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Soil salinity and nutrients pattern along a distance gradient in coastal region

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ABSTRACT

Soil salinity is considered as one of the major challenges in coastal agriculture in Bangladesh yet geographical extent of soil salinity and nutrients status have received little or no attention. This study investigated the patterns of soil salinity, total nitrogen, phosphorous, potassium and sulfur between agricultural and fallow land along a 90 km distance from the coastline in Noakhali, Bangladesh. Soil samples were collected from three depths (0, 10, and 30cm) in four different locations from coastline towards inland (0, 30, 60, and 90km) following a systematic random sampling. Soil salinity and total nitrogen, phosphorous, potassium and sulfur were analyzed by fitting fixed effect linear models for a full factorial design and then inverse distance weighted interpolation technique was applied to map spatial patterns of selected soil parameters. Highest soil salinity and sulfur were recorded in surface soils at coastline (0 km), whereas least in 90 km far from coastline. Soil depth resulted significant differences in phosphorous, potassium and showed significant interactions among the distant points. This study delineates the soil nutrients patterns and salinity as baseline information to explain salinity driven soil nutrient dynamics in coastal region of Bangladesh.

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INTRODUCTION

The coastal areas of Bangladesh cover 19 districts facing or near the Bay of Bengal which includes 148 sub-districts, comprising about 32% of the country's land area (47,211 square kilometers) and 25.7% of the population of Bangladesh (Haque, 2006; BBS, 2011; Anisuzzaman *et al.,* 2013). Bangladesh has total 2.85 million hectares (ha) of coastal and offshore land areas and about 0.83 million hectares are arable land situated in the coastal and offshore area including tidal, estuaries and river floodplains (Noakhali, Barisal, Patuakhali and western part of Chittagong) in the south along the Bay of Bengal (Haque, 2006). Major land use system in the coastal region of Bangladesh is agriculture dominated by paddy cultivation with seasonal *rabi* crops (that are sown at the end of the monsoon or beginning of winter). Continuous saline water intrusion due to sea level rise and increased shrimp cultivation are resulting altered nutrient status in coastal area of Bangladesh that is eventually impacting coastal agricultural production on a large scale. Soil provides a significant source of nutrients for crop production and the growth of plants (Ashman and Puri., 2013). Again, soil nutrients provide a crucial role for the sustainability of soil quality, crop production and environmental quality (Andrews *et al.,* 2004). Among all the nutrients, nitrogen (N) is the fundamental nutrients that needed most for crop production (Cao *et al.*, 2018) while N deficiencies result yellowing crop leaves and reduce tillering of cereal crops. Next to N, phosphorus (P) is a vital nutrient for plant growth and productivity that modifies cell division, enzyme activity and carbohydrate processes (Malhotra *et al*., 2018). Moreover, phosphorus also plays vital role in cellular processes by maintaining membrane structures, synthesizing biomolecules and forming high-energy molecules (Malhotra *et al.,* 2018) where, potassium (K) increase water-holding capacity of soils (Zorb *et al.*, 2013) and sulfur (S) contributes to synthesize coenzyme A and vitamins during plants metabolism (Lucheta and Lambais, 2012). Thus, soil quality affects economic growth and lives of local people by regulating crop production and function of the ecosystem (Brady and Weil, 2002). Nonetheless, being a floodplain area, the coastal regions of Bangladesh are fragile in terms of soil fertility although more than 30% of the cultivable lands of the country are covered by the coastal lands (Haque, 2006). In Chittagong, Barguna, Satkhira and Patuakhali, P deficient soils were reported by Dasgupta *et al.,* (2015). Soil properties such as soil pH, salinity, nutrient biogeochemical and physicochemical processes regulate the bioavailability of soil nutrients and soil salinity is recognized as a serious challenge in land cultivation (El-Ramady *et al*., 2018). Hasanuzzaman *et al.,* (2013) argued that salinity in soil act as important abiotic stress causing a remarkable decrease in the crop production. Moreover, soil salinization deteriorates one or more functions of soil that emerges as a major environmental constrain impeding soil productivity, agricultural sustainability, and food security (Cuevas *et al.,* 2019). While, soil pH affects all biological, chemical and physical soil properties (Brady and Weil 2002) and soil salinity can alter soil pH condition resulting modified nutrients patterns (Mokarram *et al.,* 2016). As a result, the varying degrees of soil salinity create the unfavorable condition for cultivation in coastal lands. Moreover, excess salinity deteriorates the hydrological situation and even restricts normal crop production throughout the year (Haque, 2006). The physiographic features i.e., slope aspect, relief, altitude and depth that influencing growth and yield are finally influenced by the physicochemical properties and the nutrient supplying capacity of the soils. Leaching and biological cycling influence the vertical transport of nutrients in opposite ways and leaching moves nutrients downward and may increase nutrient concentrations with depth (Jobbagy and Jackson, 2001). Characteristics of surrounding land site such as climate, land use, and landscape position helps in predicting rates of crop production (Schimel et al., 1991), assessing the effects of future land use change on nutrients (Kosmas *et al.,* 2000). Land use and cultural practices become the dominant factors affecting soil properties and crop production (Nnaji *et al.,* 2002). Types of agricultural land use and their associated management practices are strictly related to soil nutrients (Duiker and Beegle, 2006) which may affect soil properties (Chen *et al.,* 2011). Among the elemental properties, soil macro-nutrients such as N, P, K, and S are the primary nutrients that dominate the properties of soil while salinity intrusion may impact the status and distribution of these major nutrients thereby sustainability of coastal region. While salinity intrusion, contaminating soil and water, is causing significant economic and environmental loss in coastal zone of Bangladesh, it is still unknown how distant this salinity has spread so far towards inland. It is critical to understand how soil salinity may affect other elemental soil nutrients that are mandatory for sustainable agricultural production in disaster-prone coastal zone. In addition, this is also important to understand how soil salinity and other nutrients differ in response to soil depth profile and land use types to ensure sustainable coastal zone management. The objectives of this study were to assess and mapping the electrical conductivity (EC) as a measure of soil salinity and soil total nitrogen, phosphorus, potassium and sulfur variability between agricultural and fallow land along a 90 km distance gradient from coastline to inland in coastal Bangladesh. The present investigation has been conducted at Noakhali and Cumilla coastal regions of Bangladesh in 2018.

MATERIALS AND METHODS

Study area

This study has been performed in and around Noakhali District which is a southeastern part of Bangladesh and located between 22°38” and 23°37” North latitude and between 90°89” and 91°30” East longitude with an area of 1443.46 km^2 (Fig. 1) which surrounded by Cumilla and Chandpur, the Meghna estuary and the Bay of Bengal, Feni and Chittagong Districts, Lakshmipur and Bhola Districts on the north, south, east and west, respectively. Four points were selected in the study site namely Chairman Ghat, Banglabazar Vatirtek, Begumgonj and Doulatgonj (Laksam Upazilla, a part of Cumilla) maintaining 30km from each point. The total area was occupied with a population of 1,379,512 (BBS, 2011).

