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Soil Organic Carbon Variations and Selected Soil Chemical Properties As Affected By Different Land Use Types in Benin (South-Southern Nigeria)

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Abstract
Soil organic carbon is an essential component of soil quality assessment. It determines soil chemical and physical properties, soil fertility and ultimately soil productivity. Essentially, organic carbon storage in soil organic matter has a way of mitigating climate change by reducing greenhouse gas emission. This study therefore examined the soil organic carbon content of different land use and selected soil chemical properties. Organic carbon at the soil depth of 0-25cm in four different land use namely Rubber age (Young rubber; 3-10yrs;, Middle aged : 12-20 yrs.; Old rubber : > 25yrs), Fallow/ forest, Arable farm and Residential area were examined. Organic carbon revealed significant differences among the land use types considered. Highest organic carbon of 33.4 g kg-1 was obtained in the fallow/forest while the lowest was recorded for residential (13.4g/kg) land use. However, there existed significant differences in soil pH, exchangeable acidity, ECEC, Base saturation, Fe and the land use types. The lowest soil acidity (highest pH) of 4.7 was obtained at the young rubber plots, while the lowest pH of 4.41 was obtained in the old rubber plots. The pH values obtained from the old rubber compared favorably with the 4.48 value obtained from the forest soils. Result also shows that fallow/forest land use with the highest organic carbon content had a corresponding significant value for exchangeable acidity, ECEC and Mg, while the concentration of Ca and Cu were highest for same land use. This implies that soils with high organic carbon enhance soil fertility, hence, forest and fallow soils had more organic matter than the other land use type. Agricultural activities that will promote soil organic carbon like manuring, little or no tillage, crop rotation, allowing the land to fallow for couple of years and afforestation should also be encouraged through agricultural extension education and farmers' demonstrations plots will in no measure conserve soil fertility and organic soil carbon and consequently mitigate climate change effects.

Keyword*; Land use, organic carbon, rubber age, Arable farm and Forest*

Introduction

Soil organic carbon (SOC) is a component of soil organic matter which is a fraction of the soil that comprises of decomposed plant and animal materials as well as microbes. These exclude fresh and un-decomposed plant material like straw and litter on soils surfaces. Soil organic carbon is paramount in all the aspects of soil fertility, namely the chemical, physical and biological fertility (Quedraogo et al., 2007). When Soil organic matter decomposes major nutrient elements like Nitrogen, phosphorus and a range of other nutrients elements are released for plant growth. Soil organic carbon also promotes soil structure by holding the soil particles together as stable aggregates, improves soil physical properties like the water holding capacity, water infiltration, gaseous exchange, root growth and ease of cultivation (Chan, 2008).

Increase in soil organic matter has a long way to improve soil health and help to mitigate climate change. Especially when increase in the atmospheric CO_2 is reduced after they are stored in the terrestrial ecosystem as soil organic carbon (Carbon sequestration). The world soil had been reported to contain an important pool of active carbon which plays an important role in the global carbon cycle, Lal 1995, Melillo *et al* 1995, Prentice *et al* 2001). The soils contain roughly twice as much carbon as the atmosphere and 2.5times as much as the biota (Anikwe, 2010 and Davidson *et al* 2000). Soil organic carbon is found in the upper twelve inches of the soil and can be readily depleted by anthropogenic disturbances like the issues of land use changes and cultivations. Different land use and soil managements greatly influence soil organic carbon dynamics and carbon flux from the soil (Batjes 1996, Tian *et al.*, 2002). Examples of some of the land use and practices that has potential to sequester SOC are converting crop land to pastoral and forest lands, conventional tillage to conservation and no tillage, regular addition of manure to specific fertilization rate (Rasmussen *et al.*, 1980; Ismail *et al.*, 1994; Campbell *et al.*, 1997; Paustian *et al.*, 1997; Smith *et al.*, 1997; Rasmussen *et al.*, 1998; Dick *et al.*, 1998; Huggins *et al.*, 1998; Collins *et al.*, 1999; Post and Kwon, 2000). Also Soil nutrients and soil processes like erosion, oxidation, mineralization and leaching depend on land use and soil managements practices. (Celik,2005 and Liu *et al.*, 2010). Therefore it can modify the process of nutrient redistribution and transportation (Liu et al., 2010).

