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RESEARCH ARTICLE

CHANGES IN SOIL PHYSICO-CHEMICAL PROPERTIES AND FERTILITY STATUS OF LONG-TERM CULTIVATED SOIL: A CASE STUDY IN SOUTHWESTERN BANGLADESH

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ABSTRACT

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Sustainable soil management is essential for maintaining soil health properly for future production. A comparative study was carried out at Dumuria soil series in Khulna district to observe the current fertility and physical changes of soils over a period of time due to different land use. The soil physical (Soil Texture, Water Holding Capacity, Bulk Density and Total Porosity) and chemical (Nitrogen (N), Phosphorous (P), Potassium (K), Sulfur (S), Soil Organic Matter (SOM), Soil Organic Carbon (SOC) along with Cation Exchange Capacity (CEC), Sodium Absorption Ratio (SAR), Exchangeable Sodium Percentage (ESP), Base Saturation Percentage (BSP), %Salt) properties were determined. Except for the control, all the soils had silt loam texture. Water holding capacity varied from (33.57%±3.3 to 55.57±5.2) % and all soil indicated good porous soil (average 47±5.59)%. Soil pH (5.96 to 7.4) indicated that the soils were neutral to alkaline in nature and had an average salt content of (0.11±0.05) %. SOM was higher in natural vegetative soil (2.45±0.46) % and decreased over the period of land use for cultivation. In terms of ESP and SAR, 50 to 10 years cultivated soil showed the highest value and a significant difference was observed among the treatments ($p \leq 0.05$). In BSP, 100 to 50 years cultivated soil showed the highest value and uncultivated soil showed the lowest value and statistically insignificant among treatment ($p \leq 0.05$). Overall observation showed that long term land use reveals a significant decline of soil quality. So, sustainable soil management should be incorporated for addressing soil fertility management.

KEYWORDS

Water holding capacity, Bulk density, Porosity, CEC, SAR.

1. INTRODUCTION

Soil health is a key factor for increasing agricultural production. This called for long-term studies at fixed sites for monitoring changes in soil fertility status. The rapidly increasing human populations and their needs of the land for various agricultural activities have brought about extensive land use changes and soil management practices throughout the world [1]. It has been found that long-term cultivation results in a statistically significant decrease in the total amount of soil organic matter (SOM) along with concentrations of all carbon compounds [2]. Agricultural sustainability requires periodic evaluation of soil fertility status. This is important in understanding factors which impose serious constraints to increased crop production under different land use types and for adoption of suitable land management practices [3]. However, information about the effects of land use changes on soil physico-chemical properties is essential in order to present appropriate recommendations for optimal and sustainable utilizations of land resources. Soil physical and chemical properties play a central role in transport and reaction of water, solutes and gases in soils, their knowledge is very important in understanding soil behavior to applied stresses, transport phenomena in soils, hence for soil conservation and planning of appropriate agricultural practices. The anthropogenic changes in land use have altered the characteristics of the Earth's surface, leading to changes in soil physico-chemical properties such as soil fertility, soil erosion sensitivity and soil moisture content [4]. These changes may be caused by soil compaction that reduces soil volume and consequently lowers soil productivity and environmental quality [4]. Soil physical and chemical properties have been proposed as suitable indicators for assessing the effect of land-use changes and management [5,6]. This approach has been used extensively by several authors to monitor land-cover and land-use change patterns [7-9]. Therefore, this study was carried out to in order to evaluate the influence of different land use on soil physicochemical properties in soils of Dumuria Upazilla, Khulna, Bangladesh.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experimental site was at Chechuria village in Dumuria Upazilla under Khulna district (22°39'00''N 89°15'00''E and 22°56'00''N 89°32'00''E). Five sites have been chosen where 4 were from different ages of agricultural field and one was from uncultivated soil. All soils are in Dumuria soil series. In Table 1, details of sampling code are presented.

