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Study of Soil Organic Carbon Pool and Its Variation with Depth in the Tropical Dry Deciduous Forest of Ranchi, Jharkhand, India

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Abstract: ***Soil organic carbon pool is very important parameter to understand the health of the soil. Therefore it is necessary to have a check on the organic content and its related soil parameters which effects its distribution in various layers of the soil. pH and bulk density are negatively correlated with the SOC content. In the tropical dry deciduous forest of Ranchi, pH ranged from 5.95- 7.12 in the 0-30 cm, 30-60 cm and 60-90 cm depths and it increased with depth ($F= 5.12$, $p<0.005$). Bulk density also showed same trend ($F= 11.53$, $p< 0.001$) and it ranged between 1.24-1.54 g cm^{-1} in all the three depth distribution. Soil organic carbon and total carbon decreased while going down the soil profile. SOC and TC ranged from 29.78-55.43 Mg ha^{-1} and 41.17-63.23 Mg ha^{-1}, respectively. The soil carbon density ranged from 106.91- 144.8 Mg ha^{-1} in the top 90cm soil. Soil carbon pool of the forest area ranged from 0.0124- 0.0169 PgC.***

Keywords: Soil organic carbon, pH, bulk density, carbon pool, tropical forest

1.Introduction

Soil is the largest carbon pool in the terrestrial biosphere, and hence minor changes in soil organic carbon (SOC)storage could have significant impacts on atmosphericCO_2 concentration (Johnston *et al*. 2004).It is the largest contributor to total global carbon stocks. SOC pool has been estimated to be approximately three times the size of the atmospheric pool, and about four times the size of the biotic pool (Janzen2004, Lal 2004). Organic carbon is the basic building block for all life on the earth. It is widely accepted that the organic carbon content of soil is a major factor in its overall health (Mishra *et al.* 2002).

Because of the large areas involved at regional/global scale, forest soils play an important role in the global C cycle (Detwiler and Hall, 1988; Bouwman and Leemans, 1995; Richter *et al*., 1995; Sedjo, 1992; Jabaggy and Jackson, 2000). Land use change causes perturbation of the ecosystem and can influence the C stocks and fluxes. In particular, conversion of forest to agricultural ecosystems affects several soil properties but especially soil organic carbon (SOC) concentration and stock (Schlesinger, 1985; Post and Mann, 1990; Davidson and Ackerman, 1993).Interest in the ability of forest soils to sequester atmospheric CO_2 derived from fossil fuel combustion has increased because of the threat of projected climate change. Thus, understanding the mechanisms and factors of SOC dynamics in forest soils is important to identifying and enhancing natural sinks for C sequestration to mitigate the climate change (Lal, 2005).Studies also report that tropical forest carbon stocks are currently declining with losses due to deforestation and habitat degradation (Borah *et al*. 2015). Thus, an accurate characterization of carbon pool in tropical forest is utmost importance to estimate their contribution to global carbon stocks.

2.Material and methods

Study site

The present study was carried out in Ranchi which is located on southern part of the Chota Nagpur plateau. It is located at 23°21′N 85°20′E/ 23.35°N 85.33°Eand its average elevation is651 m above sea level. Ranchi has a hilly topography and is surrounded by dense tropical forests. The forests come under the Dry peninsular sal-Type 5B/C -IC. Total forested area of Ranchi is 0.1164 Mha which is 22.84 % of total geographical area (FSI, 2017 Report). Relative humidity of the region remains low. December is the coldest month with minimum temperature of 10.3°C and May is the hottest month with maximum temperature of 37.2°C. Average annual rainfall of the district is 1375 mm and more than 80 percent precipitation received during monsoon months. From June to September the rainfall is about 1, 100 mm.

