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Light Fractions of Organic Carbon and Microbial Properties As Affected By Land Management In Savanna Soil.

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Abstract
This study was carried out to investigate the effect of land management on the light fraction and microbial properties in fields cultivated to pastures in National Animal Production Research Institute,(NAPRI), Shika. Soil organic carbon is the most often important indicator of soil quality and agricultural sustainability. Organic carbon, light fraction organic matter and microbial properties (soil microbial biomass carbon, nitrogen and microbial count) were examined at two depths (0-15 and 15-30cm) in six pasture fields: gamba grass, signal grass, elephant grass, Lab lab, Cook stylo and Mucuna fields in Savanna soils of the sub humid zone of Nigeria. Light fraction (LF) organic matter (LFOM), carbon (LFC) and nitrogen (LFN) were significantly ($p<0.05$) lower at sub surface than at surface levels. Total heterotrophic count and EMB colony were lower at surface than at sub surface levels being 303cfu/g and 52cfu/g for THC and EMB respectively at surface level. Similarly, microbial biomass C and N were higher at surface than sub surface levels. Results obtained indicated that light fraction and soil microbial properties may be used as indicator for organic carbon in pasture lands.

Introduction

Soil organic matter (SOM) has been an object of investigation not only in soil but also in environmental sciences. The physical, chemical and biological properties of soil are attributed to SOM (Chang *et al.* 2007). Soil organic matter is fundamental to the maintenance and sustainability of natural and managed ecosystem, pasture management inclusive. Soil organic matter is a product of organic residues (mainly partially decomposed vegetation) in diverse stages of complexity (Feldpausch *et al*, 2004). Soil organic carbon (SOC) is the largest carbon reservoir in terrestrial ecosystem and act as both a source and a sum in response to changes in climate land use. (Murty *et al*., 2002; Houghton, 2005). The difference between inputs from primary production and the return of carbon to atmosphere through decomposition of organic matter determines the soil carbon budget in semi-arid and other terrestrial ecosystems (Austin et al., 2008).

According to Lal (2004) and supported by Houghton (2005), annual soil C sequestration is 0.4-1.2 Pg C yr^{-1} globally. This is equivalent to 6-20% of the annual CO_2 released from fossil fuel combustion (Lal 2004). The control of SOC is potentially an important factor in mitigating atmospheric C accumulation. It is also critical to understand how SOC varies in response not only to climate but also to other factors such as land management when evaluating the role of terrestrial ecosystem processes affecting C cycle.

SOC plays a vital role in soil fertility maintenance, soil productivity and regional and global C cycle. Knowledge of the quantity, quality and spatial distribution of SOC is essential for evaluating soil function and evaluating soil C sequestration processes (Lal, 2004).
SOC is important for all aspects of soil fertility: physical, chemical and biological. Physically, SOC promotes better aggregation of soil particles and improve water holding capacity, soil growth and tilth. Biologically SOC act as source of energy for soil flora and fauna, thus playing role in nutrient cycling and availability. Chemically, SOC act as buffers against

harmful substances by way of sorting toxins and heavy metals thereby reducing their bioavailability.
Several factors including vegetation type and soil management (Carvalho *et al.,* 2009; Maia *et al.*, 2009) have been identified as controlling the magnitude and speed of change in the context and quality of SOM. Therefore, the extent to which land use management influences SOM dynamics can be best evaluated by separating SOM into fractions including light fractions of organic matter (LF-OC). Light fraction organic matter is free (not complexed with soil mineral matter) particulate plant and animal residues at different stages of decomposition (Spycher et al, 1983). It is the labile fraction of organic carbon, which serves as readily decomposable substrate for microorganisms in soils. The organic matter in this fraction decompose quickly despite a wide C:N ratio (Collins *et al,* 1984)> The light fractions compose of relatively labile constituents such as carbohydrates and are not protected by clay minerals and are therefore very susceptible to microbial attack.

SMBC is a key component of the active SOM pool and serves as a source and sink of soil nutrients (Gonzalez-Quiñones *et al*., 2011) and/or as an ecological marker to understand soil microbiological fertility (Ge *et al.* 2010). These indices are most likely influenced by agricultural practices of which land management is an important practice. Changes in SOC turnover are influenced by soil fertility, and other factors such as temperature, moisture and C/nitrogen (N) ratio (Pan et al. 2009; Schmidt et al. 2011).

