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Original Research Article

Estimation of Fertility Status of Coastal Soils for Agricultural Planning in Bangladesh

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Abstract

A study was conducted to know the fertility status of coastal soils of Bangladesh for agricultural planning. Thirty composite soil samples were collected from different locations of Kalapara upazila under Patuakhali coastal district in Bangladesh with Geographic Positioning System (GPS) positions. The soil samples were analyzed for physical properties (moisture, texture, bulk density, particle density and porosity) and chemical properties (pH, electrical conductivity, total nitrogen, organic carbon, exchangeable sodium, exchangeable potassium, available sulphur and available phosphorus). The range of moisture contents of collected soils was 24 to 29% and the textural class was silty clay. The bulk density ranged from 1.30 to 1.47 gcm^{-3}. The particle density ranged from 2.31 to 2.49 gcm^{-3}. The porosity of soil samples ranging from 40.96 to 46.06%. The pH ranged from 5.85 to 6.45. The EC value of collected soils ranged from 3.10 to 5.12 dSm^{-1}. The total nitrogen and organic carbon content was low to medium. The exchangeable sodium and potassium content of soils ranged from 9.22 to 18.47 meq 100g^{-1} and 0.16 to 0.27 meq 100g^{-1}, respectively. The available sulphur and phosphorus content of soils ranged from 17.21 to 33.21 mg kg^{-1} and 17.12 to 33.09 mg kg^{-1}, respectively. The results revealed that the soils of the study area were slightly to moderately saline and thus the nutrients present in the soils were low to medium level. Hence, salinity problem of soils should be considered before agricultural planning in the study area.

Keywords: Fertility, Coastal soils, Agricultural planning, Bangladesh.

INTRODUCTION

Bangladesh is among the world's most climate-vulnerable nations. Climatic change's effects on agriculture can no longer be ignored, and future climate threats to agriculture are likely to rise in the coming decades. Because of the loss of soil health caused by unfavorable climatic occurrences and pollution from various sources, the productivity of various crops has decreased in Bangladesh. Bangladesh's coastal areas account for almost a third of the country's arable land [1]. According to the Government of Bangladesh's coastal zone policy [2], 19 of the country's 64 districts are located in the coastal zone, which includes 147 upazilas. Noakhali, Barisal, Bhola, and Patuakhali districts make up the central coastal zone, which stretches from the Feni river estuary to the eastern corner of the Sundarbans. Kalapara upazila is under the Patuakhali coastal district located at 21.98610 N 90.24220 E [3]. This region is low-lying, with most elevations less than 8 meters above sea level. During the monsoon season, the areas experience floods. The Ganges Tidal Floodplain dominates Kalapara, with saline subregions and clayey soil being the predominant soil type [3]. Farmers of the study area are frantically seeking to boost crop yields by using increasingly inorganic fertilizers and pesticides. Excessive use of one fertilizer can make other nutrients unavailable. The farmers are unaware of the soil's underlying nutritional condition and utilize fertilizers in an inefficient and wasteful manner. It is critical to assess the fertility state of our soils at the farmer level in order to minimize these concerns [4]. The extent and gravity of a given area's biological activity and fertility are dictated by its soil qualities (physical and chemical); therefore adequate management is required for improved crop output. Soil is a heterogeneous body with many different properties. Depending on their physical and chemical features, different soils have varying requirements for fertilizers, liming, irrigation, and tillage procedures. Evaluation of soil physical and chemical parameters aids in the efficient use of fertilizer and irrigation water, allowing crop output to be maximized [5]. Soil characterization (physical and chemical) research has been ignored in Bangladesh in the past. Several research organizations, including SRDI, BINA, BAR1, BRRI, and universities of Bangladesh, have recently undertaken comprehensive studies to characterize several soil series in depth in order to improve agricultural planning. But on this matter, only a little amount of literature has been assessed in coastal area of Bangladesh. In light of the foregoing, the current research was carried out to know the fertility status of the coastal soils of Kalapara upazila of Bangladesh and acquire information on their nutrient condition for suitable and sustainable agricultural planning in coastal areas of Bangladesh.

MATERIALS AND METHODS

Study area

Thirty composite soil samples were collected from different locations of Kalapara upazila under Patuakhali district of Bangladesh for analyzing some physical and chemical properties (viz. texture, moisture content, bulk density, particle density, porosity, pH, EC, organic carbon, total nitrogen, available phosphorus, available sulphur, exchangeable sodium and exchangeable potassium) during September, 2018. The map showing the study site is given in plate 1 and the detailed information about the locations and samples collected from those sites are given below in Table-1.

