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Studies on some micronutrient status of soils of two South-Eastern forest and agricultural areas of Bangladesh

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Abstract: *The present study was conducted to assess the contents of total iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) and their distribution in different layers of soils under natural forested and nearby agricultural sites of Bangladesh. The studied sites were located at Guimara of Khagrachari district and Thandachori of Rangamati districts respectively. Soil samples were collected from three different soil depths i.e. 0–15 cm (top), 15–55 cm (middle) and 55–85 cm (bottom) of each location. The soils of forested areas contained higher amounts of total micronutrients in three layers in comparison to that of agricultural areas. The study also revealed that total soil micronutrients like Fe, Mn and Cu of the studied areas were found relatively higher compared to that of other areas of Bangladesh. The middle soil layers of both forested and agricultural sites contained higher amounts of total micronutrients than that of the top and bottom layers. Clay particle was relatively significant to the concentrations and distribution of total micronutrients in soils under study. Soil organic matter, pH and cation exchange capacity also play the important roles in total micronutrient contents at different soil layers of both forested and agricultural areas.*

Keywords: *Forested soils, agricultural soils, total micronutrients, soil layers, soil characteristics*

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I. Introduction:

Land uses play a key role in status and distribution of nutrients in soils [1,2,3]. Different authors have shown that most of the total microelements detected mainly originated from the parent materials[4,5,6]. The total concentration of chemical elements in soils under native vegetation is primarily influenced by the type and mineralogical properties of the parent material, as well as the process by which the soil was formed and the proportion of mineral constituents in the solid phase. Soils derived from basic igneous rocks, are higher in metals compared with soils that have originated from other rocks such as granites, gneisses, sandstones and siltstones[7,8,9]. The factors, including the proportion and composition of the clay and/or organic matter fraction, soil pH, redox potential, CEC may also influence the levels of metals in soils[8,10,11]. Among them, clay and organic carbon content are generally considered to be important factors affecting trace element contents in soils [12,13]. Iron and manganese are the most abundant heavy metals in a soil. Their levels can vary widely with changing the amount and nature of soil minerals[14]. There are several factors which affect the status and mobilization of trace elements in soils: chemical character of the particular element, its origin, physical and chemical composition of soil and the external effects surrounding the area[15]. Changes in land use and management practices affect the physical, chemical and biological properties of soils to a greater extent and thus modify the concentrations of heavy metals in the soil[16,17].

Chaignon and Hinsinger[18] indicates that the total amounts of trace elements present in soils depend on the mineralogical composition of the parent material, the type and intensity of weathering and on climatic and other factors predominating during the process of soil formation. Chaignon and Hinsinger[18] also reported that formation of complexes with soil organic matter, adsorption onto the surfaces of clays and Fe and Mn oxides regulate the behavior and bioavailability of micro elements in the soil. The total amount of trace elements in soil naturally have the influence on the soluble or plant-available amounts. The total content of the nutrients is a reliable index of the available trace element status in the soil and widely used in estimating the soluble or available forms of trace element[19].

Recently, in Bangladesh, some studies have reported on the status and distributions of total micronutrients in different agricultural soils[20,21], but very little information is available on total micronutrients in forest soils and after the forest clearance for agriculture. The objective of this study was to determine the levels of total Fe, Mn, Zn and Cu in soil samples at different depths in forest and nearby agricultural areas.

II. Materials and Methods

2.1 Study area:

The study included two natural forests and their adjacent agricultural areas located at Guimara of Khagrachari district and Thandachori of Rangamati district in Chittagong Hill Tracts (CHTs) of Bangladesh. The geographic locations of the sites were: Guimara (22º58'11″N-91º53'9″E for forested site; 22º57'58″N-91º52'46″E for agricultural site) and Thandachori (22º29´56″N- 91º48´29″E for forested site; 22º29´42″N-91º48´21″E for agricultural site). Soils of the studied sites are classified as brown hill soils [22]. Climate in the region is characterized by tropical monsoon with mean annual temperature of 25.7°C and mean annual rainfall 3,627 mm, most of which fall between May and October. The relative humidity ranges between 60% in the dry season and 90% during monsoon.

