water due to climate induced salinity. The coastal region is facing salinity problem including shortage of drinking water, and irrigation (The World Bank, 2015, 2017). From **Table 7**, it is shown that among the 4 (four) areas of this study, major problems are involved in safe drinking water and it has a major impact in the study area as the mean is high i.e., 4.58. It is seen that the community people identified so many problems for safe drinking water such as lack of sufficient water reservoir for rain water harvesting, lack of sufficient allocation of money to set-up solar/pond filter, lack of community pond as water reservoir, very few projects about digging on pond, construction of insufficient river osmosis plant etc.

3.3. Existing Adaptation Capacity with Salinity

The existing adaptation capacity with salinity in water, agriculture, livestock and fisheries sectors are shown in **Tables 8-12**.

Table 8. Adaptation capacity with water salinity.

Category	Number	Percentage	Mean	Standard deviation
Rain Water Harvesting	26	26	2.36	1.124
Seasonal storage of water	31	31		
Desalinization of water	30	30		
Construct sluice gates	7	7		
Others	6	6		
Total	100	100		

Table 9. Adaptation capacity with salinity in agriculture sector.

Category	Number	Percentage	Mean	Standard deviation
Crop rotation	32	32	2.65	1.07
Stop rice cultivation	30	30		
Cultivate saline tolerant variety	32	32		
Others	6	6		
Total	100	100		

Table 10. Existing adaptation capacity with salinity in livestock sector.

Category	Number	Percentage	Mean	Standard deviation
Increase dependency of artificial food	20	20	2.53	1.141
Better management practices	39	39		
Better coverage of vaccination	9	9		
Changing of livestock raring to another profession/culture practices	32	32		
Total	100	100		

Table 11. Existing adaptation capacity with salinity in fisheries sector.

Category	Number	Percentage	Mean	Standard deviation
Cultivating new species	17	17	2.45	1.10
Changing culture from fresh water fish to marine water fish	38	38		
Intending towards shrimp/crab cultivation	38	38		
Changing the culture practices like semi intensive to intensive fish cultivation	7	7		
Total	100	100		

Table 12. Existing adaptation capacity of different sectors due to salinity.

Category	Mean	Standard deviation	Overall mean	Adaptation level
Safe drinking water	2.36	1.124	2.50	In between of medium to high-level adaptation
Agriculture	**2.65**	1.07		
Livestock	2.53	1.14		
Fisheries	2.45	1.10		

People of Rampal, Bagerhat and Dacope of Khulna have adapted them with scarcity of safe drinking water. They adapt with safe drinking water by 26% through rain water harvesting, 31% seasonal storage of water, 30% desalinization of water, 7% constructing sluice gates, and other 6% developing pipe line water supply system, installing deep tube-well, pond re-excavation, enhancement of social and physical capital, developing social networking. Collectors have to travel at least 3 to 5 km in collecting safe drinking water. Local people developed indigenous technology for rain water harvest. Like Caribbean countries, our local people have developed special design of houses and constructed concrete tanks to harvest rain water in that particular tank. During rainy season, most people of this region collect rainwater in this way. During FGD, the community people informed the researchers that different aquatic organisms, bugs, annelids and plankton growing stored water during long term preservation of rain water. They informed that different approved disinfectants are applied to overcome such problems.

Rain water and surface run-off are also collected in ponds during rainy season for using domestic and drinking purposes. Generally, pond water is treated with water purifying chemicals and medicines. Ground water is also collected for drinking and domestic purposes. Aquifer of the Southwestern region is severely contaminated by arsenic. Local people generally, collect ground water that contains arsenic and store in an earthen pond for settling of arsenic (Table 8).