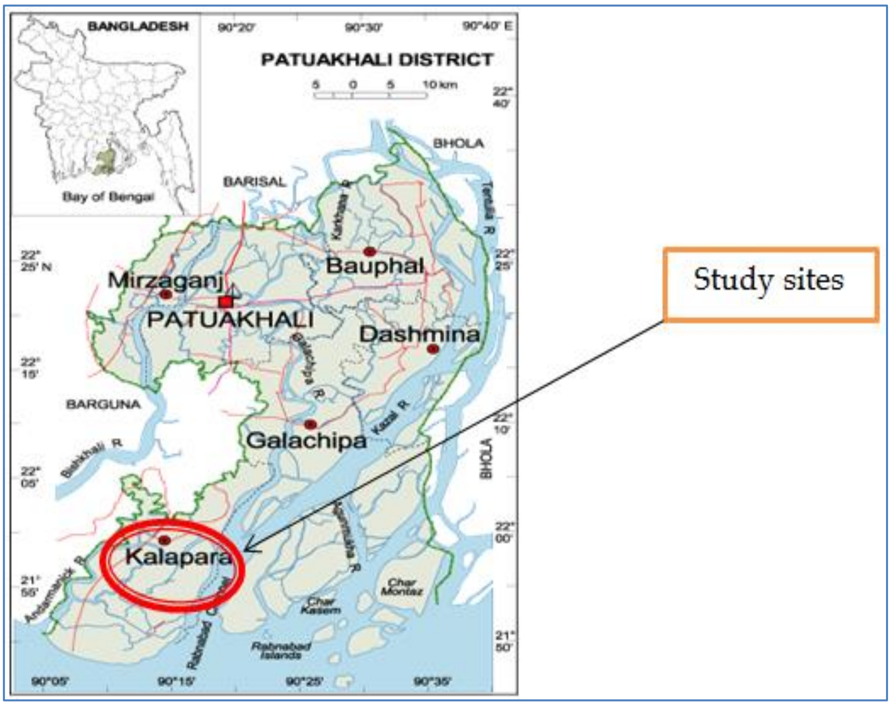

Plate-1 Map of Patuakhali district

Table-1: Soil sample number with corresponding location details and GPS reading

Sample no.	Location	GPS Reading
S_1	Nilgonj union	Latitude-21.908, Longitude-90.144
S_2	Nilgonj union	Latitude-21.913, Longitude-90.148
S_3	Nilgonj union	Latitude-21.922, Longitude-90.155
S_4	Nilgonj union	Latitude-21.942, Longitude-90.171
S_5	Nilgonj union	Latitude-21.853, Longitude-90.159
S_6	Nilgonj union	Latitude-21.854, Longitude-90.139
S_7	Nilgonj union	Latitude-21.892, Longitude-90.138
S_8	Nilgonj union	Latitude-21.925, Longitude-90.158
S_9	Nilgonj union	Latitude-21.931, Longitude-90.162
S_{10}	Nilgonj union	Latitude-21.892, Longitude-90.139
S_{11}	Nilgonj union	Latitude-21.929, Longitude-90.152
S_{12}	Nilgonj union	Latitude-21.957, Longitude-90.187

Sample no.	Location	GPS Reading
S_{13}	Nilgonj union	Latitude-21.955, Longitude-90.185
S_{14}	Nilgonj union	Latitude-21.949, Longitude-90.178
S_{15}	Nilgonj union	Latitude-21.942, Longitude-90.171
S_{16}	Latachapli Union	Latitude-21.835, Longitude-90.141
S_{17}	Latachapli Union	Latitude-21.841, Longitude-90.118
S_{18}	Latachapli Union	Latitude-21.842, Longitude-90.119
S_{19}	Latachapli Union	Latitude-21.840, Longitude-90.117
S_{20}	Latachapli Union	Latitude-21.845, Longitude-90.123
S_{21}	Latachapli Union	Latitude-21.846, Longitude-90.122
S_{22}	Latachapli Union	Latitude-21.894, Longitude-90.124
S_{23}	Latachapli Union	Latitude-21.854, Longitude-90.142
S_{24}	Latachapli Union	Latitude-21.875, Longitude-90.131
S_{25}	Latachapli Union	Latitude-21.878, Longitude-90.133
S_{26}	Latachapli Union	Latitude-21.880, Longitude-90.134
S_{27}	Latachapli Union	Latitude-21.885, Longitude-90.137
S_{28}	Latachapli Union	Latitude-21.888, Longitude-90.139
S_{29}	Latachapli Union	Latitude-21.889, Longitude-90.138
S_{30}	Latachapli Union	Latitude-21.902, Longitude-90.142