There is the need to quantify soil organic carbon and some selected soil properties in order to predict their changes in response to different land use. Such analysis can be used to estimate organic carbon and nutrient storage in both cultivated and semi-natural ecosystem. This study therefore was conducted to generate information on soil organic carbon variations and selected soil chemical properties as affected by different land use types in Benin (South-Southern Nigeria).

Materials and Methods

Description of Study Areas:

This study was carried out in Rubber Research Institute of Nigeria (RRIN) main station at Iyanomo (near Benin City), Ikpoba-Okha Local government Area of Edo State, within the conventional rubber growing belt of Nigeria. The Iyanomo study area (Fig 1) occupies a land area of 2070 hectares that has no record of a comprehensive soil inventory. It is situated about 29 kilometers away from Benin City. The main access road is through Obaretin Village situated at km 19, Benin-Sapele highway. The study area has a fairly rectangular shape. The Area is located within the co-ordinates of 5º 34'E and 5º 38'E Longitudes; 6º 08'N and 6º 11'N Latitudes bordered by Ogbekpen village (southwest); Benin Owena River Basin Development Authority [BORDA] (south east); Uhie village (Northeast) and Obayantor village (northwest). The study area is characterized by hot humid tropical climate with a dominant rainy season and two or three months dry season. Relative humidity (> 70 % average) is high almost throughout the year, sunshine hour vary widely between three (3) to nine (9) hours/day during the rainy and the dry seasons respectively. Rainfall is fairly distributed with 85 -95 % falling within the nine months from March to October. The mean annual rainfall is about 1952 mm in Benin city and has a bimodal having two peak raining periods with a higher peak in July and the lesser peak in September and a short dry spell usually, in August. An average of more than 16 raining days per month usually occurs from May to October. Soil leaching is also strong in the months of April to October when rainfall exceeds evapotranspiration and soil moisture storage capacity which is estimated at 100 mm per one meter of soil (Ojanuga, 2006) and is lower than the rainfall amount during these months. High Temperature is usually recorded throughout the year. Mean annual temperature of about 26ºC and evapotranspiration of 1150 mm have been observed in Benin

