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ORIGINAL RESEARCH PAPER

Assessment of soil quality after constructing a closure dam on a river

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ABSTRACT

BACKGROUND AND OBJECTIVES: Reducing the salinity intrusion from sea water, a closure dam has been constructed on Little Feni River at Musapur Union in 2016. The objective of this research was to assess the soil quality based on the variables, i.e., PH, total organic carbon, total organic matter, total nitrogen, phosphorous, potassium, electrical conductivity, salinity and total dissolved solids, respectively.

METHODS: A total of 21 soil samples were collected from 7 sampling stations with 10-15cm depth. The PH, total organic carbon, total organic matter, total nitrogen, phosphorous, potassium, electrical conductivity, salinity and total dissolved solids were measured with pH meter, titration, Van Bemmelen factor, spectrophotometer, conductivity meter and salinity meter, respectively. Data were analyzed by statistical package for the social sciences, maps were produced by Arc GIS software and cluster analysis was done by Ward method, respectively.

FINDINGS: The mean concentrations of PH, total organic carbon, total organic matter, total nitrogen, phosphorous, potassium, electrical conductivity, salinity and total dissolved solids were 8.1±0.169, 0.506±0.278%, 0.873±0.465%, 0.044±0.023%, 21.599±8.312ppm, 0.462±0.47ppm, 2.024±526.76dS/m, 2.024±2.382ppt and 222.448±259.927ppm, respectively. The study result revealed that the ranges of these soil parameters were 7.19-8.5, 0.27-1.07%, 0.50-1.82%, 0.02-0.09%, 9.45-32.19ppm, 0.25-1.53ppm, 123.23-1625dS/m, 0.64-7.37ppt and 63.57-802.33ppm, respectively. Strong positive correlation observed between total organic matter and total organic carbon (r=0.999), total nitrogen and total organic matter (r=0.998), potassium and electrical conductivity (r=0.991), salinity and potassium (r=0.994), potassium and total dissolved solids (r=0.989). Likewise, phosphorous was positively correlated with potassium (r=0.444), electrical conductivity (r=0.476) and salinity (r=0.467) with significance level of $p \leq 0.05$. The variance test elicited that F value of PH, total organic carbon, total organic matter, total nitrogen, phosphorous, potassium, electrical conductivity, salinity and total dissolved solids were 25.505 ($p<0.000$), 18.011 ($p<0.001$), 14.013 ($p<0.003$), 23.478 ($p<0.000$), 29.393 ($p<0.000$), 17.924 ($p<0.001$), 9.502 ($p<0.009$) and 4.944 ($p<0.046$), respectively. The spatial distribution showed the reducing pattern of concentrations from outside to inside area of the closure dam. The cluster analysis showed the same sources of origin for pH, total organic carbon, total organic matter, total nitrogen, potassium, phosphorous and salinity (NaCl) which might be the possible cause of anthropogenic activities, i.e., use of chemical pesticide/fertilizer for agricultural cultivable land.

CONCLUSION: It is concluded that inside soil was more fertile rather than outside soil after the construction of closure dam. Lastly, the rate of crop production will be increased and soil should be more productive in the study area.

NUMBER OF REFERENCES
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INTRODUCTION