Adaptation to agricultural area is great and huge among the community people of the study area. Among the community people, people practise crop diversification is 32%, use salinity-tolerant varieties is 32%, 30% people have stopped rice cultivation and others 6% which digging of canals. Community people store grains to adapt with salinity, savings for the crisis period due to salinity. They use modern technology in agriculture; grow crops which are suitable for climate. They change land use pattern which is included in the adaptation capacity with climate induced salinity disaster in terms of agriculture. Moreover, different varieties of crops with reduction of cultivation period have been developed. Nevertheless, varieties of vegetable having year-round production capacity have been developed for Southwestern region of Bangladesh. Diversified cropping pattern has also been developed (Table 9).

It is shown from Table 10 that majority of the farmers practice better management system (39%) and changing the livestock raring to another profession or culture (32%). In livestock and poultry area, the adaptation capacity of community people is low in compare with agriculture. However, saline tolerant variety of fodder has been developed for cattle and goat farming. Buffalo farming is popularising in the south western region of Bangladesh as it can withstand considerable amount of salinity than cattle. Poultry birds are farming with fresh drinking water.

Table 11 illustrates that the adaptation capacity with climate-induced salinity disaster in fishery sector is low in compare to agriculture sector. According to the owners of farm, and hatchery, freshwater fish has been replaced by the estuarine fish and shrimps. Community people reported that major carps and freshwater catfishes have been replaced by fishes like Tilapia, Pangas, Mugil, Koral/Vetki Nona Tengra, and Phishsha, and shrimp like Bagda, Chaka and Horina. Except Tilapia, Pangas and Bagda, seed of all other fishes and shrimp are natural.

According to analysis of Table 12, it is found that existing adaptation level of agriculture sector is high as the mean is 2.65 and standard deviation is 1.07 among the different areas. It indicates that farmers are coping with agriculture sector at highest level among the four. Moreover, taking the score of adaptation mentioned in Table 2, it is found that among the different sectors, the existing adaptation capacity with salinity in agriculture sector lies in between of medium to high-level adaptation. Here, the mentionable strategies were that Upazila Agriculture Office arranged different motivational meeting, training about cultivation on climate-smart agriculture for the farmers. Moreover, Upazila Agriculture Office and NGOs provided different trainings based on the demand of local community. The Upazila Agriculture Office by the assistance of Ministry of

Agriculture (MoA) provided saline-tolerant variety of seed under impetus program. Different projects such as NATP (National Agricultural Technology Program), GKBSP, SCPPIPM, AMISDP (Agro-Meteorological Information Systems Development Project) are working rigorously to implement the activities. The local people also mentioned that so many mini ponds, canalizing program, necessary number of sluice-gates were available there which were helpful for agricultural irrigation. For the sake of irrigation in agricultural cultivation, farmers also harvest rain water in pond or stagnant canal, jar-irrigation, mini-pond, two-staged mulching methods for irrigation in agriculture.

3.4. Barriers of the Existing Adaptation Strategies

According to Table 13, it is seen that majority of people (93%) are to face for collecting safe drinking water for existing adaptation. People said that environmentally, the study area is very much vulnerable in respect of natural calamities and tidal effects. Aquifer is also contaminated by salinity. Rivers of surrounding areas are not getting sufficient water to push back tidal water containing salinity. Technically, declining process of saline water is costly which needs international aid and support. Affected people of the study area are not economically sound to bear such huge cost to establish such plants for supplying safe drinking water. Communication infrastructures of the study area are poor which prevent them from collecting safe drinking water from a distance point. Local government representative and local alites reported that government support on economic and technical issues are necessary for supplying safe drinking water to the affected people of the southwestern region of Bangladesh.

Table 13. Barriers to collect safe drinking water.

Category	Number	Percentage	Mean	Standard deviation
Yes	93	93		
No	7	7	1.07	0.256
Total	100	100		

According to Table 14, it is seen that getting appropriate variety of seed (57%) for agricultural crops is the main barrier to adapt with the increased salinity problem. Fertilizers, pesticides and chemicals (36%) appropriate for saline zone are also the barriers to withstand increased salinity. Long cultivation period is a barrier for producing safe vegetable.

