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Assessment of the microbial biomass carbon, nitrogen and phosphorus in relation to physico-chemical properties of Acric Luvisols in Ibadan South West, Nigeria

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Abstract: Maintenance of soil quality is a key component of agriculture sustainability and there is an increase in the use of soil microbial parameters as sensitive indicators. This study aimed to determine the impact of different agricultural land uses on soil microbial biomass and to study the interrelationships between microbial biomass carbon (MBC, μgCg^{-1}), Nitrogen (MBN, $\mu gN\ g^{-1}$) and Phosphorus (MBP, $\mu gC\ g^{-1}$) with the physicochemical characteristics of the soil. A total of 100 soil samples were taken from four different agricultural land uses: cocoa plantation, grazed land, arable land and fallow land. Average MBC was 200.04 μgCg^{-1}, 189.24 μgCg^{-1}, 180.04 μgCg^{-1} and 129.18 μgCg^{-1}; average MBN was 19.84 μgNg^{-1}, 18.16 μgNg^{-1}, 17.60 μgNg^{-1} and 12.74 μgNg^{-1} while the average MBP was 7.62 μgPg^{-1}, 7.26 μgPg^{-1}, 7.22 μgPg^{-1} and 6.40 μgPg^{-1} for cocoa plantation, grazed land, arable land and fallow land respectively. One-Way ANOVA showed a significant difference in microbial biomass C, N and P among the study areas. MBC, MBN and MBP were significantly correlated to the physico-chemical properties of the soil ($P \leq 0.05$) under the same ecological conditions. The significant relationship between soil nutrients and microbial biomass facilitates the use of microbial biomass as an important soil quality indicator in relation to land use types.

Key words: microbial biomass, land use, soil quality, soil physico-chemical properties.

Introduction

Measuring microbial biomass is a valuable tool for understanding and predicting long-term effects on changes in land use and associated soil conditions (Sharma *et* *al.*, 2004). Maintenance of soil quality is a key component of sustainability wherein soil microbial biomass was used as indicators (Kara and Bolat, 2007; Tóth *et al.*, 2007 and Kaschuk *et al.*, 2011). Dry and rainy seasons are two extrema in tropical ecosystems which have a major influence on productivity, nutrient cycling and microbial biomass. Several studies reported seasonal variability of microbial biomass, with more contents of soil microbial biomass in both, dry (Maithani *et al.*, 1996 and Montaño *et al.*, 2007) and wet seasons (Devi and Yadava, 2006). The agricultural productivity in the East African region varies enormously during the year and is strongly affected by climatic change (Thornton *et al.*, 2009). Due to the slow plant growth and nutrient uptake during dry seasons, it has been reported that high amounts of microbial biomass retain nutrients (Singh *et al.*, 1989). In the rainy seasons, fast plant growth and root activity as well as drastic changes in soil moisture stimulate fast turnover of microbes (Fierer and Schimel, 2003). This leads to lower microbial biomass contents and increasing CO2 efflux rates (Otieno *et al.*, 2010; Singh *et al.*, 1989 and Sugihara *et al.*, 2010). Hence, it is assumed that in tropical ecosystems with a bimodal climatic pattern soil microbes represent both a sink and source of nutrients (Srivastava, 1992). The tropical ecosystems are in special focus due to increasing anthropogenic disturbances and decreasing C budgets (decrease in C stocks of 25 - 30%, Don *et al.*, 2011). Land use due to human perturbations strongly alters natural tropical ecosystems in terms of C turnover and sequestration (Katovai *et al.*, 2012). Soil and crop management research over the years has helped in understanding the impact of various natural factors and agricultural practices on the population and diversity of microorganisms in the soil (Venkateswarlu and Srinnivasa Rao, 2014). The soil biomass work with respect to land use in Nigeria is scanty. Hence, in the present study, an attempt is made to analyze the soil microbial biomass nitrogen, carbon and phosphorus under four dominant land use systems in South Western, Nigeria (cocoa plantation, grazed land, arable land with mixed cropping (vegetables and maize) and fallow land) and studied their relationships between MBC, MBN and MBP with the physico-chemical characteristics of some Acric Luvisols of Institute of Agricultural Research and Training, Ibadan.

