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Soil Microbial Status under Different Land-Use and Depth in the Humid Tropical Alfisol of Akure, Southwest, Nigeria.

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Abstract

Changes in land use are known to cause significant variations in soil microbial properties either by directly altering biological conversions in the rhizosphere or by disrupting organic matter (OM) transformations in the soil. The complete flow of soil nutrients might also be adversely affected. Thus, the present study was carried out in Akure, south west Nigeria, to ascertain the responses of selected soil microbial properties under five land-use systems, viz., Cultivated land (LUC), Grassland (LUG), Agro-plantation (LUA), Teak forest (LUT), Secondary forest (LUF) across five depths, viz., 0 – 5, 5 – 15, 15 – 30, 30 – 60, 60 – 100 cm. The experiment was laid out in a 5 x 5 factorial design in a randomized complete block design (RCBD) with three replications per treatment. Results revealed that, LUF gave the highest bacterial counts of 6.31 cfu×10^{-4} g^{-1} soil while, the least counts of 5.01 cfu×10^{-4} g^{-1} soil was found in LUC. The highest mean values of MBC (5.21 mg g^{-1}), MBN (4.62 mg g^{-1}), fungal (6.03 sfu×10^{-4} g^{-1} soil) and actinomycetes (6.03 cfu×10^{-4} g^{-1} soils) counts were observed in LUA while the least MBN (3.77 mg g^{-1}), fungal (3.47 sfu×10^{-4} g^{-1} soil) and actinomycetes (5.13 cfu×10^{-4} g^{-1} soils) counts were found in LUC. Our findings confirmed that, amongst the land-use types, forest soils have the most promising significant effect on microbial biomass and activities and which also appears to be prominent in the surface soil, and least in deeper soil depths. This result must have been due to the occurrence of a larger organic matter base (food source) in the form of leaf/litter fall in forest soils, compared with other land-uses.

Keywords: Land-use systems; microbial biomass; microbial count; soil respiration; alfisol

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1.0 Introduction

Land-use is categorized by the arrangements, activities and involvements, carried out by people in a particular land cover type to bring about modification or maintain it (Abad et al., 2014; Wani et al., 2018). It impacts the physicochemical and overall health of soil by directly influencing the stability and the biological conversions in the rhizosphere (Nisar and Lone, 2013). The conversion of forests into agricultural land had been previously documented to have negative impacts on the soil and consequently affects nutrients distribution and availability in the soil, especially carbon and nitrogen (Michel et al., 2010; Wani et al., 2018).

In recent years, the extents of land degradation resulting from incessant conversion of natural forests into low-input agricultural systems have been terrific (Awotoye et al., 2013; Wani et al., 2018). These changes in land use systems, viz., inappropriate conversion of forests to agricultural land uses, has amassed so much significance due to its potential involvement in soil quality decline and land degradation with consequent implications on environmental quality, ecosystem conservation, agronomic productivity, climate change, and ultimately food security (Kizilkaya and Dengiz, 2010). These changes often involve changes in soil physicochemical properties, vegetation cover, overall biomass production, microbial decomposition of organic residues and nutrient cycling (Landgraf et al., 2003). In Nigeria, agricultural land-use systems have been generally adopted without recognizing the consequences on soil conservation and environmental quality, and which has led to significant decline in agricultural soil quality (Imeson et al., 2006), especially in sub-Saharan Africa where the resilience ability of the soil is limited (Lal, 1995). However, the level of responses to such changes depends on the intensity of anthropogenic activity and the overall management practices across the soil depth.

