SOIL ORGANIC CARBON STORE UNDER DIFFERENT LAND USE SYSTEMS IN GIRI CATCHMENT OF HIMACHAL PRADESH

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Introduction

Increasing levels of carbon dioxide in the atmosphere during the past few decades has drawn the attention of the scientific community towards the process of carbon sequestration and soil organic carbon store. Concentration of atmospheric CO_2 can be lowered either by reducing emissions or by enabling the storage of CO_2 in the terrestrial ecosystems. Soil plays an important role in the carbon cycle by storing it in the form of soil organic carbon. 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. Intergovernmental Panel on Climate Change has recognized soil organic carbon pool as one of the five major carbon pools for the LULUCF (Land Use, Land Use Change and Forestry) sector. It is mandatory for all nations to provide soil organic carbon pool and changes from LULUCF sector of the forests under Nation Communications to the UNFCCC (United Nation's Framework Convention on Climate Change). Soil organic carbon is sensitive to impact of anthropogenic activities. The conversion of natural vegetation to various land uses results in rapid decline in soil organic matter (Post and Kwon, 2000). Totey *et al.*, (1986); Rajamanner and Krishnamoorthy (1978) and Singh *et al.* (1995) have reported up to 87 % decrease in soil organic carbon due to deforestation.

Accurate quantification of soil organic carbon is necessary for detection and prediction of changes in response to changing global climate. No systematic study has been undertaken to estimate the soil organic carbon pool in Himachal Pradesh, by following uniform methodology for field and labóratory work. Estimation of Bulk density and coarse fragments of soil are very important to reduce the uncertainty about the weight of soil of the study area, and finally for calculating the SOC Pool.

This paper presents the results of a study conducted by FRI to provide the authentic and comprehensive estimates of the SOC pool under different land uses and topo sequences in Giri Catchment of Himachal Pradesh. Information generated from this study can be used as a benchmark for future work to estimate the changes in

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SOC pool in these land uses of Giri catchments.

Material and Methods

Study Sites

The Giri river is a tributary of the Yamuna river and it drains south eastern Himachal Pradesh. Giri catchment is spread over an area of 2,63,861.86 ha from Rajban to the origin of the Giri ganga *i.e.* Near Kuppar Tibba (Kata Pather). The elevation ranges from 391 m to 3600 m amsl. Main land use in Giri catchment includes agriculture which includes wheat, vegetable crops and apple orchards, forests which includes Sal, Chir, Deodar, Quercus, Kail + Quercus, Kail + Silver fir, Spruce and Grasslands.

Input of organic matter is largely from above ground litter, 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 decomposable and the most directly exposed to natural and anthropogenic disturbances (IPCC, 2003). Therefore, soil organic carbon pool was estimated up to the depth of 30 cm, in this study.

Soil samples for the estimation of organic carbon store were collected from the entire catchment area starting from Rajban to origin of Giri and all the land uses were covered to estimate soil organic carbon. The locations for soil survey included all altitudinal variations *i.e.* < 1000 m, 1000-1500 m, 1500- 2000 m, 2000-2500 m and > 2500 m. The soil samples were collected to estimate soil organic carbon store. Khair and Eucalyptus plantations were also available in catchment area but they occupy a small area. Samples were also collected from these plantations and SOC store was estimated. Latitude, longitude and altitude of each sampling point were recorded by GPS (Global Positioning System).

Five representative samples were collected randomly, for organic carbon estimation and two separate samples were collected for bulk density and coarse fragment estimation from each sampling sites under different land uses in Giri Catchment. Different sites were selected in each land use *viz.* Forests, agriculture and plantations, at different locations. Sampling was done from the origin of Giri Ganga *i.e.* Near Kuppar Tibba (Kata Pather) to the last point located in Himachal Pradesh *i.e.* Rajban which is at the confluence of the Giri river with Yamuna river. Latitude, Longitude and altitude of each sampling site were recorded by GPS.

Forest floor litter of an area of 0.5 m x 0.5 m, at each sampling point was removed and a pit of 30 cm wide, 30 cm deep and 50 cm in length was dug. Soil from 0 to 30 cm depth, from three sides of the pit, scraped with the help of Kurpee. This soil was mixed thoroughly and gravels removed. The sample were kept in a polythene bag and tightly closed with thread with proper labeling. In the laboratory, samples were air dried and after drying the samples, ground and sieved through 100 mesh. This 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 per ha basis and soil organic carbon estimation. Bulk density of every site was estimated by standard core method (Wilde *et al.*, 1964). All the methods used in this study are in accordance to Ravindranath and Ostwald (2008).