The study area is a tropical climate based area with a short dry season and has a significant rainfall. The average temperature and rainfall of the study area is about 25.6°C and 3.3mm, respectively. The

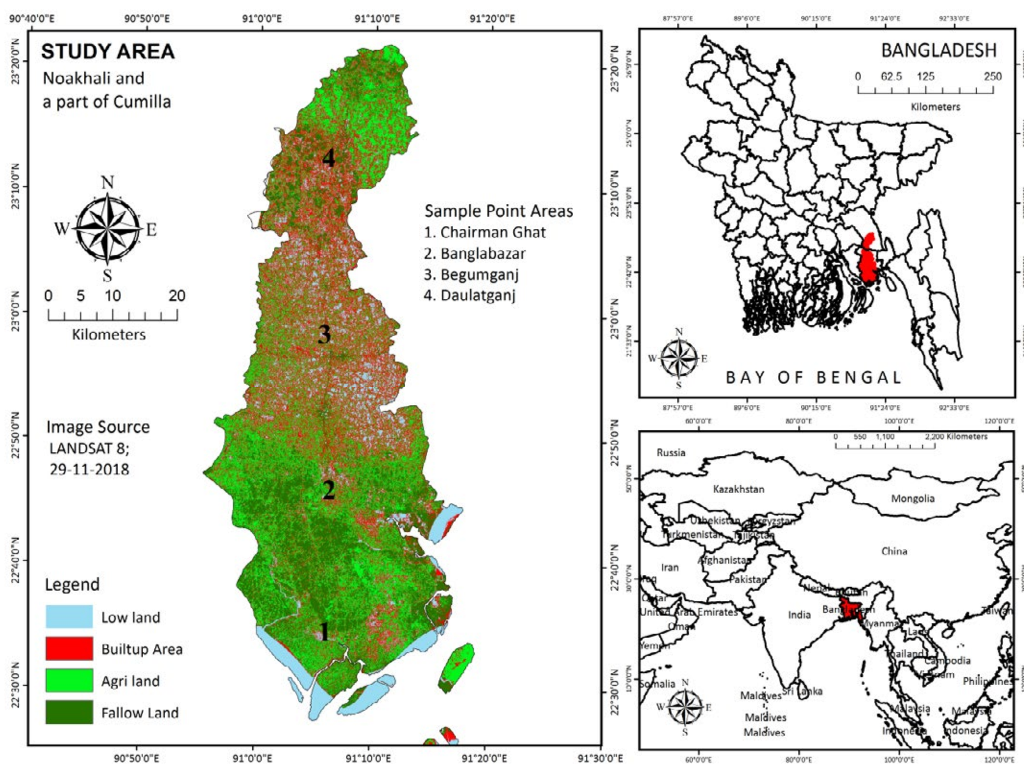

Fig. 1: Geographical location of the study area at coastal district Noakhali and a part of Cumilla, Bangladesh

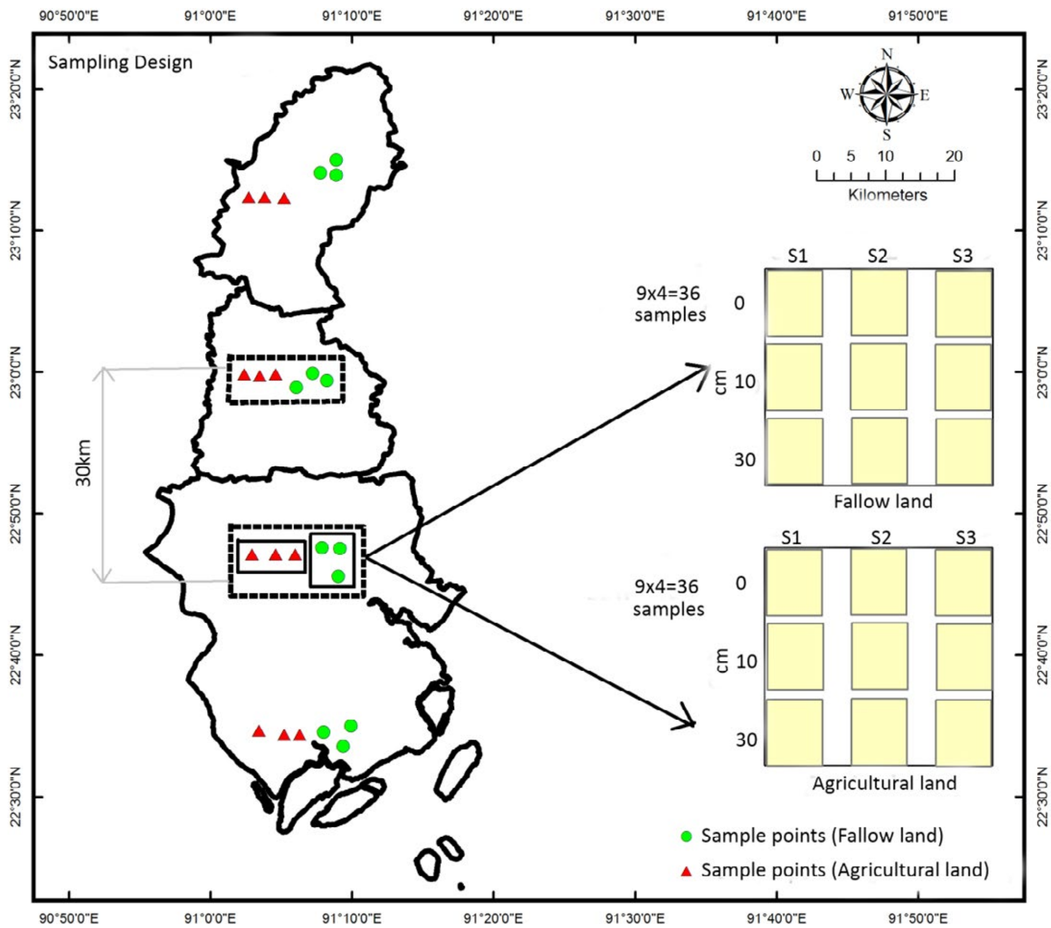

Fig. 2: Map depicting sampling protocol applied for soil sampling in the present study

site embodies an extensive flat, coastal and delta land, located on the tidal floodplain of the Meghna River delta, characterized by flat land and low relief. The general soil types of the study area are calcareous alluvium, Calcareous Grey Flood-plain soils and Calcareous Brown Flood-plain soils (BBS, 2011).

Soil sampling

A Total of 72 soil samples were collected from four different locations starting from 0 km of the coast (Chairmanghat, Subornochor, Noakhali) to 90 km towards inland applying a systematic random sampling. The distance between the sample locations was about 30km. We considered two different land uses such as agricultural versus fallow land (not cultivated for at least 5 years) and three soil depths such as 0cm, 10cm and 30cm. The collected soil samples were tightly sealed in a polyethylene bags as soon as possible to avoid air exposure. Global Positioning System (GPS) locations from each sample location were recorded accordingly.