Table1: Site coding at different stages of soil and its cropping pattern in Dumuria Upazilla

Farming status	Stages of soil	Sampling code	Land use pattern
Under Cultivation	>100 years	A	Rice-Rice-Rice Wheat-Rice-Rice
	100-50 years	B	Wheat-Rice-Rice Vegetable-Rice-Rice
	50-10 years	C	Rice-Fallow-Rice Wheat-Fallow-Rice
	<10 years	D	Rice-Rice-Rice Rice-Rice-Fallow
Non-cultivated soil	Control	E	Natural vegetation

2.2 Collecting, processing and storing of soil site

Composite soil sites were collected from 0-15 cm then air dried, grinned and passed through 2 mm sieve for nutrient analysis. Three replications were taken for the study and sites were sent to the laboratory of Soil, Water & Environment Discipline, Khulna University for physico-chemical analyzes.

2.3 Analytical procedure of soil physicochemical properties

Chemical characterization of the sited soils included the analysis of organic matter (SOM), organic carbon (SOC), cation exchange capacity (CEC) at pH 7.0, base saturation, soil EC, soil pH, nitrogen, phosphorous, potassium and sulfur; whereas the physical characterization consists of particle size analysis, soil structure, water holding capacity (WHC), bulk density (BD) and total porosity (PT) determination. The sites were allowed to dry in the open air until reaching friability. The organic carbon was determined using the Walkley - Black wet oxidation procedure and the soil organic matter content was determined from the organic carbon [10]. Soil pH was determined in distilled water using the pH meter with water ratio of 1:2. Available phosphorus (P) and exchangeable cations were determined. Available P was determined by Bray-1 extraction followed by molybdenum blue colorimetry [11]. The exchangeable potassium (K^+) and sodium (Na^+) were determined by flame photometry [12,13] where exchangeable magnesium (Mg^{2+}) and calcium (Ca^{2+}) were determined by atomic absorption spectrophotometer after extraction with 1M KCl 1.0 mol l^{-1} [14]. The cation exchange capacity (CEC) at pH 7.0 was determined following the procedure described by Reeuwijk (2002) [15]. Soil particle sizes were determined using the hydrometer method described in Agbede and Ojeniyi (2009) [16] and classification was carried out using the USDA classification system [17]. Soil water holding capacity (WHC) was determined following the method described by Ibitoye (2006). The bulk density (BD) was obtained by the gravimetric soil core method described by Blake and Hartage, 1986 [18] and the particle density (PD) was assumed to be 2.65 g cm^{-3} [19-22]. The total porosity (PT) was obtained from BD and PD using the equation and relationship developed by Danielson and Sutherland (1986) [23].

$$\% \text{ Porosity} = (1-(BD/PD) \times 100)$$

where: BD = Bulk density and PD = Particle density (= 2.65 Mg/m^3). The default value of 2.65 Mg/m^3 is used as a 'rule of thumb' based on the average bulk density of rock with no pore space [24].

$$BSP (\%) = [(\text{Summation of } Ca^{2+}, Mg^{2+}, K^+ \text{ and } Na^+ \text{ content in cmolc /kg soil}) \div \text{CEC (cmolc /kg soil)}] \times 100$$

$$SAR = [Na^+] \div (\sqrt{½ \{[Ca^{2+}] + [Mg^{2+}]\}})$$

$$ESP = ([Na^+] \div CEC) \times 100$$

Where, BSP is base saturation percentage SAR is sodium absorption ratio and ESP is exchangeable sodium percentage. Percent of salt presented in the soil was determined by the following equation:

$$\text{Salt} (\%) = 0.064 \times EC$$

2.4 Statistical Analyses

The statistical analyses of the analytical results obtained from soil sites were performed as described by Zaman et al., (1982) [25]. One way ANOVA (SPSS version 16.0) [26] was used to test for significance among the treatment means and post hoc comparison was used to compare the soil chemical properties from the different land uses.