In this study it is shown that controlling diseases (47%) in livestock and poultry is the main barrier for adaptation strategies. Providing grazing land and producing fodder (44%) for cattle farming are the challenges in livestock sector. The concerned farm owners consider that providing quality and high yielding poultry birds are essential to flourish poultry sector. Availability of safe and approved chemicals and medicines (9%) in poultry sector are the major barriers for adaptation strategies (Table 15).

Table 14. Barriers of existing adaptation with salinity in agriculture.

Category	Number	Percentage	Mean	Standard deviation
Variety of seed	57	57	1.5	0.627
Fertilizer, chemical and pesticides	36	36		
Long-time cultivation	7	7		
Total	**100**	**100**		

Table 15. The barriers of existing adaptation with salinity in Livestock and Poultry sector.

Category	Number	Percentage	Mean	Standard deviation
Disease control	47	47	1.62	0.647
Grazing land producing fodder	44	44		
Safe and approved chemical and medicine	9	9		
Total	100	100		

According to study, availability of quality seeds of fishes and shrimps (52%) for climate-induced saline intrusion areas are the main barriers of adaptation. Controlling mortality of shrimps and ponds (37%) are also the important barrier for adaptation (**Table 16**). Water logging and draining create severe problems for adaptation. Disseminating technical knowledge to affected fishers, farmers, hatchery operators and local people are also a barrier.

Table 16. Barriers of existing adaptation with salinity in the area of fisheries.

Category	Number	Percentage	Mean	Standard deviation
Quality seeds of fishes and shrimps	52	52	1.59	0.683
Controlling mortality of shrimps and ponds	37	37		
Water logging and draining	11	11		
Total	100	100		

It is found from the study, the main barrier is in livestock sector (as the mean is 1.62 and standard deviation 0.647) among the four areas. It was found different types of barrier in the coastal region to adapt existing strategy (Shahriar, Hussain, & Saha, 2019). The mentionable barriers of adaption with salinity for livestock sectors are lack of inspiration among the khamari about cultivating salin-tolerant grass, lack of inspiration of rearing saline-tolerant species of livestock, fresh water preservation of rain water, canals, sufficient water-tanks, deep tube well and nutrient food for the livestock. Moreover, scarcity of fodder due to storm-surge, lack of proper treatment for the saline-affected livestock, lack of consciousness for preservation of grass and fodder for the year-round, lack of

ingredients/materials for making for livestock, lack of appropriate training for the farm owner of livestock, lack of inspiration of the farm owners to cultivate green grass for the livestock, lack of macha (local-term) for livestock before the storm-surge (Table 17).

Table 17. Barriers to the existing adaptation strategies in different sectors.

Category	Mean	Standard deviation
Safe drinking water	1.07	0.256
Agriculture	1.5	0.627
Livestock	**1.62**	0.647
Fisheries	1.59	0.683

3.5. Strengthening of Existing Adaptation through Building Strategic Framework

According to Table 18, majority of people (41%) expressed their opinion on rain water harvesting for adaptation with safe drinking water where 34% focused on household filtering and 20% responded on digging pond and filtering with salinity for drinking water to strengthen strategic framework for adaptation. The community people opined that as safe drinking water is a basic and crucial need for the people of the south western part of Bangladesh. For house hold harvest of rain water, houses of special design should be built with storage facilities. In this regard, linkage and cooperation between Local Government Body and Public Health Engineering Department should be strengthened. They also consider that for the sake of long-term storage of rain water, works should be done on the purification process of water for making which is health-friendly and safe. Moreover, door to door supply of safe drinking water should be ensured. Both flexible and fixed pipelines should be connected to the main storage tank. Pump-houses are needed to be established for supplying of safe drinking water. During KII (Key Information Interview) with Sub Assistant Engineer, Public Health Department, it was known that for supplying safe drinking water, financial supports and logistics support to the local people and the concerned organizations are necessary. Access to loans and credits for the affected people should be easy and smooth. According to the opinion of community people, in all cases, both GOs and NGOs could work together by strengthening strategic framework to provide safe drinking water for the affected people of the southwestern region of Bangladesh. Moreover, exchange of views and ideas and sharing of knowledge should be done among different countries having similar problems like Caribbean countries, South East Asian Countries, Pacific Ocean Islands. In this regard, training and visiting programmes could be arranged for the GOs and NGOs which might strengthen the strategic framework for combating intrusion of salinity in the Southwestern region of Bangladesh.