The soil microbial biomass represents the fraction of the soil responsible for the energy and nutrient cycling and the

regulation of OM transformations (Fließbach et al., 2000), and as such represent a fundamental measurement at the ecosystem level (Visser et al., 1992). Systems with high available SOM tend to have higher microbial biomass contents because they are preferred energy sources for soil microbes (Landgraf et al., 2003). Undoubtedly, microbial populations in soil are prone to alterations arising from different land-use types and management. Studies on the effects of land-use change on the soil microbial status have mostly been limited to the other continents of the world (Kizilkaya and Dengiz, 2010; Wani et al., 2018; Sui et al., 2019), while studies addressing the sub-Saharan ecosystem have been limited or close to none. However, the continued capacity of the soil to function as a dynamic living system within ecosystem and land-use boundaries ought to be evaluated and maintained for a sustained biological productivity, and ultimately towards promoting plant, animal and human health (Laishram et al., 2012). This study was therefore, carried out to (i) evaluate the effects of each land-use systems and depth on soil microbial biomass C and N; (ii) determine the effects of these land uses on the population of soil microbes within each land-use ecosystem and at varying depths; and to (iii) assess the interaction effects of the land-uses and depths on soil biota in the humid tropical Alfisol of Southwest Nigeria.

2.0 Material and Method

2.1 Study site

The research was carried out in Federal University of Technology, Akure located on latitude 7° 30' N and longitude 5° 14' E with a bimodal rainfall pattern. Climate information of the study area indicates an equatorial rain forest belts with annual mean temperature of 25.3°C (Awopegba et al., 2017). Also, the mean annual precipitation in Akure is 1450 mm with the most rainfall occurring between May and September. Soil textural class was classified as Typic Oxic-Paleustalf (USDA Soil Taxonomy, year). Soil bulk density averaged 1.52 g cm^{-3} while pH (H_2O) ranged between 5.25 and 5.94.

2.2 Soil sampling and collection

Soil samples were collected under five different land-use systems namely; cultivated land (LUC), Grassland (LUG), Agro-plantation (LUA), Teak plantation (LUT), and Forest (LUF). LUC evolved from forest cover about 30 years back with continuous plowing, clearing, removal of aboveground biomass, and use of agrochemicals. Major crops found are mainly cereals (maize, sorghum, and rice), legumes (cowpea, groundnut), and sugarcane. LUG was formerly under forest cover over 20 years back, but has now evolved with continuous grass cover of different species such as *Heteropogon triticeus*, *Pennisetum purpureum*, *Cynodon dactylon*, and other short grass species. LUA (oil -palm) is covered with more than 70% canopy from matured *Elaeis guineensis* and less than 30% grass cover. The area is dominated with plant species such as *Chromolaena odorata, Cynodon dactylon, Lilium candidum, Pteridium aquilinum*, amongst others. LUT was covered with more than 65% canopy from growing *Tectona grandis*, while the forest floor was covered with thick layer of litter. LUF (secondary forest) land-use was predominantly covered with long and dense trees forming about 70-100% closed canopy and without apparent human impacts. There are several species of climbers, creepers, shrubs and trees with dense canopy. In each land use system, 3 profile pits were dug to a depth of 100 cm (making a total of 15 profile pits). Core sampler was used to take soil samples across the 5 depths (0-5 cm, 5-15 cm, 15-30 cm, 30-60 cm, and 60- 100 cm), kept in ice while on transit to the laboratory for microbial analysis.

2.3 laboratory Determinations

Microbial biomass carbon (Cmic) and microbial biomass nitrogen (Nmic) were determined following the procedures of Brookes et al. (1985) and Vance et al. (1987). The wet combustion method was adopted in the determination of microbial biomass carbon, while the Kjeldahl method was used to determine the available N in the extract (Brooks et al., 1985). Both Cmic and Nmic were estimated by the differences between fumigated and unfumigated samples and dividing with k-factors of 0.38 for Cmic (Vance et al., 1987) and 0.54 for Nmic (Brooks et al., 1985). Microbial enumerations (bacteria, fungi/mould and actinomycetes) of the soil samples were carried out using the standard plate count technique (Wollum, 1982). At the end of the incubation period, the total viable microbial counts were carried out and the mean results recorded per gram of each sample. Nematode extraction and count from soil sample was carried out using the decanting method of Oostenbrink (1960).

2.4 Data Analysis

All data collected were subjected to the analysis of variance (ANOVA) using the Minitab software statistical package and mean separation was done using Tukey's test at 5 % level of significance.

