Modeling alternative mitigation strategies of salinity intrusion on food production by integrating SWOT and TEAM decision models

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Abstract Salinity intrusion is one of the major concerns for the coastal people of Bangladesh. The impacts of salinity intrusion on food production of coastal districts are likely to be severe. Since the extensive shrimp farming cultivation started in the 1970s, it has spread throughout the coastal region, increasing soil and water salinity levels. A mixed-method approach was employed by coupling with SWOT (strength, weakness, opportunities and threats) models for identifying alternative mitigation strategies of salinity intrusion on food production at coastal districts in Bangladesh. A variety of stakeholders and policymakers were first interviewed, being asked to participate in an exercise identifying their perceptions of the greatest challenges facing coastal districts people due to salinity intrusion on food production. The study results reveal that large part of the land of coastal districts intrude with high salinity and a little part is under moderate and low salinity. Therefore, the agricultural land is decreasing and shifting into shrimp farming and settlements. The salinity intrusion affects the soil surface is to decrease food crop production of the study areas about approximately 0.45 metric tons

every year. The integrating SWOT and TEAM models analysis were shown that the indigenous agricultural systems, NGOs activities and community people adaptive potency were the strength whereas sensitive environment and absence of strict law of environmental management and implication gap of policy options were found to be the weaknesses. Foreign aid and research results and shrimp export facilities were found to be the main opportunities. Land scarcity, food security issues and political interventions were found to be the main threats. The SWOT model identified several alternative mitigation strategies for salinity intrusion in coastal districts context have been identified which are funding opportunities, alternative income generation, sustainable shrimp aquaculture, salinity tolerant crop varieties, climate smart agriculture and environmental education and research etc. In the end, it is a case study that might shed some useful schemes combining scientific assessment models such as SWOT and TEAM, which could feed evidence-based decision-making processes for generating alternative mitigation strategies of environmental threats.

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Introduction

Salinity intrusion is an increasing problem in the coastal areas around the world (Ali 2006; Banglapedia 2013; BBS 2011; BCAS 2012; Frihy and El-Sayed 2013). Recent climate change and its associated hazards like sea level rise, cyclone and storm surge have been increasing the salinity problem in many folds (Seal and Baten 2012; Anik and Khan 2012;

Eitzinger et al. 2014). Continued population growth, urban development and climate change are putting increased pressure on coastal water resources (Osuna et al. 1998; Douglas et al. 2012). As governments worldwide struggle to supply their citizens with freshwater, they will be forced to contend with saltwater intrusion along their coastlines (Karim 2008; Soboll et al. 2011). Agriculture, forestry, and fisheries might face severe adverse effects due to increase water and soil salinity (Rahman and Ahsan 2001; Hoa et al. 2014). The extent of increase in soil salinity in a particular area within the coastal zone would determine the extent of crop loss (Karim et al. 1990a, b; Kausher et al. 1993). Bangladesh an integral part of the world's largest Ganges Delta, with very large population and high dependence on crop agriculture is susceptible to a number of environmental stresses (Ahmed et al. 1996; Mirza 1998; Mallick et al. 2011). Over thirty per cent of the net available cultivable land of Bangladesh is located in the coastal areas (Aftabuzzaman 1990).

There are 2.8 million hectares of land including deltaic floodplains and offshore islands affected by salinity and poor quality water in Bangladesh (Haque 2006; Khan et al. 2011). The saline soils are mainly found in Bagerhat, Khulna, Satkhira and some other districts of the coastal and offshore lands in Southern part of the Country (Monir 2010). The coastal zone is extremely vulnerable to a number of rapid and slow onset events that affect rice production and related livelihoods (Kallioras et al. 2006a, b; Yadav et al. 2009). Generally, in this area salinity intrudes by natural processes such as recent past super cyclone-Sidr, Aila and tidal floods and by the artificial process for shrimp farming (Shamsuddoha and Chowdhury 2007). It has been observed that all the coastal cultivable lands are not being utilized for crop production, mostly due to soil salinity (Ahmad et al. 2013). Increased soil salinity limits growth of standing crops and affects overall crop production, and also makes the soil unsuitable for many potential crops (Karim 1990; Moradi et al. 2013). Soil salinity has been considered a major constraint to food production in coastal areas of Bangladesh (Zhen and Routray 2000; Rosenzweig and Tubiello 2007). Agricultural land use in these areas is very poor, which is roughly 50 % of the country's average (Karim et al. 1982). The water salinity in 2010 at Bagerhat district ranged from 0.7 to 24.8 dS m⁻¹, whereby it was highly saline for several months of the year (Smith 2000). Standard quality of water salinity above 2.5 dS m⁻¹ is not suitable for irrigation and food production in Bangladesh (Aftabuzzaman 1990). Shrimp Farms in this region are well known for their black tiger shrimps that grow in salt water. These lands were once cultivated with mainly paddy which are now being used for shrimp cultivation (Boyd and Clay 1998; Bromley et al. 2001). The saline water which is used for shrimp farming is impacting on the food production in the study

