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CLIMATE CHANGE EFFECTS AND ADAPTATION MEASURES FOR CROP PRODUCTION IN SOUTH WEST COAST OF BANGLADESH

Rajib Jodder[1], Mohammad Asadul Haque[1*], Tapan Kumar[1], M Jahiruddin[2], M. Zulfikar Rahman[3] and Derek Clarke[4]

[1]Department of Soil Science, Patuakhali Science and Technology University, Patuakhali-8602, Bangladesh; [2]Department of Soil Science and [3]Department of Agricultural Extension Education, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh; [4]Department of Civil and Environmental Engineering, University of Southampton, UK

***Corresponding author:** Mohammad Asadul Haque; E-mail: masadulh@yahoo.com

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A survey was conducted to determine the effect of climate change on crop production and water quality in 12 villages of Deluty and Garaikhali unions under Paikgacha upazila of Khulna district, Bangladesh. Total of 100 farmers were interviewed using a pre-tested questionnaire. The climatic hazards as reported on the study area are salinity, cyclone, drought, hailstorm, river erosion and waterlogging, of them salinity is the most dominant hazard. Due to salinity the cropping system has undergone changes. Many crops and varieties have been either extinct or their cultivation has come down. Both soil and water are severely affected by salinity. Most of the farmers (90%) use pond water for irrigation and the majority farmers use pond and rain waters for drinking purpose. Results of the present study serves as a good basis for in-depth study to achieve successful crop production in the south west coastal area of Bangladesh.

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INTRODUCTION

Bangladesh is often cited as one of the most vulnerable countries to climate change in the world (MoA and FAO, 2013). The vulnerability to climate change is high due to a number of hydro-geological and socio-economic factors (Ahmed, 2004, 2006). The country often experiences natural disasters as an effect of climate change, particularly in coastal areas. Crop agriculture is often constrained by different hazards and disasters such as floods, droughts, soil and water salinity, cyclones and storm surges (MoEF, 2009).Salinity is a great constraint to growing crops, especially in rabi season (dry months) when water and soil salinity arises and reaches to the peak in March-April before monsoon starts (Haque et al., 2008, 2014).

The main crop grown in the saline areas is local transplanted *aman* rice which has low yield potential. Haque (2006) reported that most of the coastal areas are located over medium highlands, where flooding depth ranges from 0.3-0.9 meter. This category of land is suitable for the minimum two crops and three crops could be possible if some suitable interventions are done. Kim et al*.,* (2016) described that the decrease in crop yields with the increase in the salinity of irrigation water was caused by disturbances in physiological and biochemical activities under saline conditions.

Salinity causes unfavorable environment and hydrological situation that restrict the normal crop growth. The factors which contribute significantly to the development of saline soil are tidal flooding during wet season (June-October), direct inundation by saline water, and upward or lateral movement of saline ground water during dry season (November-May) (Karim et al*.,*1990).The prevailing salinity intrusion due to climate change has severely affecting the crop productivity in the saline regions of Bangladesh (Haque, et al., 2015). Although people of the south-west region of the country are mostly dependent on crop farming, most of the farmers do not know how to address soil salinity by modern techniques for better crop production. The present study was done to find out the effects of climate change with special focus in salinity on crop production and to identify the adaptation measures used by the farmers to cope with salinity.

MATERIALS AND METHODS

Selection of the study area

Recent rapid industrialization in the developed countries and deforestation increased global warming. Due to global warming sea level is raised and ultimately low laying area of the world is inundated by saline sea water. Due to deltaic geography of Bangladesh, the country is most vulnerable to climate change. Among the thirteen coastal districts, Khulna is most affected by climate change. Under this district Paikgacha upazila is one of the worst affected upazilas by natural disasters such as salinization, cyclone, drought, hailstorm, river erosion and waterlogging. This situation is a big threat to successful crop production. To achieve the objectives a survey work was done at 12 villages of Paikgacha upazila under Khulna district. The villages were Fulbari, Bigordana, Gobipagla, Horinkhola, Hatbari, Senerber, Kalinagar, Telikhali, Noldanga, Darunmallik, Kumkhali and Bainbariya covering two unions - Deluty and Garaikhali.

Population and sampling

Total 100 farmers across the villages were randomly selected. In order to estimate the existing hazards with their severity and adverse effects on crop production, the respondents were asked some common questions.

