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Effect of Different Land Use Pattern on Soil Characteristics, Microbial Biomass Carbon and Nitrogen in Red Soils of Vikarabad District

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***Abstract*:** This study is aimed to determine the impact of different land use patterns *i.e.,* forest land, 100% cropping intensity (redgram-fallow), 200% cropping intensity (rice-rice) and fallow land on soil microbial biomass carbon and nitrogen. A survey was conducted in the year (2019-20 and 2020-21) in red soils of Vikarabad district covering eight mandals and soil samples were collected from four different land use pattern at two depths (0-15 and 15-30cm). Soil characteristics like bulk density, pH, EC, organic carbon, total nitrogen varied significantly with land use patterns and soil depth was significantly higher in forest soils compared to other land use patterns. The mean microbial biomass carbon was 242.8 mg kg^{-1}, 128.1 mg kg^{-1}, 119.0 mg kg^{-1}, 69.0 mg kg^{-1}and the mean soil microbial nitrogen was 35.6 mg kg^{-1}, 21.9 mg kg^{-1}, 17.7 mg kg^{-1}and 11.0 mg kg^{-1} respectively for forest, 100% and 200% cropping intensity and fallow land. There was significant positive correlation of microbial biomass carbon with per cent clay (0.998**), soil organic carbon (0.992**), total nitrogen (0.984**) and microbial biomass nitrogen (0.997**). The results confirm that alterations in soil physical and chemical properties due to deforestation and intense anthropogenic activity at agriculture lands may cause disturbances and ultimately affect the soil microbial biomass.

***Keywords*:** Microbial biomass C, Microbial biomass N, Land use pattern, Red soils, Forest

Soil organic matter is an important component of soil quality and productivity. However, its measurement alone does not adequately reflect changes in soil quality and nutrient status. Measurements of biologically active fractions of organic matter, such as microbial biomass carbon (MBC) and nitrogen (MBN) and potential C and N mineralization, could better reflect changes in soil quality and productivity that alter nutrient dynamics. This reflection is based upon rapidly changing capacity of both C and N forms (Pal et al 2020). These fractions gives an indication of soil organic matter changes induced by management practices. The importance of microorganisms in ecosystem functioning has led to an increased interest in determining soil microbial biomass. The soil microbial biomass is the active component of the soil organic pool, which is responsible for organic matter decomposition affecting soil nutrient content and consequently, primary productivity in most biogeochemical processes in terrestrial ecosystems (Haney et al 2012). Therefore, measuring microbial biomass is a valuable tool for understanding and predicting long-term effects under the influence of different land use pattern and associated soil conditions (Sharma et al 2011). The present study was conducted to assess the impact of different land use patterns on soil characteristics, microbial biomass carbon and nitrogen in red soils of Vikarabad district.

MATERIAL AND METHODS

Vikarabad district is one of the newly carved district from erstwhile Rangareddy in Telangana state. The geographical area of the district is 3,386 sq.km and is situated between 17°20'11.15"N latitude and 77°54'17.45"E longitude. The net cropped area in the district is about 20.4 lakh ha and has a forest cover of 44,548 ha and fallow land to an extent of 20,769 ha. The main crops cultivated in the district are redgram, maize, rice and vegetables. The main tree species found in the forest were *Tectona grandis, Eucalyptus, Acacia nilotica, Tamarindus indica, Leucaena leucocephala, Dalbergia sissoo, Ficus benghalensis, Pongamia pinnata, Syzygium cumini etc.* Fallow land was not disturbed and unmanaged and they were having mixed grasses other plant species and weeds. The climate in this region is semi-arid and characterized by warm summers. According to the climatological data gathered over the past 30 years, the mean maximum and minimum temperatures found to be in the range of 28-45^{0}C and 12-26^{0}C (Directorate of Economics and Statistics, 2021).

Soil sampling: A survey was carried out in the year (2019-20 and 2020-21) and soil samples at two depths (0-15 and 15-30cm) were collected from eight mandals in Vikarabad district predominantly covered by red soils. Five villages in each mandal were selected and from each village, four land use patterns were selected out of which two were from agricultural land use with different cropping intensity *i.e.,* 100% cropping intensity (redgram-fallow cropping system), 200% cropping intensity (rice-rice cropping system) and two from natural conditions *i.e.,* forest and fallow land. A total of 320 soil samples were collected at two depths. The microbial biomass carbon and microbial biomass nitrogen were analysed in fresh soil samples within 24h. For determination of other soil properties, the soil samples were air dried, pounded and stored in polythene bags for further analysis.