Collection and preparation of soil samples

Soil samples were collected from thirty different locations. Before sampling, existing plants and vegetation were removed with the help of spade. Then, an aluminum core was inserted to take a topsoil sample from each location for bulk density analysis and after that composite sub-soil samples at a depth of 15 cm was also taken from the same site for analyzing the above stated parameters. The samples were brought to the laboratory in the Department of Soil Science at PSTU and left for air-drying. After that, the larger aggregates were broken down gently and were passed through a 2 mm sieve. The sieved samples were then weighed and collected in a plastic container for the further analysis. All the parameters were measured using standard procedures in the Soil Science laboratory at PSTU.

Determination of Soil texture

Hydrometer method [6] was followed for particle size analysis. The particles were separated according to USDA system limits. The textural classes of the soils were determined using Marshall's Triangular Coordinate diagram [7].

Determination of moisture content

Soil moisture content was measured by gravimetric method. According to this method, soil water consists of measuring the moist and dry soil and was determined by weighing the sample as it was at the time of sampling, and the dry weight was obtained after drying the sample to a constant weight in an oven at 100-105 ^{0}C for 24 hours. An empty aluminum can was weighed and 40g soil was taken into the can and weighed again immediately. Then, the can with soil was placed into an oven for 24 hours at 105 ^{0}C for drying. Finally, the oven-dry weight was measured and moisture percentage was determined using the following equation:

$$\% \text{ Moisture in the sample} = (W_1\text{-}W_2/W_2\text{-}W_3)\times 100$$

Where, W_1 is the weight of wet soil + can; W_2 is the weight of oven-dry soil + can; and W_3 is the weight of the empty can.

Determination of Bulk density

Soil bulk or apparent density was measured by using Core sampler method [8]. A cylindrical metal core sampler of known height and diameter was driven into the soil to the desired depth and was carefully removed. Each end of the sample holder was trimmed and flushed with a sharp spatula to establish the soil sample volume same as the volume of the core. Bulk density was then calculated using the following equation:

$$D_b = ms/V_t$$

Where, D_b is the bulk density of the soil in gcm^{-3}; ms is the oven-dry weight (g) of the soil; and V_t is the volume of the soil (cm^3) filled in the core sampler.

Volume of soil or core sampler (V_t) was calculated using the equation given below:

$$V_t = \pi r^2 h$$

Where, r is the radius of the core sampler and h is the height of the sampler.

Determination of particle density

Particle density of soil was determined by volumetric flask method [9].

$$\text{Particle density } (gcm^{-3}) = \frac{\text{Weight of oven dried soil in g}}{\text{Volume of soil particles in } cm^3}$$

Determination of Soil Porosity
The total porosity of soil was calculated from the formula given by Vomocil [10] shown below:

Total porosity (%) = 100(1 - Db/Dp)
Where,
D_b = Bulk density (gcm^{-3})
D_p = Particle density (gcm^{-3})

Determination of Soil pH
Soil pH was measured in a suspension of soil and water on a glass electrode pH meter using a combined glass/calomel electrode, the soil-water ratio was being 1:2.5 [11]. Prior to making pH measurement, the electrode was calibrated using standard buffer solution at pH 4.0 and 7.0.

Determination of Electrical conductivity ($EC_{1:5}$)
Soil $EC_{1:5}$ were measured in 1:5 soil-water suspensions using EC meter (HANNA EC 214) [12]. Ten grams of air dried soil from the sample was taken in 100 ml beaker and 50 ml of distilled water added to the beaker. The suspension was stirred well for several times during the next 30 minute and then filtered. Soil $EC_{1:5}$ were measured in soil-water suspensions by using EC meter.

Determination of Organic carbon
Soil organic carbon was determined by wet oxidation method, as outlined by Nelson *et al.* [13]. The underlying principle was to oxidize the organic matter with an excess of N $K_2Cr_2O_7$ in presence of conc. H_2SO_4 and conc. H_3PO_4 and to titrate the residual $K_2Cr_2O_7$ solution with N $FeSO_4$ solution. To obtain the organic matter content, the amount of organic carbon was multiplied by the Van Bemmelen factor 1.73. The result was expressed in percentage.

