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Effect Of Agricultural Land Use On Carbon Sequestration And Chemical Properties Of Soil In Lafia, Southern Guinea Savanna Agroecological Zone, Nigeria.

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ABSTRACT

The experiments was conducted during 2010 rainy season at the research and teaching farm of the college of agriculture, Lafia, Nasarawa state, Nigeria. The study area falls within southern guinea savanna agroecological zone of Nigeria, to investigate the effect of agricultural land use types on soil chemical properties and amount of soil carbon that can be sequestered in the soils that are exposed to these different agricultural land uses. The data for this study were collected from the field survey of different agricultural land uses and soil samples were collected from farm lands that were subjected to maize, maize and groundnut, oranges and maize. The sizes of the experimental plots were 50M X 50M each. Systematic soil sampling method was used to divide each of the experimental plots into five equal strata. Then five soil samples were collected after harvest from two different depths (0-15cm) and (15-30cm) of the experimental plots; making a total of 30 soil samples. Laboratory analyses were carried out to determine the amount of carbon in the soil and other chemical properties of soil. The result showed that, the mean contents of N, P, K and C in the soil were low (13%, 18.08mg/kg, 0.16Cmol/kg and 0.52 mg/kg respectively); these soils are exhausted due to intensive cultivation and absence of adequate application of replenishment measures to sustain their productivity .The CV% of the soil chemical properties decreased in the order of C>P>N>Ca>Mg>CEC>K>pH>Na. Soil pH was mostly concentrated in the range of 5.40-5.68, which indicates that the soil was acidic. Results of the study also showed that, there were differences in total quantity of carbon sequestered in the different agricultural land utilization types in the study area. The highest quantities of 4257t/ha of SOC were stored in groundnut + maize agricultural land use. G/nut + maize land use type also reported a significantly higher amount of N: 0.17%, P: 23.55mg/kg, C: 0.88mg/kg, and CEC: 2.77cmol/kg compare with the other land use practices. Therefore, G/nut + maize agricultural land used type is recommended to farmers because, it highest capacity to reduce the emission of soil organic carbon into the atmosphere; it is adjudged the best ecologically friendly agricultural land use.

Key words: Land use, carbon, soil, sequestration, and chemical properties

Introduction

Agricultural land use is important among global issues, because of its impact on world food security and quality of the environment. Land use in a particular location is based on the extent to which the land characteristics match the use the land will be utilized (Verheye, 1986). Soil chemical properties are very important land characteristics particularly when they are to be put into agronomic uses. Arable lands all over Nigeria have seen an alarming decline in soil productivity as a result of continuous agricultural practices without application of adequate restorative measures (Ndor *et al* 2010). Changes in land use may alter land cover, which results in carbon stock changes in biomass as well as in the soil. Carbon capture and storage (or sequestration) is receiving increasing attention as one tool for reducing carbon dioxide concentrations in the atmosphere. Land use change, inappropriate agricultural practice, and climate change can all lead to a net release of C from soils to the atmosphere, enhancing the problems of greenhouse gas release (Nguyen, 2011). Several scientists pointed out that carbon dynamics in the soil ecosystems has been one of the major factors affecting CO2 concentration in the atmosphere (IPCC, 1996; Houghton, 1999; IPCC, 2001; Pacala *et al*., 2001). Carbon sequestration in soil organic matter is increasingly advocated as a potential win–win strategy for reclaiming degraded lands, mitigating global climate change, and improving the livelihoods of resource-poor farmers (FAO, 2001). Many studies have been conducted to assess the effects of land use changes on soil carbon stocks and soil properties (Raji and Ogunwole 2006; Tieszen L.L, 2000; Schlesinger W.H.1999; and Martin AN, A.,2010). However, during agricultural land use changes, soil may act either as a carbon source or as a carbon sink, depending on the ratio between the inflows and outflows. Studies addressing soil organic carbon (SOC) dynamics when land is converted from one use to another would be valuable in improving our understanding and increasing our predictive capability over both short and long timescales (Post and Kwon *2000*). The aim of this study was to investigate the effect of agricultural land use practices on chemical properties of the soil and

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then calculate the amount of soil carbon stock that can be sequestered in the soils that are exposed to different agricultural land uses.

