Short Scientific Report

doi:10.25081/jpc.2021.v49.i2.7262
Journal of Plantation Crops, 2021, 49(2): 146-150

Soil organic carbon stocks (SOCS) in different land uses of Western Ghats, Karnataka - A case study

B. Kalaiselvi*, Rajendra Hegde, K.S. Anil Kumar, R. Vasundhara, S. Dharumarajan, R. Srinivasan, M. Lalitha and S.K. Singh[1]

ICAR-National Bureau of Soil Survey and Land Use Planning, Regional Centre, Bangalore-560 024, Karnataka, India
[1]ICAR-National Bureau of Soil Survey and Land Use Planning, Nagpur-440 033, Maharashtra, India

(Manuscript Received: 09-07-2020, Revised: 30-06-2021, Accepted: 02-07-2021)

Keywords: Carbon sequestration, SOC stocks, pedons, Western Ghats

Soil organic carbon is the prime indicator of soil quality and environmental sustainability. Sequestering organic carbon in the terrestrial pool helps to reduce the atmospheric CO_2 concentration, improves soil quality and prevents soil from further degradation. Soil is the largest organic carbon pool with 1115 to 2200 Pg globally (Batjes, 1996) and 9 Pg in India (Bhattacharyya *et al.*, 2000), which interacts strongly with the atmospheric concentration of CO_2 and other greenhouse gases. Overall, in India, the organic carbon content is low when compared to world scenario owing to the influence of arid to semi-arid, and sub-humid to per humid climate, which is the major factor for poor productivity of tropical soils (Syers *et al.,* 1996; Katyal *et al.,* 2001). Maintaining organic C levels in tropical soils is more difficult because of the rapid oxidation of organic matter under prevailing high temperatures as the need arises to increase organic carbon content (Lal, 2002). Soil organic carbon stocks and fluxes are strongly influenced by changes in climate and land cover or land use (Yigini and Panagos, 2016). Land use has a great influence on soil physical, chemical and biological properties since it affects the amount and quality of litter input, litter decomposition rates and processes of organic matter stabilization in the soils (Murty *et al.,* 2002). Finding the carbon sequestration potential of different land uses is of paramount importance to recommend appropriate land use to enhance SOC stocks as it gives voluminous benefits. With this view, a study was conducted in Bilalgodu micro-watershed, Mudigere Taluk, Chikkamagaluru district to compare soil organic carbon stocks of plantation systems compared to forest and agricultural systems.

Bilalgodu microwatershed is located in Kalasa Hobli, representing the eastern side of (Central Sahyadris) Western Ghat and experiencing humid tropical climate. The micro-watershed with a total area of 710 hectares lies between 13°11'54" and 13°13'49" N latitudes and 75°17'54" and 75°20’03" E longitudes. The general elevation of the area ranges from 700 to 1100 m above mean sea level (MSL). It comes under agro-ecological sub-region (AESR) of 19.2- hot, moist, sub-humid to humid with the annual precipitation is 2000-3000 mm. The average annual temperature is 22.5 °C, and the length of growing period (LGP) ranges from 210-270 days. Hence, these areas are predominant with deep, well-drained, acidic, red and lateritic soils. Physiographically, it ranges from steep hills of Western Ghats to nearly level lower lateritic terraces with all slope classes ranging from 1 to 33 per cent. Terracing is the common practice for field crops such as paddy in the lower sector, whereas, in the summit and side slopes, coffee, arecanut, coconut and forest are the major land-use types.

---

*Corresponding Author: kalaimitra15@gmail.com

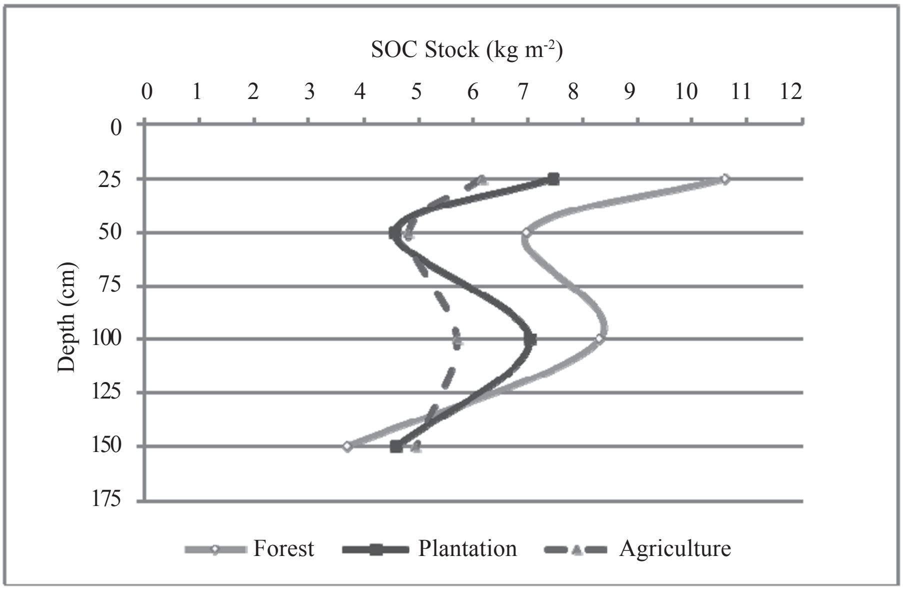

Fig.1. Depth wise soil organic carbon stock (kg m^{-2}) under different land uses