Data collection and analysis

Before data collection, an interview schedule was prepared keeping in view the objectives of the study. Then it was pre-tested among the population who were not included in the sample. After necessary corrections and modifications, a final questionnaire was prepared and multiplied. Data were collected through face to face interview with the respondents. The data generated from this experiment were entered in Microsoft Excel Worksheet, checked, organized and processed for further analysis. Frequency and percentage for different variables were estimated with help of SPSS 17 computer software.

RESULTS AND DISCUSSION

Socio-economic status of the farmers

The socio-economic status in the present study includes age, education and land ownership of the farmers. It is summarized and presented in Table1. It was found that 14% of the respondents belonged to young aged group (15-30 years), followed by 33% middle aged group (31-45 years), 36% 46-60 years aged group,15% 61-75 years aged group and only 2% old aged group (76-90 Year). About 47% of the farmers received secondary education followed by 30% primary education, 8% higher secondary education, 6% illiterate, 4% can sign only, 3% above higher secondary education and 2% can read and sign only. In case of household size,46% households were small (1-4), 49% medium (5-8), 5% large and 1% was very large.

Table 1 also shows the land holding status of the farmers. Most of them (74%) were marginal farmers(<1 ha), 21% small farmers (1-2 ha) and 5% semi-medium farmers (2-4 ha). None of the farmers belonged to medium and large categories. Table 1 also reveals that 46% farmers earned 5-8 thousand taka per month followed by 22% less than 5 thousand taka, 14% 8-11 thousand taka, 12% more than 14 thousand taka and 6% earned 11-14 taka per month.

Table 1. Socio-economic status of the farmers

Age category (yr)	Frequency	No. of household members	Frequency	Farmer category (land ownership)	Frequency
15-30	14%	1-4	46%	Marginal (<1 ha)	74%
31-45	33%	5-8	49%	Small (1-2 ha)	21%
46-60	36%	8-12	4%	Semi-medium (2-4 ha)	5%
61-75	15%	above	1%	Medium (4-10 ha)	0%
76-90	2%			Large (>10 ha)	0%

Level of education	Frequency	Monthly income (Tk × 10^3)	Frequency
Below primary	30%	<5	22%
Below SSC	47%	5-8	46%
Below HSC	8%	8-11	14%
HSC and above	3%	11-14	6%
Illiterate	6%	>14	12%
Can sign only	4%		
Can read and sign	2%		

Temporal variability of crop cultivation

Cultivation of crops markedly varied with advancement of years. Variation was recorded from past 15 years to the present year (Table 2). The most common crop in the area is T. *aman* rice followed by bitter gourd. *Aus*rice cultivation ceases and *Boro* cultivation is minimum. In case of *Aus* rice, watermelon, sweet potato, jute, dhaincha, melon and cucumber cultivation, a decreasing trend was found. Ten percent of the farmers were engaged in *Aus* rice cultivation in 10-15 years ago but now *Aus* rice is no more cultivated. In this salt affected area transplanted *Aman* rice (July-November) is the dominant crop and farmers mainly cultivate it. But a decreasing trend also found in case of *Aman* rice due to salinity. Rahman *et al.*(2015) reported that risk of cyclone occurrence is high in April - May (pre-monsoon) and October - November (post-monsoon). Local farmers cultivate pulse, T-*aus*, T-*aman* and some minor vegetables during pre and post monsoon and these crops are highly vulnerable to cyclone and storm surges.

Presently the farmers have started to use drought and salinity tolerant crops and varieties as adaptive measures. These crops include bitter gourd, sweat gourd, okra, sesame, ridge gourd and bottle gourd. Cultivation of bitter gourd has remarkably increased.

Table 2. Temporal variability in cultivation of major crops in Paikgachaupazila, Khulna