Determination of EC, TN, P, K and S

All soil parameters were determined in Soil Research Development Institute (SRDI) laboratory in Noakhali, Bangladesh. EC was measured by using an EC meter (HANNA Instrument, Model: HI-2315 Bench-Top Conductivity Meter). Soil total nitrogen (TN) was determined by Walkley and Black oxidation method (Sahrawat, 1982). Soil P was measured by following the method of Bray and Kurtz (1945) when the sample pH < 7 and the Olsen method (Watanabe and Olsen, 1965) when the sample pH >7, respectively. K and S were measured colorimetrically with a spectrophotometer (U-2910, HITACHI, USA) (Schmidt, 1951).

Statistical analysis

Three-way analysis of variance (ANOVA) for EC, TN, P, K and S were applied separately to examine if there is any overall significant difference among the factors after checking the linearity assumptions. After ANOVA, Tukey's HSD post-hoc was applied for multiple comparisons among the groups in each case separately (post-hoc results are shown as letterhead in above the bars in Figs. 3, 5 and 6). While ANOVA only resulted overall significant difference (not specifying where those differences lie), Tukey's HSD resulted pairwise differences among the multiple groups within a factor. All analyses were done by using the R programming environment. For Tukey's post-hoc this research utilized "*glht*" function in "*multcomp*" package in R. For mapping the spatial distribution of soil parameters with depth, inverse distance weighted (IDW) interpolation technique and geographical information systems (GIS) were applied. The main formula followed in the IDW method is given as Eq. 1

$$S_p = \frac{\sum_{i=1}^{N} w_i S_i}{\sum_{i=1}^{N} w_i} \quad (1)$$

Where, S_p means the unknown concentration of soil parameters, Si means the concentration of known points; N means the number of data points; w_i means the weighting of each point. Weights can be calculated as a function of the distance between reference and interpolation point (Eqn. 2 and 3).

$$w_i = \frac{1}{d_i^k}; \quad (2)$$

$$d_i = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \quad (3)$$

Where di is the horizontal distance between the interpolation point (x_1, y_1) and the reference points (x_2, y_2); k is the power of the distance and i= 1,2,3……,n. (Bartier and keller 1996; Huang *et al.,* 2011; Harman *et al.,* 2016). Spatial interpolation of soil parameters was carried out by using ArcGIS 10.3.1.

RESULTS AND DISCUSSION

Descriptive statistics

Table 1 illustrates the summary information for 5 selected soil variables for agricultural and fallow land. Among the variables, highest EC was recorded in agricultural land as 13.9 dS/m whereas maximum EC value for fallow land was recorded as 33.4 dS/m (higher than agricultural land). Similarly,

Table 1: Summary statistics for the soil variables (A=Agricultural Land; F= Fallow Land)

Variables	Maximum		Minimum		Mean		Variance		SD	
	A	F	A	F	A	F	A	F	A	F
EC (dS/m)	13.9	33.4	0.25	0.23	1.44	3.49	6.04	40.859	2.457	6.39
TN (%)	0.11	0.19	0.01	0.01	0.05	0.07	0.0007	0.0014	0.027	0.03
P (µg/g)	115.8	265	0.07	0.66	29.8	29.85	1046.7	2770.8	32.35	52.6
K (meq/100g)	0.4	0.68	0.09	0.1	0.19	0.32	0.0054	0.0272	0.074	0.16
S (µg/g)	673.7	489.5	0.39	2.52	108.9	115.4	23196.9	14460.2	152.3	120.25

Table 2: Three-way ANOVA table for EC on distance (km) from the coastline, land uses (agriculture vs. fallow land) and soil depth. Significant differences are marked in bold in the table (α=0.05).

Factor	Df	Sum sq	Mean sq	F value	p-value
Distance (A)	3	404.6	134.86	16.281	**1.96e-07**
Land Use (B)	1	75.1	75.13	9.070	**0.00414**
Soil Depth (C)	2	195.7	97.86	11.814	**6.73e-05**
Distance ×Land Use (AB)	3	94.9	31.65	3.821	**0.01558**
Distance ×Soil Depth (AC)	6	427.6	71.27	8.604	2.30e-06
Land Use× Soil Depth (BC)	2	41.1	20.56	2.482	0.09421
Distance ×Land Use× Soil Depth (ABC)	6	79.9	13.31	1.607	0.16566
Residuals	48	397.6	8.28		

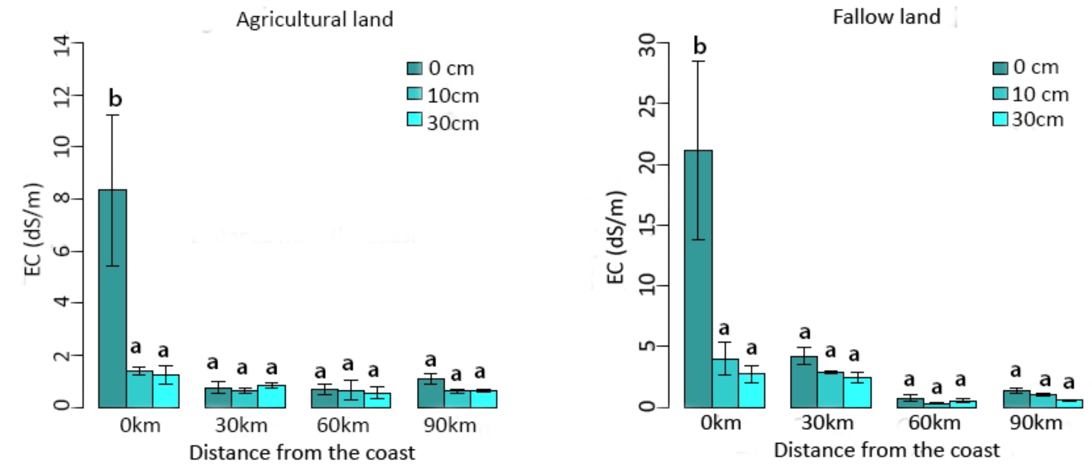

Fig. 3: Bar graphs showing the EC differences along a distance gradient from coastline between agricultural and fallow land in different soil depths. Different letters above the error bars denote significant differences among the groups based on Tukey's post-hoc test at α≤0.05 where homogeneous letter subsets are expressing non-significant difference