3.0 Results

3.1: Effects of land uses on selected soil microbial population in Akure, humid tropical alfisol of South west, Nigeria

Table 1 shows the populations of selected microorganisms captured within the different land uses, viz., LUA, LUF, LUT, LUG and LUC. Significant differences ($P<0.05$) existed among the selected microbial populations. Agro-plantation (Oil palm) recorded the highest significant populations of fungi (6.03 sfu×10^{-4} g^{-1} soil), actinomycetes (6.03 cfu×10^{-4} g^{-1} soil) and nematodes (11.48/100 g soil). The highest bacteria count was found in LUF (6.31 cfu×10^{-4} g^{-1} soil), with no significant difference from that of LUT (6.17 cfu×10^{-4} g^{-1} soil). In all, LUC recorded the least microbial population of fungi (3.47 sfu×10^{-4} g^{-1} soil), actinomycetes (5.13 cfu×10^{-4} g^{-1} soil), bacteria (5.01 cfu×10^{-4} g^{-1} soil) and nematodes (2.95/100 g soil) and which were significantly different ($P<0.05$) from those of other land-uses.

Table 1: Effects of land-uses on selected soil microbial population in Akure, humid tropical alfisol of South west Nigeria

Land Use	FUNGI (sfu×10^{-4} g^{-1} soil)	ACTINOMYCETES (cfu×10^{-4} g^{-1} soil)	BACTERIA (cfu×10^{-4} g^{-1} soil)	NEMATODES/100g soil
LUA	6.03 a	6.03 a	5.62 b	11.48 a
LUF	5.62 ab	5.62 ab	6.31 a	9.55 ab
LUT	5.23 bc	5.46 bc	6.17 a	6.76 b
LUG	4.68 c	5.01 c	5.49 b	7.08 b
LUC	3.47 d	5.13 c	5.01 c	2.95 c

Means with the same letters are not significantly different at $P<0.05$, while means that do not share a letter are significantly different.

3.2: Effects of varying depths on selected soil microbial population in Akure, humid tropical alfisol of south west Nigeria

Table 2 shows the effects of varying depths on selected soil microbiota. Also, significant differences ($P<0.05$) were recorded among the microbial populations of fungi, actinomycetes, bacteria and nematodes at the various levels of depth. Depth 0-5 cm had the highest populations of fungi (5.89 sfu$\times10^{-4}$ g^{-1} soil), actinomycetes (6.91 cfu$\times10^{-4}$ g^{-1} soil) and bacteria (6.30 cfu$\times10^{-4}$ g^{-1} soil) while depth 60-100 cm recorded the least populations of fungi (3.98 sfu$\times10^{-4}$ g^{-1} soil), actinomycetes (4.37 cfu$\times10^{-4}$ g^{-1} soil), bacteria (5.01 cfu$\times10^{-4}$ g^{-1} soil) and nematodes (3.47/100 g soil). Generally, the populations of microorganisms decreased down the soil profile depth i. e, microbial populations decrease as the depth increases. Only 5-15 c m depth recorded the highest nematode count of 9.55/100 g soil.

3.3: Interaction effects of land-uses and varying depths on selected soil microbial population in Akure, humid tropical alfisol of south west, Nigeria

Table 3 shows the interaction effects of land use and depths on the selected soil microbial populations in the study area. There were significant differences ($P<0.05$) among the treatment interaction means. In all, 0-5 cm depth recorded the highest significant population of microorganisms while 60-100 cm depth recorded the least microbial population. Also, LUA had the most abundant fungi, actinomycetes and nematodes. This was followed by LUF and LUT. Cultivated land (LUC) recorded the least significant population of total microorganisms.

Table 2: Effects of varying depths on selected soil microbial population in Akure, humid tropical alfisol of south west Nigeria

Depth (cm)	FUNGI (sfu$\times10^{-4}$ g^{-1} soil)	ACTINOMYCETES (cfu$\times10^{-4}$ g^{-1} soil)	BACTERIA (cfu$\times10^{-4}$ g^{-1} soil)	NEMATODES/100g soil
0-5	5.89 a	6.91 a	6.30 a	8.51 ab
5-15	5.49 ab	5.89 b	6.03 ab	9.55 a
15-30	4.79 bc	5.49 b	5.62 bc	6.17 b
30-60	4.79 c	4.89 c	5.49 cd	8.71 ab
60-100	3.98 d	4.37 d	5.01 d	3.47 c

Means with the same letters in each column are not significantly different at $P<0.05$, while means that do not share a letter are significantly different.