Materials And Methods

The experiments was conducted during 2010 rainy season at the research and teaching farm of the college of agriculture, Lafia, Nasarawa state, Nigeria. The study area falls within southern guinea savanna agroecological zone of Nigeria, and is located between Latitude 08.33N and Longitude 08.32E. Rainfall usually starts from March – October and the average monthly rainfall figures ranges from 40mm-350mm. The months of July and August usually records heavy rainfall. The daily maximum temperature ranges from 20.00C – 38.50C and daily minimum ranges between 18.70C – 28.20C. The months of February to early April are the months that have the highest maximum temperature while the lowest maximum temperature months are recorded in December and January because of the prevailing cold harmattan wind from the northern part of the country at this period. The relative humidity rises as from April to a maximum of about 75- 90 percent in July (NIMET Lafia, 2010). The soil type of the study area composed of highly leached ultisols with low base saturation. The soil is strongly acidic and has high content of iron and Aluminium oxides hence reddish brown in colour with very low organic matter content and low total nitrogen and available phosphate. The dominant clay type is Kaolinite. The vegetation of the study area is that of the southern Guinea Savanna with interspersion of thicket, grassland, trees, fringing woodlands or gallery forest along the streams. The natural vegetation of the area is made up of grasses and some traces of scattered wild and economic trees like *Butyrosperoum peradoxum* (Shear butter tree) *Parkia* spp (locust bean tree) *Gmelina* arborea (Gmalina trees) *Anacadium* spp (Cashew trees) *Magnifera indeca (.Mango).* These trees usually shed off their leaves in the long dry season to conserve the available water. The data for this study were collected from the field survey of farm land and soil samples were collected from farm lands that were subjected to maize, maize and groundnut, oranges and maize to determine the effect of these agricultural practices on chemical properties of the soil and amount of soil carbon that can be sequestered in the soil. The sizes of the experimental plots were 50M X 50M each for maize, maize and Groundnut, maize and oranges. Both experimental plots are adjacent to each other within the same climatic region, relief, parent material and soil types. This makes comparison of soil properties between the agricultural land use types possible. Thus any difference observed between the soils under maize, maize and groundnut, maize and oranges will be accounted for by differences in nature of the plant cover. Systematic soil sampling method was used to divide each of this 50M X 50M of land into five equal strata. Then two soil samples were collected after harvest from two different depths (0-15cm) and (15-30cm) from maize plot, maize + groundnut plot and maize + oranges plot, at alternate spots from each stratum at equal interval, so that the soil will be adequately covered and the soil of the entire land will have equal opportunity to be collected without bias. Laboratory analyses were carried out to determine the amount of carbon in the soil and other chemical properties of soil. Ten soil samples were collected from each experimental plot. Therefore, a total of 30 soil samples at two depths (0-15cm and 15-30cm), were collected air-dried, and thoroughly mixed, then passed through 2mm sieve mesh to obtain a homogeneous particle sizes, after which standard laboratory procedures as described by Agbenin (1995) was used to determine soil organic carbon and other chemical properties. The Macro-Kjeldahl method was used to determine the total nitrogen in the soil samples. Available phosphorus was determined using extractable solution of sodium bicarbonate $Na(HCO_3)_2$.(Olsen method). Exchangeable bases were determined in the soil sample and the concentration of potassium was determined using the flame photometer. The organic carbon was determined using the Walkley-Black chromic acid titration method. Soil pH was determined using the electrometric method. Cation exchange capacity (CEC) is determined using ammonium acetate method; that is measuring the total amount of a given cation needed to replace all the cation from a soil exchange site and it is expressed in centimoles per 100 gram soil (Cmol/100g soil).

Soil bulk density measurements are required to calculate soil carbon stock in the soil studies that report only carbon or organic matter concentrations. For this studies where bulk density measurements were not taken, we estimated bulk density (BD) using the Adams (1973)

Equation:

$$\frac{100}{\frac{\%\,OM}{0.244} + \frac{100 - \%OM}{MBD}} \quad \text{--------------------------} \quad \text{(equation i)}$$

Where:

O M =is organic matter
MBD =is mineral bulk density.