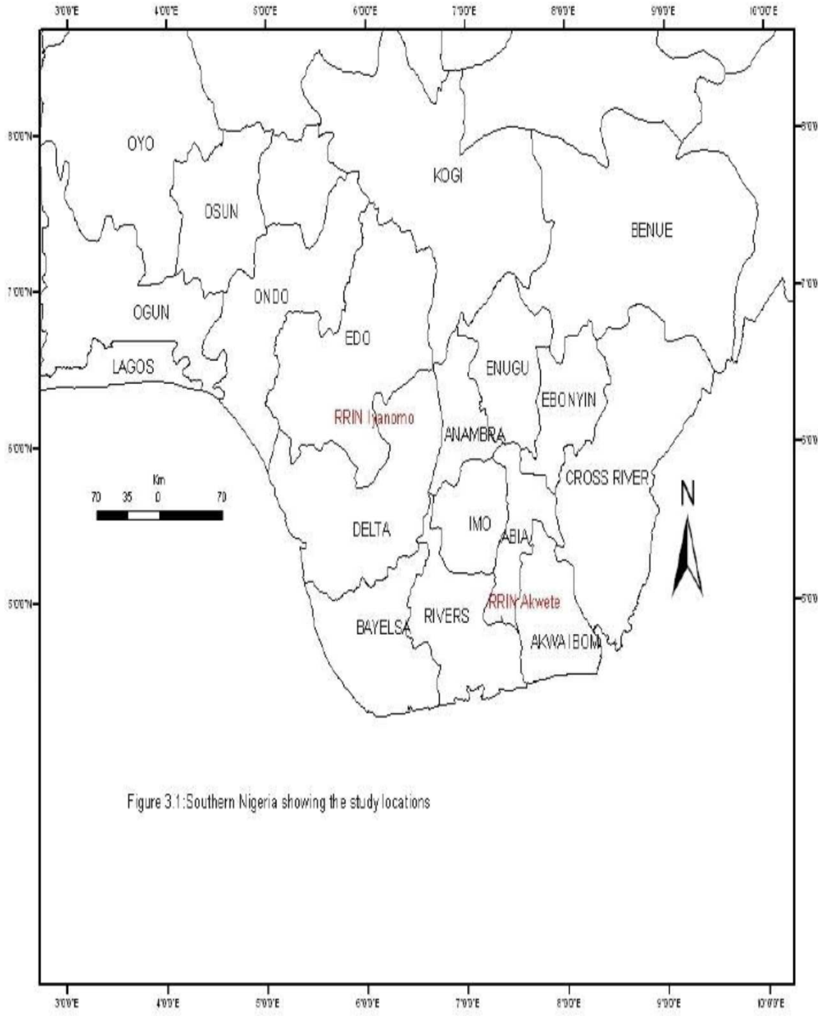

Fig 1: Southern Nigeria showing Iyanomo the study location.

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Laboratory analysis

Soil samples were passed thru 2mm sieve after air drying. The soil samples were then analyzed using the following standard laboratory procedures:

Particle size analysis was carried out using the Bouyoucous hydrometer method (Gee and Or, 2002). While Soil bulk density as a ratio of the dry mass to volume was determined in triplicate from undisturbed core samples (Grossman and Reinsch, 2002). Total porosity was derived from the relationship of particle density to the bulk density using the formula $1- [\rho s/\rho b]$ x100. Where ρs = particle density and ρb = bulk density. The average particle density of mineral soils (1.65 kg m-3) was used for the computation. Saturated hydraulic conductivity was determined in the laboratory using undisturbed core samples that were saturated overnight, using the modified falling-head method suggested by Klute (1965). Soil moisture characteristics was determined by subjecting saturated core samples to 0, 10, 20, 30, 40, 50 and 60 cm suctions on a pressure plate apparatus. Soil pH was determined potentiometrically in water and in KCl. In water, 10g of soil sample to 25ml of distilled water was added (ratio 1:2.5) while pH in KCl was also determined at a ratio 1:2.5 soil to solvent and the readings were taken using the glass electrode (Methler) pH meter buffered at pH 7. Organic carbon was determined by the Walkley-Black wet oxidation method (Walkley and Black, 1934). Exchangeable bases (Ca, Mg, K, Na) were extracted with IN NH4OAC (pH 7). Exchangeable Ca and Mg were determined by atomic absorption spectrometer while K and Na by flame photometer (Black, 1965). Exchange acidity (A13+, H+) was determined by titration of soil solution with IN KCI (Black, 1965). Extractable micronutrients, Mn, Zn, Cu and Fe were leached with 0.1N HCl using the method of Wear and Summer (1948), and were determined on the atomic absorption spectrophotometer. Effective CEC was computed by the summation of exchangeable bases (Ca, Mg, K and Na) and exchange acidity (Al and H).

Data Analysis

One way Analysis of variance was used to determine the effects of land use types in rubber estate on soil properties. Means were separated by the Duncan Multiple Range Test (DMRT) at 0.05 probability level. Correlation was also done to detect the relationships between soil carbon and other soil parameters.