Field sampling and laboratory analysis

Sampling was done from the Kanke and Mahilong range of the forest of Ranchi. From these ranges, eight sites was selected i.e. Menhri, Uparonki, Sadma and Charo from Kanke range and Gango, Kundla, Huringdih and Banda from Mahilong range. Field sampling was done in October and November, 2015. Five soil replicates, from three depths i.e. 0-30, 30-60 and 60-90 cm, were collected from each site to estimate different physio-chemical parameters. Soil pH and bulk density was estimated following Allen *et al.* (1974). SOC and total carbon was measured through combustion process (Liqui II TOC Elementar Analyser). Carbon concentration was converted into unit of Mg per hectare by formula given by Batjes (1996). The SOC pool was calculated using mean SOC densities and forest area (Chhabra *et al*. 2003).Observed data was statistically analyzed by main effect ANOVA, with depth as a factor. Correlations between variables were calculated using

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Pearson's correlation coefficient. The statistical analysis was performed using the Statistica version 6, Statsoft. Inc.2001, USA.

3.Results

Variations of the soil parameters

In all the sites, soil pH in the upper soil profile was lower than the next 2 depths and varied significantly (F= 5.12, p<0.005). It also varied significantly with the sites (F= 33.01, p< 0.001). It ranged from 5.95- 6.79 in 0-30 cm and6.24- 6.88 in 30-60 cm depth and was found maximum in Uparonki. Charo had highest pH in 60- 90 cm and in this depth pH ranged from 6.78- 7.12. Soil pH increased with soil depth in all soil profiles (Figure 1A.). The soil bulk density also increased with depth and varied significantly (F= 11.53, p< 0.001) (Figure 1B.). It showed significant variation with the sites (F= 9.52, p< 0.01). In 0-30 cm depth it ranged from 1.24-1.45 g cm^{-1} and was found to be highest in Uparonki. The next depth showed range of 1.26-1.54 g cm^{-1}. Uparonki had highest bulk density in the 30-60 cm depth. In 60-90 cm depth, highest was in Banda site and the range in this depth was 1.31-1.50 g cm^{-1}. Distribution of pH and BD in various sites are shown in figure 2A and B respectively.

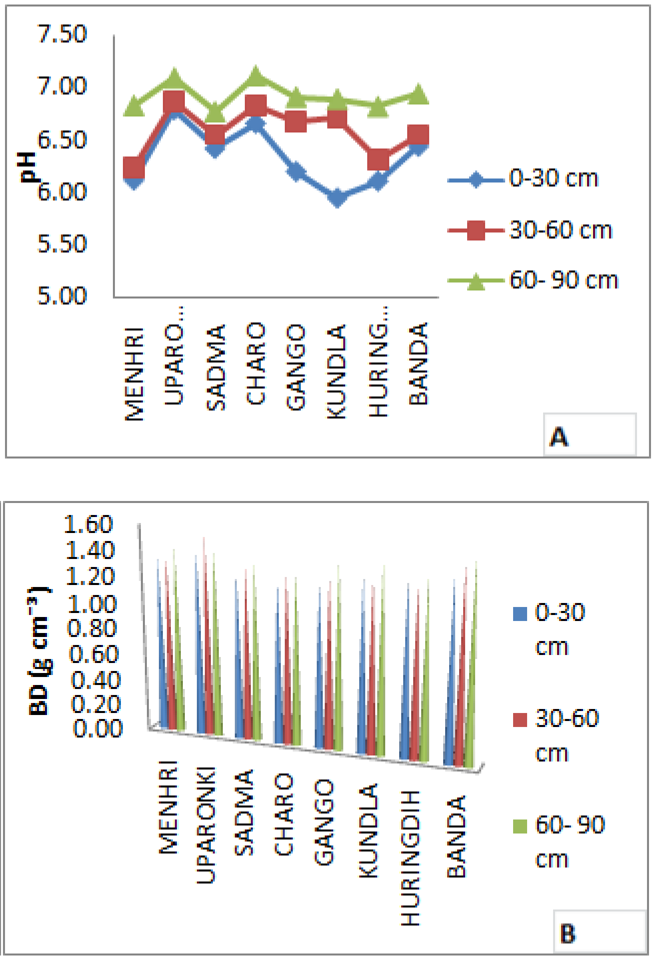

Figure 1: Graph showing variations in (A) pH and (B) bulk density in different depths and sites.

