SOIL SCIENCE SOCIETY OF NIGERIA

PROCEEDINGS OF THE 38TH ANNUAL CONFERENCE

NIGERIAN AGRICULTURAL TRANSFORMATION AGENDA

SOIL AS A KEY TO NATIONAL DEVELOPMENT

DATE: March 10 - 14, 2014

HOST: Department of Soil Science and Land Resources Management, University of Uyo, Uyo, Nigeria

EDITED BY:

PROF. S. O. OJENIYI
DR. J. C. OBI
PROF. T. O. IBIA
DR. P. I. OGBAN
MISS A. A. ONWUKWE

TABLE OF CONTENTS

DYNAMICS OF SOIL MICROBIAL BIOMASS UNDER DIFFERENT LAND USES IN SOUTHERN GUINEA SAVANNA ZONE OF NIGERIA

Tanko, F., Uzoma, A.O. and Bala, A.

Upper Niger River Basin Development Authority, KM 5 Minna Zungeru Road. PMB 68, Minna Niger State.Department of Soil Science, School of Agriculture and Agricultural Technology Minna. Federal University of Technology Minna, PMB 65, Minna Niger State.Email: Tyma2k4@yahoo.com

ABSTRACT

Management practices and vegetation exert a profound influence on microbial biomass carbon and nitrogen. This study was carried out to estimate microbial biomass carbon and nitrogen at three soil depths (0-5cm, 5-10cm and 10-15cm) and in relation to physico-chemical properties of the soils under four land uses (Teak, gmelina , cashew and fallow soil) in Minna, Niger State. The experiment was a 4 x 3 factorial in Randomized Complete Block Design (RCBD). Soils under Teak had the highest microbial biomass carbon (1347.3 mg kg^{-1}) followed by soils under gmelina (1281.1 mg kg^{-1}), fallow (1032 mg kg^{-1},) and cashew (678.2 mg kg^{-1}) in that order. On the other hand, soils under gmelina (13.569 mg N kg^{-1}) and cashew (9.647 mg N kg^{-1}) had the highest microbial biomass nitrogen, followed by those of fallow (8.9873 mg N kg^{-1}) and teak (6.778 mg N kg^{-1}). Both microbial biomass C and N were significantly affected by soil depth with the 0-5cm depth having the largest amount. This study showed that land use has a significant effect on microbial biomass C and N in soil by altering natural soil characteristics.

INTRODUCTION

The soil microbial biomass is fundamental to maintaining soil function because it represents the main source of soil enzymes that regulate transformation processes in soils (Bohme, 2006). Soil microbial biomass has been suggested as possible indicator of soil environmental quality and is employed in national and international monitoring programmes/space (Spedding *et al.*, 2004). Microbial biomass is an active component of soil ecosystem and is primarily composed of bacterial and fungal mycelia and spores. This component is usually influenced by seasonal moisture and temperature fluctuations in addition to organic matter and tillage management.Soil microbial biomass helps in transformation of all organic materials that enter the soil and act as a dynamic pool containing appreciable reserves of carbon, nitrogen, phosphorus, and sulphur (Jenkinson and Ladd, 1981). It is also frequently used as an early indicator of changes in soil chemical and physical properties resulting from soil management and environmental stresses in agricultural ecosystems (Brookes, 1995; Jordan *et al.*, 1995; Trasa-cepeda *et al.*, 1998). Although the soil microbial biomass constitutes only 1-3% of total soil carbon and the microbial biomass N up to 5% of the total soil N, they are the most labile C and N pools in the soil. Therefore, nutrient availability and productivity of agro-ecosystems mainly depends on the size and the activities of microbial biomass.

Increasing concern for enhancing long term sustainable productivity for crops and cropping system has emphasized the need to develop suitable management strategies which are able to improve the quality and health of the soil (Liu *et al.*, 2001). Long-term influences of cropping practices affect the turn-over and quality of organic matter availability to microbial organism in soil, thus significantly influencing the amount and quality of microbial biomass (Bauhus *et al.*, 1989; Liu *et al.*, 2001). Agroforestry, which is the cultivation of food and tree crops on the piece of land, is gaining increasing popularity in the Guinea Savanna of Nigeria. The nature of the tree crop growing in an area will largely affect the type and amount of carbon input in the soil as well as the extent to which the micro environment is modified. This will in turn affect the productivity of the soil land performance of the component

crop. Microbial biomass is often cited as a suitable indicator of soil health because of its sensitivity to soil management practices (Bauhus *et al.*, 1989; Liu *et al.*, 2001). The aim of this study therefore is to determine soil microbial biomass carbon and nitrogen in soils planted with different Agroforestry tree species (gmelina, cashew, teak and fallow soil) in the Southern Guinea Savanna zone of Nigeria.