3. RESULTS

3.1 Soil Physical properties

Soil physical properties are presented in Table 2. All cultivated soils had a silt loam texture. Bulk density of the sites ranged from 1.63 to 1.26 g/cm^3. The highest bulk density was observed in site C and the lowest observed in site B. The water holding capacity (WHC) of all soil sites ranged widely from 33.57% to 55.57%. The average WHC was significantly affected by land uses (*p≤0.05*). The highest WHC value (55.57%) was recorded in control soil. The average porosity ranged from 38% to 52% that indicates all soils are good porous except site C.

Table 2: Summary statistics for surface soil physical parameters under different land uses

Site code	Sand (%)	Silt (%)	Clay (%)	Textural Class	WHC (%)	BD (g/cm³)	Porosity (%)
Statistics	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**	**Mean± SD**	**Mean ± SD**	**Mean ± SD**
A	23±1.27bc	60±2.75a	17±0.9c	Silt loam	33.57±3.3c	1.34± 0.05ab	49±1.33ab
B	25±1.4b	48±2.9ab	27±1.2b	Silt loam	39.57±4.3bc	1.26± 0.07c	52±1.87a
C	12±1.8c	51±3.4ab	37±2.3a	Silt loam	41.57±3.4b	1.63± 0.02a	38±0.53b
D	23±1.6bc	54±4.5ab	23±1.76bc	Silt loam	46.43±4.4ab	1.39± 0.04b	48±1.07ab
E	30±1.95a	33±3.2b	37±1.65c	loam	55.57±5.2a	1.31± 0.04ab	51±1.07a

3.2 Soil chemical properties

The results of the chemical properties of the site soils were presented in Table 3. The average pH value of all sites ranged from 5.96 to 7.4 that indicated medium acidic to mildly alkaline pH. The soil organic carbon (SOC) of site soils varied from 0.27% to 1.42% and soil organic matter (SOM) of site soils varied from 0.47 % to 2.45%. The organic carbon which is an index of the soil organic matter differs among the different land uses. The SOC was found higher in control soil. The total nitrogen of all sites ranged from 0.83% to 2.9%. The highest value observed in control soil and the lowest value observed in site B. The available phosphorus of all sites ranged from 3.73 mg/kg to 12.16 mg/kg. Site D slightly have lower values than soils where as site B showed the highest value. The potassium of all sites ranged from 26.05 mg/kg to 120.91 mg/kg. The highest value observed in site A and the lowest value observed in site C. The sulfur concentration of all sites ranged from 14.74 mg/kg to 75.79 mg/kg. The highest value observed in site C and the lowest value observed in control soil. The cation exchange capacity (CEC) of all sites ranged from 5.52 cmolc/kg to 8.75 cmolc/kg. The highest value observed in control soil and the lowest value observed in site D. The sodium absorption ratio (SAR) of all sites ranged from 0.074 to 0.096. The highest value observed in site C and the lowest value observed in site A. The Exchangeable sodium percentage (ESP) values ranged from 2.14% to 2.95%. In all sites, Base saturation percentage (BSP) ranged from 76.95% to 84.83%.

Table 3: Summary statistics for surface soil chemical parameters under different land uses

	Sites				
	A	**B**	**C**	**D**	**E**
Soil Parameters	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**
pH	5.96±0.30c	6.6±0.39b	7.4±0.45a	6.16±0.6b	6.25±0.5b
EC (ds/m)	1.18±0.03ab	1.83±0.04ab	2.7±0.06a	0.52±0.024b	2.25±0.035a
SOC (%)	0.72±0.07ab	0.27±0.03b	1.09±0.06a	0.31±0.04b	1.42±0.12a
SOM (%)	1.24±0.11bc	0.47±0.12c	1.88±0.18b	0.54±0.15c	2.45±0.46a
Total Nitrogen (%)	2.30±0.87b	0.83±0.14c	2.37±0.89b	1.33±0.72bc	2.9±0.94a
Available Phosphorus (mg/kg)	9.92±1.13b	12.16±2.2a	11.01±1.7a	3.73±0.9c	3.89±0.6c
Potassium (mg/kg)	120.91±7.7a	44.08±3.32b	26.05±2.2c	45.34±3.87b	76.83±6.45ab
Sulfur (mg/kg)	23.58±3.34bc	45.05±6.65b	75.79±3.5a	57.26±5.58ab	14.74±2.89c
CEC (cmolc/kg)	4.78±1.23bc	5.18± 1.03b	5.52± 1.01b	4.65± 1.03c	8.75± 1.05a