The data for SOC pool was calculated by using the following equation as suggested by IPCC Good Practice Guidance for LULUCF (IPCC, 2003):

Equation for SOC

$$SOC = \sum_{Horizon=1}^{Horizon=n} SOC_{horizon} = \sum_{Horizon=1}^{Horizon=n} ([SOC] * Bulk\ density * depth * (1 - C\ frag) * 100)_{horizon}$$

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, t 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 Fragments = % volume of coarse fragments / 100, dimensionless.

Results and Discussion

The data for soil organic carbon pool under different land uses are presented in Table 1. Data revealed that maximum SOC pool (93.47 t ha^{-1}; SD ±16.4548) was in the soils where under Spruce and fir with Kail and Quercus at higher altitude followed by soils under Deodar forests (82.14 t ha^{-1}; SD ± 3.8217). SOC pool under Chir and Miscellaneous forests were more or less equal *i.e.* 57.33 t ha^{-1} (SD ± 22.0379) and 57.66 t ha^{-1} (SD ± 18.6653) respectively. Soils under Sal have the least SOC pool (47.29 t ha^{-1}; SD ± 4.6517). Standard Error of all the SOC pool estimated under Deodar is 2.21, Sal 2.69, Miscellaneous 3.98, Chir 6.11 and Kail+ Silver Fir and Spruce is 8.23.

An average SOC pool under forests land use is 61.68 t ha^{-1} having standard error 3.22. Statistically SOC pool under all the forests is significantly different at 5 % level.

Standard error of SOC pool, in all the forest covers is varied from 2.21 to 6.11 which reflect low variation in the data. However, Standard error in Kail + Quercus and Kail+ Sliver Fir and Spruce forests is slightly higher (8.23) as compared to others. This higher variation may be because of topography and altitudes. Availability of these types of forests is at three different altitudes *i.e.* 1500-2000 m, 2000-2500 m and > 2500 m ranges, therefore, SOC pool has little higher variations.

Contribution of individual forests in SOC pool is depicted in Fig. 1 and observed

Table 1

Soil Organic Carbon pool (t ha^{-1}) under different land uses in Giri Catchments.

Sl. No.	Land Use	Soil Organic Carbon (t ha^{-1})	Standard Error
1	*Forests*:		
	i) Sal	47.29 (44.20 – 52.64) ± 4.6517	2.69
	ii) Deodar	82.14 (77.87 – 85.24) ± 3.8217	2.21
	iii) Chir	57.33 (29.71 – 89.03) ± 22.0379	6.11
	iv) Kail + Silver Fir and Spruce; Kail + Quercus	93.47 (71.16 – 109.35) ± 16.4548	8.23
	v) Miscellaneous	57.66 (31.57 -95.07) ± 18.6653	3.98
	Weighted Average SOC Pool under Forest	61.68	3.22
2	*Agriculture*:		
	i) Crop	53.62 (31.33 – 91.46) ± 19.4721	6.49
	ii) Apple Orchards	53.96 (41.18 – 81.33) ± 15.9838	7.15
	Weighted Average SOC Pool under Agriculture	53.74	4.72
3	*Plantations*:		
	i) Khair	67.72	-
	ii) *Eucalyptus*	59.21	-
	Weighted Average SOC Pool under plantations	63.47	4.26
	Overall Weighted Average SOC pool in Giri Catchment	**59.92**	**2.63**

(Figures in parenthesis are ranges and with ± are standard deviation).

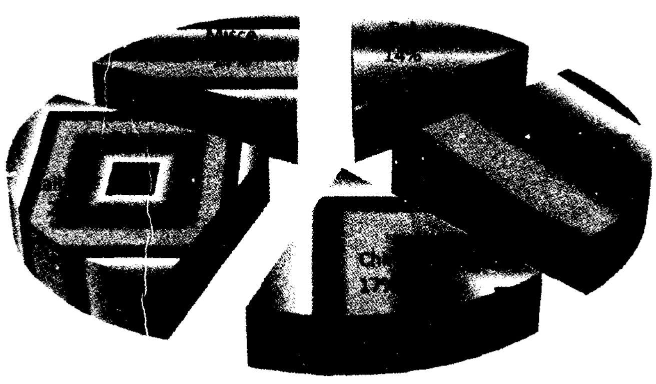
that maximum SOC pool (27.66 %) was contributed by Kail + Quercus and Kail+ Silver Fir and Spruce forests followed by Deodar forests 24.3 per cent. Chir forests (16.97%) and Miscellaneous forests (17.06%) are contributed nearly same and the least was by Sal forests (14.00 %).

