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Extractable Micronutrients in Soils of Some Forested and Deforested Sites of South Eastern Hilly Areas of Bangladesh

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Abstract

Extractable iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) contents and their distribution with depths in soils of forested and adjacent deforested areas at Jahazpura, Teknaf, Cox's Bazar of Bangladesh were studied. The soils under forest showed higher levels of DTPA-extractable micronutrients in all three layers of soil in comparison to those of the deforested areas. The differences between forested and deforested sites were, in most cases, significant.. The top soils of forested sites had the higher contents of micronutrient and generally decreased with depth in forested soils, while there was no regular trend of distribution in deforested soils. The study also revealed that contents of extractable Fe, Mn and Cu were sufficient in all depths and sites but Zn was deficient in bottom layer of forested and all three layers of deforested sites. The results suggested that organic matter, clay and soil pH could play important roles in concentrations and distributions of micronutrients in soils of the study areas.

Key Words: forested soils, deforested soils, DTPA extractable micronutrients, depth of soil, Bangladesh

Introduction

Soil fertility is one of the most important factors controlling yields of the crops. Soil characteristics associated with soil fertility status of an area are the important aspects in relation to proper growth of forest vegetation, forest development and soil management. Micronutrients play a vital role in maintaining soil health and productivity of crops although these elements needed in very small amounts by plants. Still for normal growth of plants adequate contents of micronutrients should br present in soil. The deficiencies of micronutrients have become major constraints to productivity, stability and sustainability of soils. The availability of micronutrients is particularly sensitive to changes in soil environment. Micronutrient cycling is quite different among various terrestrial ecosystems (Rengel 2007) and land use changes may strongly affect their distributions in agro-forestry ecosystems (Han et al. 2007). The factors that affect the contents of such micronutrients are organic matter, soil pH, lime content, sand, silt, and clay contents (Alloway 2008).

The hill forests in Bangladesh have experienced severe deforestation in the past (Evans 1982). The annual deforestation rate in Bangladesh is about 3.3% (Rasul and Kakri 2007). Land cover changes due to deforestation affect soil properties and distribution of available nutrients and their supply. However, little information on the changes in concentrations and distributions of extractable micronutrients

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in hill soils of Bangladesh is available. The present investigation is, therefore, aimed at studying the changes in micronutrient status of different soil depths due to deforestation.

Materials and Methods

Study area

The study sites were located at Jahazpura, Teknaf upazilla of Cox's Bazar in Bangladesh. The studied area was situated between sea and hills at Shilkhali Forest Beat under Shilkhali Range, in Cox's Bazar South Forest Division. Shilkhali Forest Beat was lying between 20°45´12" and 21°01´14″N latitude and 92°10´18" and 92°21'25"E longitude (Fig. 1). Soils of the study sites were classified as brown hill soils (Brammer 1971). Soil in general is well drained. Climate in the region is moist tropical maritime with mean annual temperature of 25.5°C and mean annual rainfall of 384.2 cm, most of which fall between May and October. The region experiences high humidity, except in the hot dry season, and winter heavy dew and thick mist. Jahazpura forest is about 200 years old and it covers an area of 2978 hectare. In this natural forest of Jahazpura, the dominant tree species are Garjan (*Dipterocarpus spp*.). Other tree species such as Telsur (*Hopea odorata*), Gutgutiya (*Protium serratum*), Chapalish (*Artocarpus chaplasha*), Boilam (*Anisoptera scaphula*), Urium (*Mangifera sylyatica*), Jarul (*Legarstromia speciosa*), Hargoza (Dillenia pentagyna), Horitoki (*Terminalia chebula*), Bohera (*Terminalia bellerica*), Hizol (*Barringtonia acutangula*) etc. are also frequent in the forest.