Environmental quality is consisted of air, water and soil quality (Andrew *et al*., 2002). Air and water quality is mainly depended upon the degree of pollution and the impacts on environmental and/or human health as well as biodiversity but soil quality is measured broadly the capacity of plant growth in a soil (Bünemann *et al*., 2018; Rosa and Sobral, 2008; Davidson, 2000). The term soil quality was introduced in 1971 and replaced with land quality (Mausel, 1971) and land evaluation. Soil quality influenced the crop production as well as soil fertility that is determined based on the nutrients existing in the soil. Bangladesh, a deltaic plain low and flat topographic country (except some hilly areas), faced severe salinity intrusion in its 148 upazilas of the entire coastal floodplain region (Haque, 2006) and affects both soil and water (Khanam *et al.,* 2020). This salinity concentration increases in winter season both surface and ground water (Dasgupta *et al*., 2014) as well as soil and moves from one area to another area through leaching and runoff of water and reduces the crop production (Haque, 2018; Qadir *et al.,* 2014; Munns and Gilliham, 2015; Hossain *et al.,* 2015). In addition, soil salinization through land inundation is also observed from shoreline to the inland areas because of frequent tidal surges and about one-third of the coastal areas of the country is directly affected by tidal surges and flooding during the rainy season (Kawser *et al*., 2022). Likewise, globally 600 million people are living in low laying coastal zones and (in) directly victimized of salinity (Haque, 2018; Payo *et al.,* 2017; Dasgupta *et al.,* 2015). Excessive soil salinity strongly degraded the soil quality and surface soil had negatively affected agricultural production (Corwin and Yemoto, 2017; Haque, 2006) as well as reduces the crops yields. Rahman *et al.* (2017a) claimed about 0.83 million hectares of agricultural land are affected by salinity intrusion and tidal flooding. Rasheed (2016) claimed that the central coast (Noakhali region) is the most dynamic because of continuous (de)formation and erosion of landmass round the year. SRDI (2010) studied that saline area had increased from 0.883-1.056 million hectares in the coastal regions of Bangladesh since the last four decades. The total 710 kilometers coastline of Bangladesh are parallel to the Bay of Bengal and declared as the most victimized among 22 coastal countries in the world (Kawser *et al.,* 2022). Bangladesh Water Development Board (BWDB) constructed a closure dam on the little Feni River in 2016 to protect salinity intrusion into the agricultural land from the sea water (Mushfika and Rahman, 2018). BWDB seemed that soil fertility and quality would be improved after construction of closure dam and ultimate goal is the increase of agricultural production. Several research were done by Kawser *et al.* (2022); Rahman *et al.* (2018); Saroar (2014); Rahman *et al.* (2014) on salinity of the coastal areas of Bangladesh and Dasgupta *et al.* (2015) claimed the salinity impacts on agricultural production which indicated the indirect research on soil quality. In addition, the research conducted on physio-chemical properties of soil of two coastal district Barishal (Khan *et al.,* 2020), and Khulna (Zafar *et al.,* 2015) Bangladesh. But best of our knowledge, there is no research conducted in our study area to find out the soil quality after constructing the closure dam. So, the objective of this scientific research was to assess the soil quality, based on the variables, i.e., P^H, total organic carbon, total organic matter, total nitrogen, phosphorous, potassium, electrical conductivity, salinity and total dissolved solids, after constructing the closure dam on little Feni River of Musapur Union of Noakhali District in Bangladesh.

MATERIALS AND METHODS

Description of the study area

About 147 upazilas of 19 districts are declared as coastal zones divided into exposed and interior (PDO-ICZMP, 2003) coastal area of the country which covers about 20% of total land area (Haque, 2018). The study area Musapur Union in Companiganj Upazila of Noakhali District is located in South east part of the Chattagram Division of Bangladesh (Fig. 1a). The total area of Companiganj Upazila are 305.33km^2 that lies between 22°37'-22°54'N latitudes and 91°10'-91°31'E longitudes which is bounded by Senbagh Upazila of Noakhali and Daganbhuiyan Upazila of Cumilla District on the north, Subarnachar Upazila of Noakhali District and Sandwip Upazila of Chattagram District on the south, Sonagazi Upazila of Feni District and Mirsharai Upazila of Chattagram District on the east, Noakhali Sadar and Kabirhat Upazila of Noakhali District on the west (Banglapedia, 2021). The total population of this upazila are 2.5 lakhs (BBS, 2011) and major occupation of this area was agricultural activities and soil fertility was reduced due to salinity intrusion.