Soil analysis: The soil samples were analysed for salient characteristics like texture, pH, EC, bulk density, soil organic carbon (g kg^{-1}) and total nitrogen (kg ha^{-1}) following standard procedures. For determination of Soil Microbial Biomass Carbon, field-moist soil samples (10.0 g) were exposed to $CHCl_3$ vapour for 24 h and extracted with 0.5 M K_2SO_4. A second set of non-fumigated samples was also extracted under similar conditions. The difference between C obtained from the fumigated and from the non-fumigated ones was taken to represent the microbial C-flush and converted to MBC using the relationship : MBC = 1/0.41 C-flush (Christian et al 2000).All results are expressed on an oven-dry soil basis (105°C, 24 h).

Microbial biomass nitrogen was also estimated using the same principle of microbial biomass carbon. The K_2SO_4 extractant of both fumigated and un-fumigated soil was digested for 3 h with addition of digestion mixture and sulphuric acid. After cooling, distillation was carried out to find the total nitrogen content. The difference between fumigated and un-fumigated extracted nitrogen of soil divided by a calibration factor (KEC) 0.38 gives the measure of microbial biomass nitrogen in soil and expressed as micro gram of microbial biomass-N per gram of dry soil (Beck et al 1997).

Statistical analysis: The data collected was statistically analysed using SPSS statistical package version 18.0.

RESULTS AND DISCUSSION

The data on salient soil characteristics *viz;* bulk density, pH, EC, organic carbon and total nitrogen obtained are presented in (Table 1). The soil samples in general were sandy loam to sandy clay loam in texture with clay per cent ranging from 35.96 to 40.28 %.

Bulk density (Mg m^{-3}): The average bulk density indicated that 200% cropping intensity (rice-rice) recorded the highest bulk density (1.45 Mg m^{-3}) followed by 100% cropping intensity (1.41 Mg m^{-3}), fallow land (1.39 Mg m^{-3}) and forest land recorded the lowest bulk density (1.33 Mg m^{-3}). The interaction effect between depth and land use pattern for soil bulk density was significant. Across the depth at 15-30cm the highest BD was obtained by 200% cropping intensity (1.48 Mg m^{-3}) this was followed by 100% cropping intensity, fallow land and the lowest were recorded under forest land use (1.36 Mg m^{-3}). There was an increase in bulk density from 0-15cm (1.37 Mg m^{-3}) to 15-30cm (1.43 Mg m^{-3}). The increase in bulk density with increase in depth in all the land use system may be attributed to lower organic matter content and soil compaction from the pressure of upper soil layer (Devi et al 2013).

Soil pH and EC: The soil pH under different land use pattern on an average, indicated that the soils under forest land use recorded the lowest soil pH (6.68) followed by fallow land, 100% cropping intensity (redgram-fallow) and the highest was recorded in 200% cropping intensity (rice-rice) (7.72). Among the depths there was increase in soil pH from 7.27 to 7.43. Interaction effect between soil pH and land use pattern was significant with forest soils recording the lowest soil pH (6.56) followed by fallow land, 100% cropping intensity, 200% cropping intensity at 0-15cm.At 15-30cm soil depth the pH of the soil increased and same trend was followed among all the land use patterns.

The highest soil electrical conductivity was recorded under 200% cropping intensity (rice-rice) (0.28 dSm^{-1}) this was followed by 100% cropping intensity (redgram-fallow) cropping pattern, fallow land and the lowest was recorded under forest land use (0.18 dSm^{-1}).With increase in soil depth the EC of the soil decreased in all the land use pattern. The interaction between depths and land use pattern for soil EC was significant with highest EC being recorded by 200% cropping intensity (rice-rice) (0.30 dSm^{-1}) at 0-15 depth. A close perusal of the data on soil pH and EC indicates that the soils sites having lower pH shows lower EC values especially in forest and fallow lands. Similar results were obtained by (Barros and Chaves 2014 and Shah et al 2013). An increase in total soluble salt content has been reflected by an increase in EC under cultivated soils this could be due to the addition of fertilizers and other amendments.

