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Using Geospatial Techniques to assess the Salinity Impact on Agricultural Landuse: a study on Shyamnagar Upazila, Satkhira

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Abstract: The research attempts to know the present extent of salinity and how much agricultural land has reduced gradually during last decade in the study area. The collected soil samples were analyzed with different laboratory techniques. Plot to plot survey was conducted by using satellite image and ArcGIS10v was used to detect the agricultural land use change and soil salinity zoning map. Qualitative and quantitative data were collected by applying different methods like Focus Group Discussion (FGD), checklist, in-depth interview and Participatory Rural Appraisal (PRA) and finally these collected data were analyzed and presented. The present study found that salinity exists in every portion of the study area which was classified as moderate to highly saline. The research also found that the agricultural land use in the study area reduced gradually due to salinity. The study area has an area of about 8018 hectare of which 15.1% is agricultural land compared to 24.52% 10 years ago. Overall, the agricultural land is decreasing at the rate of 0.94% per year.

Keywords: Salinity, Agriculture, Land use, Remote Sensing, Bangladesh

Introduction

Salinity has been a typical environmental issue not only for Bangladesh but also for all coastal areas of the world. It is the single most significant problem in southwestern coastal belt of Bangladesh. The southwestern region of Bangladesh is a food deficit area. The net food production and diversity of food production have declined significantly over recent decades. Moreover, the salinity problem received very little attention in the past, nevertheless the increasing demand for growing more food to feed the booming population of the country. In recent past observations, it is noticed that due to increasing degree of salinity and expansion of affected areas normal agricultural land use practices become more restricted (Karim *et al*., 1990). The affected areas of Bangladesh are still increasing rapidly (SRDI, 2010). In the recent past two devastating cyclones and storms induced a change in the level of salinity in south-western regions leading to normal crop production conditions. Thus, crop yields, cropping intensity, production levels since then decreased much more than other part of the country (Rahman and Ahsan, 2001). The total area affected by salinity has increased to about 0.1056 million hectares from 0.833 million hectares in the last four decades. In 2001, the size of the salinity-affected land was nearly 0.1020 million hectares. The worst salinity conditions are reported from the Khulna, Bagerhat, Satkhira and Patuakhali districts (SRDI, 2010). This study has identified suitable land use practices and available adaptation measures or technologies for crops that potentiality allows farmers to adapt to certain level of salinity. The aim of this study is to present the extent of salinity and level of impact in agricultural land use and finally to develop better adaptation strategies in the sector.

Methods and Materials

The study was conducted in two selected small administrative areas called union (Gabura and Munshigonj) of Shyamnagarupazila, Satkhira district (Figure 1) which has six mouzas (revenue villages with a jurisdiction list number and defined area) such as Harinagar, Munshigonj, Gabura, Parshemari, khalishabonia and Dumuriamouza. Gabura union is entirely enclosed by Kholpetua and Kobodakhho rivers and Munshigonjunion is like a peninsula. These two unions are very close to Sundarban reserve mangrove forest (SRDI, 2001).

The methodology started systematically with problem identification and ended by explaining the effects of salinity of land use change. Focus Group Discussions were made from different community group (such as fisherman, agriculture farmer, shrimp farmer, housewives etc.) in each study area to know their adaptation measures under the given circumstances. Information was collected from 169 respondents belonging to 16 FGD's and 50 checklists. The collected qualitative and quantitative information were analyzed by the Grounded Theory Approach (Miles and Huberman, 1994) and other statistical tools and techniques i.e. M.S. Excel. A series of high resolution satellite imagery which was acquisitioned from Google Earth based on 1 km eye altitude was used at ground level to identify the present land use pattern and to know the previous land use pattern. Checklist survey was conducted and respondents' comments were incorporated as an ancillary data to prepare the GIS database. By using ArcGIS 10v

