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Chemical characteristics of soils under different land uses in a micro-watershed of Sundarban

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ABSTRACT

The study was undertaken in a micro-watershed of Sundarban with the aim to study some chemical properties of soil like organic carbon, pH, electrical conductivity (EC), cation exchange capacity (CEC), sodium adsorption ratio (SAR), exchangeable sodium percentage (ESP) as well as available total nitrogen (N), phosphate (P_2O_5) and potash (K_2O) and their interrelationships in double cropped, mono-cropped, grassed and barren lands under two (medium and low) land situations. Results revealed that organic carbon content, in general, was one of the prime factors in regulating most of the chemical properties of the soil. It varied from 0.20 to 0.48% among the land uses and was considerably higher in double and mono-cropped lands. Organic matter decreased pH in general and EC_e of the cropped lands as well, which varied from 0.4 -1.9 d Sm^{-1} indicating low salinity under these land uses. SAR and CEC were found to be relatively higher in low lands because of high clay content and the crop management practices. Thus both organic carbon and CEC played role in lowering EC_e. But, CEC increased linearly (r = 0.67) with the increase in pH as well as organic carbon (r = 0.66). However, as far as nutrient availability is concerned phosphate and potash availability was considerably higher in cropped lands.

Key words**:** Cation exchange capacity, electrical conductivity, land use, organic carbon, sodium adsorption ratio

Soil serves as a medium for plant growth by providing physical support and acts as a source of water, essential nutrients and oxygen for the plants. The suitability of soil for sustenance of plant growth and related biological activities is a function of physical properties like porosity, water-holding capacity, structure and tilth including chemical properties like nutrient supplying capacity, pH and salt concentration. In fact, a large number of physical, chemical and biological properties of soil are function of soil organic matter content. The quality of soil determines land use, sustainability and productivity and plays an important role not only in production of food, fuel and fiber but also in the maintenance of regional, national and international environmental quality. The necessity for development of a soil health index was stimulated by the perception that human health and welfare is associated with the quality and health of the soil (Haberern, 1992). Soil quality investigations are, therefore, essentially needed to provide information for resource management and regulatory decisions on land use system.

Very limited information on the quality of coastal saline soil of east coast of India is available, but it is meager for the deltaic ecosystem of Sundarban. Considering the ever-increasing population pressure, it has become imperative to change the existing agricultural scenario of the region with proper and effective management of its abiotic resources. The pre-requisite of developing and planning of any land and soil management system is to make a detail analysis, assessment and note on the quality and health of soil resources. The present study was, therefore, been considered essential to investigate the effect of various land use systems on chemical properties of soil and the relationship amongst them.

MATERIALS AND METHODS

The study was conducted in a micro-watershed of coastal Saline Zone of West Bengal, located at Kakdwip Block, lying between $21^0 32'$ and $22^0 40'$ N latitude and $87^0 30'$ and 89^0E longitude at about 3 m above mean sea level and 35 km away from the Bay of Bengal. Under low (LL) and medium (ML) land situations four land-use systems viz. (i) Double cropped land (L_1), (ii) Mono-cropped paddy land (L_2), (iii) Grassed/forested (L_3), and (iv) Barren (L_4) lands were taken into consideration.

Climate of the zone is subtropical humid. Mean annual rainfall ranges from 1450 to 1925 mm and more than 80% of it occurs during monsoon (June to September). Heavy rains usually occur in the month of July followed by August. Mean monthly maximum and minimum temperature are 32.5^0C and 15.5^0C respectively. The climate is normally hot except for a short winter span from December to January.

Composite soil samples (> 2 mm), collected from 0-15 cm depths of profile from each of the land uses following reconnaissance survey under both the land situations, were used for analyzing organic carbon, pH, electrical conductivity (EC), cation exchange capacity (CEC), sodium adsorption ratio (SAR), exchangeable sodium percentage (ESP) as well as available total nitrogen (N), phosphate (P_2O_5) and potash (K_2O).

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Organic carbon, determined following the method suggested by Jackson (1973), was converted to organic matter. pH and EC were determined using suspension of soil and water in 1:2.5 ratios respectively with pH-meter and Conductivity Bridge. Cation exchange capacity (CEC) was determined following the procedure suggested by Black (1965). Ca^{2+}, Mg^{2+}, Na^{+} ions were isolated from the soil complex with flame photometer to estimate SAR and ESP using following equations (Richards, 1954).

$$\mathrm{SAR}=\frac{\mathrm{Na}}{\sqrt{\dfrac{\mathrm{Ca}^{2}+\mathrm{Mg}^{2}}{2}}}$$

Where SAR = Sodium Adsorption Ratio and ESP = 100 [(Exchangeable Na^{+} ions)/ (CEC)] CEC is the cation exchange capacity. Total available nitrogen, phosphorus and potassium were estimated respectively by modified Kjeldahl method (Jackson, 1973), spectrophotometer (Jackson, 1967) and flame photometer (Hesse, 1971).