MATERIALS AND METHODS

Study area and location

Soil samples were collected in July 2009 from the farm of School of Agriculture and Agricultural Technology Federal University of Technology Minna permanent site situated at kilometer sixteen (16 km) along Minna-Bida road. Minna lies within the Southern Guinea Savanna zone of Nigeria, (9^0 41 N and Longitude 6^0 30 E) and has sub-humid tropical climate with a mean annual rainfall of 1200 mm of which 90% of falls in June to August. The temperature rarely falls below 22°C with a peak at 40°C in February to March and 36°C in November to December. (Juo, 1998).

Soil description and vegetation

Soils of Minna are derived from Basement Complex material. They range from shallow to very deep soils over-lying deeply weathered gneisses and magmatites. Some are underlain by iron pan to varying depth. They are strong brown to red sandy clay or clay with often gravely loamy sand or sandy surface layer (FDALRI, 1990).

The cropping pattern of the area is that of Agroforestry consisting of crops cultivated with Teak (*Tectona grandis*), gmelina (*Gmelina aborea*), and Cashew (*Anacadium occidentalis*). In between the forest tree are grasses, shrubs, grass clippings crop residue and organic wastes. The fallow land had some yam heaps.

Soil sampling and experimental design

The experiment was a 4 x 3 factorial in Randomised Complete Block Design (RCBD), with four land uses (Teak, gmelina, Cashew and fallow land) at three soil depths (0-5 cm, 5-10 cm, 10-15 cm). Soil samples were collected on 16th June, 2009 to, from 20 different points each using a sterilized Auger. The soil samples were bulked into composites for laboratory analysis. The soil samples were taken into the laboratory and sieved through (2 mm sieve) for microbial studies and (2 mm and 0.5 mm) sieve for physico-chemical studies. Each soil samples at different depth were divided into four one of which was each stored in the refrigerator at 4° C for microbial analysis and the rest of the air dried for physico-chemical analysis.

Determination of Physico-chemical Properties of soil

Physical and chemical properties were carried out by standard methods. Soil particle size distribution was determined by the hydrometer method (Bouyoucos, 1962). pH was measured using pH-meter in both water and 0.01M $CaCl_2$ solution (soil solution ratio 1:2:5) (Rowell, 1994) and total nitrogen by the Kjeldahl method (Bremner and Mulvaney, 1982). Organic carbon in the soil was analyzed by dichromate oxidation and titration with ferrous ammonium sulphate (Walkley, 1947) while phosphorus was determined using Bray-1 method. Exchangeable bases were extracted using 1N Ammonium acetate (pH=7.0). Sodium and potassium in the extract were measured using flame photometer (Systronic-modiflame 127), while calcium and magnesium were determined using atomic absorption spectrophotometer (Perkin Elmer 373 AAS).

Extraction of microbial biomass

Soil microbial biomass was estimated by extracting 10g of moist soil sample in 2 M KCl process known as chloroform fumigation extraction method described by Brookes *et al,* (1982) and Vance *et al.,* (1987a).Triplicate sub-samples from each soil type at different depth were placed in 50 ml glass beakers. Samples designated for fumigation were placed in incubator. Ethanol free $CHCl_2$ was placed in a 50ml beaker in the centre of the incubator. Beakers containing distilled water were also placed in the incubator to help maintain the water content of the soil during fumigation. Samples were fumigated for 5 days at 25 °C after which the soil samples were removed and transferred into 250 mls bottle to which 50 mls of 2 M KCl was then added. At the same time un-fumigated samples were placed in the bottles and were treated in the same way where they serve as controls. Bottles were shaken for 30 minutes on a

mechanical shaker and were filtered through a whatsman number 42 filter paper. Filterates were kept in the refrigerator at 4°C.

Determination of microbial biomass carbon (Cmic)

Microbial biomass carbon was measured in 4 mls aliquots of 2 M KCl extract after oxidation with 1ml $K_2Cr_2O_7$, 5mls of conc. H_2SO4 and 2 and 3 drops of indicator (Barium diphenylamine) and back titration with ferrous sulphate to get a green colour end point. Microbial biomass carbon was calculated by measuring the difference in extractable organic carbon between the fumigated and un-fumigated soils.

