



## Soil organic carbon under various land uses in alfisols of Eastern India

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Received: 12 November 2019; Accepted: 18 January 2021

### ABSTRACT

Majority land use changes from the natural forests to commercial agricultural lands, orchards and grazing lands have occurred due to deforestation and land degradation. Soil organic carbon (SOC) is considered as one of the important soil quality parameters for sustainable land management. The present study was formulated to understand the effects of land use changes from forest land to cultivated lands, orchards and grazing lands on carbon pools and carbon stocks in subtropical alfisol ecosystem of Banka district of Eastern India 2015–16. Results showed that soil organic carbon (SOC) in the cultivated land was declined by 47%, 23% and 13%, respectively as compared with the forests, orchards and grazing lands of the soil depth 0-15 cm and 37%, 12% and 12%, respectively in the same order of the soil depth 15-30 cm. The loss of carbon stock in the cultivated soil in the top 30 cm was 14%, and in orchard and grazing land was almost similar while keeping forest soils as a reference. In surface soil, carbon management index (CMI) values for grazing, cultivated and orchards were 93, 83 and 95, respectively, whereas in subsurface soil CMI values for grazing, cultivated and orchards were 95, 92 and 96, respectively as compared to forest land. Overall, SOC content was declined on conversion of forest land to cultivated land in the region. This is alarming situation and requires managing cultivated soil properly otherwise soil productivity will deteriorate and in turn will affect crop productivity in the region.

**Keywords:** Active carbon, Carbon stocks, Carbon management index, Cultivated land, Forest

Soil organic carbon (SOC) is considered as one of the important indices of sustainable land management, which contributes to improving soil health and sustainability (Sharma *et al.* 2019). The degradation of land due to improper practices affects the soil and ecological quality (Papini *et al.* 2011) and it is mainly related to the organic matter depletion from the soil (Virto *et al.* 2014). Change in land use affects the soil properties and the quantification is important for assessing the effects of current land management practices (Padbhushan *et al.* 2020). Active carbon pools in a soil are good soil quality indicators (Padbhushan *et al.* 2020). They play an active role in the nutrient availability and microbial transformations in different land use systems. The understanding of active carbon and carbon stocks helps to determine the sustainability of agro-ecosystem. The study area was Banka district of Bihar (India) which is prominent by red soil with different land use systems. The main land use systems found in the region is forest, grazing, orchards, and cultivated land. The area of agricultural land is about

40% of the total land and area of the forest and grazing is sum of about 50% of the total lands. Some of the area is under newly developed orchards of different trees converted from forest land.

Climate can be considered as a major parameter for determining the level of organic carbon in the soil. It seems a big challenge to maintain higher equilibrium levels of organic matter due to the relatively fast rate of decomposition and thus it calls for the management of organics so that adequate labile SOC pool could be maintained (Padbhushan *et al.* 2016a, b). The eastern part of India is facing the problem of land degradation resulted from human interventions and sudden climate change. However, there is no published information regarding the comparative active carbon pools and organic carbon stocks across various land use systems in Eastern India. The present study has been designed to generate information in relation to pools of carbon and carbon stock in the alfisol of Banka district.

### MATERIALS AND METHODS

The study was targeted for Banka district which is located in South Bihar Alluvial Plain Zone, i.e. the Agroclimatic Zone IIIA of Bihar (Ghosh 1996). Geographic coordinates of district Latitude, Longitude and Altitude 24°03' to 25° 008' N, 86° 030' to 87° 012' E and 79 m, and average annual rainfall 1200 mm respectively.

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**Collection, preparation and analysis of soil samples:** Soil samples were collected from six different locations using GPS (global positioning system) from the identified four land use systems: forest, grazing, cultivated and orchards during 2015–16, which makes the 24 sampling sites. Further, at each of these sites, thrice replicated soil samples at two soil depths (0-15 and 15-30 cm) were collected. Total soil samples were 144. Collected soil samples were divided in two parts. First portion is stored fresh at 4°C for estimating SMBC, whereas second portion is air-dried, ground and sieved for analyzing soil properties and pools of carbon. Physico-chemical properties and pools of carbon were estimated for these soil samples using standard methodology (Table 1).

**Soil organic carbon stocks:** Total organic carbon (TOC) was estimated by wet oxidation method as outlined by Snyder and Trofymow (1982).

**Carbon Management Index (CMI):** The CMI is estimated on the basis of Blair *et al.* (1995).

**Statistical Analysis:** Soil properties and pools of carbon under land use systems were statistically analyzed by using analysis of variance (ANOVA) and results are interpreted (Panse and Sukhatme 1985 and Gomez and Gomez 1984). The least significance difference (LSD) test signifies the main effect of treatment means at  $P < 0.05$ .