In the savanna ecosystem, labile soil organic carbon fractions play vital roles in soil quality and are greatly affected by agricultural practices (Franzluebbers and Arshad, 1997). The study of SOM in its various fractions as well as its relation to soil management can generate the theoretical basis for adoption of sustainable land use strategies. Carbon is the main constituent of soil and accumulates as stable fractions and labile fractions (Bayer et al, 2006). Several studies on SOM dynamics in the savanna ecosystem focused on its absolute quantity especially in pasture management. This study therefore examines the light fractions of organic matter and microbial properties of pasture management in Northern Guinea Savanna.

Materials and Methods.

The Study Area

This study was carried out at the Pasture fields at National Animal Production Research Institute (NAPRI), Shika located at longitude 11^0 13'N and latitude 6^0 55' -7.33^0 33'E in the sub humid zone of Nigeria (Amodu et al, 2002). Mean annual rainfall ranged from 700-1300mm occurring between May to October while the dry season is November-April. The highest temperature 36^0C is in April while the lowest mean annual temperature 11^0C in December/January (Kowal and Knabe, 1972).

Soil

The soils of Shika are ferruginous tropical soils developed over schist, gneiss and quartzite (Klinkenberg and Higgins, 1968).

Pasture Species

Six land use managements were selected for this study. Soil sampling was done on three fields cultivated to perennial pasture grasses: *Andropogon gayanus* (Gamba grass, GB), *Bracharia decumbens* (signal grass, SG), *Pennisetum purpureum* (elephant grass, EG) and three fields cultivated to perennial pasture legumes: *Stylosanthes guianensis* (Cook stylo, CS), *Mucuna pruriens* (mucuna, MC) and *Lablab purpurius* (Lablab, LL).

Soil Sampling and Analysis

Soil samples were collected from several points at each pasture field with the aid of soil auger at 0-15 cm and 15-30 cm depth and bulked for each plot. The bulked samples were air-dried and sieved using a 2 mm mesh sieve. The sieved soil samples were subjected to laboratory analyses.

Light Fraction

Light fraction organic carbon was determined by the method of Gregorich and Ellert (1993). About 20g of each sample was weighed into 250ml beaker to which was added 80ml NaI solution and homogenized mechanically. The suspended light materials were transferred to a filtration unit with Whatman filter paper No1 using a vacuum. The light fraction was washed three times with 20 ml 0.01M $CaCl_2$ and 20 ml distilled water. The residue was allowed to dry on the filter paper in an oven at 65 ^oC for 16 hours. The dried residue was scrapped carefully and weight determined. The oven dried sample and the soil samples were finely grinded and analysed for carbon and nitrogen contents. Organic carbon content was determined by dichromate wet oxidation method while nitrogen content was determined by Kjeldahl method (Bremner and Mulvaney, 1982).

Estimation of Soil Microbial Biomass Carbon and Nitrogen and microbial colony.

The soil microbial biomass carbon (SMBC) and nitrogen (SMBN) were estimated by the chloroform fumigation incubation (FI) method of Jenkinson and Powlson (1976) as modified by Goladi (1997). Twenty grams dry soils sample were placed in 150 ml narrow neck bottles and moistened. These were then treated with ethanol-stabilized chloroform ($CHCl_3$) at the rate of 0.5ml/g soil and closed tightly for 24 hours. The chloroform was evacuated under the fume hood by suction for six hours and fumigated samples inoculated with 1.0g of moist unfumigated soil and mixed thoroughly. The mixed soil was incubated at 25^Oc for 10 days with 20ml of 1M NaOH to trap evolved carbon dioxide (CO_2). A set of control samples (without) fumigation, but treated the same way also set up. After the 10 days incubation, the quantity of CO_2 evolved was determined by titrating the NaOH with standard 1.0M HCl .the SMBC was estimated by the equation

$SMBC = [(CO_2\text{-}C)\ fumigated - (CO_2 - C)\ unfumigated/K_c]$ ……Equation 1

Where $K_c = 0.41$ (Voroney and Paul, 1984)

To determine the SMBN, 1g portion of the $CHCl_3$ fumigated soil was extracted at the end of the 10 days incubation with 2M KCl for one hour by shaking in an end-to-end shaker. The soil was then analyzed for NH_4-N by the Kjeldahl Method (Bremmer and Mulvaney, 1982). The SMBN was calculated using the equation

$SMBN = [9\ NH_4\text{-}N)\ fumigated - (NH_4\text{-}N)\ unfumigated/\ K_N]$ ……Equation 2

Where $K_c = 0.41$ (Voroney and Paul, 1984).