Determination of microbial biomass nitrogen (Nmic)

Microbial biomass N was determined by distillating 10 mls of the 2 M KCL extract to which 0.2 g MgO was added .The distillate was collected in a boric acid mixed indicator solution and titrated with 0.005M H_2SO_4 to a pink end point Ammonium- nitrate was then calculated (Anderson and Ingram, 1993). To determine NO_3 Nitrogen, 0.2g of devarda alloy was placed in the distillation inlet in place of MgO.

Analysis of microbial biomass

Microbial biomass carbon was calculated

Microbial biomass carbon = 2.64 x Ec (Vance *et al.*, 1987a).

Where Ec refers to the difference in extractable organic carbon between the fumigated and unfumigated treatment, 2.64 is the proportionality factor for biomass carbon released by fumigation extraction.

Microbial biomass N = (Extracted N_{ti} - Extracted N_{to} X 1.46) (Brooks *et al.*, 1985). Where extracted N_{ti} is the fumigated value, extracted N_{to} is the unfumigated value, and 1.46 is the proportionality factor for biomass nitrogen.

Statistical analysis

Statistical Analysis was carried out using SAS window version 8.1 (SAS Institute, 2000). Analysis of variance (ANOVA) was used to determine treatment effect at 5% level of significance, Duncan multiple test was used to separate significantly different ($P<0.05$) means.

RESULTS

Physico-chemical properties of the soil and their relationship with different land use system

The result of the physical properties of the soil at various depths and under different land uses are shown in Table 1, Soil texture did not differ with depth in any of the land uses. They all had soils that were classified as sandy loam. Soil moisture appears to increase with depth in Teak and Cashew soils while decreasing with depth in fallow and remaining unchanged in gmelina. The result in Table 2 indicates that pH for all the land use type were slightly acidic, with increase in depth, organic carbon content remain unchanged under teak, declined under gmelina and cashew and increased in fallow soil. Nitrogen content did not change with depth under teak and cashew but declined in gmelina and fallow soil. Phosphorus content did not change with depth in cashew and fallow soils but increase in gmelina and declined in teak. With increase in depth the value of potassium increase in teak and gmelina but decreases in cashew and remain unchanged in fallow. Calcium decreases with depth in teak, gmelina, and fallow but remain unchanged in cashew. The value of sodium decreases with depth in the three land uses except in cashew which increase with depth. Magnesium content declined with depth in teak, gmelina, cashew, and remain unchanged in fallow. Soil acidity increases with depth for the three land uses but in teak the value of acidity remain unchanged.

Table 1: Soil physical properties of different land uses in the study area

Variables/ Depth (cm)	Sand ← g Kg^{-1} →	Silt	clay	Moisture content (%)
0-5cm				
Teak	700^{ab}	200^{ab}	100^{cd}	4.02^{b}
gmelina	700^{ab}	210^{a}	90^{d}	2.92^{cd}
Cashew	710^{ab}	170^{abc}	120^{abc}	3.20^{c}
Fallow	700^{a}	200^{ab}	100^{bcd}	3.20^{c}
5-10cm				
Teak	720^{a}	170^{abc}	110^{c}	3.09^{c}
gmelina	680^{b}	200^{abc}	120^{abc}	2.88^{cd}
Cashew	700^{ab}	170^{bc}	130^{ab}	3.95^{b}
Fallow	720^{a}	170^{bc}	110^{bcd}	1.25^{g}
10-15cm				
Teak	680^{b}	180^{a}	140^{a}	4.49^{a}
gmelina	710^{ab}	$170^{bc\ b}$	120^{abc}	2.64^{de}
Cashew	720^{a}	140^{c}	140^{a}	4.46^{a}
Fallow	700^{ab}	170^{abc}	130^{abc}	1.79^{f}

Soil microbial biomass carbon and nitrogen under different land use system

The interaction between land use and depth was significantly affected by soil microbial biomass carbon (Fig. 1). Soils under gmelina at 0-5cm and under teak at 5-10 cm had the highest amount of microbial biomass carbon (Cmic). The Cmic content at 10-15 cm under teak was similar as that at 5-10 cm under gmelina. The smallest amount of Cmic was observed under cashew especially at 10-15 cm depth. The interaction of land use and depth also significantly affected microbial biomass N (Nmic) (Fig. 2).The Nmic content under gmelina at 0-5 cm was not different from that at 5-10 cm.These were also similar to the Nmic under cashew at 0-5 cm.The Nmic at 0-5 cm under fallow and Teak were similar but significantly lower than those of gmelina and cashew with the same depth. The smallest amount of Nmic was observed under teak at 10-15 cm depth.