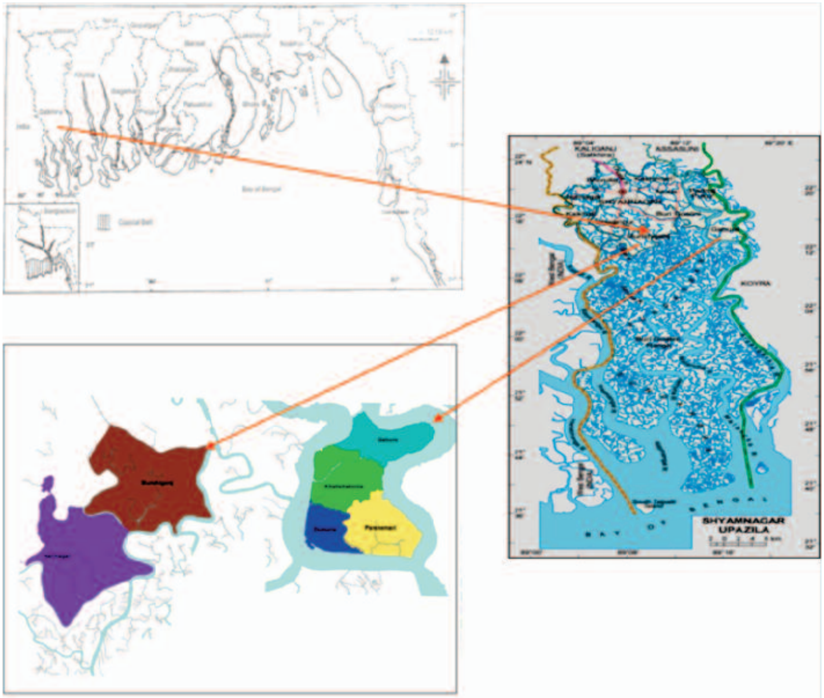

Figure 1 - Location Map of the Study Area

software all digitization works were performed on Google earth high resolution satellite imagery.

Results and Discussions

Level and Zonation of Soil Salinity

By field level investigation with Google earth satellite image digitization was performed and a database was generated by on screen digitizing using ArcGIS 10v software. The area was measured in hectares. The salinity level thematic map was generated based on measured values which were finally distributed on mouza map to know the exact salinity level status of the study area. Saline and highly saline areas covered about 3336.67 hectares and 2941.94 hectares respectively which are 41.46% and 36.69% land of the total study area (Table 1). Category wise saline area delineation was done by using ArcGIS 10v software. Salinity exists in the whole study area but maximum parts fall into moderate to highly saline zone categories. The pH value ranges from 5.94 to 7.44 generally. The higher and lower salinity values were observed

Table 1- Different Salinity Class and affected land area

Salinity class	Area (ha.)	Percent of Land Affected
Slightly Saline (S1)	291.46897	3.64
Moderately Saline (S2)	1448.5589	18.06
Saline (S3)	3336.6741	41.61
Highly Saline (S4)	2941.941	36.69
Total	8018.64297	100

in the Horinagar and Munshigonj mouza which were 22.4 dS/m and 3.99 dS/m respectively (Figure 2). From the comparative study between two unions in Shyamnagar upazila, it is seen that the southern part of Munshigonj union is highly affected by soil salinity. In this union from north to south salinity range has raised. The whole union is surrounded by Churkoni, Dumkhali and Kadamtoli tidal canals which bring saline water regularly during tidal period. Moreover the local people are extracting local techniques to utilize this saline waters utility. As a result they allow saline water into their locality that is prominently responsible for raising soil salinity being leached into the soil. The Gabura union is surrounded by Khalpetua and Kobotakkho rivers by two sides. It is more salinity affected area in comparison to Munshigonj union. All areas of this union are highly affected by soil salinity.

Effects of salinity on land use change (from 2002-2011)

Agricultural knowledge of local people

Two recent devastating cyclonic disaster (Aila in 2009 & Sidr in 2007) and excavated flood control embankment has increased the level of salinity in the study area. The local people do not know how to cope with the changing salinity situation. Since the level of salinity is increasing continuously, measures taken by the local people are not adequate to cope with the problem. In this situation the traditional farmers are not able to produce more crops. The researchers asked the local people, especially about their level of agricultural knowledge to tackle this specific situation. About 58% of the farmers have medium agricultural knowledge while about 26% of respondents have low agricultural knowledge (Figure 3). Only 16% respondents of the study area have enough agricultural knowledge. It is also a burden to agricultural land use practices in the study area with low agricultural knowledge for the changing salinity situation.