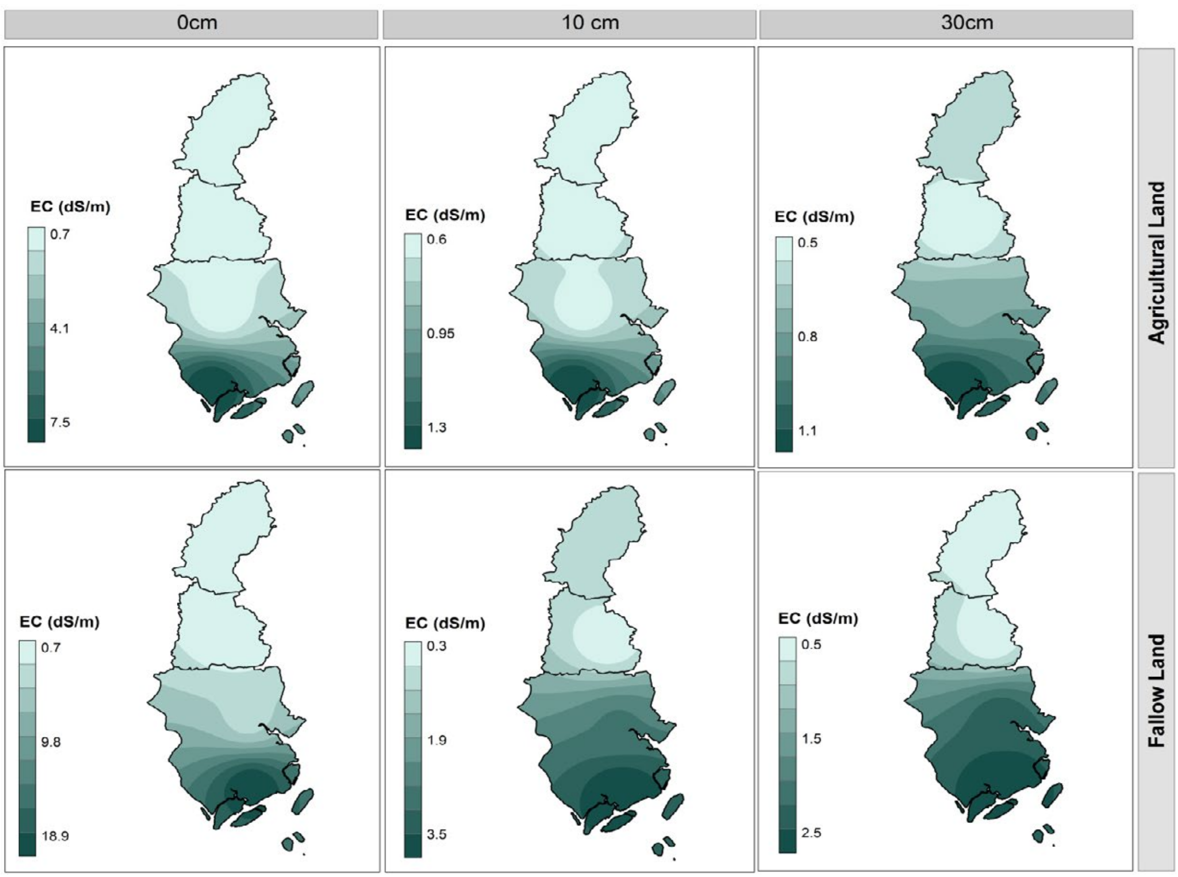

Fig. 4: Trends of Electric Conductivity (dS/m) along with the distances

Table 3: Three way analysis of variance table for soil TN and P on distance (km) from the coast, land use type (agriculture vs. fallow land) and different soil depth. Significant differences are marked in bold in the table (α=0.05)

Factors	Total Nitrogen					Phosphorus				
	DF	SS	MS	F val.	p val.	DF	SS	MS	F val.	p val.
Distance (A)	3	0.004	0.002	2.187	0.1	3	16529	5510	5.969	**0.001**
Land use (B)	1	0.003	0.003	3.748	0.06	1	875	875	0.949	0.33
Soil depth (C)	2	0.009	0.005	6.590	**0.003**	2	558	279	0.302	0.74
A×B	3	0.004	0.001	1.674	0.18	3	12053	4018	4.353	**0.008**
A×C	6	0.011	0.002	2.418	**0.04**	6	3209	535	0.579	0.74
B×C	2	0.002	0.001	1.111	0.34	2	466	233	0.253	0.78
A×B×C	6	0.011	0.002	2.419	**0.04**	6	298	50	0.054	0.99
Residuals	48	0.035	0.001			47	43381	923		

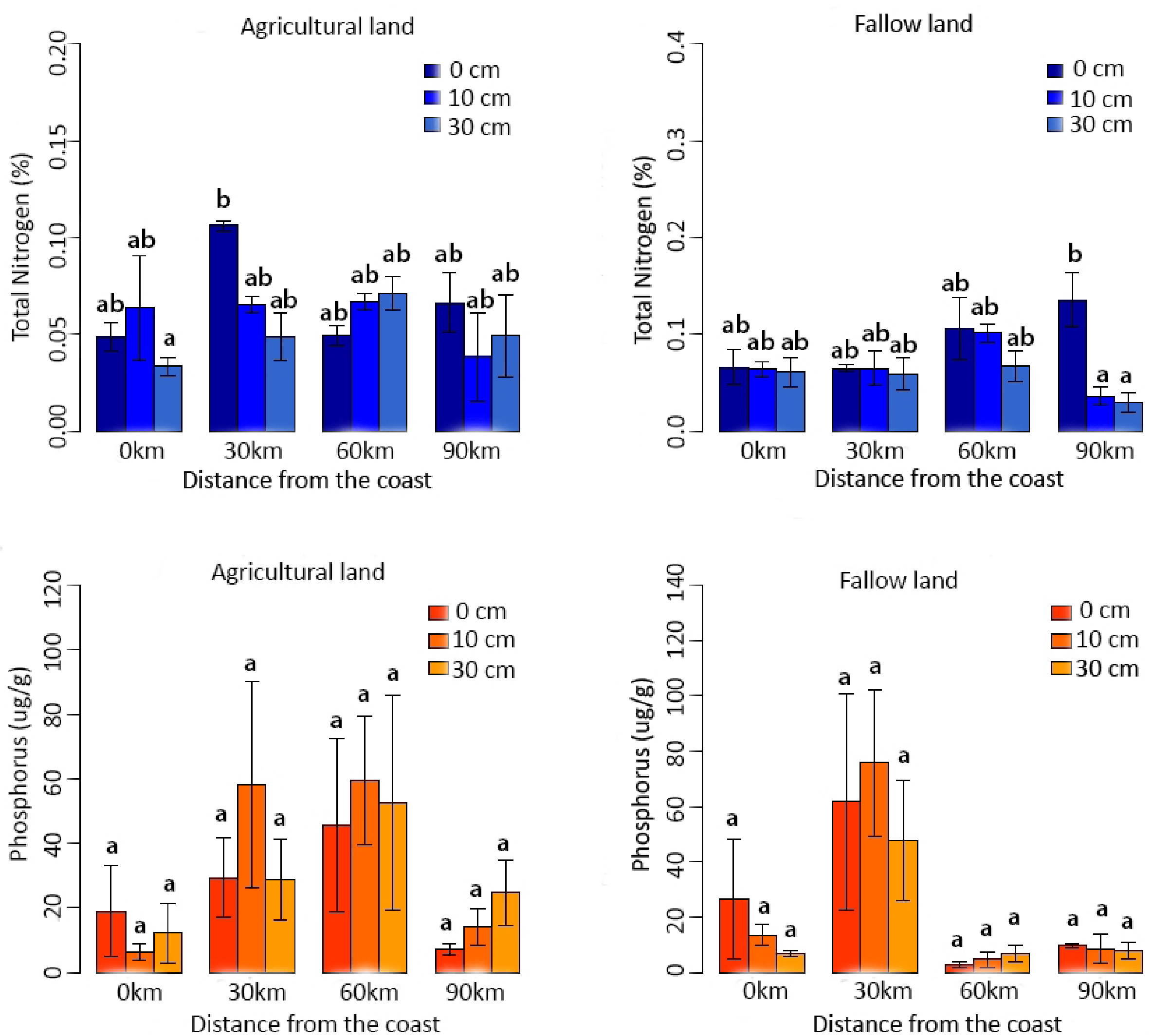

Fig. 5: Bar graphs showing the soil TN (5a) and P (5b) differences along a distance gradient from the coast in different soil depth in both agricultural and fallow land. Different letters above the error bars denote significant differences among the groups based on Tukey's post-hoc test at α≤0.05 where homogeneous letter subsets are expressing non-significant difference.

mean TN (%) was higher in fallow land compared to agricultural land (Table 1). Besides, the highest value of soil P and K were recorded as 265 µg/g and 0.68 meq/100 g respectively for fallow land whereas, for agricultural land the quantities were 115.85 µg/g and 0.4 meq/100g, respectively (less in agricultural land). Furthermore, the maximum value of soil S was recorded as 673.75µg/g and minimum value 0.39 µg/g in agricultural land whereas maximum soil S in fallow land was recorded 489.51µg/g (less than agricultural land).

