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Assessing the Status of Soil Organic Carbon under Different Land Use Systems in Hill Agroecosystem in Ukhrul District Manipur, Northeast India

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ABSTRACT

One of the main factors impacted by land-use change is the content of soil organic carbon (SOC) in the soil. The objective of this study was to assess the SOC in various land-uses at varying soil depths in Ukhrul District, Manipur, Northeast India. Soil samples at 0-10 cm and 10-30 cm depths were collected from very dense forest, moderately dense forest, open forest, agricultural land, tea farm, home garden and shifting cultivation from the study site. SOC varied significantly ($p < 0.05$) across the different land uses and depths. With a mean value of 4.05 % the SOC for very dense forest was found to be highest which may be due to residue accretion of vegetation and reduced decomposition of organic matter. The minimum SOC was seen in the open forest (1.18 %) and shifting cultivation (1.41 %), this could be because of removal of the crop residues from the land and continuous tillage practice, leading to the loss of SOC. The study found that the content of SOC in the soil is impacted by changes in land-use systems. Sustainable land-use management and efforts to preserve forested areas are required to enhance the content of carbon in the soil.

Keywords Soil, Organic Carbon, Land-use, Climate change.

INTRODUCTION

In the present scenario, climate change is one of the significant issues. The most crucial challenge is reducing the concentration of carbon dioxide (CO_2), which acts as a greenhouse gas that traps the long wave radiation reflected from the earth making the earth's atmosphere warmer and influencing climate change (Meetei *et al.* 2019). According to a report by Intergovernmental Panel on Climate Change (2013), the concentration of carbon dioxide has increased by 40% since pre-industrial times, primarily from the utilization of fossil fuels and secondarily from land-use changes. The change in climate and altering of landuse significantly impact soils (Stockmann *et al.* 2015).

Soil is an integral part of the climate system, the second largest carbon sink after the oceans.Carbon that the plants do not use for their growth is distributed through the roots of plants which in return deposits carbon in the soil. If it is undisturbed, this carbon is stable and can remain trapped for thousands of

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years; healthy soils can help mitigate climate change (European Environment Agency 2021). Soil carbon is a critical component of functional ecosystems and crucial for food, soil, water, and energy security. The influence of these factors creates dynamic feedback between soil and the environment (Stockmann *et al.* 2015). For increasing soil quality SOC has been has regarded as one of the key parameters (Bünemann *et al.* 2018).

The land-use system is one of the leading causes of controlling SOC levels, as it affects the quantity and quality of litter input, rates of decomposition of litter, and the processes of organic matter stabilization in soils (Saini *et al*. 2021). The changes in land use from its native ecosystem to the cultivated ecosystem are the primary cause of the loss of SOC (Yang *et al.* 2019). The primary way carbon is stored in the soil is as soil organic carbon, which includes plant, animal, and microbial residues in all stages of decomposition; the inputs to the system are mainly from leaf litter and root detritus, and the outputs are root respiration and the microbial decomposition of organic matter (Post and Kwon 2000, Davidson and Janssens 2006).

Manipur, with 74.34% (Forest Survey of India 2021) forest cover of its total geographical area, has ignificant potential to sequester soil organic carbon. This present study was carried out with the objectives of assessing the SOC in different land uses and the relationship between SOC and land use types.

MATERIALS AND METHODS

Study area

Ukhrul District is situated in Manipur state which is in the north-eastern part of India (Fig. 1). It lies between $94^{o}0'$E to $94^{o}45'$E longitude and between $24^{o}15'$N to $24^{o}45'$N latitude. It is bounded by Myanmar (Burma) in the east, Senapati District in the west, Nagaland in the north and Tengnoupal of Chandel in the South. Tangkhul Nagas constitute the population of this district. This study area were chosen as there are frequent changes to the land use system and the presence of different types of land cover. The primary type of cultivation practiced by the community is ‘Ngaralui’ (terrace cultivation), and every household practices home gardens, whether big or small. Shifting cultivation was the first agricultural practice by the Tangkhuls. However, due to the various effects, such as a decrease in forest areas, and water scarcity, faced by the people, they have reduced the practice of this cultivation method.