Remote sensing data products from IRS-P6-LISS IV and Cartosat-1 (ortho-corrected) at the same scale were used in conjunction with the cadastral maps to identify the landforms and other surface features. These base maps and imageries helped in the identification and delineation of different land uses. Based on the physiography and land uses, 21 soil profiles were located and opened up to 2 meters or shallower if the depth is limited by a rock or hard substratum. Profiles were studied in detail for all their morphological and physical characteristics (Soil Survey Staff, 2003), and horizon wise samples were collected for laboratory analysis. The horizon-wise collected soil samples were, air-dried, powdered and sieved using a 2 mm sieve. Particle size distribution was determined by the International pipette method (Piper, 1966), and organic carbon was estimated by Walkley and Black (1934) method. The bulk density of the samples was determined by the field moist method using core samples (diameter 50 mm) of known volume (100 cubic cm) (Jackson, 1973). Range in soil characteristics of forest, plantation and agricultural systems was used to estimate the SOC stocks of different land-use systems. SOC stocks were calculated for soil horizons using the Grossman equation (Grossman *et al.,* 2001), and the weighted average of SOC was calculated for top 25 cm, 25-50 cm, 50-100 cm, 100-150 cm and 0-50 cm, 0-100 cm and 0-150 cm layers. For each of the soil profiles, SOC stocks were calculated for 150 cm by summing the stocks of different layers in the proportion of their occurrence within this reference thickness. The total organic carbon stock in kg m^{-2} soil for each pedon was estimated using the general equation presented below (Grossman *et al.,* 2001).

$$\text{SOC stocks} = \sum_{i=1}^{n} [(1-\theta i\%) \times \rho i \times Ci \times Ti/100]$$

Where SOC = soil organic carbon in kg m^{-2}

n is the number of soil layers in the soil profile,

θ_i% represents the volumetric percentage of gravel (>2 mm) content,

ρ_i is the soil bulk density (g per cm^3),

C_i is the organic carbon content (C g kg^{-1}), and

T_i represents the thickness (cm) of layer i.

The soil properties of representative pedons under different land uses are presented in Table.1. The soils were extremely acid (pH-4.39) to slightly acid (pH-6.01), which did not exhibit any significant difference between the systems. The acidic pH of the soils is attributed to the leaching of the bases and acidic parent materials (Srinivasan *et al.,* 2013). Invariably, the study area soils are non-saline due

Table 1. Soil properties of representative pedons of forest, plantation and agricultural land use systems

Forest land use systems														
Depth (cm)	**Horizon**	**Sand (2.0-0.05)**	**Silt (0.05-0.002)**	**Clay (<0.002)**	**Coarse fragments v/v(%)**	**Textural class (USDA)**	**pH (1: 2.5) Water**	**EC (1:2.5) dS m^{-1}**	**OC (%)**	**BD (Mg m^{-3})**	**CEC (cmol kg^{-1})**	**CEC/ clay**	**Base saturation (%)**	**SOCS (kg m^{-2})**
0-16	O	55.44	12.07	32.49	12	scl	6.01	0.038	2.84	1.46	9.28	0.29	63	7.543
16-37	Bt1	44.63	15.42	39.96	30	cl	5.89	0.02	2.05	1.57	7.24	0.18	48	7.189
37-64	Bt2	43.42	11.68	44.89	55	c	5.73	0.018	1.26	1.54	3.67	0.08	87	5.988
64-101	Bt3	62.22	8.94	22.84	65	scl	5.52	0.019	0.39	1.64	3.37	0.15	43	5.364
101-140	Bt4	69.83	4.36	25.81	60	scl	5.62	0.017	0.47	1.68	3.06	0.12	79	3.079
140-172	Bt5	61.26	18.33	20.41	-	scl	5.79	0.012	0.27	1.75	2.35	0.12	80	1.540
Plantation land use systems														
0-24	A	54.68	15.35	29.97	-	scl	5.43	0.047	1.97	1.54	9.28	0.31	40	7.281
24-55	Bt1	52.68	15.20	32.12	-	scl	5.2	0.012	1.04	1.59	8.16	0.25	9	5.674
55-80	Bt2	50.05	17.83	32.12	-	scl	5.3	0.02	0.76	1.69	7.34	0.23	15	3.667
80-109	Bt3	55.96	16.63	27.41	-	scl	5.25	0.011	0.72	1.68	6.02	0.22	22	3.560
109-141	Bt4	63.47	14.23	22.30	-	scl	5.57	0.013	0.52	1.76	3.57	0.16	31	3.145
141-170	Bt5	63.86	17.46	18.68	-	sl	5.43	0.013	0.24	1.71	2.75	0.15	38	1.121
Agricultural land use systems														
0-19	AP	39.44	30.20	30.36	-	scl	4.39	0.151	1.81	1.27	9.59	0.32	21	4.883
19-44	Bw1	36.39	30.03	32.58	-	scl	5.75	0.038	1.32	1.62	6.83	0.20	59	5.346
44-75	Bw2	41.32	24.33	33.89	-	c	5.89	0.02	0.76	1.64	5.81	0.19	47	3.864
75-110	Bw3	37.84	27.20	34.96	-	sc	5.5	0.02	0.58	1.65	5.30	0.15	60	3.613
110-150	Bw4	38.24	26.31	35.45	-	sc	5.79	0.017	0.56	1.72	3.6	0.10	90	3.920
	150+ Saturated water layer													