RESULTS AND DISCUSSION

Organic carbon

It was revealed that medium and low land did not differ in organic carbon content (Table- 1), but it largely varied from 0.20 to 0.48% among the land uses. Higher carbon content in double and mono-cropped land uses was mainly due to addition of organic matter as well as *in situ* decomposition of plant residues. In fact, intensive cultivation largely increased organic carbon content in the soils under double cropping. Similar result was reported by Egawa and Sekiya (1956) for grass land.

pH

Soils under both the land situations were found to be acidic (Table1), which was relatively higher (pH - 5.3-4.6) especially in cropped lands (both double cropped and mono-cropped). Reasons behind such transformation of inherent saline soil to acidic one may be ascribed to the application of chemical fertilizer for crop production as well as construction of high peripheral bunds to protect the lands from getting flooded with tidal saline water. pH of the grassed and barren lands under both the land situations, on the other hand, showed alkaline reaction as it varied from 7.2 to 8.0, which was due to non-cultivation of crops vis-à-vis non application of any chemical fertilizer in these lands. However, pH, in general, showed a decreasing trend with the increase in organic matter content (Figure 1).

Electrical conductivity (EC)

Electrical conductivity (EC_e) indicates that the soil under both the situations (medium and low) are saline in nature ($EC_e > 2$ dSm^{-1}). However, higher EC_e values under low land situation indicate higher concentration of salt due to overland flow and/or sea-water intrusion followed by capillary rise due to evaporation of soil moisture. It was 2.2 times higher in low lands than that in the medium lands (Table 1). On the contrary, under double and mono-cropped lands EC_e varied from 0.4 -1.9 d Sm^{-1} indicating the fact that the soils under these land uses is non-saline. This may possibly be associated with the soil management practices followed under these land uses. But, relatively higher EC_e under low land situations might be due to prolong stagnation of tidal saline water. Large variation in EC_e (2.6 to 6.6 d Sm^{-1}) in rest of the land uses was associated with the organic carbon content (Figure - 4) and CEC as well. In fact, higher organic carbon as well as CEC lowered EC_e (Figure 2) to a large extent. Significant inverse relation of EC_e with either organic carbon (-0.60) or CEC (-0.82) further confirms the findings.

Sodium Adsorption Ratio (SAR)

Sodium adsorption ratio (SAR) did not show any difference between the land situations, but marginal difference was observed among the land uses (Table 2). It was maximum (9.54) in grassland under medium land situation. Minimum SAR under barren lands was probably associated with its low organic matter content and low rate of soil moisture evaporation. It, in general, did not show any specific relation with either of the chemical properties considered in the study.

Cation Exchange Capacity (CEC)

CEC did not vary between the land situations (Table 2), but variation was observed among the land uses. It was maximum (21.97) for double cropped lands followed by mono-cropped, grassed and barren lands. Relatively higher CEC in low lands, in general, was associated with higher deposition of silt and clay (Table 3 and Figure 2), which was confirmed by highly significant relationship with clay (r = 0.80). The result corroborates the findings of Devilliers and Jackson (1967). It was further observed that CEC of soil under double cropped lands in low land situation was 28.5% higher (22.32 meq/100g) than that in the barren lands. It significantly increased linearly with the increase in pH (r = 0.67) as well as organic carbon (r = 0.66) but conversely, it was observed that significantly inverse (r=-0.82) relationship exists with EC_e (Figure 3). Such characteristic of soil is associated with clay minerals which exhibit increases in negative charge in CEC as the pH is raised (Schofield, 1949; Fields and Schofield, 1960; Jackson 1963).