## RESULTS AND DISCUSSION

**Soil properties:** Forest land had significantly higher SOC content in comparison to other land use pattern both in surface and subsurface layer. The highest SOC in soil depth 0-15 cm was recorded in forest land use (7.3 g/kg soil) followed by orchard land (5.1 g/kg soil), grazing land (4.5 g/kg soil) and the lowest in cultivated land (3.9 g/kg soil), however in 15-30 cm the maximum SOC was observed in forest land (4.6 g/kg soil) than followed by

orchard and grazing land (3.3 g/kg soil) and cultivated land (2.9 g/kg soil). An overall decreasing trend in the organic carbon content of the soils was observed with depths in all the land use systems (Fig 1). SOC at the 0-15 cm and 15-30 cm soil depth in the cultivated lands was 47%, 23% and 13%; and 37%, 12% and 12% lower than the forests, orchards and grazing lands; in the same order. Highest organic carbon content was observed forest soil that may be due to continuous leaf fall and growing of grasses on the surface layer of soil. The continued tillage operation year after year, less use of organic matter and turning over of soil has resulted in a decrease of organic carbon content in cultivated soil (Ahukaemere *et al.* 2015) in forest, fallow and cultivated land.

In case of the bulk density, it was recorded highest in cultivated land use (1.59 Mg/m<sup>3</sup>) followed by grazing land (1.56 Mg/m<sup>3</sup>), orchard land (1.55 Mg/m<sup>3</sup>) and the lowest in forest land (1.52 Mg/m<sup>3</sup>) in soil depth 0-15 cm, whereas in 15-30 cm, the maximum bulk density was observed in cultivated land (1.65 Mg/m<sup>3</sup>) followed by grazing land (1.61 Mg/m<sup>3</sup>), orchard land (1.60 Mg/m<sup>3</sup>) and the minimum in

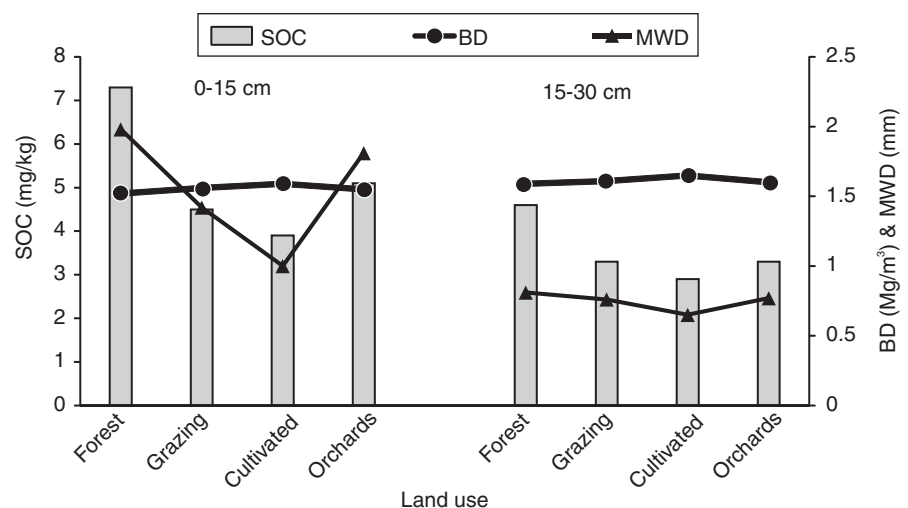


Fig 1 Effect of land use on soil organic carbon (SOC), bulk density (BD) and mean weight diameter of water stable aggregates (MWD) under different land use systems. (\*Figure represents the mean data of soil samples collected from six locations and thrice samples from each location). Here, Bar diagram represents SOC and line diagrams represents BD and MWD.

Table 1 Methodology of estimation of soil characteristics and pools of carbon

Soil characteristics	Soil: Water/method	References
Bulk density	Core method	Uhland (1949)
Oxidizable organic carbon (SOC)	Wet digestion method	Walkley and Black (1934)
Cation exchange capacity	Sodium acetate saturation method	Black (1965)
Aggregate size distribution of soil	Wet sieving method	Yoder (1936)
Soil texture	Bouyoucos hydrometer method	Day (1965)
KMnO <sub>4</sub> oxidizable carbon (PmOC)	33 mM KMnO <sub>4</sub> method	Blair <i>et al.</i> (1995)
Soil microbial biomass carbon (SMBC)	Chloroform fumigation-extraction method	Vance <i>et al.</i> (1987)
Water-soluble carbon (WSC)	1:2 Dichromate digestion method	Ghosh (2003)
Water soluble carbohydrate (WSCHO)	Phenol-sulphuric acid method	Dubois <i>et al.</i> (1956)

