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Seasonal variation of Soil respiration in dry deciduous forest of Palakondalu hills, Southern Eastern Ghats, Andhra Pradesh, India

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ABSTRACT

The objective of the study was to estimate seasonal variation in soil respiration (SR) rate and its relationship with soil microclimate variables. The field experiments was carried out during 2018 August to 2019 July to record the monthly soil respiration (SR) rate, soil moisture, soil temperature and soil organic carbon in the study site. Significant seasonal variation in SR rates was recorded similar trend in soil moisture levels and soil organic content was also observed. SR was found to be higher in rainy season (148.7 CO_2mg/m^2/h) followed by summer season (135.9 CO_2 mg/m^2/h) and winter season (121.8 CO_2mg/m^2/h). A significant positive relationship between monthly SR rate and soil moisture was observed. SR rates featured non-significant negative relationship with soil temperature and a weak positive relationship with SOC. The study indicates that the rate of soil respiration was mainly influenced by soil moisture levels followed by soil temperature.

Key words : *Dry deciduous forest, Soil respiration, Soil moisture, Soil temperature, Seasonal variation*

Introduction

Soil respiration involves efflux of CO_2 into the atmosphere from soil surface through root respiration in the rhizosphere and heterotrophic respiration by soil microbes by decomposing the soil organic matter (Davidson and Janssen's 2006). Soil Respiration (SR) represents the second largest Carbon flux between ecosystems and atmosphere; globally soil respiration rate is in the range of 68 - 76.5 Pg CO_2-C year $^{-1}$ and is at least 10 times greater than the fossil fuel combustion emission rates (Bhupinderpal *et al.*, 2003). Soil Respiration contributes 30 - 80% of the total forest ecosystem respiration depending on the vegetation and climatic conditions and thus it forms an important flux in influencing global warming (Yang *et al.*, 2018).

Soil respiration is considered as a biochemical process and seasonal variations in efflux rates are influenced by soil micro-climate variables like soil moisture, soil temperature and soil organic matter which in turn influence biological activity and CO_2 diffusion (Mohanty and Panda, 2011). In temperate forest ecosystems soil respiration rates, temperature and moisture are strongly correlated as root productivity and above ground biomass are also linked with temperature and moisture (Bhupinderpal *et al.*, 2003). In Indian tropical forests, studies revealed contrast relationships between SR rates and with soil moisture, soil temperature (Pandey and Singh, 2018; (Mishra and Gorai, 2020). Thus more studies in less studied dry forest types are needed to generate data on soil respiration rates and its relationship with soil microclimate and vegetation. In this line the present

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study tries to identify how the soil respiration rates are affected by soil microclimate variables like soil moisture, soil temperature in a dry forest.

Materials and Methods

Study site

The present study was carried out in a dry deciduous forest site in Palakondalu reserve Forest in Kadapa hill ranges, Southern Eastern Ghats, India (14º 25′ 08.5″ N; 078º 52′ 29.8″ E and 14º 25′ 25.4″ N; 078′ 52″ 34 E). The elevation of Palakondalu reserve ranges from 302 m to 376 m and Dry deciduous forests are dominated by tree species such as *Anogeissus latifolia, Pterocarpus santalinus, Ziziphus xylopyrus*, *Givotia moluccana* and *Gardenia resinifera.* Sandy loam and loamy sand red soils with quartzite rock boulders are present in the Palakondalu reserve forest (Ramana and Reddy, 2019). The study area receives a mean annual rainfall of 678 mm and the mean monthly temperature range is 27 ºC - 46 ºC.

Methodology

A total of 72 soil samples were collected randomly in two-ha area of Palakondalu Reserve forest area from 2018 August to 2019 July for estimation of soil organic carbon at two different depths - top surface layer (0-10 cm) and subsurface layer (10-30 cm). Mean SOC values were obtained after performing three replications following Walkley and Black (1934) rapid titration method and the estimated SOC were converted to Mg C ha^{-1}. Soil variables such as pH, Electrical Conductivity, moisture content (Oven dried method), texture and bulk density (Core method) were estimated by following standard procedures (Kapur and Sudharani, 2007). SR rate was measured insitu the amount of CO_2 evolved per unit area and time on a monthly interval based by alkali absorption method (Singh and Gupta, 1977). The experiment was carried out at six different locations in each month by fixing six open ended cylindrical boxes (30 cm diameter x 20 cm height). At each place the above ground vegetation was clipped and the cylinder was pushed up to 5 cm depth. The evolved CO_2 was collected in a vial for reaction with 20 ml 1 M NaOH over a 24 h period to avoid diurnal changes. The amount of CO_2 absorbed was estimated by titrating with 1 M HCl using two drops of phenolphthalein indicator and estimated by using the formula ($mgCO_2 = V \times N \times 22$).

