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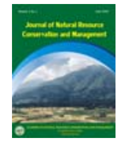

Soil organic carbon stock under different forests in mid hills of Himachal Pradesh

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ABSTRACT

This study was carried out in mid hills of Himachal Pradesh during 2019-2020 to assess the soil organic carbon stock under different forest types and different depths. The seven forest types selected for study were northern dry mixed deciduous forests, Himalayan chir pine forest; ban oak forest, moist deodar forest, mohru oak forest, low level blue pine forest and Kharsu forest. The Highest SOC content (32.3 g kg^{-1}) was recorded under Kharsu forests followed by Deodar (27.7 g kg^{-1}), blue pine and the lowest SOC content (11.6 g kg^{-1}) was noticed under northern dry mixed deciduous forests. The Bulk density of all the forests was ranged from 0.95 to 1.12 Mg m^{-3}. The highest bulk density (1.12 Mg m^{-3}) was recorded under mohru and northern dry mixed deciduous followed by chir pine (1.10 Mg m^{-3}), ban oak (1.09 Mg m^{-3}), blue pine (1.07 Mg m^{-3}), deodar (1.02 Mg m^{-3}) and kharsu forests (0.95 Mg m^{-3}). The soils of different forests contained 26.8 to 37.4 per cent coarse fragments. The kharsu forests stored the highest carbon stock (41.4 Mg C ha^{-1}), whereas Northern dry mixed deciduous forests contained lowest SOC stock (16.6 Mg C ha^{-1}). The contribution of deodar forests towards the total SOC pool of the district was 46.32 per cent followed by23.24, 15.7, 6.14, 5.89, 1.64 and 1.03 per cent by chir pine, blue pine, ban oak, kharsu, and mohru oak and northern dry mixed deciduous forests, respectively.

Keywords: Forest types, soil organic carbon, forest soils, mid-hills of Himachal Pradesh.

INTRODUCTION

Forest is a complex ecosystem consisting mainly of trees that buffer the earth and support innumerable life forms. The FAO (Food and Agriculture Organization) has defined forest as land with tree crown cover (or equivalent stocking level) of more than 10% and area of more than 0.5 hectare. The five major groups of forest in India are tropical montane, montane sub-tropical, montane temperate, sub alpine and alpine which is further subdivided into 16 types.

Evaluation of soil properties under different forest covers revealed profound impact on soil health (Thakur *et al.,* 2020). Inputs like forest productivity, litter decomposition and incorporation into the mineral soil whereas the rates of organic matter decay and the return of carbon to the atmosphere through respiration control outputs (Pregitzer *et al.,* 2003). The variability in soil organic carbon (SOC) is highly dependent on land use, management practices, vegetation type, landscape, anthropogenic influences and climate (Post *et al.* 2000). Soil organic carbon may also be lost through soil erosion and dissolution of organic carbon, but these processes do not result in immediate carbon emissions. Deforestation can contribute a large volume of carbon to the atmosphere either by reducing the amount stored in above ground biomass or increasing the oxidation of SOC. Currently, annual global deforestation is of the 15 × 106 ha, releasing 1.6 × 1015 g C to the atmosphere (Dixon *et al.,* 1994). Soil organic carbon is sensitive to impact of anthropogenic activities. Several studies have been conducted highlighting the impact of land use shift from forest to agricultural lands. It has been observed that forest soils had significantly higher quantities of labile carbon pools as well as that of total organic carbon stocks (Sharma *et al.,* 2004) in comparison to farmlands. Forest, therefore, are a major store house of organic carbon. However, there are variations within the forest themselves on the amount of carbon they can store. Land-use, including land user with permanent vegetation types, and associated management determines carbon stocks and sequestration rates (Nagaraja *et al.*, 2018; Nagaraja *et al.,* 2016; Bhardwaj *et al.,* 2019; Mishra *et al.,* 2015; Bhagat *et al.,* 2003).

Physical properties of soil like structure, texture, particle size and composition have profound impact on soil organic carbon. The release of nutrients from litter decomposition is a fundamental process in the initial biogeochemical cycle of an ecosystem and decomposers recycle large amount of carbon that is sequestered in the plants and soil. The nature and amount of organic carbon produced after decomposition of litter depends on the dominating tree species present and the site characteristics which regulate the physical and chemical properties of soil (Balamurgan *et al.,* 2000). The OC content has been noted to be more near the surface, and it declines, with depth under *Eucalyptus hybrid, Terminalia arjuna* and *Prosopis juliflora* (Jain *et al.,* 1996). A lot of research has been reported for SOC, but no systematic study has been conducted to estimate the soil organic carbon pool of different forest types especially in mid hills of Himachal Pradesh. Most of the researchers have estimated soil organic carbon as one of the soil attributes depending more on the depth of soil sampling and the method of analysis. Keeping this gap in view the present study was done to quantify the soil organic carbon stock under different forests in mid hills of Himachal Pradesh.

