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Determination of Soil Carbon Pools in Selected Soils of Abia State, Nigeria

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Abstract

Soil carbon pools exist in Abia State soils but variation, quantification and speciation remain unascertained. This study was carried out on soils collected from two locations (Umuahia North and Ikwuano LGAs) under three land use systems: arable land (AL), forest land (FL) and palm plantation (PP). The aim of the study was to assess carbon pools in the study soil. Laboratory data was subjected to analysis of variance (ANOVA) in Randomized Complete Block Design (RCBD). Significantly different means were separated using Fisher's least significant difference (F-LSD) at 5% level of probability ($p \leq 0.05$). Correlation analysis was used to assess the relationship between the selected soil properties. It was observed that organic carbon increased significantly ($p<0.05$) 2.47 under forest land in Umuahia North and decreased to 0.97 under arable land in Ikwuano, permanganate oxidizable carbon (POC) increased significantly in Umuahia North ($p<0.05$) while decreasing in Ikwuano, the POC interaction on the both locations were significant, water soluble organic carbon (WSOC) and microbial biomass carbon (MBC) were neither significant in location, land use or their interaction.

Keywords: Soil, Organic carbon pools, Microbial biomass carbon, Permanganate oxidizable carbon and variation.

1.0 Introduction

Soil natural carbon assumes an extremely vital part in the dependability and fertility of soil and is impacted by various management practices. Soil organic carbon (SOC) is quite possibly one of the most broadly utilized soil health markers. In terrestrial ecosystems, it determines the fertility and productivity by improving the physical, chemical and biological properties, and also useful in predicting climate change and its effects (Krischbaum, 2000). Land use/land cover change is one of the key elements that influence the soil natural carbon pool. The transformation of tropical forests into other land uses like manors and croplands through anthropogenic exercises may act as a carbon source (Fan *et al.*, 2016; Byrne et al., 2020; Igbal and Tiwari, 2016). Golchin and Asgari (2008) observed that at the point when natural woodlands are switched over completely to croplands, the soil structure gets disrupted improving the mineralization of natural matter by organisms accordingly prompting SOC reduction. Plant characteristics regulate soil carbon storage through the outcomes of C assimilation and its storage in the soil system (De Deyn, 2008).

The presence of SOC and its connected supplements contribute decidedly and successfully to soil versatility. Most as of late in an efficient survey, Obalum et al, (2017) featured the significance of soil natural matter as the sole mark of soil debasement in this way focusing on the requirement for preserving the SOC pool. Nevertheless, owing to the disastrous environmental consequences of global climate change, recent concern have shifted from the importance of carbon in food production to more concerted studies on the quantities, distribution, kinds, and dynamics of carbon in different ecosystems (Nwite and Okolo 2017).

In any case, transformation of land use altogether affects soil natural matter (Abbasi and Rasool 2005). Changes in agricultural practices-notably changes in crop varieties, application of fertilizer and manure, rotation and cultivation practices affect quantity and rate of carbon storage or release from soils. Carbon enters the soil as roots, litter, harvest residues and animal manure (Matazu *et al*, 2024). It is stored principally as soil natural matter. The density of carbon is highest near the surface, but soil organic matter decomposes rapidly, releasing CO_2 to the atmosphere. There is huge decrease in topsoil natural matter (Mohawesh, 2015), as a subsequent of progress from forest to arable farming. Farming and other land use rehearses impact how much carbon can be sequestered and the way in which long it tends to be put away in the soil before it is returned to the atmosphere (Tieszen 2000). The best methodologies center around the assurance of soil natural carbon against additional consumption and disintegration, or the renewal of exhausted carbon stocks through specific administration procedures (Anikwe 2010). The aim of this study is to assess carbon pools in the soil of forest, arable cropping and palm plantation of Ikwuano and Umuahia North Local Government Areas (LGAs) of Abia State.