In Guimara, the forest comprised mainly of sagon (*Tectona grandis)*, acacia (*Acacia auriculiformis*), chapalish (*Artocarpus chaplasha*) etc. In Thandachori natural forest, the vegetation consisted of mahogani (*Swietenia macrophylla*), sagon (*Tectona grandis)*, Gamhar (*Gmelina arborea*), sil-koroi (*Albizia procera)*, etc.

2.2 Soil sample collection and analysis:

Soil samples were collected from 10 locations of forested and adjacent agricultural areas (5 locations from each of natural forest and agricultural areas) from different depths i.e. 0–15 cm (top), 15–55 cm (middle) and 55–85 cm (bottom) from each location.

Soil samples were air-dried, and sieved through 2.0 mm screen. Particle size distribution of the soils was determined by hydrometer method[23]. Cation exchange capacity (CEC) was determined after extraction with 1N ammonium acetate solution[24]. 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 [25] and the percentage of soil organic matter was calculated by multiplying value of organic carbon with 1.724, the Van Bemmelon factor [26]. For the determination of total micronutrients in soil, 1 g of soil sample was mixed with HNO_3 and $HClO_4$ acid and allowed to keep overnight for pre-digestion. The contents were digested on the sand bath until the white colour was developed. The sample was cooled and diluted with 25 ml of distilled water and filtered into plastic vial as suggested by Parkinson and Allen[27]. The amounts of Fe, Mn, Zn and Cu, were determined by an atomic adsorption spectrophotometer. All statistical analyses were carried out using Minitab[28]. 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 agricultural sites respectively.

III. Results

3.1 Soil properties:

The clay content, soil organic matter, soil pH and cation exchange capacity (CEC) of soils under study were shown in Table 1. In the forested areas, clay content varied widely between 8 and 40% with an average value of 21.00% while in agricultural areas it ranged from 3 and 31% with a mean value of 18.00%. Soil organic matter content was higher in the forested sites (0.38-2.47%; mean 1.28%) than that of the agricultural areas (0.24-1.31%; mean 0.83%). The soils under both forested and agricultural areas were acidic in nature ranging from 4.27 to 5.43 with an average of 4.98 in forested soils and from 4.11 to 5.12 with average of 4.75 in agricultural soils. Cation Exchange Capacity (CEC) in forest soils ranged from 7.85 to 11.84 $cmol_c\ kg^{-1}$ (mean 9.61 $cmol_c\ kg^{-1}$); and at the nearby agricultural areas, CEC was between 5.58 and 9.09 $cmol_c\ kg^{-1}$ (mean 8.00 $cmol_c\ kg^{-1}$). Soil organic matter was observed higher in surface soil and decreased with soil depth in both studied areas. On the other hand, clay, soil pH and CEC did not show any specific trend of distribution with soil depth in both forested and agricultural areas.

Table 1: Soil properties under forested and agricultural areas

Soil properties	Forested area			Agricultural area		
	Minimum	Maximum	Mean± SEM*	Minimum	Maximum	Mean± SEM
Clay (%)	8.00	40.00	21.00±6.24	3.00	31.00	18.00±4.58
Organic matter (%)	0.38	2.47	1.28±0.36	0.24	1.31	0.83±0.14
pH	4.27	5.43	4.98±0.19	4.11	5.12	4.75±0.19
CEC($cmol_c\ kg^{-1}$)	7.85	11.84	9.61±0.60	5.58	9.09	8.00±0.81

SEM*=standard error of mean

3.2 Total Fe:

Total Fe contents in forest soils ranged from 10.75 to 12.45 percent while in agricultural sites, total Fe varied between 9.23 and 10.50 percent (Table 2). Total Fe contents in the three depths of forested areas were higher in comparison to the agricultural sites under study. Khan et al.[29] reported the values of total Fe in some alluvial soils of Bangladesh which were ranged from 5.3 to 6.6 percent, while in some acid soils of Gazipur District it was found between 0.14 and 0.49% percent reported by Begum et al.[20]. On the global basis, total Fe content of the soils usually varied from about 1 to 5 percent with an average value of 3.8 percent[30]. The observed total Fe content of the studied soils was relatively higher than that of the other studied areas. Total Fe content of the forest sites are significantly differed with that of agricultural sites irrespective of soil depth (Table 2). Table 3 showed that total Fe showed significant correlation with clay content in forested areas (r=+ 0.889**) and agricultural areas (r=+0.751*).

