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SEQUESTERED ORGANIC CARBON STATUS IN THE SOILS UNDER FORESTS LAND IN HARYANA STATE, INDIA

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Abstract: Soil organic carbon has been ignored since long because it was treated as a dead biomass. After the awareness of climate change, its importance has been recognized worldwide. Carbon remains in the soil for much longer duration than the carbon in the vegetation that the soils support. A study was undertaken to estimate the Soil Organic Carbon Stock under forests in Haryana state of India. SOC stock under different forests in Haryana was estimated and data reveals that maximum SOC stock (58.24 t ha^{-1}) was under chir (*Pinus roxburghii*), followed by dhak (*B. monosperma*) (51.41 t ha^{-1}), miscellaneous forests (43.55 t ha^{-1}) and the least was under sal (*Shorea robusta*) (40.97 t ha^{-1}). Organic carbon stock under chir was 33.73 % and 42.15 % higher as compared to miscellaneous and sal respectively. SOC stock under miscellaneous was 6.30 % higher as compared to sal. Maximum SOC stock was in the forests under north circle (4326371.19 t which is 54.89 % of total SOC stock of Haryana forests) and the least was in central circle (1078400.07 t, 13.68 % of total SOC stock of Haryana forests). Maximum organic carbon stock was in the soils in Panchkula district *i.e.* 21,16,652.22 tons which was 26.85 % of the total SOC stock in Haryana followed by in Yamunanagar district which contains 11,13,145.25 t which was 14.12 % of total stock of Haryana. Among the Wild life sanctuaries, Conservation reserves and National parks, maximum SOC stock was under wild life sanctuaries (1.09 million tons) which was 66.65 % of the total SOC stock under NP, WLS and CR, followed by conservation reserves (0.30 million tons) which was 18.43 % of total SOC stock in NP, WLS and CR and the least was in national parks (0.25 million tons).

Keywords: Forests; Forest circles; Mitigation potential; Soil organic carbon stock; Wild life sanctuaries.

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INTRODUCTION

Recent global concerns over increased atmospheric CO_2, which can potentially alter the earth's climate systems, have resulted in rising interest in studying SOC changes and carbon sequestration capacity in various ecosystems. Promoting soil carbon sequestration is an effective strategy for reducing atmospheric CO_2 and improving soil quality (Lal *et al*., 1998, 1999). There is concern that increase in global temperature may result in a long term loss of SOC (Jenkinson *et al.,* 1991). Depleted of organic carbon, soils develop a carbon deficit. Soils can regain lost carbon by reabsorbing it from the atmosphere. This process is called carbon sequestration (Bowen and Rovira, 1999). Soil organic carbon has been ignored since long because it was treated as a dead biomass. After the awareness of climate change, its importance has been recognized worldwide. Soil organic matter (SOM) and SOC constitute usually a small portion of soil, but they are one of the most important components of ecosystems. Soil contains an important pool of active carbon that plays a major role in the global carbon cycle (Melillo *et al.,* 1995, Prentice *et al.,* 2001). The build-up of each ton of soil organic matter removes 3.667 tons of CO_2 from the atmosphere

(Bowen and Rovira, 1999). Scientists working on global warming and climate change have recently focused attention on soil as a major source and sink for atmospheric CO_2 (Jensen *et al.,* 1996). SOM and SOC play an important role in mitigating greenhouse gas emissions (Lal *et al*., 1995; Flach, *et al*., 1997). SOC sequestration is the most cost-effective strategy during the first half of the 21st century (Battelle, 2000) with numerous ancillary benefits. In addition to the high costs of geologic and oceanic sequestration, there are also concerns about the adverse effects on aquatic ecosystems and risks of leakage. Soils contain 3.5 % of the earth's carbon reserves, compared with 1.7 % in the atmosphere, 8.9 % in fossil fuels, 1.0 % in biota and 84.9 % in the oceans (Lal *et al*., 1995). The pre-industrial concentration of CO_2 at 280 parts per million (0.028 % or 600 Gt) increased to almost 365 ppm (0.037 % or 770 Gt) in 1998 and is increasing at the rate of 0.43 % per year or 3.2 Gt /y. The historic gaseous increase between 1850 and 1998 has occurred due to deforestation and soil cultivation which has emitted 136 (±55) Gt (Lal, 2003). The IPCC Third Assessment Report (Kauppi *et al*., 2001) concluded that the forest sector can sequester 5.38 Gt CO_2 per year on an average until 2050, whereas an earlier IPCC report (Watson *et al*., 2000) had quoted an even higher technical mitigation potential of 11.67 Gt CO_2 per year.