Table 18. Strengthening of strategic framework for safe drinking water.

Category	Number	Percentage	Mean	Standard deviation
Digging pond and filtering	20	20		
Household filtering	34	34		
Rain water harvesting	41	41	2.31	0.849
Water treatment plant	5	5		
Total	100	100		

In this purpose, Power supply connection should be established. Moreover, road communications have to be improved to make the task easier. Sanitation and drainage system should also be developed. Technical supports for drawing, designing, constructing and maintaining special houses to harvest rain water can strengthen the strategic framework. For harvesting and storage of rainwater, establishing large size of ponds or reservoirs with high dykes at different places can provide safe drinking water to the affected people. In this regard, providing more training for better management of water for the local people can essentially strengthen the strategic frame work.

It is seen from Table 19, Supplying quality seed (67%), chemicals and fertilizers (17%) are the main inputs to strengthen the strategic frame work. Farmers of this area, consider that application of safe and approved pesticides can increase agricultural production. They also said that training with technical support to the affected people can help in strengthening the strategic framework. Maintaining and improving top Soil of the Southwestern region is very important. During KII (Key Information Interview) with Upazila Agriculture officer and officials of concerned NGOs it was known that quality and productivity of top Soil of the affected areas are declining due to intrusion of salinity of both in water and soil. Therefore, these officials consider that training for farmers, concerned staffs and officers of Upazila Agriculture Office and NGOs about management and improvement of top soil are mandatorily needed. According to community people, mass awareness should create among the affected people by exploring the scope of print and electronic media. Farmers think that management and supplying quality seed, chemicals and fertilizers are the main inputs to strengthen the frame work for convenient strategy. Moreover, easy and timely access to those inputs is very important. Therefore, strong supply chain system for such inputs should be developed by utilizing both the GO and NGO networks. Saline tolerant variety of crops, vegetable and fruits can also help to maintain the production level of agriculture sector.

In this regard, community people think that scientists should develop saline tolerant variety of crops, vegetable and fruits. Concurrent and alternative cropping patterns should also be adopted for high saline and lean periods. Similarly, changing patterns of crops, vegetable and fruits can help the affected people to cope with economic loss due to saline intrusion. Southwestern region should be

Table 19. Strengthening of strategic framework for adaptation with salinity in agriculture.

Category	Number	Percentage	Mean	Standard deviation
Training and technical support	16	16	2.01	0.57
Supplying quality seed	67	67		
Chemicals and fertilizers	17	17		
Total	100	100		

mapping on agro-ecological zones with demarcations of hyper, hypo and neutral saline zones. Accordingly, seed variety and cropping pattern should be supplied and adopted for the particular zone. Application of safe and approved pesticides can increase agricultural production. Moreover, effectiveness of pesticides and chemicals varies with the concentrations of salinity both in water and soil. Therefore, research should be conducted to develop soil-friendly, crop-friendly and human-health-friendly pesticides and chemicals to sustain agricultural production in the Southwestern region of Bangladesh. For mass public awareness, all possible media are to be explored. Credit facilities should be easily accessible to the affected farmers and traders. Marketing facilities for produced crops, vegetable and fruits should be developed. In this regard, cold storage facility should be established and transporting network system should be developed. Training of farmers, traders, GO officials and NGOs should be arranged both in home and abroad for gathering updated information and knowledge on the concerned issues.