MATERIALS AND METHODS

Description of the study area

The present investigation was carried out in the Department of Environmental Science, College of Forestry, Dr. Y S Parmar University of Horticulture and Forestry, Nauni, Solan (HP) by selecting seven different forest types of Mandi district of Himachal Pradesh. The geographic location of the study site was between 31°42′25′′ Northern latitude to 76°55′54′′ East longitudes with altitude varying between 503m to 4,034 m amsl. The sub-mountainous soil is rich in organic carbon with blackish colour, low in available phosphorous and medium in potassium, whereas the mountainous soil is brown in colour, medium in available nitrogen and potassium and deficient in available phosphorous.

It experienced a subtropical highland climate under the Köppen climate classification but climate is composite having hot summers and cold winters, and generally experiences rainfalls during end of summer season. Lower regions enjoy a wet-sub temperate climate at the foothills (450–900 m) as against the dry-cold alpine climate with snow fall at higher altitudes (2400 m – 4800 m). Temperatures typically range from 6.7 °C to 39.6 °C over the course of a year. The average temperature during summer is between 18.9 °C and 39.6 °C, and between 6.7 °C and 26.2 °C in winter. Monthly precipitation varies between 25.4 mm in November to 228.6 mm in August. The average total annual precipitation is 832 mm.

Sample collection and analysis

Seven different forests types' *viz*. Northern dry mixed deciduous forest, Himalayan chir pine forest, Ban oak forest, Mohru oak forest, Moist deodar forest, Low level blue pine forest and Kharsu oak forests of the district were selected for the study. Under each forest type three prominent locations based on spatial variations were identified with three replications (Fig. 1). The soil samples were collected from the identified locations at 0-20 (D1), 20-40 (D2) and 40-60 cm (D3) depth. The samples were then brought to the laboratory, air dried under the shade, ground with wooden pestle mortar, passed through 2 mm sieve and further through 0.5 mm sieve, and stored in cloth bags for analysis. Soil organic carbon was determined by Walkley and Black[7] method and soil bulk density was measured by core method and then the soil organic carbon stock (Mg C ha^{-1}) was calculated by the following formula as:

SOC = [SOC] × Bulk Density × Depth × Coarse Fragments x 10

Where:

SOC = Soil organic carbon stock for soil of each forests, Mg C ha^{-1}

[SOC]= Concentration of SOC in given soil mass, g C (kg soil)$^{-1}$, obtained from lab analysis