forest land (1.59 Mg/m<sup>3</sup>). The trend of bulk density in surface and subsurface soil was similar but overall, the bulk density value was higher in lower soil depth (Fig 1). The cultivated soil was found to have higher bulk density than rest of land uses due to the higher sand content, low organic matter and destruction of soil aggregates by intensive tillage operation. A similar result was reported by Sharma *et al.* (2014). According to Chauhan *et al.* (2014) cereal based upland soil has highest bulk density while lowest bulk density was in pasture land.

In surface soil, increasing trend of MWD was cultivated soil <grazing land <orchard land <forest land. A similar trend of MWD was recorded in subsurface soil. The highest MWD was recorded in forest land (surface soil-1.98 mm and subsurface soil-0.81 mm) while lowest MWD was observed in cultivated land (surface soil-1.00 mm and subsurface soil-0.65 mm) (Fig 1). This may be due to aggregate stability depends on the interaction between primary particles and organic constituents to form stable aggregates, which are influenced by various soil factors related to environmental conditions and management practices. Intensive cultivation and lower organic matter content in cultivated land decrease the aggregate stability. Abad *et al.* (2014) observed that the cultivated soils were considerably lower in aggregate stability properties in comparison to forest and pasture land use types.

**Soil active carbon pools:** The highest PmOC was recorded in forest land (552 mg/kg) followed by orchard land (525 mg/kg), grazing land (514 mg/kg) and lowest in cultivated land (458 mg/kg), whereas in subsurface soil the highest PmOC was observed in forest land (397), followed by orchard land (383 mg/kg), grazing land (377 mg/kg) and the lowest in cultivated land (364 mg/kg) was observed (Fig 2). In surface soil, the highest WSC was recorded in forest land (182 mg/kg) followed by orchard land (149 mg/kg), grazing land (122 mg/kg) and lowest in cultivated land (87 mg/kg). The highest WSCHO was recorded in forest land (414 mg/kg) followed by orchard land (402 mg/kg), grazing land (370 mg/kg) and lowest in cultivated land (348 mg/kg) in surface soil. In surface soil, the highest SMBC was recorded in forest land (326 mg/kg) followed by orchard land (301 mg/kg), cultivated land (204 mg/kg) and lowest in grazing land (145 mg/kg). A similar trend was observed in the subsurface soil for all the above-mentioned parameters. PmOC, WSC, WSCHO and SMBC were decreased in the quantity from surface soil to subsurface soil. Intensive cultivation, no use of organics, crop residue burning and conventional tillage practices results decline in soil carbon content. The forests

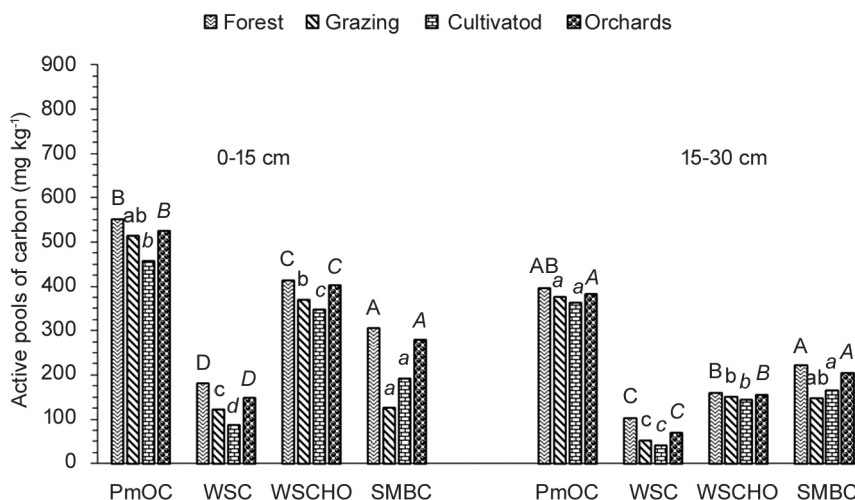


Fig 2 Effect of land use on active pools of carbon under different land use systems (\*Figure represents the mean data of soil samples collected from six locations and thrice samples from each location). Here, PmOC – Permanganate oxidizable carbon, WSC – Water soluble carbon, WSCHO – Water soluble carbohydrate, SMBC – Soil microbial biomass carbon. Values denoted with same letter are not significantly different at P<0.05 using Duncan’s Multiple Range Test.

soils having higher levels of active fractions of C were on expected lines (Aumtong *et al.* 2009, Sharma *et al.* 2014). Due to human and animal activities cultivated land, orchard and grazing land have lower levels of active fractions of C. This could be due to more disturbance of soil system and loss of plant residues due to fast decomposition. The amount of PmOC, WSC, WSCHO and SMBC content were affected by cultivation period, moisture level, biomass retention period, and decomposition rate (Sharma *et al.* 2014).

