International Journal of Farm Sciences **3(2)** :81-89, 2013

Soil organic carbon pool under different forest types in Himachal Pradesh

VIJENDER PAL PANWAR and MK GUPTA*

Himalayan Forest Research Institute, Conifer Campus, Panthaghati, Shimla, HP
***Forest Research Institute, Dehradun 248 006 UK**
Email for correspondence: vppanwar@yahoo.com

ABSTRACT

A study was conducted to estimate the organic carbon pool in the soils under different forest types in Himachal Pradesh. Soil organic carbon (SOC) pool was also estimated in all forests sub-group types available in Himachal Pradesh. Maximum pool was in the soils under moist Alpine Scrub (73.26 tonnes/ ha) followed by Himalayan Moist Temperate Forests (55.20 tonnes/ha), Himalayan Dry Temperate Forests (47.61 tonnes/ha) and Sub-alpine Forests (45.67 tonnes/ha) and the least was under Tropical Dry Deciduous Forests (36.04 tonnes/ha). Moist Alpine Forests had maximum mitigation potential (2.03) and the least was in Tropical Dry Deciduous Forests (1.00). Maximum share was occupied by Moist Alpine Scrub (28%) followed by Himalayan Moist Temperate Forests (21%), Himalayan Dry Temperate Forests (19 %), Sub-alpine Forests (18 %) and the least was occupied by Tropical Dry Deciduous Forests (14 %). SOC pool under Moist Alpine Forests was statistically significantly different from the SOC pool under Himalayan Moist Temperate Forests, Himalayan Dry Temperate Forests, Sub-alpine Forests and Tropical Dry Deciduous Forests.

Keywords: Soil Organic Carbon; SOC; mitigation potential; forest types

INTRODUCTION

The concept of carbon sequestration emerged in eighties due to the consequences of steadily increasing level of carbon dioxide in the atmosphere. Concentration of atmospheric CO_2 can be lowered either by reducing emissions or by enabling the storage of CO_2 in the terrestrial ecosystems. Most of the carbon enters the ecosystem through the process of photosynthesis in the leaves. After the litter fall the detritus is decomposed and forms soil organic carbon by microbial process. World soil contains an important pool of active carbon that plays a major role in the global carbon cycle (Lal 1995, Melillo et al 1995, Prentice et al 2001). Soils store 2.5 to 3.0 times carbon as much that is stored in plants (Post et al 1990) and two to three times more than the atmospheric as CO_2 (Davidson et al 2000). Inter-governmental Panel on Climate Change has recognized soil organic carbon pool as one of the five major carbon pools for Land Use and Land Use Change in Forestry (LULUCF) sector. Soil organic carbon is concentrated in the upper twelve inches of the soil. It is readily depleted by anthropogenic disturbances such as land use changes and cultivation. The magnitude of soil carbon depletion is increased by soil degradation especially due to erosion. Land use and soil management practices can significantly influence soil organic carbon dynamics and carbon flux from the soil (Batjes 1996, Tian et al 2002).

Accurate quantification of soil carbon is necessary for detection and prediction of changes in response to changing global climate. No systematic study has been undertaken to estimate SOC in forests soils of India by following uniform methodology for field and laboratory work. Estimation of bulk density and coarse fragments of soil are very important to reduce the uncertainty about the weight of soil of a study area for calculating the SOC pool. A study was therefore conducted so that information generated from this study on SOC store in different forest types serves as a benchmark information for the future investigations and provides authentic information on this very important aspect of climate change.

MATERIAL AND METHODS

The input of organic matter is largely from above ground litter hence forest soil organic matter tends to concentrate in the upper soil horizons with roughly half of the soil organic carbon of the top 100 cm of mineral soil being held in the upper 30 cm layer. The carbon held in the upper profile is often the most chemically

