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Short Communication

Profile Distribution of Soil Organic Carbon in Major Land Use Systems in Bishalgarh Block, Tripura

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Understanding the distribution of soil organic carbon (SOC) is the key component for evaluating current and potential soil productivity, and suggesting necessary protection measures. Soil and climate have long-term effects on SOC, while land use has a strong and direct impact (Cantarello *et al.* 2011). The SOC content, for example, may quickly decline once a forest is converted into cropland and plantation (Kurbah *et al.* 2016).

Profile distribution of SOC under different land uses is important for evaluating soil functions and understanding SOC sequestration process (Venteris *et al.* 2004). The soil ecosystems in tropical and sub-tropical regions are highly fragile and, therefore, any change (depletion, enhancement or no change) in SOC as a consequence of change in land use is critical (Sharma *et al.* 2005).

The north-east part of India with a very diverse land use system could be an ideal region to explore. The current study was, therefore, undertaken in three major land use systems prevalent in Bishalgarh block of Sepahijala district of Tripura state with the objective to examine effects of land use on SOC density and a few other soil properties.

Geomorphologically, the study area (23°36′51″-23°45′02″ N, 91°08′58″-91°23′00″ E) represents undulating topography (3-25% slope), with high hills, hillocks and patches of plains interspersed with rivers and valleys. Rocks are sandstone, siltstone and shale grading into clay, arranged in layers one above the other. The climate is moderately warm and humid.

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Soil samples were collected from three major land use systems located on varying slopes, where degraded forests were cleared 20-25 years ago. The slope gradient was 3-5% in the lower, 5-10% in the middle and 10-25% in the upper units dominated by cropland, tea plantation and rubber plantation, respectively. A total of 51 soil samples were collected from three depths (0-25, 25-50 and 50-100 cm) of representative soil profiles (five from tea and rubber plantation each, and seven from cropland). Soil pH was determined in 1:2.5 soil:water ratio (Richards 1954), SOC was analyzed by wet oxidation method (Walkley and Black 1934), and bulk density (BD) was measured through undisturbed core method (Blake and Hartge 1986). Cation exchange capacity (CEC) was determined following Jackson (1973), and exchangeable aluminium (Al) was extracted with 1 *N* potassium chloride (KCl) solution and titrated with 0.1 *N* sodium hydroxide (NaOH) solution (Page *et al.* 1982).

The SOC density was calculated with the following equation:

$$\text{SOC density (Mg ha}^{-1}\text{)} = \frac{\underset{(\text{g kg}^{-1})}{\text{SOC}} \times \underset{(\text{Mg m}^{-3})}{\text{BD}} \times \underset{(\text{cm})}{\text{soil depth}}}{10}$$

Statistical analyses were performed using SPSS v.17.0. One-way analysis of variance was performed to test the effect of land use on SOC content and SOC density. Turkey's HSD test was used for mean separation when the analysis of variance showed significant difference at $p < 0.05$ between the variables.

The sand content in all the depths was higher in cropland compared with rubber and tea plantation (Table 1). Significant differences in sand and silt at 0-25 and 25-50 cm depths were recorded among land uses, although the clay contents were similar.

Table 1. Soil properties in 0-25, 25-50 and 50-100 cm layers in relation to land uses

Soil variables	Soil layer (cm)	Rubber plantation	Tea plantation	Cropland
BD (Mg cm^{-3})	0-25	1.29^{a}	1.54^{b}	1.66^{b}
	25-50	1.49^{a}	1.64^{a}	1.71^{a}
	50-100	1.50^{a}	1.59^{a}	1.64^{a}
θg (g g^{-1})	0-25	0.37^{a}	0.16^{b}	0.20^{b}
	25-50	0.20^{a}	0.15^{a}	0.21^{a}
	50-100	0.23^{a}	0.21^{a}	0.26^{a}
Sand content (%)	0-25	17.8^{a}	29.9^{a}	52.6^{b}
	25-50	14.9^{a}	26.1^{a}	51.4^{b}
	50-100	15.3^{a}	24.8^{a}	42.8^{a}
Silt content (%)	0-25	43.3^{a}	36.7^{a}	21.7^{a}
	25-50	41.4^{a}	34.6^{a}	22.6^{a}
	50-100	42.2^{a}	31.5^{a}	26.9^{a}
Clay content (%)	0-25	38.9^{a}	33.4^{a}	25.8^{a}
	25-50	43.7^{a}	39.2^{a}	26.0^{b}
	50-100	42.5^{a}	43.7^{a}	30.3^{a}
pH-H_2O (1:2.5)	0-25	4.8^{a}	4.6^{a}	5.1^{b}
	25-50	4.8^{a}	4.7^{a}	5.2^{b}
	50-100	5.1^{a}	4.6^{b}	5.2^{ac}
Exch. Al^{3+} [cmol(p^{+}) kg^{-1}]	0-25	2.11^{a}	2.53^{a}	0.64^{b}
	25-50	2.46^{a}	3.15^{b}	0.87^{c}
	50-100	2.04^{a}	3.59^{b}	1.09^{c}
CEC [cmol(p^{+}) kg^{-1}]	0-25	8.2^{a}	7.7^{a}	6.0^{b}
	25-50	9.3^{a}	8.1^{b}	6.0^{c}
	50-100	8.8^{a}	8.0^{ab}	6.8^{ac}

BD-Bulk density; θg-Gravimetric moisture content
Means within a row followed by a different letter are significantly at *p≤0.05*.