Soil analysis

The study was carried out in the western part of the

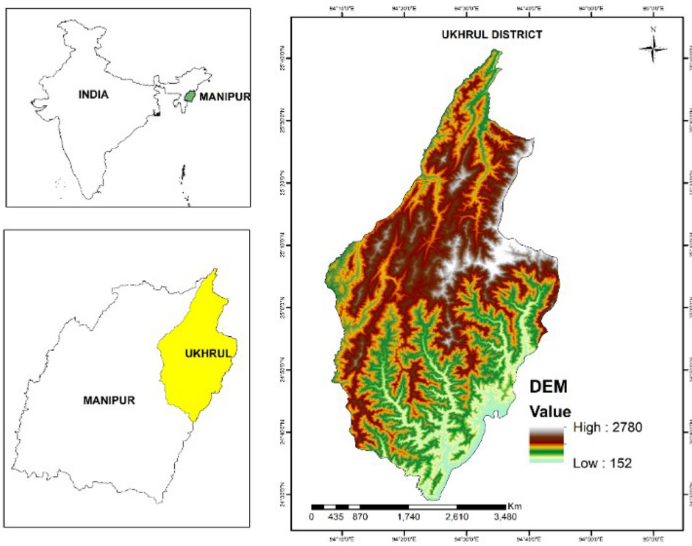

Fig. 1. Map of Ukhrul District, Manipur (study area).

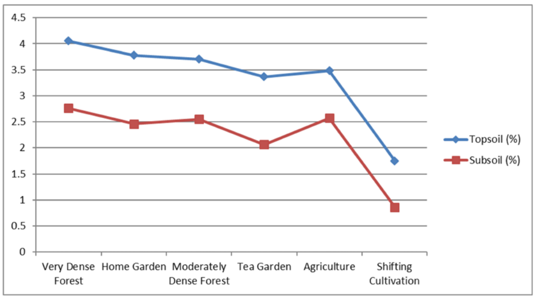

Fig. 2. SOC (Mean %) of different land-use system and soil depths.

district. The soil samples were collected randomly from different land-use systems in the study area; very dense forest (four), moderately dense forest (four), open forest (four), agricultural land (four), tea farm (four), home garden (four) and shifting cultivation (three). The soil samples were collected randomly from January to March 2019 from the study area. The soil sample was taken by driving a core sampler up to 30 cm in depth. Soil cores were sectioned into 0-10, 10- 20 and 20-30 cm, then it was categorized as topsoil (up to 10 cm) and Sub soil (up to 30 cm). The soil was collected using an augur and kept in polythene bags so that they remained in field moist conditions. After removing stones, granules, plant parts, leaves, and stubbles, from the soil samples, it was dried at room temperature, followed by thorough mixing, crushing, and sieving with a 2 mm sieve. Composite samples were prepared by mixing the sieved soils and preserved in polythene. Soil samples were analyzed using the wet oxidation method modified Walkley-Black method.

Statistical analysis

The data which were obtained from the laboratory analysis were put through statistical analysis. The statistical analysis was carried out by using IBM SPSS 25 version.Mean, and standard deviation (SD) for all land use was calculated, and independent sample t-test was carried out to determine the significant variations across the topsoil and subsoil for the various land-use system. In addition, a one-way analysis of variance was used to check the variations across the different land-use types.

RESULTS AND DISCUSSION

The SOC percentage for different land-use systems for different depths is shown in Table 1. The estimates of very dense forest (4.05 %) were recorded as the maximum, followed by the home garden (3.77 %) and then moderately dense forest (3.71 %) in regards to the content of organic carbon out of all the land use typed studied; this could be due to residue addition of vegetation and reduced decomposition of organic

Table 1. Independent samples T-test for determining the significant variations across the different land use system and soil depth layers.

Land use type	Soil iayer	SOC % (Mean)	Range SOC % Min	Max	Std deviation	Std error mean	t	df	Sig. (2-tailed p)
Very dense forest	Topsoil	4.0550	3.67	4.46	0.3529	0.1764	3.698	6	0.010
	Subsoil	2.7625	2.01	3.36	0.6033	0.3016			
Moderately dense forest	Topsoil	3.7075	3.23	4.30	0.4902	0.2451	2.977	6	0.025
	Subsoil	2.5500	1.98	3.18	0.6037	0.3018			
Open forest	Topsoil	1.1850	0.83	1.67	0.3838	0.1919	0.886	6	0.410
	Subsoil	0.9625	0.65	1.34	0.3237	0.1618			
Agricultural land	Topsoil	3.4850	3.12	4.14	0.4577	0.2288	2.719	6	0.035
	Subsoil	2.5700	2.19	3.29	0.4934	0.2467			
Home garden	Topsoil	3.7775	3.37	4.58	0.5514	0.2757	3.686	6	0.010
	Subsoil	2.4600	2.08	3.12	0.4549	0.2274			
Tea farm	Topsoil	3.2100	2.83	3.63	0.4040	0.2020	4.739	5.494	0.004
	Subsoil	1.5875	1.09	2.11	0.5528	0.2764			
Shifting Cultivation	Topsoil	1.4167	0.79	2.27	0.7655	0.4420	0.461	4	0.669
	Subsoil	1.1333	0.57	1.97	0.7389	0.4266			

Topsoil = 0 -10 cm depth, Subsoil = 10 – 30 cm depth.

Table 2. Soil organic carbon percentage content in various forest soils from different sources in Manipur.