It is found from the Table 20, 22% people want new variety or artificial insemination, 65% people want to get soft condition loan for the women by NGO. It is found that salinity is squeezing the grazing land both for the livestock and poultry birds. Moreover, drinking water both for the livestock and poultry birds are crucial. Diseases and mortalities are related to the safe drinking water of animals and birds. For managing and controlling diseases, test laboratories with diagnostic facilities should be established. Therefore, strong linkage among concern departments like Department of Livestock, Department of Public Health Engineering and Department of Local Government should be strengthened. Research should be undertaken to develop high-yielding variety or strains of animals and birds which can withstand salinity problems. In this connection, training, visits, knowledge sharing, field tours both in home and abroad should be arranged for the scientists, field workers, planners and entrepreneurs. During KII, Upazila Livestock officer (ULO) mentioned that marketing chains for milk, milk products, eggs, bird and meat should be established for the Southwestern region of Bangladesh. Technical and financial supports for getting quality animals and birds are the main actors for strengthening the strategic frame work. ULO and local farm-owners of livestock consider that high yielding variety of animals such Shahiwal, Australian, Danish and American varieties of cattle, Black Bengal Goat, Chattagram Hilly variety etc., having disease resistance capacity

Table 20. Strengthening strategic framework in livestock and poultry sector.

Category	Number	Percentage	Mean	Standard deviation
New variety/artificial insemination	22	22	2.01	0.810
Provide loan soft condition to women by NGO	65	65		
Government support to one house one farm' to be stressed more	3	3		
Insurance to be introduced	10	10		
Total	100	100		

and birds such as layers, broiler, Chinese ducks etc. should be developed and adopted through research. They also consider that disease control and management capacities may contribute in strengthening the strategic frame work to combat the impacts of salinity intrusion in the region. In this regard, appropriate veterinary hospitals having disease diagnostic facilities should be established in that region. Veterinary medicines and chemicals should be made available to the farmers and entrepreneurs for taking measures against outbreak of diseases. Quality feeds both for animals and poultry birds should be developed for farming of cattle and birds. In this purpose, natural grazing land should be maintained for cattle. Artificial Insemination is one of the main factors which can help in success of cattle farming in this region. In this connection, cold-chain system of semen preservation and application should be developed. Upazila Agriculture Officer and relevant NGO workers consider that providing technical man power and quality semen to the farmers and entrepreneurs are the key factors in strengthening the strategic frame work to combat the impacts of salinity intrusion in the region. Development of incubating and rearing facilities for poultry birds is also essential for strengthening the frame work. Mass awareness should be created through training and demonstration. Low interest credit facilities should be easily accessible to the affected farmers and entrepreneurs.

From Table 21, majority of people expressed their opinion to get the financial assistances from the Government (61%) which are essential to strengthen the strategic frame work for fisheries sector in the coastal area. Local farm owners of fisheries, fishers consider that providing SPF (Specific Pathogen Free), PL (Post Larva) of Bagda shrimp (*Penaeus monodon*) is essential for adapting with increased salinity in water. Research should be strengthened to produce SPF PL of Bagda. For higher production and controlling diseases, depth of shrimp ghers should be increased. Works should be done on maintaining the ecology and environment of ghers. Growth and production of shrimp should be maintained through adopting concurrent and alternative cropping patterns. Fishers of this area focused on estuarine fin-fishes like Koral/Vetki (*Lates calcarifer*), Mugil (*Mugil cephalus*), Bishtara (*Scatophagus argus*), Muni/Tapsay (*Polynemous paradiseus*), Nona Tengra (*Mystus gulio*), Datina (*Pomadasys hasta*) should be cultured in ghers. In addition to estuarine fishes, hyposaline fishes like Pangas

Table 21. Strengthening the existing adaptation strategies in fisheries.