Table 3: Interaction effects of land-uses and varying depths on selected soil microbial population in Akure, humid tropical alfisol of south west Nigeria

Land Use	Depth (cm)	FUNGI (sfu$\times10^{-4}$ g^{-1} soil)	ACTINOMYCETES (cfu$\times10^{-4}$ g^{-1} soil)	BACTERIA (cfu$\times10^{-4}$ g^{-1} soil)	NEMATODES/100g soil
LUA	0-5	7.41 a	6.91 ab	6.76 a	11.74 ab
	5-15	5.89 abcde	6.46 ab	6.31 abc	11.75 ab
	15-30	5.75 abcde	6.03 abc	5.62 abcdef	11.22 ab
	30-60	5.25 abcdef	5.49 bc	5.13 bcdef	11.22 ab
	60-100	5.89 abcde	5.49 bc	4.47 fg	10.96 ab
LUF	0-5	6.31 abcd	7.76 a	6.76 a	25.70 a
	5-15	6.76 abc	6.17 abc	6.03 abcde	1.26 ab
	15-30	5.89 abcde	6.17 abc	5.62 abcdef	9.12 abc
	30-60	5.25 abcdef	5.62 bc	6.17 abcd	7.24 bcd
	60-100	4.47 defghi	3.39 e	6.61 ab	4.57 bcd
LUT	0-5	6.91 ab	7.59 a	6.76 a	10.71 ab
	5-15	7.08 ab	6.03 abc	6.17 abcd	9.12 abc
	15-30	4.79 cdefgh	5.75 bc	6.03 abcde	7.41 bcd
	30-60	5.01 bcdefg	4.89 cd	6.17 abcd	6.17 bcd
	60-100	3.47 hij	3.89 de	6.03 abcde	3.31 cde
LUG	0-5	5.13 bcdefg	6.03 abc	7.24 a	9.77 abc
	5-15	4.89 bcdefg	4.79 cd	6.17 abcde	8.13 abc
	15-30	5.23 abcdef	4.79 cd	4.89 cdef	8.71 abc
	30-60	4.47 defgh	6.30 de	4.89 def	9.77 abc
	60-100	3.98 fghij	6.03 abc	4.89 cdef	2.51 de
LUC	0-5	4.27 efghi	6.03 abc	4.68 efg	1.48 e
	5-15	3.55 ghij	6.17 abc	5.75 abcdef	9.33 abc
	15-30	3.09 ij	4.89 cd	5.89 abcde	1.35 e
	30-60	3.80 fghij	4.89 cd	5.01 cdef	10.71 ab
	60-100	2.82 j	3.89 de	3.72 g	1.17 e

Means with the same letters in each column are not significantly different at $P<0.05$, while means that do not share a letter are significantly different.

3.4: Effects of land-uses on microbial biomass nitrogen (MBN) and microbial biomass carbon (MBC).

Figure 1 shows the effects of land use on microbial biomass nitrogen (MBN) and microbial biomass carbon (MBC). There were significant differences ($p \leq 0.05$) in the amounts of MBN recorded in the five land-uses under study. Secondary forest (LUF), LUA and LUT recorded MBN values of 4.75 mg g^{-1}, 4.62 mg g^{-1} and 4.57 mg g^{-1}, respectively. These values, although not significantly different from each other, were different significantly from those of LUG and LUC with MBN values of 4.01 mg g^{-1} and 3.77 mg g^{-1}, respectively. Additionally, significant values of MBC were recorded among the various land uses following this trend LUA>LUT>LUF>LUC>LUG.