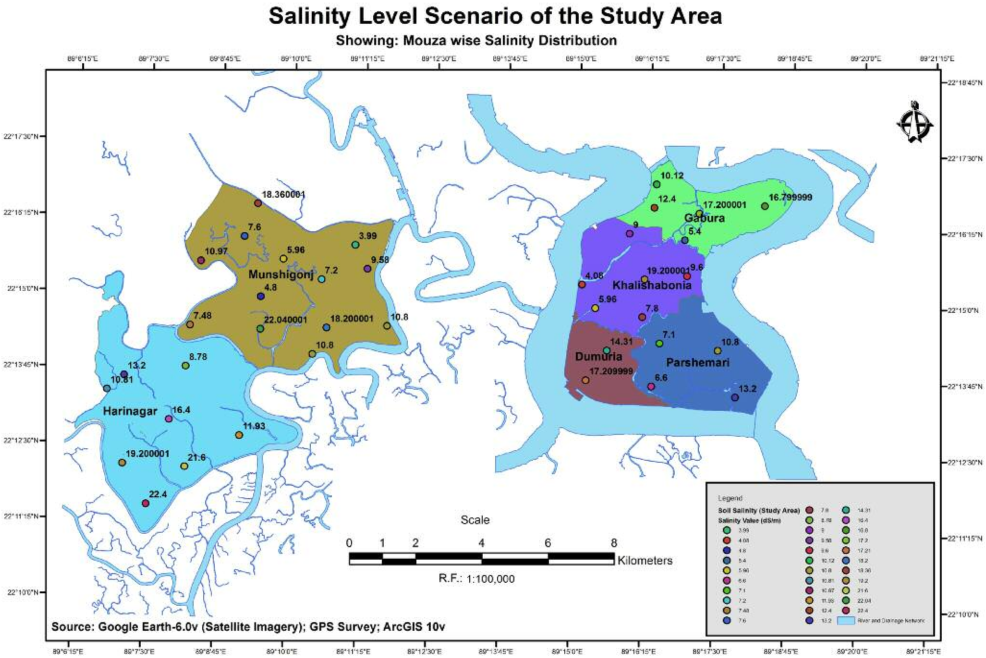

Figure 2 - Present Salinity Scenario in the Study Area

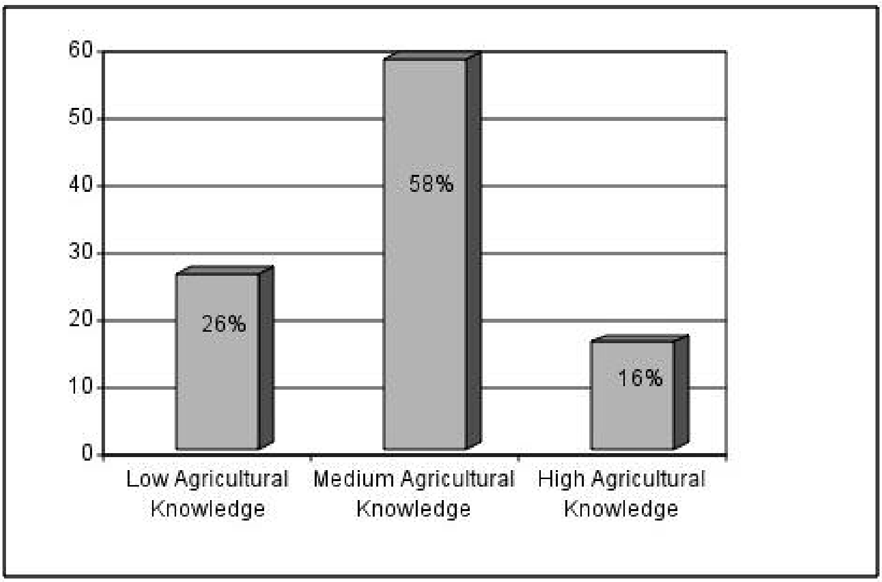

Figure 3 - Level of Agricultural Knowledge of the Local People

Impact of Salinity on Agricultural Land Use Change

The presently practiced rice varieties may not be adapted to grow under increased soil salinity conditions (Habibullah *et al.*, 1999). The food production does not seem to have a better future in the light of climate change (Basar, 2009). 10 years ago there has been intensive agricultural practice in the study area particularly along the northern part of Munshigonj mouza (Figure 4). But at present the major land use practice in the study area is shrimp cultivation. More than 4966 hectares of land in the study area (8018 hectares) is under this type of 'landuse' due to the fact that saline water is increasing there. The Gabura union is almost covered by shrimp cultivation practices and also same in the Harinogor mouza and south-eastern part of Munshigonj mouza (Figure 6). In the study area 81 plots of land are being used in shrimp cultivation purpose at present. Agricultural lands have decreased and at present standing at the position of vanishing. Only a tiny amount of four pieces of agricultural lands was found through this study at Gabura union. Homestead agriculture was widely used in the study area because the level of salinity is low other than house yards. The northern parts of Munshigonj union are mostly being used for agriculture. In the study area forty plots have been found for which are being used for agricultural purpose which vicinity is 1210.46 hectares. The settlement found in the study area belongs to liner type which passes along both sides of the