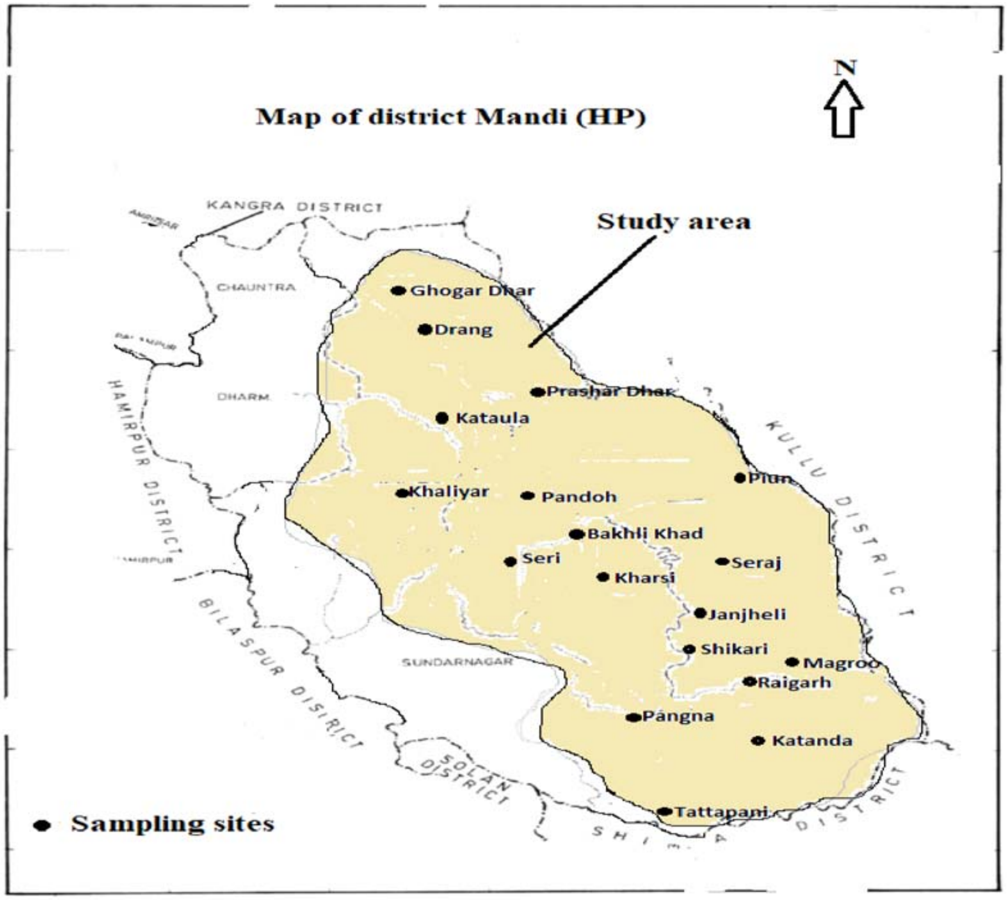

Figure 1. Location of sampling sites in the study area in the Mandi district of Himachal Pradesh.

Bulk Density = soil mass per sample volume, Mg m^{-3}

Depth = Sampling depth or thickness or soil layer (m).

Coarse Fragments = 1-(% volume of coarse fragments/100) being ration it is dimensionless.

Statistical Analysis

The data generated from soil sample analysis was statistically analyzed in accordance with the procedures given by Gomez and Gomez (Gomez *et al.,* 1984).

RESULT AND DISCUSSION

Soil organic carbon (SOC)

The highest SOC content (32.4 g kg^{-1}) was recorded under Kharsu forests followed by Deodar (27.8 g kg^{-1}), blue pine (18.7 g kg^{-1}), ban oak (18.6 g kg^{-1}), chir pine (15.8 g kg^{-1}) and mohru oak (13.6 g kg^{-1}) forests (Table 1).

Table 1. Soil Organic carbon (g kg^{-1}) under different forest typesat different depths

Forest types	Soil depth (cm)			
	D_1	D_2	D_3	Mean
Deodar	31.4	28.4	23.8	27.8
Blue Pine	21.7	18.7	15.4	18.7
Chir Pine	19.3	15.1	12.7	15.8
Ban Oak	20.7	18.4	16.5	18.6
Kharsu Oak	33.8	32.3	31.1	32.4
Mohru Oak	14.8	13.6	12.2	13.6
Northern dry mixed deciduous	13.6	11.3	10.3	11.7
Mean	22.2	19.7	17.4	19.8

The lowest SOC content (11.6 g kg^{-1}) was observed under northern dry mixed deciduous forests. Similarly, the highest SOC (22.2 g kg^{-1}) was found in surface layer (D_1), followed by D_2 (19.6 g kg^{-1}), whereas minimum (17.3 g kg^{-1}) at D_3 (40-60 cm).Among the locations and depths the highest amount of SOC (33.8 g kg^{-1}) was recorded in Kharsu forests at depth D_1 followed by the same forest (32.2

g kg^{-1}) at depth D_2 and Deodar (31.3 g kg^{-1}) forests at D_3 depth. However, minimum SOC content (10.2 g kg^{-1}) was observed under northern dry mixed deciduous forests at 40-60 cm depth. A decreasing trend in SOC with depth was observed with a rate of 2.4 g kg^{-1} per 20 cm of depth (Fig.2).The soil organic carbon content of ban and oak forests showed consonance with findings of Reddy and Gupta (Reddy *et al.,* 2018). Similar results were also reported by Bhoumik and Totey in different forest types (Bhoumik *et al.,* 1990).