Category	Number	Percentage	Mean	Standard deviation
Insurance to be introduced	21	21	2.13	0.981
Loan without interest	61	61		
Hatchery/Nursery/aquaculture	7	7		
Start new training	6	6		
Providing SPF	5	5		
Total	100	100		

(*Pangasius hypophthalmus*) and Tilapia (*Oreochromis niloticus* GIFT variety) could be cultured in the ghers of Southwestern region of Bangladesh to cope with the loss of fish production due to intrusion of salinity.

Upazila fishery Officer gave his opinion that monitoring system and facilities of water quality parameters should be established to facilitate fish and shrimp culture in ghers. Research should be undertaken to develop induced breeding techniques of estuarine fishes to flourish coastal aquaculture in the study area. Works should be done on preventing, controlling and managing fish and shrimp diseases to combat with intrusion of salinity. More laboratories should be established to diagnose and identify the bacterial, viral and parasitic diseases of fish and shrimp. Research should be undertaken to develop low-cost quality feed for fish and shrimp of that region. Moreover, safe chemicals and medicines for shrimp culture are also essential. Transporting system of PL (Post Larva) should be easy and quick for avoiding mortality. Mapping of agro-aquaculture zones should be established for estuarine fish and shrimps. Training should be arranged both in home and abroad about different aspects of estuarine fish and shrimp culture systems for farmers, entrepreneurs, hatchery operators, GO officers and NGOs. Mass-awareness should be created through training and demonstration by exploring all possible print and electronic media. Zero interest credit facilities should be easily accessible to the affected farmers, hatchery-operators and entrepreneurs.

It is necessary to take proper step in safe drinking water for building adaptation strategies to strengthen strategic framework. Among the four sectors mean of safe drinking water is high 2.31 (**Table 22**). Adaptation plans in the coastal area should be strengthened because it will help to reduce the problems of the region through applied solutions (Rabbani et al., 2018). Based on the respondents' opinion, our authority can develop the different sectors like dig the canals for normal and smooth flow of water, more ponds and their maintenance, construct necessary number of sluice gates, renovation and maintenance in a regular basis, mobilize community people to protect saline water intrusion constructing dam and embankments, ensure the availability of Reverse Osmosis (RO) plant, water desalinization project, improve of agriculture, livestock, and fisheries sector to strengthen the strategic framework for adaptation with salinity.

Table 22. Strengthening adaptation strategies for building strategic framework in four areas.

Category	Mean	Standard deviation
Safe drinking water	**2.31**	0.849
Agriculture	2.01	0.57
Livestock	2.01	0.810
Fisheries	2.13	0.981

4. Conclusion

This study has illustrated the current issue, capability of adaptation, barriers to adaptation, the adaptation strategy of climate-induced salinity and its effects on coastal area. In this regard, it is seen that majority of residents are struggling to find out clean drinking water. The study has also shown that majority of agricultural land have been turned into shrimp production due to the rise of salinity. Thus, the residents of this region have rightly made a variety of adaptation strategies like harvesting of rainwater, desalination of water, storing water seasonally, building of sluice gates, rotating crops, stopping the cultivation of rice, cultivating saline-tolerant varieties, increasing reliance on artificial food, better management practices, better vacation coverage, switching livestock to another profession, breeding new species, and aiming for shrimp cultivation etc. This study has also analyzed the different challenges faced by the people living along the coast. In this regard, they have identified a number of issues which are very much related to environmental, technological, and financial factors.

It can also be mentioned that the study has found out some ways of strengthening the current adaptation strategies through developing strategic frameworks namely increasing of fund for saline water intrusion, fostering collaboration between government and non-governmental organizations regarding saline water intrusion adaptation, introducing salt-tolerant agricultural seeds, cultivating hypo-saline fishes, developing high yielding varieties of animals or birds and providing climate change adaptation training to people. Finally, it can be said that this research would come out with necessary policy recommendation for practitioners, government and development workers. On other hand, this research finding would bring potential academic value in the field of climate change study as well as in the area of disaster management.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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