Microbial count was estimated by the pour plate technique of Harrigan and McCance (1966). A sterile stock solution was prepared by dispensing 1g of soil into 10ml distilled water from which the ten-fold serial dilution was carried out. These were plated out on relevant media for colony formation: nutrient agar for the Total Heterotrophic Count (THC) and Eosin Methylene Blue, for Escherichia coli and other Enterics. The plated out materials were incubated at 37 °C for 48 hours and the number of colonies which developed after incubation were counted and recorded in colony forming unit per gram (cfu/g).

Data Analysis

All data collected were analysed using the general linear model (GLM) of SAS software (SAS 2001). Means were separated using analysis of variance (ANOVA) and Duncan's Multiple Range Test.

Results

Table 1 presents the results for soil reaction and particle size distribution. The soil texture in the pasture fields is sandy loam while the pH is slightly acidic.

Organic carbon ranged between 13.3g/Kg to 17.6g/Kg in the pasture fields (Table 2) and was significantly higher (17.6g/Kg) in the field cultivated to MC than all other fields. It is noted that organic carbon contents in the pasture fields were higher than other workers (Agbenin and Goladi, 1998; Enwezor et al., 1990) reported for cultivated soils in the study area. Significantly ($p<0.05$) highest (756.8 mg/kg) LFOM was obtained under field cultivated to Mucuna (MC) followed by CS, LL and SG fields (Table 2). The plot cultivated to EG had the least LFOM (355.6 mg/kg). Significantly ($p<0.05$) LFC and LFN was higher in fields cultivated to legumes (LL, CS and MC) than fields cultivated to pasture grasses (GB, SG and EG plots). Light fraction C and N ranged from 526 mg/kg to 1227g/kg and 97mg/kg to 342 mg/kg respectively.

Soil microbial biomass C ranged from 168.7 mg/kg in EG field to 692.8 mg/kg in LL field which was significantly higher than all other pasture fields. The trend of SMBC did not seem to follow the distribution of OC in the pasture fields. The distribution of SMBN did not reflect the pattern of SMBC distribution (Table 2). Significantly, the fields under GB and EG were lower in the values of SMBN than other fields but at par with each other. The highest SMBN 191.7 mg/kg was found in CS field followed by 117.8 mg/kg SMBN in MC field.

Total heterotrophic count of the pasture fields ranged from 402 cfu/g in CS field which was significantly at par with MC field (396 cfu/g) followed by LL field. The fields cultivated to GB, and EG had THC of 214.6, and 202.3 cfu/g respectively and significantly at par with one another, while the lowest THC (198.1 cfu/g) was found in the field cultivated to SG. Similarly, significantly lowest EMB colony (32.6 cfu/g) was found in the field cultivated to EG follow by 47.6 and 56.8 cfu/g for GB and SG fields respectively. The fields under CS (72.6) and MC (77.8) had EMB colony at par with each other.

Table 1: Mean results of soil reaction and particle size distribution

Land Use Types	pH_{H2O}	SAND	SILT	CLAY	TEXTURAL CLASS
GB	**6.0**	**53.0**	**33.5**	**14.7b**	**Sandy loam**
SG	**6.5**	**51.2**	**35.7**	**13.1b**	**Sandy loam**
EG	**6.6**	**53.0**	**31.3**	**16.7a**	**Loamy sand**
LL	**6.4**	**52.7**	**34.3**	**13.0b**	**Sandy loam**
CS	**6.1**	**53.0**	**32.5**	**14.5b**	**Sandy loam**
MS	**6.7**	**54.2**	**30.7**	**15.1b**	**Sandy loam**

Means within the same column followed by the same letter are not significantly different at $p< 0.05$

Table 2: Effect of land management on light fraction, microbial biomass properties and microbial colony in pasture fields

	OC	LFOM	LFC	LFN	SMBC	SMBN	THC	EMB
	g/kg	←			mg/Kg			→
GB	13.3c	483d	526e	137e	580.9b	19.9d	214.6c	47.6d
SG	14.2b	592c	728d	154d	497.2d	88.8c	198.1d	56,8c
EG	12.7c	356e	893c	97.0f	168.7e	24.6d	202.3c	32.6e
LL	13.6c	577c	1146b	342a	692.8a	82.4c	375.4b	97.8a
CS	15.4b	631b	1227a	318b	518.2c	191.7a	402.0a	72.6b
MC	17.6a	756.8a	1213ab	298c	472.4d	117.8b	396.0a	77.8b

Means within the same column followed by the same letter are not significantly different at p< 0.05.