to leaching losses of the bases by high rainfall. The clay content increases with the depth due to illuviation (32-44%) between 20 cm and 75 cm depth attributed to downward translocation of finer particles from the surface layers (Bhaskar and Subbaiah, 1995). The subsurface clay content of the agricultural system was registered comparatively higher, indicating the continuous deposition of finer soil particles in the low-lying areas from the higher elevation. Sand content of the plantation systems recorded high (50-64 %), which might be due to high erosional loss of finer particles as the plantation crops are being preferably cultivated in highly sloping landscapes to maintain water drainage. In contrast, the agricultural systems recorded low sand content (36-41%). The forest soils are very gravelly (35-60 %), which might be due to high erosional soil losses from steep sloping undulating terrain. The SOC of the study area, which was high (>0.75%), could be attributed to the density of the vegetation and conducive climatic conditions for the accumulation of organic matter. The organic carbon content of the soils is high in surface soils (1.04-3.07%) and tend to decrease with increasing depth, which might be due to poor accumulation of organic matter in the subsurface. Among the different land-use systems, the forest system has recorded the highest organic carbon content (2.84%) in the surface layer with mean SOC content of 1.21 per cent, followed by the plantation system (1.97%). In contrast, the agricultural land use system recorded comparatively lesser OC content ranged between 0.56 and 1.81 per cent, with a mean of 1.11 per cent. From the depth-wise distribution of soil organic carbon, it was evident that the high organic carbon content of forest land-use systems than others are attributed to maximum litter fall and plant residues associated with microbial activities (Iqbal and Tiwari, 2016). Irrespective of the land use, surface soils found to be high in SOC content might be due to a high rate of biomass deposition than removal and slow decomposition rate (Kharche *et al.,* 1999). While comparing the bulk density of the surface soils amidst the systems, low lying agricultural land uses recorded low (1.27 Mg m^{-3}), but throughout the depth, the forest land uses recorded the lower bulk density might be because of high litter fall and organic residues on the surface (Lal and Kimble, 1997). Regardless of the land uses, the bulk density increased with depth, which might be due to compaction and dominance of finer particles in deeper layers (Thangasamy *et al.*, 2004). In this study area, the agricultural land use system soils had a water saturated layer beneath 150 cm depth attributed to the narrow valley of the high rainfall region.

Soil organic carbon stocks of the soil horizons were calculated using weighted averages for variable depths *viz.*, 0-25 cm, 25-50 cm, 50-100 cm, 100-150 cm using SOC content, soil depth and bulk density. The surface soil organic carbon stock of the forest system ranged between 5.7-8.2 kg m^{-2}, followed by plantation land use ranging from 3.6 to 7.3 kg m^{-2}. The computed SOC stock for different depth levels 0-25 cm, 25-50 cm, 50-100 cm and 100-150 cm registered that the forest system had higher SOC stocks *viz.,* 10.62 kg m^{-2}, 6.99 kg m^{-2}, 8.32 kg m^{-2} and 3.71 kg m^{-2}, respectively (Fig. 1). It might be attributed to the greater canopy, higher litter deposition and reduced soil disturbance of forest land use (Gupta and Sharma, 2011). SOC stocks of agricultural systems were also found on par with plantations because of better management practices and the addition of biomass (Bhattacharyya *et al.,* 2007).

