Article

Estimation of soil organic carbon and soil respiration in a dry forest - Guvvalacheruvu Reserve Forest of Kadapa hill ranges

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Abstract
Forest soils are considered as one of the major carbon sinks in terrestrial ecosystems owing to their higher amounts of soil organic matter/carbon. The objective of the study is to estimate the SOC content and soil respiration, their spatial variations and the relationship between them. The study was undertaken in a dry deciduous forest of Kadapa hill ranges. The samples were taken from two study sites namely site 1 at foot hills and site 2 on the hill slopes. The samples were analyzed for SOC by Walkley-Black method and soil respiration by alkali absorption method and several physio-chemical parameters were also measured. The SOC values up to 30 cm depth indicated that site 1 registered a high value (32.3 t/ha) than the site 2 value (27.59 t/ha). The mean SOC values of the upper surface layer (0 – 10cm) in the two study sites were 0.65±0.092 and 0.596±0.083 respectively and the average values of SOC in the bottom layer (10 - 30cm) are 0.78±0.105 and 0.32±0.051 respectively in the two study sites. A negative relationship between SOC and bulk density was recorded. The mean soil respiration values were found to be 108.9 mg/m^2/hr in site 1 and 78.1 mg/m^2/hr in site 2. A strong positive correlation between SOC and soil respiration was observed. The variation in SOC values in the study site can be related to soil depth and location and the observed values were found to be lesser than the values in other Indian tropical deciduous forests.

Keywords bulk density; dry deciduous forests; soil organic carbon; soil respiration.

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1 Introduction

Forest ecosystems with active plant-animal-soil microbe interactions can play a crucial role in global carbon cycling acting as sink as well as some times as source (Lal, 2005). Especially forest soils under natural vegetation are regarded as one of the major sinks of carbon (Dinakaran et al., 2011). This sink capacity by comprising of varied quantity and quality of Soil Organic Carbon (SOC) in forests is largely affected by local site conditions such as climate, nutrient, water availability and tree species age (Mani et al., 2017). In the world wide the top 30cm of soil comprise of 1500 Pg (1 Pg = 10^{15} g) and in India the amount is about 6.8 to 9

Pg (Bhattacharya et al., 2009). This kind of huge storage capacity infers that any disturbances to the land use system can cause emission of the sequestered carbon into the atmosphere (Lal, 2010). Soil carbon has much longer residence time than the carbon in the vegetation and thus carbon sequestration in soils and plants is the only strategy that can remove carbon from the atmosphere and, overtime, reduce atmospheric concentration of CO_2 (Schlesinger, 1990).

Soil respiration is the primary path by which CO_2 fixed by plants in forests returns to the atmosphere (Moon et al., 1998). Soil respiration rate, i.e. the amount of CO_2 release per soil surface and time, is considered as a good estimator of microbial activity (Mohanty and Panda, 2011). In addition, soil respiration accounts for second important flux between land- atmosphere CO_2 exchange in an ecosystem (Davidson et al., 2006) and thus becoming an important process of carbon cycle. In forest ecosystems, soil respiration is profoundly affected by vegetation, transfer of above ground biomass to below ground (Tang et al., 2014). Although few studies were carried out in Northern Eastern Ghats the studies on SOC and soil respiration in southern Eastern Ghats are lacking. Hence the objective of the study is to estimate the SOC content and soil respiration in a dry forest of Kadapa hill ranges.

2 Study Area and Methodology

2.1 Study site

The study was carried out in a dry forest of Guvvalacheruvu Ghat forest area in the Kadapa hill ranges 14^0 19' 13.6'' N and $78^0$46' 24.1'' E and 14^0 18' 43.7''N and 78^0 45' 28'' E. The elevation is in the range of 292 m to 488m (Fig. 1). The hill ranges comprise of mainly Quartzite's and the varied topography resulted in rich plant diversity. The dominant tree assemblage that occurs in the forests is *Pterocarpus santalinus* - *Chloroxylon swietenia* – *Terminalia chebula*. It receives an annual average rainfall of 680cm and temperature lies in the range of 16^{o}C to 45^{o}C.

