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RESEARCH ARTICLE

ALTITUDINAL VARIATION OF SOIL ORGANIC CARBON STOCK IN ACHANAKMAR

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ABSTRACT

The Achanakmar Amarkantak Biosphere reserve is one of the premium Biosphere reserves of India. The human induced agricultural and cultivation practices in forest lands of Achanakmar not only affect the genetic diversity conservation but also affect the storage of carbon stocks.The present paper deals with measuring the SOC stocks along different sites and altitudinal gradients in Mixed Sal Forests of Bilaspur District of Achanakmar. The stocks of SOC were found to be decreasing with decreasing altitude and Significant variations across different altitudinal sites and depths were observed (significance at 0.05% level of probability). The present study calls for the development of sustainable forest management practices against human influences especially along the lower altitudinal gradients where lower carbon stocks and vulnerability of carbon loss have been found.

INTRODUCTION

Soil Organic Carbon (SOC) is a measure of the total amount of organic carbon (C) in soil, independently of its origin or decomposition. Interest in SOC is common among soil scientists and related practitioners because of the importance for principle physical, chemical and biological soil ecological functions and because SOC is a universal indicator of soil quality. Consequently, as variations in SOC levels can have serious implications on many environmental processes such as soil fertility, erosion and greenhouse gas fluxes, the need to estimate SOC changes has become central to global environmental policies. At the international level, all the various Conventions arising from the 1992 United Nations Conference on Environment and Development in Rio (Climate Change, Biodiversity and to Combat Desertification) have the issue of SOC levels at their core. The Kyoto Protocol (UNFCCC, 1998) in particular, allows the use of biospheric carbon sinks and sources originating from human-induced activities to meet the Countries' commitments of greenhouse gas emissions reduction. These activities, listed in Article 3.3 (afforestation, reforestation and deforestation since 1990) and Article 3.4 (forest management, cropland management, grazing land management, re-vegetation) of the Kyoto Protocol, are collectively named "Land Use, Land-Use Change and Forestry" (LULUCF) activities.