Mineral particle density is usually assumed to be the specific gravity of quartz (2.65 Mg m^{-3}). Actual MBD is considerably lower than rock bulf density since soil consists of irregularly shaped mineral particles that allow large voids between them. We used a typical value of 1.64 for MBD (Mann 1986).

The calculation of organic matter was done using the formula by Agbenin (1995)

Organic Matter (%) = Soil Organic Carbon (%) x 1.72 -------------------------------- (equation ii)

The carbon stock in each agricultural land use was calculated using the formula by: CSE (2011)

Ct = Kd x ρ x % C ……………………………………………. (equation iii)

Where:

Ct = is the soil carbon stock, expressed in gram per square centimeter (g/cm2);

Kd = is the depth of the soil sample/depth of peat soil, expressed in centimeter (cm)

ρ = is soil bulk density, expressed in grams per cubic centimeter (g/cm3);

%C =is the percentage value of carbon content, using the values obtained from measurements in the laboratory

Calculation of organic soil carbon content per hectare was done using the following equation by**:** (CSE 2011)

Csoil = Ct x 100 ……………………………………………… (equation iv)

Where:

Csoil = is the organic soil carbon content of organic soil per hectare, expressed in tons per hectare (ton/ha);

Ct = is the soil carbon content, expressed in gram per square centimeter (g/cm2);

100 = is the conversion factor from g/cm2 to ton/ha. The method of statistical analysis adopted was simple descriptive statistics and two ways analysis of variance (ANOVA) using GENSTAT to determine the significant differences that existed in the agricultural land use systems and chemical soil properties. Where there is a significant difference; the means were separated using F-LSD at 5% probability level

Results And Discussions

The result on Table1 gave the descriptive statistical summarizes of the chemical composition of the experimental site; where the mean contents of N, P, K and C were low (13%, 18.08mg/kg, 0.16Cmol/kg and 0.52 mg/kg respectively). This result agrees with the findings of Sabo and Odus (2008), who reported that these soils are exhausted due to intensive cultivation and no adequate application of replenishment measures to sustain their productivity. The CV% of the studied soil chemical properties decreased in the order of C>P>N>Ca>Mg>CEC>K>pH>Na. Soil pH was mostly concentrated in the range of 5.40-5.68, which indicates that the soil was acidic. This is similar to the work of Jeyeoba *et al* (2012) who reported that the soils around Nasarawa state were moderately acidic.

Table 1: Descriptive statistics of soil chemical properties measured on 30 soil samples

	Total N %	Avail P(mg/kg)	K (cmo/kg)	% C (mg/kg)	pH	Mg (cmol/kg)	Na (cmol/kg)	Ca (c/mol/kg)	CEC (cmol/kg)
Mean	0.13	18.08	0.16	0.52	5.45	4.49	89.43	6.34	2.51
Median	0.12	19.91	0.17	0.49	5.41	4.39	89.66	6.32	2.44
Mini	0.09	10.11	0.13	0.32	5.40	3.23	84.76	3.56	2.10
Max	0.23	27.41	0.19	0.90	5.68	6.45	91.34	9.23	2.98
SD	0.04	5.64	0.02	0.16	0.09	0.88	1.34	1.56	0.25
SE	0.01	1.03	0.01	0.02	0.02	0.16	1.81	0.29	0.05
%C.V	27.48	30.20	9.31	30.98	1.59	19.53	1.50	24.74	10.16

The result in table two showed that the different agricultural land use and the soil depth have a significant effect on these chemical (N, P, C, Ca, and CEC) properties in the soil. G/nut + maize land use reported a significantly higher amount of N: 0.17%, P: 23.55mg/kg, C: 0.88mg/kg, and CEC: 2.77cmol/kg compare with the other land use practices. This result agrees with the work of Roberts (2008), who reported that there is always a gradual increase in the quantity of nitrogen, phosphorus and carbon when a leguminous crop is incorporated in a mixed cropping system, because the leguminous crop is responsible for symbiotic nitrogen fixation; CEC of the soils also shows variations due to changes in land use. The significantly higher amount of CEC recorded in soil of mixed cropping of cereal and legume increases the Organic carbon and clay which play a major role in controlling the CEC; Organic carbon content of soil across land use decreases with depth in all soils and also the same with CEC. Also the surface layer (0-15cm) of the soil recorded a significantly higher amount of all the chemical properties of the soil assessed except in K and Mg. This may be traced to fact that most of organic matter ontent of soil which is the primary source of some these chemical elements carbon, nitrogen and phosphorus is located on the surface layer of the soil. This result is in conformity with the work of Nguyen, *et al* (2011), who reported that large quantities of soil chemical elements were located within the top soil region.