The common method of quantifying soil organic carbon is to use the total soil organic carbon data for specific sites and scale up to regional or global estimates using soil maps (Lacelle *et al.,* 2001). Carbon concentration (g C g^{-1} soil or % basis) is an unreliable indicator of C loss/gain, because the total amount (mass) of C present within the soil also depends on bulk density, stoniness, and depth of soil. Each of these attributes has their own associated suites of uncertainties (Batjes, 1996; Eswaran *et al*., 1995; Sombroek *et al*., 1993). Therefore, a study was undertaken to estimate the SOC pool under forests by following uniform methodology for field and laboratory work in Haryana state**.**

EXPERIMENTAL

The State of Haryana is situated between 27° 39' to 30° 56' N latitude and 74° 27' to 77° 36' E longitude and comprises 21 Districts. The state has a geographical area of 44,212 Sq km and occupies 1.35% of the land area of the country. The average rainfall is 560 mm, varying from less than 300 mm in the southwestern parts to over 1200 mm in hilly tracts of the Shivalik Hills.

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). Estimates of topsoil soil organic carbon (SOC) pool may be crucial for understanding soil C dynamics under human land uses and soil potential of mitigating the increasing atmospheric CO_2 by soil C sequestration (Song *et al.,* 2005). The soil organic carbon pool therefore, was estimated up to the depth of 30 cm in this study.

All the twenty one districts *viz.* Ambala, Bhiwani, Faridabad, Fatehabad, Gurgaon, Mewat, Palwal, Jhajjar, Jind, Kaithal, Karnal, Kurukshetra, Mahendragarh, Panchkula, Panipat, Rewari, Rohtak, Sirsa, Hissar, Sonipat and Yamunanagar of Haryana were selected for the study (Table 1). In total, 1,252 soil samples from forests land have been collected. In the forest land, sampling was done in the different Forest Divisions. Three Forest Ranges in each Forest division were selected randomly and in each Forest Range, three blocks were selected randomly. In each block a sampling site were selected in all available forest. At each sampling site, an area of about ½ km was covered and collected five soil samples from this area for soil organic carbon estimation and two separate samples were collected for bulk density and coarse fragment estimation. It was ensured that sampling points typically represent the study area.

After selecting the sampling points the soil samples were collected. 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 out. Soil from 0 to 30 cm depth, was taken out with the help of Khurpee and this soil was mixed thoroughly. The soil was transferred to a polythene bag and the bag was tightly closed with proper labeling. In the laboratory, samples were air dried, grinded and sieves through 100 mesh sieve. The sieved sample was used for soil organic carbon estimation by standard Walkley & Black (1934) method. Bulk density value is necessary to convert organic carbon (OC) content per unit area (Sakin, 2012). Bulk density of every sample 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 mitigation potential of the soils under different land-uses and the soils supporting different species in a particular land-use was estimated for the soils of Haryana with respect to the species / land use having minimum SOC stock by assuming 1 as describe by Jha *et al*., (2001).

Appropriate statistical analysis was carried out for obtaining standard error, standard deviation and one way ANOVA for estimating the differences in the means of soil organic carbon store under different vegetation covers as well as under different land uses by using SPSS software.