Determination of Total nitrogen
Total N content in soil was determined by micro-Kjeldahl method [14]. Soil samples were digested with conc. H_2SO_4 in presence of K_2SO_4 catalyst mixture (K_2SO_4:Cu_2SO_4, $5H_2O$:Se = 100:10:1). Nitrogen in the digest was estimated by distilling the digest with 10N NaOH followed by titration of the distillate trapped in H_3BO_3 indicator solution with 0.01N H_2SO_4.

Determination of Exchangeable K
Exchangeable K content of soil was extracted by ammonium acetate extraction method. Extraction was done by repeated shaking and centrifugation of the soil (5gm) with neutral 1M NH_4OAc (25 ml) followed by decantation. 5ml extract was taken in a 10ml test-tube and diluted in up to the marks by distilled water then the reading was taken by flame photometer [15].

Determination of Exchangeable Na
Exchangeable Na content of soil was determined by 5gm soil was taken in a plastic bottle then added 25ml 1M ammonium acetate (NH_4OAc). It was shaken for five minutes then filtered this solution. 5ml extract was taken in a 10ml test-tube and diluted in up to the marks by distilled water then the reading was taken by flame photometer [15].

Determination of Available P
Available P content in soil was extracted by shaking the soil with 0.5M $NaHCO_3$ (pH 8.5). The extractable P in solution was then determined colorimetrically at 890 ηm wavelength by developing blue colour with reduction of phosphomolydate complex using molybdate ascorbic acid reagent [16].

Determination of Available S
The available S content of soil was determined by extracting the soil samples with $CaCl_2$ solution (0.15%). The S content in the extract was estimated turbidimetrically with spectrophotometer at 420 ηm wavelength [17].

STATISTICAL ANALYSIS
Data were compiled and tabulated in proper form for statistical analysis. The Pearson's correlations were conducted among the parameters.

RESULTS AND DISCUSSION
The results of physical and chemical properties of collected soils are presented in table 2 and 3, respectively.

1. Physical properties

Particle size distribution
The results of particle size distribution indicated that silt and clay were the dominant fractions of the study areas (Table 2). The sand content was lower than silt and clay content of the study area. The sand content was increasing from Nilgonj to Latachapli union. The range of sand, silt and clay content ranged from 9 to 14%, 45 to 50% and 40 to 44%, respectively. The same results were found by Naher *et al.* [3] at Kalapara coastal soils of Bangladesh.

Texture
Soil texture is important to identify soil characteristics, their saline holding capacity and also suitability for different crops. The texture of the soils of study area was silty clay (Table 2) that means the soils of study area had the highest percentage of silt, then clay and a lower amount of sand. These results are coincided with the values found by Tanu *et al.* [18].

Moisture content
The moisture content of the soil samples ranged from 24 to 29% (Table 2) i.e. the collected soil

samples were within the good range of moisture content. The actual soil moisture content at field capacity depends on soil texture ranging from 15 to 45% by volume. The plant can easily uptake soil water when its moisture is at or near field capacity. The soils of the study area were almost suitable for related crop production on the basis of moisture content. The almost similar results were found by Tanu *et al.* [18] in Kuakata soils of Bangladesh.

Bulk density

The content of bulk density of the soils of study area ranged from 1.30 to 1.47 g cm^{-3}. The highest bulk density was found in sample number S_{16} and the lowest bulk density was found in S_1, S_{10}, S_{12}, S_{13}, S_{15} and S_{27} samples (Table 2). The bulk density is indicator of plant root penetration in soil. The results of soil bulk density of the study area indicate the favorable condition for plant growth. Similar results were found by Tanu *et al.* [18].

Particle density

The particle density of the collected soils ranged from 2.31 to 2.49 g cm^{-3} where the highest value was found in sample number S_{16} and the lowest value was found in S_{27} (Table 2). Particle density of a soil sample is actually a weighted mean value for the various kinds of minerals and humus. The measured density depends on the relative proportions of constituent minerals and humus. The results were agreed with earlier work of Tanu *et al.* [18].

Porosity

The particle density of the collected soils ranged from 40.96 to 46.06% where the highest value was found in sample number S_1 which was collected from Nilgonj union and the lowest value was found in S_{16} which was collected from Latachapli union (Table 2). The soils were highly porous soil (25-40%) according to the micromorphometric method [19].