Soil salinity pattern along the distance gradient

Figs. 3 and 4 show the graphical representation of soil salinity pattern along the distance gradient in the study area. To compare the significance differences among the land uses (agriculture vs fallow), soil depth, distance in terms of soil salinity, three-way ANOVA was conducted. Residuals of the model were normally distributed according to the Shapiro-Wilk test and variances among the groups were homogeneous according to Bartlett's test.

Table 2 summarizes the ANOVA results where significant differences are marked in bold. The interaction between the three factors (Distance ×Land use× Soil depth) was not significant (p = 0.16). However, the interaction between the individual factors (AB, BC and AC) showed significant results. Among the factors soil depth is the most significant (p=6.73e-5) for changing EC pattern i.e., the soil EC differed significantly to soil depth. But among the two factor interaction, AC showed the best interaction with soil salinity (p = 2.30e-06). In terms of distance from the coast, the soil salinity pattern differs as *p*-value shows a significant result (p = 1.96e-07). It was evident that, the value of soil EC is comparatively higher in the coastal area than the mainland area for both agricultural and fallow land (Fig. 4) which supports the hypothesis of higher soil EC value in coastal area because of high soluble salts are present in coastal area, conversely, lower in the mainland area because of comparatively low soluble salts are present there. Soil salinity is commonly measured by the determination of the apparent electrical EC (Hardie and Doyle, 2012). It was evident that soil salinity is directly related to soil electrical conductivity (Pathak and Rao, 1998). Besides, coastal soil salinity is a salt content within the soil and it is the concentration of soluble mineral salts present in soils (Page *et al.,* 1982). Therefore, there is higher soil salinity in coastal soil because of the higher value of soil EC resulted there that correlates with the hypothesis of this project and also supported by the following Author's statement. Thus, it can be said that the result is valid. Results suggested that soil EC is higher in topsoil rather than deep soil (Fig. 3). Moreover, there have been heavy rainfall and seawater intrusion. Furthermore, saline water cannot be diluted properly and high amount salts are present in surface soil and as result surface soil of coastal region resulted higher salinity. Khan *et al.* (2019) also reported higher soil salinity in coastal sub-district of Bangladesh located in south-western coastal region.

Nutrients pattern along the distance gradient

Patterns of soil TN and P

Table 3 represents the results of three-way ANOVA comparing soil TN and P by distance from the coastline, land use and soil depths. Residuals of the model were normally distributed according to the Shapiro-Wilk test (W=0.96, p=0.19) and

Table 4: Three way analysis of variance table for soil K and Son distance (km) from the coast, land use type (agriculture vs. fallow land) and different soil depth. Significant differences are marked in bold in the table (α=0.05)

Factors	Potassium					Sulfur				
	DF	SS	MS	F val.	p val.	DF	SS	MS	F val.	p val.
Distance (A)	3	0.56	0.185	71.47	<2e16	3	142653	47551	3.6	0.019
Land Use (B)	1	0.35	0.348	134.3	1.63e-15	1	752	752	0.05	0.811
Soil Depth (C)	2	0.07	0.035	13.54	2.16e-05	2	44613	22306	1.71	0.192
A×B	3	0.31	0.103	39.74	4.67e-13	3	41596	13865	1.06	0.374
A×C	6	0.07	0.011	4.342	0.0014	6	315759	52627	4.02	0.002
B×C	2	0.02	0.001	0.464	0.63	2	57517	28759	2.19	0.121
A×B×C	6	0.02	0.002	1.003	0.43431	6	88126	14688	1.12	0.363
Residuals	48	0.12	0.002			48	627739	13078		