0-5 years	5-10 years	10-15 years
Aus rice- Nil	Aus rice-2%	Aus rice-10%
Aman rice-90%	Aman rice-100%	Aman rice-100%
Boro rice-4%	Boro rice-8%	Boro rice-1%
Bitter gourd-43%	Bitter gourd-21%	Bitter gourd-2%
Sweat gourd-20%	Sweat gourd-10%	Sweet gourd-17%
Sweet potato-10%	Sweet potato-5%	Sweet potato-15%
Sesame-35%	Sesame -3%	Sesame -15%
Pulse- 28%	Pulse-1%	Pulse-Nil
Water melon-15%	Water melon-6%	Water melon-32%
Okra-14%	Okra-7%	Okra-13%
Ridge gourd-12%	Ridge gourd-2%	Ridge gourd-1%
Bottle gourd-9%	Bottle gourd-3%	Bottle gourd-7%
Amaranth-7%	Amaranth-5%	Amaranth-14%
Potato-13%	Potato-14%	Potato-Nil
Brinjal-8%	Brinjal-8%	Brinjal-Nil
Yard long bean-5%	Yard long bean-5%	Yard long bean-Nil
Banana-2%	Banana-12%	Banana-19%
Jute-2%	Jute-9%	Jute-23%
Dhaincha-Nil	Dhaincha-8%	Dhaincha-11%
Tomato-11%	Tomato-25%	Tomato-Nil
Melon-1%	Melon-1%	Melon-6%
Chili-3%	Chili-8%	Chili-3
Groundnut-2%	Groundnut-Nil	Groundnut-Nil
Wax gourd-1%	Wax gourd-1%	Wax gourd-Nil
Radish-18%	Radish-Nil	Radish-Nil
Snake gourd-2%	Snake gourd-Nil	Snake gourd-Nil
Taro-1%	Taro-Nil	Taro-Nil
Cucumber-Nil	Cucumber-Nil	Cucumber- 5%
Winter vegetables-8%	Winter vegetables-9%	Winter vegetables-11%

Changes in cropping pattern

Due to ingression of salinity, cyclone, drought, continuous rainfall and other climatic factors, cropping pattern in the study area undergoes changes and *rabi* crops are mostly affected. In the recent years, occurrence of late monsoon rain has affected *aus* rice, jute and dhaincha cultivation. In *kharif* II season cultivation of T. *aman* rice is also hampered by climatic hazards which are clear from the information that in last year 90% of the farmers were engaged in T. *aman* rice cultivation whereas in last 0-5 and 5-10 years it was 100%. Rahman *et al*. (2015) reported that that cultivation of *rabi* crops viz. sunflower, chili and wheat decreases. However, development of saline and drought tolerant varieties, coupled with modern soil & crop management technologies have positively impacted on crop production via increasing cropping area as well as cropping intensity. The changes in cropping pattern are shown in the Table 3.

Table 3. Temporal variability in cropping patterns in the study area

Time	Cropping season		
	Rabi	Kharif I	Kharif II
0-5 years	Bitter gourd-28%, Sweet gourd- 11%, Sweet potato- 4%, Melon-1%, Ground nut-1%, Water melon-8%, Teel-33%, Pulse-24%,*Boro*rice-2%, Okra-5%, Bottle gourd-5%, Radish-18%, Potato-25%, Tomato-17%, Brinjal-21%, Winter vegetables-18%	Bottle gourd-3% Bitter gourd-17% Ridge gourd-6%, Jute-3% Yard long bean-2% Snake gourd-2%	T. *Aman* rice- 90%
5-10 years	*Boro* rice-4%, Bitter gourd-35%, Bottle gourd-4%, Sweat gourd-20% Groundnut-2%, Sweet potato-10%, Sesame-35%, Pulse-28%, Water melon-15%, Okra-14%, Amaranth-7%, Radish-18%, Potato-13%, Brinjal-8%, Banana-2%, Melon-1%, Tomato-11%, Wax gourd-1%, Chili-3%, Winter vegetables-8%	Bitter gourd-13% Ridge gourd-12% Bottle gourd-9% Yard long bean-5% Snake gourd-2% Jute-2%	T. *Aman* rice-100%
10-15 years	*Boro* rice-8%, Bitter gourd-13% Sweat gourd-10%, Sweet potato-5%, Teel-3%, Pulse-1%, Water melon-6%, Okra-7%, Amaranth-5%, Potato-14%, Brinjal-8%, Banana-1%, Melon-1%, Tomato-25%, Chili-8% Winter vegetables-9%	*Aus* rice-2% Ridge gourd-2% Bottle gourd-3% Bitter gourd- 8% Yard long bean-5% Jute-9% Dhaincha-8% Wax gourd-1%	T. *Aman* rice-100%

Major climatic hazards

While investigating farmer's perception, different farmer emphasize on different problems that constrain crop production, it is shown in Table 4. It is clear that salinity, cyclone and monsoon storm is the most impacted hazards in crop agriculture. Next to them, drought, continuous rain,hailstorm, river erosion and waterlogging are the common limitations for crop production in the area. As per World Bank report (2001), 14, 32, and 88 cm sea level rise will occur in 2030, 2050 and 2100, respectively which may inundate about 8, 10 and 16% of total land of Bangladesh. Sea level is rising by about 3 mm/year. Cyclone, floods and tidal surges are common disasters in the coastal regions. Table 4 also indicates that the frequency of salinity, drought and continuous rain are increasing with time. About 95% respondents opine that in the previous year their crops were heavily affected by salinity.

