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Soil organic carbon fractions under different land use systems of Jorhat district

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ABSTRACT

The present study was conducted using soil profiles of Jorhat district under different land use systems (LUS) i.e. Bamboo field, tea plantation and rainfed rice. The total soil organic carbon content at 0-15 cm depth varied from 7.86 to 8.43 g kg^{-1}, wherein rainfed rice land use system recorded significantly higher total organic carbon (TOC) than tea plantation but at par with that of bamboo field. However, at 15-30, 30-60 and 60-100 cm soil depths bamboo field recorded significantly higher over other land use systems. Among these LUS, rainfed rice showed significantly higher very labile carbon (C_{VL}) in soil than tea plantation and bamboo field at 0-15 cm depth whereas in 15-30 cm depth C_{VL} in tea plantation was found to be significantly higher than bamboo field and rainfed rice. However, Bamboo field and tea plantation had C_{VL} significantly higher than rainfed rice under 30-60 and 60-100 cm depths, respectively. In all the depths, labile carbon pool (C_L) was significantly higher in bamboo field ranging from 1.01 to 1.67 g kg^{-1} whereas under bamboo field, less labile carbon (C_{LL}) pool 0-15, 15-30 and 30-60 cmdepths was significantly higher than tea plantation and rainfed rice soils. However, the recalcitrant carbon (C_R) pool did not vary significantly among different LUS. Soil organic carbon stock in soil at 0-15 cm depth was found to be significantly higher in rainfed rice soil than tea plantation and bamboo field whereas in the remaining depths the SOC stock was significantly higher under bamboo field. Moreover, the interaction between LUS and depths varied significantly. Among different fractions (C_L, C_{LL}, C_{VL} and C_R fractions), C_R fraction had the smallest variation among land uses, which indicate that the non-labile fraction was less sensitive to land use systems.

Key words: Soil organic carbon, land use systems, fractions, carbon stock and soil carbon pools

INTRODUCTION

Land use is one of the important factors that influence soil organic carbon (SOC) balances between storages and losses of organic carbon (OC) from soils. Change in land use system (LUS) like conversion of native vegetation's to croplands accelerates the loss of OC from soils (Sahoo *et al.*, 2019). However, efficient LUS have a positive effect on SOC and even higher SOC storage (Yu *et al.*, 2017). The SOC is the most complex component of soils because of the heterogeneous mixture of organic compounds (labile to non-labile fractions) and association with different soil components. So, to know the influence of different land uses on SOC and various fractions representing SOC pools is crucial, as it leads to a better understanding of SOC dynamics than the study of the total SOC concentration alone (Chan *et al.*, 2001). There is information available on SOC fractions in relation to vegetation and different land uses in the different parts of the country are available in previous studies (Datta *et al.*, 2015). However, data on SOC fractions in relation to land uses are limited to North-Eastern parts of India. Keeping this in view, an attempt was made to study the changes in SOC fractions under different land uses in North-Eastern India. Most of the Indian soils have the potential to sequester SOC up to 82 Pg per unit area whereas North East Region (NER) of the country is rich in SOC content as compared to other states of the country (Choudhury *et al.*, 2013). Among all the states of NER, Arunachal Pradesh reported the highest carbon stock (1051 million ton) followed by Mizoram (Sharma *et al.*, 2018) while Assam reported only 172.6 million-ton of carbon stock (Choudhury *et al.*, 2013) within 1 m depth, which indicates the immediate attention towards the improvement of carbon stock in Assam. Moreover, regional level data on carbon stock of Assam state is very negligible. So, in order to improve overall carbon sequestration in Assam, it is very important to act locally. As importance of regional study of carbon stock is increasing in the present condition, this study was designed to determine SOC fractions and carbon stock under different land use systems of Jorhat district of Assam.

