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Bangladesh J. Sci. Ind. Res. **54(1)**, 67-72, 2019

BANGLADESH JOURNAL OF SCIENTIFIC AND INDUSTRIAL RESEARCH

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Macro nutrient status of Sundarbans forest soils in Southern region of Bangladesh

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Abstract

An attempt has been made to evaluate the condition of soil of the Sundarban mangrove forest of Bangladesh by applying standard method. Soil pH was varied from 6.63 to 7.87. Organic carbon of soil was found 4.06, 4.79, 5.59, 9.38 and 9.80 (gKg^{-1}) at Kotka, Kochikhali, Hironpoint, Harbaria, and Dublarchar, respectively. The electrical conductivity of soil was varied from 14.39, to 42.89 (dSm^{-1}) in the study areas.The cation exchange capacity in the soils was varied from 22.32 to 27.2 $Cmol_c kg^{-1}$ in the study area. The average percentages of total nitrogen content in the soil were varied from 0.04 to 0.08%. The soils of Oligohaline zone of Sundarban mangrove forest are rich in water soluble and exchangeable magnesium followed by calcium and the potassium. The percentages of silt and clay were higher than sand in all study areas. Dissolved chloride in the soil was found 7010, 4186,11750 and 16389 ($\mu g\ g^{-1}$) at Hironpoint, Harbaria, Dublarchar and Kotka respectively.

Received: 22 January 2018

Revised: 17 April 2018

Accepted: 23 May 2018

DOI: https://doi.org/10.3329/bjsir.v54i1.40732

Keywords: Sundarbans; Forest; Chemical attributes

Introduction

The Sundarbans is the largest, ecologically and biologically richest, and most extensive mangrove forest in the world. Ecosystems of this world heritage site supports versatile interactions and correlations and relationships among its vertebrates and invertebrates, flora, fauna, aquatic organisms, marine lives, wildlife, fishes, birds, natural habitats, micro soil and water relationship supports this largest wildlife habitats (Awal, 2007). Sundri (*Heritierafomes*) is the predominant tree species, supporting about 65% of the total merchantable timber (Chaffey *et al.,* 1985; Pasha and Siddiqi, 2003). The Sundarbans forest is still the largest natural single tract of mangrove forest and habitats in the world (Hussain and Acharya, 1994) with 10, 029 km^2 area. The total area of the part of Sundarbans in Bangladesh is now about 6,017 km^2 (Chaffey *et al.,* 1985), which arose due to the eastward shift of the Ganges (Naskar and Mandal, 1999).

The Sundarbans mangrove forests is the largest single block of the tidal halophytic mangrove forest of the world (Pasha and Siddiqui, 2003). Due to various anthropogenic activities, this forest is now under various stresses such as increased salinity and alteration in other physical and chemical composition in soil and water. Such changes in the soil properties are likely to affect the microbial communities in soil and hence the ecosystem properties including organic matter decomposition, nutrient mineralization and vegetation above the ground (Wardle, 2002). A mixture of these distinct soil types in various ratios forms loamy soil which usually has high humus content. Many soil properties are affected by soil texture, including drainage, water holding capacity, aeration, susceptibility to erosion, organic matter content, cation exchange capacity (CEC), pH buffering capacity and soil tilth (Berry, 2007).

The soils of Sundarbans are regularly flooded by diurnal tides. The knowledge of mangrove ecosystems is continually expanding. This knowledge is critical in order to ensure that effective mangrove management is maintained within the context of ecologically sustainable development. Though it is an important forest for its plants, animals and mangrove fishery but there is limited information regarding its soils.

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So, the present study has been undertaken to characterize the surface layer of Sundarbans forest soils in terms of macro nutrient status.

Methods and materials

The Bangladesh Sundarbans (between 21°13′ N and 22°40′ N latitude and 88°03′ E and 89°55′ E longitude) mangrove forest is bordered by Bangladesh in the east, the Hooghly River (a continuation of the River Ganga) in the west and the Bay of Bengal in the south. The temperature is moderate due to its proximity to the Bay of Bengal in the south. Average annual maximum temperature is around 35°C. Average annual rainfall is 1920 mm. Average humidity is about 82% and is more or less uniform throughout the year (Imam, 1982).