Soil organic carbon (g kg^{-1}): The data pertaining to soil organic carbon is presented in (Table 1). Irrespective of soil depth on an average, the highest soil organic carbon content was under forest land (7.05 g kg^{-1}) which was followed by 200% cropping intensity (rice-rice), 100% cropping intensity (redgram-fallow) and lowest was seen in fallow land (2.68 g kg^{-1}). However with increase in depth the mean organic carbon decreased from (4.72 gkg^{-1}) to (3.87 g kg^{-1}). Interaction effect between soil depth and land use pattern was significant and it varied from 7.30 g kg^{-1} in forest soils at 0-15cm to 2.24 g kg^{-1} in fallow land at 15-30cm.

Higher amount of organic carbon under forest land could be attributed to leaf litter decomposition at the surface. It was observed that about 60-80% total carbon resources are in oxidizable form due to the presence of higher amount of soluble extractives like fat, waxes and alcohol soluble extractives in forest residues. Among the cropping systems, 200% cropping intensity (rice-rice) has shown significantly higher SOC. This might be due to continuous submergence of soils for 8-9 months in an year under rice-rice cropping system, prolonged water logging conditions may reduce the decomposing of added crop residues (Mandal et al 2008). However the lower values of SOC under fallow lands could be attributed to the very low amount of addition of residues in the form of leaf litter to the soil though the soil was not disturbed for longer period of time. Significant decrease in organic carbon in the lower layers could be due to the decreasing input of surface litter in the lower depth.

Total nitrogen (kg ha^{-1}): The total nitrogen varied across the land use patterns and soil depth. The forest land recorded the highest mean total nitrogen (1577.1 kg ha^{-1}) followed by 100% cropping intensity (redgram-fallow) (1250.5 kg ha^{-1}) and 200% cropping intensity (rice-rice) (1212.5 kg ha^{-1}) but were on par with each other and lowest was under fallow land .With increase in depth of soil the total nitrogen content reduced from 1346.8 kg ha^{-1} (0-15cm) to 1150.8 kg ha^{-1} (15-30cm).Interaction effect between depth and land use pattern was significant with highest total nitrogen content in forest land at 0-15cm (1679.4 kg ha^{-1}) and lowest was recorded in fallow land at 15-30cm depth (897.6 kg ha^{-1}). The higher total nitrogen in the surface soil layers of forest land might be due to lack of disturbance which reduced the mineralization rate which contain plenty of plant litter. Similar results showing

Table 1. Effect of land use patterns on soil characteristics in Red soils of Vikarabad district

Depth	Bulk density (Mg m^{-3})	pH	EC (dSm^{-1})	Organic carbon (g kg^{-1})	Total nitrogen (kg ha^{-1})
D_1 (0-15cm)	1.37^{A}	7.27^{B}	0.25^{A}	4.72^{A}	1346.8^{A}
D_2 (15-30cm)	1.43^{B}	7.43^{A}	0.23^{B}	3.87^{B}	1150.8^{B}
Land use pattern					
L_1:100% cropping intensity (redgram-fallow)	1.41^{b}	7.59^{b}	0.25^{ab}	3.42^{c}	1250.5^{b}
L_2:200% cropping intensity(rice-rice)	1.45^{a}	7.72^{a}	0.28^{a}	4.14^{b}	1212.5^{b}
L_3:Forest land	1.33^{d}	6.68^{d}	0.18^{b}	7.05^{a}	1577.1^{a}
L_4:Fallow land	1.39^{c}	7.43^{c}	0.23^{c}	2.68^{d}	955.0^{c}
Interaction					
D_1L_1	1.39 ± 0.01^{d}	7.50 ± 0.05^{c}	0.27 ± 0.04^{ab}	3.90 ± 0.21^{d}	1375.0 ± 96.8^{d}
D_1L_2	1.43 ± 0.02^{bc}	7.64 ± 0.07^{b}	0.30 ± 0.03^{a}	4.54 ± 0.18^{c}	1320.3 ± 56.35^{c}
D_1L_3	1.30 ± 0.02^{f}	6.56 ± 0.09^{f}	0.19 ± 0.01^{de}	7.30 ± 0.14^{a}	1679.4 ± 97.53^{a}
D_1L_4	1.36 ± 0.01^{e}	7.38 ± 0.09^{d}	0.25 ± 0.02^{bc}	3.12 ± 0.16^{e}	1012.5 ± 85.08^{f}
D_2L_1	1.44 ± 0.01^{b}	7.66 ± 0.04^{b}	0.24 ± 0.04^{bc}	2.94 ± 0.26^{e}	1125.1 ± 95.69^{f}
D_2L_2	1.48 ± 0.02^{a}	7.79 ± 0.05^{a}	0.26 ± 0.03^{ab}	3.73 ± 0.24^{d}	1105.7 ± 65.04^{e}
D_2L_3	1.36 ± 0.03^{ef}	6.80 ± 0.06^{e}	0.17 ± 0.01^{e}	6.80 ± 0.15^{b}	1474.8 ± 83.00^{b}
D_2L_4	1.42 ± 0.01^{b}	7.48 ± 0.03^{c}	0.22 ± 0.02^{cd}	2.24 ± 0.16^{f}	897.6 ± 90.25^{g}