DISCUSSION AND CONCLUSION

It is generally accepted that organic carbon readily increase with greater fallow time (Landgraf *et al.*, 2002) but there can be different result for total nitrogen during succession of fallow. In this study, it was found that there was an increase in total Nitrogen as a result of fallow, these was in agreement with the observation by Havinet *et al.*, (1990) that organic carbon and total nitrogen content increased after agricultural land had been set aside especially under semi-natural condition. The pH of the soil under Teak, gmelina, Cashew, and Fallow land ranged between slightly acidic to near neutral (pH 4.73 - 6.85) respectively. Soil pH is one of the mitigating factors that can suppress the growth and activities of native micro flora especially those with low pH ratio smith and Paul,

Table 2: Soil chemical properties of different land uses in the study area

Variables / Depth (cm)	pH H_2O	pH $CaCl_2$	OC (g kg^{-1})	N (g kg^{-1})	P (mg kg^{-1})	Na	Ca	Mg	K	Acidity
0-5cm					Cmol kg^{-1}					
Teak	6.50^{a}	5.93^{c}	13.80^{bc}	3.20^{ab}	37.33^{a}	0.51^{c}	7.47^{a}	16.0^{b}	0.89^{c}	6.40^{c}
gmelina	6.21^{c}	5.94^{c}	15.40^{ab}	3.00^{ab}	19.50^{e}	0.87^{a}	4.87^{d}	17.0^{ab}	0.48^{de}	3.33^{f}
Cashew	6.34^{bc}	4.73^{i}	13.60^{bc}	3.30^{ab}	31.50^{abc}	0.27^{ef}	7.40^{ab}	14.47^{bc}	0.48^{de}	10.00^{a}
Fallow	6.44^{a}	6.44^{a}	14.40^{bc}	3.50^{a}	26.13^{cde}	0.41^{d}	5.27^{c}	8.81^{e}	0.38^{ef}	8.00^{b}
5-10cm										
Teak	6.43^{a}	6.03^{d}	12.50^{c}	2.80^{ab}	22.53^{de}	0.31^{e}	5.20^{d}	13.90^{c}	3.32^{a}	5.67^{cde}
gmelina	6.85^{a}	5.85^{f}	12.60^{c}	2.60^{ab}	32.67^{abc}	0.19^{f}	2.80^{e}	19.6^{a}	1.96^{b}	6.00^{cd}
Cashew	5.79^{e}	5.44^{g}	13.60^{bc}	2.60^{ab}	23.83^{cde}	0.30^{e}	7.60^{a}	9.20^{de}	0.33^{f}	4.50^{ef}
Fallow	6.23^{c}	6.22^{b}	17.00^{a}	2.50^{c}	32.67^{abc}	0.35^{de}	4.67^{dc}	9.86^{de}	0.48^{de}	9.00^{ab}
10-15cm										
Teak	6.02^{d}	6.10^{c}	13.80^{bc}	3.10^{ab}	36.17^{a}	0.63^{b}	6.60^{b}	15.60^{bc}	0.55^{d}	4.67^{def}
gmelina	6.73^{a}	6.07^{cd}	12.90^{c}	1.70^{c}	28.37^{abcd}	0.39^{d}	1.27^{f}	12.73^{cd}	0.83^{c}	9.33^{ab}
Cashew	5.61^{f}	5.42^{g}	9.40^{d}	2.50^{ab}	33.83^{ab}	0.49^{cd}	6.87^{ab}	15.33^{bc}	0.28^{f}	6.00^{cd}
Fallow	6.70^{a}	5.26^{h}	16.50^{a}	2.60^{ab}	31.92^{abc}	0.54^{c}	2.80^{e}	10.53^{d}	0.35^{ef}	5.33^{cde}