3.5: Effects of depths on microbial biomass nitrogen (MBN) and microbial biomass carbon (MBC)

Figure 2 represents the effects of varying depths (0-100 cm) on microbial biomass nitrogen (MBN) and microbial biomass carbon (MBC). Significant differences ($p \leq 0.05$) existed among the recorded MBN values across the various levels of depths. The values of MBN decreased with increasing depth. Depth 0-5 cm had the highest significant MBN value of 5.91 mg g^{-1} while 60-100 cm recorded the least significant MBN value of 3.03 mg g^{-1}. The same trend was noticeable for MBC in that the values decrease as the depth increases. While 0-5 cm depth recorded the highest and significant value of 5.85 mg g^{-1} for MBC, 60-100 cm depth gave the least significant value of 3.36 mg g^{-1}.

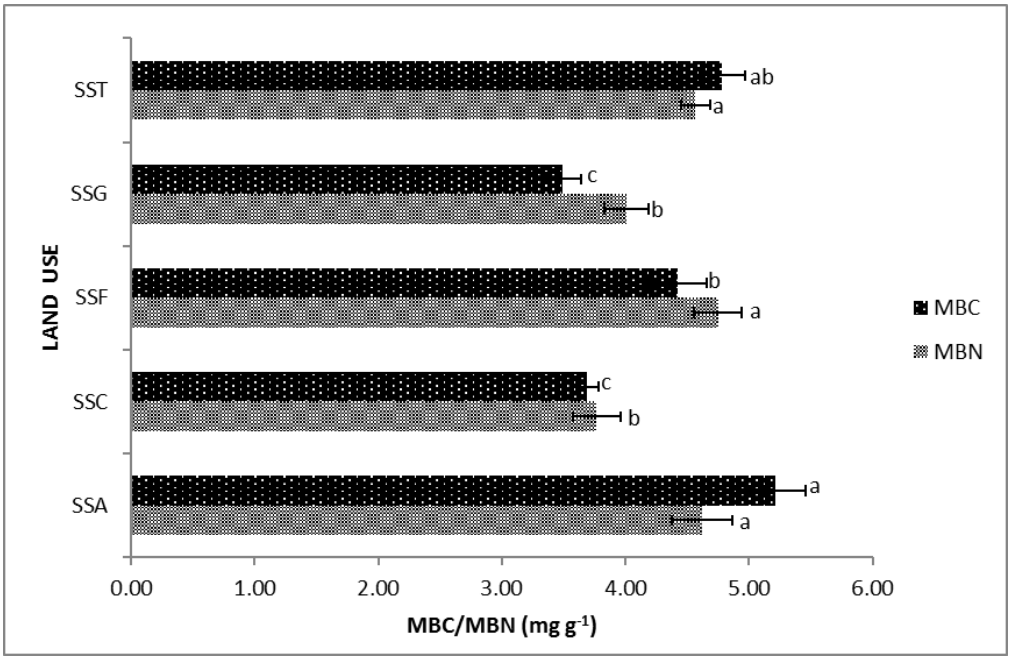

Figure 1: Effects of land uses on microbial biomass nitrogen (MBN) and microbial biomass carbon (MBC). Means with the same letters are not significantly different at P<0.05, while means that do not share a letter are significantly different.