Table 2: Effect of agricultural land use on chemical properties of soil

Treatment	chemical properties of the soil								
Agric. Land Use type	Total N %	Avail P(mg/kg)	K (cmo/kg)	% C (mg/kg)	pH	Mg (cmol/kg)	Na (cmol/kg)	Ca (cmol/kg)	CEC (cmol/kg)
Maize sole	0.11	19.63	0.15	0.61	5.55	4.50	88.81	7.71	2.45
G/nut + maize	0.17	23.55	0.18	0.88	5.54	4.41	89.75	5.83	2.77
Oranges + maize	0.12	11.06	0.17	0.56	5.48	4.09	89.73	5.46	2.28
LSD(0.05)	0.001	0.65	0.009*	0.04	0.08*	0.42*	1.08*	0.56	0.1
Soil depth(cm)									
0-15	0.15	19.49	0.17	0.59	5.53	5.15	89.86	7.37	2.62
15-30	0.12	16.67	0.17	0.34	5.52	5.23	88.99	5.30	2.39
LSD(0.05)	0.008	0.53	0.008*	0.01	0.16*	0.34*	0.88*	0.34	0.08

*= not significantly different at (p=0.05)

Results of the study showed that there were differences in total quantity of carbon sequestered in the different agricultural land utilization types in the study area (table 3). The highest quantities of 4257t/ha of SOC were stored in groundnut + maize agricultural land use. This was attributed to the difference of plant biodiversity and groundnut plants were allowed to decayed and decomposed on the farm land after harvesting the pods thereby increasing the quantities of organic matter which also result in proportional increase in soil organic carbon. This is in tandem with the result obtained by Bationo *et al*.(2007) in studying soil organic carbon dynamics, functions and management in West African agro-ecosystems reported rapid increase of SOC levels with differences in plant biodiversity. Lowest carbon stocks of 2620t/ha was stored in oranges + maize agricultural land use. Also, the study revealed that SOC were mostly stored in the surface layer (0-15cm) of the soil across the different agricultural land use types compare to the sub- surface layer (15-30). The application of manure tends to increase soil organic matter because of the supply of nutrients and organic material to the soil surface and most of the soil organisms are concentrated in the top 0 - 20 cm of soil because C substrates are more plentiful there. Microorganisms use litter and other organic compounds for respiration, where organic material is mineralized and CO_2 and inorganic elements are released within the soil.

Table 3: Total quantity of soil organic carbon (gC m^{-2}) stored in the study soils

Agric. Land use type	Soil depth (cm)	Soil Bulk density(g/cm3)	Carbon stock (gcm^2)	Carbon stock per hac (t/ha)	Total carbon stock (t/ha)
Maize sole	0-15	1.51	13.82	1382	2659
	15-30	1.33	12.77	1277	
G/nut + maize	0-15	1.74	22.97	2297	4257
	15-30	1.42	19.60	1960	
Oranges + maize	0-15	1.52	13.45	1345	2620
	15-30	1.25	12.75	1275	

Conclusions:

There are many factors and processes that determine the direction and rate of change in SOC and soil chemical content, when land use practices are changed. This includes increasing the input rates of organic matter which is important for increasing SOC storage and other soil chemical properties. Conditions favoring these processes generally occur when soils are converted from cultivated use to plant biodiversity ecosystems. To obtain a higher predictive capability of detecting changes in SOC and chemical properties of soil; additional empirical studies are needed combined with a better understanding of the biological and physical processes

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involved and additional long term experiments that address SOC and soil chemical dynamics when land is converted from one agricultural land use to another with known management histories would be valuable in improving our understanding and increase our predictive capability over short and long time scales.

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