OC= Organic Carbon, K = potassium, Na= sodium, Mg = Magnesium N =Nitrogen

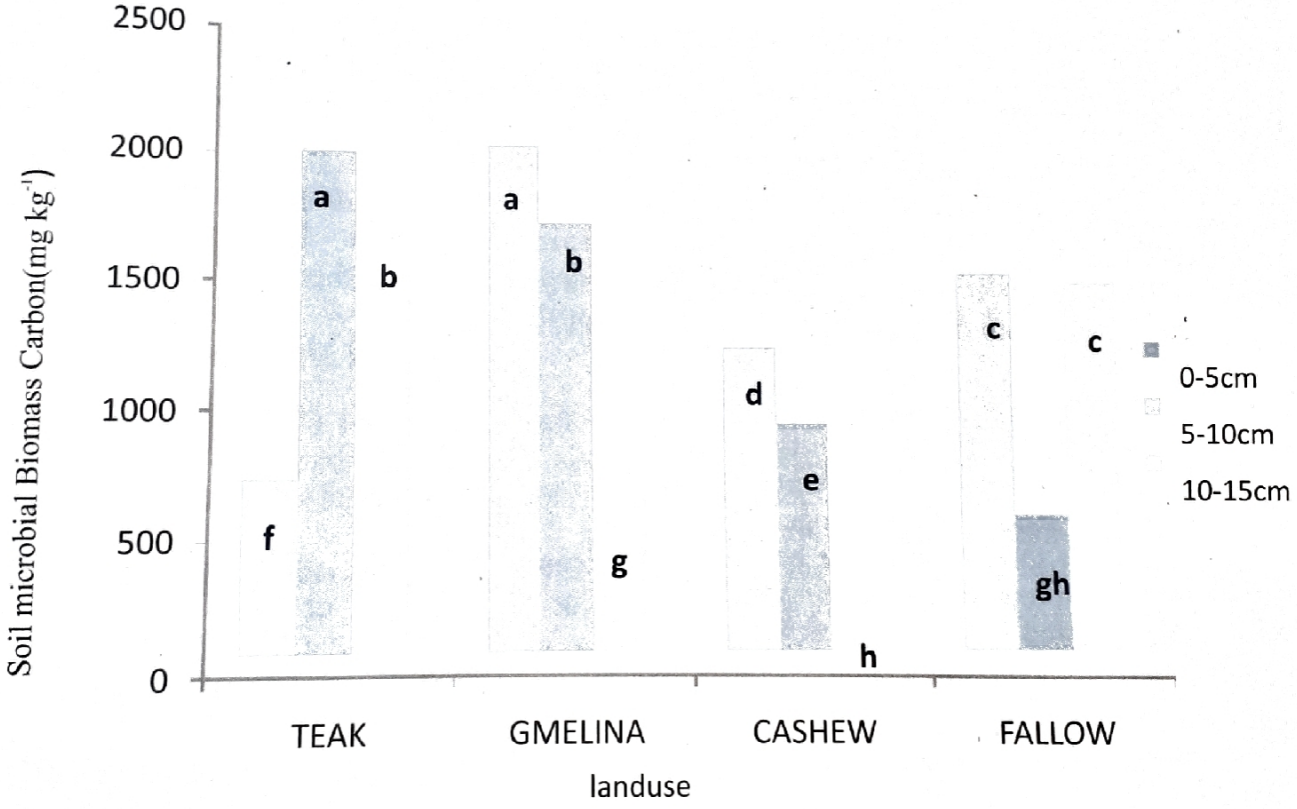

Fig: 1 Microbial Biomass Carbon (MBC) Accumulation (mg kg $^{-1}$) as affected **by Land use at different depths.**

(1990) .fallow had highest organic carbon. This is in consistent with the findings of Landgraf, (2002) that Fallow can increase organic carbon and recover soil fertility by increasing microbial biomass carbon. Soil microbial biomass C values of 150-1960 mg kg^{-1} obtained in this study compares well with a range of 60-2070 mg kg^{-1} reported from other studies (Vance *et al.*, 1987b; Hernot and Robertson, 1994). Generally, teak and gmelina had the highest Cmic, most likely because of better improvement in constraining factors (Smith and Paul, 1990).Suggesting nutrient under teak and gmelina may be more limiting. The soil Nmic of 6-13 mg kg^{-1}observed in the present study is consistent with the range of 10-68 mg kg^{-1} reported previously for tropical

soils (Smith and Paul, 1992).the relative greater Nmic in soils under gmelina and cashew than in teak and fallow suggests a tendency towards relatively lower C;N ratio in the former than in the latter. Given that a high Cmic/Nmic ratio indicates fungal dominance of a microbial community, while a low ratio suggest the prevalence of bacteria (Jenkinson, 197 Anderson and Domsch, 1980), it would b expected that the microbial community in tea and fallow would be dominated by fung suggesting the performance of low qualit organic materials.