Table 4. Perception of respondent (%) on temporal variability of climatic hazards in the study area

Names of major hazards	Year-1	1-5 years	5-10 years	10-15 years
Salinity	95	87	82	85
Cyclone	28	38	48	48
Drought	10	8	7	6
Monsoon storm	18	10	9	10
Continuous rain	8	5	3	3
Hailstorm	4	2	2	5
River erosion	8	12	9	1
Waterlog	3	4	2	3

Adaptation measures to cope with the salinity

Table 5 demonstrates the existing adaptation options against the climate stress in the study area. It appears that salinity, cyclone, monsoon storm, excessive rain, waterlog, river erosion, droughts and hailstorms are the major climate stresses across the regions. Different types of adaption options are found from the study areas against the climate stresses to minimize the loss and damage. Adaptation practices varied depending on the technical and financial capacity of the farmers. Most of the farmers (65%) prefer homestead cultivation, appropriate fertilization (56%) and mulching (28%) as adaptive measures to suppress salinity.

Table 5. Adaptive measures used by the farmers to cope with salinity

Adaptive measures	% of respondent
Cultivation of salt tolerant rice variety	14
Cultivation of salt tolerant crop variety	3
Appropriate fertilization of crops	56
Mulching	28
Homestead cultivation	65
Frequent irrigation	4
Leveling of land	1
Ridge cropping	15

Causes of salinity

There are two main causes of salinity, one is natural causes and another is human induced causes. In case of natural causes, the majority farmers (70%) emphasized on tidal flooding. They also mentioned sea level rise (37%), increasing temperature (23%), increase of saline intrusion (32%), reduced dry season flow in the Shoilmari River (3%) and cyclone (11%) as a natural causes of increasing salinity in their locality. On the other hand, according to farmer's perception extensive shrimp cultivation, construction of Farakka barrage, faulty management of coastal polders and faulty management of sluice gate are human induced causes of increasing salinity (Table 6).

Table 6. Percent respondent perception about causes of increasing salinity in the study area

Natural causes	% of respondent	Human induced causes	% of respondent
Sea level rise	37	Extensive shrimp cultivation	31
Increasing temperature	23	Construction of Farakka barrage	3
Increase of saline intrusion	32	Faulty management of coastal polders	30
Tidal flooding	70	Faulty management of sluice gate	6
Reduced dry season flow in the Shoilmari river	3		
Cyclone	11		
River erosion	8		

Salinity effects on farming enterprises

Crop agriculture is highly affected by salinity and farmers are the direct victims. Farming enterprises affected by salinity is summarized and presented in Figure 1. It was found that 95% of the farmer thought that their crops are affected by salinity followed by homestead by 32%, fisheries by 18% and livestock by 3%.

Sources of sweet water for irrigation

Data analysis shows that in the current study area there are very limited sources of sweet water for irrigation. About 70% farmers view that there is unavailability of sweet water for irrigation, they have accessibility to use only four types of sweet water sources for irrigation namely pond water, tube well, rain water and canal water.

Farmers widely use pond water as irrigation water and the rest of the sources have very limited use. About 90% of the farmers use pond water while tube well by 1%, rain water by 1% and canal water by 2%.

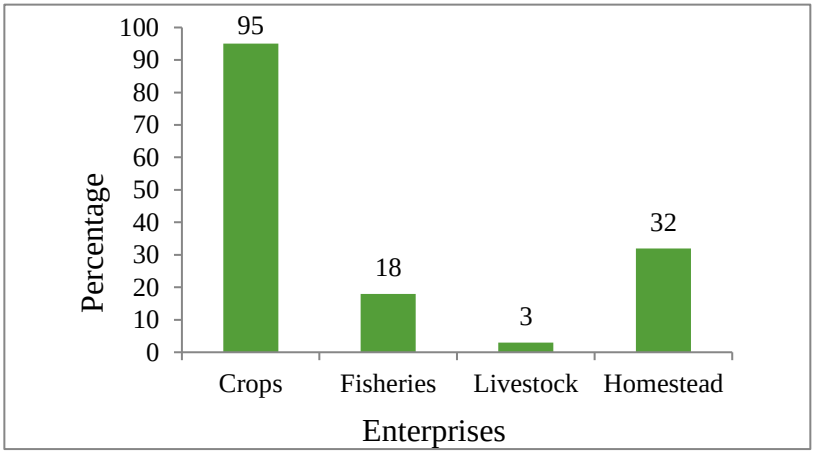

Figure 1. Enterprises affected by salinity

Distance of fresh water source for irrigation

Figure 2 portrays the distance of fresh water source from farmer's crop field which they use for irrigation purpose. Distance of fresh water source is classified into five categories: 0-100 m, 101-200 m, 201-500 m, 501-800 m and 800 m- above. About 24% of the farmers reported that their crop field is within 100 m away from the nearest irrigation water source followed by 201-500 m by 23%, above 800m by 20%, 101-200 m by 15% and 501-800 m by 14%.