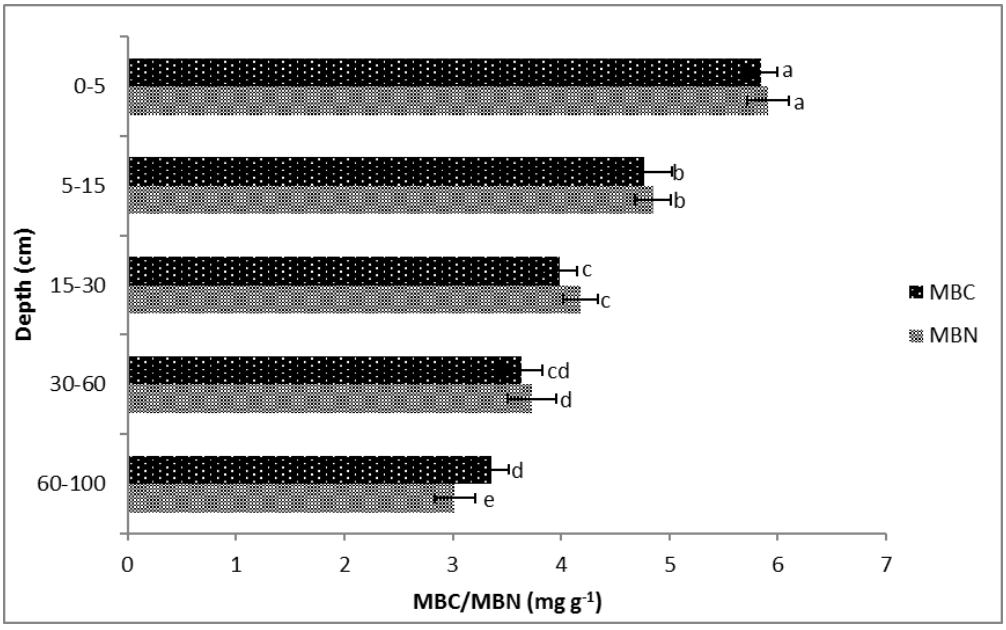

Figure 2: Effects of depths on microbial biomass nitrogen (MBN) and microbial biomass carbon (MBC). Means with the same letters are not significantly different at P<0.05, while means that do not share a letter are significantly different.

3.6: Interactive effects of land-uses and depths on microbial biomass carbon (MBC)

Figure 3 illustrates the interactive effects of the different land uses and varying depths on microbial biomass carbon (MBC). Significant differences (P<0.05) were recorded for the MBC values (in mg/g) obtained among the treatment interaction means. The obtained values decreased down the soil profile, with LUT (0-5 cm) recording the highest significant value of 7.67 mg g^{-1}, while LUT (60-100 cm) recorded the least value of 2.57 mg g^{-1}. Additionally, the highest and significant MBC value ($p \leq 0.05$) was observed in LUA with 0-5 cm depth (mg g^{-1}) while grassland with 60-100 cm depth recorded the least significant value of mg g^{-1}.

3.7: Interactive effects of land-uses and depths on microbial biomass nitrogen (MBN)

Figure 4 explains the interaction effects of varying depths and land-uses under study on the amounts (mg g^{-1}) of MBN. Significant values of MBN were recorded among the treatment interaction means. Teak forest (LUT) with 0-5 cm depth recorded the highest significant value of 6.53 mg g^{-1} while the least significant ($p \leq 0.05$) value (2.53 mg g^{-1}) was observed in LUT with 60-100 cm depth.

