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Research Article

Influence of Land Use Types on Carbon Bioaccumulation InAchalla and Mamu Forest Reserves, Anambra State, Nigeria

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Abstract

This study examined the carbon bioaccumulation capacities of Achalla and MamuRiver Forest reserves in Anambra State as influenced by land use types. Profile pits measuring 0.60m×0.60m×0.60m were constructed in the residential, deforested, taungya and non-impacted land use areas within each forest reserve. Soil samples were collected from the depths of 0-20cm, 20-40 cm, 40-60cm and analyzed for physico-chemical properties -particle size, porosity, organic matter and carbon, cation exchange capacity, pH, total nitrogen. Data collected were subjected to T-test to compare the carbon bioaccumulated in the two forest reserves while ANOVA was used to ascertain the influence of different land use types and significant means were separated using Duncan multiple range test at 5% level of probability. The result showed that there was no significant difference in carbon accumulation in the forest reserves with Mamu (1.213±0.185)>Achalla (0.797±0.103). There was also no significant difference ($p > 0.05$) within and between land use types in different forest reserve with respect to soil physico-chemical properties in MamuRiver Forest reserve except in Achalla forest reserve on the pH-H_2O ($p < 0.05$) with the pH as residential < deforested < taungya < non-impacted LUTsin the non–impacted land use types. This revealed that the non–impacted area have the highest organic matter content that potentially facilitated carbon bioaccumulation for climate change mitigation in Anambra State and suggest the need to restrict exploitation, expansion of residential and taungya lands as check to improve carbon sink in the forest reserves.
Keywords: Forest reserves; land use types; organic matter; carbon; pH range

Introduction

Carbon has in recent times become the currency of environmental management in the forestry subsector due to the critical role it plays in the sustained yield management objective, global carbon decapitalization schemes and indexing of dynamic forest ecosystems (Sanderman et al., 2010; Hoyle, 2013). The forest ecosystems store more carbon per unit area than any other land use type, with the soils accounting for approximately 40 percent of the total carbon (Hillel and Rosenzweig, 2011), with the legally constituted forest reserves notably holding higher bioaccumulation terrestrial carbon of over 312Gt carbon representing 15% of terrestrial carbon stock (Campbell et al, 2006).

Forest reservation in Nigeria accounts significantly in the management of forest resources for the attainment of set national and international goals. Constituted forest reserves occupy approximately 99,991.92km^2 representing 10.99% land area protected as forest reserve across Nigeria, with the southeast accounting for barely 446.31km^2 of the area of forest reserved (Onochie, 1984; FAO, 2010) [19, 9]. However, the relatively intact forest reserves and adjoining free area community forests have been altered by inadvertent land use practices through gradual encroachment for resources essentially that represent over 80% of daily household requirement in rural communities where products are packaged as primary goods for urban populace. This chain of forest ecosystem reliance has resulted in growing pressure and over exploitation with significant reduction in the annual proportionate organic matter return for the sustenance of forest ecosystem and effectively contribute to sequestering carbon. This increasing anthropogenic activities reportedly accounted for less carbon bioaccumulation with approximately 15-17 million ha per annum lost in the tropics (FAO, 2004).

Although the implications of forest lost have been well documented (FAO, 2011), the threat to soil organic C lost, with commensurate rise in global CO_2 emission has been attributed to poor forest resources management across the globe, especially in developing nations as a result of intense pressure for scarce economic potentials of the timber and non-timber forest resources, land hunger for agriculture and food security as well as urban growth and infrastructural development (Butler, 2005; Mojiri, et al, 2011; Erika et al, 2015). These carbon footprints have contributed immensely to approximately 20% of total global emission warming and climate change (Brown and Gaston 2007; Cao et al. 2001) due to reduced turn over and residence time of organic matter deposits in forest floor layers (Robert, 2004b; Cerriet al., 2006) that have a key influence on the physical and chemical properties of soils.