Table-2: Physical properties of soil samples collected from Kalapara coastal upazila of Bangladesh

Sample number	Particle size distribution			Texture	Moisture content (%)	Bulk density (g cm^{-3})	Particle density (g cm^{-3})	Porosity (%)
	Sand (%)	Silt (%)	Clay (%)					
S_1	9	50	41	Silty clay	29	1.30	2.41	46.06
S_2	12	46	42	Silty clay	26	1.35	2.42	44.21
S_3	11	46	43	Silty clay	27	1.31	2.40	45.42
S_4	11	45	44	Silty clay	27	1.32	2.41	45.23
S_5	12	45	43	Silty clay	26	1.31	2.35	44.26
S_6	11	47	42	Silty clay	27	1.32	2.41	45.23
S_7	12	46	42	Silty clay	26	1.36	2.43	44.03
S_8	11	46	43	Silty clay	27	1.31	2.40	45.42
S_9	11	47	42	Silty clay	26	1.33	2.42	45.04
S_{10}	10	47	43	Silty clay	28	1.30	2.39	45.61
S_{11}	11	45	44	Silty clay	27	1.32	2.40	45.00
S_{12}	10	46	44	Silty clay	28	1.30	2.40	45.83
S_{13}	10	47	43	Silty clay	28	1.30	2.39	45.61
S_{14}	12	45	43	Silty clay	26	1.35	2.41	43.98
S_{15}	10	47	43	Silty clay	27	1.30	2.40	45.83
S_{16}	15	45	40	Silty clay	24	1.47	2.49	40.96
S_{17}	11	48	41	Silty clay	27	1.31	2.39	45.19
S_{18}	12	48	40	Silty clay	26	1.32	2.38	44.54
S_{19}	13	45	42	Silty clay	25	1.40	2.45	42.86
S_{20}	12	48	40	Silty clay	26	1.35	2.41	43.98
S_{21}	11	46	43	Silty clay	27	1.32	2.41	45.23
S_{22}	14	46	40	Silty clay	24	1.31	2.42	41.74
S_{23}	12	48	40	Silty clay	26	1.35	2.39	43.51
S_{24}	12	47	41	Silty clay	27	1.33	2.38	44.12
S_{25}	12	46	42	Silty clay	26	1.32	2.37	44.30
S_{26}	14	45	41	Silty clay	25	1.42	2.43	41.56
S_{27}	12	48	40	Silty clay	26	1.30	2.31	43.72
S_{28}	13	46	41	Silty clay	27	1.33	2.39	44.35
S_{29}	13	47	40	Silty clay	25	1.38	2.41	42.74
S_{30}	12	47	41	Silty clay	27	1.34	2.40	44.17
Range	9 to 14	45 to 50	40 to 44		24 to 29	1.30 to 1.47	2.31 to 2.49	40.96 to 46.06

Here, S_1 to S_{15} from Nilgonj union and S_{16} to S_{30} from Latachapli union.

2 Chemical properties

Soil reaction (pH)

The pH of soil samples ranged from 5.85 to 6.45 i.e. the soil samples were neither strongly acidic nor basic in nature (Table 3). The highest result was found in sample S_{16} which was collected from Latachapli union and the lowest result was found in sample S_7 which was collected from Nilgonj union. The estmated values of pH were suitable for both plant and microbial growth. The similar pH values (5.82 to 7.80) of Kuakata soils under Kalapara upazila in Bangladesh were found by Tanu *et al.* [18]. The similar pH values ranged from 5.90 to 6.20 was also found in Kalapara upazila coastal soils in Bangladesh by Masum *et al.* [20].

Electrical conductivity ($EC_{1:5}$) in soil

The EC values varied from 3.10 to 5.12 dS m^{-1} indicating the soil samples are saline in nature. The highest EC value 5.12 dS m^{-1} was found in sample S_{16} which was collected from Latachapli union and the lowest EC value 3.10 dS m^{-1} was found in sample S_7 which was collected from Nilgonj union (Table 3). This might be due to flooding of soil with saline sea water. The similar EC value (5.14 dSm^{-1}) was found by Khanam *et al.* [21] in Hazipur village of Kalapara upazila coastal soils in Bangladesh.

Organic carbon content in soil

From the Table 3 the organic carbon range was 0.56 to 0.92% at Kalapara upazila. The maximum organic carbon content 0.92% was found in sample S_7 which was collected from Nilgonj union and the minimum organic carbon content 0.56% was found in sample S_{29} which was collected from Latachapli union. The organic carbon of the study was belongs to low range. It might be due to the lower topographic position of the soils Kalapara upazila and excessive rates of organic matter decomposition due higher temperature in the study area. Similar findings were observed by Naher *et al.* [3] in Kalapara coastal soils of Bangladesh.