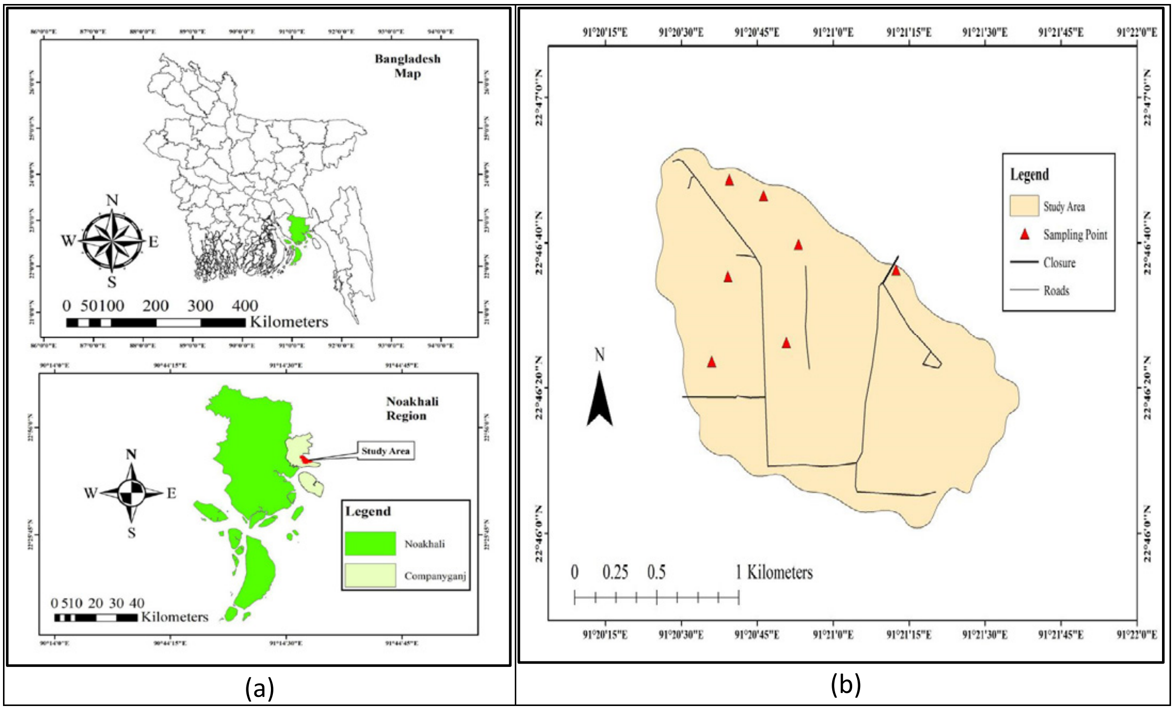

Fig. 1: Map of the study area (a) Companiganj Upazila (b) sampling points of Musapur Union (Base map was retrieved from LGED (2019)

Soils of the study area

The study area is very dynamic due to erosion and accretion of land masses with continuous circulation of water. This district is basically divided into two special characteristics, i.e., young charland and old charland; formed by the upstream sedimentation from Himalayas (Brammer, 2012) and continuously formed new regions and expanding to southwards (Das *et al.,* 2020). The mean elevation ranges from 2-9 meters for young charlands and 9-35 meters for old matured charlands from the mean sea level (Kawser *et al.,* 2022). More than 90% of annual total rainfall occurs in the monsoon period, from March to October (Rahman *et al.,* 2014). Brammer (2012) told that the majority portion of young soil of Noakhalli is classified as calcareous alluvium and comparatively old mature soil is dark grey to grey types in the old flood plain area. Deep loamy soils are also existed in this area. In the dry season, the top soil is turned into saline because of the evaporation of the moisture content and in the wet season, peripheral zones of river and coasts are likely to be saline round the year because of the continuous flooding and tidal surges (Kawser *et al.,* 2022). This south-central coastal zone is already a victim of excessive salinity in the inland which is very harmful for agricultural production and coastal fresh water fish farming (Paul, 2011).

Samplings

A total of 21 soil samples (400-500g from each location) were collected at the depth of 10-15 cm during June-July 2019 from 7 different geographical locations (Table 1 and Fig. 1b) to justify the soil's fertility which almost covered the entire area. The soil samples were put into individual polythene bags with proper marking and tagging. Then, samples were brought to Soil Resource Development Institute (SRDI), Noakhali regional laboratory for analysing the properties.

Lab experiment and analysis

Nine soil quality parameters, such as, pH, total organic carbon (TOC), total organic matter (TOM), total nitrogen (TN), potassium (K), phosphorous (P), electric conductivity (EC), salinity and total dissolved solids (TDS) were tested to perform the study. This

Table 1. Geographical position of sample sites and methods of parameter/indicators for experiments

ID	Latitude (°N)	Longitude (°E)	Parameter/ Indicators	Symbol	Unit	Methods
S-1	22.776751°	91.353427°	Soil pH	pH	unitless	pH meter
S-2	22.777721°	91.348067°	Total organic carbon	TOC	percent	Titrimetric
S-3	22.779577°	91.34616°	Total organic matter	TOM	percent	TOC x 1.73*
S-4	22.78019°	91.344298°	Total nitrogen	TN	percent	TOM x 0.05*
S-5	22.776499°	91.344216°	Potassium	K	ppm	Spectrophotometer
S-6	22.773226°	91.343316°	Phosphorous	P	ppm	Spectrophotometer
S-7	22.773951°	91.347419°	Electrical conductivity	EC	(dS/m)	Digital EC meter
			Salinity	S	ppt	Salinity meter
			Total dissolved solids	TDS	ppm	Digital EC meter