Table 1. Details of the sites under Forest land in Haryana

S. No	Forest Cover	Altitude (m)	Area Covered (Forest Ranges)	District	No. of samples
1	*Shorea robusta* (Sal)	321 - 480	Keleswer	Y Nagar	14
2	*Butea monosperma* (Dhak)	336 - 345	Ambala	Ambala	6
3.	*Pinus roxburghii* (Chir)	600 - 1125	Morni, panchkula range	Panchkula	35
4.	Miscellaneous	249 - 312	Ambala, Saha, Naraiangarh range	Ambala	49
		210 - 250	Bhiwani, Siwani, Charkidadri Range	Bhiwani	63
		188 - 210	Faridabad, Ballabgarh Range	Faridabad	42
		200 - 223	Tohana, Fatehabad Range	Fatehabad	42
		206 - 283	Gurgaon, Helamandi, Sohana Range	Gurgaon	63
		202 - 215	Hisar, Hansi, Adampur range	Hisar	63
		193 - 229	Matanhail, Jhajjar, Bahadurgarh Range	Jhajjar	63
		209 - 236	Jind, Safidon, Narwana Range	Jind	63
		200 - 235	Saraswati, Kaithal, Pundri range	Kaithal	63
		225 - 250	Indri, Munuk, Karnal Range	Karnal	56
		228 - 255	Pheowa, Thenesar Range	Kurukshetra	49
		260 - 370	Mahendra Garh, Narnaul, Nagal Chaudhari Range	M garh	63
		176 - 240	Nuh, Puhnana, Firozpur jirka Range	Mewat	56
		325 - 965	Kalka, Pinjore, Panchkula, Raipurrani range	Panchkula	91
		180 - 208	Palwal, Hodal Range	Palwal	42
		206 - 226	Panipat ,Samalakha range.	Panipat	42
		220 - 275	Rewari, Bawal, Nahar Range	Rewari	63
		192 - 215	Rohtak, Maham Range	Rohtak	42
		186 - 207	Dabwali, Raina, Sirsa Range	Sirsa	63
		203 - 222	Sonipat, Gohana, Rai Range	Sonipat	63
		286 - 388	National park Keleswer range, Sudhaura, Jagdhari Range	Y Nagar	56
			Total samples Collected		**1,252**

Amount of coarse fragments was estimated and deducted from the soil weight to get an accurate soil weight per ha basis for soil organic carbon pool estimation. 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 :

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

Where,

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

$SOC_{horizon}$ = Soil organic carbon content for a constituent soil horizon, tons 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, tons soil m^{-3} (equivalent to Mg m^{-3})

Depth = Horizon depth or thickness of soil layer, m

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

RESULTS AND DISCUSSION

Large Reserved Forest areas are mainly confined to the Himalayan ranges in Panchkula (600 ha very dense forests) and Yamunanagar districts (2100 ha very dense forests). Small reserved forests are found at a number of places in the districts of Yamunanagar, Kaithal, Ambala, Jind and Hisar. Pine forests are located at higher reaches in the protected forests of Morni Hills in Panchkula district, whereas sal forests dominate the reserve forests in the Shiwaliks of Yamunanagar districts.

SOC stock under different forests in Haryana was estimated and data reveals (Table 2) that maximum SOC stock (58.24 t ha^{-1}) was under chir (*Pinus roxburghii*), followed by dhak (*B. monosperma*) (51.41 t ha^{-1}), miscellaneous forests (43.55 t ha^{-1}) and the least was under sal (*Shorea robusta*) (40.97 t ha^{-1}). Organic carbon stock under chir was 33.73 % and 42.15 % higher as compared to miscellaneous and sal respectively. SOC stock under miscellaneous was 6.30 % higher as compared to sal. Mitigation potential indicates that soils under chir can hold nearly one and half time more SOC stock in comparison to sal. Standard error of SOC stocks, in all the forest covers varied from 0.84 to 5.48 which reflect low variation in the data. Paul *et al*. (2002) suggested that tree species had different impacts on soil carbon stocks and dynamics. The amount of SOC stored within an ecosystem, is dependent on the quantity and quality of organic matter returned to the soil matrix, the soils ability to retain organic carbon (a function of texture and cation exchange capacity), and biotic influences of both temperature and precipitation (Grace *et al.,* 2005).

