Soil Carbon Sequestration Potentials of Four Different Land-Use Types in Ogba/Egbema/Ndoni Local Government Area, Rivers State, Southern Nigeria

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Abstract
The determination of the potential of soil for carbon sequestration is important because of the issue of global warming, which is a threat to human life. This information is not readily available in Ogba/Egbema/Ndoni Local Government of Rivers State. To this end, the study was conducted to determine the carbon potential and carbon dynamics in soils of four different land use types (pipeline right of way, crop cultivated land, forested land, and fallow land use) in Okposi, Omoku, and Obrikom communities. Disturbed and undisturbed soils were taken at three depths (0-20, 20-40, 40-60cm). The data were subjected to descriptive statistics. From the result, the Total organic carbon ranged from 1.053 – 5.421 %. The forested land use type had the highest total organic carbon of 2.220- 5.421 %, followed by crop cultivation land use type with values of 3.560-4.630 % while soils of pipeline right of way had the least TOC of 1.053- 1.780 % and the highest bulk density. The soil organic carbon stock was further calculated in (t C/ha), and the SOC stock ranged from 0. 610912 – 2.166840 t C/ha. The highest SOC Stock was recorded in crop cultivation land use type with values ranging from 1.845504 – 2.166840 t C/ha, followed by forested land use type at 0-20cm having values of 1.910360 t C/ha. High carbon sequestration in cassava cultivation plots could be attributed to the age, type of vegetation, and plants' ability to capture and store atmospheric carbon since young plants sequester more carbon than old ones.

Keywords: *carbon sequestration, land use types, global warming, climate change, soil organic carbon stock, total organic carbon.*

1.0 Introduction
Soil carbon sequestration, the process of capturing and storing atmospheric carbon dioxide in the soil organic matter has emerged as a critical strategy for mitigating climate change. Soil can either be a source or sink for atmospheric carbon dioxide depending on land use and management of soil and vegetation (Lal, 2005) because Soils are important reservoirs of active organic components (such as carbon dioxide, methane, and nitrogen) that play a significant role in the global cycle of these elements. Steven proposed that over 60% of the world's carbon is held in both soils (more than 40%) and the atmosphere (as carbon dioxide; 20%) (Stevenson, 1994). Carbon sequestration is both the natural and deliberate ways by which CO_2 is either removed from the atmosphere or diverted from emission sources and stored in the ocean, terrestrial environments (vegetation, soils, and sediments), and geologic formations.

Different land use types have varying capacities to sequester carbon due to the difference in vegetation cover, management practices, and soil properties. Carbon sequestration is also said to be the process of the capture and long-term storage of atmospheric carbon dioxide to mitigate global warming and avoid the dangerous impacts of climate change. In other words, it also refers to the process of removing carbon from the atmosphere and depositing it in a reservoir, which is usually at the subsurface of the earth. This carbon storage or reservoir is also known as a carbon pool. Carbon pool refers to a system or mechanism which can accumulate or release. It can be natural or human-induced. Examples are forest biomass, wood products, soils, and the carbon pools in a forest are a complex mix of live and dead organic matter and minerals. Human-induced carbon pools are geological storages of carbon dioxide. The quantity of carbon in a pool is known as carbon stock and any change may be an express process of carbon sequestration.

The earth's temperature has risen alarmingly over the past 20 years than ever all because of human activities which have led to an imbalance in the natural carbon cycle thus resulting in global warming and the greenhouse effect. Human activities such as the burning of fossil fuel, and incomplete combustion of carbon from transportation, generators, and production processes release more carbon into the atmosphere than it is removed naturally. This has consequently put the earth on the path of global warming and climate change.

Global warming and climate change refer to an increase in average global temperatures. Natural events and human activities are believed to be contributing to an increase in average global temperatures. This is caused primarily by increases in “greenhouse” gases such as carbon dioxide. Climate change is a global threat that needs urgent action from the global community. All countries will be affected by climate change and its impacts, particularly developing countries.