* Van Bemmelen factor used for conversion of TOM and TN

investigation also determined the relationship among all tested parameters and five parameters were compared with the recommended standard reference value. These variables were tested by glass electrode pH meter (HI 3220) with dilution of water (1:2.5) determined by Debi *et al.* (2019), titrimetric, Van Bemmelen factor, Spectrophotometer (Lambda 365 UV/Vis, Perkin Elmer, USA), conductivity meter (Mi 170 Bench Meter, Martini instruments, Italy) and salinity meter, respectively (Table 1). The data were analyzed by using Special Packages for Social Sciences (version 22.0) and maps were produced by using Arc GIS software (version 10.3).

RESULTS AND DISCUSSION

pH

The pH is the indicator of soil alkalinity and acidity in any area. It is ranged between 0-14 of which value 7 is the neutral. The pH of soil samples was ranged between 7.19-8.5 with mean of 8.136±0.169 (Fig. 2a). This result is consistency with 8.12 (Khan *et al.*, 2020) and inconsistency with 7.19 (Jafar *et al.*, 2015). The highest pH value of 8.45 was recorded in sample no. 5. The lowest pH value was observed at 7.91 in sample no. 3. Saline water intrusion, use of excessive chemical fertilizers, pesticides or other natural phenomena might be responsible for pH variation. The study revealed that 100% samples were exceeded the reference value (Table 2).

Total organic carbon, total organic matter and total nitrogen

Total organic matter is very prominent for the determination of soil quality by which possible to equilibrium state of air-water and reduces soil erosion as well as increases the fertility (Peraza *et al.*, 2017). The organic matter is >1.29% for the good quality of soil. Total nitrogen is another essential nutrient for growing plants. Plants absorb nitrogen in the form of either NO_3^- or NH_4, which are significantly develop the plants and increase the growth and ultimately accelerate the crop production (Legheri *et al.*, 2016). Sometimes, 50% of nitrogen loses from soil due to leaching, or volatilization (Osmond and Kang, 2008). The study result showed that the TOC, TOM and TN were ranged between 0.27-1.07%, 0.5-1.82% and 0.02-0.09%, respectively (Fig. 2b, 2c and 2d). It also represented the highest TOC at the second sampling station, while highest TOM and TN were observed at the same sampling station. Another point of view that 28.57% sampling station's TOC were within the standard reference value and 71.43% sampling station's TOC were exceeded the reference level. In addition, TN was under the reference level for 100% samples that might be very poor quality of soil and responsible for low plant growth. The mean of TOC, TOM and TN were 0.506±0.278%, 0.873±0.465% and 0.044±0.023%, respectively (Table 2). The result was almost consistency with Jafar *et al.* (2015) for TN (0.20%) and TOC (0.82%).

Phosphorus, potassium, electrical conductivity, salinity and total dissolved solids

Phosphorous should be reduced due to prolonged cultivation or cropping diversification/ intensification (Grant *et al.*, 2002) without considering/balancing the concentration and should be reduced naturally for intense soil weathering (Hongwei *et al.*, 2003). It