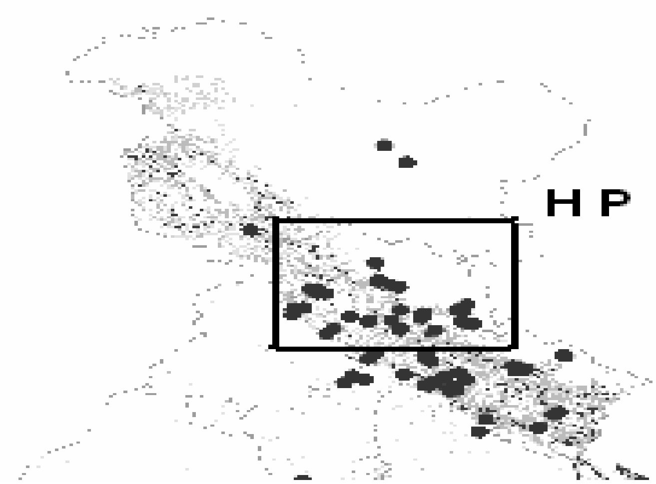

Fig 1. Location of sampling points in Himachal Pradesh

decomposable and the most directly exposed to natural and anthropogenic disturbances (Anon 2003) . Therefore soil organic carbon pool was estimated up to the depth of 30 cm in this study.

Soil samples were collected from all forest types (as described by Champian and Seth (1968) available in Himachal Pradesh. Representative sampling sites were selected under different sub-group types available in each forest type (Fig 1) there. Three soil samples from each sampling site were collected for soil organic carbon estimation and separate samples were collected for bulk density and coarse fragment estimation. Details of sampling sites are given in Table 1.

Table 1. Details of sampling sites under different forest types

Forest type	Sub-group type	Location	Altitude range (m)
Tropical Dry Deciduous Forests	5B/C2 Northern Dry Mixed Deciduous Forests	Jwalamukhi (Kangra)	608-678
	DS1 Dry Deciduous Scrub	Dehra (Kangra)	628-650
Himalayan Moist Temperate Forests	C1f Low Level Blue Pine	Khaknal (Kullu)	1597-1635
	C1e Moist Temperate Deciduous Forests	Rampur (Shimla)	2470-2475
	1S1 Alder Forests	Manali (Kullu)	1631-1684
	DS3 Himalayan Temperate Pasture	Kumarsain (Shimla)	3030-3140
	C1d Western Mixed Coniferous Forests	Narkanda (Shimla)	2580-2645
Himalayan Dry Temperate Forests	C2a Neoza Forests	Kalpa (Kinnaur)	2110-2308
	1S2 Populus & Salix Forests	Kelong (Lahaul & Spiti)	3028-3033
	C3 Western Himalayan Dry Temperate Deciduous Forests	Banjar (Kullu)	2270-2322
	C4 West Himalayan High Level Dry Blue Pine Forests	Kalpa (Kinnaur)	2401-3381
Sub-alpine Forests	C2b Himalayan Birch or Fir Forests	Sangla (Kinnaur)	3622-3825
	C1a West Himalaya Sub-alpine High Level Fir Forests	Kullu (Kullu)	2700-2784
Moist Alpine Scrub	C2 Deciduous Alpine Scrub	Pooh (Kinnaur)	3489
	C1 Birch, Rhododendron Scrub Forests	Sangla (Kinnaur)	3501-3785
	C3 Alpine Pasture	Rohru (Shimla)	3406-3927

Latitude, longitude and altitude of each sampling site were recorded by GPS. Forest floor litter of an area of 0.5m x 0.5 m at each sampling point was removed and a pit of 30 cm width, 30 cm depth and 50 cm in length was dug out. Soil from 0 to 30 cm depth from three sides of the pit was scraped with the help of Khurpee. The soil was mixed thoroughly, gravels removed, kept in a polythene bag and tightly closed with thread with proper labeling. In the laboratory samples were air dried ground and sieved through 100 mesh sieve (2 mm sieve). The sieved sample was used for soil organic carbon estimation. Soil organic carbon was estimated by standard Walkley and Black (1934) method. Amount of coarse fragments was estimated in each sample collected from different forests and deducted from the soil weight to get an accurate soil weight and soil organic carbon estimation on per ha basis. Bulk density of every site was estimated by standard core method (Wilde et al 1964). The methods used were as per given by Ravindranath and Ostwald (2008).

