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IMPACTS OF SALINITY ON SOIL PROPERTIES OF COASTAL AREAS IN BANGLADESH

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ABSTRACT

Sea level rise is a growing threat for the coastal regions of Bangladesh. It is one of the most densely populated countries of the world where 28% of the population are living in the coastal area. Bangladesh has already been affected by sea level rise through land erosion, salinity intrusion and loss in biodiversity. Saline soil has a detrimental effect upon soil physical and chemical properties. The dominant soil textural classes that occur in the saline areas of these regions are silty clay. In both of the soils pH value of the surface horizon is slightly lower than those of the subsoil and sub stratums. Cation Exchange Capacity (CEC) of all these soils varies from 12.0 to 27.6 meq/100 g soil expressing medium to high status. The organic matter content is medium to high at Asasuni and pretty low at Kalapara. In both areas, nutrient deficiencies of total nitrogen, phosphorous and potassium were quite dominant but sulphur was high. Exchangeable sodium, potassium, calcium and magnesium were in high level. The dominant water soluble cations were Na^+, Ca^{2+}, Mg^{2+} and K^+ and anions Cl^- and SO_4^{2-}.The amount of accumulated salt was found higher at the surface and decreases with depth.

Keywords: sea level rise, coastal areas, salinity, soils, flood plain

INTRODUCTION

Climate change is an important issue nowadays. Various human activities turn the warm world to warmer. The ultimate result is global warming, i.e. climate change. Rising temperature in the atmosphere raises sea level and affects low lying coastal areas and deltas of the world. Bangladesh is highly vulnerable to sea level rise (Brammer *et al*., 1993). The whole coast runs parallel to the Bay of Bengal, forming 710 km long coastline (CZPo, 2005) (Figure 1). The area lies at 0.9 to 2.1 meters above mean sea level (Iftekhar and Islam, 2004). The country has three distinct coastal regions, namely the western, central and eastern regions. Out of 2.85 million hectares of coastal and off shore, (30% of net cultivable area) about 0.831 million hectare of arable land were affected by varying degrees of soil salinity (Karim *et al.,* 1990). Soil resource development Institute (2000) showed that soil saline area in the country has increased to 1.02 million ha. Agricultural land used in these areas is very poor, which is roughly 50% of the country's average (Petersen and Shireen, 2001). In general, soil salinity is believed to be mainly responsible for low land use as well as cropping intensity in the area (Rahman and Ahsan, 2001).

Soil with an electrical conductivity of saturation extracts above 4 dSm^{-1} is called saline soil. The proportions of cations and anions in the natural soil water solution are a function of soil type, climate and land use. The concentration and relative proportions of these salts play a critical role in the 'salinity hazard` of soil. The attractive forces which bind clay particles together are disrupted when too many sodium ions get between the clay particles. When such separation occurs, repulsive forces begin to dominate, and the soil disperses (Hanson *et al*., 1999; Buckman and Brady, 1967; Falstad, 2000; Saskatchewan Water Corporation,1987). Salinity can have a flocculating effect on soils, causing fine particles to bind together into aggregates. When high concentrations of sodium affect a soil, the subsequent loss of structure reduces the hydraulic conductivity, or rate at which water moves through a soil (Shainberg and Letey, 1984; Hanson *et al.,* 1999).