Results

The range of soil pH values was 5.02-6.22 indicating weak acidic nature. The electrical conductivity values were in the range of (77.5-168.5 (μ_s/cm) with a mean of 131.31±30.95 μ_s/cm. The mean and range of SOC values (0-30 cm) were 1.09±0.13 and 0.79 to 1.26 (Table 1). Monthly mean soil micro climate variables such as soil moisture (SM), soil temperature

Table 1. Monthly mean and range values of soil physico-chemical properties along with soil organic carbon and soil respiration rate values in Palakondalu hills

S. No	Month	Soil pH	Electrical conductivity (μ_s/cm)	Soil temperature (ºC)	Soil moisture (%)	Soil organic carbon (%)	Soil bulk density (g/cm^3)	Soil respiration (CO_2mg/m^2/h)
1	June	6.22	161.3	32.6	5.23	1.26	1.28	157.3
2	July	5.8	167.3	29.2	6.5	1.17	1.33	155.46
3	August	5.64	160.9	31.6	5.84	1.12	1.3	141.9
4	September	5.55	128.6	34.2	5.78	1.07	1.44	142.26
5	October	5.57	119.9	32.4	7.79	0.79	1.58	146.6
6	November	5.69	118	27.6	6.48	1.05	1.37	143.73
7	December	5.93	116.6	30.6	3.59	1.14	1.38	114.03
8	January	5.07	168.6	30.7	2.73	1.13	1.33	107.8
9	February	5.02	156.1	38.7	2.83	0.92	1.41	146.51
10	March	5.18	109.6	40.2	2.44	1.14	1.31	139.7
11	April	6.18	77.53	43.9	2.24	1.14	1.29	129.8
12	May	6.12	91.53	44.5	2.05	1.27	1.15	127.96
	Mean	5.66±0.41	131.31±30.95	34.6±5.71	4.45±2.01	1.09±0.13	1.34±0.10	137.75±15.21
	Range	5.02-6.22	77.5-168.5	27.6-44.4	2.04-7.78	0.92-1.26	1.15-1.58	107.8-157.3

(ST) along with Soil Respiration rate (SR) and soil organic carbon (SOC) were provided in the (Table 1). The mean SOC values present in the surface layer (0-10 cm) (1.55%) got decreased by a proportion of 42.5% to 0.66% with depth at the subsurface layer (10-30 cm). A strong negative relationship between soil organic carbon and bulk density (R^2=0.82) was observed. The mean soil moisture content at 0-10cm depth was 2.79% and 5.86% at 10-30cm depth indicating that soil moisture content was nearly two times higher at subsurface layer than the top surface layer.

The mean monthly SR rate was in the range of 107.8-157.3 CO_2mg/m^2/h with a maximum recorded in June (157.3 CO_2mg/m^2/h) and minimum in January (107.8 CO_2mg/m^2/h) (Table 1). The mean soil respiration rate was higher in rainy season (148.70 CO_2mg/m^2/h) followed by summer season (135.99 CO_2mg/m^2/h) and winter season (121.85 CO_2mg/m^2/h) (Figure 1). SR rate has marginally increased with the onset of summer season in February and gradually decreased till May and remarkably increased with the beginning of rainy season in June and July months and further maintained steady rate till November. While in winter season lower mean SR values with high C.V. value (24%) were recorded. Higher SR value (157.3 CO_2mg/m^2/h) was recorded at 32 ^{o}C in rainy season and the results show that SR rates decrease when the temperature rises ≥ 40 ^{o}C and soil moisture decreases by 2.5%. Soil respiration rates have showed a significant positive relationship with soil moisture (Table 2) and weak positive relationship with soil organic carbon and a non-significant negative relation with soil temperature. While a significant negative relationship with soil moisture and soil temperature was observed (Table 2). The multi-variate linear regression models with three independent variables SM, ST and SOC against the dependent SR variable have explained 65% (R^2 = 0.65) of variation. The regression equation for estimating SR in the present dry forest study site is Y (SR) = - 63.72 +2.709*ST + 49.037*SOC + 11.048*SM and the standard beta-coefficients values suggest that the SM variable represented as a higher explanatory variable in the model