2.0 Materials and Methods

2.1 Study Area

The study was carried out in two locations within Abia State, they include; Ikwuano LGA and Umuahia North LGA. Ikwuano LGA is located within latitude $5^0 27^1$N and longitude $7^0 35^1$E while Umuahia North is located within latitude $5^0 32^1$N and $7^0 29^1$E. The two locations are highly populated, with Ikwuano L.G.A having a typical average population density of 2100 occupants for each square kilometer (Adindu *etal.,*2012), Umuahia North likewise has a population of 220,660 individuals (National Population Census (NPC), 2006); (Chukwu,2013).

2.2 Climatological Data of the Study Area

The agro-ecological climatic state of the region is commonplace of the tropics, having average annual temperature of 27^0C and relative humidity range of 80-90% (National Root Crop Research Institute – NRCRI, 2002). The locations have a mean annual rainfall of 2201.92 mm (Nigeria Meteorological Agency, 2015). The rainfall is bimodal, starts in April and ends in October with peaks in July and September (Nigeria Meteorological Agency, 2015). The soils of the two locations are derived from coastal plain sand parent materials.

2.3 Soil Sampling and Location Description

The soil sample for laboratory analysis was collected using an auger and core samplers. (core sampler of a 5cm diameter and 5cm height). It was collected from three (3) land use systems in the two (2) locations and replicated six (6) times within the depth of 0-30 cm. This constituted 18 samples from each location and a total of 36 samples from the two locations. Boundary effects were observed and the Global Positioning System (GPS) was used to obtain the sample point directions/slope and elevation. The auger soil samples were used for the analysis of particle size distribution, organic matter, and aggregate stability. The samples were air dried and passed through a 2mm sieve to remove stones, roots and un-decomposed organic materials. Undisturbed soil samples were used for the analysis of bulk density, total porosity and moisture content and saturated hydraulic conductivity.

2.4 Soil Analysis

Particle size distribution was analysed by the hydrometer method as outlined by Kettler *et al.,* (2001). The organic carbon level of the soil sample was determined by Walkely and Black method (Nelson and Summers 1982). Water Soluble Organic Carbon (WSOC) was analyzed by the method of Mazzarino et al. (1993). The procedure used for permanganate oxidizable carbon determination is synonymous with the 'Active Carbon' method described by Weil et al. (2003). Soil microbial biomass carbon was measured by the chloroform fumigation-incubation method as described by Jenkinson and Powlson (1976). Bulk density was analyzed by the method as described by Blake (2003).

Table 2.1: Location and history of the three land use types used for the study

Name	Location	Year of existence and history	Land cover descriptive features
Forest land (FL)	Umuahia North (Apiece) and Ikwuano (Umudike)	Natural forest land has been in presence for over 60 years. The forest is saved to catch biodiversity which might be lost from the other land use. The region is barricaded Entrance into the forestland is extremely severe, with the exception of significant exploration purposes.	Some major trees found in the forest included; Ogbono, gmelina, whisling pine, *Allanblackia floribunda*,olive family (Clusiaceae) *Brachystigia eurycoma*, *Milicia excels*,*Treculia Africana* and *Pterocarpus osun*.
Arable land (A L)	Umuahia North (Umueze) Ikwuano (Isiala Oboro)	These lands have been under ceaseless use beyond 40 years. The land was manually tilled.	The major planted crops were *Manihot esculenta*, and *Zea mays*.
Palm plantation (PP)	Umuahia North (Nkwoegwu) Ikwuano (Nnono)	The palm plantations have been in existence for over 30 years.	*Elaeis guineensis, Ageratum conzoides, Emilia sonchifolia, Mimosa invisa and Nephrolepis*

2.5 Statistical Analysis

Laboratory data was subjected to analysis of variance (ANOVA) to assess variations in selected properties in the study soils. Means were separated using Fisher's least significant difference (F-LSD) at 5% level. Correlation analysis was used to determine the relationship between the selected soil properties. Spatial variation of selected soil properties was carried out using a geo-statistical package.