The study revealed that land use and its management influence soil organic carbon stocks by biomass accumulation and level of decomposition at high temperatures, its microclimate and control on soil erosion. Forest land-use system, associated with good ground and canopy cover, significantly increased the soil organic carbon content and stock compared to plantation and agricultural land-use systems. But in the current situation of increasing food demand and reduction in cultivable areas, recommending forest crops will not be functional and fruitful. Still, the areas must be protected and preserved against land degradation and wildlife habitation apart from above-ground biomass creation. Forest, plantations, agro-forestry systems, high carbon accumulating grass and multistoried cropping options can be recommended in per-humid sub-humid areas of India to make the soil and environment ecologically sustainable. Liming of soils can be advocated to agricultural and plantation land use systems for enhancement of mineralization and biomass production as the soils are acidic; this ensures the rejuvenation of microbes and betterment of C-sequestration.

References

Batjes, N.H. 1996. Total carbon and nitrogen in the soils of the world. *European Journal of Soil Science* **47**: 151-163.

Bhaskar, B.P. and Subbaiah, G.V. 1995. Genesis, characterization and classification of laterites and associated soils along the east coast of Andhra Pradesh. *Journal of the Indian Society of Soil Science* **43**: 107-112.

Bhattacharyya, T., Pal, D.K., Mandal, C. and Velayutham, M. 2000. Organic carbon stock in Indian soils and their geographical distribution. *Current Science* **79**(5): 655-660.

Bhattacharyya, T., Chandran, P., Ray, S.K., Pal, D.K., Venugopalan, M.V., Mandal, C. and Wani, S.P. 2007. Changes in levels of carbon in soils over years of two important food production zones of India. *Current Science* **93**: 1854-1863.

Grossman, R.B., Harms, D.S., Kinngsbury, D.F., Shaw, R.K. and Jenkins, A.B. 2001. Assessment of soil organic carbon using the U.S Soil Survey. In: *Assessment Methods for Soil Carbon.* (Eds.) Lal, R., Kimble, J., Follet, R.F. and Stewart, B.A. CRC press. Boca Raton, pp. 87-102.

Gupta, M.K. and Sharma, S.D. 2011. Sequestrated carbon: Organic carbon pool in the soils under different forest covers and land uses in Garhwal Himalayan Region of India. *International Journal of Agriculture and Forestry* **1**(1): 14-20.

Jackson, M.L. 1973. *Soil Chemical Analysis*, Prentice-Hall of India Pvt. Ltd. New Delhi, pp. 40.

Katyal, J.C., Rao, N.H. and Reddy, M.N. 2001. Critical aspects of organic matter management in the tropics: The example of India. *Nutrient Cycles in Agro Ecology* **61:** 77-88.

Kharche, V.K., Sehgal, J. and Challa, O. 1999. Evaluation of land resources for coffee plantations-A case study from Karnataka. *Journal of Indian Society of Soil Science* **47**(4): 754-760.

Lal, R. and Kimble, J.M. 1997. Conservation tillage for carbon sequestration. *Nutrient Cycling in Agroecosystems* **49**(1): 243-253.

Lal. R. 2002. The potential of soils of the tropics to sequester carbon and mitigate the greenhouse effect. *Advances in Agronomy* **76**: 1-30.

Murty, D., Kirschbaum, M., McMurtrie, R. and McGilvray, H. 2002. Does conversion of forest to agricultural land change soil carbon and nitrogen? A review of the literature. *Global Change Biology* **8**(2): 105-123.

Piper, CS. 1966. *Soil Plant Analysis*. The University of Adelaide, Australia.

Iqbal, S. and Tiwari, S.C. 2016. Soil organic carbon pool under different land uses in Achanakmar Amarkantak Biosphere Reserve of Chhattisgarh, India. *Current Science* **110**(5): 771-773.

Soil Survey Staff. 2014. *Keys to Soil Taxonomy*. 12th Edn. Washington, DC: United States Department of Agriculture, Natural Resources Conservation Service.

Srinivasan, R., Natarajan, A., Anil Kumar, K.S. and Kalaivanan, D. 2013. Characterization of major cashew growing soils of Dakshina Kannada district of Karnataka. *Agropedology* **23** (2): 59-64.

Syers, J.K., Lingard, J., Pieri, J. and Ezcurra, G. 1996. Sustainable land management for the semiarid and sub-humid tropics. *Ambio* **25:** 484-491.

Thangasamy, A., Naidu, M.V.S. and Ramavatharam, N. 2004. Clay mineralogy of soils in the Sivagiri micro-watershed of Chittoor district, Andhra Pradesh. *Journal of the Indian Society of Soil Science* **52**: 454-461.

Walkley, A. and Black, C.A. 1934. Estimation of organic carbon by chromic acid titration method. *Soil Science* **37:** 29-38.

Yigini, Y. and Panagos, P. 2016. Assessment of soil organic carbon stocks under future climate and land cover changes in Europe. *Science of the Total Environment* **557-558:** 838-850.