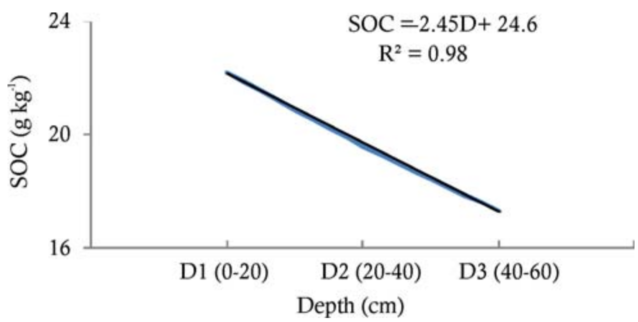

Figure 2. Variation of SOC with depth under different forest types

Soil bulk density

Among all the locations and depths the average soil bulk density ranged from 0.95 Mg m^{-3} to 1.12 Mg m^{-3}. It was found highest (1.25 Mg m^{-3}) under northern dry mixed deciduous forests at depth 40-60 cm followed by Mohru forests (1.24Mg m^{-3}) at the same depth, whereas, lowest (0.86 Mg m^{-3}) was recorded under Kharsu forests at depth 0-20 (Table 2).

The highest bulk density (1.17 Mg m^{-3}) was recorded at depth 40-60 cm, whereas, lowest (0.96 Mg m^{-3}) at depth 0-20 cm. These results were in conformity with the observations of Karan *et al.* (1991), and Cihacek *et al.* (1998). The mean soil bulk density under all the forests continuously decreased with depth at a rate of 0.10 Mg m^{-3} per 20 cm depth (Fig.3). This reduction of bulk density may be due to the decrease in soil organic carbon (Sharma *et al.,* 1995).

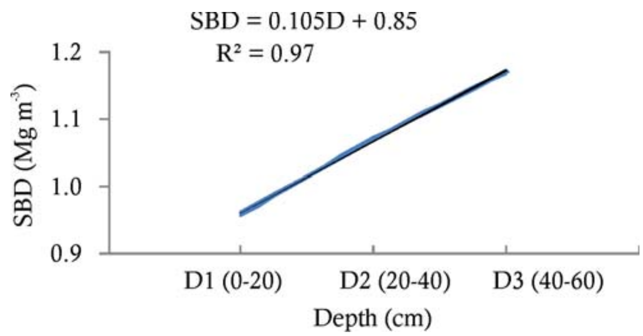

Figure 3. Variation of SBD with depth under different forest types (average)

Soil coarse fragments (SCF*)*

The average gravel contents of the soil under different forest types and depth was found between 26.8 to 37.4 per cent. Highest coarse fragments were found under Mohru Forest (37.4%) followed by Northern dry mixed deciduous forest (36.7%) which was at par with Blue pine (36.6%), Chir pine forest (33.5%), Kharsu forest (32.3%), Deodar forest (28.6%) and Ban oak forest (26.8%) in descending order (Table 3).The highest coarse fragments (37.0%) were observed at depth D_3 followed by D_2 (33.1%) and lowest at depth D_1 (29.3%). Similar results were obtained by Anu (2011) with depths (Anu *et al.,* 2011). The mean soil coarse fragments under all the forests was continuously increasing with depths at a rate of 3.85% per 20 cm depth (Fig.4)

Table 2. Bulk Density (Mg m^{-3}) at different depths under different forests types

Forest types	Soil depth (cm)			
	D_1	D_2	D_3	Mean
Deodar	0.91	1.05	1.14	1.03
Blue Pine	0.96	1.08	1.18	1.06
Chir Pine	1.02	1.12	1.19	1.11
Ban Oak	1.02	1.10	1.19	1.09
Kharsu Oak	0.87	0.95	1.04	0.94
Mohru Oak	1.01	1.11	1.23	1.11
Northern dry mixed deciduous	1.02	1.13	1.26	1.13
Mean	0.97	1.08	1.18	1.07

Table 3. The SCF (%) distribution under different forests at various depths

Forest types	Soil depth (cm)			
	D_1	D_2	D_3	Mean
Deodar	23.1	27.8	35.2	28.7
Blue Pine	33.2	37.1	39.9	36.5
Chir Pine	29.3	33.8	37.6	33.6
Ban Oak	24.1	26.7	29.6	26.7
Kharsu Oak	25.2	32.8	39.1	32.4
Mohru Oak	35.7	37.1	39.3	37.5
Northern dry mixed deciduous	34.8	36.7	38.6	36.8
Mean	29.3	33.1	37.0	33.2

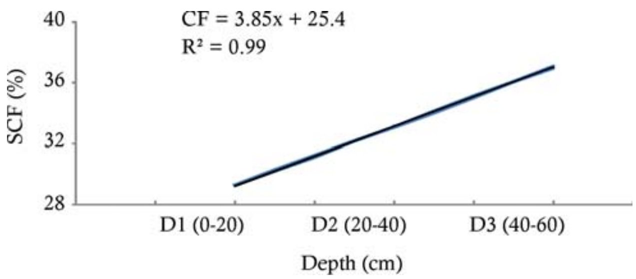

Figure 4. Variation SCF with soil depth under different forest types (average)