3.0 Results and Discussion

3.1 Soil Particle Size Distribution

The table 3.1 shows the particle size distribution of the soils studied. The result showed that the sand particle was highest in arable land (79.63%) under Ikwuano location, followed by palm plantation (72.97%) in Ikwuano, indicating that these land uses had more soil disturbance and erosion than forest land (71.63%) in Umuahia North. There was also a significant difference among the land uses for clay percentage, which implies that this clay content was influenced by the management practices and vegetation cover of each land use. There was also a significant interaction effect between location and land use for sand percentage, meaning that sand size varies depending on the combination of location and land use. However, there was a significant difference among the locations for clay percentage, meaning that this property was influenced by the geological and climatic factors of each location studied in the survey.

3.2 Bulk Density, Total Porosity and Saturated Hydraulic Conductivity

Table.3.2 shows the effects of location and land use on bulk density (BD), total porosity and saturated hydraulic conductivity (Ksat). The table indicates that there was no significant difference in BD and total porosity between the two locations, but there is a significant difference in Ksat. This suggests that the soils in Umuahia North have higher permeability and drainage than the soils in Ikwuano.

Table.3.2 also showed that there was a significant difference in bulk density, total porosity and Ksat among the three land uses: arable land, forest land and palm plantation. These results indicate that forest land has the most favorable soil conditions for water movement and storage, while arable land had the least favorable soil conditions. The result also reveals that there is no significant interaction effect between location and land use on bulk density and total porosity, but there were significant differences in saturated hydraulic conductivity.

Forest land may have lower bulk density and higher total porosity and Ksat than arable land and palm plantation because of lower compaction, higher organic matter content, higher biological activity and higher aggregation; this is in line with the reports of Birhanu et al (2016), Amir et al, (2010).

3.3 Forms of carbon

Table 3.3. shows the values of different carbon fractions in soils from two locations (Umuahia north and Ikwuano) and three land uses (arable land, forest land and palm plantation). The mean organic carbon (OC) content was higher in Umuahia north (2.15%) than in Ikwuano (1.75). It was observed that the mean microbial biomass carbon (MBC) content was significantly lower in Umuahia north (17.60 Ug/kg) than in Ikwuano (19.20 Ug/kg). The mean permanganate oxidizable carbon (POC) content was significantly higher in Umuahia north (88.30 Ug/kg) than in Ikwuano (54.40 Ug/kg). However, the mean water-soluble organic carbon (WSOC) content was similar in both locations (0.397% and 0.406%, respectively).

The results also showed that the organic carbon (OC) content was highest in forest land under Umuahia north (2.47%) and lowest in arable land under Ikwuano (0.97%) among the land uses. This may indicate that forest land has more organic matter input and less decomposition than arable land, which is subject to cultivation and erosion. Microbial biomass carbon (MBC) content was highest in forest land under Umuahia north (23.20 Ug/kg) and lowest in arable land under Ikwuano (13.80 Ug/kg) among the land uses. This could suggest that forest land has more microbial activity and turnover than arable land, which may have lower soil moisture and nutrient availability. From table 3.3, it was observed that permanganate oxidizable carbon (POC) content was highest in forest land under Umuahia north (103.40) and lowest in palm plantation under Ikwuano (50.20) among the land uses.

Table 3.1: Particle size distribution of the soils studied

Location	Land use	Sand (%)	Silt (%)	Clay %	Textural class
Umuahia north	Arable land	79.53	7.03	13.44	Sandy loam
	Forest land	73.13	6.87	20.00	Sandy loam
	Palm plantation	74.13	10.87	15.00	Sandy loam
	Mean	**75.60**	**8.26**	**16.15**	
Ikwuano	Arable land	79.63	8.37	12.00	Sandy loam
	Forest land	71.63	6.90	21.47	Sandy loam
	Palm plantation	72.97	7.20	19.83	Sandy loam
	Mean	**74.74**	**7.49**	**17.77**	
LSD $_{(0.05)}$ location		NS	058	1.889	
LSD $_{(0.05)}$ land uses		NS	0.71	2.314	
LSD $_{(0.05)}$ interaction		1.36	1.01	NS	

This may reflect that forest land had more labile organic matter that can be easily oxidized by permanganate than arable land, which may have more recalcitrant organic matter. The water-soluble organic carbon (WSOC) content was highest in arable land (0.412%) and lowest inpalm plantation (0.398%) among the land uses.