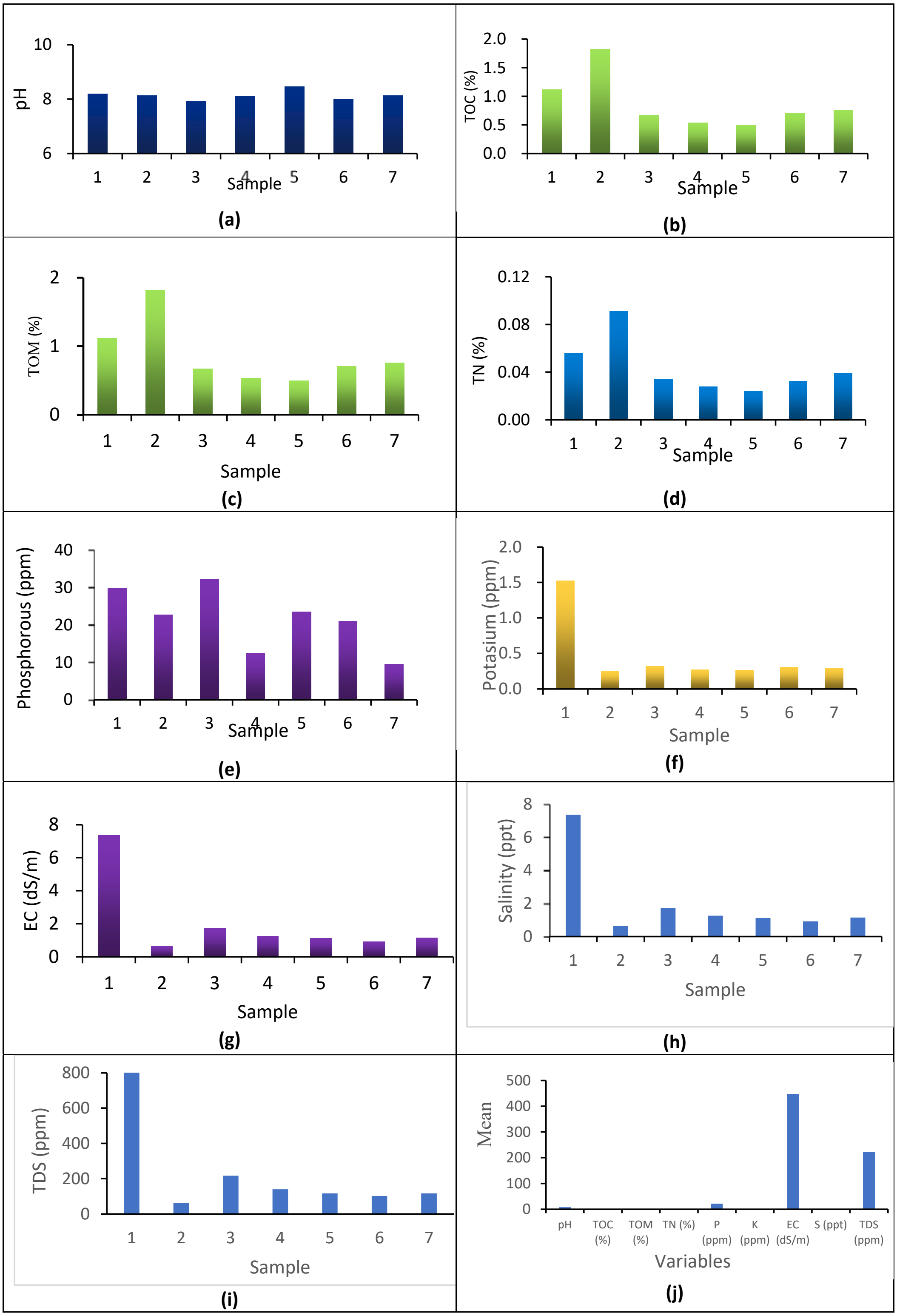

Fig. 2: Station wise value of (a) pH, (b) TOC, (c) TOM, (d) TN, (e) Phosphorous, (f) Potassium, (g) EC and (h) Salinity (i) TDS and (j) mean of variables of all soil samples

Table 2. Statistical analysis of different soil parameters

Sample	pH	TOC (%)	TOM (%)	TN (%)	P (ppm)	K (ppm)	EC (dS/m)	S (ppt)	TDS (ppm)
1	8.2	0.65	1.12	0.06	29.78	1.53	1625	7.37	802.33
2	8.14	1.07	1.82	0.09	22.73	0.25	123.23	0.64	63.57
3	7.91	0.41	0.67	0.03	32.19	0.32	408.37	1.72	216.57
4	8.11	0.31	0.54	0.03	12.52	0.27	281.87	1.26	139.97
5	8.45	0.27	0.5	0.02	23.55	0.27	234.43	1.12	116.33
6	8.01	0.38	0.71	0.03	20.97	0.31	204.01	0.92	101.87
7	8.14	0.44	0.76	0.04	9.45	0.3	248.46	1.15	116.5
Range	8.14-8.45	0.27-1.07	0.50-1.82	0.02-0.09	9.45-32.19	0.25-1.53	123.23-1625	0.64-7.37	63.57-802.33
Mean	8.136	0.506	0.873	0.044	21.599	0.462	446.481	2.024	222.448
SD*	0.169	0.278	0.465	0.023	8.312	0.47	526.769	2.382	259.927
SRV**	6.5	-	0.63	0.27-0.36	22.51-30.0	0.27-0.36	-	-	-