road, embankment and canal. In addition to linear settlement, dispersed settlements were also found here and there in the study area. The settlement area in the study area is 655.53 hectares. Settlements with vegetation coverage were scattered in whole study area because the local vegetation varieties are vanishing as they cannot cope with this situation. Due to changing situation of salinity, settlements with vegetation are transformed to settlements without vegetables (Figure 5). About 33 pieces of plots of land have been found having settlements with vegetables that covers more than 362 hectares. Crab culture is a good substitute for the local people's survival in the salinity changing situation. This type of farming is increasing day by day and it consisting of 122.80 hectares of land in the study area. Some areas are being used for agriculture as well as for shrimp cultivation. As the present study was conducted in the post-monsoon season, from which 269.936 hectares of lands were found as shrimp with agriculture. In the monsoon period, due to heavy rainfall in the study area salinity reduces and at that time people try to use the lands of shrimp cultivation for agricultural purposes. About 269.94 hectares of land was found in that category. In the study area Kholpetua and Kobotakkho are the only rivers and some small and big canals are passing through the study area.

The present studies state that, shrimp cultivation is expanding widely in the study area. The land area for shrimp cultivation purpose has been increased gradually in the last decade. In 1994, the government, favoured shrimp cultivation and declared

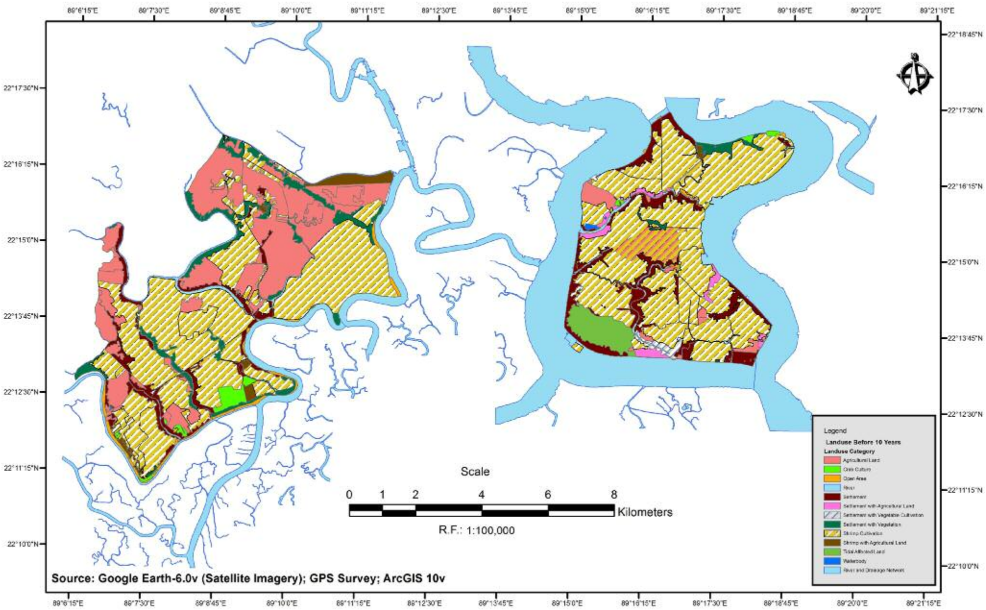

Figure 4 - Land Use pattern of the Study Area before 10 Years (2002)