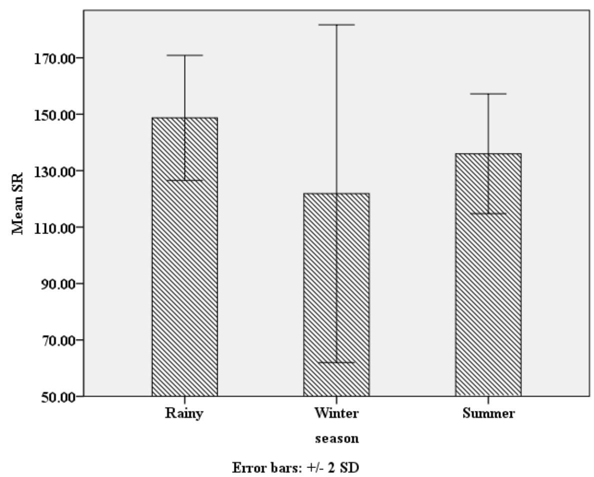

Fig. 1. Soil respiration (SR) rate during different seasons in Palakondalu hills

Table 2. Multi variate linear Regression models showing regression weights of the dependent variables Soil Respiration and Soil Moisture (0-10 cm; 10-30 cm) and Soil Temperature on the independent variable Soil Organic Carbon

S.No	Variables	Model 1	Model 2	Model 3	Model 4	Model 5
1	SOC	49.033	18.33	52.48	-20.475	-
2	SM	11.048	-	-	-	8.114
3	SM_{10}	-	11.266	-	-	-
4	SM_{30}	-	-	7.98	-	-
5	ST	2.709	2.39	2.1	-0.399	1.889
6	Constant	-63.772	-2.74	-44.138	174.8	32.964
7	R^2	0.654	0.551	0.568	0.05	0.541
8	Adjacent R^2	0.525	0.383	0.406	0.161	0.439
9	ANOVA	0.03	0.08	0.069	0.792	0.03
β coefficient						
10	SOC	0.426	0.159	0.456	-0.178	-
11	SM	1.448	-	-	-	1.063
12	SM_{0-10cm}	-	1.235	-	-	-
13	$SM_{10-30cm}$	-	-	1.287	-	-
14	ST	0.922	0.816	0.718	-0.136	-0.643

followed by soil temperature and SOC (Table 2). Among the models (Table 2), model 1, produced with variables SM, ST, SOC was found to be the best fit model (Adj. $R^2 = 0.525$) and model-5 figured as 2^{nd} best model when soil moisture and ST variables were considered and SOC was omitted indicating that these two variables prominently influence the SR rate. While Model 4 represented the least best fit model in which SOC and ST variables are considered and SM was omitted indicating that SM acts as the most important independent variable that influence the SR.

Discussion

Soil respiration rate increased rapidly once rains got initiated after the dry summer months. This stimulation of high CO_2 efflux after rains is due to the rapid decomposition of organic matter by the microbial activity that got accumulated during the dry months as warm and moist conditions are most suitable for fungal and other soil microbial activities which release air rich in CO_2 from soils rich in organic matter (Mohanty and Panda, 2011). Such seasonal increase of SR rates in rainy season can be comparable with the studies carried out in semi arid regions (Saraswathi *et al.*, 2008 and Mohanty and Panda, 2011) and as well in moist forests (Thokchom and Yadava, 2014). The present study SR rates were found to be in the range recorded in Northern tropical forest (Rajyavanshi and Gupta, 1986), tropical deciduous forest (Basu *et al.*, 1991), Moist deciduous forest (Mohanty and Panda 2011). Although non-significant, SOC values showed poor negative relationship with ST and positive relationship with SM due to lower SOC values being recorded in dry summer period and cool rainless periods indicating that SM limits the SR rates depending on the SOC content as well as ST in explaining the monthly variation in this dry deciduous forest as also observed in young forest plantations of semiarid region (Saraswathi *et al.*, 2008), grasslands study of Kurukshetra region (Arora and Chaudhry, 2017) and Riparian buffer of the semi-arid-region of North-West India (Jha and Mohapatra, 2011). Soil temperature limitation in winter season and soil moisture limitation in summer season was clearly observed. SR rates were found to be less in summer season under conditions of SM less than 2.5% and >40 ^{o}C and these results corroborates with the report that at higher temperatures a partial inhibition of respiration occurs due to the inactivation of biological oxidation systems in the dry forest ecosystems (Pandey and Singh, 2018).

Conclusion

The Present study suggests that Soil moisture acts as the primary variable that influence the SR rates and the interactive effects of soil moisture and soil temperature further contribute to the seasonal variation of the soil respiration rate in dry deciduous forest study site of Palakondalu hills. The higher SR rate in rainy season as well as in each of the rainy month indicates that SM limits the SR rate which corresponds to significant correlation of SR with SM but not with ST. Hence seasonal Soil CO_2 rate mainly correlated with the patterns of SM observed throughout the year which depends upon the rainfall distribution rather than on the total annual rainfall amounts.

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