Mean values with different lower case superscript letters indicate significant difference between land use patterns for each soil depth and all land uses.Uppercase superscript letters indicate significant difference between depths for all land use system respectively at ($P<0.05$).± indicates standard deviation of mean

Table 2. Correlation matrix between different soil properties, microbial biomass carbon and nitrogen

Parameters	Clay	pH	EC	Bulk density	Organic carbon	Total nitrogen	MBC	MBN
Clay	1							
pH	0.220	1						
EC	0.602	0.810	1					
Bulk density	0.886	0.292	0.775	1				
Organic carbon	0.992**	-0.320	-0.699	-0.917	1			
Total nitrogen	0.984*	-0.101	-0.560	-0.920	0.990**	1		
MBC	0.998**	-0.240*	-0.631	-0.905	0.996**	0.992**	1	
MBN	0.997**	-0.217	-0.630	-0.922	0.993**	0.994**	0.973**	1

*Correlation is significant at the 0.05 level; **Correlation is significant at 0.01 level higher total nitrogen concentrations in the top soils under forestland than agricultural land use was also been reported by (Bohra and Ghosh et al 2013).

Effect of land use pattern on soil microbial biomass carbon and nitrogen (mg kg^{-1} soil): Among all the land use patterns studied the highest microbial biomass carbon was recorded in forest land (242.8 mg kg^{-1}) which was followed by 100% cropping intensity (redgram-fallow), 200% cropping intensity (rice-rice) and lowest was recorded in fallow land (69.0 mg kg^{-1}) (Fig. 1). While considering the land use pattern across the depths the interaction effect for microbial biomass carbon was significant and forest land use recorded the highest value (262.10 mg kg^{-1}) followed by 100% cropping intensity, 200% cropping intensity and lowest was in fallow land (82.8 mg kg^{-1}) at 0-15cm. At 15-30cm similar pattern was seen where forest soils recorded the highest MBC (223.6 mg kg^{-1}) and lowest was in fallow land (55.2 mg kg^{-1}). With increase in depth the average, microbial biomass carbon decreased from (158.2 mg kg^{-1}) to (121.3 mg kg^{-1}). The higher content of microbial biomass carbon under forest as compared to other land use could be possibly due to the effect of more addition of litter in the form of fine roots biomass and aerial plant residues. Among the cropping systems comparatively higher MBC under redgram-fallow cropping system could be due to the diversity of organic materials which contained greater concentration of MBC and enzymes under redgram especially under long term experiment in semiarid tropics. The MBC under 200% cropping system (rice-rice) were lower than that of 100% cropping system (redgram-fallow). The shift in microflora from aerobic to facultative anaerobes and weak microbial metabolism caused by oxygen limitation as a result of continuous water logging resulted in decreased biomass carbon in rice-rice system (Pal et al 2020). Compared to all the land use patterns the fallow land contained lower values of biomass carbon this could be attributed to the very little turnover of plant residues to the soil and also could be attributed partly due to less input of organic matter resulting in lack of substrate of growth of microbes in soil (Pal et al 2020).