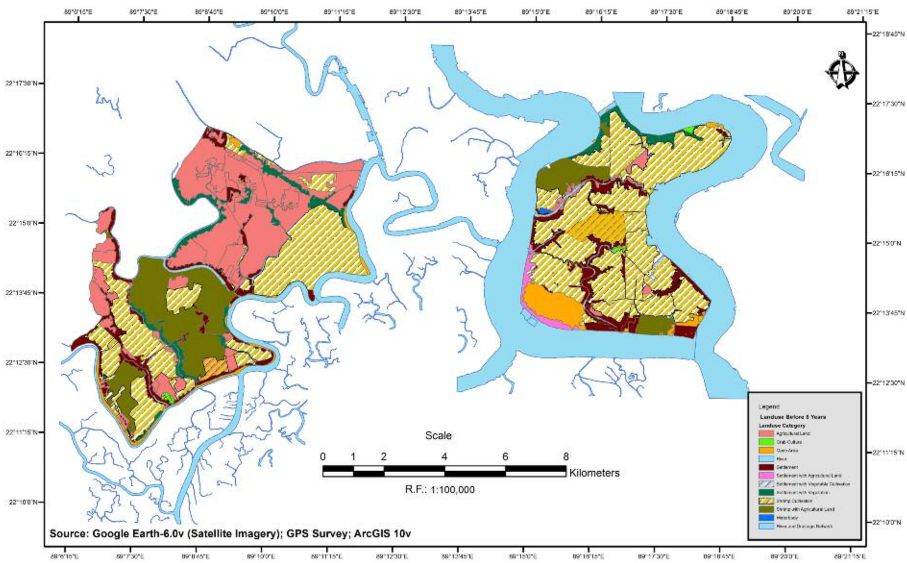

Figure 5 - Land Use Pattern of the Study Area before 5 Years (2007)

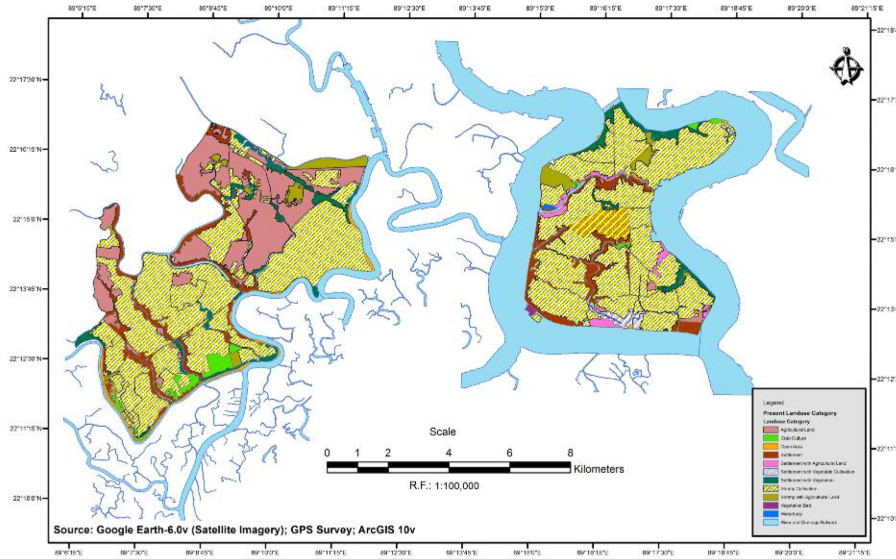

Figure 6 - Land Use Pattern of the Study Area at Present (2011)

the coastal area as "free zone" for shrimp cultivation through a public notification (Rahman *et al.*, 2006). Quickly the powerful villagers in the study area established numerous illegal pipes and gates to enter saline water to cultivate shrimp in the agricultural land.

Before 10 years, shrimp cultivation was limited within 39.31% of the total 9023.66 hectares of land. Shrimp is said to be the golden price for the country and it has a great importance in the international market. So its cultivation has expanded radically. For this reason shrimp cultivation has increased drastically from 56.6% to 61.94% before five years to present. More than 61.94% of land in the whole study area (8018 hectares) is under shrimp cultivation which was 39.31% before 10 years. The shrimp cultivation is increasing rapidly at the rate of 2.26% per year (Table 2). Crab farming has increased as saline water has been increasing in the study area. About 0.2% of land using for crab farming has changed to 1.53% during last ten years to the present. The crab is being changed at the rate of 0.133% annually. In addition to this the local people have been using their indigenous knowledge to produce vegetables in their yards.