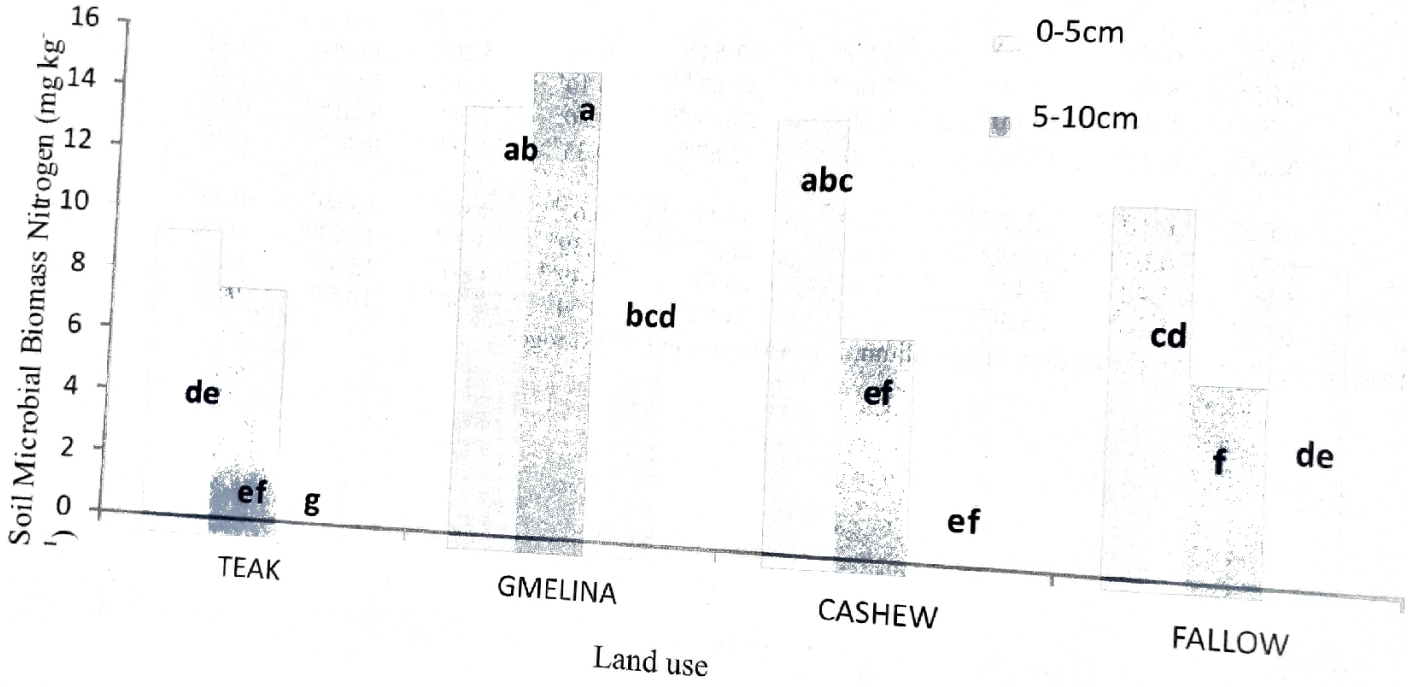

Fig: 2 Microbial Biomass Nitrogen (MBN) Accumulation (mg kg $^{-1}$) as affected by Land use at different depths.Bars with different letters are significantly different

Results from present study demonstrate that the management practice and certain type of vegetation exert a profound influence on microbial biomass carbon and Nitrogen. Our data suggested that gmelina may be healthier when compared to other land use systems. Further studies should however be carried out soil microbial biomass phosphorus using different land system.

REFERENCES

Acosta-Martinez, V. and M.A Tabatabai. (2000). Enzyme activities in a limed agricultural soil. Soil Biol. Fertil. Soils. 31:85-91.

Anderson, T.H. and Domsch, K.H. (1989). Ratios of microbial biomass carbon to total organic carbon in arable soils. Soil Biology and Biochemistry 21, 471-479.