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MATERIALS AND METHODS

The present study was conducted during 2017 using different LUS i.e. bamboo field (26° 44′ 58.6″ N latitude and 94° 08′ 35.1″ E longitude), tea plantation (26° 45′ 27.5″ N latitude and 94° 08′ 46.7″ longitude E) and rainfed rice (26° 55′ 29.5″ N latitude and 94° 04′ 41″ E longitude) from the Jorhat district. Jorhat is situated under Upper Brahmaputra valley zone of Assam. It has flat topography with some undulating foot hill areas. It has total geographical area of about 2,851 sq km and experiences 138.04 mm of mean annual rainfall. The average temperature varies from 13.2 ºC to 32.15 ºC with January being the coldest month having minimum average temperature of 11.6 ºC and August the hottest month with average maximum temperature of 31.78 ºC. The relative humidity ranges from 52.34 per cent during February to 96.5 per cent during June-July. The elevation of the district varies from 80 to 120 m above mean sea level (MSL). For the analysis, horizon-wise composite soil samples were collected in triplicate from different depths i.e. 0-15, 15-30, 30-60 and 60-100 cm from three different land use systems. The samples were air-dried, ground and passed through a 2 mm sieve and stored in plastic container for routine laboratory analysis. For OC fractionation, 100 mesh soil samples were used. The total carbon in the sample was determined by dry combustion method using CHNS Analyzer (Nelson and Sommers, 1982). Total inorganic carbon (TIC) was determined using Gas volumetric method (Calcimeter) as described by Sherrod *et al.*, 2002. Total soil organic carbon (TOC) in each sample was calculated by subtracting total inorganic carbon from total carbon contents. This was approximated into different pools by the modified Walkley and Black method as described by Chan *et al.*, 2001 using 5, 10 and 20 ml of concentrated (36N) H_2SO_4 that resulted in three acid- aqueous solution ratios of 0.5:1, 1:1 and 2:1 (corresponding to 12, 18 and 24N of H_2SO_4 respectively). The amount of carbon (C) thus determined allowed the sub-fractionation of TOC into the following four different pools according to their decreasing order of oxidizability. Pool I (C_{VL}: Very labile soil carbon): OC oxidizable by 12 N H_2SO_4. Pool II (C_L: Labile soil carbon): The difference between C oxidizable by 18N and that by 12 N H_2SO_4. Pool III (C_{LL}: Less labile soil carbon): The difference between C oxidizable by 24 N and that by 18 N H_2SO_4. Pool IV (C_{NL}: Non labile soil carbon): The difference between TOC and oxidizable C by 24 N H_2SO_4. Soil carbon stock in soil (Mg C ha^{-1}) = Carbon content (g C kg^{-1}) × Soil layer thickness (cm) ×BD (Mg m^{-3}) × 0.1. The statistical analysis was done as per standard ANOVA of two factorials completely randomized design (CRD) using OP-STAT software.

RESULTS AND DISCUSSION

The TOC content at 0-15 cm depth varied from 7.86 to 8.43 g kg^{-1}, in which rainfed rice LUE recorded significantly higher TOC than tea plantation but it was at par with that of bamboo field (Table 1). The greater percentage of TOC in the upper soil layer (0-15 cm) could be attributed to the presence of litter debris in this layer; which facilitates the availability and supplying of mineralizable and easily hydrolysable carbon leading to higher activity and population of microbes (Kumar *et al.*, 2020) and similar results were observed by Brar *et al.* (2013) who reported that long term application of balanced fertilizer along with manure or paddy straw or green manure enhanced TOC in surface paddy soil. However, TOC of 15-30, 30-60 and 60-100 cm soil depths from bamboo field had significantly higher over other two LUS (Table 1). The above results were in accordance with the findings of Geraei *et al.* (2016) who also reported that the highest TOC content in the lower depths of the forest soil was due

Table 1: Total soil organic carbon g kg^{-1} as affected by different cropping systems of Jorhat district

Land use	0 - 15 cm	15 - 30 cm	30 - 60 cm	60 - 100 cm	Mean
Bamboo Field	8.16	7.46	7.10	5.43	7.04
Tea Plantation	7.86	7.13	6.13	4.44	6.43
Rainfed rice	8.43	6.20	4.70	4.30	5.9
Mean	8.15	6.93	5.97	4.73	
LSD (P0.05)	L0.34	D=0.40	LxD = 0.69		

L= land use systems, D= Depth, L×D= land use systems × depth, LSD = Least significant difference to addition of organic matter in the form of leaf litter, which remains in the lower depths of soil as there was absence of any disturbance such as tillage operation which consequently increased the SOC. The soil under rainfed rice LUS recorded significantly higher very labile carbon (C_{VL}) than tea plantation and bamboo field at 0-15 cm (3.27 to 4.25 g kg^{-1}) depth. Application of balanced fertilizer with manure increases polysaccharides (cellulose and hemi-cellulose) in soil that leads to production of higher amounts of C_{VL} in paddy soil. Whereas, in 15-30 cm depth, C_{VL} in tea plantation was found to be significantly higher than bamboo field and rainfed rice (Table 2).

Table 2: Carbon pool–I (very labile pool) g kg^{-1} as affected by different cropping systems of Jorhat district

Land use	0-15 cm	15-30 cm	30-60 cm	60-100 cm	Mean
Bamboo Field	3.27	2.20	1.63	1.10	2.05
Tea Plantation	3.84	2.77	1.50	0.92	2.26
Rainfed rice	4.25	1.80	0.88	0.49	1.85
Mean	3.79	2.26	1.34	0.84	
LSD (P=0.05)	L= 0.14	D= 0.17	L×D=0.29		

However, bamboo field and tea plantation had significantly higher C_{VL} than rainfed rice under 30-60 and 60-100 cm depths. The increase in C_{VL} at lower depths in case of bamboo field soils was attributed to accelerated leaching process of SOC due to the deep root system of bamboo plantation thus contributing for more active carbon in sub-surface soils. Similar results were also observed in case of agroforestry where the C_{VL} constituted 40% of TOC (Benbi *et al.,* 2015). Labile carbon pool (C_L) in bamboo field was significantly higher under all four depths, with mean range of C_L content which varied from 1.01 to 1.67 g kg^{-1} (Table 3).