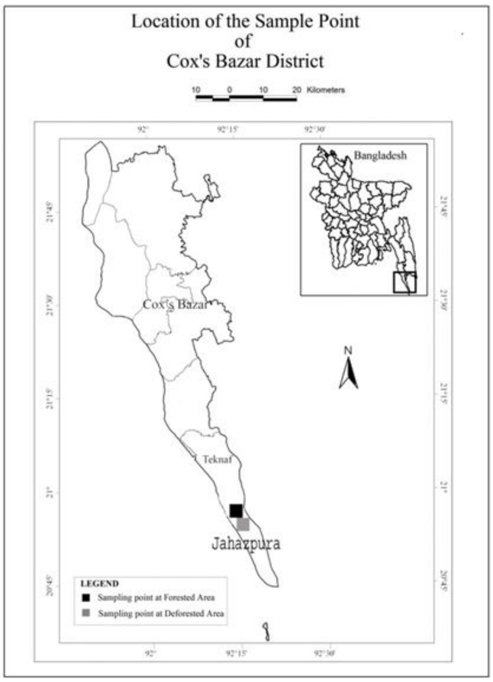

Fig. 1. Map of the study area.

Soil sample collection and analysis

Soil profiles were dug in each site and soil samples were collected from 10 profiles (six profiles from natural forest area, four profiles from deforested area) for analysis. Soil samples were collected at the depths of 0-15 cm (top), 15-55 cm (middle) and 55-85 cm (bottom) from each profile.

Soil samples were air-dried, and sieved through 2.0 mm screen. Particle size distribution of the soils was determined by hydrometer method (Day 1965). Cation exchange capacity (CEC) was determined after extraction with 1N ammonium acetate solution (Black and Dinauer 1965). Soil pH was measured in soil-water suspension (1:2.5) using a corning glass electrode. Soil organic carbon was determined by wet-oxidation method of Walkley and Black (1934) and the percentage of soil organic matter was calculated by multiplying value of organic carbon with 1.724, the Van Bemmelen factor. Available Fe, Mn, Zn and Cu in soil were determined by DTPA (diethylene-triamine pentaacetic acid) extraction method (Petersen 2002) followed by determination in an AAS. All statistical analyses were carried out using Minitab (1996). The *t*-test and correlation analysis were used to compare the differences in soil micronutrient and relationships between soil properties and micronutrient contents at the forested and deforested sites respectively.

Results

Soil properties

The clay content, soil organic matter, soil pH and cation exchange capacity (CEC) of soils under study were shown in Table 1. The soils were poor in clays ranging from11 to16% with a mean of 13.11% while in deforested areas clay ranged between 3 and 15% with a mean of 10.50%. Soil organic matter content in the forested sites (0.52-2.76%) was higher in comparison to that in deforested areas

Table 1. Soil properties under forested and deforested areas

Soil properties	Forested area		Deforested area	
	Range	Mean± SEM*	Range	Mean± SEM
Clay (%)	11-16	13.11±0.512	3.00-15.00	10.50±1.59
Organic matter (%)	0.52-2.76	1.53±0.312	0.210-1.33	0.731±0.149
pH (H2O)	4.48-5.36	4.99±0.124	4.20-5.12	4.619±0.112
CEC ($cmol_c$ kg^{-1})	6.30-9.80	8.64±0.396	5.47-7.47	6.583±0.223

n=18 for forested sites, n=12 for deforested site; SEM*, standard error of mean; CEC, cation exchange capacity.

Table 2. Extractable micronutrients in different soil depths under forested and deforested areas

Extractable micronutrients (mg kg^{-1})	Soil layer	Forested area	Deforested area	t-value	Significance level
Available Fe	Top	104.53±2.43	69.8±17	0.26	*
	Middle	81.77±1.50	84.4±8.2	0.29	ns
	Bottom	70.35±5.81	64.4±21	1.66	*
Available Mn	top	49.56±3.57	29.9±8.4	0.40	ns
	Middle	44.51±3.35	30.1±6.6	3.53	**
	Bottom	45.9±9.2	32.33±0.08	1.70	*
Available Zn	top	0.99±0.16	0.79±0.15	0.90	*
	Middle	0.92±0.17	0.64±0.19	3.15	*
	Bottom	0.67±0.32	0.55±0.11	1.84	ns
Available Cu	top	0.56±0.054	0.32±0.058	3.21	*
	Middle	0.31±0.12	0.28±0.058	3.71	**
	Bottom	0.29±0.068	0.27±0.030	0.31	ns

n=18 for forested sites, n=12 for deforested site; Value represented as mean value± SEM; *$p<0.05$; **$p<0.01$; ns-not significant.

(0.210-1.33%). These soils under both studied areas were acidic in nature. Soil pH in forest areas was relatively higher compared to the deforested areas. Cation Exchange Capacity (CEC) was higher in forest areas than that of the nearby deforested areas. Soil organic matter was higher in surface soils and decreased with soil depths in both areas. Conversely, clay, soil pH and CEC did not follow any regular patterns of distributions through soil depths in both studied areas.