*SD represents standard deviation and **SRV indicates standard reference value derived from Rahman *et al.* (2017b)

is a strong positive relationship between crop growth and phosphorous fertilizer as well as called energy dynamics (Osmond *et al.*, 2008) in the soil. Potassium is also essential for growth and reproduction of plants which helps to overcome winter hardness, drought stress, increase disease resistance (Brady and Weil, 2016). The study depicted that the phosphorus and potassium were ranged between 9.453-32.19 ppm and 0.25-1.53 ppm, respectively (Fig. 2e, 2f) with a mean of 21.599±21.59 ppm and 0.462±0.47 ppm. The phosphorous concentration was consistency with Jafar *et al.,* (2015), 0.20 ppm. The result also observed that all the values of phosphorous concentrations were within the standard reference value except third sampling station which indicated the sufficient phosphorous were present in the soil and soil quality was good for crop cultivation. The potassium concentrations of all soil samples were found within the standard reference (acceptable values 0.27-0.36 ppm), except first sampling station. Based on these results it was told that the soils were good for cultivation in the Musapur Union of Noakhali District. Excessive salinity is very harmful for the proper growth of plants and could not always tolerate. The electrical conductivity (EC), salinity and total dissolved solids (TDS) of the soil ranged between 123-1625 ds/m, 0.64-7.37 ppt and 63.57-802.33ppm, respectively with a mean of 446.48±526.76 dS/m, 2.024±2.382 ppt and 222.45±259.93 ppm (Table 2).

Pearson correlation matrix

The Pearson correlation matrix showed statistically strong positive relationship between TOM: TOC (r=0.999), TN: TOM (r=0.998), K:EC (r=0.991), salinity: K (r=0.994), K: TDS (r=0.989) and salinity: TDS (r=0.999), respectively with a significance level of $p \leq 0.01$ which might be the indication of homogeneous sources of these variables in the study area. The perfect strong relationship (r=1.0) was observed between EC: TDS and salinity: EC which meant the same sources of these variables were present in the soil. The phosphorous was positively correlated with K, EC, salinity and TDS with significance level of $p \leq 0.05$ (Table 3).

ANOVA (analysis of variance) test was performed to control the important effects of variables of different sampling sites. Each soil quality parameter was considered as dependent variable and seven locations were considered as explanatory variables. The probability of significance (p>0.05) was termed as insignificant. The study resulted the significant difference among nine parameters from seven sampling sites. These were pH=25.505 (p< 0.000), TOC=18.011 (p< 0.001), TOM=14.013 (p< 0.003), TN=23.478 (p< 0.000), phosphorus=29.393 (p< 0.000), potassium=17.924 (p< 0.001), EC=4.939 (p< 0.046), salinity=9.502 (p< 0.009) and TDS=4.944 (p< 0.046), respectively (Table 4). Finally, the researcher concluded that seven different locations had

Table 3: Correlation among different variables of soil samples

	pH	TOC	TOM	TN	P	K	EC	S	TDS
pH	1	-0.076	-0.058	-0.055	-0.104	0.132	0.098	0.119	0.086
TOC		1	.999**	1.000**	0.21	0.205	0.134	0.147	0.134
TOM			1	.998**	0.208	0.205	0.129	0.143	0.129
TN				1	0.195	0.207	0.136	0.149	0.135
P					1	.444*	.476*	.467*	.494*
K						1	.991**	.994**	.989**
EC							1	1.000**	1.000**
S								1	.999**
TDS									1

** Significant at the 0.01 level (2-tailed) and *0.05 level (2-tailed).

Table 4: Analysis of variance (ANOVA) for soil samples

Parameter	F value	Significance value (p)
pH	25.505	0
TOC	18.011	0.001
TOM	14.013	0.003
TN	23.478	0
Phosphorus	29.393	0
Potassium	17.924	0.001
EC	4.939	0.046
Salinity	9.502	0.009
TDS	4.944	0.046

significantly influenced the value of all measured parameters in the study area.

Distribution of the variables

The distribution of eight selected variables was presented in Fig. 3. The pH distribution was increased from south eastern to north western parts of the study area. The similar distribution of TOC, TOM and TN were found and the pattern was increased from south western to north eastern parts of the Musapur Union. The distribution of phosphorous was decreased from north to south and potassium was increased from western to eastern zones of the study area. The TDS and EC were showed almost same pattern that increased from north eastern to western zones of the study area (Fig. 3).