The increase in exploitation of forest resources above the allowable annual cuts, de-reservation of forest reserves for infrastructure and deforestation for agricultural programs due to population have been reported in different geopolitical zones of Nigeria (FAO, 2016; Popoola, 2018). The free area forest in communities have been destroyed following unregulated patterns of harvest and exploitation and replaced with agricultural tree crops. More so, under the communal forestry hold regime, the capacity for forest regeneration as veritable source for carbon mitigation and management have been unappreciable as agriculture and other development are more preferred to carbon mitigation. MOE (2014) reported higher degradation and deforestation in community forests in the lowland rainforest and derived savannah forest compared to protected areas which became adopted as pilot areas for the UN-REDD+ and carbon credit scheme programs in Delta State. This same opinion holds for the private sector forest investors' scheme that till date has remained a mirage in addition to the long gestation period, which ordinarily is the ecological benefit with respect to carbon sequestration. These failures with respect to community and private forest estates in Anambra State, has therefore greatly entrenched the capacity for carbon bioaccumulation andsequestration to the protected forest reserves across the State as the major sources of sink. Unfortunately, urbanization, inter-state boundary crisis and encroachment of donor community have led to de-reservation of Osamala, degradation of Mamu river and Achalla forest reserves respectively in Anambra State with significant loss in contribution to the global carbon decapitalization scheme. Even amidst the shrinkage of reserved forest landscape, the remnant forest reserves are under pressure with latent encroachment by degradation form unseen land use patterns that typically undermine carbon capture and return within the forest ecosystem.

Therefore, monitoring of activities that influence the capacity of forest reserves to accumulate carbon cannot be overemphasized because changes in vegetation due to encroachments for either forest resources or residential permits could lead to reduction. This study was aimed at determining the capacity of Achalla and MamuRiver Forest reserves to store soil organic carbon in the different land use types that have been accommodated over time by the regulatory agencies in pursuit of revenue generation and sustained yield management objective.

Materials and Methods

Description of study area

This study area consisted of two forest reserves-MamuRiver Forest reserve in Orumba North L.GA of approximately 46.9km^2 and Achalla forest reserve in Awka North with approximately 2.19km^2 in Anambra State between latitude 5˚32`and 6˚ 45`N and longitude 6˚43` and 7˚22`E in South eastern Nigeria (Figure 1). The study areas have tropical rain forest vegetation that is predominantly grassland, with scattered forests and woodlands. The annual rainfall total exceeds 3500mm with mean maximum and minimum temperatures of 32°C and 21°Crespectively (NiMet, 2019).

These forest reserves were constituted in 1930 and currently managed for timber and pole production with plantations of fast growing *Tectona grandis* (Teak) and *Gmelina arborea* (Gmelina) that were established at various times. There are relics of indigenous tree species in Achalla due to swamp forest that pose difficulty to timber extraction. *Gmelina arborea* made up the emergent layer of the strata; *Chlorophora excelsa* and *Khaya grandifolia* constituted the dominant layer while *Piptadeistruimafricanaum*, *Tectona grandis* and *Brachystegiaeurycomamade* up the abundance of the intermediate layer in Mamu river forest reserve (Bodman, 2019).

There are camps within the forest reserves that provided accommodation for transiting taungya farmers. However, these have become residentials that till date still encroach deeper toward the forest reserve edges. High traffic and frequency of collection both timber and non-timber forest products were observed during the study.

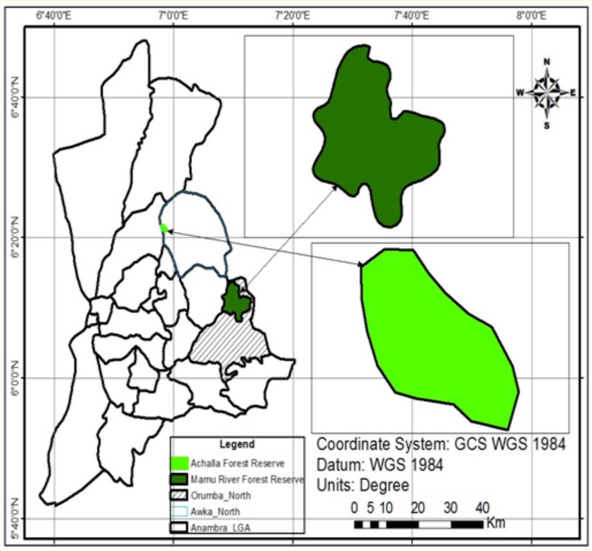

Figure 1: Map showing Achalla and MamuRiver Forest reserves in Anambra State.

Data collection and analyses

A reconnaissance survey was first carried out to establish the four land use types that included - residential, taungya, deforested, and non–impacted areas in each forest reserve. A profile pit of 0.60m×0.60m×0.60m were constructed in each land-use area in each forest reserves. Twenty-four (24) soil sample are collected at 0-20, 20-40, 40-60cm at four (4) samples per depth range.