area. In a vast area, due to salinity intrusion rice cultivation is gradually being replaced by shrimp farming (Monir 2010). Most of the agricultural lands of the study area are shifting into shrimp farming and settlements (Agrawal 2001; Miah et al. 2004). In Bangladesh, shrimps are mainly cultivated in two coastal regions south-west coastal region comprising the districts of Khulna, Bagerhat, Satkhira and south-east coastal region which includes Chittagong and Cox's Bazar.

Present salinity concentration has already put a threat to the crop production and a significant yield loss has already been observed in the dry season. In the changing scenario of sea level rise, it has been predicted that the increasing concentration of salinity will create more pressure to the farmer by reducing yield on one hand and threatening livelihood, income generation and food security on the other hand. Recently, the government has taken some initiatives for saving agricultural lands. But the initiatives are very limited. Mitigation and adaptation practise are not well identified in this study area so that it would be more effective for prioritizing to cope with alternative mitigation strategies. Considering this concern, the present study attempted to integrate SWOT (S-strengths, W-weaknesses, O-opportunities and T-threats) (Dillan 1988; Yuksel and Dagdeviren 2007; Panigrahi and Mohanty 2012) model for prioritizing the alternatives for mitigation strategies of salinity intrusion on food production of Bagerhat coastal district in Bangladesh (Fig. 1) and TEAM (Tool for Environmental Assessment and Management) (Tsuiji et al. 1995; Smith et al. 1996; Scheraga and Julius 1995) as a Multi-Criteria Decision Analysis (MCDA) tools.

Current conditions of salinity intrusion at coastal districts in Bangladesh

Causes of salinity intrusion in the case study area

The coastal zone is extremely vulnerable to a number of rapid and slow-onset events that affect rice production and related livelihoods (Khan 1998; Kim et al. 2006). Currently, cyclones accompanied by storm surge and increased salinity intrusion into fresh water and soils are the most catastrophic phenomena for coastal communities, especially in Bagerhat, Satkhira and Khulna is the most vulnerable coastal districts in Bangladesh (Ali 2005). The actual nature of salinity intrusion in above mentioned coastal districts in Bangladesh is severe (Sarwar and Khan 2007). The freshly deposited alluviums from upstream in the coastal areas of Bangladesh become saline as it comes in contact with the sea water and continues to be inundated during high tides and ingress of sea water through creeks (Alam 2001). Similarly, at the present case study Bagerhat

Fig. 1 Bagerhat coastal district in Bangladesh, the case study area (Alam 2001; Haque et al. 2010; SRDI 2010)

district is very close to salinity water covered the Bay of Bengal salinity which is very acute in this area (Sarwar and Khan 2007). The factors which contribute significantly to the development of saline soils are, tidal flooding during wet season (June–October), direct inundation by saline or brackish water and upward or lateral movement of saline ground water during dry season (November–May). Observations in the recent past indicated that due to increasing degree of salinity of some areas and expansion of salt affected area as a cause of further intrusion of saline

water, normal crop production becomes more restricted comparing to the previous three decades. Table 1 shows the estimation of salinity affected areas (in '000' ha) by against fiscal years in major coastal districts in Bangladesh. In general, soil salinity is believed to be mainly responsible for low land use as well as cropping intensity in the area. There is high salinity observed at the Rampal, Morelgonj and Sadar thana in Bagerhat district, at Shyamnagar, Assasuni and Kaligonj thana in Satkhira districts and the Dacope, Koyra and Paikgacha thana in Khulna district. In

Table 1 Estimation of salinity affected areas (in '000' ha) in major coastal districts (Bagerhat, Satkhira and Khulna) in Bangladesh