SAR	0.074±0.02b	0.095 ± 0.039a	0.096± 0.023a	0.074 ± 0.04b	0.089±0.031ab
ESP (%)	2.71± 0.75ab	2.65± 0.68ab	2.95± 0.98a	2.14± 0.64b	2.48±0.88ab
BSP (%)	78.68± 11.94bc	84.83± 11.94a	80.79± 10.94b	79.80± 14.94b	76.95± 13.94c
%Salt	0.08±0.02ab	0.12±0.06ab	0.17±0.04a	0.03±0.001b	0.14±0.01a

3.2.1 Correlation between soil properties

There was a considerable degree of correlation among various chemical properties measured that was presented in Table 4. The linear correlation analysis of the 5 soil chemical properties for the study area, showed a significant correlation soil attribute pairs (*p≤0.01; p≤0.05*) (Table 4).

Table 4: Correlation Matrix: N (mg/g), P (mg/kg), k(mg/kg), S (mg/kg), Ca (%), Mg (%), % OC, % OM, %S with %OC and %OM

N P K S Ca Mg
% OC % OM
% SOC 0.566 0.204* 0.656 -0.007 0.710 0.657* 1
0.955** 0.524 0.020 0.983** 0.010 0.020
1
% SOM 0.563* 0.206 0.655* -0.005 0.708 0.659
1* 1
0.957** 0.522** 0.021 0.989** 0.010 0.020 0.01
1

Cell Contents: Pearson correlation, P-Value (**p≤0.01 & **p≤0.05*)

4. DISCUSSION

In studying physical parameters, it can be stated that all soils are good in texture and porous but site C contained more clay that indicated less chance of forming soil pores. This is due to long term soil tillage affects on soil particle size. Gülser et al. (2016) [27] reported that heterogeneity and variation of soil physical parameters in a field due to soil plowing should be taken into consideration for a successful agricultural management. [20]. Bulk density is a good indicator of soil porosity. Bulk density is primarily affected by soil texture [28] since well graded soils containing both fine and coarse particles results in a higher number of contact points than in a poorly graded soil [29]. Soil organic matter (SOM) acts as a sponge in the soil, thereby retaining soil moisture. Organic matter intimately mixed with mineral soil materials has a considerable influence in increasing moisture holding capacity [30]. The studied soil contained less amount of organic matter, so the water holding capacity was also moderate. ANOVA table presents that the WHC of the sites was not homogenous and there was a significant difference among the treatments (*p≤0.05*). The pH level of the soil directly affects soil life and the availability of essential soil nutrients for plant growth. Factors such as parent material, rainfall, and type of vegetation are dominant in determining the pH of soils. Analysis of variance of the soil properties between land uses showed that the pH distribution was also not homogenous (*p≤0.05*) among the different treatments. In terms of soil EC, the average value indicated non saline to slightly saline characteristics. Percent salt also indicated that all soil sites carried minimal amount of salt that showed good soil behavior. Analysis of variance of the soil properties between land uses showed that the EC distribution is also not homogenous (*p≤0.05*) among the different treatments. The nitrogen value significantly differed among the land uses (*p≤0.05*). Site E showed the highest value. This may due to higher nitrogen mineralization of nitrogen in the natural vegetative soil due to continuous addition of organic matter. Sommerfeldt, (1988) [2] found that long-term annual manure applications increase soil organic matter and nitrogen that is very similar to the result. The available phosphorous value significantly differed among treatments (*p≤0.05*). Site E showed the lowest value. This may due to the availability of phosphorus under most soils decline by the impacts of fixation, abundant crop harvest and erosion [31,32]. Soils with inherent pH values between 6 and 7.5 with moist and warm conditions are ideal for P-availability, while pH values below 5.5 and between 7.5 and 8.5 limits P-availability to plants due to fixation by aluminum, iron, or calcium, often associated with soil parent materials [17]. The potassium value also significantly differed among treatments (*p≤0.05*). Site C showed the lowest value. This may due to the decrease clay content creating barrier to build water-stable aggregates thus decrease K content that supports the study of Zhang and He, (2014) [33]. The sulfur content was significantly different among treatments (*p≤0.05*). Because of uncultivated soil, site E slightly had lower values due to no addition of sulfur containing fertilizer.