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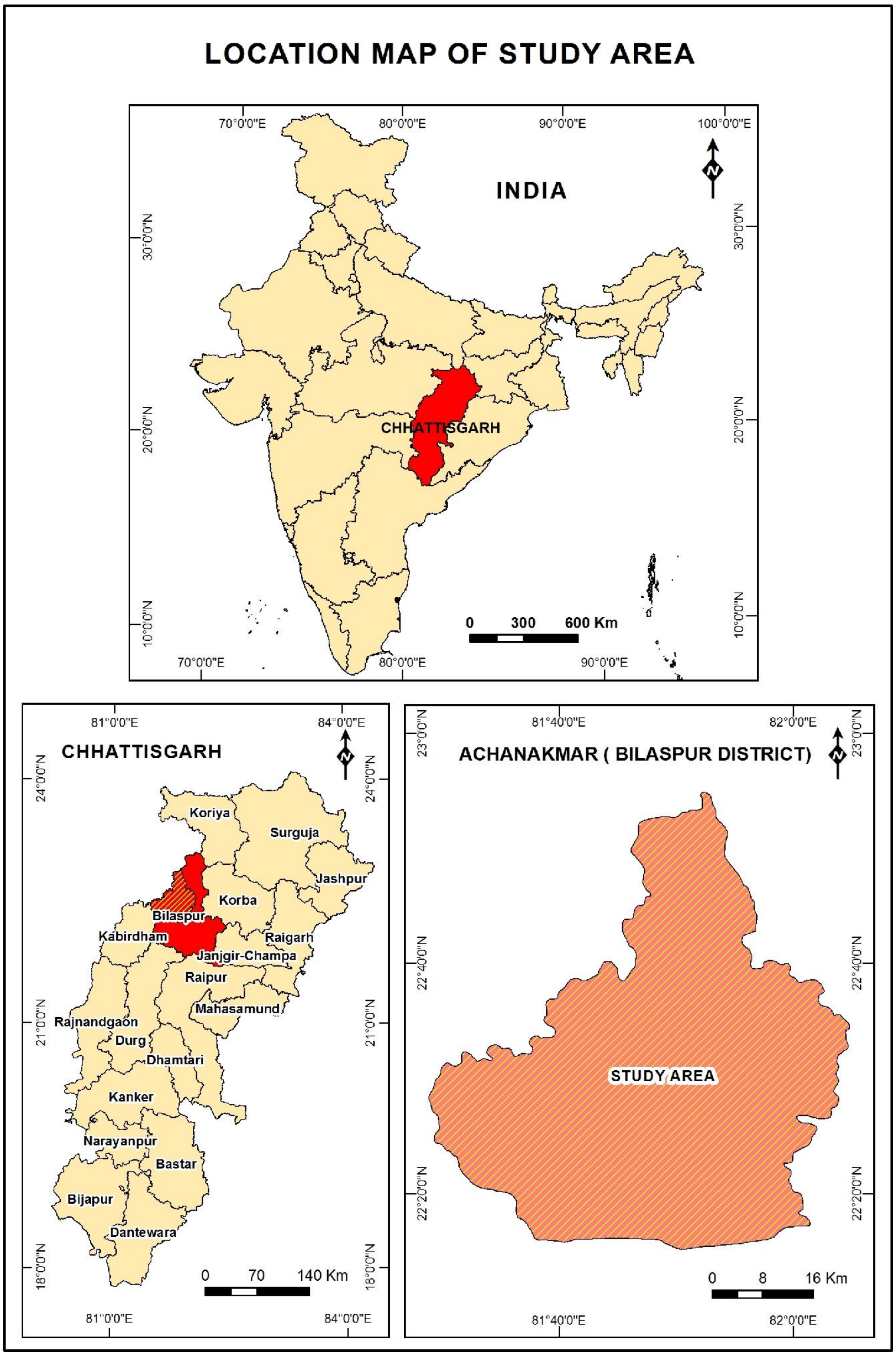
The soil is among the mandatory carbon pools to be reported for these activities under the Kyoto Protocol and it is certainly one with the highest potential, both in terms of enhancement of C sink and reduced C emission. The procedures for estimating changes in SOC under the Kyoto Protocol are described by the International Panel on Climate Change report 'Good Practice Guidance for LULUCF' (IPCC, 2003). The carbon cycle is essential for life on earth. Within the carbon cycle, the soil acts as a major reservoir. It is estimated that global soils contain between 1400 and 1600 pentagrams (Pg) of carbon (1 Pg = 10^{15} g) in the upper meter, and that the next meter of soil contains an additional 500-1000 Pg C (Batjes, 1996). These estimates imply that the soil organic carbon pool is more than twice the size of the atmospheric carbon pool (800 Pg) and that it contains about three times the amount of carbon in vegetation (550 Pg C). The exchange of C between terrestrial and atmospheric reservoirs by photosynthesis and respiration is of the order of 120 Pg C per year in each direction (Houghton, 2003). The overall size of the soil C reservoir is therefore relatively large compared to these gross annual fluxes of Carbon.

Altitude is often employed to study the effects of climatic variables on SOM dynamics (Garten *et al*., 1999; Lemenih *et al*., 2004). Temperature decreased and precipitation increased with increasing altitude. The changes in climate along altitudinal gradients influence the composition and productivity of vegetation and, consequently, affect the quantity and turnover of SOM (Garten *et al.,* 1999; Quideau *et al.,* 2001). Altitude also influences SOM by controlling soil water balance, soil erosion and geologic deposition processes (Tan *et al.,* 2004). The advantages of altitudinal gradients in forest soil for testing the effects of environmental variables on SOM dynamics is emphasized (Garten *et al*., 1999). The relationship between SOM and altitude has also been investigated and positive correlations were reported (Sims *et al*., 1986; Tate, 1992). There is a strong relation between climate and soil carbon pools due to altitudinal variations where organic carbon content decreases with increasing temperatures, because decomposition rates doubles with every 10°C increase in temperature (Schlesinger, 1997).The present paper deals with the variation in soil organic carbon stock values across different altitudinal gradient sites in Bilaspur District of Achanakmar.