Districts name	Years	Salinity level ^a				Average	Salinity increase over four decades		Remarks
		SL ₁	SL ₂	SL ₃	SL ₄		Area ('000'ha)	%	
Bagerhat	1973	8.30	77.08	3.60	1.20	90.18	48.03	53.26	Rampal, Morelgonj and Bagerhat Sadar Thana
	1983	19.21	46.02	25.30	5.30	95.83	50.12	52.30	
	2003	35.66	42.56	41.23	6.74	86.19	54.54	63.27	
	2009	32.33	42.48	52.96	9.24	94.01	62.01	65.96	
	2013	34.12	43.41	58.23	14.38	97.14	65.23	67.15	
Average salinity increases in agricultural land over four decades (1973–2013)								60.39	
Satkhira	1973	26.50	85.60	34.50	10.90	157.50	4.76	3.02	Shyamnagar, Assasuni and Kaligonj
	1983	28.23	42.56	52.30	12.57	135.66	14.23	10.48	
	2003	29.03	39.01	60.55	22.01	150.60	19.23	12.76	
	2009	31.00	32.96	69.72	28.58	162.26	24.54	15.12	
	2013	34.94	25.34	74.32	32.45	167.05	35.01	20.95	
Average salinity increases in agricultural land over four decades (1973–2013)								20.78	
Khulna	1973	3.90	92.52	13.95	9.80	120.17	21.39	17.79	Dacope, Koyra and Paikgacha
	1983	17.25	43.25	65.23	12.45	138.18	25.12	18.17	
	2003	29.04	38.32	59.49	19.61	146.46	26.78	18.28	
	2009	24.64	26.88	47.78	30.57	129.87	28.12	21.65	
	2013	29.32	24.24	41.25	42.52	137.33	29.85	21.75	
Average salinity increases in agricultural land over four decades (1973–2013)								19.53	

Source: SRDI data base (1973–2013)

^a SL₁ = 2.0–4.0 ds/m (slightly salinity), SL₂ = 4.1–8.0 ds/m (moderate salinity), SL₃ = 8.1–16.0 ds/m (high salinity), SL₄ ≥ 16.0 ds/m (severe salinity)

these area salinity intrudes by both natural and anthropogenic processes such as super cyclone *Sidr*, *Aila* and tidal flood etc. and by the artificial process for extensive shrimp farming.

Current management and mitigation measures

The salinity intrusion problem received very little attention in the past. It has become imperative to explore the possibilities of increasing potential of these (saline) lands for increased production of crops. Thus it is necessary to have an appraisal of the present state of land areas affected by salinity. In 1973, about 53 % of the coastal areas are affected by salinity (Bhuiyan 2001) but recent year 2013 the salinity affected areas in Bagerhat districts 67.15 %. Agriculture is the major sector of Bangladesh's economy and the coastal areas of Bangladesh are very fertile for growing rice and other food crops production (Ahmed et al. 1996). But recently severe salinity intrusion and increase in soil salinity are causing serious negative impacts on food production and above all on agriculture. It is generally considered that salinity will have a negative impact on rice production but favor shrimp production. Figure 3 Salinity intrusion scenarios shrimp farming and decreasing

agricultural land in Bagerhat districts (A1 and A2), salinity intrusion impacts on food crop production (B1), salinity intrusion on mangrove Sundarban Forest in Bagerhat areas (B2); experiment for salinity sensitive food crops by local agricultural scientists (C1) and alternative hydroponics or floating agricultural practice (C2).

Methodology and data

This study was conducted on the coastal district Bagerhat in Bangladesh to prioritize alternative mitigation strategies of salinity intrusion on food production by coupling SWOT model approaches. Specific causes have been identified, which are responsible for the salinity intrusion, reduction of food production and possible alternative mitigation and adaptation strategies in the study area. Primary data are collected by interview, questionnaire and field observation from local administrator, academicians, NGOs individual, buyers, shrimp farming owners, laborers and farmers etc. Secondary data are collected from the different sources such as relevant documents of Agriculture and Fisheries offices of Bagerhat district published and unpublished reports and documents.

Application of SWOT model approach

The SWOT model is first introduced by Albert Humphrey at Stanford University in the 1960–1970s, and is an acronym of its main components: S-strengths, W-weaknesses, O-opportunities and T-threats (Coetzee and Middelmann 1997; Kajanus et al. 2012). It was subsequently applied as a general managerial tool in several scientific fields, including business, economics, law, environmental sciences and engineering, and has been used in many case studies in water resources management and engineering (Ferreira et al. 2007; Diamantopoulou and Voudouris 2008). The SWOT model approach could generate many ideas which could be useful in summarizing key management issues and opportunities. The SWOT model presented in this paper can easily be seen as such, in order to prioritize the most important alternative mitigation strategies to address salinity intrusion at the coastal districts of Bangladesh.