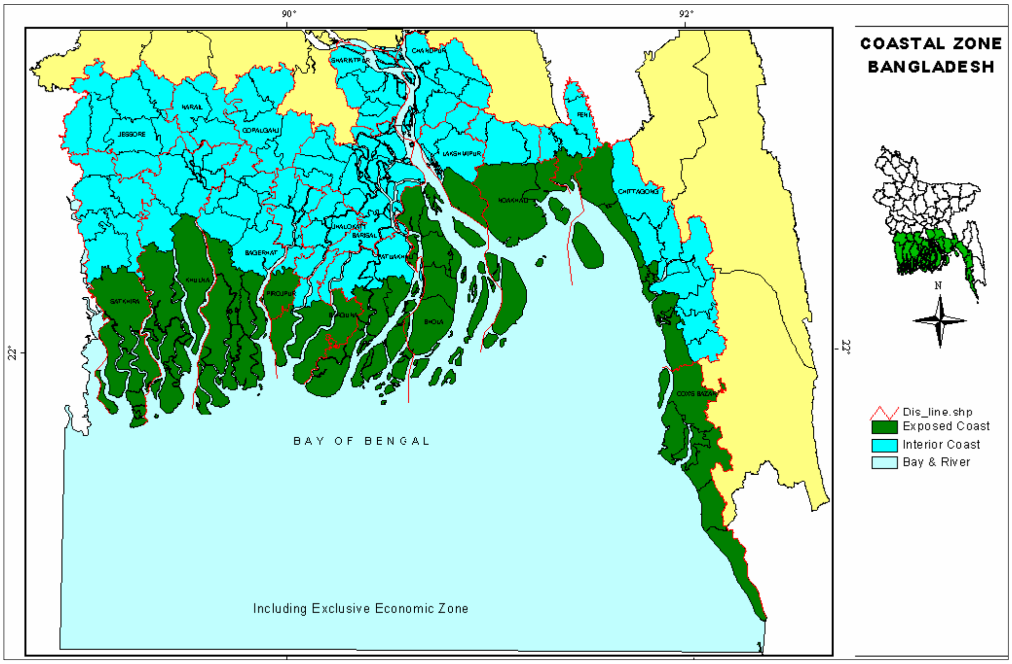

Figure 1. Coastal zone of Bangladesh (Source: Iftekhar and Islam, 2004)

Salinity became a serious problem for agriculture all over the world. (Charman and Murphy, 2000). On a global scale, nearly 40% of the earth`s land surface is potentially endangered by salinity problems. Salinity problem received very little attention in the past, but due to increased demand for growing more food to feed the booming population of the country, it has become imperative to explore the potentials of these lands. So the present study was conducted to know the salinity level at different saline areas and study the effect of salinity on soil physical and chemical properties.

MATERIALS AND METHODS

Environmental Characteristics of The Study Areas

There is a broad range of agro ecological environments in Bangladesh because of differences in climate, physiography, soil and hydrology. A field survey was carried out in the area at Asasuni upazila at Satkhira district located at 22.5500^{0}N 89.1681^{0}E and kalapara at Patuakhali district located at 21.9861^{0}N 90.2422^{0}E (Figure 2). Topographically these areas are low lying and have elevation mostly less than 8 m above the mean sea level. The areas are subjected to flooding in the monsoon season. Asasuni and Kalapara include mainly Ganges Tidal floodplain and their sub regions are saline, non calcareous, and the main soil types are loamy and clayey (Table 1).

Soils Used

Soil samples were collected from 0-50 cm, 50-100 cm and 100-150 cm in depth by auger. The soil samples were dried at room temperature, crushed, mixed thoroughly, sieved with 2mm sieve and preserved in plastic bags for subsequent laboratory analyses.