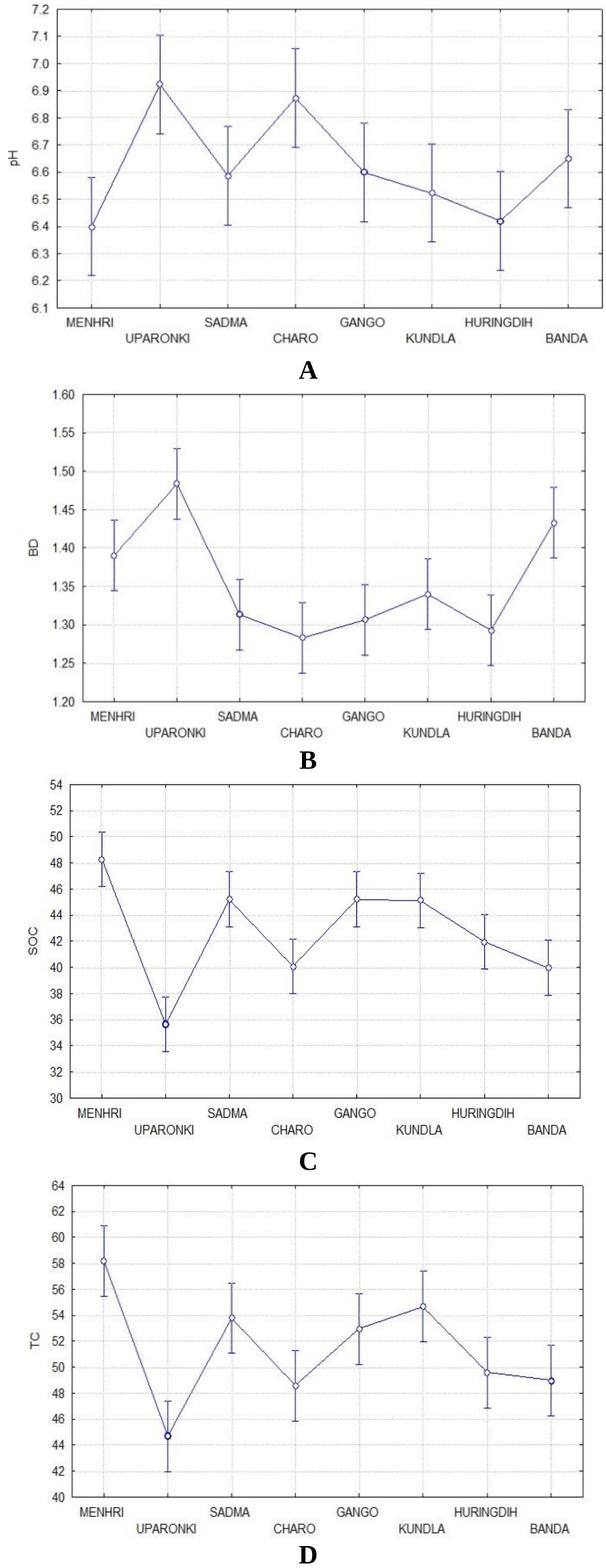

Figure 2: Vertical distribution of (A) pH, (B) bulk density, (C) soil organic carbon and (D) soil total carbon in the different forest sites.

Variations of the soil carbon

Soil organic carbon decreased while going down the soil profile (F=17, p< 0.001). It varied significantly with change in site (F= 143.04, p< 0.001). Maximum carbon density was found in the upper profile i.e. 0-30 cm and it ranged from 41.45- 55.43 Mg ha^{-1}. Kundla had highest carbon density in this depth. In 30-60 cm depth, range was

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between 35.68-48.65 Mg ha^{-1} and Menhri had the highest. Range of 29.78-42.58 Mg ha^{-1} was found in 60-90 cm depth with Menhri having the maximum carbon density (Table.1).