MATERIAL AND METHODS

The present study was carried out in Bilaspur District of Achanakmar, at four selected sites (Lamni, Chhapparwa, Achanakmar and Surhi) along four different altitudinal gradients (Figure 1). Bilaspur District of Achanakmar is located on the northwestern part of the Chhattisgarh state and is bounded by East longitudes 81°29’02” & 82°27’44” and by North latitudes 21°42’40” & 23°06’58”. The altitudinal range of four sites lies between Site-I (420-530 m) Site-II (390-420 m) Site-III (330-390 m) Site IV (290-330 m).The months of July and August are the heaviest rainfall months and nearly 95% of the annual rainfall is received during June to September months.



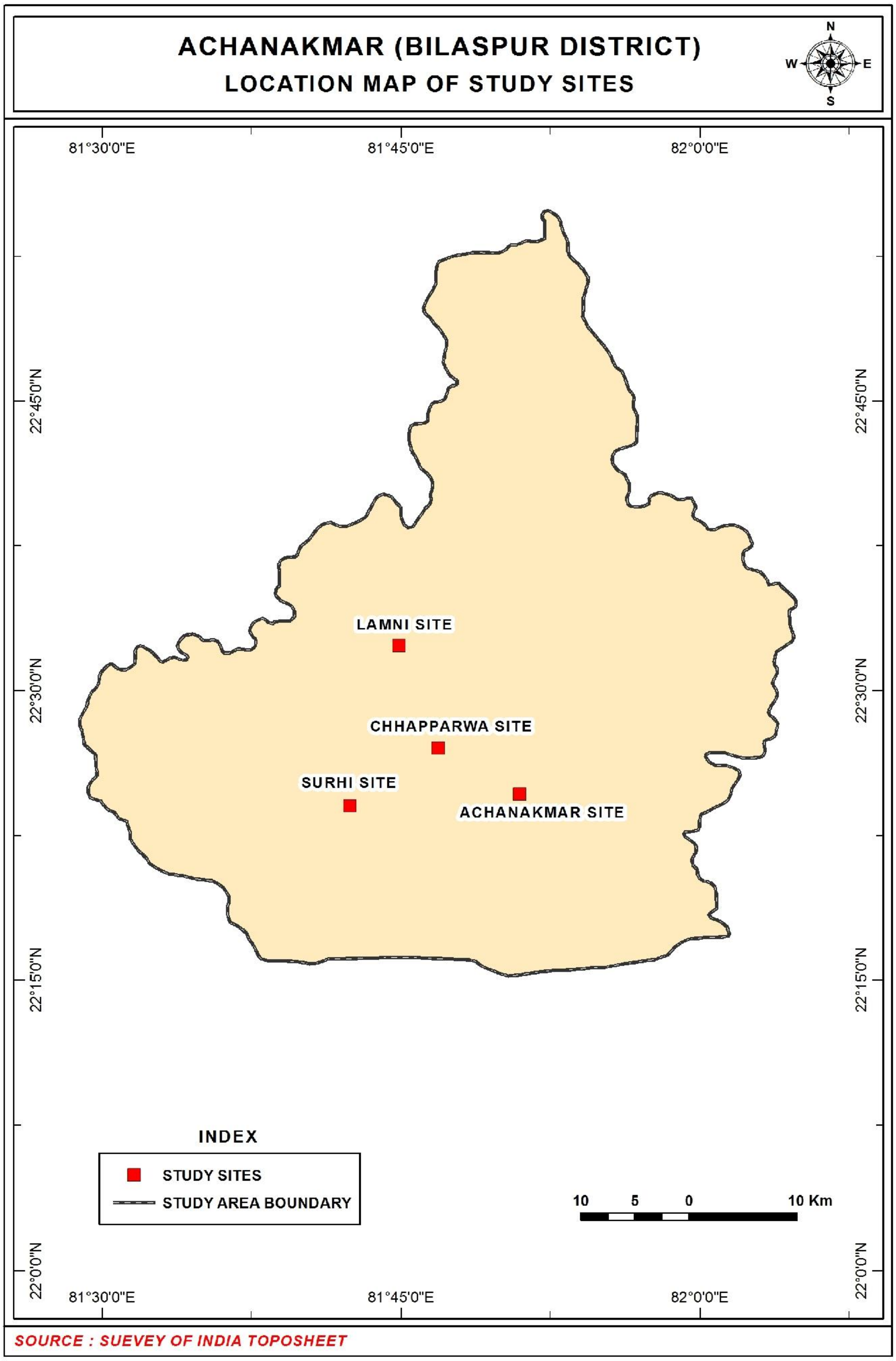


Figure 1. Location Map of Study area and Study sites

The rainfall is unevenly distributed and also the amount of rainfall varies from year to year and experiences a hot and semi-humid climate. The annual temperature varies from 9.2°C to 42.1°C. The hottest months are May and June and the minimum temperature is observed in the months of December and January. The maximum temperature in May 46^0 C and mean minimum temperature is 9^0c to 7^0c in December. May is the hottest month & December is the coldest. The average rainfall is 130.04 cm.

The relative humidity is higher during the South West monsoon season, being generally over 75%. After Monsoon Season, humidity decreases and during the winter season, air is fairly dry. Rainfall observations indicate that annual rainfall in the area is around 1400 mm. The sampling was done by laying plots of 100×20 m size and ten sampling points were selected in each plot by the standard method (Hairiah *et al*., 2001). Three samples were collected at each sampling point at three depths (0–20, 20-50 and 50-100 cm). A total of 120 soil samples (30 from each site) were collected by digging soil pits (30x 30x 100 cm). Exact location of each site and sampling points (altitude and geomorphic coordinates) was recorded by GPS *(Garmin etrex-30)*. The soil samples were air dried and sieved (< 2 mm) before analysis. Soil