These were analyzed for physicochemical properties- Particle size distribution by Bouyoucos hydrometer method as described by Gee and Bauder (1986), pH with a pH meter in 1:2.5 soil: water ratio (Mclean, 1982), total nitrogen using micro-Kjedahl method (Jackson, 1962), available phosphorus by Bray No. 1 method (Bray and Kurtz, 1945), organic carbon by dichromate oxidation method (Walkley and Black, 1934), exchangeable cations (K, Ca, Mg and Na) were extracted with 1M NH_4OAc and the amounts in extracts were then determined using the atomic absorption spectrophotometer (Thomas, 1982). The base saturation was determined by calculating the exchangeable base forming cation (mol/kg) with cation exchange capacity in mol/kg, it is expressed in percentage.

Data collected were subjected to analysis of variance (ANOVA) and significant means were separated with the Duncan Multiple Range Test (DMRT) at 5% probability level.

Result

The result of descriptive statistics was used to determine the capacity for carbon bioaccumulation is shown (Table 1). The total mean organic carbon in Achalla forest reserve was 9.56%with minimum and maximum means of 0.43%and 1.73% respectively. Mamu recorded a minimum mean of 0.51% and maximum of 2.47%with a total mean of 14.55%.The mean organic carbon of Achalla forest reserve irrespective of the land use is 0.797 while of MamuRiver Forest reserve is 1.213.

Table 1: Soil organic carbon bioaccumulation status

Forest Reserve	*Soil Properties*	*Mini*	*Maxi*	*Total*	*Mean± Std. Error*
Achalla	Organic carbon	0.43	1.73	9.56	0.797±0.103
Mamu	Organic carbon	0.51	2.47	14.55	1.213±0.185

The result of T-test conducted to compare the difference in organic carbon in the forest reserves is shown (Table 2). There was no significant difference in the accumulation of soil carbon between the forest reserves ($p = 0.63>0.05$).

Table 2: T-test comparison of soil organic carbon in the forest reserves

	Std. Error Difference	*Df*	*T*	*Mean Diff.*	*p-value*	*F*
Organic carbon	0.212	22	-1.960	-0.416	0.063	2.514

Effect of the land uses on soil physio-chemical properties

The result analysis of variance conducted on the effect of land use in carbon bioaccumulation (Tables 3 and 4). There were no significant differences in all the physico-chemical properties between and within land use types in Achalla except for pH ($p= 0.002 \leq 0.05$).

In MamuRiver Forest reserve, there was no significant differences among the different land use types. The physico-chemical properties within individual as well as between land use types were not significantly different ($p > 0.05$).

Table 3: Effects of the land use types on soil physical properties in Achallaand Mamu

Soil Properties		*Forest Reserve*			
		Achalla		*Mamu River*	
		F	*Sig*	*F*	*Sig*
Sand	Between LUTs Within LUTs	0.166	0.917ns	1.322	0.333ns
Silt	Between LUTs Within LUTs	2.153	0.172ns	0.935	0.467ns
Clay	Between LUTs Within LUTs	0.302	0.823ns	0.553	0.660ns
O.M	Between LUTs Within LUTs	0.212	0.885ns	0.629	0.616ns

Legend: Not significant-ns

Table 4: Effect of land use types on soil chemical properties in Achalla and Mamu

Soil Properties		***Forest Reserve***			
		Achalla		***Mamu River***	
		F	***Sig***	***F***	***Sig***
pH	Between LUTs Within LUTs	12.898	.002*	2.371	.146ns
O.C	Between LUTs Within LUTs	.213	.884ns	.616	.623ns
TEA	Between LUTs Within LUTs	.655	.602ns	.473	.710ns
Al^{3+}	Between LUTs Within LUTs	.938	.466ns	.174	.911ns
H+	Between LUTs Within LUTs	.486	.701ns	.810	.523ns
TN	Between LUTs Within LUTs	.230	.873ns	.592	.638ns
Ca^{2+}	Between LUTs Within LUTs	2.602	.124ns	.341	.796ns
Mg^{2+}	Between LUTs Within LUTs	.429	.738ns	1.367	.321ns
K^{+}	Between LUTs Within LUTs	2.012	.191ns	.110	.952ns
Na+	Between LUTs Within LUTs	.353	.788ns	1.029	.430ns
CEC	Between LUTs Within LUTs	1.214	.366ns	.498	.694ns
BS	Between LUTs Within LUTs	1.673	.249ns	.868	.496ns
P(mgkg^{-1})	Between LUTs Within LUTs	1.176	.378ns	.977	.450ns

Legend: LUTs- Land use types; H+- hydrogen ion; TN-total nitrogen;; OC-organic carbon; OM- organic matter; TEA- total exchangeable acidity; Al- aluminumCa2+- calcium; K+- potassium;Na+- sodium; CEC- cation exchange capacity; BS- base saturation; P-phosphorus;ns-Not significant; *-significant

Effect of land use on pH

The follow-up test conducted with Duncan multiple range test (Dmrt) showed that the pH of the non–impacted land use area (6.55) was significantly different in Achalla forest reserve. There were no significant differences in the mean pH of deforested area (pH=5.41), residential area (pH=5.02) and taungya (pH=5.55) in Achalla forest reserve.