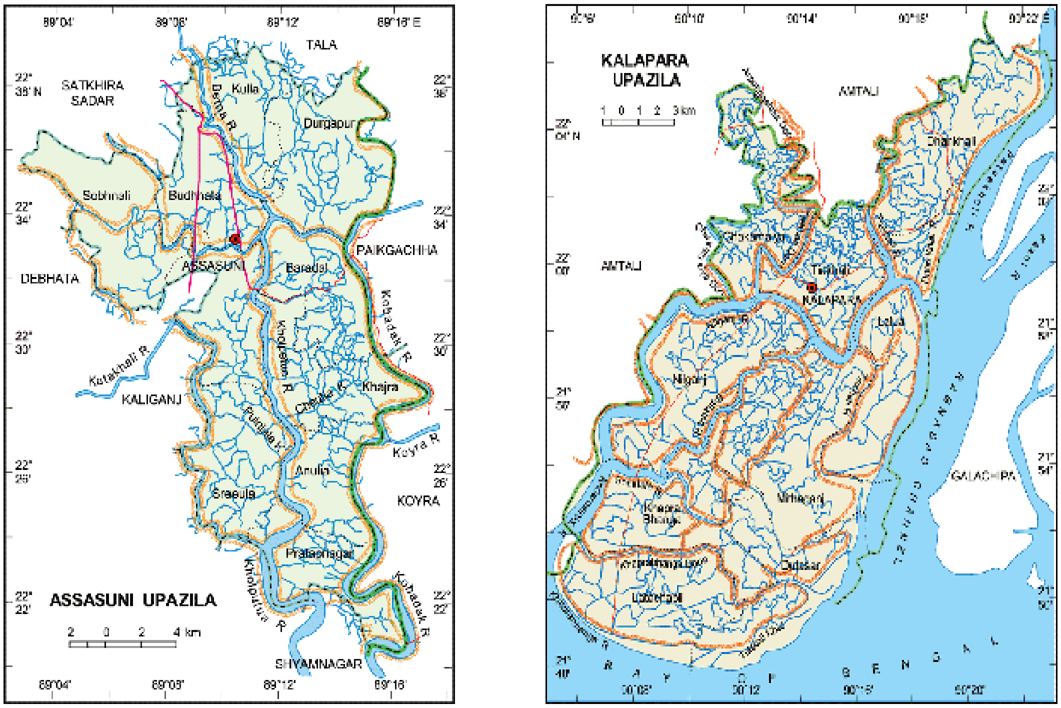

Figure 2. Study areas Assasuni upazila in the district of Satkhira and Kalapara in Patuakhali district of Bangladesh

Table 1. Distribution and extent of different categories of soil salinity in the studied saline areas of Bangladesh

Locations	Total Area (ha)	Total Saline Area (ha)	Percent	Salinity Catagories			
				S1	S2	S3	S4
				2.1-4 (dS/m)	4.1-8 (dS/m)	8.1-15 (dS/m)	>15 (dS/m)
				Slightly saline	Moderately saline	Saline	Strongly saline
				(Hectares)			
Asasuni	40.982	34.860	85	910	7400	6480	3100
Kalapara	47.194	35.400	75	31400	12100	7400	2300

Source: Soil salinity in Bangladesh (SRDI) 2000

Analytical Procedures

Particle-size analysis was carried out by the hydrometer method as outlined by Bouyoucos (1927). The textural classes were then determined by plotting the results on a triangular diagram designed by Marshall (1947) following the U.S. Department of Agriculture classification system. The pH was determined by a glass-electrode pH meter in the soil suspension having a soil: water ratio of 1:2.5, after 30-min shaking. The Electrical Conductivity (EC) was measured by an EC meter in the soil suspension having a soil: water ratio of 1:5, after 30-min shaking.

The organic carbon content was determined by the wet oxidation method and the organic matter content was calculated by multiplying the organic carbon content with a conventional factor of 1.724.The total nitrogen content was determined by the micro-Kleldhal digestion method. Cation Exchange Capacity (CEC) was determined by the sodium saturation method as described by Chapman (1965). The available phosphor was determined by the method as given by Olsen *et al.* (1954). The available sulphur was determined by the calcium chloride (0.15%) extraction method (Williams and Steinbergs, 1959).The non-exchangeable potassium content was determined by the boiling HNO_3 method (Knudsen *et al*., 1982). Exchangeable calcium, sodium and potassium were extracted from soil using 1M CH_3COONH_4 and their concentrations in the extract were directly determined by a flame photometer. Exchangeable magnesium was extracted by Diethylene Triamine Penta Acitate (DTPA) solution and its concentration in the extract was determined directly by an atomic absorption spectrophotometer (ASS). Exchangeable Sodium Percentage (ESP) and Sodium Adsorption Ratio **(**SAR) were determined by

$$ESP = \frac{\text{Exchangeable } Na^+}{CEC} \times 100$$

$$SAR = (\text{sodium}^+ / \text{calcium}^+ + \text{magnesium}^+)/2)^{1/2}$$

RESULTS AND DISCUSSION

Soil Physical Properties:

Particle Size Distribution

Data on the particle-size distribution and the USDA textural class of the soils is presented in Table 2 which indicates that the dominant soil textural classes that occur in the saline areas of these regions are silty clay; however, some loamy and sandy soils occur at kalapara. The clay and silt contents were observed to increase with the depth at kalapara while sand content decreased a phenomenon, which described as clay migration by lessivage to produce the process of alluviation.

Chemical Properties:

Soil Reaction

Data on the soil pH are presented in Table 3 and 4. The pH value of the topsoil at Asasuni ranges from 5.39 to 6.02 i.e. the soils were slightly acidic to acidic in reaction. In 50-100 cm depth in this area the pH ranges from 6.7 – 6.85 which is nearly neutral and this range is 7.70 – 8.2 in 100 -150 cm in depth which is strongly alkaline. At Kalapara the p^H values in 50 – 100 cm deep is 5.9 to 6.20 which is slightly acidic. The pH range of the soils from 50 -100 cm deep was 6.49 and 7.2, and from 100 – 150 cm deep was 7.2 – 8.1 which is strongly alkaline. In most of the soils, pH value of the surface horizon is slightly lower than that of the subsoil and sub stratums which are similar to the report published by SRDI in 2000. The higher pH values of the soils are likely to create micronutrient deficiency and phosphate fixation problem. But according to Tamhane *et al.,* (1970) the most soil nutrients were available for plants in a pH range from 6.5 to 7.5.