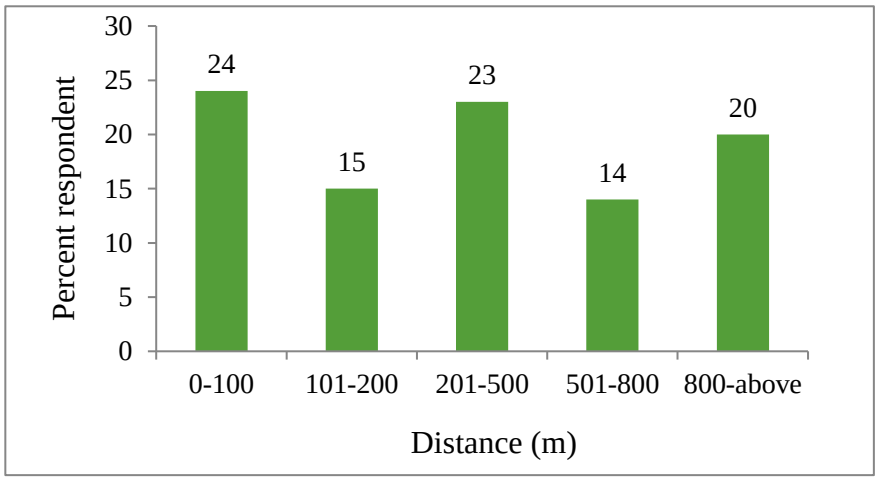

Figure 2. Distance of fresh water source for irrigation from farmer's crop field

Adaptation measures in collecting drinking water

Table 7 is designed to identify the adaptation measures followed in collecting drinking water to cope with salinity both at individual and community levels. Different farmers follow different methods but in few cases they have high similarities. They collect water from far distance, harvest rainwater, dug well, conserve pond water, install tube-well and purchase water as methods of individual effort. Among these methods most of the farmers follow collecting water from far distance and harvesting rainwater. On the other hand in case of community basis effort farmers emphasize on use of pond and filter water (34%) followed by conservation of pond water (29%), digging of pond (11%) and installation of deep tube-well (4%).

Table 7. Adaptation measures followed by farmers to cope with salinity

Individual level	Percentage	Community level	Percentage
Collect water from far distance	64	Conservation of Pond water	29
Rainwater harvest	57	Installation of deep tube-well	4
Dug well	2	Use of pond sand filter	34
Conservation of pond water	26	Digging of pond	11
Installation of tube-well	18		
Purchase water	2		

Organizations involved in salinity mitigation

Figure 3 shows that government, some international and some local organizations have programmes to mitigate salinity in their locality, and however they did not mention any private sector or any other organizations. About 37% of the farmers tell that government organization do this job where 13% by international organization and 16% by local organization.