Materials and Methods

Study area

The study area is located in the vicinity of the Institute of Agricultural Research and Training, Moor Plantation, Ibadan, Oyo State, South West, Nigeria (7° 23' N; 3° 51'E and 160 m above mean sea level). The tropical climate is marked with wet and dry seasons having a bimodal rainfall pattern with rainfall peaks mostly in June to September and annual temperature of 21.3°C to 31.2°C. The soils in the study area are mostly sandy loam at the top, to brown loamy sand sub-soil well drained, and formed on a plain level ground with the slope of 2-6%. The dominant soil is the Iwo series, also known as Acric Luvisol (Smyth and Montgomery, 1962), it is also classified under the world reference base (WRB) as KanhaplicHaplustalf. The soils are mostly sandy loam at the top, to brown loamy sand sub soil and they are well drained. Four different representative locations having similar ecological conditions under the land use types of cocoa plantation, grazed land, arable land with mixed cropping (vegetables and maize) and a fallow land were chosen for this study.

Soil sampling

The sampling of surface soils (0 - 5cm) was done in a completely randomized design using stainless steel rings (10 cm diameter, 5 cm height) from 25 different points of each land use types, and mixed to form five composite samples at each site. Each land use type covers an area of approximately 1.2 ha and soil samples were collected during May, 2012. Stones, plant and root debris were removed and stored at 4°C before microbial analysis whereas subset of fine earth fraction (<2mm) was used for physical and chemical analysis.

Analysis of physical and chemical properties

Physical and chemical properties of soils were determined by standard methods as listed: Soil particle size distribution by the hydrometer method (Bouyoucos, 1962), pH in 1:2.5 soil/water suspension by pH-meter (Rowell, 1994), organic carbon content (OC) by the Walkley-Black method (Allison and Moodie, 1965), conversions between values of organic carbon and organic matter was made using Van Bemmelen factor of 1.724 on the assumption that, on average, Soil organic matter contains 58% of organic C, total nitrogen by the Kjeldahl method (Bremner and Mulvaney, 1982) and available P by the method of Olsen *et al.* (1954). Exchangeable bases were extracted with 1 M NH4OAC (pH 7.0) to determine K and Na using flame photometer and exchangeable Mg and Ca by atomic absorption spectrophotometer (Sparks, 1996).

Determination of soil microbial biomass

The microbial biomass Carbon (MBC) was determined by fumigation extraction method. MBC was calculated from the relationship depicted in the equation as: $MBC = EC - k_{EC}$, where EC is the difference between the amount of organic C extracted from the fumigated and non-fumigated soils (Vance *et al.*, 1987). Summarily, ethanol-free $CHCl_3$ was used to fumigate 7 - 8 g of each field-moist soil sample for 24 h in an exsiccator at room temperature. After fumigation, $CHCl_3$ was removed and soluble

C from fumigated and non-fumigated samples was extracted with 60 ml of 0.5 M K_2SO_4 by shaking on an orbital shaker (60 min, 120 rotations min^{-1}). The C content in K_2SO_4 extracts from respective soil samples without $CHCl_3$ fumigation was estimated as water-extractable organic carbon (WOC) (Beck *et al.*, 1997 and Blagodatskaya *et al.*, 2009). Soluted organic C in fumigated and non-fumigated extracts was determined. Since not all of the soil carbon can be extracted by K_2SO_4, a k_{EC} factor of 0.45 (Joergensen, 1996) was used to convert microbial C flush (difference between extractable C from fumigated and non-fumigated samples. Microbial biomass N (MBN) was calculated from the equation of MBN = EN/k_{EN}, where EN is the difference between the amount of organic N extracted from the fumigated and non-fumigated soils and k_{EN} is 0.54 (Brookes *et al.*, 1985). Microbial biomass Phosphorus (MBP) was determined as the difference in total P of $NaHCO_3$ extracts from fumigated and unfumigated samples using the procedures earlier described by Olsen *et al.* (1954) and $CHCl_3$ fumigation technique by Brooks *et al.* (1985).

Statistical analyses

The (ANOVA) and correlation statistical analysis was done with SPSS 11.5. One way analysis of variance (ANOVA) was used to test the effects of the different land use types on MBC, MBN, and MBP. Pearson's correlation was used to determine interrelationships among soil properties.