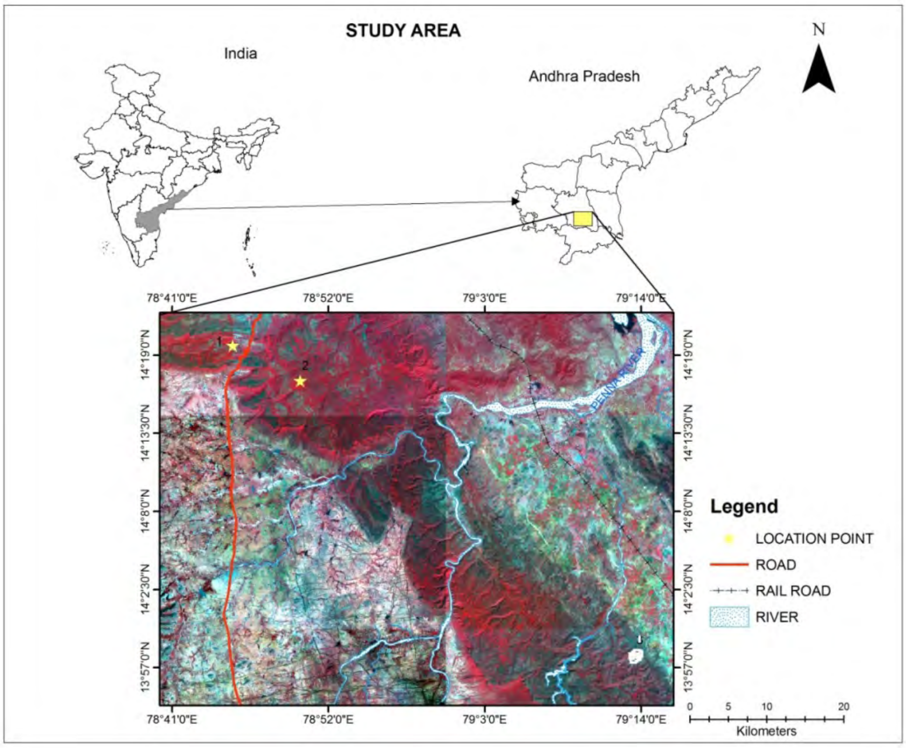

Fig.1 Location of the study area.

2.2 Data collection

The soils were collected from two areas; one at foot hills and another at hill slopes at two depth intervals of 0-10 cm and 10-30cm. In each area, with three sample replications at three locations, were marked for soil collection at both 0-10 cm and 10-30 cm soil depths. The top surface layer is considered as 0-10 cm and the below surface layer is 10-30 cm.

2.2.1 Soil samples were air dried and passed through 2 mm sieve for analysis.

2.2.2 Estimation of Soil organic carbon in soil samples was done by Walkley and Black (1934). The estimated SOC% is converted into tons/ha using the formulae SOC (t/ha) = 10000 m^2 X Soil depth X Bulk density X SOC%.

2.2.3 Soil respiration was carried out by measuring the amount of CO_2 evolved per unit area and time based on alkali absorption method (Gupta and Singh, 1977). The experiment involves three replicates by fixing three open ended cylindrical boxes (10 × 15 cm) at four different areas. At each place the above ground vegetation was clipped and the cylinder was pushed up to 3 cm depth. The evolved CO_2 was collected in 20 ml 1 M NaOH over a 24 h gap. The amount of CO_2 absorbed was estimated by titrating with 1 M HCL using 2-3 drops of phenolphthalein indicator (Gupta and Singh, 1977) and estimated by using the formulae (mg CO_2= V x 0.5 N x 22).

2.2.4 Soil parameters such as soil PH, soil moisture content, soil electrical conductivity and soil bulk density were estimated by following standard procedures (Kapur and Sudharani, 2004).

2.2.5 Statistical analysis was done by using IBM SPSS20 software.

3 Results and Discussion

The mean SOC value of the top surface layer (0 – 10cm) in site 1 (foot hills) is 0.65±0.092 and in the below surface layer (10 - 30cm) is 0.78 ± 0.105. While the average values of SOC on the hill slopes are 0.596 ± 0.083 and 0.32 ± 0.051 at top and below surface layers respectively (Table 1). A contrasting trend in SOC values was observed between the two study sites, in the foot hills site, a higher rate of increase in SOC value (19%) from top layer to bottom layer and a significant rate of decrease of SOC values (46.3%) from top to bottom layer in site 2 (hill slopes) was observed. The SOC values estimated up to 30 cm depth indicated that foot hill site registered a high value (32.3 t/ha) than the hill slopes site value (27.59 t/ha).