The soil reaction in Achalla forest reserve is as shown (Table 5). The pH was residential < deforested <taungya< non-impacted land use types. There were no significant differences ($p \geq 0.05$) between the pH of residential, deforested and taungya land use types.

However, the pH in non-impacted land use type was significantly different from the other land types.

Table 5: Effect of land use types on pH (H_2O) in Achalla forest reserve

Land Use Types	***N***	***Subset for alpha = 0.05***	
		B	***A***
Residential area	3	5.02	
Deforested area	3	5.41	
Taungya farm	3	5.55	
Non-impacted area	3		6.55

Means under the same alphabet are not significantly different (p > 0.05)

Discussions

The minimum organic carbon in both reserves were quite low (<1.00%) while the maximum was high. The mean carbon bioaccumulated in Achalla was low (0.40-1.00%) compared to Mamu with moderate (1.00-1.50%) as classified by the USDA. These bioaccumulation values which actually reflect the organic matter return rate to the forest reserves implied that Mamu have better organic matter rating than Achalla forest reserve (Brown and Gaston, 2008). This may not be unconnected with the higher traffic for removal of various forest resources, especially the unregulated thinning regime of Teak for electric poles, in comparison to Mamu that is managed for timber. This finding agrees with Clark et al (2008) that protected areas constitute significant legal land use change and potentially plays an important role in maintaining carbon sink.

However, there was no significant difference (p≥0.05) in the organic carbon bioaccumulated in the two forest reserves. This actually showed the trend of carbon profile in the reserved areas and the likely contribution of Anambra State to the global carbon decapitalization scheme. Even though low, the mitigation ratio is in consonance with Article 3.4 of the Kyoto Protocol that soil organic carbon stored in forest soils represent 36% of the total carbon soil pool to 1m (NASEM, 2019).

Furthermore, only pH at 0.002≤0.05 showed significant difference in the soil physico-chemical properties in Achalla forest reserve and with significantly highest value in the non–impacted area than other land use areas in the same reserve. The soil reaction in Achalla forest reserve showed four wide pH spectrum band from the very strongly acidic (pH 4.5-5.0) residential area to the strongly acidic (pH 5.1-5.5) deforested area. The taungya area was moderately acidic (pH- 5.6-6.0) and pH 6.6-7.3 as neutral for the non-impacted forested area (Schoenebergeret al, 2012). This wide pH range could be as a result of the various influence of land utilization types and depicted the level of organic matter degradation and effect on bioaccumulation of carbon (Kilic et al, 2012). This is because organic matter potentially acts as source of moisture storage that may significantly assist in the dilution of concentrate acidic soils. Consequently, the reduced quantity of organic matter in the residential and deforested areas may have been responsible for the very strongly to strong acidic conditions of these LUTs in Achalla forest reserve (Moges et al, 2013). In addition, the result showed the likelihood of nutrient lock-up in all the landuse types in Mamu as well as the residential and deforested LUTs in Achalla due to the pH indices that potentially regulate solubility of nutrients.

The combined silvical and agricultural organic matters seem to have equally accounted for the deviant pH in the taungya land utilization area even though it could not compare favorably with the non-impacted forest areas in the Achalla forest reserve with richer litter components as well as higher resident time due to more stable decomposition profile. This finding revealed that organic matters of forest origins may be better soil management materials for natural adjustment of acidic soils and carbon enrichment programs. This is because very few nutrients are below 5cm surface of the forest soil as most of them are contained within the vegetation and not the soil (Keks, 2009; Mbagwu and Scott, 2000). Therefore, the need to increase the forest tree species component in taungya LUT in Achalla and MamuRiver Forest reserves cannot be overemphasized. This implied that natural forest can be in dynamic equilibrium with regard to the physio–chemical properties under certain climatic condition but as soon as deforestation and any other anthropogenic activities set in unmitigated, the equilibrium will be affected (FAO 2008). This seems to be the case in Mamu forest reserve where the LUTs showed no significant difference in soil physico-chemical properties to assert that Mamu is under greater threat than Achalla forest reserve even though it showed higher organic carbon value which of course was statistically not significant.