Cluster analysis

Cluster analysis was applied by Ward method to find out the sources of the variables. Same cluster showed same sources of variables and the study resulted that the same cluster for pH, TOC, TOM, TN, K, P and salinity (NaCl) indicating the same sources of origin, representing manmade activities, might be use of chemical pesticide or chemical fertilizer used for agricultural activities. Another cluster was found for EC and TDS in the study (Fig. 4).

The salinity, TDS and EC of the study area were highest for first sampling station (outside the dam), followed by other sampling stations (inside the dam). The present study demonstrates that the mean concentrations of soil parameters of pH, TOC, TOM, TN, P, K, EC, salinity and TDS were 8.1, 0.506%,

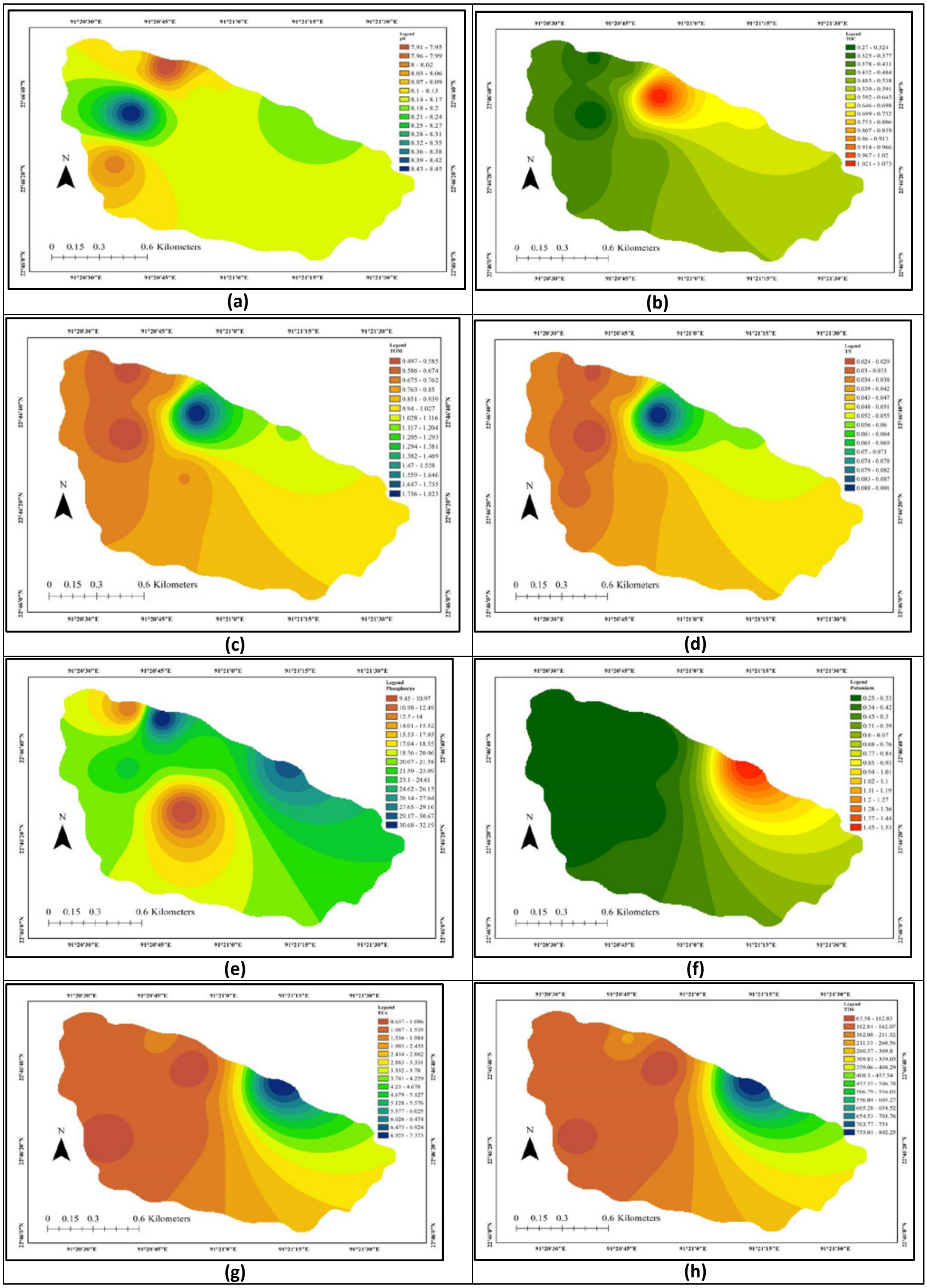

Fig. 3: Distribution of (a) pH, (b) TOC, (c) TOM, (d) TN, (e) Phosphorous, (f) Potassium, (g) EC and (h) TDS