Some of the conditions and characteristics (i.e. NGOs activities and foreign aids) of the study area appear to be the *Strengths (present positives)* of the SWOT analysis for the mitigation and adaptation strategies for the salinity intrusion of food production. Some of the main *Weaknesses (present negatives)* (i.e. funding problems and poverty) regarding the mitigation strategies of salinity intrusion management of coastal areas of the country are the lack of the application of an integrated approach, in terms of alternative mitigation approach (Fig. 2). Supportive external and thematic policies and aid from foreign donor agencies facts may be proposed to be considered as positive features for the *Opportunities (future positives)* after appropriate elaboration. It is observed that Government restrictions and lack of political will and food production crisis and security issues would be the most pessimistic *Threats (future negatives)* scenarios would include a further inland intrusion of seawater. Preparing shortlist and ranking of existing S-strengths, overall W-weakness, possible O-opportunities and future T-threats were identified of salinity intrusion impacts on food production by the SWOT questionnaire analysis. For short analysis, the study has been conducted 75 respondents from each administrative sub-district in Bagerhat district and total numbers of respondent were $(75 + 75 + 75) = 225$ from three selected Thana.

Application of TEAM model approach

Each step in TEAM (Tool for Environmental Assessment and Management) is designed to provide easy management of information and the ability to manipulate presentation of information while investigating tradeoffs. In the first step of TEAM, the geographic region is identified, and the

resources of Bagerhat coastal district are characterized according to its vulnerabilities to salinity intrusion and others factors. The second step is to specify the actions to be considered for addressing the identified vulnerable system involved for salinity intrusion. The types of actions that may be specified range in nature from action oriented (e.g., sluice gate on the embankment), to planning oriented e.g., legal or regulatory changes such as introduction of salt tolerant crops). The system provides a list of suggested actions within each of these categories, and allows for additions or modifications to the list.

The third step, selection of evaluation criteria, is central to this tool. TEAM provides suggested criteria, and allows for additions to be made to the list. The fourth step is evaluating and scoring the selected actions (Tsuji et al. 1995). This step encourages qualitative assessments of mitigation and adaptation strategies options, but allows for quantitative comparisons to be made where that data exist (Smith et al. 1995a, b). Scoring is done based on the questionnaire respondents' opinions appraisal of the effectiveness of some known strategies as expressed through the criteria selected. The scores entered are based on a relative comparison of specified strategies, and the scoring categories of "excellent (5)," "very good (4)," "good (3)," "fair (2)," and "poor (1)" but it could be vary from criterion to criterion. The final step, assessing results, promotes consideration of the consequences of each action under review.

Results

Salinity intrusion and food production in the study area

The clearance of saline coastal swamps for the construction of shrimp farms has changed the salinity regime even further, since the soil is flooded with saline water for 24 h each day instead of only during peak tides. Thus, it was found that the rate of increase of shrimp farming areas was high (22.6 %) during the period from 1983 to 1990 but in the period of 1975 to 1983 was 5.6 % (Karim 2008). Agricultural land use in these areas is very poor, which is much lower than country's average cropping intensity. According to local inhabitants and SWOT questionnaire respondents the major cropping pattern is single crop and multi crops are the minor. The major crops are paddy such as Aman, Aus and Boro etc. At present the most dominant cropping pattern is single crop land and which was double or multi crops three decades ago in the study area. Moreover there is some wheat, potato, sugarcane, garlic, onion chili and robe vegetables are grown in this coastal area.

Fig. 2 The SWOT model analysis and identification of strengths, weaknesses, opportunities and threats for salinity intrusion on food production coastal district in Bangladesh

From the Fig. 4a average Aman rice production area (in hectares) period 2005–2012 in Bagerhat District, it is observed that in the fiscal years 2007–2008 and 2008–2009 the Aus production target area were accordingly 300 and 250 hectares and acquisition area were 575 and 130 hectares. But in the fiscal years 2009–2010 and 2010–2011 the Aus production target area were 450 and 322 hectares and acquisition area were 380 and 141 hectares as there salinity intrude by super cyclone *Sidr* and *Aila* and the crop land

became infertile due to salinity intrusion to decrease the production of Aman rice.

According to Fig. 4b average Aus rice production area (in hectares) from 2005 to 2012 in Bagerhat District is shown that in the fiscal years 2007–2008 and 2008–2009 the Aus production target area were accordingly 300 and 250 hectares and acquisition area were 575 and 130 hectares. But in the fiscal years 2009–2010 and 2010–2011 the Aus production target area were 450 and 322 hectares and

Fig. 3 Salinity intrusion scenarios shrimp farming and decreasing agricultural land in Bagerhat districts (**A1**, **A2**), salinity intrusion impacts on food crop production (**B1**), salinity intrusion on Mangrove

