Indian Journal of Ecology (2023) 50(5) (SI): 1653-1656
DOI: https://doi.org/10.55362/IJE/2023/4112

Manuscript Number: 4112
NAAS Rating: 5.79

Study on Soil Microbial Biomass Carbon and Variation due to Land Use and Season in Semi-Arid Region of Southern Andhra Pradesh

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Abstract: Soil microbial biomass is the active and labile part of the soil organic carbon that constitutes living microorganisms smaller than 5-10 μm^3. These soil microorganisms play a key role in the release and retention of essential nutrients for plant growth. Soils in the semiarid region of the study sites are nutrient poor on which dry deciduous forests occur and alkaline nature of soils prevail in agriculture and grasslands. Chloroform fumigation extraction method was used to determine the soil microbial biomass (SMB) content in the four land use types and across three seasons. There was significant difference in SMB content across the four land use types and seasons. Maximum SMB content was recorded in agricultural land use (216.3 µg/g) followed by forest (174.37 µg/g), miyawaki plantation (124.38µg/g) and grassland (72.47µg/g). The higher SMB content was recorded in rainy season followed by winter and summer season. The study suggest that soil moisture conditions, soil organic carbon content influence the variation in the SMB content in these study sites.

Keywords: Dry deciduous forests, Land use type, Soil organic carbon, Soil microbial biomass, Soil moisture

Soil microbial biomass (SMB) represents the living component of soil organic carbon (SOC), comprising mainly bacteria, fungi, actinomycetes, rotifers and protozoans up to 5 X 10^3 μm^3 size (Singh and Gupta 2018). In addition SMB forms only 1-5% of the SOC, but represents the major active and labile fraction of nutrients that are available to plants due to rapid turnover rate of less than one year (Brady and Weil 2013). SMB is inferred to play a key role in nutrient cycling through immobilisation and mineralisation of nutrients, by decomposing the plant litter, thus providing essential nutrients for plant growth and as well improving the soil quality by forming aggregates of<250µm diameter (Thakur et al 2022). The seasonal dynamics in regard to microbial biomass suggest that the SMB upholds the nutrients when they are in large amount and releases them when the plant growth is maximum (Bhattarai and Mandal 2020). The seasonal environmental conditions like soil moisture and temperature have a direct effect on microbial biomass cycle and these variables may also show influence indirectly on the SMB content by means of interaction with other factors like vegetation (Yang et al 2010), topography and landscape (Chang et al 2016) soil depth (Pal et al 2020). Thus factors such as topography (Bargali et al 2018), soil properties (Arunachalam and Arunachalam 2000), plant litter (Fang et al 2014), SOC content, land-use pattern and vegetation type (Lepcha and Devi 2020) influence the SMB variation. In India majority of the studies on SMB dynamics were carried out in humid regions like North western Himalaya (Singh et al 2018), Central forest Himalayan soils (Bargali et al 2018). In nutrient poor soils of semi arid region of Andhra Pradesh the information on Soil organic carbon (Ramana and Reddy 2019) is available but information on SMB dynamics was not carried out. Hence the main objectives of the present study were to analyse the variation in SMB values across the four land use types and across three seasons.

MATERIAL AND METHODS

The study was carried out in four land use types namely Guvvalacheru forest (GF;14˚16' 28.3" N 78˚51'57.6" E), Miyawaki plantation in Yogi Vemana University campus (MW; 14˚28'10.8" N, E 78˚42' 43.56,'), agricultural land (AG; 14˚28'10.8" N, 78˚42' 43.56 E) in which paddy and maize are grown and natural grassland in the Yogi Vemana University campus (NG; 14˚28'10.8" N, 78˚42' 43.56, E') in the semi-arid region of Kadapa district, Andhra Pradesh. All the four study sites feature a tropical monsoon climate with three distinct seasons namely summer (March to May), rainy (June to October) and winter seasons (November to February). Summer is very severe, while winter is mild and rainy season is moderately wet. The four study sites receive an average annual rainfall of 680 cm with a maximum of total rainfall occurs in the monsoon period of June to September. In the study sites, the mean monthly maximum temperature ranged between 28˚C to 44˚C and mean monthly minimum temperature range between 14˚C to 37˚C.