Traditional agricultural land has been affected drastically in the study area due to increasing salinity. In this changing salinity situation most local rice varieties have been thwarted. Due to agricultural knowledge gap of the local farmers, agricultural land use is decreasing in this changing situation. In addition, lack of proper irrigation facilities and poor drainage condition the agricultural practice has fallen in a threat.

Table 2 - Land use changes in last decade

Present Land use (A) in 2011			Land use before 5 years (B) in 2007		% of change (B-A)	Land use before 10 years (C) in 2002		% of change (C-A)
Purpose	Area (ha)	% of land	Area (ha)	% of land	% of changed	Area (ha)	% of land	% of changed
Agricultural land	1210.457	15.100	1645.288	20.4	-5.3	2212.304	24.52	-9.42
Crab culture	122.804	1.530	93.553	1.14	+0.29	18.178	0.2	+1.33
Open area	253.242	3.160	197.744	2.41	+0.75	467.975	5.2	-2.04
River	13.837	0.170	7.537	0.09	+0.08	13.837	0.15	+0.02
Settlement	655.537	8.180	771.228	9.25	-1.07	1007.579	11.17	-2.99
Settlement with agriculture	84.196	1.050	84.196	1.07	-0.02	65.333	0.72	+0.33
Settlement with vegetation	362.490	4.520	374.866	4.48	+0.04	637.284	7.06	-2.54
Settlement with vegetables	63.704	0.790	35.399	0.43	+0.36	17.229	0.19	+0.55
Shrimp cultivation	4966.941	61.94	4663.112	56.6	+5.34	3547.573	39.31	+22.63
Shrimp with agriculture	269.936	3.370	155.177	1.89	+1.48	1029.009	11.40	-8.03
Water body	7.980	0.100	-	-	-	7.5175	0.08	+0.02
Tidal affected land	-	-	176.743	2.15	-	-	-	-
Vegetation bed	7.537	0.090	7.980	0.097	-0.007	-	-	-
Total	8018.666	100	8204.829	100		9023.83	100	

The study area embraces a vicinity of 8018.66 hectares from which 15.1% is covered by agricultural land which was 24.52% before 10 years (Table 2). Agricultural land use has reduced to 9.42% during last one decade, which is decreasing at an annual rate of 0.942%. Due to salinity increase and failure to cope with this situation the local people are shifting to the nearby suitable places. So, settlements and the related vegetation coverage in the study area are decreasing as well. It has reduced from 11.17% to 8.18% during last 10 years. Moreover, shrimp with agricultural land use practice is increasing gradually at the place of agricultural practice. During monsoon period rain water is conserved in the field of shrimp cultivation land. Then after decreasing salinity level in those reservoirs agriculture practice introduces. Shrimp with agricultural practice in the study area is 3.37% at present but before five years it was only 1.89%.

Coping Strategies of Local People

The coping mechanisms, the farmers adopt, have been developed by their family and community wisdoms, which is considered as indigenous knowledge. Depending on the types of impacts, various adaptation techniques are identified at the community level that would reduce the vulnerability, enhance resilience capacity and enforce changes to protect from exposure to adverse impacts (Ahmed, 2000). Although several treatments and management practices can reduce salt levels in the soil, there are some situations where it is either impossible or too costly to attain desirably low soil salinity levels. In some cases, the only viable management option is to plant salt-tolerant crops. It is a fact that the study area is in the lower coastal part of deltaic floodplains which is considered one of the primary reason of its vulnerability to salinity in agriculture. There are a number of strategies and practices which have evolved over time to deal with the adverse effects of salinity. A wide variety of adaptive actions may be taken to cope with or overcome adverse effects of salinity on agriculture. At the level of agricultural farms, adjustments may include the introduction of new crop varieties or species, switching cropping sequences, sowing earlier, adjusting timing of field operations, various fertilizer and pesticide use, conserving soil moisture through appropriate tillage methods, and improving irrigation efficiency are suggested. Some options such as switching crop varieties may be inexpensive while others, such as introducing irrigation (especially high-efficiency, water conserving technologies) involve major investments (Chhabra, 1996).