Extractable Fe

The mean values of extractable micronutrients (i.e. Fe, Mn, Zn and Cu) in different soil depths of forested and deforested sites were shown in Table 2. The mean value of extractable Fe in the forested soil ranged from 70.35 to 104.53 mg kg^{-1}. On the other hand, in deforested soils, available Fe content ranged from 64.40 to 84.40 mg kg^{-1} (Table 2). The study showed that all the three soil layer of forested areas had higher contents of available Fe as compared to that of deforested areas while extractable Fe showed the significant variations at top and bottom soils. The available iron content was found to be higher in top soils and decreased with depth in forested areas. On the other hand, distribution pattern of Fe in deforested sites was found irregular (Table 2).

Tables 3 revealed that DTPA extractable Fe showed a significant and positive correlation with organic matter (r=0.753*).

Extractable Mn

The mean concentration of extractable Mn in forested soils ranged from 45.90 to 49.56 mg kg^{-1} while in deforested sites it varied from 29.90 to 32.33 mg kg^{-1} (Table 2). In forested areas available Mn showed a decreasing pattern with depth while in deforested areas, no definite pattern of

Table 3. Correlation coefficients between extractable micronutrients and soil properties under forested and deforested areas

Soil parameters	Forested area				Deforested area			
	Extractable Fe	Extractable Mn	Extractable Zn	Extractable Cu	Extractable Fe	Extractable Mn	Extractable Zn	Extractable Cu
Clay content	0.540	0.551	0.342	0.454	0.311	0.464	0.503	0.435
Organic matter	0.753*	0.736*	0.790**	0.712*	0.655	0.662	0.592	0.691
Soil pH	-0.514	-0.522	-0.528	-0.585	-0.601	-0.670	0.223	-0.278
CEC	0.382	0.413	0.284	0.315	-0.356	-0.399	0.267	0.528

distribution was observed (Table 2).

The extractable Mn contents in forested areas in the three depths were higher in comparison to deforested areas and the significant variations were observed in middle and lower layers of the studied areas.

In Table 3, DTPA extractable Mn showed a positive and significant correlation with organic matter (r=0.736*).

Extractable Zn

The content of available Zn in forested soils ranged between 0. 67 and 0.99 mg kg^{-1} while it varied between 0.51 and 0.79 mg kg^{-1} in deforested soils (Table 2). Forested soils at each depth had higher concentration of extractable Zn than that of the deforested soils and significant variations in extractable Zn were found in top and middle soils of studied areas. The Zn contents in soils of both forested and deforested areas under study were relatively lower as compared to that of the previous study in Bangladesh.

The vertical distribution of available Zn showed the decreasing trend with soil depth in both forested and deforested areas. The available Zn showed significant positive correlation with organic matter only (r=0.790**).

Extractable Cu

In forested soils, the extractable Cu content ranged between 0.29 and 0.56 mg kg^{-1} and in deforested sites it varied between 0.27 to 0.32 mg kg^{-1}. The results showed that the forested soils in different depths contained higher amount of available Cu as compared to the deforested soils and top and middle soil depths under study showed significant variations in extractable Cu. The extractable Cu status was higher in the surface layers and decreased with soil depth in both forested and deforested sites. The soils under study contained relatively lower concentration of extractable Cu in comparison to other parts of Bangladesh.

Table 3 showed that extractable Cu had a weak significant and positive correlation with organic matter (r=0.712*).

Discussion

The lower values in soil properties (i.e. clay, organic matter, soil pH and CEC) in deforested areas might be associated with loss of clay and organic matter. Early study revealed that removal of forest vegetation deteriorates soil quality through soil erosion, loss of organic matter and nutrient elements (Pritchett and Fisher 1987; Islam and Weil 2000).

The study showed that the forested soils had relatively higher concentrations of available micronutrients (Fe, Mn, Zn and Cu) in different soil depths compared to that of the deforested soils. Forest vegetation is considered as the leading factor that affects the accumulation, concentrations and vertical distributions of nutrients in a forest ecosystem.

Forest clearance accelerates the decline in contents of micronutrients. Clays and soil organic matter might decline rapidly after soil is exposed due to forest clearing activities (Kizilkaya and Orhan 2010).