Soil total carbon also decreased with the depth ($F=11.28$, $p< 0.001$). It varied significantly with change in site ($F= 41.18$, $p< 0.001$). Highest carbon density was found in the 0-30 cm depth ranging from 48.41-63.23 Mg ha^{-1}. Kundla had the highest carbon density in this layer. In the next layer, range was from 44.46-57.83 Mg ha^{-1} and in 60-90 cm depth, range was found to be between 41.17-56.31 Mg ha^{-1}. Menhri had the highest in both the depths (Table.1). Distribution of SOC and TC in various sites are shown in figure 2C and D, respectively.

Carbon pool of the forest soil

The estimated mean soil carbon density ranges from 106.91- 144.8 Mg ha^{-1}.Menhri and Uparonki showed the highest and lowest carbon density, respectively and both belonged to the Kanke range. It did not vary significantly with the range ($F=0.06$, $p> 0.05$). Carbon density of Kanke range was found to be 126.89 Mg ha^{-1} and of Mahilong range was 129.2 Mg ha^{-1}(Table 2).Soil carbon pool of the forest area ranged from 0.0124- 0.0169PgC (1 PgC = 10^{15} gC) (Table. 2).

Table 1: Soil carbon density in various depths in the different sites

RANGE	SITE	SOC (Mg ha^{-1})						TC (Mg ha^{-1})					
		0-30 cm		30-60 cm		60- 90 cm		0-30 cm		30-60 cm		60- 90 cm	
KANKE	MENHRI	53.57	±3.16	48.65	±3.2	42.58	±3.17	60.36	±3.11	57.83	±4.1	56.31	±4.16
	UPARONKI	41.45	±4.1	35.68	±3.1	29.78	±4.1	48.41	±5.12	44.46	±3.15	41.17	±2.1
	SADMA	51.68	±3.25	45.38	±4.18	38.57	±3.12	57.59	±5.21	53.42	±3.17	50.32	±3.12
	CHARO	46.25	±4.44	41.37	±3.04	32.58	±4.89	51.83	±4.16	49.17	±4.11	44.76	±4.1
MAHILONG	GANGO	54.64	±4.16	43.18	±4.2	37.84	±2.15	61.34	±2.17	50.48	±4.11	47.08	±3.1
	KUNDLA	55.43	±3.21	43.69	±3.1	36.27	±3.2	63.23	±4.15	53.52	±3.05	47.27	±4.2
	HURINGDIH	50.25	±3.19	41.58	±3.15	34.02	±2.15	56.10	±4.21	48.38	±3.05	44.31	±3.04
	BANDA	46.17	±4.2	40.79	±2.2	32.95	±3.1	55.07	±3.05	48.13	±3.19	43.75	±2.2

±means SE

Table 2: Soil carbon density and pool estimates in different sites of Ranchi forest

RANGE	SITE	Soil C density (Mg ha^{-1})		Soil C Pool (Pg C)	
KANKE	MENHRI	144.80	±9.53	0.0169	±0.001
	UPARONKI	106.91	±11.3	0.0124	±0.001
	SADMA	135.63	±10.56	0.0158	±0.005
	CHARO	120.20	±12.38	0.0140	±0.001
MAHILONG	GANGO	135.66	±10.51	0.0158	±0.003
	KUNDLA	135.39	±9.51	0.0158	±0.005
	HURINGDIH	125.85	±8.49	0.0146	±0.001
	BANDA	119.91	±9.5	0.0140	±0.008

Correlations of soil carbon and soil parameters

Correlation analysis showed that soil organic carbon was positively correlated with TC ($p<0.01$) and was negatively correlated with depth, pH and BD ($p<0.01$) (Table 2). Increasing depth showed positive correlation with pH ($p<0.01$) and BD ($p<0.05$). pH showed positive correlation with BD ($p<0.05$) and negative correlation with SOC and TC ($p<0.01$). TC had negative correlation with depth, pH and BD ($p<0.01$) (Table 2). In general SOC and TC had similar correlation trends with soil factors as total carbon pool.