Microbial biomass nitrogen (mg kg^{-1}): Among all the land use pattern studied the highest microbial biomass nitrogen (MBN) was recorded in forest land (35.6 mg kg^{-1}) which was followed by 100% cropping intensity (redgram-fallow), 200% cropping intensity (rice-rice) and lowest was seen in fallow land (11.0 mg kg^{-1}). While considering the land use pattern across the depth the interaction effect for microbial biomass nitrogen (Fig. 2) was significant and forest land use recorded the highest mean (40.0 mg kg^{-1}) which was followed by 100% cropping intensity (redgram-fallow), 200% cropping intensity (rice-rice) and lowest was recorded in fallow land (13.9 mg kg^{-1}) at 0-15cm. At 15-30cm the similar pattern was seen where forest soils recorded the highest MBN (31.2 mg kg^{-1}) and lowest was recorded in fallow land (8.2 mg kg^{-1}). With increase in depth the average, microbial biomass nitrogen decreased from (24.7 mg kg^{-1}) to (18.2 mg kg^{-1}). MBN was much lower in fallow soils as compared to other land use pattern. The higher amount of MBN in 100% cropping intensity than 200% cropping intensity could be attributed to the biological N fixation by rhizobia in root nodules of redgram in addition to the fertilizers addition to the soil which might have been utilized by microbes for their growth. A close perusal of the data indicated that MBN followed the same trend as MBC indicating that the dynamics of nitrogen in soil is closely linked to carbon which is present in the organic form for their energy which in turn influences the microbial activity in soil.

Correlation matrix between different soil properties, microbial biomass carbon and nitrogen: The per cent clay had a significant positive correlation with organic carbon (r=0.992**), MBC (r=0.998**), MBN (r=0.997**) and the total nitrogen (r=0.984**). The microbial biomass carbon values showed significant positive correlation with MBN (r= 0.973**), organic carbon (r=0.996**), total nitrogen (r

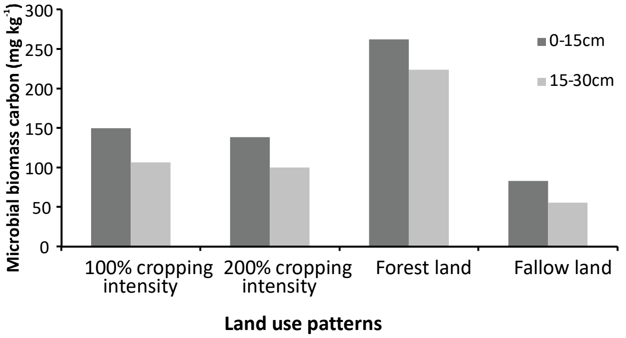

Fig. 1. Effect of land use pattern on soil microbial biomass carbon (mg kg^{-1} soil)

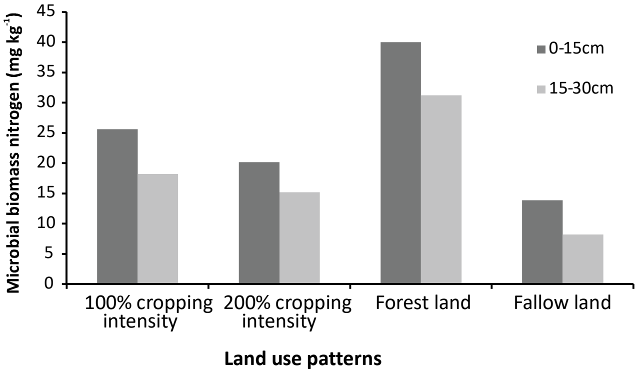

Fig. 2. Effect of land use pattern on soil microbial biomass nitrogen (mg kg^{-1} soil)

=0.990**). Significant positive correlations have also been recorded between MBN and organic carbon (r =0.993**), total nitrogen (r = 0.994**).

CONCLUSIONS

Land use pattern and soil depth significantly influenced soil physical, chemical properties, microbial biomass carbon and nitrogen. Organic matter or litter layer in forest land increased soil carbon thereby helping in the restoration of better soil health and fertility. Land use pattern and soil depth strongly influenced the top soil of all the study sites. Forest had the highest microbial biomass C and N, suggesting better C and N immobilization in the land use. Low SOC and MBC in fallow land confirmed that the lack of organic matter inputs and external factors like erosion, grazing by animals decreased soil fertility and in turn microbial activity in soil. The study suggests that MBC, MBN may be considered as a key indicator of soil fertility, while land uses are a major cause for loss of microbial biomass.

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