Results and discussion

Physical and chemical characteristics of soils

The effect of land use on major physical and chemical properties is presented in Table 1. The soil organic carbon (SOC) varied from 1.84% (cultivated land) to 3.29% in cocoa plantation, total nitrogen (TN) from 1.16% to 1.81% and available phosphorus from 0.51ppm to 1.4ppm. The results further show that the soils under fallow and cultivated are slightly alkaline with clay content less than 8 per cent and K content less than 2 $cmol/kg^{-1}$. The soils under cocoa and grazing are moderately alkaline (pH of 8) with clay between 7 and 9 percent and K content more than 0.2 cmol/kg. It is interesting to note that sandy soils under cocoa have low exchangeable Ca (0.49 cmol/kg) with exchangeable Mg of 2.56 cmol/kg as against the loamy sand grazing soils having Ca of 1.18cmol/kg and Mg of 2.15 cmol/kg. There are slight variations in exchangeable Na contents in soils of four land use types with values of 0.33 to 0.34 cmol/kg. The ANOVA test ($P \leq 0.05$), shows a significant difference in clay, pH, available phosphorus and total nitrogen with respect to land use types.

Table 1 - Physical and chemical properties of soils in the four study sites.

Type of Land Use	TN %	SOC %	AvP (mg/kg)	PH	Ca	K	Mg	Na	% Clay	Textural Class
					cmol/kg					
Cocoa plantation	1.81a	3.29a	1.40a	8.09a	0.49a	0.24a	2.56a	0.34a	7.28c	Sand
Grazed land	1.66b	3.25a	1.36a	8.08a	1.18a	0.24a	2.15a	0.34a	9.04a	Loamy sand
Fallow land	1.61b	2.20a	1.13ab	7.53b	1.09a	0.18a	2.23a	0.33a	7.84bc	Loamy sand
Cultivated land	1.16c	1.84a	0.51b	7.43b	0.67a	0.19a	1.67a	0.33a	7.68b	Loamy sand

Means with the same letter are not significantly different at $P \leq 0.05$

Status of microbial biomass carbon, nitrogen and phosphorus

The results of microbial biomass analysis show that cocoa plantation has a mean microbial biomass carbon (MBC) of 200.04 μgCg^{-1}, mean microbial biomass nitrogen (MBN) of 19.84 μgNg^{-1} and mean microbial biomass phosphorus (MBP) of 7.62 μgPg^{-1} as against other land use systems under study (Table 2). Relatively dense growth of plants, *vis-à-vis* greater accumulation of litter and fine roots in the understorey plots, favour the growth of microbial populations and accumulation of C in the microbial biomass (Kara and Bolat, 2008). The cultivated lands have low contents (MBC of 129.18 μgCg^{-1}, MBN of 12.74 μgPg^{-1} and MBP of 6.4 μgPg^{-1}) as against grazing and fallow land soil microbial biomass. There is a significant difference in soil MBC, MBN and MBP among the land use types. Nutrient availability, such as P, greatly influences soil microbial activity and function (Wright and Reddy, 2001) and as seen in this study, there was a negative correlation between the available P and the MBC, MBN, MBP suggesting a decline in the available P due to microbial activity and weak alkalinity of soils (pH 7.43-8.09) under four land use systems as against maximum activities of soil microbial biomass which occurred at pH values of about 6.5 (Acosta-Martinez and Tabatabai, 2000). The correlation analysis (Table 3) shows that MBC is positively correlated with clay ($r = 0.059$, $P < 0.01$) while MBN and MBP are negatively correlated with clay ($r = - 0.022$, $P < 0.01$ and $r = -0.057$, $P < 0.01$ respectively). The poor relationship of clay with microbial biomass is partly masked by soil organic matter, management practices, and plant species composition as reported earlier by Kara and Bolat, (2008). The significant positive relations between the soil MBC and SOC agrees withearlier reports by Yao *et al.* (2000) and Cookson *et al.* (2007). The correlation between soil MBN and TN is in agreement with previous studies (Kara and Bolat, 2008; Wright *et al.*, 2005; Yang *et al.*, 2010). The greater accumulation of litter and fine roots under-storey of the cocoa plantation may favour the growth of microbial populations and the accumulation of C in microbial biomass. The MBP showed a significant positive correlation with microbial biomass C supporting earlier research findings (Kujur and Patel, 2012).

Table 2 - Microbial biomass C, N and P values of soils in different land uses.

Land Use Type	MBC μgCg-1	MBN μgNg-1	MBP μgPg-1
Cocoa plantation	200.04a	19.84a	7.62a
Grazed land	189.24ab	18.16b	7.26b
Fallow land	180.04b	17.60b	7.22b
Cultivated land	129.18c	12.74c	6.40c

Means with the same letter are not significantly different at P ≤0.05

Table 3 - Correlation matrix for physical, chemical, and microbiological characteristics of soils from different land uses.