The accumulation of carbon in the atmosphere is dangerous to life and the ecosystem. If the atmospheric carbon is not sequestered there will be a continuous increase in the effect of greenhouse gases and global warming thereby causing more harm to humans and the ecosystem at large (National Energy Technology Laboratory, NETL, 2003). This project is necessary because the information gained will ultimately lead to a reduction in the intensity of carbon and stabilize the overall concentration of atmospheric CO_2. Considering that oil and gas production is high in Ogba/Egbema/Ndoni Local Government Area in Rivers State, there will be a need to balance the production of fossil fuel with sequestration in carbon. In Southern Nigeria, where agriculture and land use changes are prevalent, understanding the soil carbon sequestration potentials of different land use types essential for sustainable land management and climate mitigation is very essential.

2.0 Materials and Methods

2.1 The study area

The study was conducted in Ogba/Egbema/Ndoni Local Government Area of Rivers State also called’ ONELGA’ or Ali-Ogba which it’s central ‘Omoku’. ONELGA stretches from about latitude: $5^0$20’18.00” N or (5.400016^0N) and longitude $6^0$39’11.99” E (6.632433^0E). Spatially, it covers an area of 626 sq mi or (1,620 $km^{2)}$ in the northern part of the Niger Delta region located within Niger Delta flood plains. It is bordered on the west by the Orashi River and on the east by the Sombrero River. The area is typically a rural and semi-urban agrarian setting with reported declining land productivity associated with more than forty years of neglect due to the production of oil and gas. Three representative communities: Obrikom, Omoku, and Okposi, were randomly selected for the study.