Sundarban Forest in Bagerhat areas (**B2**); experiment for salinity sensitive food crops by local agricultural scientists (**C1**) and alternative hydroponics or floating agricultural practice (**C2**)

acquisition area were 380 and 141 hectares as there salinity intrude by Aila and the crop land became infertile to produce Aman rice. Figure 4c average Boro rice production area (in hectares) from 2005 to 2012 in Bagerhat District is reflected that the Boro production target areas were accordingly 1500 and 3000 hectares and acquisition areas were 3000 and 4800 hectares. But in the fiscal years 2009–2010 and 2010–2011 the Boro production target areas were 4800 and 1480 hectares and acquisition areas were 1470 and 2700 hectares as there salinity intrude by super cyclone *Sidr* and *Aila* and the crop land became

infertile to produce Boro rice. It has been found that constraints increased with increasing intensity of salinity. It affects certain crops at different levels of soil salinity and at critical stages of growth, which reduces yield and in severe cases total yield is lost. A substantial area of land is tidally affected by saline water.

In figure, Fig. 5a–c are shown that the food demand, food production, food surplus and food deficit scenarios of several fiscal years on current case study at Rampal thana, Morelgonj than and Sadar thana in Bagerhat District (2001–2012). According to sources in Agriculture

Fig. 4 **a** Average Aman rice production area (in hectare) from 2005 to 2012 in Bagerhat District. **b** Average Aus rice production area (in hectare) from 2005 to 2012 in Bagerhat District. **c** Average Boro rice production area (in hectare) from 2005 to 2012 in Bagerhat District

Extension Department (AED), 2,20, 853 tons of food grains were produced in the district in 2008–09 fiscal year against the demand for 2,35,88 tones indicating the deficit of 14,235 tons. The sources say natural calamities including cyclone as *Sidr* and *Aila* left an adverse impact on cultivation of crops causing deficit of 61,940 tons of food grains in the 2007–08 fiscal year. The above fiscal years were food surplus as proper management, sowing of seed, fertilizer and harvesting had been completed. On the other hand the fiscal year 2003–2004 was food deficit as the lack of irrigation water due to drought. The fiscal year 2004–2005 was food deficit as the heavy rainfall, fail to use fertilizer. The fiscal year 2007–2008 was food deficit as the salinity intrudes due to super cyclone *Sidr* and *Aila*.

Fig. 5 **a** Food demand, food produced, food surplus and food deficit scenarios of several fiscal years on current case study at Rampal Thana in Bagerhat District (2001–2012). **b** Food demand, food produced, food surplus and food deficit scenarios of several fiscal years on current case study at Morelgonj Thana in Bagerhat District (2001–2012). **c** Food demand, food produced, food surplus and food deficit scenarios of several fiscal years on current case study at Sadar Thana in Bagerhat District (2001–2012)

Implementation of SWOT and TEAM model for salinity mitigations measures

Effectiveness of present management options were analyzed among public, private and community level respondents by coupling with SWOT and TEAM model analysis. Community based management option founds to be the most effective one. In this study, some alternative

mitigation measures were identified for further improvement of the technologies, operational efficiency and management options for the salinity intrusion impacts on coastal districts in Bangladesh. A prepared SWOT analysis was the starting-point of the process. The SWOT factors was determined separately within each SWOT group by use of the participatory method as follows: twenty alternative possible mitigation and adaptation strategies were given to SWOT respondents for scoring the most important SWOT factor inside the examined SWOT group and the importance of other SWOT factors was determined in relation to the most important factor. The respondents of the coastal inhabitants indentified and scored possible 8 (eight) strength, 10 (ten) weakness, 7 (seven) opportunities

and 9 (nine) Threats are the main scopes and challenges for the mitigation and adaption strategies of salinity intrusion impact on the coastal community in Bangladesh (Table 2). The mutual importance of the SWOT groups was determined similarly. After the analysis of the SWOT-factors scores, weight and rank the two by two matrixes were constructed for the analysis of the interactions between internal and external mitigation challenges for salinity intrusion (Fig. 6). For example, in the case of SO mitigation strategies (Influence strengths to maximize opportunities = attacking strategies), the specific strength and opportunity are considered together and attempts are made to generate ideas on how to combine these factors. The process is repeated for each combination of factors in each

Table 2 Shortlist and ranking of existing strengths, overall weakness, possible opportunities and future threats of salinity intrusion on food production in by the SWOT model analysis