A total of five spots were selected (Fig. 1). From each of these spots, seven soil samples were collected; one from the centre of the spot, four (one each) from all the corners, and two from the middle sides of the spot. Therefore a total of 35 soil samples were taken. Soil samples were collected from 0-15 cm (surface) soil depth and all soil samples were kept in sealed plastic bags. Marking and labelling was performed with a detailed description of the selected sampling site on both the soil- plastic bags, and preserved in plastic bags until arrival at the laboratory for sample preparation and chemical analyses.

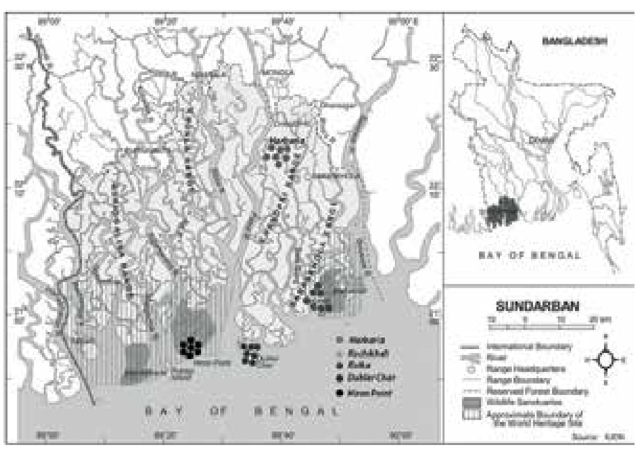

Fig. 1. Selected five soil sampling sites are showing the map(Gain and Das, 2014)

The collected soil was sieved through a 2 mmmesh screen to remove plant roots, rocks, and macro fauna. After sieving, soil samples were analyzed for physical, chemical and physicochemical properties. The particle size analysis of the soils was carried out by hydrometer method as described by Bouyoucos (1936) and Day (1965). Textural classes were determined using Marshall's Triangular Coordinate. Soil pH was determined electrochemically with the help of glass electrode pH meter maintaining the ratio of soil to water was 1: 2.5 as suggested by Jackson (1962). The electrical conductivity of the soil was measured at a soil: water ratio of 1: 5 by the help of EC meter (USDA, 2004). The CEC of the soils were determined by extracting the soil with 1N KCl (pH 7.0) followed by the replacing the potassium in the exchange complex by 1 N NH_4OAc. The displaced potassium was determined by a flame analyzer (Jackson, 1967). Total nitrogen of the soils was determined by colorimetric method (Bremner and Mulvaney, 1982) following H_2SO_4 acid digestion as suggested by Jackson (1967). Available phosphorus was extracted from the soil with 0.5 M $NaHCO_3$ (Olsen Method) at pH 8.5 and Molybdophosphoric blue colour method of analysis was employed for determination (Murphy and Riley, 1962). The available Na and K were determined from NH_4OAc. (pH 7.0) extract as described by Jackson (1967). The extract was analyzed for available K and Na by a flame analyzer at 589 and 767 nm, respectively (Jackson, 1967). Available sulphur content was determined by turbidimetric method as described by (Jackson, 1973). It was measured by spectrophotometer at 420 nm. Organic carbon of samples was determined by Walkley and Black's wet oxidation method as outlined by Jackson (1962). The Ca^{2+} and Mg^{2+} of the soils were determined by extracting the soil with 1 N NH_4OAc (Soil: extractant = 1:10) followed by the replacing the Ca^{2+} and Mg^{2+} in the soil solution. Then the replacing the Ca^{2+} and Mg^{2+} was determined by titrimetric method (Lanyon and Heald, 1982). Chloride (Cl^-) was extracted from the soil with distilled water and determined by Precipitation Titration method (Skoog *et al.,*1996). Data were processed and arranged by Microsoft Excel version, 2013 (Vermaat, 2014).