The top soils contained higher amount of available micronutrients which may be attributed to the accumulation of biomass in the surface layer of soils (Setia and Sharma 2004). Jobbáge and Jackson (2001) reported that root distributions and maximum rooting depth may play an important role in shaping micronutrient profiles in a forest ecosystem. Jiang et al. (2009) stated that nutrients taken up by deep roots of tree stands are transported into the above-ground parts and re-deposited on the soil surface through litterfall, stemflow and throughfall.

Trace metal concentration and distribution in soils are influenced by several factors such as types of clay minerals, nature of organic matter, surface conditions, pH, ligand formation, temperature, redox potential, composition and quantity in soil solution, land cover change (Harter 1991; Alloway 1995; Alva et al. 2000). Fe and Mn deficiencies are most common in sandy, acidic mineral soils (Hodges 2015). But in these sandy soils under both forested and deforested areas, Fe and Mn content seemed to be adequate because the parent materials might be rich in Fe and Mn. The previous studies also reported that the hill soils of Bangladesh are rich in iron and manganese (RSS 1976; Gafur 2014).

All the soils under both forested and deforested sites were found adequate in available Fe considering 4.5 mg kg-1 as critical limit (Lindsay and Norvell 1978). The values of extractable Mn suggested that the soils of both forested and deforested sites under study contained sufficient Mn because they are above the critical limits of 3.0 mg kg-1 as reported by Lindsay and Norvell (1978).

Akter et al. (2012) reported that showed available Zn content were between 1.77 and 2.32 mg kg^{-1} in some acidic soils of Tangail in Bangladesh. The extractable Zn content in the studied areas seemed to be lower compared to the above study could be explained as sandy nature of the studied soils enhanced higher leaching of micronutrients.

Taking 0.8 mg kg^{-1} as the critical limit of DTPA-extractable Zn (Lindsay and Norvell 1978), surface and middle depths of forest soils contained available Zn above the threshold value while soils in all the depths (top, middle and lower) in deforested soils were found below the critical limit (Table 2).

The result showed that extractable Zn was deficient in the lower depth of forested areas and in the three depths of the deforested areas. Gafur (2014) reported that the hill soils of Bangladesh are deficient in zinc although soils are acidic in nature. A number of authors (Alloway 2008; Brown 2008; Sinclair and Edwards 2008; Hodges 2015) reported that lower level of Zn or its deficiency might occur particularly in acid sandy soils due to leaching loss of this metal from some horizons. Higher levels of free Fe and Mn oxides and hydroxides in the hill soils could fix the available zinc to make it unavailable or deficient to the plants. Phogat et al. (1994) also stated that the lower level of extractable Zn in soil is probably due to high contents of free Fe and Mn ions which enhance transformation of Zn to non exchangeable form on their hydrated oxide surfaces.

Some studies revealed that available Cu content were between 1.27 and 3.29 mg kg^{-1} in acid soils of Madhupur tract in Bangladesh (Sarker 1995) and 0.39 and 0.62 mg kg^{-1} in acid forest soils of India (Venkatesh et al. 2003). The soils in both areas under study had also relatively lower content of Cu. The lower concentration of this element might be due to the leaching loss in the sandy forest soils under study. McBride (1981) reported that a considerable amount of available Cu might be leached out from acid sandy soils, in spite of the fact that Cu is considered rather stable. Considering 0.2 mg kg^{-1} as the critical limit for Cu (Lindsay and Norvell 1978), all the soils in both forested and deforested areas were adequate in available Cu.

The correlation analysis showed that only organic matter had a significant and positive role in the availability of micronutrients in the forest soils of the studied areas. Similar correlations of available micronutrients with organic carbon were also reported by Sakal et al. 1986; Jiang et al. 2009). According to Sharma and Chaudhary (2007), organic matter is responsible for increasing solubility and extractability of soil micronutrients by forming organo-metal complexes.

Conclusions

The study showed that the soils in forested areas were higher in available micronutrients in comparison to the deforested sites. Soils of deforested areas were found deficient in extractable Zn content although bottom soils of the forested areas were deficient in extractable Zn. The results revealed that organic matter and clay might play the important roles in controlling the availability of Fe, Mn, Cu and Zn in these soils. The study suggested that proper protection of the forested area from further forest degradation is required.

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