Table 3: Correlation for the relationship between light fraction, microbial biomass properties and microbial colony in pasture fields.

	LFOM	LFC	LFN	SMBC	SMBN	THC	EMB
LFOM	-						
LFC	0.178	-					
LFN	0.339	0.741	-				
SMBC	0.67	0.637	0.477	-			
SMBN	0.592	0.132	0.622	0.581	-		
THC	0.339	0.046	-0.227	0.386	0.223	-	
EMB	0.122	0.580	0.386	0.297	0.401	0.706	-

Table 4: Effect of soil depth on light fraction pools and microbial properties of pasture fields.

	Soil Depth	
	0-15cm	15-30cm
LFOM mg/kg	0.55a	0.42b
LFC mg/kg	1.67a	1.22b
LFN	0.26a	0.16b
SMBC	472a	408b
SMBN	68a	52b
THC cfu/g	303b	321a
EMB	52b	64a

Means within the same row followed by the same letter are not significantly different at p< 0..05.

There were positive and significant correlations (Table 3) between LFOM and SMBN (59.2%), LFN and LFC (74%) and SMBC and LFC of over 63 percent. The effect of soil depths on the parameters measured in this study showed that LFOM, LFC and LFN were significantly ($p<0.05$) lower at sub surface than at surface levels (Table 4). Total heterotrophic

count and EMB colony were lower at surface than at sub surface levels being 303cfu/g and 52cfu/g for THC and EMB respectively at surface level. Similarly, microbial biomass C and N were higher at surface than sub surface levels.

Discussion

The results showed significant variations among light fraction pools and soil microbial properties in the pasture fields.

Differences in the values of LFOM, LFC and LFN in the pasture fields may be due to differences in the composition of litters, which have slightly different potentials to fix nitrogen and other elements to the soil. This is clearly corroborated in the significantly higher LFN values in legume pasture fields (LL, CS and MC) compared to grass pasture fields (GB, SG and EG).

The obvious increase in LFN as both LFOM and LFC increase across the pasture fields is an indication that soil nitrogen is intricately tied to soil organic matter content because the bulk of soil nitrogen is in the organic pool. Increase in carbon in surface soil can be interpreted as a partial mitigation of the effect of increased carbon dioxide in the atmosphere (Tanner et al, 2016). Differences in light fraction components may also be due to variations in environmental factors such as moisture and temperature, which greatly affects decomposition (Oyun 2004, Austin et al, 2008).

The variations in the microbial population are an indication in the differences in soil carbon content. Pasture fields cultivated to LL and GG supported higher microbial biomass C than other fields. This may be a result of exudation of easily mineralizable C and higher amount of litter deposition. Groffman *et al* (1996) reported that variation on microbial biomass was a result of labile C input to the soil. The significantly higher SMBN in legume pasture fields compared to grass pasture fields is an indication of higher N-immobilization by microbes. Conditions in the fields cultivated to legumes seem to support nutrition for soil micro fauna. Microbial population is determined not only by the quantity of organic materials into the soil but also by nitrogen input (Malik and Gleixner, 2013). Therefore, the more of these materials input into the soil, the more microbial population induced as obtained in Table 2.

Significant decrease in the values of LFOM LFC and LFN across soil depth is consistent with Jamala and Oke (2013) who reported decrease in particulate (labile) mineral associated and total organic carbon with increase in soil depth. Aboveground residues decompose more slowly than incorporated residues because reduced contact with the soil reduces interaction of litter with soil fauna.

Strong correlations among light fractions (Table 4) across the land management systems are an indication of strong relationship among organic C fractions, suggesting that C accumulation in the pasture fields was due to increase in light fractions of organic carbon. This is consistent with the work of Franzluebbers and Stuedemann (2002) who reported 57% particulate organic C for every unit of total SOC under long-term pastures. A high but positive correlation (0.64 or 64%) between LFC and SMBC is indicative of active carbon of exogenous material.

Conclusion

Land use Management and soil depths influence contents of light fractions of organic carbon and soil microbial biomass properties. All the different land use types showed accumulation of organic carbon and light fraction carbon at the soil surface (0-15cm). Light fraction of organic carbon was strongly correlated to soil organic carbon showing that carbon accumulation on soil surface was due to increased light fractions of organic carbon. High

values of microbial population (colony count) and biomass properties pointed to the increased input of labile carbon into the soil. Therefore, light fraction contents and microbial biomass properties may be used as a measure of indices of organic matter in pasture fields of savanna.

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