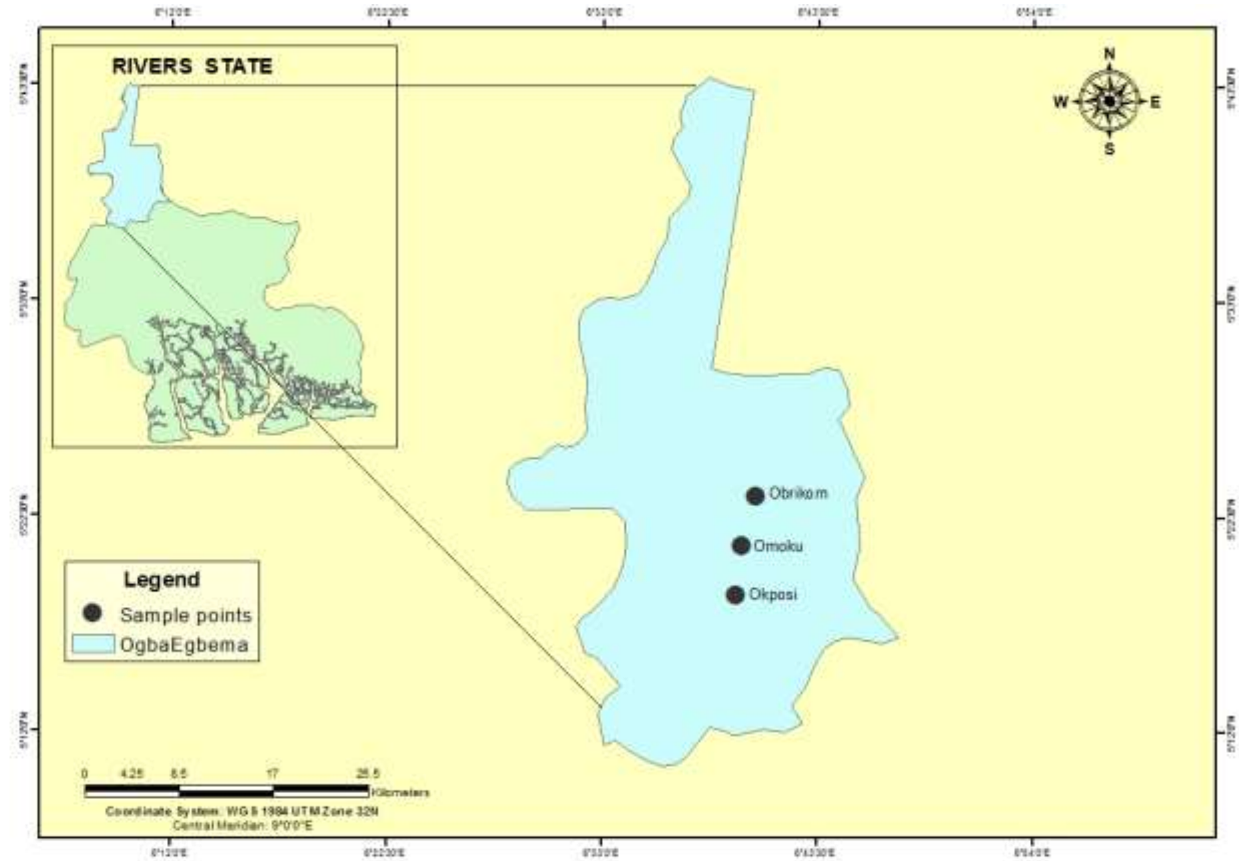

Fig1: Map of Rivers State showing the Study Area

2.2 Field Study and Laboratory Analysis

Four land use types (pipeline right of way, cassava cultivated land, forested land, and fallow land use) in three communities (Okposi, Omoku, and Obrikom) were randomly selected. Twelve minipedons were studied. A total of 36 samples of disturbed and undisturbed soils were taken. Soil samples were collected from the minipedons at three depths (0-20, 20-40, 40-60cm). Three samples were collected from each pedon. A cylindrical corer of 5cm diameter and 5cm height was used. Undisturbed soil samples for determination of bulk density(BD) were collected and determined as described by Grossman and Reinsh (2002), while the disturbed samples were taken for the Physico-chemical analyses.

2.3 Soil Organic Carbon Stock Determination

Soil samples were crushed and allowed to pass through a 2mm sieve to obtain uniform subsamples and further ground with mortar and pestle to pass through a 0.5mm sieve. Organic carbon was obtained after soil oxidation with a dichromate-sulfuric acid mixture using the Walkley Black method (1934). The stock was obtained from Bulk density (BD) and organic carbon concentration with the following equation:

$$SOC(kg/m^2) = \frac{OC(gkg^{-1}) \times \rho_b(Mg/m^3) \times ST(m) \times FEC}{100}$$

Where $SOC(kg/m^2)$ is the stock of soil organic carbon, OC is the organic carbon concentration, ρ_b is the measured or calculated bulk density, ST is the soil layer thickness, and FEC is the fine soil content.

3.0 Results and Discussion

The properties of the soil at the surface and subsurface soils from the different land use types studied are presented in Tables 1 and 2.

Table 1: carbon dynamics and nitrogen in the soil

Location identity	TOC (%)	N (%)	Inorganic (%)
L9 (0 – 20 cm)	1.78	0.142	0.3276
L9(20 –40cm)	1.36	0.120	0.3480
L9(40 – 60 cm)	1.273	0.071	0.4728
Mean	1.470	0.111	0.3828
L8(0 – 20 cm)	3.66	0.255	0.3096
L8(20 –40cm)	3.06	0.211	0.3600
L8(40 – 60 cm)	2.50	0.120	0.3000
Mean	3.073	0.1953	0.3232
L11(0 – 20 cm)	4.63	0.198	0.2844
L11(20 – 40 cm)	3.94	0.175	0.3240
L11(40 – 60 cm)	3.56	0.172	0.3780
Mean	4.043	0.1817	0.3288
L10(0 – 20 cm)	3.63	0.255	0.3360
L10(20 – 40 cm)	2.964	0.111	0.3408
Mean	3.2970	0.1830	0.3384
L5(0 – 20 cm)	1.51	0.165	0.4056
L5(40 – 60 cm	1.053	0.148	0.3360
Mean	1.2815	0.1565	0.3708
L4(0 – 20 cm)	2.028	0.268	0.3900
L4(40 –60cm)	1.86	0.198	0.3276
Mean	1.9440	0.2330	0.3588
L3 (0-20cm)	5.421	0.465	0.5400
L3 (20-40cm)	2.390	0.295	0.4692
L3 (40-60cm)	2. 220	0.200	0.4968
Mean	3.3437	0.3200	1.1748
L6 (0-20cm)	4.35	0.270	0.4908
L6 (40-60cm)	2.27	0.178	0.3660
Mean	3.3100	0.4480	0.4284