Table 3.2: Bulk density, total porosity and saturated hydraulic conductivity of soils studied

Location	Land use	BD (g cm^{-3})	Total porosity (%)	Ksat (cm^3 hr^{-1})
Umuahia north	Arable land	1.50	40.19	23.40
	Forest land	1.32	50.06	67.10
	Palm plantation	1.45	39.75	42.20
	Mean	**1.50**	**43.33**	**44.23**
Ikwuano	Arable land	1.52	41.26	25.00
	Forest land	1.38	47.80	66.70
	Palm plantation	1.48	40.19	36.20
	Mean	**1.51**	**43.08**	**42.60**
LSD $_{(0.05)}$ location		NS	NS	4.21
LSD $_{(0.05)}$ land uses		0.0476	1.798	5.15
LSD $_{(0.05)}$ interaction		NS	NS	7.29

BD= bulk density; Ksat= saturated hydraulic conductivity

Table 3.3: Forms of carbon in soils studied

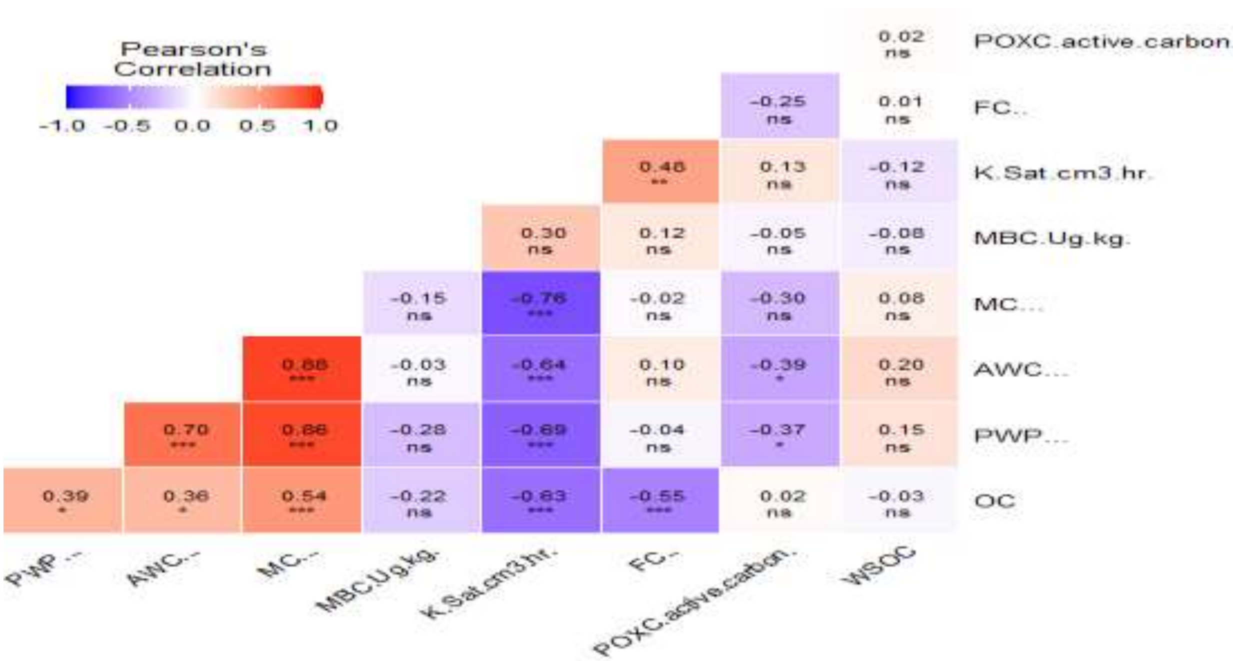
Location	Land use	OC (%)	MBC (Ug/kg)	POC	WSOC (%)
Umuahia north	Arable land	1.56	14.50	73.40	0.400
	Forest land	2.47	23.20	103.40	0.393
	Palm plantation	2.04	15.10	88.00	0.398
	Mean	**2.15**	**17.60**	**88.30**	**0.397**
Ikwuano	Arable land	0.97	13.80	59.80	0.412
	Forest land	2.12	21.50	73.10	0.407
	Palm plantation	2.13	22.30	50.20	0.398
	Mean	**1.75**	**19.20**	**54.40**	**0.406**
LSD $_{(0.05)}$ location		0.213	NS	8.090	NS
LSD $_{(0.05)}$ land uses		0.261	NS	NS	NS
LSD $_{(0.05)}$ interaction		NS	NS	14.01	NS