Results and discussion

The results of the study on assessment of physical and chemical properties of surface soils in sundarbans forest soils in Khulna district are presented and possible interpretations are made in this chapter. Some important physico-chemical and chemical properties are presented in Table I, II and III.

The percentage of sand, silt and clay and textural classes are presented in (Table 1). The highest clay (42.8%) was found in soils of Hironpoint and lowest clay (25.8%) was found in soils of Kochikhali area. Chaffey *et al.* (1985) found that Sundarbans soil is in general medium textured, sandy loam, silt loam or clay loam. Silt is the dominant grain in the sundarbans soil.

Table I. Percentage of sand, silt and clay was found in different study area of Sundarbans mangrove forest.

Table I. Percentage of sand, silt and clay was found in different study area of Sundarbans mangrove forest

Location	%Sand	%Silt	%Clay	Textural class
Harbaria	9.3 ± 0.06	52.4 ± 1.20	38.3 ± 1.65	Silty clay loam
Kochikhali	22.8 ± 0.09	51.4 ± 1.30	25.8 ± 0.98	Silt loam
Kotka	20.3 ± 0.08	42.8 ± 1.45	36.9 ± 1.21	Silty clay loam
Dublarchar	10.2 ± 0.07	58.4 ± 1.85	31.4 ± 1.30	Silty clay loam
Hironpoint	10.3 ± 0.09	46.9 ± 1.56	42.8 ± 1.85	Silty clay

The pH values in the soils was varied from 6.63 ± 0.14 to 7.83 ± 0.04 in the study area (Table II). The highest pH (7.83) was found in soils of Kotka and lowest pH (6.63) was found in soils of Harbaria area. It is found that Harbaria area is neutral and the other four areas are mildly alkaline in the study area. Hassan and Razzaque (1981) found that the pH value of soil in Sundarbans is neutral to mildly alkaline under field conditions but in some localities the pH value of dried up sub soil samples drops to 6.5. Mahmood and Saikat (1995) reported the acidic pH values in the soil of Chakaria Sundarbans area and consequently, this area has a rich reserve of pyrite in its soil.

The electrical conductivity values in the soils were varied from 14.39 ± 3.74 dSm^{-1} to 42.89 ± 9.38 dSm^{-1} in the study area (Table II). The highest EC (42.89 dSm^{-1}) was found in soils of Kotka and lowest EC (14.39 dSm^{-1}) was found in soils of Harbaria area. It is found that Harbaria area is saline soil and the other four areas are highly saline soil.

The organic carbon content in the soils was varied from 4.06 ± 0.26 gkg^{-1} to 9.80 ± 0.35 gkg^{-1} in the study area (Table 3). The highest organic carbon (9.80 gkg^{-1}) was found in soils of Dublarchar and lowest organic carbon (4.06 gkg^{-1}) was found in soils of Kotka area. Due to more decomposition of plant and animal residues in mangrove area the percentage of organic matter is higher than other soil tract. For this reason the biological activity in mangrove forest area is highly active. Zafar *et al.* (1999) stated that organic matter varied between 8.6 gkg^{-1} and 19 gkg^{-1} in the intertidal muddy beach of Bankhali river. Anderson (1977), Escourt (1967) and Mayer *et al.* (1985) reported that organic carbon is related to mud percentage in the soil. Mud percentage in the study areas were higher than sand and that is why organic matter was higher in the Sundarbans areas.

Total nitrogen content in the soils was varied from 0.04 ± 0.003% to 0.08 ± 0.011% in the study area (Table III). The highest nitrogen (0.08%) was found in soils of Harbaria and lowest nitrogen (0.04%) was found in soils of Kotka area.