Table 2: SOC Stock in t C/ha

Location identity	TOC (g/kg)	B.D (Mg/m^3)	SOC Stock (kg/m^2)	SOC Stock (t C/ha)	Land use types
L9 (0-20cm)	17.80	1.107	0.078814	0.788184	Pipeline right Of way
L9 (20-40cm)	13.60	1.123	0.061091	0.610912	
L9 (40-60cm)	12.73	1.220	0.062122	0.621224	
L8 (0-20cm)	36.60	1.194	0.285336	1.749480	Fallow land
L8 (20-40cm)	30.60	1.195	0.146268	1.462680	
L8 (40-60cm)	25.00	1.221	0.178608	1.786080	
L11 (0-20cm)	46.30	1.1701	0.216684	2.166840	Cassava cultivated plot
L11(20-40cm)	39.40	1.245	0.196212	1.962120	
L11(40-60cm)	35.60	1.296	0.184550	1.845504	
L10 (0-20cm)	36.30	1.164	0.169013	1.691028	Fallow land
L10 (40-60cm)	29.64	1.185	0.140494	1.404936	
L5 (0-20cm)	15.10	1.636	0.098814	0.988144	Pipeline right of way
L5 (40-60cm)	10.53	1.799	0.075774	0.757738	
L4 (0-20cm)	20.30	1.101	0.089368	0.893687	Cassava cultivated plot
L4 (40-60cm)	18.60	1.220	0.090768	0.907680	
L3 (0-20cm)	54.21	0.881	0.191036	1.910360	Forested land
L3 (20-40cm)	23.90	0.954	0.091202	0.912024	
L3 (40-60cm)	22.20	1.157	0.102742	1.027416	
L6 (0-20cm)	43.50	0.859	0.149466	1.494660	Forested land
L6 (40-60cm)	22.70	0.912	0.082800	0.828005	

3.1 Carbon Forms and Dynamics in Soils

The soil carbon content varied significantly among the different land use types studied.

The data on carbon forms are presented in (Table 1). The total organic carbon (TOC) contents of soils ranged from 1.053 to 5.421 (%) in soils of the different land-use types, while the inorganic carbon content ranged from 0.2844 to 0.5400(%) across the different land-use types. Soils of pipeline right of way had TOC that ranged from 1.053 to 1.78 and inorganic carbon ranged from 0.3276 to 0.4056(%). Soils of cassava cultivated land TOC ranged from 1.86 to 4.63 (%), while inorganic carbon ranged from 0.2844 to 0.3900 (%). The soils of forested land use had TOC that ranged from 2.22 to 5.421 (%) and inorganic carbon ranged from 0.3660 to 0.5400 (%), while the fallow land-use type had TOC that ranged from 2.50 to 0.3600(%).

From the result, forested land-use type has the highest percentage of total organic carbon and inorganic carbon. This is because forests contain huge reservoirs of carbon in their vegetation and soils (Percy et al., 2003). According to Batjes, Forest ecosystems retain more than 80% of all terrestrial aboveground C and more than 70% of soil organic carbon (Batjes, 1996, Jobbagy and Jackson, 2000, Six *et al.*, 2002). Cassava cultivated land-use type has the second-highest percentage of TOC, followed by the fallow land-use type then the pipeline right of way had the least TOC. Also from the results, pipeline right of way has the second highest percentage of inorganic carbon, followed by cassava cultivated land-use type, and fallow land-use type has the lowest percentage of inorganic carbon. The differences in carbon content among land use types can be attributed to variations in vegetation cover, land management practices, and soil organic matter decomposition rates. Generally, the values reported in this study were low compared to those reported by Kamalu, O. J. (2015) in selected communities of Ogba/Egbema/Ndoni Local Government Area of Rivers State, Nigeria. The significant variations in total organic carbon (TOC) and inorganic carbon across the land-use types investigated may be attributed to heterogeneity in the characteristics of land-use patterns, rainfall, and temperature regimes. Furthermore, higher TOC content of the forest, crop cultivated, and fallow land-use types may be attributed to the organic carbon contents (3.3302, 3.2036, 3.1628) of these soils. The low organic carbon content of the pipeline right of way, cassava cultivated land-use could be a consequence of the land-use pattern, agricultural practices, climate, and soil conditions that favor rapid decomposition. Conversion of natural forest to cultivated land.

Inorganic carbon in soil occurs largely in carbonate minerals such as calcium carbonate (CaCO3) and dolomite (MgCO3) (Schlesinger, 1990; Sombroek *et al*., 1993). The average inorganic carbon content of the soils across all the land-use types ranged from 0.2844 to 0.5400 (%). The highest percentage of inorganic carbon was observed in forested land-use type (0.5400%) while those of crop cultivate land-use type had the lowest percentage 0.2844 (%). The low significant quantity of inorganic carbon of crop cultivated land-use types could be attributed to low pH and total carbon present in these soils. Batjes (1996) stated that acid and strongly weathered soils do not contain an appreciable quantity of inorganic carbon because the carbonates originally present in the parent materials have been dissolved.