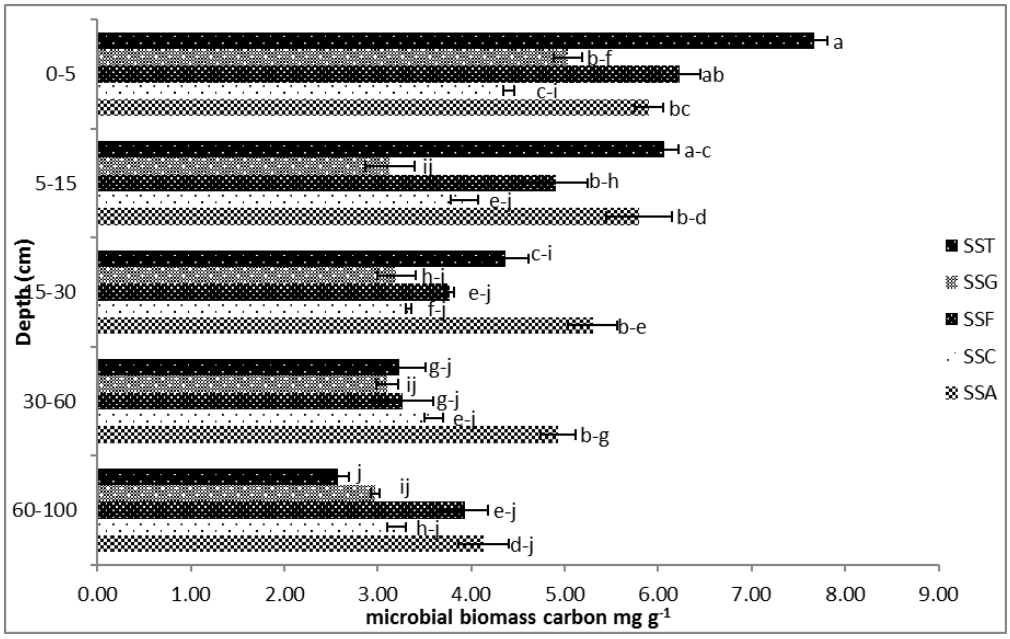

Figure 3: Interactive effects of land-uses and depths on microbial biomass carbon (MBC). Means with the same letters are not significantly different at P<0.05, while means that do not share a letter are significantly different.

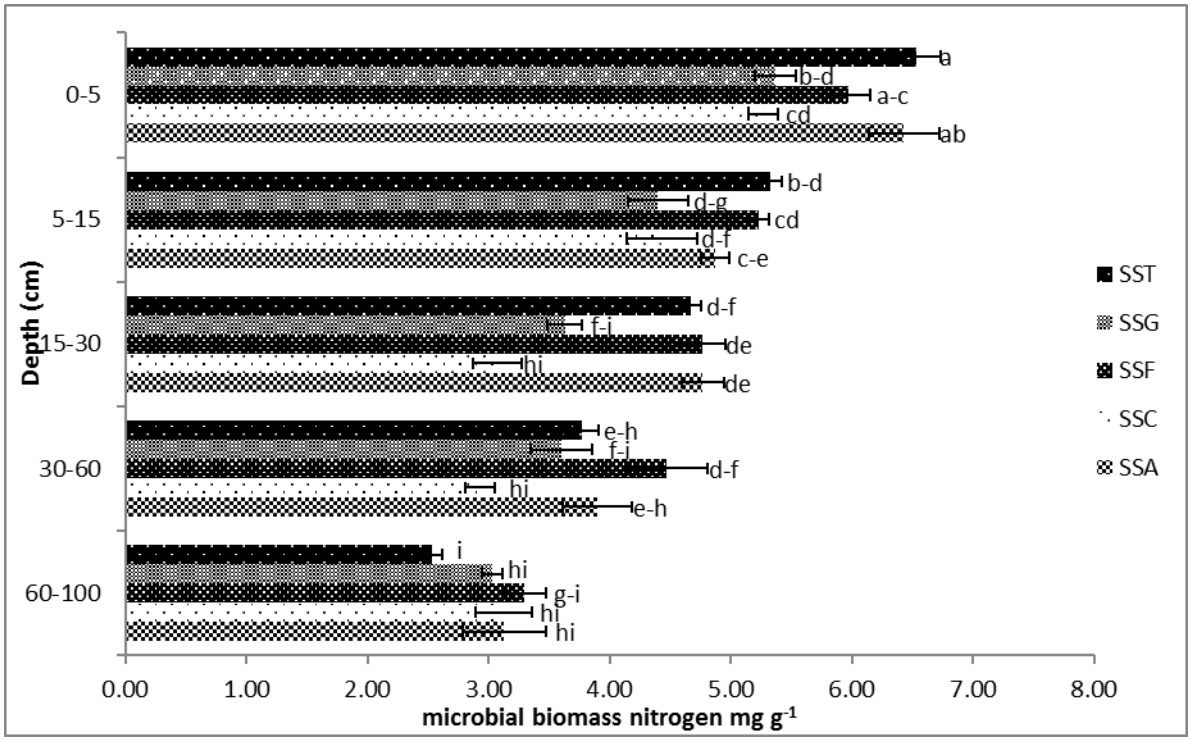

Figure 4: Interactive effects of land-uses and depths on microbial biomass nitrogen (MBN). Means with the same letters are not significantly different at P<0.05, while means that do not share a letter are significantly different.