Table 3: Correlations of soil carbon, depth and other soil parameters

	site	DEPTH	pH	BD	SOC	TC
site	1.00					
DEPTH	0.00	1.00				
pH	-0.10	0.75**	1.00			
BD	-0.18	0.41*	0.47*	1.00		
SOC	-0.08	-0.83**	-0.90**	-0.55**	1.00	
TC	-0.08	-0.68**	-0.85**	-0.48**	0.96**	1.00

SOC: soil organic carbon, TC: total, carbon, BD: bulk density: * significant at 0.05, ** significant at 0.01 level.

4.Discussion

Soil pH was acidic in the studied sites except in the site of Uparonki and Charo at the depth of 60-90 cm, which was slightly basic. It was due to the increased carbonate content in the deeper layers (Kaul, 2009). Soil pH significantly increased with increasing soil depths across all the sites which were due to less soil organic matter at deeper soil layers (Kaul, 2009; Toni et al., 2009). Increase in pH with increasing soil depth could be because of increase in the concentration of carbonates (Kaul, 2009). In our work soil pH is significantly negatively correlated with soil organic carbon ($p < 0.01$). It indicates that increased SOC decreases the soil pH. Low soil pH in natural forest as compared to the disturbed sites could be the result of lower rate of leaching leading to greater accumulation of reaction products in the soil (Arunachalam et al.1999). Decrease in pH was observed as number of tree in the land-use increased due to the addition of more organic matter which results in production of organic acid during decomposition (Kaul, 2009; Chavan et al. 1995). Contractor & Badnur (1996) have also supported the low pH under natural forest. In the present study, soil bulk density is negatively correlated with soil organic carbon. Similar results were observed in

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many studies (Tremblay et al., 2002; Prevost, 2004; Mestdagh, 2006 and Sakin et al., 2012). So our results were therefore consistent with previous research. Present study indicates that the bulk density increase with increasing soil depths as a result of change in organic matter content, porosity and compaction (Lal, 2004 and Sakin et al, 2012).

Our data showed that SOC decreased toward the depths. This trend is consistent with previous studies (Lal 2004). Higher concentration of SOC and TC at top soil layer is mainly due to the fallen leaves and branches on the first horizon. The decrease of SOC with the soil depth is also because of reduced soil organic matter (Jobbagy and Jackson, 2001). Several other authors also observed a decrease in organic matter, total carbon, and total nitrogen with an increase in depth (Fernades et al., 2002; Annan-Afful et al., 2004; Toni et al., 2009).

The soil organic carbon density estimate of tropical dry deciduous forest of India varied from 7.7-85.6 Mg ha^{-1} in top 50 cm soil and 18.5-147.7 Mg ha^{-1} in top 1m soil depth (Chhabra et al. 2003). In our study, the result was in concurrence with the above data i.e. range was between 106.91-144.8 Mg ha^{-1} in top 90 cm soil depth. The soil carbon pool of the forest ecosystem of Ranchi was in the range of 0.0124-0.0169 PgC. The tropical dry deciduous forest of India had soil carbon pool of range between 0.75-1.39 PgC (Chhabra et al. 2003).

5.Conclusion

It may be concluded that SOC concentrations and storage were highest in surface soil and depth of 30cm. The organic C contents decreased significantly with increasing soil depth. The other soil parameters were highly correlated with each other and SOC, indicating that they were sensitive to changes in SOC. This study can be used to set an upper limit of soil organic carbon distribution to net carbon release due to deforestation in Ranchi. Difference in total carbon through time reflects both changes in carbon pool and changes in forest area. The forest soil carbon estimates are significant as soils provide an option for rising greenhouse gas CO_2 mitigation by potential soil C sequestration.

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