3.3 Total Mn:

Total Mn contents in the forested soils ranged between 1033.00 and 1142.00 mg kg^{-1}. On the other hand, in agricultural sites, total Mn varied from 781.00 to 797.00 mg kg^{-1} (Table-2). From the experimental value it was found that the forested soils contained higher amount of total Mn than that of the agricultural soils. In Bangladesh, total Mn content varied from 94 to 804 mg kg^{-1} in some acid soils[20] and some floodplain soils[21] the value ranged from 527 to 1125 mg kg^{-1}. Pais and Jones[31] reported the total Mn content of soils and which ranged between 200 and 3000 mg kg^{-1}. However, the contents of total Mn in three different soil depths of both the studied sites were relatively higher than that of the other reported soils of Bangladesh. Total Mn content showed significant variation only in middle soils in both forested and agriculture sites (Table 2). Table 3 revealed that total Mn in the studied soils had significant positive coefficient of correlation with clay and organic matter in forested areas (r=+ 0.851*; 0.683*) and with clay in agricultural areas (r=+0.764*).

Table 2: Total micronutrient contents in differenEt soil depths under forested and agricultural areas.

Total micronutrients	Soil layer	Forested area	Agricultural area
Total Fe (%)	Top	$11.17^{a}\pm0.20$	$9.83^{a}\pm0.21$
	Middle	$12.45^{a}\pm0.98$	$10.50^{b}\pm0.16$
	Bottom	$10.75^{a}\pm0.35$	$9.23^{b}\pm0.30$
Total Mn (mg kg^{-1})	Top	$1033.00^{a}\pm20.0$	$781.00^{a}\pm10.00$
	Middle	$1142.00^{a}\pm18.0$	$797.00^{b}\pm7.00$
	Bottom	$1041.00^{a}\pm15.0$	$790.00^{a}\pm 10.50$
Total Zn (mg kg^{-1})	Top	$168.00^{a}\pm17.00$	$117.50^{b}\pm9.50$
	Middle	$168.50^{a}\pm7.50$	$119.00^{b}\pm5.50$
	Bottom	$121.00^{a}\pm6.00$	$113.00^{a}\pm3.00$
Total Cu (mg kg^{-1})	Top	$106.00^{a}\pm13.0$	$75.00^{a}\pm3.00$
	Middle	$109.00^{a}\pm8.50$	$83.00^{b}\pm5.50$
	Bottom	$102.00^{a}\pm3.50$	$64.50^{a}\pm3.50$

Each value is the mean of soil sample under each land use. The same lowercase letter within each soil depth indicates no significant difference ($p<0.05$)

3.4 Total Zn:

Total Zn content in the studied soils was ranged from 121.00 to 168.50 mg kg^{-1} in forested soils and 113.00 to 119.00 mg kg^{-1} in agricultural sites (Table 2). The soils of forested areas had higher content of total Zn as compared to the soils of nearby agricultural areas.

Total Zn content in some acid soils of Gazipur[20] ranged from 30 to 1216 mg kg^{-1} and in Ganges River Floodplain[21] between 105 to 393 mg kg^{-1} . Hodges[32] reported that in most of the cases the total Zn contents in soils remain within 10 to 300 mg kg^{-1}. Total Zn content of the studied soils was comparatively lower than the other two areas of Bangladesh.

Total Zn in both top and middle soils of forested site were significantly higher compared to agriculture site (Table 2). Table 3 showed that significant positive coefficient of correlation was observed between total Zn and clay in forested areas (r=+ 0.742*) and in agricultural areas (r=+0.703*).