Total Nitrogen

The total nitrogen content of the topsoil is generally low to occasionally high ranging from 0.01 to 0.3%. The total nitrogen of the soils in Asasuni varied from 0.1 to 0.3% (Table 3) while that of Kalapara was 0.05 to 0.09% (Table 4).

Table 2. Physical properties of different soils in studied areas of Bangladesh

Locations	Depth (cm)	Particle size Distribution (%)			Texture
		Sand	Silt	Clay	
Asasuni	0-50	6	52	42	Silty Clay
	50-150	9	59	42	Silty Clay
	100-150	10	59	23	Silty Clay
Kalapara	0-50	12	51	37	Silty Clay
	50-100	9	52	39	Silty Clay
	100-150	4	57	39	Silty Clay

Total nitrogen content of the soil from Kalapara was evaluated to be low to very low level than that of the soils from Asasuni according to the grading of BARC (1997). Nitrogen content of the surface horizon is higher than that of subsoil. The poor nitrogen status of salt affecting soil is due to high cropping intensity, high rates of decomposition of organic matter and inadequate application of organic matter in terms of manure, compost, and high volatilization of ammonium nitrogen. Portch and Islam (1984) also found that 100% of the soils studied in saline areas were deficient in available nitrogen, which was similar to the present findings.

Cation Exchange Capacity (CEC)

Cation Exchange Capacity of soils of different horizons varies from 12.8 to 27.2 meq/100 g soil and 12.4 to 21.0 meq/100 g soil at Asasuni and kalapara respectively. CEC of all these soils varies from 12.7 to 27.2 meq/100 g soil expressing medium to high status. The high CEC values of these soils denote the comparatively high chemical activity of soil.

Organic Matter

Topsoil organic status in all the horizons ranges from medium to high at Asasuni according to the grading of BARC (1997). From the Table-3 and Table-4, it is shown that this range is 0.85 to 2.8% at Asasuni and 0.55 to 1.89% at Kalapara. Top soil organic matter content in almost all the soils collected from Kalapara are found very low mainly due to the lower topographic position of the soils. Organic matter content gradually decreases with depth followed by increasing trend due to the presence of buried mineral and organic horizons.

Phosphorous

The phosphorous contents of these areas estimated by the Olsen method are shown in Table 3 and 4. The ‘P’ content of the soils ranged from 1.25 to 9.50 mg/kg and 0.70 to 1.75 mg/kg at Asasuni and Kalapara, respectively, so most of the soils are found deficient in phosphorous. In some areas, phosphorous is found well below the critical level for most of the agricultural crops (SRDI, 2003). Acute deficiency of phosphorous was observed at Kalapara.

Potassium

Potassium status of the soils of different horizons varies from 0.09 to 0.18 meq/100 g soil (Table 3) and 0.06 to 0.17 meq/100 g soil (Table 4) at Asasuni and Kalapara respectively. These ranges indicate very low to low. High cropping intensity, inadequate application of potash fertilizer and limited scope of tidal water inundation may be the cause of lower potassium content.

Table 3. Physico-chemical properties of soils collected from Asasuni

Location	Sample No	Soil Layer Depth (cm)	pH	Total N (%)	CEC meq/100 g soil	Organic Matter (%)	P (mg/kg)	K (mg/100 g soil)	S (mg/kg)
Asasuni	1	0-50	5.39	0.1	17.0	2.23	4.00	0.18	20.00
		50-100	6.70	0.06	17.6	1.06	2.70	0.15	17.00
		100-150	7.75	0.08	12.8	1.37	1.25	0.09	16.50
	2	0-50	5.65	0.09	20.80	2.16	9.50	0.17	19..00
		50-100	6.80	0.05	27.20	0.85	3.75	0.13	17.00
		100-150	8.20	0.07	24.80	1.23	2.30	0.10	15.00
	3	0-50	6.02	0.10	17.6	2.80	5.60	0.17	20.00
		50-100	6.85	0.16	25.60	1.93	2.50	0.16	19.00
		100-150	7.90	0.30	17.6	1.47	1.35	0.11	15.00
	Average		6.80	0.11	20.11	1.68	3.67	0.14	17.44
	STD		1.0002	0.0772	4.8074	0.6389	2.5800	0.0335	2.0255
	CV (%)		14.69	68.85	23.90	38.08	70.47	23.96	11.62