4.0 Discussion

Microbial populations in soil are prone to alterations arising from different land-use types and management. From this study, a general increase in the overall microbial (bacteria, fungi, actinomycetes and nematodes) populations was recorded in the forest land-use systems, while a significantly lesser microbial counts was observed with the cultivated and grass lands (Table 1). This was probably due to the presence of larger carbon source in the form of OM present in the forest land-use systems, which must have functioned as a food source for improved microbial metabolism while fostering increased microbial growth and activities. A contradictory result was however, reported by Bello et al. (2013), who stated a consistently higher microbial population in cultivated and grassland soils compared with other land-use systems in his study on the effects of land-use on the nature and population of microorganisms in north-eastern Nigeria. The mean fungal counts of forest soils (LUA>LUF>LUT) were generally much higher than those of LUG and LUC (Table 1). This fungal population increase might be due to the capacity of fungi to proliferate rapidly across a wider pH range. This finding was equally reported by Bello et al. (2013) and Okonkwo (2010), who both attributed fungal abundance to their ability to proliferate in acidic soils with a wide selection preference at varying soil depths. Also, it is likely that the presence of canopy-forming trees in these forest land-use systems may have fortified the existence of ectomycorrhizal fungi which colonize a host of tree species hence, higher fungal counts. On the other hand, alterations in soil physical attributes as a result of tillage operations common in cultivated land may have likewise contributed to the reduced fungi counts in the LUC. This is because fungi are easily affected by alterations in soil and environmental conditions (Sui et al., 2019), and most importantly, the fungal hyphae growth is usually affected significantly by frequent tillage practices. Additionally, the occurrence of abundant trees in the forest land-use systems (LUA>LUF>LUT) might have possibly reduced rainfall impact thus, reducing the chances of soil erosion and favoring microbial growth and activity in the forest soils (Asadu et al., 2015; Wani et al., 2018). This assertion in turn must have also been responsible for the general abundance of the total microbial population on the surface soil (0-15 cm) (Table 2) and least at the depth of 60-100 cm. Moreover, the more activity of microorganisms in LUA, LUF and LUT are also due to the presence of more plant roots, creating a rhizosphere environment which helps to balance and stabilize soil nutrients availability, while the least microbial population found in LUC was due to lower OM additions to the soil in form of crop/residue removal, use of fertilizers, increased and inappropriate tillage practices. Also, the absence of leaf litters and dense canopy covers might have exposed the soil to erosion and contributed to the significantly low levels of microbial population, biomass and activity in LUC and LUG (Bello et al., 2013). The reduced microbial population in LUC further stressed the findings of Okonkwo (2010) who also reported that continuous cultivation led to a decrease in the population of bacteria, actinomycetes and algae.

Additionally, forest soils have the most significant effect on microbial biomass among the land uses (Fig. 1) as well as a significant microbial activity was prominent in the surface soil 0-15 cm (Fig. 2). This possibility is not far-fetched as microbes make use of energy derived during the decomposition and mineralization processes of litter falls (which is most prevalent at the surface soil of forests) for their metabolic activity. Results of previous research studies have showed a close correlation between the soil microbial biomass and total microbial count and activity. For example, Landgraf and Klose (2002) found that easily degradable carbon source, could make the soil microbes propagate and increase their activity rapidly, suggesting that the MBC&N contents are significantly limited or enhanced by a decrease or increase in microbial population and activity, respectively.

5.0 Conclusion

The land use under agro-plantation (oil palm) (LUA) had higher values for fungi, actinomycetes, and nematodes counts than all the other land-uses considered, whereas cultivated land-use (LUC) recorded the least values. The total microbial population, biomass and activity was decreasing in these land-uses following the trend LUA>LUF>LUT>LUG>LUC, thus indicating that greater attention must be given to the maintenance of our forest lands, especially in the wake of global climate changes. This study reveals the importance of preserving the microbial biota inherent within the forest land-use systems through afforestation, regulation on land reclamation and adoption of sustainable agricultural practices. Therefore, the adoption of agroforestry systems where the planting and maintenance of well-adapted and fast growing tree species can be managed alongside the cultivation of crops is highly recommended.

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