Total forest area in Giri catchment is 132,386.4 ha out of which 32,742.4 ha is dense forests having density more than 40 %, 47,877.4 ha is moderately dense forest having density in between 10 – 40 % and 51,766.6 ha is open forests having density less than 10 per cent. On an average, forests have 61.68 t ha^{-1} soil organic carbon store. Therefore, Giri catchment has 8,165,593.15 tones (8.16 million tons) soil organic store in the forest area.

Under agriculture land use, soil organic carbon pool under cropping system was 53.62 t ha^{-1} (SD ± 19.4721). Wheat and vegetables are the main crops in this catchment. Under apple orchards SOC pool is 53.96 t ha^{-1} (SD ± 15.9838). Standard error varied from 6.49 to 7.15 under cropping system and apple orchards respectively. There is not much difference in both the systems probably because in both the cases soil was maintained in a similar way to get the better productivity. Giri catchment has 58,941.6 ha agriculture area and on an average, agriculture soils have 53.74 t ha^{-1} soil organic carbon store. Therefore, under agriculture land use soil organic carbon store is 3,167,521.58 tones (3.16 million tons).

General characteristics of soil in Giri are presented in Table 2. Under the forests land uses, sal forests has the least coarse fragments (6 per cent) while miscellaneous forests has the maximum (23 per cent). Bulk density was observed the least in the soil under kail + silver fir and spruce followed by deodar and maximum was under chir. Under agriculture land use bulk density and coarse fragments were higher in the soils of agriculture as compared to apple orchards.

Fig.1



Per cent Contribution in SOC pool by Individual forest

Soils under deodar, kail + silver fir and spruce, miscellaneous was medium textured while under sal and chir, it was coarse textured.

Altitude varies in Giri catchment from 391 m to 3000 m amsl. Data of SOC pool at different altitudes is presented in Table 3. SOC pool was estimated altitude wise and data revealed that maximum SOC pool (97.31 t ha^{-1}; SD ± 14.4195) was observed in the soil between the altitude of 2500 and 3000 m amsl followed by 88.68 t ha^{-1} (SD ± 4.8578) at an altitude of 2000-2500 m; 64.46 t /ha (SD ± 16.3334) at an altitude of 1500-2000 m and 55.69 t/ha (SD ± 17.2749) at the altitude of 1000-1500 m. The least SOC pool (54.34 t ha^{-1}, SD ± 21.3991) was observed in the soils in between the altitude of 500-1000 m. Soils at higher altitude have higher SOC pool as compared to lower altitude. This may be because of the lesser decomposition and higher accumulation of organic matter at higher altitudes due to the climatic conditions. Standard error was varied from 2.96 to 8.33. Slightly higher SE (8.33) was observed at an altitude range of 2500-3000 m as compared to other altitude ranges indicate more variations in SOC pool, reason probably because of availability of agriculture land use at this altitude along with the forests and differences in SOC pool under agriculture land use and forests land use are more, therefore, this variation in SOC pool was observed.

Table 2

General Characteristics of the soil in Giri Catchment.

Sl. No.	Land use	Average bulk density (g/cm^3)	Average coarse fragment (%)	Texture
1	*Forests* :			
	i) Sal	1.14	8	Loamy sand
	ii) Deodar	1.04	16	Loam
	iii) Chir	1.24	21	Sandy Loam
	iv) Kail + Silver Fir & Spruce; Kail + Quercus	1.03	16	Loam
	v) Miscellaneous	1.22	23	Loam
2	*Agriculture* :			
	i) Crop	1.12	27	Loam
	ii) Apple Orchards	1.04	20	Loam
3	*Plantations* :			
	i) Khair	1.28	40	Sandy Loam
	ii) *Eucalyptus*	1.14	40	Sandy Loam

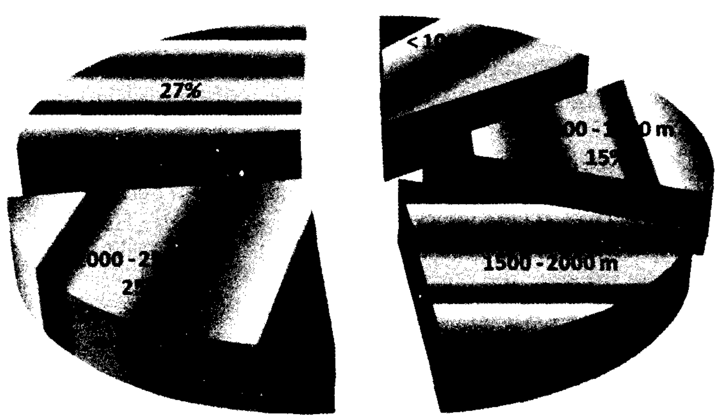
Maximum proportion of SOC pool (27 %) was observed in soils of an altitudinal range between 2500 and 3000 m amsl followed by the soils of the altitudes 2000 - 5000 m *i.e.* 25 % of the total pool (Fig.2). Soils at altitudes between 1500 and 2000 m was occupied the 18 % share and 15 % was shared by the soils at altitudes 1000-1500 m and 500-1000 m above mean sea level.