Table 4. Physico-chemical properties of soils collected from Kalapara

Location	Sample No	Soil Layer Depth (cm)	pH	Total N (%)	CEC (meq/100 g soil)	Organic Matter (%)	P (mg/kg)	K (mg/100 g soil)	S (mg/kg)
Kalapara	1	0-50	6.20	0.09	12.80	0.90	1.90	0.07	67.00
		50-100	6.44	0.08	20.80	0.62	0.96	0.17	44.00
		100-150	7.20	0.06	18.40	0.58	0.75	0.11	38.00
	2	0-50	5.92	0.08	12.70	1.87	1.75	0.06	65.00
		50-100	6.49	0.07	20.60	0.58	0.90	0.12	42.00
		100-150	8.10	0.06	17.90	0.52	0.80	0.10	40.00
	3	0-50	5.90	0.09	13.00	1.89	1.65	0.07	63.00
		50-100	7.20	0.08	21.00	0.60	0.95	0.13	40.00
		100-150	7.90	0.05	17.50	0.55	0.70	0.11	39.00
	Average		6.89	0.07	17.19	0.90	1.15	0.11	48.67
	STD		0.8417	0.0141	3.5040	0.5658	0.4738	0.0346	12.4096
	CV (%)		12.21	19.28	20.39	62.79	41.16	33.20	25.49

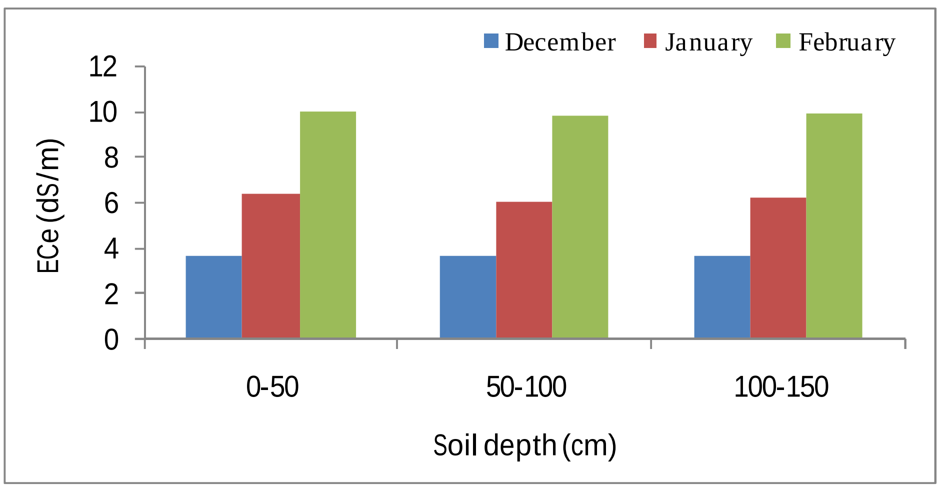

Figure 3. ECe (dS/m) at Asasuni in December, January and February at different soil depth

Sulphur

Topsoil sulphur status of all the soils were found medium to high and the content was higher at Kalapara than the other site. Regular inundation with tidal water may be the cause of higher sulphur content which ranged from 15.0 to 20 mg/100 kg at Asasuni and 38.0 to 67.0 mg/kg at Kalapara.

Salt Characteristics

Soils occurring in the saline areas of Bangladesh show a wide variation in salinity. The salinity of these areas ranges from slight to moderate, but during dry season the salinity dramatically increases the salinity increases. Table 5 shows that soil salinity was lowest in December and gradually increased in January and February at both Asasuni and Kalapara. The degree of salinity varies widely in area and season, depending on the availability of fresh water, the intensity of tidal flooding and the nature of movement of saline ground water. Soil salinity shows an upward trend in February and reaches a maximum level in April- May (Panaullah, 1993). The range of soil salinity at the studied sites at different times of the year 2008 and 2009 is shown in Figure 3 and 4.