OC= organic carbon, MBC= microbial biomass carbon, POC= permanganate oxidizable carbon, WSOC= watersoluble organic carbon

This may imply that arable land has more soluble organic matter that can be leached by water as supported by (Al- Graiti et al 2022) who stated that SOM in arable land is mobile, reactive and available by diffusion and convection to all compartments of the soil environment than palm plantation, which may have more insoluble organic matter.

3.4 Correlation between the measured forms of soil carbon and hydrological properties

Figure 3.1 shows the correlation between the measured forms of soil carbon and the hydrological properties. The result showed that organic carbon had a positive significant relationship with permanent wilting point (0.39*) at p<0.05, available water content (0.36*) at p<0.05 and moisture content (0.54***) at p<0.001. Moreover, organic carbon had a negative relationship with saturated hydraulic conductivity (-0.63***) at p<0.001 and field capacity (-0.55***) at p<0.001. This shows that as organic carbon increases, the moisture content also increases while saturated hydraulic conductivity reduces.



ns=P>0.05 *=p≤0.05 ** p≤0.01 and ***p≤0.001

Figure 3.1. A correlogram showing the relationship between some soil carbon pools and hydrologicalproperties in the study soils

positive significant relationship with available water content (0.70***) at p<0.001 and moisture content (0.86***) at p<0.001 and also a negative correlation relationship with saturated hydraulic conductivity (-0.69***) at $p<0.001$ and permanganate oxidizable carbon (-0.37*) at $p<0.05$.

The correlation relationship in the study shows that organic carbon plays an important role in influencing the hydrological properties of the soil. Organic carbon can improve the soil structure, porosity, water retention and infiltration, and reduce soil compaction and erosion. The negative correlation between permanganate oxidizable carbon and permanent wilting point, available water content and saturated hydraulic conductivity suggests that permanganate oxidizable carbon is a more labile form of organic carbon that is easily decomposed by microbes and usually contributes much to the soil hydrological properties. The positive correlation between permanent wilting point, available water content and moisture content reflects the consistency of these parameters in measuring the soil water status.

4.0 Conclusion and Recommendation

From the study, it was observed that the particle size distribution of the soils studied varied according to the location and land use. The results also indicated that soil water characteristics vary significantly among different land uses and locations in the study area. The soils in Ikwuano had higher water holding capacity and plant available water than those in Umuahia North. The impact of land use on soil water characteristics was consistent across the two locations, as there was no significant interaction between land use and locations.

The results of this study indicate that the organic carbon fractions varied with location and land use in the study area. The location effect was significant for POC, which was higher in Umuahia North than in Ikwuano, due to differences in soil texture, climate, and vegetation. The land use effect was significant for OC, MBC, and POC, which were higher in forest land than in other land uses, likely due to higher organic matter input and preservation in forest land. The WSOC was not affected by location or land use, suggesting that it is a relatively stable fraction of organic carbon in the soil.

There was a strong link between soil carbon and hydrological properties. The permanganate oxidizable carbon, which reflects the labile part of soil natural matter, also influenced the hydrological properties, but in a negative way. This suggests that different forms of soil carbon have different roles and impacts on soil hydrology.

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