The data for SOC pool were calculated by using the following equation as suggested by (Anon 2003):

Equation for SOC

$$SOC = \sum_{Horizon=1}^{Horizon=n} SOC_{horizon} = \sum_{Horizon=1}^{Horizon=n} ([SOC] * Bulk\ density * depth * (1 - C\ frag) * 10)_{horizon}$$

Where

SOC = Representative soil organic carbon content for the forest type and soil of interest, tonnes C ha^{-1}

$SOC_{horizon}$ = Soil organic carbon content for a constituent soil horizon, tonnes C ha^{-1}

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

Bulk density = Soil mass per sample volume, tonnes soil m^{-3} (equivalent to Mg m^{-3})

Depth = Horizon depth or thickness of soil layer (m)

C Fragment = % volume of coarse fragments/100, dimensionless

RESULTS AND DISCUSSION

Data on soil organic carbon pool under different forest types are presented in Table 2. Data reveal that maximum pool was in the soils under Moist Alpine Scrub (73.26 tonnes/ha) followed by Himalayan Moist Temperate Forests (55.20 tonnes/ha), Himalayan Dry Temperate Forests (47.61 tonnes/ha), Sub-alpine Forests (45.67 tonnes/ha) and the least was under Tropical Dry Deciduous Forests (36.04 tonnes/ha). Under the Tropical Dry Deciduous Forest types two sub-group types were available in Himachal Pradesh; Northern Dry Mixed Deciduous Forests which contain 40.23 tonnes/ha SOC pool and other one is Dry Deciduous Scrub which has 31.84 tonnes/ha SOC pool. Standard error varied from 3.12 to 6.46 which is not on higher side and indicates low variation in the results. Under Himalayan Moist Temperate Forest types five sub-group types are available there viz Low Level Blue Pine having 60.755 tonnes/ha, Moist Temperate Deciduous Forests having 56.59 tonnes/ha, Alder Forests having 42.27 tonnes/ha, Himalayan Temperate Pasture having 42.85 tonnes/ha and Western Mixed Coniferous Forests having 83.40 tonnes/ha SOC pool. Western Mixed Conifers Forests were growing at an elevation of > 2500 m therefore higher SOC pool was expected. Hart and Perry (1999) found that high-elevation old-growth forest soils had higher carbon and nitrogen storage than their low-elevation analogues primarily because low temperatures limit net carbon and nitrogen mineralization rates at higher elevation.

Himalayan Dry Temperate Forests type has four sub-group types in Himachal Pradesh viz Neoza Pine, Populus and Salix Forests, Western Himalayan Dry Temperate Deciduous Forests and Western Himalayan High Level Dry Blue Pine which have 37.11 tonnes/ha, 69.06 tonnes/ha, 64.37 tonnes/ha and 19.90 tonnes/ha SOC respectively. Sub-alpine Forests type has Himalayan Birch or Fir Forests and West Himalayan Sub-alpine High Level Fir Forests and these sub-group types have 43.99 tonnes/ha and 47.35 tonnes/ha SOC pool respectively. In Moist Alpine Scrub Forest type of Himachal Pradesh three sub-group types are available viz Deciduous Alpine Scrub which has 39.22 tonnes/ha SOC pool, Birch, Rhododendron Scrub Forest which has 59.67 tonnes/ha and Alpine Pasture which has 98.18 tonnes/ha SOC pool. Alpine pasture has maximum SOC pool as it is at very high altitude. Grassland soils are high in soil organic carbon and contain an extensive fibrous root system that creates an environment ideal for soil microbial activity (Conant et al 2001). Soil organic carbon content was also found to be strongly correlated with elevation in the grass lands by Saby et al (2008). Subset for á = 0.05 indicate that Moist Alpine Scrub stands separately (a), Himalayan Moist Temperate Forests stand separately (b) Sal and Himalayan Dry Temperate

Forests, Sub-alpine Forests and Tropical Dry Deciduous Forests are together (c) (Table 2).

Mitigation potential for all forest types was worked out against Tropical Dry Deciduous Forests as it contained the least SOC pool and it was observed that Moist Alpine Forests have maximum mitigation potential (2.03). It indicates that soils under Moist Alpine Forests can hold more than double SOC pool as compared to Tropical Dry Deciduous Forests. Himalayan Moist Temperate Forests have 1.53 mitigation potential indicating that these can hold more than one and a half time more SOC pool as compared to Tropical Dry Deciduous Forests. Differences in mitigation potential in Himalayan Dry Temperate Forests and Sub-alpine Forests are not much and nearly similar to Tropical Dry Deciduous Forests.

Per cent share of total SOC pool occupied by different forest types was also worked out and observed that maximum share was occupied by Moist Alpine Scrub (28%) (Fig 2) followed by Himalayan Moist Temperate Forests (21%), Himalayan Dry Temperate Forests (19%), Sub-alpine Forests (18%) and the least was occupied by Tropical Dry Deciduous Forests (14%).