Table 2. Soil Organic Carbon Stock under Forest Land use in Haryana (up to 30 cm)

S.No	Vegetation Cover	SOC Stock (t ha^{-1})	Standard Deviation	Mitigation Potential (Forest wise)	Standard Error
1.	Sal	40.97	± 18.1653	1.00	5.48
2.	Misc.	43.55	± 24.5125	1.06	0.84
3.	Dhak	51.41	± 3.9594	1.25	2.29
4.	Chir	58.24	± 23.5621	1.42	4.71

Same alphabets represent statistically at par group

When SOC stock under different forest covers was tested by one - way ANOVA, it was found that SOC stock under different vegetation covers was significantly different (Variance ratio, F = 3.081; p = < 0.05). SOC stock under chir forests was statistically significantly different with the SOC stock under miscellaneous forests with mean difference 14.6839*.

Haryana has four forest circles *viz.* north, west, south and central circles. North circle consists of Ambala, Kaithal, Kurukshetra, Panchkula and Yamunanagar districts and the West circle is comprised of Bhiwani, Fatehebad, Hissar, Jind, and Sirsa district. South circle has Faridabad, Gurgaon, Mahendragarh, Mewat, palwal and Rewari districts and central circle is made up of Jhajjar, Karnal, Panopat, Rohtak and Sonipat districts. All the areas under different circles, districts, national parks and wild life sanctuaries were taken from Forest Department, Haryana (Anon., 2013). SOC stock in the forests under all the circles was estimated (Table 3) and it was observed that maximum SOC stock was in the forests under north circle (4326371.19 t which is 54.89 % of total SOC stock of Haryana forests) followed by south circle (1249300.67 t which is 15.85 % of total SOC stock of Haryana forests), west circle (1249300.67 t, 15.58 % of total SOC stock of Haryana forests) and the least was in central circle (1078400.07 t, 13.68 % of total SOC stock of Haryana forests).

Table 3. Soil Organic Carbon Stock in different Forests Circle in Haryana (up to 30 cm)

S. No.	Circles	Area (ha)	SOC Stock (t)	Per cent of total stock of Haryana
1	North Circle	77,525	43,26,371.190	54.89
2	Central Circle	27,702	10,78,400.070	13.68
3	South Circle	32,090	12,49,300.670	15.85
4	West Circle	31,065	12,27,585.140	15.58
	Total	**1,68,382**	**78,81,657.070**	**100.00**

District wise SOC stock in Haryana state Forests:

Haryana is comprised of twenty one districts and the SOC stock under forests in all the districts was estimated (Table 4). Maximum organic carbon stock was in the soils in Panchkula district *i.e.* 21,16,652.22 tons which was 26.85 % of the total SOC stock in Haryana followed by in Yamunanagar district which contains 11,13,145.25 t which was 14.12 % of total stock of Haryana. Kaithal district was next with 4,90,195.33 tons SOC stock which was 6.21 % of total SOC stock. Organic carbon stock in the soils under forests in Ambala, Faridabad, Gurgaon, and Jind did not vary much and lied in the range of 3,17,898.62 t to 3,82,849.23 tons. SOC stock in Bhiwani, Hisar, Kurukshetra and Sonipat also varied within a narrow range of 2,58,668.85 tons to 3,14,912.97 tons. SOC stock in Fatehabad, Jhajjar, Mahendragarh, Mewat, Panipat, Palwal and Rohtak was in lower range. Organic stock in the soils under forest in Mahendragarh district was the least *i.e.* 90,028.44 tons which was only 1.142 % of total SOC stock in Haryana. In total, forest land of Haryana holds 7.88 million tons of soil organic carbon which is equivalent to 28.92 million tons of CO_2. Findings of this study indicates that forest soils in Haryana was holding 28.92 m t of CO_2 which can be enhanced by adopting suitable measures to increase SOC in these soils.

Table 4. District wise Soil Organic Carbon Stock under Forest in Haryana (up to 30 cm)