organic carbon for various depths was determined by chromic titration method (Walkley and Black,1934). Soil samples from each depth were analyzed, to express the total SOC stock in different soil depths. Bulk density at each site was estimated by standard core method (Wilde *et al*., 1964). Three undisturbed soil core samples at different depths were also collected for measuring the soil bulk density from each site. The weight of oven dried soil samples was divided by its volume to estimate bulk density. The total organic carbon stock (ton/ha) was calculated by following formula;

SOC stock (ton/ha) = soil depth (cm) × bulk density (g cm^{-3}) × C conc. (%) × CFst (1- % stone + % gravel/100).

RESULTS

Soil organic carbon were studied in Mixed Sal Forests in Achanakmar at four different selected sites with varying altitudes, viz. Site-I having altitude range (420-530 m), Site-II having altitude range (390-420 m) Site-III having altitude range (330-390 m), Site-IV having altitude range (290-330 m elevation). The data collected on each of the parameters were subjected to statistical analyses using the statistical package, *SPSS-16 and Microsoft Office Excel-2007*. The findings of the analysis are given below in the Table 1.

Table 1. Soil Bulk density (Mean ± S.E) and carbon status (Mean ± S.E) at different altitudinal sites in Achanakmar

Site Altitude/Elevation a.s. l. (meter)	Soil depth (cm.)	B. D. (gm cm^{-3})	SOC (%)	SOC (t/hac)
Site-I (Lamni) (420-530)	0-20	0.97 ± 0.03	2.62 ± 0.16	51.64 ± 6.90
	20-50	1.11 ± 0.03	1.21 ± 0.13	41.08 ± 5.55
	50-100	1.24 ± 0.02	0.52 ± 0.07	30.71 ± 3.83
Site-II (Chhapparwa) (390-420)	0-20	0.94 ± 0.10	2.57 ± 0.10	49.77 ± 7.71
	20-50	1.09 ± 0.07	1.18 ± 0.20	39.55 ± 4.95
	50-100	1.21 ± 0.01	0.51 ± 0.01	30.44 ± 0.42
Site-III (Achanakmar) (330-390)	0-20	0.95 ± 0.06	2.46 ± 0.22	48.50 ± 6.67
	20-50	1.13 ± 0.05	1.17 ± 0.09	38.59± 3.42
	50-100	1.22 ± 0.11	0.50 ± 0.04	29.27 ± 4.71
Site IV (Surhi) (290-330)	0-20	1.01 ± 0.09	2.41 ± 0.09	46.79 ± 7.10
	20-50	1.20 ± 0.15	1.16 ± 0.16	37.89 ± 5.41
	50-100	1.26 ± 0.10	0.47 ± 0.08	27.95 ± 4.41