The CEC value was significantly different (*p≤0.05*). The highest value observed in control soil which may be due to their high organic matter content From our observation, high CEC values were found in soils with high organic matter content and clay particles. This shows that CEC is mainly dependent on soil clay minerals and organic matter [34] and silt to a lesser extent [35]. There is a strong correlation between the CEC values, and the amount of organic matter present in the soil as Organic matter is a major source of negative electrostatic sites. The research findings conform to the works of [36] who all reported that soil samples with higher values of CEC were found to have high levels of organic matter and pH levels. Likewise, in any given soil, soil pH; type, size and amount of clay; and amount and source of the organic material influenced the number of exchange sites [35]. The BSP and ESP content were significantly different among the land uses (*p≤0.05*). Soils with 70% or greater BS are unlikely to limit agronomic crop growth due to acidity. Base saturation was higher in all sites that indicated future possibilities of limiting crop production. Soils that have more than 6% ESP are considered to have structural stability problems related to potential dispersion [37]. But the average value of the experimental sites was below the critical limit that indicated soils had no problems in structural stability.

In Table 4, correlation matrix among the chemical parameters, soil organic carbon (%SOC) and soil organic matter (%SOM) was done. All properties were positively correlated with SOC & SOM and statistically significant except sulfur (*p≤0.05*). Number of studies has reported similar observations. Overall studied revealed that soil SOC, SOM, total N, WHC are continuously decreasing in terms of land use pattern whereas other nutrients are increasing. Yimer et al. (2007) [38] in Ethiopia also compared croplands, forestlands and grazing lands and found that soil organic C and total N decreased in croplands as compared to forestlands. Soils underlying native vegetation (e.g., undisturbed) generally feature high SOM, as a result of ample litter cover, organic inputs, root growth and decay, and abundant burrowing fauna [22].

5. CONCLUSION

This research evaluated and characterized physiochemical properties of soils of similar geological and climatic conditions but under different land uses in Southwestern Bangladesh. All soils were good porous and almost similar texture. The uncultivated soil held the highest organic matter and an indication of the affinity of organic matter for water. Soils with high organic matter content and clay particles demonstrated high CEC values. Uncultivated soil naturally had the highest organic carbon value as compare to cultivated soil. Long term land use significantly decline soil organic carbon thus impacts negatively on climate in global C-sequestration. In terms of ESP and SAR, site C showed the highest value and a significant difference was observed among the treatments (*p≤0.05*). In BSP, site B showed the highest value and site E showed the lowest value and statistically insignificant among treatment (*p≤0.05*). Overall observation showed that long term land use reveals a significant decline in soil quality. Land uses and soil management appear to be good predictor of soil fertility status. Success in soil management depends on the understanding of how the soil responds to agricultural practices over time. Future research is needed to develop a sustainable agriculture in the area i.e. adaptation of organic farming, soil conservation practice and so on. Soil nutrient dynamics analysis is also needed on year basis to evaluate the nutrition status of the studied soil.

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