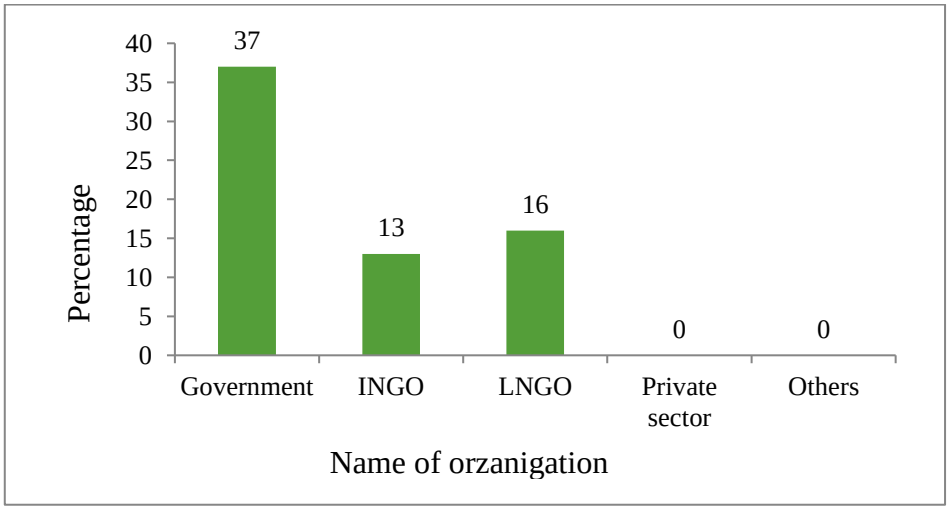

Figure 3. Organizations involved in mitigation of salinity

In study there were seven indicators of adaptive measure to assess the degree of measures that taken by different organization (Table 8) through asking the farmers. It revealed that almost all of the adaptive measures were taken by different organizations. In case of government organization farmers emphasized on Department of Agricultural Extension (DAE), Water Development Board (WDB), Local Government Engineering Department (LGED) and Soil Resource Development Institute (SRDI). In case of international organization they emphasized on Blue Gold and in case of local non-government organization they suggest two organizations- Sofol and Soliderist.

Table 8. Adaptation measures taken by different organizations

Name of the program	Organizations involved in the program
Performing and monitoring soil test- 10%	DAE- 9%, Blue gold- 3%
Establishment of embankment of suitable size and length- 31%	WDB- 31%
Provision of sluice gate on the embankment- 41%	WDB- 33%, LGED- 3%, Soliderist- 7%
Prescription of the amount of fertilizer- 8%	DAE- 8%
Installation of hand driven deep tube-well- 3%	Union porishad-3%
Extension of information about salt tolerant crop varieties- 9%	Blue gold- 7%, DAE- 5%
Arranging training program on salt tolerant crop cultivation- 17%	Blue gold- 13%, DAE- 7%, Sofol- 7%

Preference of cultivating crop varieties against salinity

The most favored crop varieties by farmers in the study area are displayed in Table 9. It shows that in case of rice variety farmers mostly choose modern varieties and among the modern varieties farmers preferred mostly BR10 (51%) and BR23 (50%). Farmers also cultivate some local rice varieties in small scale and most of the farmers (20%) preferred Jotabalam. In case of bitter gourd farmers preferred Meghna-2 variety.

Table 9. Name of the crop varieties used by the farmers to reduce risk of salinity

Name of the crop	Name of the variety				
Rice	BRRI dhan30- 10% Kachra- 12% Jotabalam- 20%	BR23- 50% Ghunshi- 9% Hogla- 2%	BRRI dhan41- 2% Hargoza- 6% Kumrogoir-2%	BR11- 6% Koijur- 1% Chappshail-3%	BR10- 51% Benapol-6%
Bitter gourd	Meghna2- 65%				

Challenges faced to overcome the salinity problem

There are five specific types of problems and based on the attitude toward the problems farmers have been classified into three categories (Table 10). For each of the statements farmers were asked to indicate whether the problem is less or medium or high to them. In case of no governmental as well as organizational support about 40% of the farmer's attitude towards high problem followed by less problem by 30% and medium problem by 28%. However majority of the farmers (39%) attitudes towards less problem, 28% attitudes medium problem and 33% attitudes high problem in case of very poor economic condition. No saline free water source near their crop field is the major problem among the farmers. About 55% of the farmers are agree with this statement, 36% are agree with medium problem and 9% are agree with less problem. Very poor linkage between community and institution is not the major problem in the study area. About 38% of the farmers are agreeing with less problem, 27% by medium problem and 35% by high problem. In case of social/political unrest most of them (44%) are agreeing with high problem.

Table 10. Challenges faced by farmers to overcome the salinity matters

Problems faced	Extent of problem (%)		
	Less	Medium	High
No governmental as well as organizational support	30	28	42
Very poor economic condition	39	28	33
No saline free water source near their crop field	9	36	55
Very poor linkage between community and institution	38	27	35
Social/political unrest	18	38	44

CONCLUSIONS

Agriculture of the coastal area is highly sensitive to climate change. Salinity intrusion was the most significant hazard causing a huge yield reduction. Next to salinity, frequent cyclone has significant influence on crop yield reduction. Due to climate change effect cultivation of some crops such as jute, dhaincha, *aus* rice, sweat potato, water melon is going to be extinct. For risk reduction in crop production farmers avoided aus and boro rice cultivation. They prefer aman season to grow rice. BR10 and BR23 was very popular T aman variety in the study area. In dry season bitter gourd cultivation is gaining popularity. Homestead gardening and appropriate fertilizer management was the promising adaptation technology to cope with salinity.

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