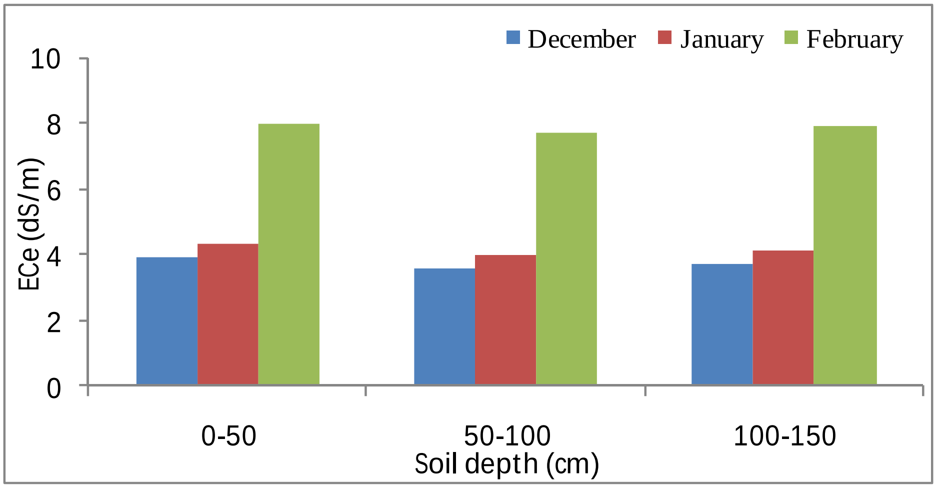

Figure 4. . ECe (dS/m) at Kalapara in December, January and February at different soil depth

The higher EC_e value found at the surface horizon followed by decrease with depth can be attributed to flooding with saline water or accumulation of salts through upward capillary movement of saline ground water. Soil salinity of different horizons ranges from 2.4 to 3.4 dS/m at Asasuni and 3.1 to 4.0 dS/m at Kalapara in December (2008) (Table 5). In dry season, this range, however, becomes 9.2 to 10 dS/m at Asasuni and 6.9 to 8.2 at Kalapara, which is under saline category according to soil report of (BARC 1990) and (SRDI 2003). Zaman and Bakri (2003) reported that Bangladesh had 3 million hectares of land affected by salinity, mainly in the coastal and south-east districts, with ECe values ranging between 4 and 16 dS/m.

Exchangeable Sodium Content

The exchangeable sodium contents of the soils of Asasuni and Kalapara at different soil depths are presented in Table 6. It was observed that the exchangeable sodium content for Asasuni varied from 0.52 to 0.56 meq/100 g soils and for Kalapara it varied from 1.67 to 2.2 meq/100 g soil (Table 6).

Exchangeable Potassium Content

The exchangeable potassium content of the soils of Asasuni and Kalapara was varied mainly based on the clay content. At Asasuni, it ranged from 0.45 to 1.45 meq/100g soil and at Kalapara it was 0.57 to 1.10 meq/100g soil. These ranges were very high in both areas (Table 6).

Exchangeable Calcium Content

The exchangeable calcium contents of the soils for Asasuni were 4.0 to 6.0 meq/100g soil and for Kalapara it was 6.73 to 10.75 meq/100g soil (Table 6). The exchangeable calcium content at Asasuni was medium to very high, and at Kalapara, the range was high to very high (BARC, 2005).

Exchangeable Magnesium Content

Exchangeable magnesium content of the two areas was in the very high level (Table-6). At Asasuni, it ranged from 4.0 to 6.0 meq/100g soil and from 4.47 to 7.85 meq/ 100g soil at Kalapara (Table 6).

Water Soluble Ions

From Table 6, it is shown that Na^+, Ca^{2+}, Mg^{2+} and K^+ ions are the dominant cations in different saline areas. On the other hand $SO_4^=$ and Cl^- ions are the dominant anions. The amount of accumulated salt is found higher at the surface horizon. It decreases with depth and then increases again.

Table 6. Salt characteristics of soils of Asasuni and Kalapara

Locations	Depth (cm)	EC (dS/m)	CEC (meq/100 g soil)	Exchangeable Cations (meq/100g soil)				Water soluble ions (meq/L)					
				Na	K	Ca	Mg	Na	K	Ca	Mg	Cl	SO_4
Asasuni	0-50	3.10	18.20	0.52	0.45	4.25	6.00	1.90	0.65	0.35	0.39	9.60	2.40
	50-100	2.80	23.40	0.54	0.60	6.80	4.00	1.70	0.38	0.38	0.42	10.70	2.80
	100-150	2.70	18.40	0.56	1.45	10.75	4.20	1.50	0.35	0.35	0.40	11.30	3.00
	0-50	4.00	12.80	1.67	0.57	6.73	4.47	0.70	0.05	0.05	0.08	1.50	3.50
	50-100	3.10		2.20	1.10	10.75	7.75	1.30	0.12	0.12	0.20	1.60	3.80
Kalapara	100-150		20.80										
		3.50	17.80	1.70	1.05	8.85	7.85	1.50	0.10	0.10	0.11	2.30	4.20