3.2 Carbon Sequestration in Soils

The Carbon sequestration of soils derived from the different land use types varied between 0.621224 and 2.166840 t C/ha (Table 2). The highest Soil Organic carbon stock was observed in the cassava cultivation plot having values of 0.893687 – 2.166840 t C/ha. The second highest SOC stock was recorded in forested land with values of 1.910360 at depth (0-20cm). The third highest SOC stock was recorded in fallow land with values ranging from 1.404936 – 1.749480 t C/ha and the least SOC stock was recorded in pipeline right of way with values ranging from 0.621224 – 0.988144 t C/ha. From the result, the highest carbon stock was observed at a depth (0-20cm) across the different land uses except for location 4 (cassava cultivation plot) which had its highest carbon stock at a depth (40-60cm). The trend of carbon sequestration under the different land use types was: Cassava cultivation plot > Forested land > Fallow land > Pipeline Right of Way.

The relatively lower carbon sequestration capacities of the forested land than that of the cassava cultivation plot may be a consequence of the low bulk density values observed despite its high total organic carbon content than that of the cassava cultivation plot. On the other hand, the lowest carbon stock of the pipeline right of way may be due to the lowest TOC values in the soils although it had the highest bulk density values than all the other land use types.

In addition, high carbon sequestration in cassava cultivation plots could be attributed to the age, type of vegetation, and plants' ability to capture and store atmospheric carbon since young plants sequester more carbon than old ones (Johnston *et al*., 2009, Poulton *et al*., 2003, Mba and Idike., 2011) reported high carbon sequestration in alley cropping farm than in forest soils.

The removal of top soil layer acting on the Pipeline Right of Way is responsible for both low TOC and Carbon Stock. The higher bulk density is associated with the impact of traction and overburden along the Pipeline.

Data obtained in this study corroborates the findings of several other authors that the ability of soil to capture and retain carbon is a function of bulk density, texture (Blanco-Canqui, H., & Lal, R(2009), land use and management (Guo, L, B., & Gifford, R. M, 2002), and farming system(Lal,2024), irrigation and tillage (Del-grosso et al., 2005), tillage techniques (Allmaras et al., 2004, Anikwe et al., 2003), cropping intensity and vegetation cover (Ortega et al., 2002) and nitrogen inputs to soil (Potter et al., (1997). Given this, land use type, and vegetation age are among the factors that influenced carbon in the soils investigated. The carbon sequestration capacity of the soils across the land use types was within the range reported by Mba and Idike, (2011) (2435-6429 gCm2) but higher than 62.48 -127.68 t/ha of Abebayehu (2013) and Eswaran et al., (1995).

4.0 Conclusion

The findings of this study highlight the significant role of land use types in carbon sequestration in the Ogba/Egbema/Ndoni local Government area of Rivers State, Southern Nigeria, and determined both the carbon stock and sequestration of these soil in the different land use. We discovered that cassava-cultivated land and forested land use contributed significantly to carbon storage in the soil emphasizing the importance of conservation and sustainable land management practices. Implementing strategies to conserve existing forests, promote crop cultivation, and agroforestry, and incorporate fallow periods into agricultural practices can enhance soil carbon sequestration efforts, thereby contributing to climate mitigation in the region. Therefore, Afforestation and reforestation initiatives to increase forest cover and enhance soil carbon sequestration should be encouraged in the area. Crop cultivation especially, cassava and agro-forestry practices that integrate the trends of agricultural landscapes to improve soil carbon storage while providing additional benefits such as biodiversity conservation and erosion control should be promoted. Farmers in the area should implement soil conservation practices such as reduced tillage and, a fallow period of at least two years of cropping to minimize soil disturbance and enhance soil organic matter and soil carbon replenishment.

Declaration of Competing Interest

The authors of this work declare that there is no conflicting interest associated with this study.

Authors Contribution

Ekeh Favour Chioma: conceptualization, analysis, draft writing, methodology, validation, editing.
Kamalu Jas Onyinyechi: supervision and editing.
Needam Great Baritosaen: Map delineation and editing
Idibia Faith Akumjeri: Data anlysis

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