SWOT group	SWOT factors selecting by respondents	Scores	Weight	Rank
Strength	NGOs activities and foreign aids	0.65	0.29	s1-NGOs aid
	The indigenous agricultural systems	0.63	0.28	s2-Indegenious
	Natural sedimentation and flooding	0.60	0.27	s3-Flooding
	Community people adaptive potency	0.58	0.26	s4-Potency
	Community strength of unity	0.58	0.25	s5-Community
	Ongoing activities and application	0.52	0.23	s6-Ongoing
	Low and normal life expectancy	0.47	0.21	s7-Expectancy
	Strong religious believe and patient	0.47	0.21	s8-Religious
Weakness	Funding problems and poverty	0.63	0.28	w1-Poverty
	Sensitive coastal environment	0.58	0.26	w2-Enviornment
	Absence of strict law for management	0.58	0.26	w3-Management
	Implication gap of policy options	0.58	0.25	w4-Implication
	Lack of political will and encouragement	0.54	0.24	w5-Political will
	Lack of operations in the organization	0.52	0.23	w6-Organization
	Unfavorable distribution of resources	0.50	0.22	w7-Resource
	Lack of interest and attitudinal problems	0.50	0.22	w8-Attitude
	Lack of access to target groups	0.47	0.21	w9-Target
	Lack of proper education and illiteracy	0.45	0.20	w10-education
Opportunities	Supportive external and thematic policies	0.87	0.39	o1-Policies
	Aid from foreign donor agencies	0.81	0.36	o2- donor
	Good community response	0.65	0.29	o3-Response
	Shrimp export and foreign currency	0.58	0.26	o4-Shrimp
	Fisheries and Sundarban forest utilization	0.54	0.24	o5-aqauculture
	Natural resources and tourisms	0.54	0.24	o6-tourism
	Support from media and advocacy	0.50	0.22	o7-Media
	Restrictions and lack of political will	0.60	0.27	t1-Government
Threats	Land scarcity and biodiversity losses	0.58	0.26	t2-Land
	Food production crisis and security issues	0.54	0.24	t3-Food security
	Mangrove Sundarban forest degradation	0.54	0.24	t4-Mangrove
	Security problems of aid workers	0.52	0.23	t5-Aid workers
	Drinking water crisis and health hazards	0.52	0.23	t6-Drinking water
	Detrimental external policies and actions	0.45	0.20	t7-Action
	Sustainability due to lack of funding	0.42	0.19	t8-Sustainibility
	Anti-NGO approaches by media	0.36	0.16	t9-Anti-NGOs

Fig. 6 Screening and identifying the possible alternative mitigation strategies by SWOT decisions model indices with Strengths-S, Weaknesses-W, Opportunities-O and Threats-T for salinity intrusion on food production in Bagerhat districts in Bangladesh

Salinity intrusion Food production Coastal districts Bangladesh	Strengths-S s1-NGOs aid s2-Indegenious s3-Flooding s4-Potency s5-Community s6-Ongoing s7-Expectancy s8-Religious	Weaknesses-W w1-Poverty w2-Enviornment w3-Management w4-Implication w5-Political will w6-Organization w7-Resource w8-Attitude w9-Target groups w10-education
Opportunities-O o1-Policies o2-foreign donor o3-Response o4-Shrimp export o5-Fishereis o6-tourism o7-Media	SO mitigation strategies Influence strengths to maximize opportunities = attacking strategies Possible strategies by SO matrix: 1.Changing agricultural practices and policies (Alt1)	WO mitigation strategies Counting weaknesses through exploiting opportunities = build strengths for attacking strategies Possible strategies by WO matrix: 2. Switching to a new type of food crops cultivation (Alt2)
Threats-T t1-Government t2-Land t3-Food security t4-Mangrove t5-Aid workers t6-Drinking water t7-Action t8-Sustainibilty t9-Anti-NGOs	ST mitigation strategies Influence strengths to minimize opportunities = defensive strategies Possible strategies by ST matrix: 3. Integrating shrimp farming and agriculture (Alt3) 4. Ensure alternative food security and income generation (Alt4)	WT mitigation strategies: Counting weaknesses and threats = build strength for defensive strategies Possible strategies by WT matrix: 5. Increasing foreign aid and stop shrimp farming immediately (Alt5) 6. No anticipatory policy action (Alt6)

of the four different strategies as examples; WO mitigation strategies, ST mitigation strategies and WT mitigation strategies. According to SWOT matrixes effectiveness and feasibility 6 (six) possible alternative strategies were built up for future mitigation measures for improving the salinity intrusion at the coastal districts in Bangladesh. Six alternatives strategies are below:

Alt1 Changing existing agricultural practices and current policies;

Alt2 Switching to a new type of food crops cultivation and technology;

Alt3 Integrating intensive shrimp farming and aquaculture;

Alt4 Ensure alternative food security and income generation policies;

Alt5 Increasing foreign aid and stop the shrimp farming immediately,

Alt6 No anticipatory policy action measures.