Results

Effect of Land use types on soil properties

The effects of rubber cultivation and some associated land use types including young rubber aged 3-10 years old, middle-aged rubber of 12-20 years old, old rubber above 25 years old, Fallow/ forest and arable farming land use types on surface soil properties at the Iyanomo study area are presented in Tables 1 and 2. There were no significant changes in Available P, Ca, Na, K, Cu Mn and Zn (Table 1). However, soil pH, organic carbon exchangeable acidity, ECEC, Base saturation and Fe showed some significant differences among the land use types considered. The lowest soil acidity (highest pH) of 4.7 was obtained at the young rubber plots while the lowest pH of 4.41 was obtained in the old rubber plots. The pH values obtained from the old rubber compared favourably with the 4.48 value obtained from the forest soils. While the highest organic carbon of 33.4 g kg-1 was obtained in the fallow, Ca and exchangeable acidity and Mg are highest in the fallow/forest land use types with 2.40, 1.68 and 0.94 cmol kg-1 respectively but are not significantly different from the 1.95, 1.19 and 0.91 cmol kg-1 of Ca, exchangeable acidity and Mg obtained at the old rubber plantations. Whereas Arable farm had the lowest values of 1.77, and 0.55 cmol kg-1 of Ca and Mg respectively, the juvenile rubber had the lowest exchangeable acidity with 0.6 cmol kg-1. The physical and microbial characteristics (Table 2) showed that the land use types did not bring any significant change in soil textural properties (sand silt and clay). The variation were however higher in sand and silt with standard error values of ±35.0 and ±34.17 respectively. Also, the lowest bulk density (BD) and by implication the highest total porosity was obtained in middle aged rubber with 1.09 kg m-3 and 58.74 % for BD and total porosity respectively. Microbial counts in the Iyanomo study area showed that the forest soils are more favourable for bacterial growth with a highly significant 84.1 x 103 count**.** Correlation between soil organic carbon and the chemical and physical parameter examined were not significant. However some positive relationship between Organic carbon in the soil and the following parameters: ECEC, Exchangeable acidity, Na, bacteria count, Total porosity and Fe were recorded. While the following parameter negatively correlated with soil organic Carbon: pH, Na, Mn and sand.

Table 2: Effects of different land use types associated with rubber cultivation on the chemical properties of the surface soils
Landuse

Land use/rubber age	pH (H_2O)	Avail P (mg/kg)	Organic C (g/kg)	Exch Acidity	Ca	Mg	Na	K	ECEC	B sat (%)	Fe	Cu	Mn	Zn
				---------------------------cmol/kg------------------							-------------mg/kg---------------			
Young rubber(3-10years	4.7a	13.3	18.5bc	0.6bc	2.00	0.80ab	0.29	0.40	4.29b	86.8ab	98bc	7.86	204.80	29.6
Middle aged rubber (12-20yrs)	4.5abc	15.6	29.4a	0.42c	1.95	0.81ab	0.26	0.56	3.83b	90.4a	91.5c	7.77	165.6	25.6
Old rubber (>25yrs)	4.41abc	18.5	29.7a	1.19ab	2.02	0.91a	0.20	0.26	5.34ab	95.0a	105.4abc	7.80	168.0	31.9
Fallow /Forest	4.48abc	16.5	33.4a	1.46a	2.40	0.97a	0.20	0.61	5.99a	75.7bc	118.9ab	8.37	175.8	32.5
Arable farm	4.30c	7.1	27.2ab	1.16ab	1.77	0.55b	0.25	0.38	2.26b	73.7c	111.0abc	7.13	188.7	30.2
SE of mean	0.12	5.72	4.04	0.30	0.26	0.14	0.12	0.24	0.64	5.19	10.06	0.68	22.05	5.15

Means bearing similar alphabets are not significantly different by DMRT (p = 0.05

Table 2: Effects of different land use types associated with rubber cultivation on selected physical and biological characteristics of the surface soils

Land use/rubber age	Sand	Silt	Clay	Bulk density (g/cm3)	Total Porosity (%)	Bacteria count	Fungal count
	-	-------g/kg------					
Young rubber (3-10years)	853.0	8.50	138.8	1.16ab	55.41ab	3.8	6.0
Middle aged rubber (12-20yrs)	814.0	5.60	180.3	1.09ab	58.7a	10.0c	9.8
Old rubber (>25yrs)	824.0	9.90	166.1	1.14b	56.85ab	41.3b	6.0
Fallow /Forest	799.0	7.30	193.6	1.10b	58.49a	84.1a	5.7
Arable farm	799.0	10.60	190.3	1.13a	57.31b	6.0c	10.7
SE of mean	35.0	6.15	34.17	0.43	1.65	0.013	0.064

Means bearing similar alphabets are not significantly different by DMRT (p = 0.05

Table 3: Pearson correlation coefficient of soil organic carbon and other soil parameters