Anderson, 1.M and J.S.I. Ingram, (1993). Tropical soil Biology and fertility. A hand book of methods, 2nd ed. CAB international, Wallingford. Soil Biol and Biochem. 25:111 **-125.**

Bauhus, J., Pare, D. and Cote, L. (1998). Effects of tree species stand age and soil type on soil microbial biomass and its activity in a Southern boreal forest (J). Soil Biol. Biochem. **30:**1077-1089.

Bohme, L. and F. Bohme, (2006). Soil microbiological and biochemical properties affected by plant growth and different long term fertilization. European Journal of soil Biology.

Bouyoucous, G .J. (1962). Hydrometer method improved for making particle size analysis of Soils. Agron.I.54! 464-465.

Bremner, J.M and Mulvaney, C.S. (1982). Nitrogen total. In methods of Soil Analysis, part 2.A.S.A Ed. & page. pp 595-624. Madison Wisconsin.

Brookes, P.C. (1995). The use of microbial parameters in monitoring soil pollution by heavy metals. Biol. Fertile. Soils 19(4), 269-279.

Brookes, P.C., Landman, A., Pruden, G., Jenkinson, D.S (1985). Chloroform fumigation and **the release** Soil Bioi. and Biochem. 17: 837-842. Soil Nitrogen; a rapid direct extraction method to measure microbial biomass Nitrogen in **soil Biol. And Biochem. 17:837-842.**

Brookes, P.C., Powlson, D.S. and Jenkinson,D.S. (1982).Measurement of microbial biomass phosphorus in soil. Soil Biol. and Biochem. 14319-329

FDALR: Federal Department o f Agriculture Land Resources, (1990). Soil Report Vol. 2 pg 166.

Havin, H.L Kibbel, D.E;Maddux, L.D Classen, M.M; Long, J.H (1990).Crop rotation and tillage effects on soil organic carbon and nitrogen. Soil Sci. SOC. A M J. 54: 448-452.

Hernot, J., and G.P. Robertson,(1994). Vegetation removal in two aeoila of the Humid Tropics, effect on microbial biomass. Soil Biol. Biochem. 26:111-116.

Jenkinson, D.S. (1976). The effects of biocidal treatment on the metabolism in soil. iv. The decomposition of fumigated organism in soil. Soil Biology and Biochemistry 8, 203-208

Juo, A.S.A. (1981). Characterization of soil in relation to Crop rotation I.I.T.A Ibadan Nigeria.

Landgraf, D and Klose, S. (2002). Mobile and readily available C and N fractions and their relationship to microbial biomass and selected enzymes activities in a sandy soil under different management systems (J). Plant nutrition soil science, 165:9-16.

McGill, W.B., Robertson, J.A, and Cook, F.D. (1986). Dynamics of soil microbial and water soluble organic C in Breton L. after 50years of cropping to two rotations. Can.J soil sci.66: 1-9.

Smith, J. L., Paul, E.A (1990). The significance of soil microbial biomass estimation. In: Bollag, J.M., Stotzkym G. (eds) soil biochemistry, Vol 6, Marcel Decker, NewYork.

Sneh, G; Mishra, M. M. J; Hooda; I.S and Raghuba, S. (1992).Organic matters and microbial Biomass relationships in field

experiment under tropical conditions. Effect of inorganic fertilizer, organic amendments Soil Biol. Biochem. 24: 1081-1084.

Tabatabai, M.A, (1994). Soil enzyme. In: Methods of Soil Analysis part 2.microbiological and Biochemical Properties of soil (Eds: R.W. Weaver, G.S. Angle.,P.S. Bottomley, D. Bezdicek, S. Smith, M.A. Tabatabai, A.Wollun). Soil Science Society of American, Madison, and PP.775-833.

Trasa-cepeda. C; Gill-sotres .F; Seoane, S; (1998). Towards a biochemical quality index for soil: an expression relating several Biological and Biochemical properties.Biol. Fertil soils. 26:100-106.

Vance, E.D., and Jenkinson, D.S. (1987a). Microbial measurement in Forest soils. Determination of Kc values and tests of hypotheses to explain the failure of the chloroform fumigation-incubation method in acid soils. Soil Biol. and Biochem. 19:689-96.

Vance, E.D., and Jenkinson, D.S. (1987b). Microbial biomass measurements in Forest Soils. The use of chloroform fumigation-incubation method in strongly acid soils. Soil Biol. and Biochem. 19:697-702.

(Walkey, A. 1947). A critical examination of a rapid method for determining organic carbon in Soils, effect of variations in digestion condition and inorganic soil constituent. Soil Sci. 63:251-264.