Site	Depth of the soil (in cm)	SOC %	Source
Imphal West Manipur	0 - 10	2.75 – 4.44	Devi and Yadava 2009
Chandel District, Manipur	-	3.44 - 4.41	Devi and Yadava 2015
Senapati District, Manipur	0 - 30	0.86 – 2.51	Niirou *et al.* 2015
Senapati District, Manipur	0 -10	2.10 – 3.20	Devi and Singh 2016
East of Ukhrul District, Manipur	0 – 15	5.25	Vashum *et al.* 2016
	15 - 30	3.12	
East of Ukhrul District, Manipur	0 – 15	2.97	Vashum *et al.* 2016
	15 - 30	1.88	
Senapati District	0 - 20	2.37	Meetei *et al.* 2017
Very dense forest	0 – 10	4.05	Present study
	10 - 30	2.76	Ukhrul District
Moderately dense forest	0 – 10	3.65	Present study
	10 - 30	2.55	Ukhrul District

matter (Amanuel *et al.* 2018, Bossuyt *et al.* 2002). While the lowest was seen in the open forest (1.18 %) and shifting cultivation (1.41 %), the reason behind this could be because removal of the crop residues from the land during crop harvesting and continuous tillage practice, and disturbances in the soil that could lead to the loss of SOC (Amanuel *et al.* 2018, Beare *et al.* 1994).

The findings showed that there is a significant difference in the SOC percentage on the topsoil and the subsoil, which was also observed in other studies in forest type land use conducted in different districts of Manipur (Table 2). With the value of $p < 0.05$ in very dense forest, moderately dense forest, agricultural land, home garden, and tea garden, it indicates that the depth has an effect on the amount of organic carbon content in the soil (Table 1). The figure below (Fig. 2) shows the difference in SOC percentage in the topsoil and subsoil in different land use systems. The topsoil will have more potential to sequester and hold carbon in it. This result could be because the upper layers of the soil generally have more favorable conditions for the growth of microbial activity in the process of organic matter decomposition (Amanuel *et al.* 2018, Vashum *et al.* 2016, Yadav *et al.* 2015, Aviles-Hernandez *et al.* 2009).

Table 3. One-way analysis of variance test for the topsoil and subsoil across the different land-use system.

Soil layer	Land-use type	SOC % (Mean)	Range SOC %	Std deviation	Std Error mean	F	df	Sig (p)
Topsoil	Very dense forest	4.0550	3.67	4.46	0.3529	21.561	6	0.000
	Moderately dense forest	3.7075	3.23	4.30	0.4902			
	Open forest	1.1850	0.83	1.67	0.3838			
	Agricultural land	3.4850	3.12	4.14	0.4577			
	Home garden	3.7775	3.37	4.58	0.5514			
	Tea farm	3.2100	2.83	3.63	0.4040			
	Shifting cultivation	1.4167	0.79	2.27	0.7655			
Subsoil	Very dense forest	2.7625	2.01	3.36	0.6033	7.330	6	0.000
	Moderately dense forest	2.5500	1.98	3.18	0.6037			
	Open forest	0.9625	0.65	1.34	0.3237			
	Agricultural land	2.5700	2.19	3.29	0.4934			
	Home garden	2.4600	2.08	3.12	0.4549			
	Tea farm	1.5875	1.09	2.11	0.5528			
	Shifting cultivation	1.1333	0.57	1.97	0.7389			

Topsoil = 0 -10 cm depth; Subsoil = 10 – 30 cm depth

The analysis of the variance test between the mean SOC percentage in the topsoil of the different land-use types and subsoil of the different land-use types shows a significantly different mean with $p<0.05$ (Table 3). This result implies that the type of land use system has a significant effect on the SOC concentration. This suggests that the vegetal cover and land use types have prominent influences on the content of SOC in the soils (Meetei *et al.* 2017, Mastan *et al.* 2015, Gupta and Sharma 2014, Dinakaran and Krishnayya 2008).

CONCLUSION

The monitoring of emission of carbon dioxide is one main natural process to mitigate global warming. This can be done by sequestering carbon in the soil using different land-use systems. From the study, it is observed that land use/land cover changes influence the content of soil organic carbon in the soil. The SOC content in the very dense forest, moderately dense forest, agricultural land, and home garden indicate the highest potential to sequester carbon; the remaining land use type could also improve its SOC holding percentage in its soil with proper management. Accordingly, for cultivated land, the need for sustainable cropping systems such as crop rotation, the addition of organic matter, and crop residues could help reverse the situation. Variations of organic carbon among different land use/land cover types were minimal on the lower soil layer compared to the surface soil layer, implying that the surface soil layer was most affected by different management practices. This study suggest that efforts must be made to preserve the remaining forests and to implement extension programs to ensure the sustainable use of lands and conservation of forested areas.

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