Soil Variable	MBC	MBN	MBP	SOC	TN	pH	%clay	AvP	K
MBC	1.0	0.990***	0.945***	0.418*	0.990***	0.644**	0.059	-0.181	0.295
MBN		1.0	0.952***	0.400*	1.0***	0.655**	-0.022	-0.143	0.314
MBP			1.0	0.350*	0.952***	0.557*	-0.057	-0.080	0.245
SOC				1.0	0.401*	0.550*	-0.01	-0.235	0.350
TN					1.0	0.655**	-0.023	-0.145	0.317
pH						1.0	0.145	-0.276	0.394
% clay							1.0	-0.519*	0.208
AvP								1.0	-0.302
K									1.0

Pearson's correlation coefficient, n = 20, * P < 0.05, ** P < 0.01., ***P<0.001

Conclusion

The results showed that the soils under the cocoa plantations have more soil organic carbon as compared to the other land use types due to storey cover and additions of plant/leaf residues with little or no human disturbance. The significant relationship between soil nutrients and microbial biomass shows that soil microbial biomass can serve as useful soil quality indicator with respect to land use.

References

Abdi O.A., Glover E.K., Luukkanen O., 2013. Causes and Impacts of Land Degradation and Desertification: Case Study of the Sudan. Int. J. Agric. Forestry, vol.2: 40-51.

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

Allison L.E., Moodie C.D., 1965. Carbonate. In: Methods of soil analysis, (Ed. C.A. Black), Am. Soc. Agron., Wisconsin: 1379^{-1}396p.

Beck T., Joergensen R. G., Kandeler E., Makeschin F., Nuss E., Oberholzer H. R., Scheu S., 1997. An inter-laboratory comparison of ten different ways of measuring soil microbial biomass C. Soil Biol. Biochem., vol. 29: 1023-1032.

Blagodatskaya E.V., Blagodatsky S.A., Anderson T. H., Kuzyakov Y., 2009. Contrasting effects of glucose, living roots and maize straw on microbial growth kinetics and substrate availability in soil. Eur. J. Soil Sci., vol. 60 (2):186-197.

Bouyoucos G.J., 1962. Hydrometer method improved for making particle size analyses of soils. Agron. J., vol. 54: 464-465.

Bremner J.M., Mulvaney C.S., 1982. Nitrogen-total. In: Methods of soil analysis, Part 2 Chemical and Microbiological Properties (Ed. A.L. Page). SSSA Book series No: 9, Madison, 595-622p.

Brookes P.C., Landman A., Pruden G., Jenkinson D.S., 1985. Chloroform fumigation and release of soil N: a rapid direct extraction method to measure microbial biomass N in soil. Soil Biol. Biochem., vol. 17: 837-842.

Cookson W.R., Osman M., Marschner P., Abaye D.A., Clark I., Murphy D.V., Stochdale E.A., Watson C.A., 2007. Controls on soil nitrogen cycling and microbial community composition across land use and incubation temperature. Soil Biol. Biochem., vol. 39:744–756.

Devi N.B., .P.S. Yadava P.S., 2006. Seasonal dynamics in soil microbial biomass C, N and P in a mixed-oak forest ecosystem of Manipur, North-east India, Appl. Soil Ecol., vol.31 (3): 220-227

Don A., Schumacher J., Freibauer A., 2011. Impact of tropical land-use change on soil organic carbon stocks, Glob. Chang., Biol., vol. 17 (4): 1658-1670.

Fierer N., Schimel J.P., 2003. A proposed mechanism for the pulse in carbon dioxide production commonly observed following the rapid rewetting of a dry soil. Soil Sci. Soc. Am. J. vol. 67 (3) : 798–805.

Joergensen R.G., 1996. The fumigation–extraction method to estimate soil microbial biomass: calibration of the kEC value. Soil Biol. Biochem., vol. 28 (1): 25-31.

Kara O., Bolat I., 2007. Impact of alkaline dust pollution on soil microbial biomass carbon. Turk. J. Agric., vol. 31: 181-187.

Kara O., Bolat I., 2008. The effect of different land uses on soil microbial biomass carbon and nitrogen in Barton province. Turk. J. Agric., vol. 32: 281-288.

Kaschuk G., Alberton O., Hungria M., 2011. Quantifying effects of different agricultural land uses on soil microbial biomass and activity in Brazilian biomes: inferences to improve soil quality. Plant Soil., vol. 338:467-481.