Table 1: Influence of land use on pH, electrical conductivity, organic carbon and organic matter under two land situations

Land use	pH			EC_e, dSm^{-1}			Organic Carbon, %			Organic Matter, %		
	ML	LL	Mean	ML	LL	Mean	ML	LL	Mean	ML	LL	Mean
L_1	5.2	5.2	5.2	0.7	1.9	1.3	0.48	0.33	0.41	0.83	0.57	0.70
L_2	5.3	4.6	5.0	0.4	1.2	0.8	0.43	0.48	0.46	0.74	0.83	0.78
L_3	7.6	8.0	7.8	4.6	2.6	3.6	0.32	0.38	0.35	0.55	0.65	0.43
L_4	7.5	7.2	7.4	5.4	6.6	6.0	0.20	0.28	0.24	0.34	0.48	0.41
Mean	6.4	6.3	--	2.78	6.15	--	0.36	0.37	--	0.62	0.55	--

Note: L_1 = Double cropped land; L_2 = Monocropped paddy land; L_3 = Grassed/Forest land & L_4 = Barren land; LL = Low land situation, and ML = Medium land situation

Table 2: Sodium adsorption ratio, exchangeable sodium percentage and cation exchange capacity of soil under different land uses at two land situations

Land use	Sodium adsorption ratio			Exchangeable sodium percentage			Cation exchange capacity (m eg/100)		
	ML	LL	Mean	ML	LL	Mean	ML	LL	Mean
L_1	8.74	8.12	8.43	8.61	10.75	9.68	21.61	22.32	21.97
L_2	6.11	8.21	7.16	9.17	12.32	10.75	19.93	20.14	20.04
L_3	9.54	7.18	8.36	8.32	9.73	9.03	18.31	19.09	18.70
L_4	6.32	6.74	6.53	8.03	10.12	9.07	17.83	17.37	17.60
Mean	7.68	7.56	--	8.53	10.73	--	19.42	19.73	--

Note: L_1 = Double cropped land; L_2 = Monocropped paddy land; L_3 = Grassed/Forest land & L_4 = Barren land LL = Low land situation, and ML = Medium land situation

Table 3: Correlation Coefficients (r) among the chemical properties

Variables	Clay	Electrical conductivity	Cation exchange capacity	Sodium adsorption ratio
Clay	1.000	-0.784**	0.804 **	0.359
Electrical Conductivity		1.000	-0.820**	-0.166
Cation Exchange Capacity				0.359

*Note: ** indicates significance at 1% level of probability*

Table 4: Correlation Co-efficient of the chemical properties

Variables	pH	Electrical conductivity	Organic carbon	Cation exchange capacity	Exchangeable sodium percentage	Sodium adsorption ratio
pH	1.000	0.650*	-0.910**	-0.667*	-0.360	-520*
EC_e		1.000	-0.595*	-0.820**	-0.290	-0.166
OC			1.000	0.659*	0.596*	0.277
CEC				1.000	0.321	0.360
ESP					1.000	0.065
SAR						1.000

*Note: ** and * indicates significance at 1 and 5 percent level of probabilities.*

Table 5: Total nitrogen, available phosphorus and potash in the soil under different land uses in two land situations of Sundarban

Land use	Total nitrogen (N) (kg ha^{-1})			Available phosphate (P_2O_5) (kg ha^{-1})			Available potash (K_2O) (kg ha^{-1})		
	ML	**LL**	**Mean**	**ML**	**LL**	**Mean**	**ML**	**LL**	**Mean**
L_1	0.038	0.031	0.04	78.20	84.12	81.16	320	434	377
L_2	0.039	0.041	0.04	77.0	87.3	82.15	357	334	346
L_3	0.032	0.016	0.02	64.01	58.00	61.01	410	383	397
L_4	0.015	0.026	0.02	47.0	60.12	53.56	297	353	325
Mean	0.03	0.03	--	66.55	72.39	--	346	376	--

L_1 = Double cropped land; L_2 = Monocropped paddy land;
L_3 = Grassed/Forest land & L_4 = Barren land
LL = Low land situation, and ML = Medium land situation

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Nutrient Availability

Total available macro nutrients like nitrogen (N), phosphate (P_2O_5) and potash (K_2O) showed variations with respect to both situations and uses of lands. Phosphate and potash were relatively higher in both double and mono-cropped lands under low land situations, whereas nitrogen (Table 5) showed marginal or no differences in either of the land uses irrespective of situations. Higher phosphate and potash content in low lands was due to higher clay content together with the application of organic and inorganic fertilizers. In fact, the small farmers in the zone mostly depend on inorganic sources for nutrients for their crops, which become an ideal contributor to the available nutrient pool in the soil. Similar observations were reported by Palm *et al.,* 2001) and Sanchez *et al.,* (2003).

It may, therefore, be inferred that most of the chemical properties are interrelated in determining its quality. The chemical properties like SAR and CEC were found to be relatively higher in low lands because of high clay content and crop management practices. Moreover, as far as nutrient availability is concerned availability of phosphate and potash was considerably higher in cropped lands.

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