This method of sulfur analysis measured mainly sulfate sulfur in soils. Available sulfur content in the soils was varied from 151.77 ± 39.59 $\mu g\ g^{-1}$ to 438.75 ± 19.56 $\mu g\ g^{-1}$ in the study area (Table III). The highest sulfur (438.75 $\mu g\ g^{-1}$) was found in soils of Kotka and lowest sulfur (151.77 $\mu g\ g^{-1}$) was found in soils of Harbaria area. Sulfur concentration >37.52 $\mu g\ g^{-1}$ indicated potential acid-sulfate soils in which oxidation of sulfides to sulfuric acid causes low pH (Soil Taxonomy Staff, 1994).

Available phosphorus content in the soils was varied from 53.16 ± 1.81 $\mu g\ g^{-1}$to 62.56 ± 8.97 $\mu g\ g^{-1}$ in the study area (Table III). The highest phosphorus (62.56 $\mu g\ g^{-1}$) was found in soils of Hironpoint and lowest phosphorus (53.16 $\mu g\ g^{-1}$) was found in soils of Kochikhali area. Phosphorus is strongly bound in soils and tend to be a sink for added phosphorus. In acidic soils, phosphorus precipitates as iron and aluminum phosphates and it may be adsorbed onto iron and aluminum oxides (Boyd, 1995). In neutral and alkaline soils, phosphorus tends to precipitate as calcium phosphates.

Water Soluble and Exchangeable potassium content in the soils was varied from 166.39 ± 48.30 $\mu g\ g^{-1}$ to 644.40 ± 55.61 $\mu g\ g^{-1}$ in the study area (Table III). The highest potassium (644.40 $\mu g\ g^{-1}$) was found in soils of Dublarchar and lowest potassium (166.39 $\mu g\ g^{-1}$) was found in soils of Harbaria area. The availability of potassium depends on primary minerals, secondary clay minerals, organic matter, potassic fertilizer etc. present in the soil. Black (1965) demonstrated that the higher concentration of potassium in the surface layer in comparison to the subsurface layer might be due to the action of plant roots in transporting potassium to the surface and

Table II. Physico-chemical properties of Sundarban mangrove forest soil (Mean ± STDEV)

Location	Physico-chemical properties		
	pH	*EC (dS/m)*	*CEC* $\{Cmol_c\ kg^{-1}\}$
Harbaria	6.63 ± 0.14	14.39 ± 3.74	22.32 ± 2.56
Kochikhali	7.61 ± 0.06	28.47 ± 7.61	24.57 ± 1.01
Kotka	7.87 ± 0.07	42.89 ± 9.38	27.24 ± 1.54
Dublarchar	7.48 ± 0.05	41.16 ± 5.80	27.02 ± 1.99
Hironpoint	7.83 ± 0.04	26.14 ± 1.49	24.57 ± 2.53

Table III. Chemical properties of Sundarban mangrove forest soil ofdifferent area (Mean ± STDEV)

Location	**Total % N**	**OC** (gkg^{-1})	**Available Nutrients** ($\mu g\ g^{-1}$)		**Water Soluble and Exchangeable Nutrients** ($\mu g\ g^{-1}$)				**Chloride (Cl)** ($\mu g\ g^{-1}$)
			P	*S*	*K*	*Na*	*Ca*	*Mg*	
Harbaria	0.08 ± 0.011	9.38 ± 1.26	57.19 ± 6.18	151.77 ± 39.59	166.39 ± 48.30	4623.66 ± 1143.17	1585.71 ± 367.09	1380 ± 84.85	4186 ± 1106
Kochikhali	0.04 ± 0.003	4.79 ± 0.43	53.16 ± 1.81	193.33 ± 49.58	259.35 ± 24.43	6022.41 ± 973.42	1185.71 ± 241.02	2057.14 ± 157.66	7010 ± 1213
Kotka	0.04 ± 0.006	4.06 ± 0.26	55.12 ± 6.60	438.75 ± 19.65	392.54 ± 61.80	12511.08 ± 2391.77	1842.85 ± 355.23	3042.85 ± 282.94	16389 ± 2845
Dublarchar	0.06 ± 0.010	9.80 ± 0.35	56.95 ± 8.93	305.87 ± 50.94	644.40 ± 55.61	13055.04 ± 4243.59	800 ± 81.64	2777.14 ± 435.03	11750 ± 393
Hironpoint	0.05 ± 0.009	5.59 ± 0.21	62.56 ± 8.97	408.60 ± 30.93	447.07 ± 30.15	7343.46 ± 587.54	2442.85 ± 97.59	2082.85 ± 118.56	7010 ± 475