S. No.	District	SOC ($t\ ha^{-1}$)	Area (ha)	SOC Stock (tons)	Per cent of total stock in Forest in Haryana
1	Ambala	67.47^{a}	5137	346593.39	4.397
2	Bhiwani	30.72^{h}	9105	279705.60	3.549
3	Faridabad	51.77^{cd}	6931	358817.87	4.553
4	Fatehabad	28.87^{h}	4021	116086.27	1.473
5	Gurgaon	43.07^{ef}	8889	382849.23	4.857
6.	Hissar	50.01^{cd}	6297	314912.97	3.996
7	Jind	46.49^{de}	6838	317898.62	4.033
8	Jhajjar	27.98^{h}	4081	114186.38	1.449
9	Kaithal	63.67^{ab}	7699	490195.33	6.219
10	Karnal	54.16^{bc}	7565	409720.40	5.198
11	Kurukshetra	57.50^{bc}	4518	259785.00	3.296
12	Mahendragarh	15.72^{i}	5727	90028.44	1.142
13	Mewat	37.54^{fg}	3216	120728.64	1.532
14	Panchkula	55.17^{bc}	38366	2116652.22	26.855
15	Panipat	38.14^{fg}	4103	156488.42	1.985
16	Palwal	50.03^{cd}	2225	111316.75	1.412
17	Rohtak	30.33^{h}	4594	139336.02	1.768
18	Sonipat	35.15^{gh}	7359	258668.85	3.282
19	Sirsa	41.42^{ef}	4804	198981.68	2.525
20	Rewari	36.37^{fg}	5102	185559.74	2.354
21	Yamuna Nagar	51.05^{cd}	21805	1113145.25	14.123
	Total in Haryana		**1,68,382**	**78,81,657.07 or 7.88 million tons**	**100.00**

Equivalent to CO_2 *Sequestered*	**2,89,25,681.45 or 28.92 million tons**	

Same alphabets represent statistically at par

When SOC stock under forests in different districts were tested by one - way ANOVA, it was found that SOC stock under forests in different districts were significantly different (Variance ratio, F = 16.316; p = < 0.05). SOC stock under forests in Ambala district was statistically significantly different with the SOC stock under forests in all the districts except Kaithal. SOC stock under forests in Bhiwani district was statistically significantly different with the SOC stock under forests in all the districts except Fatehabad, Jind, Mewat, Palwal, Rohtak and Rewari.

SOC stock under different National Parks and Wild life Sanctuary in Haryana

Organic carbon stock in the soils under different national parks (NP), wild life sanctuary (WLS) and conservation reserves (CR) was estimated (Table 5). Maximum SOC stock was under wild life sanctuaries (1.09 million tons) which was 66.65 % of the total SOC stock under NP, WLS and CR, followed by conservation reserves (0.30 million tons) which was 18.43 % of total SOC stock in NP, WLS and CR and the least was in national parks (0.25 million tons).

Table 5. SOC Stock under different National Parks and Wild life Sanctuary and Conservation Reserves in Haryana (up to 30 cm)

S. No.	Name	Area (ha)	SOC Stock (tons)	Per cent of total SOC Stock in Haryana
Under National Parks				
1	Sultanpur National Park, Gurgaon	142.52	6138.17	0.373
2	Kalesar National Park, Yamunanagar	4682.14	239023.47	14.540
	Total	**4,824.66**	**2,45,161.64**	**14.91**
Under Wildlife Sanctuaries				
1	Bhindawas Wildlife Sanctuary, Rohtak	411.53	12481.86	0.759
2	Chilchhila Wildlife Sanctuary, Kaithal	28.91	1840.98	0.112
3	Nahar Wildlife Sanctuary, Rewari	211.34	12300.22	0.748
4	Bir Shikargah Wildlife Sanctuary, Panchkula	767.27	42330.44	2.575
5	Abubshehar Wildlife Sanctuary, Sirsa	11530.13	477578.17	29.052
6	Khaparwas Wildlife Sanctuary, Jhajjar	82.70	2313.96	0.141
7	Kalesar Wildlife Sanctuary, Yamunanagar	5435.52	277483.11	16.880
8	Morni Hills Khol Hai Rattan, Panchkula	4882.78	269383.00	16.387
	Total	**23,350.20**	**10,95,711.72**	**66.65**
Under Conservation Reserve				
1	Saraswati, Kaithal	4452.69	283502.83	17.246

2	Bir Bara Van, Jind	419.25	19490.85	1.186
	Total	**48,71.94**	**3,02,993.68**	**18.43**
	Total in Haryana	**33,046.80**	**16,43,867.04 or 1.64 million tons**	**100.00**
	Equivalent to CO_2 Sequestered		***60,32,992.02 or 6.03 million tons***	