Exchangeable Sodium Percentage (ESP)
Exchangeable Sodium Percentage has been used as a parameter for assessing the severity of salinity problem. The sodium hazard is expressed as ESP. It ranges from 2.31 % to 3.04% at Asasuni which is acceptable (< 10%) and it is intermediate (10-35%) at Kalapara, i.e. 9.55% to 13.05%.

Sodium Adsorption Ratio (SAR)
The sodium hazard is denoted by the sodium adsorption ratio**.** The SAR of a soil extract gives an indication of the level of exchangeable Na^+ in comparison with that of Ca^+ and Mg^+ in soil**.** The SAR values vary from 1.72-2.22 at Asasuni upazila and 1.94 to 3.33 at Kalapara upazila (Fig.6). The SAR values of these areas are acceptable (<10).

Correlation matrix
The correlation matrix for physical and chemical properties determined in the present study of Asasuni is given in Table 7 and that of Kalapara is in Table 8. From Table 8, it is understood that the clay content is the most fundamental property to control chemical properties of soils at Kalapara.

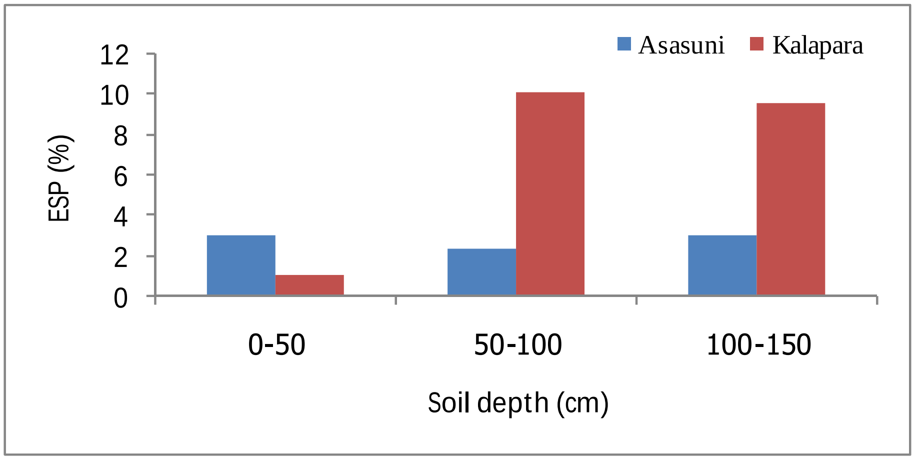

Figure 5. ESP(%) of Asasuni and Kalapara at different soil depth

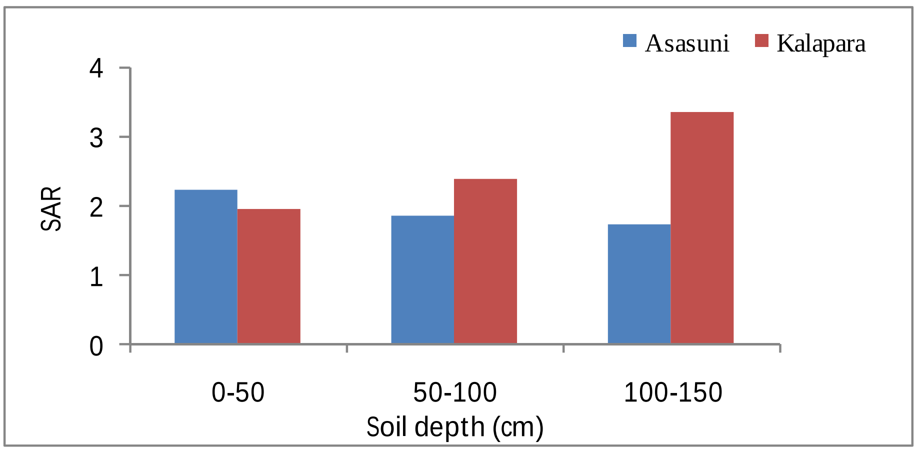

Figure 6. SAR value of Asasuni and Kalapara at different soil depth

Table 7. Correlation matrix between physical and chemical properties of the soils of Asasuni