also addition of crop residues. He called it biological recycling of potassium in soils. Kemmler (1980) reported that the potassium availability was higher in submerged soils than in upland counter parts. Fine textured soils usually have a higher CEC and can hold more exchangeable potassium.

Water Soluble and Exchangeable sodium content in the soils was varied from 4623.66 ± 1143.17 μg g^{-1} to 13055.04 ± 4243.59 μg g^{-1} in the study area (Table III). The highest sodium (13055.04 μg g^{-1}) was found in soils of Dublarchar and lowest sodium (4623.66 μg g^{-1}) was found in soils of Harbaria area. Karim (1994) reported that the sodium (Na) content is varied from 450 to 1850 μg g^{-1} in the mangrove areas.

Water Soluble and Exchangeable calcium content in the soils was varied from 800 ± 81.64 μg g^{-1} to 2442.85 ± 97.59 μg g^{-1} in the study area (Table III). The highest calcium (2442.85 μg g^{-1}) was found in soils of Hironpoint and lowest calcium (800 μg g^{-1}) was found in soils of Dublarchar area. Karim (1994) found the calcium (Ca) content was 2350 to 3950 μg g^{-1} in the Sundarbans.

Water Soluble and Exchangeable magnesium content in the soils was varied from 1380 ± 84.85 μg g^{-1} to 3042.85 ± 282.94 μg g^{-1} in the study area (Table III). The highest magnesium (3042.85 μg g^{-1}) was found in soils of Kotka and lowest magnesium (1380μg g^{-1}) was found in soils of Harbaria area. Soils with a high CEC can adsorb greater amounts of major cations than soils with a low CEC and calcium and magnesium carbonates occurred in the samples.

Chloride content in the soils was varied from 4186 ± 1106μg g^{-1} to 16389 ± 2845μg g^{-1} in the study area (Table III). The highest chloride (16389μg g^{-1}) was found in soils of Kotka and lowest chloride (4186μg g^{-1}) was found in soils of Harbaria area.

The cation exchange capacity in the soils was varied from 22.32 ± 2.56 $Cmol_c$ kg^{-1} to 27.24 ± 1.54 $Cmol_c$ kg^{-1} in the study area (Table II). The highest CEC (27.24 $Cmol_c$ kg^{-1}) was found in soils of Kotka and lowest CEC (22.32 $Cmol_c$ kg^{-1}) was found in soils of Harbaria area. Soil with a high CEC requires more liming material than soil of the same pH but of lower CEC. At the same degree of base unsaturation a soil with a higher CEC will provide greater concentration of cations such as Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} in soil solution than a soil of lower CEC (Foth and Ellis, 1988).

Conclusion

Sundarbans soils are in general silt loam or silty clay loam. Silt is the dominant grain in the sundarbans soil. Soil reaction (pH) in Sundarbans is neutral to mildly alkaline under field conditions. Electrical conductivity in the study area was higher indicating higher dissolved chloride in soil. Clay percentage in the study area were higher than sand and that is why organic matter was higher in the Sundarban area. Total nitrogen is very low but available phosphorus and sulfur concentration are higher in the study area. In highly alkaline soil, phosphorus tends to precipitate as calcium phosphates. Fine-textured soils usually have a higher CEC and can hold more exchangeable potassium. The water soluble and exchangeable cations such as Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} in soil solution are higher in the study area. The amount of macro nutrients varied due to the distance of saline water from different location of Sundarban forest soil.

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