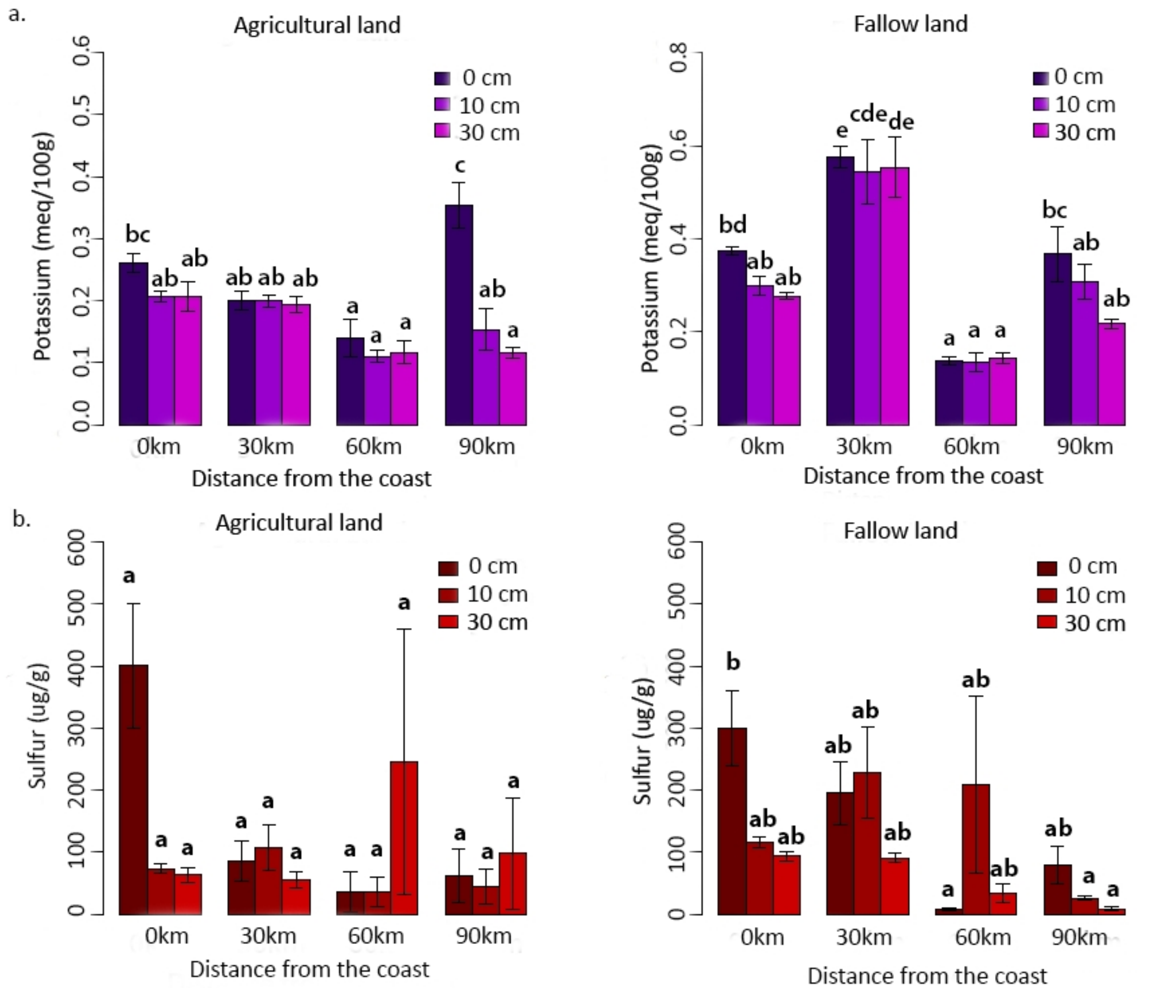

Fig. 6: Bar graphs showing the soil K (6a) and S (6b) differences between agricultural and fallow land along a distance gradient from coastline in different soil depths. Different letters above the error bars denote significant differences among the groups based on Tukey's post-hoc test at α≤0.05 where homogeneous letter subsets are expressing non-significant difference

variances among the groups were homogeneous according to Bartlett's test (K-squared=11.98 11, p=0.36). Significant differences have been marked in bold.

The results found that the soil P differed significantly with distance with its *p*-value 0.00156 whereas TN showed insignificant interaction with the distance (p=0.1). However, the soil P did not differ significantly between agricultural and fallow land use (p=0.33508) whereas, the soil TN differed significantly to soil depth (p=0.003). Moreover, the soil TN differed significantly to distance and soil depth interaction (p=0.04) whereas, the soil P was not significantly differed (p=0.74). However, the interaction among the three factors (distance*land use*soil depth) was not significant for P (p = 0.99). Furthermore, soil P had a significant interaction between distance and land use (p=0.008) whereas TN showed an insignificant result (p=0.18). Fig. 5 is showing multiple comparisons of soil TN (Fig. 5a) and P (Fig. 5b) by distance (km) from the coast, land use type and soil depth according to tukey post-hoc analysis. Overall, it showed an erratic change and there was no significant difference of soil TN and P among the levels of variables, however, soil samples collected from 0cm depth of 0km distance close to

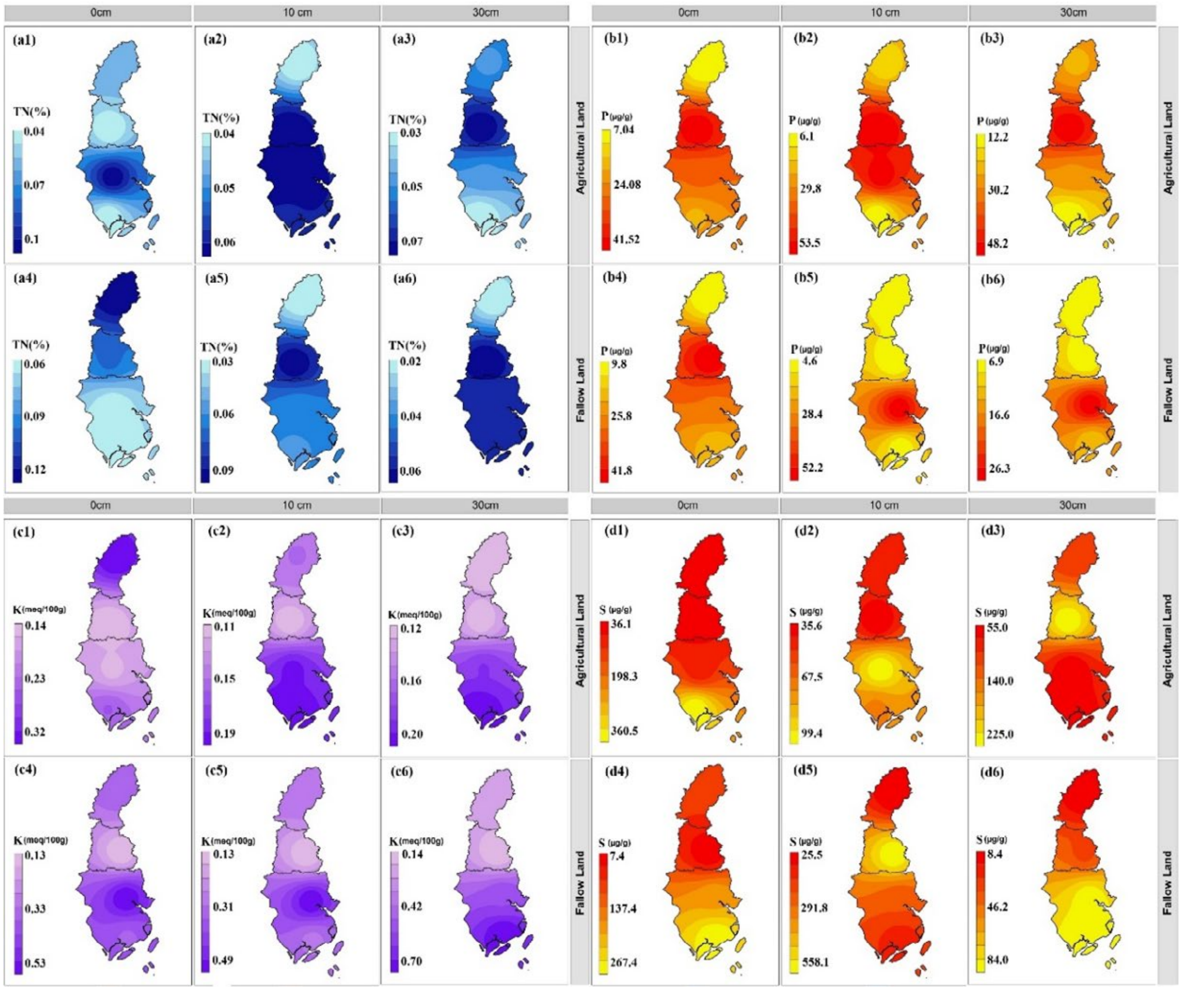

Fig. 7: The changing pattern of TN (a), P (b), K(c) and S (d) along with the distances from the coast

the coastal area for TN and 10 cm depth of 30 km and 60 km distances for P were recorded the highest value for agricultural land (Fig. 5a-5b). On the other hand, for fallow land, soil samples collected from a 0 cm depth of 0km distance close to the coastal area for TN and from 10cm depth of 30km distance for P were recorded the highest value (Figs. 5a and 5b, respectively). Moreover, the value of soil TN and P were recorded lower near 90 km close to the mainland area (Figs. 5a and 5b, respectively).