Variation in sand, silt and clay contents with depth was marginal, except sand (52.6%) and silt (43.3%) content at 0-25 cm depth in cropland and rubber plantation, respectively, the clay content (43.7%) at 50-100 cm depth in tea plantation was higher compared to other depths and/or land use.

Mean BD values were higher under the cropland with the highest value of 1.71 Mg m^{-3} in 25-50 cm layer (Table 1). This could be due to tillage and livestock movement resulting in a compact sub-surface layer. Bulk density did not vary (p < 0.05) between land uses, except under rubber plantation and cropland in 0-25 cm depth. The soil moisture content at sampling in the surface 0-25 cm layer ranged from 0.20 g g^{-1} in cropland to 0.37 g g^{-1} in rubber plantation. Variation was marginal, except in the surface layer of rubber plantation, which was higher than the tea plantation and cropland. The pH was higher under cropland (5.1-5.2) compared with tea plantation (4.6-4.7) and rubber plantation (4.8-5.1) at all depths. Lower pH under tea plantation indicated leaching of bases, while a relatively higher pH in rubber plantation could be due to the fact that trees have the capacity to contribute to soil bases to counter-balance growing acidity (Reza *et al.* 2014).

Exchangeable Al content was also influenced by land uses (Table 1). Mean value of exchangeable Al was higher in tea plantation (2.53-3.59 cmol(p^{+}) kg^{-1}) followed by rubber plantation (2.04-2.46 cmol(p^{+}) kg^{-1}) and cropland (0.64-1.09 cmol(p^{+}) kg^{-1}). The tea and rubber plantations can sustain in soils with high exchangeable Al, whereas field crops grow in low exchangeable Al soils (Bhattacharya *et al.* 2010). Maximum exchangeable Al was in tea plantation in 50-100 cm soil layer (3.59 cmol(p^{+})kg^{-1}), and the least was recorded in cropland in 0-25 cm soil layer (0.64 cmol(p^{+}) kg^{-1}). Difference in exchangeable Al across land uses was due to variation in slope which controlled the pedogenic processes on a local scale (Buol *et al.* 1997), affecting exchangeable bases. CEC of soils was significantly lower in the cropland compared with other land uses. Marginally higher clay content in soils under rubber and tea plantation was associated with relatively higher CEC in these soils.

Among land uses, rubber plantation recorded highest SOC content in the soil followed by cropland and tea plantation. Furthermore, rubber plantation had 25% greater SOC content than that in tea plantation. Relatively higher SOC contents in rubber plantation could be due to higher C input through litter, whereas lower SOC content in cropland is a result of tillage and removal of crop residues. The SOC content decreased with an increase in depth under all land uses (Fig. 1). This is in agreement with earlier studies (Singh *et al.* 2018). Below 50 cm, cropland had relatively higher values compared with other land uses, possibly owing to higher slopes with rubber and tea plantation, which contributed to runoff and translocation of soil materials to lower slopes (with cropland) (Reza *et al.* 2014). The box-plot on the distribution of SOC showed that 50% of SOC contents lie between 8.1-11.7, 3.8-7.55 and 2.4-4.7 g kg^{-1} in 0-25, 25-50 and 50-100 cm layers, respectively (Fig. 2).

Mean SOC density varied between 22.9-35.0, 21.5-29.6 and 23.4-44.2 Mg ha^{-1} under rubber plantation, tea plantation and cropland, respectively (Fig. 3). Except 0-25 cm layer, cropland had relatively large mean SOC density compared with other land uses. Differences in SOC density among land uses was marginal, except in 50-100 cm layer in cropland, wherein the same was higher (p <0.05) compared with rubber and tea plantations. Relatively high SOC density under rubber plantation could be due to high

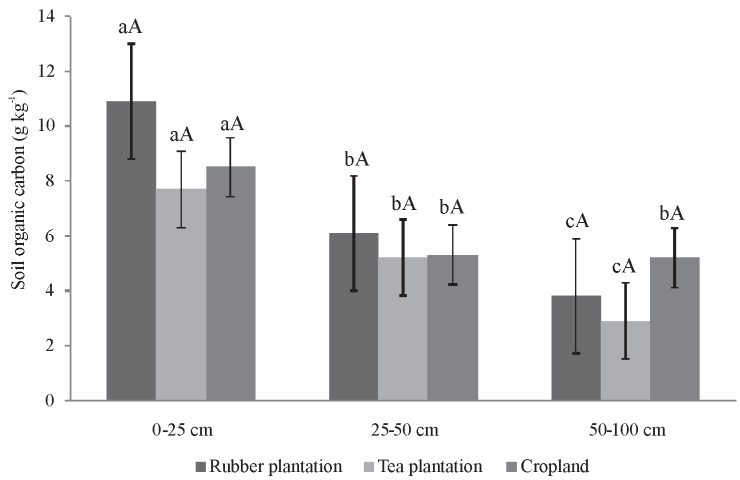

Fig. 1. Soil organic carbon content under different land uses. Mean values sharing the same lower and upper case letters are not statistically different in different soil layers at *p<0.05*.