Due to high salinity levels, it is difficult to cultivate any high yield variety (HYV), such as HYV aman and HYV aus (Karim *et al.*, 1990). As a result, people continue to cultivate the local varieties because they perceive them to be not only saline tolerant, but they also have greater plant height, comparatively low planting costs, tasty and above all easily manageable. The local rice varieties are categorized according to their different land types, such as for the shrimp farms and for other agricultural land. *Jotabalam* and *Ghunshi* varieties are selected for cultivation in the shrimp farms. *Ashfall* and *Benapol* varieties have the same qualities as the two above but they are destined for other agricultural farms. *Jotabalam* has the highest yield among them. The advantage of these varieties is that they require no irrigation and ploughing, because the shrimp farm ensures water for a long period and the soil becomes comparatively loose and muddy. During paddy production, different pesticides such as Ripcord, Nitor, and Furadan are also used. During *boro* cultivation, field is watered for two times by using shallow pump and weeding is done after 30 days and 60 days of transplantation. *Aman* is harvested in December and boro in April. Due to temperature, rainfall and humidity changes in the study area HYV rice varieties (BR-10, BR-11, BR-28 and BR-30) are introduced over time. Some low yield varieties (*Patanibalam, Horkoch, Dhulsharetc*) were cultivated in the study area. Due to the introduction of HYV rice varieties (BR-10, BR-11, BR-28 and BR-30) the indigenous rice varieties in the study area being extinct. Despite of low yield; some indigenous varieties are still cultivated in the study area due to its taste and choice of the people. Rice is grown extensively in the wet season in saline soils because of dilution of salinity with the monsoon rains and leaching of excess salts from the root zone (Habibullah *et al.*, 1999). Though rice is the single most important crop in the saline zones, modern varieties of rice so far released from BRRI could not be adopted in tidal and saline zones due to their shorter seedling height (30 cm) and non-tolerance to tidal submergence and salinity. Salinity and water stress has created serious threats to agriculture production (Chhabra, 1996) in the study area. The communities have adapted special mechanisms and raised their homestead to some extent and manage soil in a different way, such as mulching for vegetable growing and selecting salt tolerant varieties. They utilize rainy seasons for vegetable cultivation and grow some selected species i.e., creeper (*Puishak, Jhinge, guard, bitter guard* etc), ladies fingers, chilies, cauliflowers, cabbages, radishes, etc from July to March. They grow salt tolerant tree species locally called rain trees, *babla, khoibabla, tentul, coconut, koroi, khejur, paroshpipul* and a few mangrove species with fruit species like *sofeda* and *peyara*. To cope with salinity the farmers of the study area have established small fish farms. During monsoon when they cannot grow rice, they can cultivate fresh water fish and prawn though there remains scope to grow vegetables, spices and annual plants on the dykes. This technique will help to ensure the farmer's income and food security in response changing salinity situation. It is necessary to mention here that previously the farmers of this area were dependent on single crop cultivation. It was found in the study area that now-a-days a number of women are engaged with crab farming that were involved with agriculture or were housewives earlier. It indicates that the poor women are compelled to change their occupation from agriculture to crab culture due to increase of water salinity.

Conclusion

Agriculture is a major sector of Bangladesh's economy and over thirty percent of the net cultivable land is in the coastal area. Out of 2.85 million hectares of the coastal and off-shore lands about 1.05 million hectares of arable lands are affected by varying degrees of salinity (Asib, 2011). The Government of Bangladesh must lay down strict policy guidelines for shrimp cultivation in the country and those guidelines must be strictly enforced. Help and facilitate the landless, small and marginal farmers through group based approaches, especially hard core poor and vulnerable groups through agricultural input support and micro capital grant in farming practices and non-farm income generating activities. Strengthen interdisciplinary efforts involving governmental and non-governmental agencies to agriculture land use zoning. Identify and introduce salinity tolerant crop and vegetable varieties for the local people. To arrange technical support for countries in the region in order to establish a modern GIS-based land record system. To set up a commission for studying "planning and practices of land zoning in the coastal Bangladesh" and land zoning should be identified as an important instrument for sustainable land management for decades; its implementation still remains a concern. To ensure a continuous monitoring system to understand land use changes and identifies the areas under land use change due to salinity. Salinity is a vital hazard which cannot be ignored for our environmental as well as economic prosperity of our country. For better management practice focus should be given on remission of the salinity in the southwestern coastal area of Bangladesh.

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