The overall pattern of TN and P is illustrated in Fig. 7. The value of soil P is comparatively higher in the semi-coastal area than a coastal area for both agricultural and fallow land (Fig. 4b) which is being correlated with the hypothesis that soil p-value is lower comparatively in coastal area because of high soil salinity means alkaline soil. Haque (2006) studied deficient P soils are also found in Chittagong, Barguna, Satkhira and Patuakhali coastal soil of Bangladesh. Moreover, Haque (2006) reported that nutrient deficiency of N and P are quite dominant in saline soil. Thus, it is evident that saline soil of coastal area deficient to the soil P, therefore, the reports of the following researchers support the results in the present study. It is also seen that the value of soil P is lower in the mainland area (Fig. 5b) which is not being correlated with the hypothesis and the following Author's statements do not support this. Moreover, the value of soil P is comparatively lower in the surface soil and then increasing with the depth up to 10-25 cm in the sub-surface region for agricultural land (Fig. 6). The value of soil P is also decreasing when the soil depth increasing after 25cm for agricultural land. This result is being correlated with the hypothesis that soil P value may be lower in the surface soil because of agricultural practice but higher in sub-surface soil because nutrients are strongly cycled biologically that upwards the nutrients. Agricultural land use variability and management practices may affect soil properties and the amount of TP, and available phosphorus in the surface layer of 0-25 cm are affected significantly by land use and farming management and also with the increasing soil depth, soil nutrients in each agricultural land use type decrease rapidly (Chen et al., 2011). On the other hand, the value of soil P is comparatively higher in the topsoil than the deep soil for fallow land (Fig. 5b) which is being correlated with the hypothesis that is soil P value is higher comparatively in topsoil because there is no agricultural practice in fallow land and nutrients are strongly cycled by plants and concentrated in topsoil region. It was reported by Stark (1994) that due to some proportion of the nutrients absorbed by plants are transported above ground, biological cycling generally moves nutrients upwards and then recycled to the soil surface by litterfall and throughfall. Moreover, Jobbagy and Jackson (2011) proved that nutrients strongly cycled by plants, such as P and K, were more concentrated in the topsoil (upper 20 cm). Chen *et al.* (2011) investigated that with the increasing soil depth, soil nutrients in each agricultural land use type decrease rapidly.

Patterns of soil K and S

Table 4 represents the three factor ANOVA for soil K and S from the coast, land use type (agriculture vs. fallow land) and different soil depth. Overall, the soil K and S differed significantly with distance with their p values <2e-16 and 0.01918, respectively. However, the soil S did not differ significantly between agricultural and fallow land use (p=0.81145 whereas, the soil K differed significantly to land use (p=1.63e-15 respectively). Moreover, the soil K differed significantly to soil depth and the respected p value was 2.16e-05, but, the soil S was not significantly differed (p=0.19248). Furthermore, the interactions between distance and land use for the soil K was significant with p-value (4.67e-13) and also for soil K and S, the interactions between distance and soil depth were significant (p=0.00141 and 0.00241, respectively)

Fig. 6 shows multiple comparisons of soil K and S by distance (km) from the coast, land use type and soil depth according to tukey's post-hoc analysis. Overall, there was a significant difference in soil K and S among the levels of variables (Fig. 6a and 6b, respectively). The difference between soil samples collected from 30 km distances for K and S; and 10 cm and 30 cm depths of 60 km distances for S were significantly different for agricultural land and fallow land (Fig. 6a and 6b respectively). However, soil samples collected from 0 cm depth of 90 km distance for K and 0 cm depth of 0 km distance close to the coastal area for S showed the highest value for agricultural land (Fig. 6a and 6b, respectively). On the other hand, for fallow land, soil samples collected from a 0 cm depth of 30 km distance for K and 0cm depth of 0 km distance close to the coastal area for S showed the highest value (Fig. 6a and 6b, respectively). Besides, soil samples collected from 60 km distance were found lower soil potassium for both agricultural and fallow land and 0 cm depth of 30 km distance had the lowest soil sulfur (Fig. 6a and 6b, respectively).

This research reported higher soil salinity in close proximity to coastline while it decreases with distances. Again, comparatively high salinity was reported in top soil. In terms of soil nutrients, higher P concentration was found in coast. While TN was found lower in top soil of coastline, TN was higher in deep soil in coastline (Fig 7). Thus, this research can be useful in site specific crop cultivation and land management depending on salinity and nutrient status such as chemical fertilizer application planning for farmers. Again, information on spatial distribution of soil nutrients will be helpful for sustainable management of nutrient deficiency. For example, nitrogen deficient sites could be identified from this study and nitrogen fixing plants could be used to amend the soil in terms of N availability. Moreover, soil sampling for this research was conducted during wet monsoon season. As a result, this study offers baseline for future research to examine seasonal variation of salinity and nutrients status thereby, foundation to modify cropping patterns in coastal zone.

CONCLUSION

This study showed that soil properties and nutrients variability from coastal land to the mainland for agricultural and fallow land can be tracked using analysis of variance and post hoc analysis. According to result, it was suggested that the soil salinity was comparatively higher in the coastal area may be of high soluble salts present in coastal zone, conversely, lower in the mainland area probably due to comparatively low soluble salts in soil. Moreover, the results of this study revealed that there was a positive relation among soil salinity with soil K and S resulting higher concentration in the coastal zone while lower in the mainland area for both agricultural and fallow land. Study found higher concentration of P in coastal soil compared to inland suggesting that P runoff may supersede the effect of salinity intrusion in coastal zone. Soil nutrients are comparatively higher in the topsoil than the deep soil for both agricultural and fallow land because biological cycling generally moves nutrients upwards and some proportion of the nutrients absorbed by plants are transported above ground and then recycled to the soil surface by litterfall and throughfall. With the increasing soil depth, soil nutrients in each agricultural land use type decrease rapidly. Sometimes, soil nutrients such as P are comparatively lower in the surface soil but increasing with the depth up to 10-25 cm in the sub-surface region for agricultural land. It can be evident that agricultural land uses and management practices may affect soil properties and the content of P and available phosphorus in the surface layer may affected significantly by land use and farming practices. This research recommends strengthening existing polders in coastal embankment project as physical reclamation of soil salinity. However, different land management techniques such as washing salts from top soil by freshwater before cultivation, farm-pond, ridge-ditch techniques may help reclaiming soil salinity. Above all, developing salinity tolerant crop varieties should be most important research steps to ensure sustainable coastal zone management.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

ABBREVIATION

%	Percent
ANOVA	Analysis of variance
ArcGIS	Aeronautical reconnaissance coverage geographic information system
cm	Centimeter
DF	Degrees of freedom
dS/m	deciSiemens per meter
EC	Electrical conductivity
Eq.	Equation
F-value	Fisher value
g	Gram
GIS	Geographic information system
GPS	Global positioning system
HSD	Honestly Significant Difference
IDW	Inverse distance weighting
K	Potassium
Km	Kilometer
Km^2	Square kilometer
M	Meter
meq/100g	Milliequivalent/100 g
Mm	Millimeter
MS	Mean squares
^oC	Degree Celsius
P	Phosphorus

p-value	Probability value
S	Sulfur
SD	Standard deviation
Sq.	Square
SRDI	Soil Resource Development Institute
SS	Sum of squares
TN	Total Nitrogen
ug/g	Microgram per gram
vs	Versus

REFERENCES

Andrews, S.S.; Karlen, D.L.; Cambardella, C.A., (2004). The soil management assessment framework. Soil Sci. Soc. Am. J., 68(6): 1945-1962 **(18 pages).**

Anisuzzaman, Md.; Arifuzzaman.; Ridha., (2013). Sub- Soil Characteristics of Selected Coastal Regions of Bangladesh. Int. J. Chem. Environ. Biol. Sci., 1(5): 710-714 **(5 pages).**

Ashman, M.; Puri, G., (2013). Essential soil science: a clear and concise introduction to soil science. John Wiley & Sons.