Major portion of SOC stock (0.23 million tons) was held by Kaleser national park amongs all the national parks. Among all the wild life Sanctuaries, Abubshehar Wildlife Sanctuary, Sirsa was contained maximum SOC stock (0.47 million tons) followed by Kalesar Wildlife Sanctuary, Yamunanagar (0.277 m t), Morni Hills Khol Hai Rattan, Panchkula (0.269 million tons) and the least SOC stock was in Chilchhila Wildlife Sanctuary, Kaithal (1840.98 tons). Among the conservation reserve, Saraswati conservation reserve, Kaithal was having maximum SOC stock (0.28 million tons) while the least was in Bir Bara Van, Jind (19490.85 tons). In Haryana, about 33,046.80 ha area is under national parks, wildlife sanctuary and conservation reserve which collectively contain 1.64 million tons of total SOC stock. This much of SOC is equivalent to the 6.03 million tons of CO_2.

The higher litter input and fine root biomass may partly contribute to the greater SOC in the forest (Chang *et al*., 2012). The high organic carbon content at the surface layers of the soil was due to the accumulation of organic matter in surface horizon and recycling of organic matter, addition of organic manure and also because of crop residues remaining in soil surface (Ashok, 1998). The highest SOC content was found in forest, whereas lowest SOC was observed in conventionally- tilled, continuously-cropped plots by Anikwe *et al.,* (2003), Lal (2002). Soil organic carbon is concentrated in the upper 12 inches of the soil. So it is readily depleted by anthropogenic disturbances such as land use changes and cultivation. The greatest changes in carbon storage result from the conversion of forests to cultivated land typically leading to loss of soil carbon sequestration potential (Rai and Sharma, 2004).

Managing the forests may be useful technique to increase soil carbon status because the presence of trees affects carbon dynamics directly or indirectly. Trees improve soil productivity through ecological and physicochemical changes that depend upon the quantity and quality of litter reaching soil surface and rate of litter decomposition and nutrient release (Meentemeyer and Berg,1986). Conversion of marginal arable land to forestry or grassland can rapidly increase soil carbon sequestration. Analysis of long term crop experiments indicated that increasing crop rotation complexity increased SOC sequestration by 20 g carbon m^{-2} yr^{-1}, on average (West and Post, 2002). The soil carbon stocks increased mainly because litter fall from living trees increased while the other sources of soil carbon, *i.e*. the residues of harvests and natural disturbances, varied less. This litter fall was also the largest source of soil carbon accounting for 70-80% of the total. The soil carbon stocks in these forests could thus be most effectively controlled by forest management actions, such as the choices of harvest regimes or tree species, which especially affect the litter production of living trees (Liski *et al.,* 2002). Soil carbon sequestration (enhanced sinks) is the mechanism responsible for most of the mitigation potential, with an estimated 89% contribution to the technical potential (Smith *et al.,* 2007).

The per capita forest area in the State is 0.01 ha; far below the Indian average of 0.11 ha, and world average of 1.04 ha. The Haryana Forest Department plans to extend tree cover to over 25% of the land area over a 20 years period; the potential areas for which are the common lands, mainly owned by Panchayats, institutional land, river banks, privately owned sand dunes in western parts, salt affected and waterlogged areas in the central and southern plains and degraded hills in the north and the south. In addition 350,000 ha of farm bunds may also be available for tree plantation (Kaul, 2004).

CONCLUSION

This study indicates that different forest species affects the organic carbon stock in the soils. SOC stock under different forests in Haryana was estimated and data reveals that maximum SOC stock was under chir, followed by dhak (*B. monosperma*), miscellaneous forest and the least was under sal (*Shorea robusta*). Among the Wild life sanctuaries, Conservation reserves and National parks, soil under wild life sanctuaries were well enriched in organic carbon therefore, SOC stock was the maximum in National park followed by conservation reserves and the least was in national parks. Higher litter and fine root biomass production and moisture availability facilitate the higher carbon accumulation in the forests. Increase as well as conservation of forest cover will be very useful strategy for C mitigation.

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