Total nitrogen content in soil

The total nitrogen content of the soil was generally very low to low ranging from 0.05 to 0.09% (Table 3). The highest total nitrogen content (0.09%) was found in Nilgonj union and the lowest nitrogen content (0.05%) was found in Latachapli union. The nutrient deficiencies for total nitrogen were quite dominant in the study areas. Excessive rates of organic matter decomposition and inadequate application of organic matter in the form of manure, compost, and other organic matter as well as high ammonium nitrogen volatilization, contributed to the poor nitrogen status of the collected soils. The similar results to the present findings in Kalapara coastal soils of Bangladesh were also found by Masum *et al.* [20].

Exchangeable sodium content in soil

The exchangeable sodium content of Kalapara soils varied from 9.22 to 18.47 meq $100g^{-1}$ soil (Table 3). Among the soils of Kalapara upazila, the highest exchangeable sodium content (18.47 meq $100g^{-1}$ soil) was found in Latachapli union and the lowest result (9.22 meq $100g^{-1}$ soil) was found in Nilgonj union. The high soil exchangeable sodium content in the study area might be due to inundation by salt water from Bay of Bengal which significantly increases sodium levels in soil. Similar results were also found by Khanam *et al.* [21] in the soils of Kalapara upazila of Bangladesh.

Table-3: Chemical properties of soil samples collected from Kalapara coastal upazila of Bangladesh

Sample number	pH	EC (dS m^{-1})	OC (%)	TN (%)	Ex. Na (meq $100g^{-1}$)	Ex. K (meq $100g^{-1}$)	Avail. P (mg kg^{-1})	Avail. S (mg kg^{-1})
S_1	6.40	4.82	0.69	0.07	16.65	0.26	20.91	19.52
S_2	6.21	3.84	0.63	0.07	12.96	0.22	28.41	29.13
S_3	6.28	3.95	0.59	0.06	14.28	0.24	30.11	33.11
S_4	6.25	3.92	0.60	0.06	14.15	0.23	32.10	32.10
S_5	6.34	4.20	0.57	0.06	14.42	0.24	33.09	33.21
S_6	6.06	3.26	0.68	0.07	11.09	0.20	30.13	31.55
S_7	5.85	3.10	0.92	0.09	9.22	0.16	24.31	29.33
S_8	6.05	3.32	0.67	0.07	11.49	0.21	23.98	30.12
S_9	6.13	3.49	0.64	0.06	12.35	0.22	22.90	28.45
S_{10}	6.10	3.36	0.66	0.07	11.78	0.21	29.40	30.33
S_{11}	6.40	4.78	0.57	0.06	14.49	0.25	22.32	24.82
S_{12}	6.06	3.25	0.73	0.07	10.52	0.18	23.10	27.13
S_{13}	6.13	3.38	0.66	0.06	11.78	0.22	30.40	32.44
S_{14}	6.16	3.53	0.65	0.06	11.96	0.23	28.12	30.33
S_{15}	6.18	3.64	0.63	0.06	12.83	0.24	23.45	27.12
S_{16}	6.45	5.12	0.66	0.06	18.47	0.27	17.12	17.21
S_{17}	6.03	3.30	0.65	0.07	11.74	0.21	22.21	25.45
S_{18}	6.20	3.79	0.60	0.06	13.96	0.23	20.33	24.31
S_{19}	6.15	3.65	0.66	0.07	11.74	0.20	25.12	28.12