Soil samples were collected randomly at 0-15 cm depth in three replicates from the five 10X 10m quadrats laid in each of the four land use types in three different seasons. Soil samples were thoroughly mixed to form a composite sample from each of the land use study sites. The collected soil samples were air dried and passed through 2 mm sieve for soil samples analyses. Soil moisture was determined by the oven dry method, soil temperature was measured by soil thermometer, soil pH and Soil Electrical Conductivity were measured by glass electrodes immersed in the 1:5 soil: water samples respectively. Bulk density was measured by estimating the dry weight of a unit volume of soil collected by inserting metallic box of known internal volume (Brady and Weil 2013). Soil Organic Carbon was measured by using strong oxidising agent potassium dichromate, soil samples digestion was done by Conc. H_2SO_4 and titrated with ferrous sulphate (Walkley and Black 1934). Soil microbial biomass (SMB) was measured by the flush of carbon released from soil in response to chloroform fumigation which corresponds to the total microorganisms present in the soil sample. In this Chloroform-Fumigation Extraction procedure, soils are exposed to chloroform vapour for 24 hours in order to kill and lyse the microbial cells with the release of cytoplasm into the soil. Then the carbon is extracted from soil by 0.5M K_2SO_4 solution in both fumigated (CF) and non-fumigated samples (CNF) and organic carbon in the extract was estimated by acid-dichromate oxidation procedure and the difference between CF and CNF is noted as SMBC (Vance et al 1987).

SMB (µg/g soil) = $E_{CF} – E_{CNF}/K_{E.C}$. [E_{CF} = Extractable 'C' in the Fumigated Soil; E_{CNF} = Extracted Carbon in Non-Fumigated Soil; $K_{E.C}$. = 0.38].

Data analysis: The results obtained from the soil sample analyses were tested for normality and homogeneity of equal variance (Scheffe and Levene test ($F(11, 24) = 1.163$ $P>0.05$) respectively). Data transformation is not needed as the assumptions of normality and homogeneity of equal variance were met. Two-way ANOVA test was carried out to know the impact of the variation in land use types and seasons by measuring the significance level. Post–Hoc LSD (Least Significant Difference) test was undertaken to know the difference in SMB values among the four land use study sites. Pearson Correlation analysis was carried out to know the strength of the relation between SMB and Soil Moisture, Soil Temperature and SOC. Statistical tests were carried out by SPSS Version 20.

RESULTS AND DISCUSSION

Forest soils showed near neutral pH values (6.9-7.18), while alkaline nature of soils in the range of 7.42-8.85 in MW plantation and higher alkaline pH range was in AG (8.03-9.5) and in NG study sites (8.24-10.07). Similarly lower mean B.D. was in the forest followed by AG site and higher mean BD were registered in MW and NG sites. Higher mean SOC content was recorded in forest sites and nearly double the values recorded in the other three land use types. Thus reflecting a negative relationship between SOC and BD. SMB values varied with high mean registered in AG sites (216.3 µg/g) followed by forest site (174.37 µg/g) and lower were recorded in MW (124.38 µg/g) and NG (72.47 µg/g). Thus the varying litter content and root types are the prominent drivers that influence the SMB content (Lepcha and Devi 2020). The estimated range of the SMB in the present study (72.5-287.2 µg/g) are lower than Central Himalayan forest soils (Bargali et al 2018; 416-763 µg/g) sub alpine tropical montane forests (Arunachalam and Arunachalam 2000; 140-1320 µg/g). This kind of the variation in SMB content suggest that the differences in the litter quantity and quality, rhizosphere depth levels are the major factors that influence the microbial activity in the soil and in-turn microbial biomass levels (Fang et al 2014). The SMB values showed a strong relation with SOC, indicating that the higher availability of soil organic matter have led to higher microbial biomass in the order of AG>GF>MW>NG. Similar correlation between SMB and SOC and litter content producing higher microbial biomass in natural ecosystems was observed in the previous studies (Arunachalam and Arunachalam 2000; Lepcha and Devi 2020). Thus, in varied soil conditions, the soil systems with high organic inputs (freshly added SOC) tend to have higher microbial biomass content as they are preferred energy sources for microorganisms (Chang et al 2016).