Table 3: Correlation coefficients between total micronutrient and soil properties under study

Soil properties	Forested area				Agricultural area			
	Total Fe	Total Mn	Total Zn	Total Cu	Total Fe	Total Mn	Total Zn	Total Cu
Clay	0.889*	0.851*	0.742*	0.784	0.751*	0.764*	0.703*	0.715*
Organic matter	0.391	0.683*	0.692	0.684	0.355	0.362	0.685	0.640
pH (water)	-0.697	-0.562	-0.378	-0.485	-0.664	-0.548	0.321	-0.343
CEC	0.382	0.643	0.284	0.315	0.356	0.399	0.267	0.528

3.5 Total Cu:

In forested soils, total Cu content ranged from 102.00 to 109.00 mg kg^{-1} while, in agricultural soils it was varied from 64.50 to 83.00 mg kg^{-1} (Table 2). The values of Cu in soils of agricultural areas were lower in context of soils in forested areas. Krauskopf [33] stated that the normal range of total Cu in different soils is between 10 to 80 mg kg^{-1}. Hodge[32] reported that the concentrations of total Cu in this earth ranged from 2 to 250 mg kg^{-1} with an average of 30 mg kg^{-1}. In Bangladesh, total Cu content in the soils[21] ranged from 35 to 145 mg kg^{-1} and 20 to 89 mg kg^{-1} in acid soils of Madhupur[20]. Total Cu level of the studied soils was comparatively higher as compared to soils of other two areas of Bangladesh.

Table 3 showed that total Cu in forested soils only was positively and significantly correlated with clay(r=+ 0.784*) and organic matter contents in the studied soils (r=+ 0.682*). Total Cu showed significant difference only in middle soils of forested and agricultural lands (Table 2). From Table 2 it was also observed that the middle layer contained higher levels of total micronutrients as compared to top and bottom layers in both forested and agricultural sites under study.

IV. Discussion

Soils in forested areas were found higher amounts of all total micronutrients (Fe, Mn, Cu and Zn) compared to that of the nearby agricultural areas. Agricultural practices and anthropogenic activities in agricultural areas might enhance the losses of clay particles, organic matter and soil nutrients from the soil. Similar findings have been reported by several authors who showed that tillage operations could enhance organic carbon reduction, soil structure destruction and losses of soil particles and nutrients from the soil[34,35.36]. Sharma *et al.*[37] observed that the total concentrations of micronutrients increased with the increase in clay and organic matter.

The vertical distributions and top soil accumulation of nutrients under different land uses may be influenced by several factors like plant cycling, anthropogenic disturbance and leaching[38]. However, some authors[39,40] stated that metal precipitation-dissolution, adsorption-desorption, complexation and immobilization may play a significant role in their distribution in soils, especially in deeper horizons.

The higher concentration of total Fe and Mn in studied soils than that of the other regions of Bangladesh could be derived from the parent materials and the predominant soil forming processes prevailing under existing environmental conditions. The Bangladesh hill soils are slightly too strongly acidic in nature and rich in iron and manganese[41,42]. He[43] reported that the higher Fe and Mn concentrations are naturally derived from local parent rock that originally have high concentrations of both Fe and Mn.

The soils under study contained relatively lower amount of total Zn. In previous study, higher concentration of total Zn in soils were under agricultural practices where application of Zn played the important role in total form of Zn. But in the present study, total Zn in the soil derived from parent materials might be poor in Zn. The zinc content of soil is mostly influenced by the lithologic character of the soil parent material[44]. Kabata-Pendias *et al.*[45] also observed lower content of total Zn in sandy soils.

The soils under study had relatively high concentration of total Cu compared with the other parts of Bangladesh or other parts of the world as reported by different authors. Several authors [32, 46,47] also stated that copper is most efficiently scavenged by mainly iron-manganese oxide minerals, clay minerals and coatings as well as it is less mobile than other micro elements.

The present study showed that micro elements, *e.g.*, Fe, Mn, Zn and Cu, were strongly correlated with the clay content in both forested and agricultural areas indicating a strong affinity of these elements for clay, Al and Fe oxides. Adriano[48] also reported that most trace metals are known to have a high affinity for clays.

V. Conclusions

The study showed that the concentration and distribution may be influenced significantly by clay contents of the soils. Other factors like organic matter, soil pH and CEC may have some effects on the mobility of the total micronutrients. The study also indicates that tillage activities in agricultural site might affect the contents and distribution of soil micronutrients. As total elements play the important role in plant growth by affecting their solubility and availability in soil. So it is needed to adapt proper tillage and management practices that minimize the losses of micronutrient from agricultural area and finally to ensure proper crop production.

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