In the same way for comparing and identifying the possible alternative measures TEAM model utilized in this study to compare the relative strengths of adaptation strategies using both quantitative and qualitative criteria (Smith et al. 1996). According to TEAM model approach in evaluating the issue this study were considered five objectives (strength, opportunities, effectiveness, feasibility and cost) and their possible weights, current policy and SWOT identified six alternative measures, scenarios and the probabilities of each scenario. Once these have been determined and entered into the TEAM model table, we can calculated the scoring the measures on a scale of 1–5 indicating how well each measure meets each objective under different scenarios (Table 3). Decision matrix for quantitative evaluating alternative mitigation and adaptation measures by TEAM model for salinity intrusion impact on food production in coastal districts in Bangladesh. The decision matrix then

Table 3 Decision matrix for quantitative evaluating alternative mitigation and adaptation measures by TEAM model for salinity intrusion impact on food production in coastal districts in Bangladesh

Measures	Weights		Objectives					Score	Total score
	Scenario	Probs	Objective #1	Objective #2	Objective #3	Objective #4	Objective #5		
			Streanth 2	Opportunities 2	EffTectivness 1	Feasibility 2	Cost 1		
Current policy	A	0.2	3	4	3	3	3	26	23.2
	B	0.4	2	4	1	2	2	19	
	C	0.4	4	3	3	3	3	26	
Measure #Alt1	A	0.2	3	3	3	3	3	24	26.8
	B	0.4	4	3	4	3	4	28	
	C	0.4	3	3	4	4	3	27	
Measure #Alt2	A	0.2	3	2	1	2	2	17	22.6
	B	0.4	2	4	2	3	3	23	
	C	0.4	3	3	3	4	2	25	
Measure #Alt3	A	0.2	4	5	4	2	3	29	26.6
	B	0.4	4	4	4	4	4	32	
	C	0.4	3	2	2	3	2	20	
Measure #Alt4	A	0.2	2	2	4	3	3	21	25.4
	B	0.4	3	4	2	3	4	26	
	C	0.4	4	3	3	4	2	27	
Measure #Alt5	A	0.2	4	4	2	2	3	25	18.2
	B	0.4	1	2	2	2	3	15	
	C	0.4	1	2	2	3	4	18	
Measure #Alt6	A	0.2	2	2	2	4	2	20	14.8
	B	0.4	1	2	2	2	1	13	
	C	0.4	2	2	3	1	1	14	

automatically calculates weighted scenario scores for each measure. A total score is also calculated. Cost-effectiveness is also automatically calculated by dividing the cost of the measure by the incremental Total Score (Total Score for the adaptation measure minus the Total Score for current policy). The adaptation measures with the lowest cost-effectiveness scores should then be further examined to determine the extent of barriers to implementation.

In the TEAM decision matrix which analyzed the cost-effectiveness of alternative adaptation measures by comparing costs of adaptation measures with benefits of the measures measured in a common metric, but not necessarily dollars etc. Such measurements are added up across the different policy objectives (and weighted based on relative importance) and compared to costs to determine cost-effectiveness (e.g., cost per point on the ordinal scale) and rank measures (Table 4). The relative performances of the selective alternative strategies are represented by the scores using TEAM model approach.

For validating of this matrix value and ranked of the mitigation alternatives it was compared and integrated with

the SWOT model results. All the identified mitigation alternatives were the active community involvement and partnership building that is a significant part of the screening and identifying the suitable mitigation options and some of the impediments to effective mitigation. As we have said, mitigation provides a long-term benefit. Unfortunately, effective mitigation strategies and actions require political vision and will. Especially the developing nation's political system tends to focus on short-term rewards. Stakeholders are large players in the political process and are often concerned that mitigation means additional costs. In this study area many stakeholders are involved with the existing mitigation and adaption process. In most cases, the local and national policy makers of Bangladesh has given the emphasis on the short term mitigation measures that's why the salinity intrusion problems are increasing day by day (Table 5). Identifying alternative mitigation and adaptation strategies are needed to implement for reducing salinity intrusion problems in coastal districts in Bangladesh. The results show that most of the respondents of SWOT and TEAM scheme has give their opinions could be the best alternative mitigation

Table 4 The relative performances of the selective alternative strategies are represented by the scores using TEAM model approach

	Alt1	Alt2	Alt3	Alt4	Alt5	Alt6	Remarks
Strength	Good	fair	Excellent	Good	poor	poor	Positive strength
Opportunities	Good	Poor	Good	Good	Poor	Poor	
Effectiveness	Fair	Fair	Good	Fair	Poor	Poor	
Feasibility	Poor	Poor	Fair	Poor	Poor	Poor	
Short-term cost	Good	Fair	Good	Fair	Good	Excellent	Positive strength
Long-term cost	Fair	Good	Poor	Poor	Fair	Poor	