A decreasing trend in soil organic carbon (SOC) was observed with increased soil depths in all the four different altitudinal sites. Maximum soil carbon content in the top soil layer (0-20 cm) was exhibited by high altitudinal forest site-I (2.62%) followed by altitudinal forest site-II (2.57%) and altitudinal forest site-III (2.46%) and least minimum was observed at lower altitudinal forest site-IV (2.41%). In the middle layer of 20-50 cm high altitude forest site-I exhibited maximum soil carbon percent (1.21%) followed by forest site-II (1.18%) and forest site-III (1.17%) followed by low altitudinal forest site-IV (1.16%). In the 50-100 cm layer the high altitude forest site-I exhibited maximum soil carbon percent (0.52%) followed by forest site-II (0.51%) and forest site-III (0.50%) and low altitudinal forest site-IV showed lower carbon content (0.47%). Thus, maximum differences in organic carbon contents were found in higher and lower altitudinal forest sites i.e., site-I and Site-IV and little differences were found in the middle range altitudinal forest site-II and site-III. Depth wise soil bulk densities of different altitudinal sites were also carried out to estimate the SOC stock density variation among different soil depths.

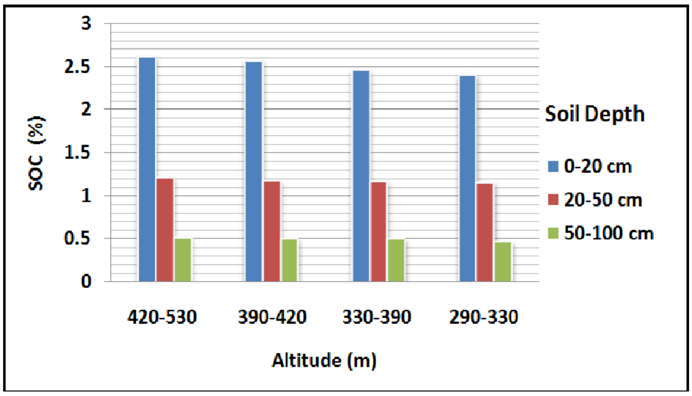


Figure 2.Variations in soil carbon content (%) across depths and altitudinal sites

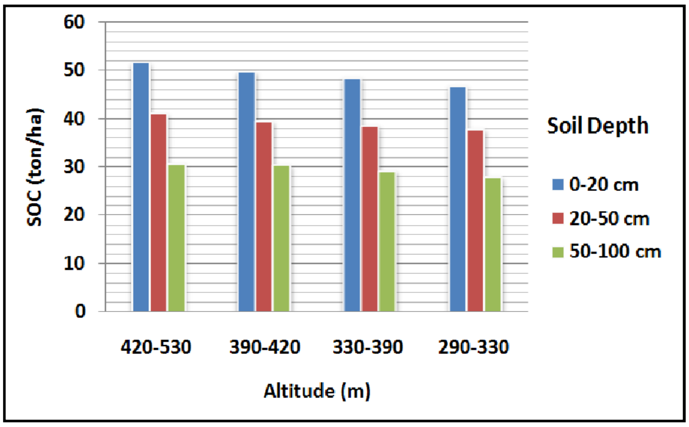


Figure 3.Variations in soil carbon stock (ton/ha) across depths and altitudinal sites

The mean bulk density values of Site-I (0.97 ± 0.03, 1.11 ± 0.03, 1.24 ± 0.02 g cm^{-3}), Site-II (0.94 ± 0.10, 1.09 ± 0.07, 1.21 ± 0.01 g cm^{-3}), Site-III (0.95 ± 0.06, 1.13 ± 0.05, 1.22 ± 0.11 g cm^{-3}), and Site-IV (1.01 ± 0.09, 1.20 ± 0.15, 1.26 ± 0.10 g cm^{-3}) were observed in (0-20, 20-50, 50-100 cm) soil depths respectively (Table 1). It shows that bulk density values increased with the increasing depths among all the four altitudinal sites. Significant variation in organic carbon content across different altitudinal sites and depths were observed (significance at 0.05% level of probability) (Figure1).