Table 3

Soil Organic Carbon pool (t ha^{-1}) at different altitudes in Giri Catchments.

Sl. No.	Altitudes (m)	Soil organic carbon (t ha^{-1})	Standard error
1.	< 1000 m	54.34	5.75
2.	1000 – 1500 m	55.69	2.96
3.	1500 – 2000 m	64.46	5.77
4.	2000 – 2500 m	88.68	3.44
5.	> 2500 m	97.31	8.33

Fig. 2



Per cent share of SOC pool occupied at different altitudes

SUMMARY

Soil samples for the estimation of organic carbon store were collected from the entire catchment area starting from Rajban to origin of Giri and all the land uses were covered to estimate soil organic carbon. Soil organic carbon store in Giri catchment was estimated (up to the depth of 30 cm), and observed that maximum SOC store (93.47 t ha^{-1}) was in the soils under Kail + Silver fir and Spruce forests and Kail + Quercus forests followed by Deodar forests (82.14 t ha^{-1}). Soil organic carbon store under miscellaneous forests (57.66 t ha^{-1}) and chir forests (57.33 t ha^{-1}) was similar and the least SOC store was under *sal forests (47.29 t/ha). Under agriculture land use, in cropping system soil organic* store was 53.62 t ha^{-1} while under orchards it was 53.96 t ha^{-1}. Altitude wise maximum soil organic carbon pool was in the soils located above the altitude of 2500 m (91.37 t ha^{-1}) followed by 2000-2500 m (88.68 t ha^{-1}). The least SOC store was in the soils located below 1000 m (54.34 t ha^{-1}). Giri catchment has 8,165,593.15 tones (8.16 million tons) soil organic carbon store in the forest area and under agriculture land use soil organic carbon store is 3,167,521.58 tones (3.16 million tons).

***Key words:* Carbon sequestration, Soil organic carbon estimation, Giri catchment, Himachal Pradesh.**

हिमाचल प्रदेश के गिरि जलग्रहण क्षेत्र की विभिन्न भूमि उपयोग प्रणालियों में संचित हुआ मृदा जैव कार्बन

एस० एस० नेगी व एम० के० गुप्ता

सारांश

जैव कार्बन संचयन का आकलन करने के लिए राजबन से आरंभ कर गिरि नदी के उद्गम तक समूचे जल ग्रहण क्षेत्र से मृदा नमूने एकत्रित किए गए और मृदा जैव कार्बन के आकलन के लिए सभी भूमि उपयोग इसमें लिए गए। गिरी जलग्रहण क्षेत्र का मृदा जैव कार्बन संचयन (30 से.मी. की गहराई तक) आकलित किया गया और देखा गया कि अधिकतम संचयन (93.47/हेक्टेयर) कैल + रजत तालीशपत्र और प्रसरल वनों में तथा कैल + क्वेरकस लगे वनों में है जिसके उपरान्त देवदारू वन (82.14 ट/हेक्टैयर) आते हैं। फुटकर वनों में मृदा जैव कार्बन संचयन (57.66 ट/हेक्टैयर) और चीड़ वनों का (57.33 ट/हेक्टै.) एक जैसा ही था, जबकि न्यूनतम संचयन शाल वन (47.29ट/हेक्टे.) का रहा। कृषि के लिए भूमि उपयोग करने पर, फसल कटाई प्रणाली में मृदा जैव कार्बन संचयन (53.62ट /हेक्टै.) निकला जबकि बाग-बगीचों में यह 53.96 ट/हेक्टे. रहा। ऊंचाई के विचार से अधिकतम मृदा जैव कार्बन संचयन उन मृदाओं में निकला जो 2500 मी. से अधिक ऊंचाई पर थी (91.37 ट/हेक्टे.) जिसके बाद 2000-2500 मी ऊंचाईयों की मृदाएं आती है (88.68 ट/हेक्टे)। सबसे कम मृदा जैव संचयन उन मृदाओं में मिला जो 1000 मी से कम ऊंचाईयों की थी (54.34 ट/हेक्टे.)। गिरी नदी के जल ग्रहण क्षेत्र में 8,165,593.15 टन (81.6 लाख टन) मृदा जैव संचयन वन क्षेत्रों में है जबकि खेती की जा रही मृदाओं का मृदा जैव कार्बन संचयन 3,167,521.58 टन (31.6 लाख टन) ही है।

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