The mean soil respiration values were found to be 108.9 mg/m^2/hr with a range of 105.6 to 112.2 mg/m^2/hr in site 1 and a mean value of 78.1 mg/m^2/hr and a range of 68.2 to 88 mg/m^2/hr in site 2 was recorded. The independent *t* test revealed a significant difference ($t_{(3, 0.05)}$ = 3.59, p= 0.036) in soil respiration rates between the two study sites. A strong positive correlation between SOC and soil respiration (r = 0.89) was recorded in the study sites. The data authenticates the observations made in deciduous forest soils of Orissa that soils with larger inputs of SOC will possess higher microbial activity (Mohanty and Panda, 2011).

Table1 The physico-chemical properties of the soil in the two forest study sites.

Guvvalacheruvu forest	PH	E.C µsiemens/cm	Soil moisture	SOC (%) (Mean)	SOC (t/ha)	Bulk density g/ cm^3	Soil respiration (Mean) mg/m^2/hr
Foot hills Site.1 Top	6.87	24.47	1.30	0.655	32.29	1.54	11 Range = (6.6 – 14.3)
Bottom	6.67	17	3.07	0.78			
Hill slopes Site.2 Top	6.93	26.8	1.43	0.596	27.59	1.80	9.9 Range = (6.6 – 13.2)
Bottom	6.83	30	2.69	0.32			

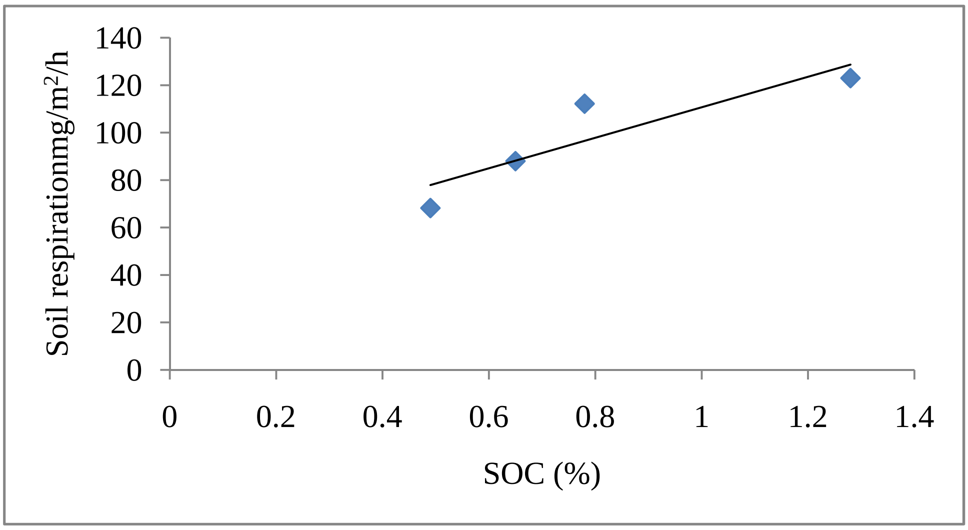

Fig. 2 The relationship between SOC and soil respiration.

The independent sample *t* test did not show a significant difference between the top and bottom layers in site 1 but a significant difference was registered in site 2 (p=0.013; Table 2) between the two layers. The high content of SOC in the top layer and less varied up to 30cm depth in foot hill sites can be related to the presence of high herbaceous cover which provide high inputs of SOC from litter fall and fine roots than the hill slopes; similar kind of variations in SOC in different vegetal covers was observed in dry forests of Shoolpaneshwar wildlife sanctuary (Dinakiran and Krishnayya, 2008). In dry deciduous forests the amount of rainfall and clay content seems to be the major factors that affect the SOC values (Mani et al., 2017). In comparison between the two forest sites, the independent sample t test did not revealed significant difference in the top layer SOC values ($t_{(4,0.05)}$=0.818, p>0.05) but a significant difference was observed in the below surface layer SOC values ($t_{(4,0.05)}$=6.75, p=0.002). These values suggest that depth has an effect on the amount of SOC in the soil as also revealed in the study carried out in primary and secondary forests of Manipur (Vashum, et al., 2016). This indicates that the decomposition rate varies between the sites 1 and 2 which effects the accumulation of the SOC content in the subsurface layers. This is substantiated by observed significant difference ($t_{(3,\ 0.05)}$=3.59, p= 0.036) in respect to soil respiration rates between the sites suggesting a differential microbial activity in the sites which needs an in depth study of the effect of microbial activity on the SOC in these forests.

Table 2 Independent sample *t*- test between upper and bottom surface layers in the two study sites.