DISCUSSION

Forest soils are entities within themselves, self organized and highly resilient over time. The transfer of energy bound in carbon (C) molecules drives the organization and functions of this biological system (Fisher and Binkley, 2000; Paul and Clark, 1996). Interest in the ability of forest soils to store atmospheric C derived from anthropogenic sources has grown in recent years (Johnson, 1992; Heath and Smith, 2000; Cardon *et al.,* 2001; Johnson and Curtis, 2001). Much of soil degradation in the planet is assumed to take place in tropical and subtropical lands, particularly from deforestation and conversion of forests into cropland and cultivated pastures. Accordingly, a considerable research effort has been devoted to the understanding of this process and its implications in terms of C dynamics (Fernandes *et al*., 1997; Tiessen *et al*., 1998). In present study the soil organic carbon (SOC) decreased with increasing soil depths in all the four altitudinal sites. Maximum soil organic carbon stock in the top soil layer (0-20 cm) was exhibited by high altitudinal forest site-I (51.64 ± 6.90 t/ha) followed by altitudinal forest site-II (49.77± 7.71 t/ha) and forest altitudinal site-III (48.50± 6.67 t/ha) and minimum SOC in low altitudinal forest site-IV (46.79 ± 7.10 t/ha). In the lower layer 20-50 cm high altitude forest site-I exhibited maximum soil carbon stock (41.08± 5.55 t/ha) followed by forest altitudinal site-II (39.55±4.95 t/ha) and site-III (38.59± 3.42 t/ha) and a minimum SOC in low altitudinal forest site-IV (37.89±5.41t/ha). In the 50-100 cm layer the altitude forest site-I showed maximum carbon amount (30.71± 3.83 t/ha) followed by forest altitudinal site-II (30.44± 0.42 t/ha) and site-III (29.74 ± 4.71 t/ha) and a minimum SOC in low altitudinal forest site-IV (27.95± 4.41 t/ha). Significant variation across different altitudinal sites and depths were observed (Figure 3).

The bulk density values were found higher in the site IV compared to the Site I, II and III. This may be due to the lower input of organic matter. The maximum carbon stock was reported in high altitudinal forest site compared to the lower altitudinal forest sites may be due the higher input of litter in to the top soil which resulted in maximum storage of carbon stock. First and second layers have more stored carbon than third layer. The higher organic carbon content in the top layer may be due to rapid decomposition of forest litter in a favorable environment. This may be because of higher rate of microbial activities releasing carbon in upper layers of soil than third layer (0-20cm) of soil. In Mixed Sal forests of low altitude, the carbon stock was reported lowest, this may be attributed to high rate of litter removal by people living nearby for burning the litter in their agricultural fields. Due to the removal of litter by people reduces the carbon stock from the forest floor and thus resulting in to less microbial activity. In present study as SOC was found decreased with increasing depth, the trend of decreasing SOC content with increase in depth is an indication of higher biological activity associated with top layers. The results of present study are in accordance with some past Indian studies related to the altitudinal variations of organic carbon stocks by Singh *et al*., 2013 in Western Himalaya and Charan *et al.,* 2012 in cold desert high altitude microclimate of India, which supported higher concentration of SOC stock in upper soil layers and high altitudinal sites. The addition of litter and the extensive root system of plants probably influenced the carbon concentration in different soil layers (Lal, 1989; Blevines and Fyre, 1993). It reflects positive correlation of SOC with the quantity of litter fall (Singh, 2005). The decomposition rate of forest woody detritus depends partially on climatic conditions and rate of microbial activity (Woodall and Likens, 2008).

Conclusion

A comparison of the soil organic carbon stock values of different altitudinal sites in Mixed Sal forests of Achanakamar show that the carbon stock tonnes per hectare decrease with decreasing altitudes. The results of the study lead to conclusion that the ability to maximize storage of carbon stocks in forest soils needs to overcome the sustainable forest management practices against human influences especially along the lower altitudinal gradients where lower carbon stocks and vulnerability of carbon loss have been found.

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