Sample number	pH	EC (dS m^{-1})	OC (%)	TN (%)	Ex. Na (meq 100g^{-1})	Ex. K (meq 100g^{-1})	Avail. P (mg kg^{-1})	Avail. S (mg kg^{-1})
S_{20}	6.00	3.25	0.71	0.08	10.65	0.19	21.32	26.33
S_{21}	6.31	3.99	0.58	0.05	14.20	0.25	20.22	29.34
S_{22}	5.96	3.23	0.72	0.08	9.62	0.17	22.11	32.35
S_{23}	6.18	3.69	0.63	0.07	11.78	0.22	29.12	30.92
S_{24}	6.11	3.47	0.75	0.08	10.35	0.17	26.15	31.12
S_{25}	6.19	3.77	0.62	0.06	13.43	0.23	28.31	20.55
S_{26}	6.24	3.96	0.59	0.06	14.00	0.24	26.12	21.22
S_{27}	6.22	3.94	0.61	0.06	13.96	0.23	30.11	21.26
S_{28}	6.04	3.30	0.78	0.08	9.83	0.18	24.44	30.12
S_{29}	6.39	4.56	0.56	0.07	14.28	0.25	21.11	33.08
S_{30}	6.27	3.85	0.64	0.07	13.09	0.22	29.16	23.21
Range	5.85 to 6.45	3.10 to 5.12	0.56 to 0.92	0.05 to 0.09	9.22 to 18.47	0.16 to 0.27	17.12 to 33.09	17.21 to 33.21

Here, EC= Electrical conductivity, TN= Total nitrogen, Avail.= Available, Ex.= Exchangeable, P= Phosphorus, Na= Sodium, K= Potassium, S= Sulphur, OC= Organic carbon, S_1 to S_{15} from Nilgonj union and S_{16} to S_{30} from Latachapli union.

Exchangeable potassium content in soil

The exchangeable potassium content of the soils of Kalapara varied from 0.16 to 0.27 meq 100g^{-1} soil (Table 3). Among the soils of Kalapara upazila, the highest exchangeable potassium content (0.27 meq 100g^{-1} soil) was found in Latachapli union and the lowest exchangeable potassium content (0.16 meq 100g^{-1} soil) was found in Nilgonj union. It might be due higher level of exchangeable sodium in the soils of the study area because soil sodium has the antagonistic effect on soil potassium. The results were coincided with the findings of Khanam *et al.* [21] in the soils of Kalapara in Bangladesh.

Available phosphorus content in soil

The available phosphorus content of collected soils of Kalapara upazila ranged from 17.12 to 33.09 mg kg^{-1} (Table 3). The highest available phosphorus content (33.09 mg kg^{-1}) was found in S_5 sample which was collected from Nilgonj union and the lowest available phosphorus content (17.12 mg kg^{-1}) was found in S_{16} which was collected from Latachapli union of Kalapara upazila. The level of available phosphorus in collected soils was fall under the optimum level. The similar results were found by Khanam *et al.* [21].

Available sulphur content in soil

Available sulphur content of Kalapara soils ranged from 17.21 to 33.21 mg kg^{-1} (Table 3). Among the soils of Kalapara upazila, the highest available sulphur content (33.32 mg kg^{-1}) was recorded in S_5 sample which was collected from Nilgonj union and the lowest available sulphur content (17.21 mg kg^{-1}) was recorded in S_{16} which was collected from Latachapli union of Kalapara upazila. The optimum level of sulphur was observed in the study area. The similar results were found by Khanam *et al.* [21].

3 Correlation matrixes among soil physical properties

The correlation matrix among the physical properties of soil was carried out and presented in Table 4. The sand exhibited the significant negative correlation with silt, clay, moisture content and porosity of soil whereas significant positive correlation with bulk density. Silt showed negative significant correlation with clay content and bulk density of soil whereas positive significant correlation with moisture content of soil. Clay presented significant negative correlation with bulk density whereas significant positive correlation with moisture content and porosity of soil. Moisture content showed significant negative correlation with bulk density whereas significant positive correlation with porosity of soil. Bulk density exhibited significant negative and positive correlation with porosity and particle density of soil, respectively. Particle density showed significant negative correlation with porosity of soils of the study area. Similar results of correlation were found by Tanu *et al.* [18]. The correlation analysis exhibited a negative relationship between bulk density and porosity which means that the higher the bulk density, the lower the porosity and vice versa [22]. It might be due to the fact that the bulk density indirectly provides a quantification of the soil porosity.

Table-4: Simple correlation coefficients (r) among soil physical properties

	Sand	Silt	Clay	Moisture content	Bulk density	Particle density	Porosity
Sand	1						
Silt	-0.438*	1					
Clay	-0.578***	-0.480**	1				
Moisture content	-0.902***	0.377*	0.539**	1			
Bulk density	0.870***	-0.404*	-0.483**	-0.829***	1		
Particle Density	0.353NS	-0.346NS	-0.030NS	-0.319NS	0.716***	1	
Porosity	-0.952***	0.341NS	0.620***	0.917***	-0.924***	-0.394*	1

*= Significant at 5% level, **=Significant at 1% level, ***=Significant at 0.1% level, NS= Not significant.