**Soil organic carbon stocks:** SOC stocks are mainly influenced by the bulk density and soil depth. SOC stocks were recorded highest in forest land (61.37 Mg/ha) followed by orchard (53.81 Mg/ha), grazing land (53.47 Mg/ha) and lowest in cultivated land (52.54 Mg/ha) (Table 2). The SOC stock was almost similar in orchard and grazing land, whereas a slight decrease was observed in cultivated land. When the different systems were compared while keeping forest soils as a reference, a loss of 7.9, 8.8 and 7.5 Mg/

Table 2 SOC stocks, SOC stock losses vis-à-vis forest land use and carbon management index (CMI) of different land use systems with reference to forest at different soil depths (0-15 cm and 15-30 cm). Values denoted with same letter are not significantly different at P<0.05 using Duncan’s Multiple Range Test

Land use	SOC stocks (Mg/ha)	SOC stock loss (Mg/ha)	CMI value	
			Soil depth (cm)	
			0-15	15-30
Forest	61.37			
Grazing	53.81	7.9	93.12a	94.96a
Cultivated	53.47	8.8	82.97b	91.69a
Orchards	52.54	7.5	95.11a	96.47a

ha were observed from grazing, cultivated and orchard, respectively (Table 2). The percentage loss of SOC stock in the cultivated soil was 14.4 % as compared to forest land. The loss of SOC stock in orchard and grazing land was almost similar while keeping forest soils as a reference. The nature and type of land use systems directly impact the dynamics of the mainly active carbon pools and its stock. Anthropogenic activities have significantly influenced carbon pools and fluxes by altering land cover and land use (Bolstad and Vose 2005). The conversion of forest lands to other land uses has been influential in altering the carbon cycle (Sellers *et al.* 1997). Li *et al.* (2007) referred as land disturbances and global warming has been decreasing SOC stocks. Suitable land use systems can help in sequestering C in the soil and reduce the greenhouse effect. Deposition carbon results into balance between input carbon and output carbon. The input carbons are crop residues, organic manure, root exudates, root biomass, and litter fall deposits and output of carbon as respiration (Benbi *et al.* 2014).

**Carbon Management Index (CMI):** For all the land use CMI values were lower than 100 while keeping forest soils as a reference indicate a negative impact of the management practices on soil organic matter content and on the soil quality/health. In surface soil CMI values for grazing, cultivated and orchards were 93.12, 82.97 and 95.11, respectively, whereas in subsurface soil CMI values for grazing, cultivated and orchards were 94.96, 91.69 and 96.47, respectively (Table 2). A substantial part of the current atmospheric carbon pool comes from the terrestrial ecosystem of which soil is a foremost component (Lal *et al.* 1997). Batjes (1996) found that SOM as a contributing component of the terrestrial ecosystem, whose abundance and composition has vital effects on the phenomenon that occur within the system. The accumulation and turnover of SOM is a key factor in soil fertility/quality and ecosystem functioning and determines whether soils act as sinks or sources of carbon in the global carbon cycle (Post and Kwon 2000).

The overall study concludes that soil quality has declined due to conversion from native forest to other land uses in Eastern India by human disturbances and climate change. Specifically, SOC and active SOC pool content was found highest in forest land followed by decreasing trend in orchard and grazing land, whereas cultivated land had relatively lowest SOC and active SOC pool content. The land use change had more impact on pools of active carbon in comparison with the various soil characteristics. SOC and SOC pool was found more in surface soil compared to subsurface soil. Cultivated land had carbon stocks 8.83 Mg/ha lower than the forest soils signifying conversion of land use system from forest to cultivated land contributed losses of 14.4 % over time in top 30 cm soil depth. Therefore, proper strategies for the eastern part of India need to be developed for creating more sustainable agricultural systems which are facing the problem of land degradation due to climate change and increasing anthropogenic pressure on natural resources.

## ACKNOWLEDGEMENTS

We thank Department of Soil Science and Agricultural Chemistry, BAU (Sabour), India for providing research facilities and financial assistance and cordial support.

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