Parameter	Significance
pH	-.624
Avail P	Ns
Exch acidity	.575
Ca	Ns
Mg	Ns
Na	-.842
K	Ns
ECEC	.571
Base saturation%	Ns
Fe	.495
Cu	Ns
Mn	-.841
Zn	Ns
Sand	-.834
Silt	Ns
Clay	.849
Bulk density	-.774
Total Porosity	.858
bacterial count	.718
fungal count	.054

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).
Ns :Not significant

Discussion

From Tables 1 and 2, it is obvious that the various land use types exerted profound influence on surface soil properties. Surface soils are the zone of plant nutrition and are of much interest to farming. The influence of land use on soil properties and formation led to the suggestion of Agbede (2009), that man's influence should be considered a separate factor of soil formation. Despite the reported export of nutrients through latex exploitation (Karthikakuttyamma, 1997), the soils under middle aged and old rubber plantations showed a lot of stability, resilience and soil health as defined by Van Bruggen and Semenov (2000) possibly due to high biological diversity and high levels of internal nutrient cycling. Under the tropical conditions of rubber cultivation in Nigeria, litter additions are rapidly decomposed under high soil temperatures and increased activities of soil microorganisms occasioned by the moist conditions. Organic matter therefore accumulates on the soil surface and thereby increases soil organic carbon. The extensive canopy cover in the rubber plantations helps to minimize erosion and run off losses thus the system eventually attains a nearly closed nutrient cycle in which the nutrient additions from the leave litter replaces to a large extent, nutrient uptake by the plantation.

The pH of soils from the different land use was not significantly difference even though they were acidic. This characterizes the nature of soils form Benin according to Ogeh and Ukodo (2012). These areas are prone to higher rainfall which could be responsible for the leaching of basic cations making the soil to be acidic. The pH of soil under the younger rubber trees was however higher than in the other land use type. Available P; Phosphorus content among the land use type falls within the critical level of 10 – 16 mgkg-1 (Adeoye and Agboola 1985) except that of the arable land use type . The slightly high phosphorus value of Older rubber plantations type could be attributed to the fact that there is also an increase in its the organic carbon content a component of organic matter of same land use type. This is in support of the findings of Materechera and Mkhabela (2001) who reported that Organic matter influence P in soil solution by complexing P from adsorption site in ligand exchange and increase the mobility of inorganic P, particularly in acid soils, by decreasing chemical activity of iron and aluminum.

Highest organic carbon value were recorded in Fallow/forest soil .This could be attributed to the accumulation of organic matter over the period of fallow and the falling leaves which must have decayed over time to enrich the soil organic matter content. Exchange acidity of the younger and middle age plantation soil were very low. This could be as a result of the lower pH associated with these soils. The following parameter: ECEC, Ca, Mg, K, Fe, Cu and Zn were higher in fallow/forest land. High organic matter and clay content will cause an increase in ECEC. Mulugeta and Karl (2010) supported the idea that high clay soils can hold more exchangeable cations than a low clay containing soils. That is why the fallow/Forest soil has more basic cation and even micronutrients than the soils of other land use type. The positive correlation between Organic carbon and the folloing parameter; ECEC, Soil porosity and bacteria count had also been reported by Mulugeta and Karl (2010). The higher sand content of these soils could be attributed to the removal of clay particles by erosion because the study area is prone to high rainfall. The reason for the lowest bulk density of the middle age rubber land could be due to high clay content and the fact that there may be fewer disturbances on the land (Selassie et al., 2015).

Conclusion and Recomendation

The study also reveals that rubber plantations compared favorably with the forest or fallow land use type with respect to soil quality indices such as soil porosity, basic Cations, soil organic matter content and microbial populations (Bacteria and fungi). Soil organic carbon however increases when ECEC, Soil porosity and bacteria counts increases in the soils: while the following: soil pH, exchangeable acidity, Mn and sand have negative impact on the soil organic carbon. So that farming activities that will increase soil organic matter, ECEC and microbial population will enhance soil organic carbon. This can be an effective tools for land use planning and crop production.

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