Table 3: Carbon pool–II (labile pool) g kg^{-1} as affected by different cropping systems of Jorhat district

Land use	0-15 cm	15-30 cm	30-60 cm	60-100 cm	Mean
Bamboo Field	1.33	1.80	2.06	1.50	1.67
Tea Plantation	1.01	1.17	1.30	0.78	1.06
Rainfed rice	1.27	1.20	0.86	0.72	1.01
Mean	1.20	1.39	1.40	1.00	
LSD(P=0.05)	L= 0.23	D= 0.27	L×D= N/A		

It may be due to the fine mesh-like root system of bamboo which might help in binding the soil aggregates together and preventing soil erosion thus preventing the soil organic carbon loss. The above process leads to increased ability of bamboo species to effectively build up soil organic carbon. The higher carbon pools under bamboo plantation may be due to the continuous litter addition and the development of ample fine root biomass by the different species of bamboos (Kaushal *et al.*, 2020a,b).

Table 4: Carbon pool–III (less labile pool) g kg^{-1} as affected by different cropping systems of Jorhat district

Land use	0-15 cm	15-30 cm	30-60 cm	60-100 cm	Mean
Bamboo Field	2.53	2.43	2.41	1.17	2.13
Tea Plantation	1.97	1.89	1.79	1.49	1.78
Rainfed rice	1.34	1.81	1.95	2.24	1.83
Mean	1.95	2.04	2.05	1.63	
LSD(P=0.05)	L= 0.26	D= 0.30	L×D= 0.52		

Less labile carbon (C_{LL}) pool in bamboo field under different depths of 0-15, 15-30 and 30-60 cm was significantly higher than both tea plantation and rainfed rice soils (Table 4) and wherein recalcitrant carbon (C_R) pool did not vary significantly among different LUS (Table. 5).

Table 5: Carbon pool–IV (recalcitrant pool) g kg^{-1} as affected by different cropping systems of Jorhat district

Land use	0-15 cm	15-30 cm	30-60 cm	60-100 cm	Mean
Bamboo Field	1.01	0.98	0.97	1.79	1.19
Tea Plantation	1.03	1.26	1.51	1.23	1.26
Rainfed rice	1.31	1.32	1.00	0.79	1.10
Mean	1.11	1.19	1.16	1.27	
LSD (P=0.05)	L= N/A	D= N/A	L×D= 0.45		

Recalcitrant fraction of organic carbon is not easily influenced by the alterations in land use management practices (Sainepo *et al.*, 2018) because these carbon fractions are strongly bound to the soil mineral matrix to form mineral-humus complexes of and thus are protected from the microbial action and least decomposed (Dwivedi *et al.*, 2019). Besides this, the bamboo also produces Phytolith occluded carbon (Phyt OC) that is highly constant and remains in the soil for long time (Huang *et al.*, 2014). In the study, soil organic carbon stock at 0-15 cm depth varied from 17.3 to 19.6 Mg/ha and it was found to be significantly higher in rainfed rice soil than tea plantation and bamboo field soils. Similarly, there are few studies which showed that the rice farming has lot of potential to improve soil carbon on surface to sequester carbon and it may also mitigate global warming process (Bhattacharyya *et al.*, 2013). However, in the remaining depths, the soil organic carbon stock was significantly higher in bamboo field soil (Table 6).

Table 6: Soil organic carbon stock (Mg ha^{-1}) as affected by different cropping systems of Jorhat district

Land use	0 - 15 cm	15 - 30 cm	30 - 60 cm	60 - 100 cm	Mean
Bamboo Field	17.3	17.7	35.6	37.4	108
Tea Plantation	17.8	15.8	26.9	30.9	91.4
Rainfed rice	19.6	14.9	22.9	27.3	84.7
Mean	18.2	16.1	28.4	31.8	
LSD (P0.05)	L=1.30	D=1.70	LxD = 2.60		

It was also observed that the soil organic carbon stock significantly increased with depths in different LUS. Similarly, soil organic carbon stock of forest under lower depths was higher as compared to agricultural land (Amanuel *et al.*, 2018) which was due to higher biomass deposit under forest compared to the agricultural land. Land use systems have a significant effect on total and SOC fractions in the study area. Among the different fractions, *viz*., C_L, C_{LL}, C_{VL} and C_R fractions, C_R fraction had the smallest variation among land uses, which indicate that the non-labile fraction was less sensitive to LUS.

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