4 Correlation matrixes among soil chemical properties

The correlation among the soil chemical properties was studied and given in Table 5. The pH showed the significant positive relationship with EC, exchangeable Na and exchangeable K whereas significant negative relationship with organic carbon, total nitrogen. The EC, exchangeable Na and exchangeable K represented mostly similar correlation with other nutrient elements as like as pH. Organic carbon (OC) showed significant positive correlation with total nitrogen (TN) and available sulphur (S) whereas significant negative correlation with exchangeable Na and exchangeable K. The total nitrogen, available phosphorus (P) and available sulphur (S) showed mostly similar relationship with other nutrient elements as like as organic carbon. The correlation results were also coincided with the results of Masum *et al.* [20] and Naher *et al.* [3].

Table-5: Simple correlation coefficients (r) among chemical properties of soil

	pH	EC	OC	TN	Ex. Na	Ex. K	Avail. P	Avail. S
pH	1							
EC	0.938***	1						
OC	-0.897***	-0.856***	1					
TN	-0.891***	-0.840***	0.912***	1				
Ex. Na	0.919***	0.920***	-0.940***	-0.905***	1			
Ex. K	0.901***	0.832***	-0.920***	-0.932***	0.928***	1		
Avail. P	-0.055NS	-0.240NS	0.153NS	0.096NS	-0.153NS	-0.078NS	1	
Avail. S	-0.335NS	-0.455*	0.441*	0.347NS	-0.524**	-0.384*	0.395*	1

*= Significant at 5% level, **=Significant at 1% level, ***=Significant at 0.1% level, NS= Not significant.
Here, EC= Electrical conductivity, TN= Total nitrogen, Avail.= Available, Ex.= Exchangeable, P= Phosphorus, Na= Sodium, K= Potassium, S=Sulphur, OC= Organic carbon.

AGRICULTURAL PLANNING

The results revealed that the fertility status of the Kalpara coastal upazila of Bangladesh soils was low to medium and the soil salinity was slightly to moderate level. Due to soil salinity huge areas of land remain fallow in the study area. To meet up the food demand of increasing population of Bangladesh we have to increase cultivable land. Otherwise Bangladesh fall a food crisis in future. So, we have to give big attention in coastal saline area of Bangladesh. We have to take this coastal saline land for cultivation by developing some sustainable techniques and then make agricultural planning for the selected coastal area of Bangladesh. Crop types and cultivation methods will be chosen based on the research area's soil characteristics. There are now only a few crop varieties in Bangladesh that can survive on salty soils. However, with better management approaches, we can partially offset this disadvantage. Raised beds, mulches, and drip irrigation are some of the approaches developed by Bangladesh Agricultural Research Institute to cultivate crops on salty soils. Employing these strategies high-value horticultural crops such as tomato, chilli, watermelon, and cucumber can be grown in 4.5-11.0 dS/m salty soils [23]. Crop production management methods must be prioritized until new varieties emerge. Farmers will now be able to see demonstrations of acceptable technology in their fields, allowing them to become familiar with them and learn how to implement them. Similarly, more focus should be placed on variety development as well as environmentally friendly pest and disease management. Identify and introduce salinity tolerant crop and vegetable varieties to the people of the coastal area of Bangladesh would be another strategy to combat soil salinity. Despite the fact that the soils under investigation were slightly and moderately salty, reclaiming soil salinity with Boro rice and sweet water shrimp is a viable option. It is known as "Lockpur model" in Khulna-Bagerhat district of Bangladesh. It is a type of fish farming in which vegetables and fish are grown in tandem. By excavating a ditch inside the dyke, a dyke/ail/bund can be formed along the plot's perimeter. The ditch can be used as a small-scale irrigation system and a water reservoir for fish cultivation. A good grade of groundwater can be used for Boro rice cultivation. Soluble salts can be easily leached out in a short time by using this form of land usage. Beside these, application of organic fertilizer with IPNS basis can be a suitable technique to improve soil fertility as well as reducing soil salinity in the research area of Bangladesh.

CONCLUSION

Salinity is a critical threat that killing microorganisms and reducing fertility in Kalapara coastal upazila of Bangladesh. As a result, crop production is hampered in this area of Bangladesh. This could have a negative impact on our economy as a whole. It must be addressed for the sake of our country's economic well-being. Hence, adopting a long-term land management strategy to tackle the problem of land salinization is critical for the food security of Kalapara coastal area as well as the whole country.

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