SOC pool in the soils under Moist Alpine Scrub was 32.72 per cent higher as compared to Himalayan Moist Temperate Forests, 53.88 per cent higher than

Table 2. Soil organic carbon pool under different forest types in Himachal Pradesh (up to 30 cm)

Forest type	SOC Pool (tonnes/ha)	SD	Mitigation potential	SE
Moist Alpine Scrub	73.26[a]	± 29.585	2.03	6.46
Himalayan Moist Temperate Forests	55.20[b]	± 21.920	1.53	3.51
Himalayan Dry Temperate Forests	47.61[c]	± 23.536	1.32	3.92
Sub Alpine Forests	45.67[c]	± 21.209	1.26	5.00
Tropical Dry Deciduous Forests	36.04[c]	± 13.252	1.00	3.12

Same alphabets represent statistically at par group

Table 3. Statistically significant mean differences on the basis of CD (LSD)

Vegetation	Mean Difference	P value
Moist Alpine Forests vs Himalayan Moist Temperate Forests	18.0543*	0.004
Moist Alpine Forests vs Himalayan Dry Temperate Forests	25.6441*	0.000
Moist Alpine Forests vs Sub-alpine Forests	27.5833*	0.000
Moist Alpine Forests vs Tropical Dry Deciduous Forests	37.2166*	0.000
Himalayan Moist Temperate Forests vs Tropical Dry Deciduous Forests	19.1623*	0.004

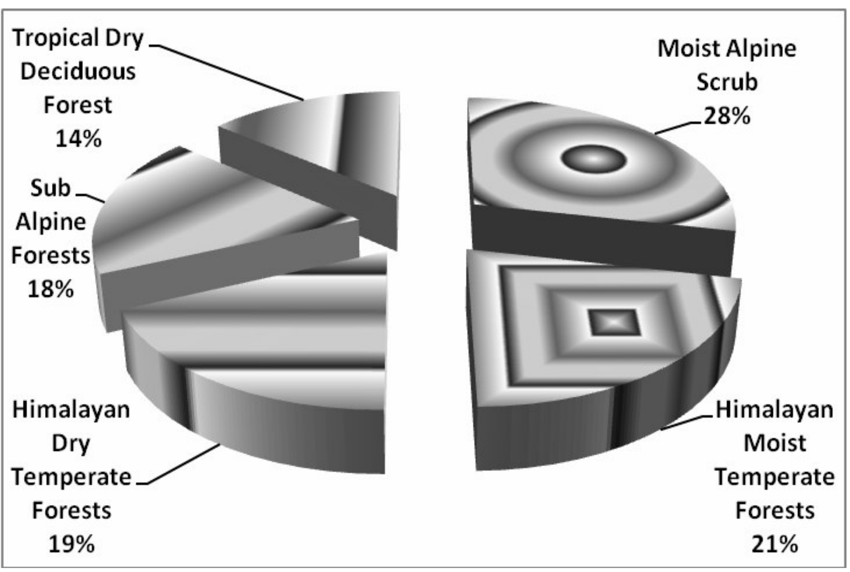

Fig 2. Per cent share of total SOC pool occupied by different forest types

Himalayan Dry Temperate Forests, 60.41 per cent more than Sub-alpine Forests and 103.28 per cent higher as compared to Tropical Dry Deciduous Forests. SOC pool under Himalayan Moist Temperate Forests was 15.94, 20.87 and 53.17 per cent higher as compared to Himalayan Dry Temperate Forests, Sub- alpine Forests and Tropical Dry Deciduous Forests respectively. SOC pool under Himalayan Dry Temperate Forests was marginally higher (4.25%) as compared to Sub-alpine Forests and 32.11 per cent higher as compared to Himalayan Dry Temperate Forests.

Results of one-way ANOVA indicate that SOC pool between the groups was significantly different at 0.05 level (Variance Ratio, $F = 7.667$, $p = < 0.05$). SOC pool under Moist Alpine Forests was significantly different from the SOC pool under Himalayan Moist Temperate Forests, Himalayan Dry Temperate Forests, Sub-alpine Forests and Tropical Dry Deciduous Forests and SOC pool under Himalayan Moist Temperate Forests was also statistically significantly different from Tropical Dry Deciduous Forests (Table 3).

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Received: 15.8.2012 *Accepted: 4.4.2013*