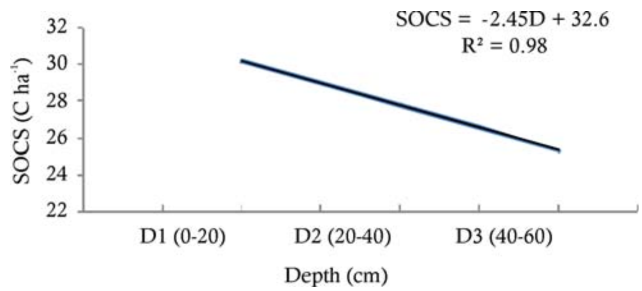

Figure 5. Variation of SOC stock under different forest types (average)

Soil organic carbon stock (SOCS)

The highest SOC stock (41.4 Mg C ha^{-1}) was recorded under Kharsu forests followed by Deodar (39.8 Mg C ha^{-1}), ban oak (29.5 Mg C ha^{-1}), blue pine (25.3 Mg C ha^{-1}), chir pine (22.9 Mg C ha^{-1}) and Mohru oak forests (18.9 Mg C ha^{-1}). The lowest SOC stock (16.6 Mg C ha^{-1}) was noticed under Northern dry mixed deciduous forests (Table 4). The highest SOC stock (30.2 Mg C ha^{-1}) was recorded at depth D_1, followed by depth D_2 (27.8 Mg C ha^{-1}) whereas, lowest (25.3 Mg C ha^{-1}) was observed at depth D_3. The mean value of SOC of all the forests was showing a decreasing trend with soil depths at a rate of 2.4 Mg C ha^{-1} per every 20cm depth (Fig. 5). These results are in tune with the findings of Minhas *et al.* (1997), and Minj *et al.* (2008).

Table 4. The SOC distribution (Mg C ha^{-1}) under different forests at varying depths

Forest types	Soil depth (cm)			
	D_1	D_2	D_3	Mean
Deodar	43.2	41.8	34.5	39.7
Blue Pine	27.8	26.1	22.3	25.4
Chir Pine	27.9	22.2	19.1	22.9
Ban Oak	32.1	29.2	27.1	29.6
Kharsu Oak	44.2	40.3	39.8	41.5
Mohru Oak	19.3	19.3	18.4	18.8
Northern dry mixed deciduous	18.1	16.1	15.8	16.5
Mean	30.4	27.9	25.3	27.8

The soil organic carbon stock of 0-60 cm layer under different forests of Mandi district ranged from 34.6 to 1549.3 Gg C. The highest SOC stock (1549.3 Gg C) was recorded under Deodar followed by chir pine (777.3 Gg C), Blue pine (525.4 Gg C), ban oak (205.4 Gg C), kharsu forests (197.1 Gg C) and Mohru oak. Whereas, lowest SOC stock was observed under Northern dry mixed deciduous (34.6 Gg C) forests. The total SOC stock of different forest was recorded to the tune of 3344.2 Gg C of the soil.

CONCLUSION

A decreasing trend in SOC with depth was observed with a rate of 2.4 g kg^{-1} per 20 cm of depth and that in bulk density was 0.10 Mg m^{-3} per 20cm. The order followed by bulk density under different forests was as Mohru > Northern dry mixed deciduous > Chir pine > Ban oak > Blue pine > Deodar > Kharsu forests. Coarse Fragments under different forests followed the order as Mohru > Northern dry mixed deciduous forest>Blue pine > Chir pine forest > Kharsu forest >Deodar forest >Ban oak forest in descending order. The deodar forests of the Mandi district contained the highest SOC stock (1549.3 Gg C), whereas, northern dry mixed deciduous forests were found to have the lowest SOC stock (34.6Gg C).The contribution of the deodar forests towards the total SOC pool of the district was 46.32 per cent followed by chir pine (23.24), blue pine (15.7), ban oak (6.14), Kharsu (5.89), Mohru oak (1.64) and northern dry mixed deciduous forests (1.03), respectively. Soil organic carbon stock followed an order of Kharsu > Deodar > Ban > Blue pine > Chir pine > Mohru > Northern dry mixed deciduous forest.

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