The mean SM was higher in AG site followed by Forest and minimum values were recorded in MW and NG sites (Table 1). Thus the study revealed a significant positive relation between SMB and soil moisture as adequate soil moisture levels improve the microbes survival rate and as well increase their activity and biomass (Singh et al 2010). But a negative relation between SMB and soil temperature was noted. Interestingly, AG sites featured high SMB content even though they comprised of lower SOC than GF site but had high SM values. It suggests that when certain SOC value is reached, SM plays a key role in regulating the SMB levels as also observed in paddy cropland of Eastern Himalayas (Lepcha and Devi 2020). The maximum concentration of SMB was in rainy season followed by winter and dry summer was observed in all the four land use types. This trend is may be due to higher decomposition rate of litter and microbial activities by which nutrients are immobilised at higher rate during the active growth season (Bhattarai and Mandal 2020). Minimum SMB was in NG site in dry summer season. Seasonal variation revealed that higher reduction between rainy Vs winter seasons was observed in NG site and higher reduction between winter Vs summer recorded in MW sites;

Table 1. Soil characteristics of the four land use types (Mean±SE)

Land use	Soil microbial biomass (μg/g)	Soil organic carbon (%)	Soil moisture (%)	Bulk density (g/cm^3)	pH (Range)	Soil temp (Range) (°C)
Agriculture (AG)	216.29±16.35	0.50±0.03	7.63±2.40	1.30±0.04	8.03-9.5	24.5-43.3
Forest (GF)	174.37±12.51	0.98±0.20	6.43±2.23	1.24±0.03	6.9-7.18	30-35.7
Miyawaki Plantation (MW)	124.38±22.65	0.46±0.16	5.12±1.30	1.43±0.12	7.42-8.85	32.7-38.7
Natural Semiarid grassland (NG)	72.47±17.65	0.33±0.06	4.81±1.48	1.44±0.12	8.24-10.07	26.6-42.2

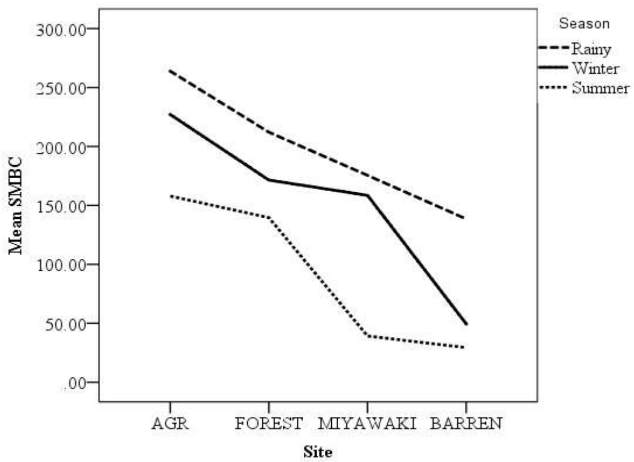

Fig. 1. Soil microbial biomass content variation across four land use types and three seasons

while forest site registered gradual decrease in SMB values from rainy season followed by winter and summer season (Fig. 1). The four land use patterns ($F_{3,8}$ = 73.81; P<0.05), three seasons($F_{2,6}$= 71.94; P<0.05) and their interaction ($F_{6,24}$ = 3.83:P<0.05) have significantly influenced the variation in SMB content. The multiple comparison post Hoc (LSD) test indicated a significant difference across the four land use types except between forest and miyawaki sites and between rainy and winter seasons. Among all the four study sites, a peak value in SMB content was recorded during rainy season followed by winter and lower value in dry summer season. Similar trend showing higher SMB values in wet rainy season and lower content in winter season and summer season was noticed in North-Eastern deciduous forest; as wet conditions favours the microbial activities which increases the decomposition rates of litter (Lepcha and Devi 2020). The lower values in winter and summer season may be due to low microbial activity and slow rate of litter and organic matter decomposition (Yang et al 2010). But in tropical forests of Vindhyan plateau, the peak values of SMB were noticed during summer season (Singh et al 2010) and in humid forests higher SMB value was recorded in winter season (Arunachalam and Arunachalam 2000) which may arise due to the differences plant litter quality and rainfall pattern. Thus in the nutrient poor soils of the present study moderate soil temperature, moderate SOC levels and high Soil Moisture conditions support high SMB content in the rainy seasons and extreme temperatures in dry summer seasons leads to lower microbial activity and even death of microbial population.

CONCLUSIONS

The four different land use types in the semiarid region featured lower SOC content and varied SMB values and as well a positive relation between SMB and SOC. Agriculture study sites featured higher SMB values although it has relatively lower SOC values; while forest, Miyawaki plantation and grassland study sites revealed strong relation between SOC and SMB. Overall SM values seem to influence the SMB values with higher values in rainy season followed by winter and summer season. Thus a positive relation between plant growth and soil microbial activity was observed in these sites.

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Received 11 May, 2023; Accepted 27 October, 2023