Katovai E., Burley A.L., Mayfield M.M., 2012. Understory plant species and functional diversity in the degraded wet tropical forests of Kolombangara Island, Solomon Islands, Biol. Conserv., vol. 145 (1): 214-224.

Kujur M., Patel A.K. 2012. Quantifying the contribution of different soil properties on microbial biomass carbon, nitrogen and phosphorous in dry tropical ecosystem. Int. J. Environ. Sci., vol. 2(3): 2272-2284.

Maithani K., Tripathi R.S., Arunachalam A., Pandey H.N., 1996. Seasonal dynamics of microbial biomass C, N and P during regrowth of a disturbed subtropical humid forest in north-east India. Appl. Soil Ecol., vol. 4 (1): 31-37.

Montaño N., García-Oliva F., Jaramillo V., 2007. Dissolved organic carbon affects soil microbial activity and nitrogen dynamics in a Mexican tropical deciduous forest, Plant Soil, vol. 295 (1): 265-277.

Olsen S.R., Cole C.V., Watanabe F.S., Dean L.A., 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA Circ. 939. GPO, Washington, DC.

Otieno D., K'Otuto G.O., Maina J.N., Kuzyakov Y., Onyango J.C., 2010. Responses of ecosystem carbon dioxide fluxes to soil moisture fluctuations in a moist Kenyan savanna. J. Trop. Ecol., vol. 26 (06): 605-618.

Rowell D.L., 1994. Soil science: methods and applications. Longman Scientific and Technical, Singapore.

Sharma P., Rai S.C., Sharma R., Sharma E., 2004. Effects of land-use change on soil microbial C, N and P in a Himalayan watershed. Pedobiologia, vol. 48:83-92.

Singh J.S., Raghubanshi A.S., Singh R.S., Srivastava S.C., 1989. Microbial biomass acts as a source of plant nutrients in dry tropical forest and savanna. Nature, 338 (6215): 499-500.

Smyth A.J., Montgomery R.F., 1962. Soil and land use in central western Nigeria. Govt. Printer, Ibadan, Western Nigeria. pp. 264.

Sparks D.L., 1996. Methods of soil analysis. Part 3. Chemical methods. SSSA and ASA. Madison W.I. 555-574 p.

Srivastava S.C., 1992. Influence of soil properties on microbial C, N, and P in dry tropical ecosystems, Biol. Fertil. Soils, vol. 13 (3): 176-180.

Sugihara S., Funakawa S., Kilasara M., Kosaki T., 2010. Effect of land management and soil texture on seasonal variations in soil microbial biomass in dry tropical agroecosystems in Tanzania. Appl. Soil Ecol., vol. 44 (1): 80-88.

Thornton P.K., Jones P.G., Alagarswamy G., Andresen J., 2009. Spatial variation of crop yield response to climate change in East Africa. Glob. Environ. Change, vol. 19 (1): 54-65.

Tóth G., Stolbovoy V., Montanarella L., 2007. Soil quality and sustainability evaluation: an integrated approach to support soil-related policies of the European Union. Institute for Environment and Sustainability, Luxembourg, Europea Communities: 52.

Vance E.D., Brookes P.C., Jenkinson D.S., 1987. An extraction method for measuring soil microbial biomass C. Soil Biol. Biochem., vol. 19: 703-707.

Venkateswarlu B., Srinivasarao Ch., 2014. Soil Microbial Diversity and the Impact of Agricultural Practices. http://www.envismadrasuniv.org/oct_news.htm.

Wright A.L., Hons F.M., Jr-Matocha J.E., 2005. Tillage impacts on microbial biomass and soil carbon and nitrogen dynamics of corn and cotton rotations. Appl. Soil Ecol., vol. 29: 85-92.

Wright A.L., Reddy K.R., 2001. Phosphorus loading effects on extracellular enzyme activity in Everglades wetland soil. Soil Sci. Soc. Am. J., vol. 65:588-595.

Yang K., Zhu J., Zhang M., Yan Q., Sun O.J., 2010. Soil microbial biomass carbon and nitrogen in forest ecosystems of Northeast China: a comparison between natural secondary forest and larch plantation. J. Plant Ecol., vol. 3(3):175-182.

Yao H., He Z., Wilson M.J., Campbell C.D., 2000. Microbial biomass and community structure in a sequence of soils with increasing fertility and changing land use. Microb. Ecol., vol. 40: 223-237.