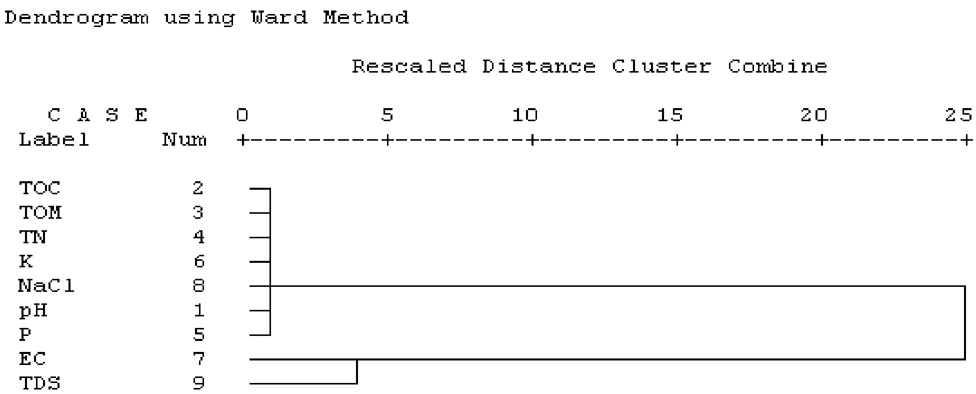

Fig. 4: Hierarchical cluster analysis

0.873%, 0.044%, 21.599 ppm, 0.462 ppm, 446.481 dS/m, 2.024 ppt and 222.448 ppm, respectively. Strong positive relationship was found between TOM: TOC, TN: TOM, K:EC, salinity: K, K: TDS and salinity: TDS with a significance level of $p \leq 0.01$ which might be the indication of homogeneous sources of these variables in the study area and perfect strong relationship (r=1.0) was observed between EC: TDS and salinity: EC. This meant the same sources of these variables were present in the soil. The phosphorous was positively correlated with K, EC, salinity and TDS with significance level of $p \leq 0.05$.

CONCLUSION

There was a severe soil salinity (7.37 ppt) outside the dam (sample 1) and the salinity is reduced (0.64-1.72 ppt) inside the dam after constructing the closure dam. The study result showed that the quality of soil around Musapur closure was improved, as a result agricultural production should be increased in this study area. The study concluded that the seven different locations had significantly prejudiced with the value of nine examined parameters. The findings also stated that the soil quality is deteriorated due to the presence of excessive concentrations of different inorganic chemicals as well as pesticides and fertilizers. The spatial distribution showed the increasing pattern of variables in thee inside area of closure dam. Likewise, the soil quality will be increased near future. The limitation of this research is that we conclude the study only based on nine variables. It should not be always performing the same result when considering more variables and further extensive analysis should be done for taking heavy metals in the soil to formulate a soil health card as well as soil quality. So, proper maintenance and monitoring should be helpful for sustaining the current soil quality in the study area.

AUTHOR'S CONTRIBUTION

M.S. Khan was responsible for methodology, supervision, reviewing, editing, critically revised and rewriting the manuscript. Author I.J. Mousumi was responsible for data curation, lab experiment, data analysis and reviewing the manuscript. Author M.H. Jaman and M.M. Billah were responsible for draft writing, critically reviewing, editing and proof reading the manuscript. All authors read and approved the final manuscript.

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CONFLICT OF INTEREST

The authors declare that there are no competing interests regarding publishing this scientific article. In addition, the ethical issues, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

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ABBREVIATIONS

%	Percentage
ANNOVA	Analysis of variance
BWDB	Bangladesh Water Development Board
dS/m	Deci-Siemens per meter
EC	Electrical conductivity
Fig.	Figure
GIS	Geographical Information System
K	Potassium
LGED	Local Government Engineering Department
NO_3^-	Nitrate ion
NH_4^+	Ammonium ion
P	Phosphorous
p	Significance level
ppm	Parts per million
ppt	Parts per trillion
r	Pearson correlation coefficient
S	Salinity
SD	Standard deviation
SPSS	Statistical Package for Social Science
SRDI	Soil Resource Development Institute
SRV	Standard reference value
TDS	Total dissolved solids
TN	Total nitrogen
TOC	Total organic carbon
TOM	Total organic matter

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