Bartier, P.M.; Keller, C.P., (1996). Multivariate interpolation to incorporate thematic surface data using inverse distance weighting (IDW). Comput Geosci., 22(7): 795-799 **(5 pages).**

BBS, (2011). Statistical Year book of Bangladesh. Bangladesh Bureau of Statistics.

Bray R.H.; Kurtz, L.T., (1945). Determination of total, organic, and available forms of phosphorus in soils. Soil Sci., 59: 39-45 **(7 pages).**

Brady, N.C.; Weil, R.R., (2002). The Nature and Properties of Soil, 13th ed. Springer Netherlands **(249 pages).**

Cao, P.; Lu C. C.; Yu, Z. (2018). Historical nitrogen fertilizer use in agricultural ecosystems of the contiguous United States during 1850–2015: application rate, timing, and fertilizer types. Earth Syst. Sci. Data, 10: 969–984 (**15 pages**).

Chen, L.; Qi, X.; Zhang, X.; Li, Q.; Zhang, Y., (2011). Effect of agricultural land use changes on soil nutrient use efficiency in an agricultural area, Beijing, China. Chin. Geogr. Sci., 21(4): 21(4): 392-402 (**11 pages).**

Cuevas, J.; Daliakopoulos, I. N.; del Moral, F.; Hueso, J. J.; Tsanis, I. K., (2019). A review of soil-improving cropping systems for soil salinization. Agronomy, 9(6): 295 **(22 pages).**

Dasgupta, S.; Hossain, M. M.; Huq M.; Wheeler, D., (2015). Climate change and soil salinity: The case of coastal Bangladesh. Ambio, 44(8): 815-826 **(12 pages).**

Duiker, S.W.; Beegle, D.B., (2006). Soil fertility distributions in long-term no-till, chisel/disk and moldboard plow/disk systems. Soil Till. Res., 88 (1-2): 30-41 **(12 pages).**

El-Ramady, H.; Alshaal, T.; Elhawat, N.; Ghazi, A.; Elsakhawy, T.; Omara, A.E.D.; Schnug, E., (2018). Plant nutrients and their roles under saline soil conditions. Plant Nutrients Abiotic Stress Tolerance, Springer. 297-324 (**28 pages**).

Haque, S.A., (2006). Salinity problems and crop production in coastal regions of Bangladesh. Pak. J. Bot., 38(5): 1359-1365 **(7 pages).**

Hardie, M.; Doyle, R., (2012). Measuring soil salinity. Plant salt tolerance. 415-425 **(11 pages).**

Harman, B.I.; Koseoglu, H.; Yigit, C.O., (2016). Performance evaluation of IDW, Kriging and multiquadric interpolation methods in producing noise mapping: A case study at the city of Isparta, Turkey. Appl. Acoust., 112: 147-157 **(11 pages).**

Hasanuzzaman, M.; Nahar, K.; Fujita, M.; Ahmad, P.; Chandna, R.; Prasad, M.N.V.; Ozturk, M., (2013). 2013) Enhancing plant productivity under salt stress: Relevance of poly-omics. Salt Stress Plants. SpringerLink, New York, NY., 113-156 (**44 pages**).

Huang, F.; Liu, D.; Tan, X.; Wang, J.; Chen, Y.; He, B., (2011). Explorations of the implementation of a parallel IDW interpolation algorithm in a Linux cluster-based parallel GIS. Comput Geosci., 37(4): 426-434 **(9 pages).**

Jobbágy, E.G.; Jackson, R.B., (2001). The distribution of soil nutrients with depth: global patterns and the imprint of plants. Biogeochemistry. 53(1): 51-77 **(27 pages).**

Khan, M.Z.; Islam, M.A.; Amin, M.S.; Bhuiyan, M.M.R., (2019). Spatial variability and geostatistical analysis of selected soil. Bangladesh J. Sci. Ind. Res., 54(1): 55-66 (**12 pages**).

Kosmas, C.; Gerontidis, S.; Marathianou, M., (2000). The effect of land use change on soils and vegetation over various lithological formations on Lesvos, Greece. Catena, 40(1): 51-68 **(18 pages).**

Lucheta, A.R.; Lambais, M.R., (2012). Sulfur in agriculture. Revista Brasileira de Ciência do Solo, 36(5): 1369-1379 (**11 pages**).

Malhotra, H.; Sharma, S.; Pandey, R., (2018). Phosphorus nutrition: plant growth in response to deficiency and excess. Plant Nutrients Abiotic Stress Tolerance. Springer, Singapore. 171-190 (**20 pages**).

Mokarram, M.; Najafi-Ghiri, M.; Negahban, S.; Roshan, G., (2016). Relationship between landform and soil salinity in the surface and subsurface soils (case study: Southeast of Fars Province, Iran). Model Earth Syst. Environ., 2(16): 1-11 **(11 pages).**

Nnaji, G.U.; Asadu, C.L.A.; Mbagwu, J.S.C., (2002). Evaluation of physico-chemical properties of soils under selected agricultural land utilization types. Agro. Sci., 3(1): 27-33 **(7 pages).**

Page, A.L.; Miller R.H.; Keeney, D.R., (1982). Methods of Soil Analysis, Chemical and Microbiological Properties. 2nd ed.

Pathak, H.; Rao, D. L. N., (1998). Carbon and nitrogen mineralization from added organic matter in saline and alkali soils. Soil Biol. Biochem., 30(6): 695-702 **(8 pages).**

Sahrawat K.L., (1982). Simple modification of the Walkley-Black method for simultaneous determination of organic carbon and potentially mineralizable nitrogen in tropical rice soils. Plant Soil. 69: 73-77 **(5 pages).**

Schimel, D.S.; Kittel, T.G.; Knapp, A.K.; Seastedt, T.R.; Parton, W.J.; Brown, V.B., (1991). Physiological interactions along resource gradients in a tallgrass prairie. Ecology. 72(2): 672-684 **(13 pages).**

Schmidt, V., (1951). A Quick Method for Colorimetric Determination of Potassium. Scan. J. Clin. Lab. Invest., 3 (4): 252-254 **(3 pages).**

Stark, J. M., (1994). Causes of soil nutrient heterogeneity at different scales. Expl. Environ. Heter. Plants. 255-284 **(30 pages).**

Zörb, C.; Senbayram, M.; Peiter, E., (2014). Potassium in agriculture–status and perspectives. J. Plant Physiol., 171(9): 656-669 (**14 pages**).

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