Forest site	Layer	SOC (%) Mean	Range (SOC %)	Std Deviation	Std Error of mean	*t*	df	Sig (2 tailed) *p*
Site 1	Top (0-10cm)	0.655	0.575 – 0.755	0.092	0.053	-1.55	4	No significance p=0.196
	Bottom (10-30cm)	0.78	0.68 – 0.89	0.105	0.061			
Site 2	Top (0-10cm)	0.596	0.5 – 0.65	0.083	0.048	4.857	4	Significant p=0.013
	Bottom (10-30cm)	0.32	0.26 – 0.35	0.051	0.03			

The physical chemical properties of the soils of the two forest study sites are provided in Table 1. In site 1, slight acidic values of 6.87 in the top surface and 6.67 in the below surface layer was observed. In site 2, slight acidic values (6.93 and 6.83) were recorded in the top surface and below surface layers respectively. A trend of higher E.C. values in upper surface layer and less value in the below surface layer was observed in site 1 (17 – 24.5 µsiemens/cm) and contrastingly in the site 2; low value in the top layer and high value in the bottom layer was recorded. With respect to soil moisture, an increase of values of soil moisture with increase in depth was recorded in both the sites 1 and 2. The hill slope (site 2) registered high bulk density value (Table 1; 1.8 g/ cm^3) and correspondingly low SOC value than the foot hill study site 1.

In comparison to the similar studies on SOC up to 30cm soil depth the results revealed that the present study values were higher than the Nanmangalam reserve forest (Radhapriya et al., 2014) (Table 3, 0.12-0.41%) but lesser than the forests of Garhwal Himalayas (4.44 - 2.55%) (Gairola et al., 2012), North Meghalaya (1.92%) (Majumdar et al., 2004) and Mizoram forests (2.22 ± 0.18%) (Tawnenga et al. 1997), Kolli hills (1.71 - 12. 6%) (Mohanraj et al., 2010), terai natural forests (1.53%) (Koul et al., 2011), Amarkantak dry deciduous forests (Iqbal and Tiwari, 2016) and the study plots laid in agro forestry (Newaj et al., 2017). The observed soil respiration range of 68.2 to 112.2 mg/m^2/hr are found to be lesser than the tropical forest (272 mg/m^2/hr) in Sambalpur (Mishra and Dash, 1982) and tropical deciduous forests (124 to 360 mg/m^2/hr) of southern Orissa (Mohanty and Panda, 2011).

Table 3 SOC percentage values of few studies on Indian forest soils up to 30 cm depth.

Site	Depth (cm) of the soil	Soc (%)	Source
Secondary forest (20yrs fallow), Mizoram, Northeast Region India	0-10 10-20	2.65 ± 0.20 2.22± 0.18	Tawnenga et al. (1997)
Natural forest, Meghalaya, Northeast region India		1.92	Majumdar et al. (2004)
Kolli hills, Tamil Nadu	0-30	1.71 - 12.59	Mohanraj et al. (2011)
Natural forest, Terai Zone, West Bengal	0-10 10-20 20-30	1.77 1.53 1.38	Koul et al. (2011)
Gharwal Himalaya, Uttarakhand	0-10 11-30	4.44 - 2.55	Gairola et al. (2012)
Nanmangalam Reserve Forest, Tamil Nadu	0-15 15-30	0.14-0.87 0.12-0.41	Radhapriya et al. (2014)
Amarkantak Biosphere Reserve, Chattisgarh	0-20cm 20-50cm 50-100cm	52.7 t/ha 41.7 t/ha 28.04 t/ha	Iqbal and Tiwari, (2016)
Mudumalai Wildlife sanctuary drydeciduous forests Mudumalai Wildlife sanctuary drydeciduous forests	0-10 cm 0-10 cm	2.5±0.2 3.7 to 1.6	Mani et al. (2017)
Agro forestry plots	0-30cm	49.6 - 57.3 t/ha	Newaj et al. (2017)
Present study Site 1 (Foot hills)	0 -10 10-30cm	0.575 - 0.755 0.68 - 0.89 32.3 t/ha	
Site 2 (Hill slopes)	0-10 10-30cm	0.5 - 0.65 0.26 - 0.35 27.6 t/ha	

4 Conclusion

The outcome results of the study in the Guvvalacheruvu forests indicate a low variation in the upper surface layer and a higher variation in the subsurface layer with respect to SOC values. Further a contrast result of both decrease and increase of SOC values in relation to the soil depth was observed. These suggest that the forest soils up to 30 cm depth have high as well as varied potential to hold carbon in the soils. The presence of significant difference in soil respiration values between the two study sites could be due to changes in the litter decomposition rates by the soil microbes which need a further in depth studies in these forests.

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