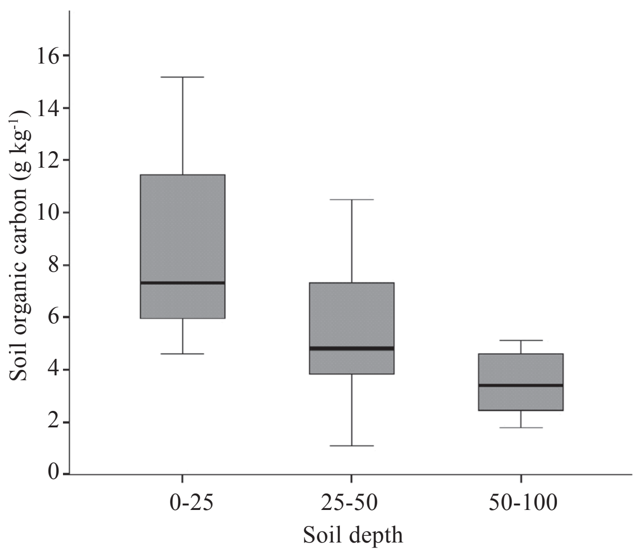

Fig. 2. The box and whisker plot showing distribution of SOC content in different soil layers at *p≤0.05*.

C input to the system, slow decomposition of the same, and deeper rooting of rubber plants compared with tea plantation (Sharma and Rai 2007). As explained earlier, a larger SOC density in the cropland might be related to accumulation of soil mass from upper to down slope through erosion and movement (Singh *et al.* 2011). Larger SOC content and SOC density, and less soil disturbance in the plantation possibly led to a lower BD at the same layer compared to cropland.

Pearson's correlation matrix revealed that SOC density was positively correlated with SOC (r = 0.75, $p < 0.01$), BD (r = 0.26, $p < 0.05$) and CEC (r = 0.24, $p < 0.05$), and inversely correlated with pH (r = 0.22, $p < 0.05$) and exchangeable Al (r = 0.29, $p < 0.05$). The negative correlation between soil pH and SOC implied that H^+ ions released from soil organic matter reduce pH since organic matter is one of the main

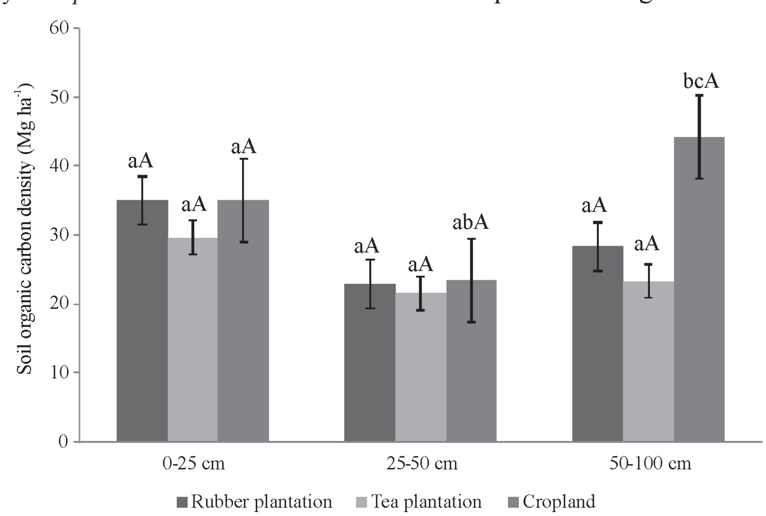

Fig. 3. Soil organic carbon density under land use systems. Mean values sharing the same lower and upper case letters are not statistically different in different soil layers at probability *p≤0.05*.

sources of H^+ in the soil (Satrio *et al.* 2009). The positive correlation between CEC and SOC and the negative correlation between CEC and soil pH recorded in all land uses was in agreement with Bahrami *et al.* (2010) and Singh *et al.* (2011).

To conclude, sand content in all soil depths was higher in cropland, whereas exchangeable Al^{3+} and CEC were lower compared with rubber and tea plantations. The values of BD and pH were also higher under cropland in all layers. The study showed that land use affected the variation in SOC content and SOC density. Profile distribution of SOC density varied with land use due to activities related to conversion of natural vegetation to cultivation which hastened depletion in SOC. Rubber plantation should be encouraged for higher sequestration of SOC in the study area.

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