Conclusion

The study revealed that land use types had more varying influence on the organic carbon bioaccumulation in Mamu forest reserves than Achalla forest reserve. The favorably carbon status of Achalla was as a result of the non-impacted and taungya land utilization areas with ambient pH spectrum that facilitated residence of organic matter for carbon mineralization and bioaccumulation. This therefore underpinned these land use types as probably better and richer carbon capture and return basins in the management of forest reserves in Anambra State and toward global climate mitigation.

References

1. Angers D and Eriksen-Bamel NS. "Full-inversion tillage and organic carbon distribution in soil profiles: a rneta-analysis". Soil Sci. Soc. Am. J. 72,1370-1374.Agronomy Journal 54 (2008): 464-465.
2. Bodman VJ. Mapping abundance of tree species with remotely sensed data at MamuRiver Forest reserve, Nigeria. B.For. and Wildlife Dissertation, Department of Forestry and Wildlife, Nnamdi Azikiwe University, Awka, Nigeria (2019).
3. Bouyoucos GH. Improved hydrometer method for making particle size analysis of soils (1962).
4. Bray RH and Kurtz LT. "Determination of total, organic and available forms of phosphorus in soils". Soil Science 59 (1945): 39-45.
5. Cao MK, QF Zhang and HH Shugart. "Dynamic responses of African ecosystem carbon cycling to climate change". Climate Research 17.2 (2003): 183-193.
6. Clark S, K Bolt and A Campbell. Campbell Protected areas: An effective tool to reduce emissions from deforestation and forest degradation in developing countries? Working paper. Cambridge, U.K: Denef, K (2008).
7. Erika R, Celso BL, Martin H, Erik L, Robert O, Arief W, Daniel M and Louis V. "Assessing change in national forest monitoring capacities of 99 tropical countries". Forest Ecology and Management 352 (2015): 109-123.
8. FAO. "Manual on integrated soil management and conservation practices". Land and water bulletin, 8, FAO, Rome (2004): 204.
9. FAO. "Global forest land use change from 1990 to 2005". Initial results from a global remote sensing survey (2011): 8.
10. FAO. "State of the World's Forests: Forests and Agriculture: Land-Use Challenges and Opportunities". Rome, Italy (2016): 1-126.
11. Gee GW and Bauder JW. "Particle size analysis in: Klute (ed). Methods of Soil Analysis". 2nd ed. No.9 ASA. Inc. SSSA Madison, Washington D.C (1986): 383-409.
12. Keks F. Forest soils. Department of Forestry and Environmental Management. MOUAU Journal (2009): 39-43.
13. Kilic C, Kilic S and Kocyigit R. "Assessment of spatio variability of soil properties in areas under different land uses". Bulgarian Journal of Agricultural Science 18 .5 (2012): 722-732.
14. Mclean EO. Soil pH and lime requirements. In: Method of Soil Analysis, (ed A. L. Page et.al), Part 2. Agronomy Monograph 9. American Society of Agronomy and Soil Science Society of America. Madison WI (1982): 199-224.
15. Mbagwu JLR and Scott TW. "Physical properties of three soils in Southern Nigeria". Journal SSN (2000): 136-148.
16. Ministry of Environment Scooping report for selected ecological zones for enrolment into the UNREDD+ Program in Delta State. Climate Change Unit, Ministry of Environment, Asaba (2014): 48.
17. Moges A, Magnachew M and Yimah F. "Land use effects on soil quality Indicator: A case study of Abo Wonsho Southern Ethiopia". Applied and Environmental Soil Science (2013).
18. Mojiri A, Emami N and Ghafari N. "Effects of land-use Changes on Soil Quality Attributes". American-Eurasian Journal of Sustainable Agriculture 5.1 (2011): 42-45.
19. Onochie CFA (1984). What is wrong with Nigerian Forestry? In: Okoro, O.O. and J.A. Fuwape (eds). Conservation and optimization of forest resources. Proceedings of the 14th Annual Conference of the Forestry Association of Nigeria held in Port Harcourt (1994).

20. Popoola L. "Emerging Issues in Sustainable Forest Management: Experiences and Lessons for Nigeria". Proceedings of the 40th Annual Conference of Forestry Association of Nigeria. Held in Lagos State (2018): 17-20.
21. Puget P, Chenu C and Balesdent J. "Total and young organic matter distributions in aggregates of silty cultivated soils". European Journal of Soil Science 46 (2006): 449-459.
22. Ryals R and Silver WL. "Effects of organic matter amendments on net primary productivity and greenhouse gas emissions in annual grasslands". Ecos Appl 23 (2013): 46-59.
23. Schoeneberger PJ, Wysocki DA, Benham EC and Soil Survey Staff. "Field book for describing and sampling soils". version 3.0. NRCS-NSSC, Lincoln, N.E (2012): 300.

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