Table 5 Identifying alternative mitigation and adaptation strategies are needed to implement for reducing salinity intrusion problems in coastal districts in Bangladesh

S.L	Mitigation and adaptation measures	Average score by SWOT	Average score by TEAM	Total scores	Rank	Remarks
Short-term management						
1	Selection of rice varieties	Fair (2)	Good (3)	5	14	
2	Fertilizers to boost up crop production	Fair (2)	Fair (2)	4	12	
3	Storing of excess rainwater	Fair (2)	Fair (2)	4	12	
4	Food import from other areas	Poor (1)	Poor (1)	2	7	
5	Migration to other areas in country	Poor (1)	Poor (1)	2	7	
Alternative mitigations and adaptation measures						
1	Changing agricultural practices (Alt1)	8.99	26.8	35.79	1	Strength
2	Switching to a new type of food crops cultivation (Alt2)	−1.01	22.6	21.59	4	
3	Integrating intensive shrimp farming and agriculture (Alt3)	−0.03	26.6	26.57	2	Strength
4	Ensure alternative food security and income generation (Alt4)	−0.03	25.4	25.37	3	Threats
5	Increasing foreign aid and stop shrimp farming immediately (Alt5)	−9.78	18.2	8.42	5	
6	No anticipatory policy action (Alt6)	−9.78	14.8	5.02	6	
Long-term mitigation and adaptation measures						
1	Introduction of salt tolerant crops	Good (3)	Fair (2)	5	14	Opportunity
2	Protective embankment	Fair (2)	Poor (1)	3	10	
3	Sluice gate on the embankment	Poor (1)	Fair (2)	3	10	
4	Provision of sub-surface drainage	Poor (1)	Poor (1)	2	7	
5	Facilitate uniform drainage	Poor (1)	Poor (1)	2	7	

$$(1) \text{ Alt1 matrix SO of SWOT Scores} = \sum_1^n S + \sum_1^n O = 4.50 + 4.49 = 8.99$$

$$(2) \text{ Alt2 matrix WO of SWOT Scores} = -\sum_1^n W + \sum_1^n O = -5.50 + 4.49 = -1.01$$

$$(3) \text{ Alt3 and Alt4 matrix ST of SWOT Scores} = \sum_1^n S - \sum_1^n T = 4.50 - 4.53 = -0.03$$

$$(5) \text{ Alt5 and Alt6 matrix WT of SWOT Scores} = -\sum_1^n W - \sum_1^n T = -5.35 - 4.43 = -9.78$$

TEAM quantitative analysis scores are taken from Table 3

measure is changing agricultural practices-Alt1 (combined highest score 35.79), integrating intensive shrimp farming and agriculture (Alt3) is the second and thirdly, ensure alternative food security and income generation (Alt4) of

this coastal area could be the alternative mitigation measures for solve the food crisis and security problem due salinity intrusion in agricultural lands. Some short term existing mitigation measures are quite effective but

unfortunately long-term mitigation adaptation measures have been neglected so far of the salinity intrusion impact at the coastal districts in Bangladesh.

Conclusions

From the above analysis, assessments and discussion it can be said that the impact of salinity intrusion on food production is likely severe in the study area. More than 30 % of net cultivable lands are located in the coastal districts in Bangladesh. So these lands are important both from the economical and environmental point of view. But these lands are shifting into shrimp farming constantly. The rate of shifting is increasing day by day. The present study found that majority part of the areas is under high salinity and a little part is under moderate salinity and low salinity. In these area salinity intrudes by natural processes such as cyclone-sidre, Aila and flood etc. and by the artificial process by shrimp farming. The lands in where produced multi crops, at present produce single crop and where produced single crop, at present produce no crop. In the study area people's staple food is rice and the area is not safe of agricultural crops. People have to import food from other areas to fulfill the demand. The laws related with coastal land use and environment is not maintained strictly. As the agricultural lands rapidly shifting, it is necessary to take proper steps to control rapid agricultural lands shifting. The area of agricultural land and shrimp farming must be identified and should be declared as protected areas. The development activities on the coastal lands should be done in a planed way and with proper design. Massive salinity intrusion for shrimping should be controlled for the sufficient food production. Proper land use pattern of the study area should be set up. Proper steps should be taken to preserve the agricultural lands for food production. People should make conscious about the adverse impacts of salinity intrusion on food production. The government and people should take combined efforts to mitigate salinity intrusion, control the agricultural land, and increase the food production. This study recommended that changing existing agricultural practices and current policies or switching to a new type of food crops cultivation and technology could be the long-term effective mitigation measures for tackling this salinity intrusion issues.

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