	Clay	**pH**	**N**	**CEC**	**OM**	**P**	**K**	**S**	**Ec**	**Ex Na**	**Ex K**	**Ex Ca**	**Ex Mg**
Clay	**1**												
pH	-0.892**	1											
N	-0.162	-0.45	1										
CEC	-0.142	0.573	-0.989**	1									
OM	0.235	-0.647*	0.971**	-0.995**	1								
P	0.655*	-0.925**	0.754*	-0.840**	0.888**	1							
K	0.821**	-0.990**	0.569	-0.681*	0.747*	0.968**	1						
S	0.866**	-0.998**	0.500	-0.618*	0.689*	0.945**	0.996**	1					
Ec	0.693*	-0.943**	0.720*	-0.812**	0.863**	0.998**	0.980**	0.960**	1				
Ex Na	-0.866**	0.998**	-0.500	0.618*	-0.689*	-0.945**	-0.996**	-1.00**	-0.960**	1			
Ex K	-0.990**	0.946**	-0.139	0.279	-0.368	-0.754*	-0.893**	-0.927**	-.786**	0.927**	1		
Ex Ca	-0.921**	0.997**	-0.389	0.516	-0.595	-0.897**	-0.948**	-0.992**	-0.919**	0.992**	0.996**	1	
Ex Mg	0.419	-0.783**	0.907**	-0.958**	0.981**	0.960**	0.861**	0.817**	0.944**	-	-0.541	-	1

Remarks = ** and * mean correlation significant at the 0.01 and 0.05 levels, respectively (2-tailed). Clay: clay percentage, N: total N content, CEC: cation exchange capacity, OM: organic matter content, P: available P determined by the Olsen method, K: available K content, S: Available S content, Ec: electrical conductivity, Ex Na: exchangeable Na content, Ex K: exchangeable K content, Ex Ca: exchangeable Ca content, Ex Mg: exchangeable Mg content

Table 8. Correlation matrix between physical and chemical properties of the soils of Kalapara

	Clay	**pH**	**N**	**CEC**	**OM**	**P**	**K**	**S**	**Ec**	**Ex Na**	**Ex K**	**Ex Ca**	**Ex Mg**
Clay	1												
pH	0.702**	1											
N	-0.866**	-0.961**	1										
CEC	0.941**	0.421	-0.647*	1									
OM	-0.999**	-0.729*	0.885**	-0.927**	1								
P	-0.995**	-0.767**	0.909**	-0.905**	0.998**	1							
K	0.944**	0.430	-0.654*	0.999**	-0.931**	-0.909**	1						
S	-0.997**	-0.751*	0.899**	-0.915**	0.999**	0.999*	-0.918**	1					
Ec	-0.896**	-0.313	0.554	-0.993**	0.878**	0.849**	-0.992**	0.862**	1				
Ex Na	0.542	-0.216	-0.050	0.793**	-0.509	-0.460	0.787**	-0.481	-0.859**	1			
Ex K	0.996**	0.638*	-0.820**	0.967**	-0.992**	-0.983**	0.969**	-0.987**	-0.930**	0.612	1		
Ex Ca	0.881**	0.282	-0.527	0.988**	-0.862**	-0.832**	0.987**	-0.845**	-0.999**	0.875**	0.918**	1	
Ex Mg	0.999**	0.720*	-0.878**	0.932**	-0.999**	-0.997**	0.936**	-0.998**	-0.884**	0.520	0.993**	0.868**	1

Remarks = ** and * mean correlation significant at the 0.01 and 0.05 levels, respectively (2-tailed).Clay: clay percentage, N: total N content, CEC: catio exchange capacity, OM: organic matter content, P: available P determined by the Olsen method, K: available K content, S: Available content, Ec: electrical conductivity, Ex Na: exchangeable Na content, Ex K: exchangeable K content, Ex Ca: exchangeable Ca content, E Mg: exchangeable Mg content

CONCLUSIONS AND SUGGESTION

Coastal area in Bangladesh constitutes 20% of the country of which about 53% are affected by different degree of salinity. The texture of most of the saline areas of Bangladesh varies from silty clay to clay soil. Land preparation for crop production in these soils becomes very difficult as the soil dries out, deep and wide cracks develop and the surface soil becomes very hard. In these areas electrical conductivity was slightly saline to saline. The higher pH values of the soils are likely to create micronutrient deficiency problem. Hence, soil fertility should be improved based on the results obtained in the present study.

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