International Journal of Research in Agriculture and Forestry
Volume 1, Issue 2, December 2014, PP 18-22
ISSN 2394-5907 (Print) & ISSN 2394-5915 (Online)

Soil Organic Carbon Storage as Affected by Physiographic Positions on a Caternary Landscape in an Ultisol in Owerri, Southeastern

M. A. Okon, G.E. Osuji, B.U. Uzoho, C.M. Ahukaemere

Department of Soil Science and Technology, Federal University of Technology,
Owerri, Imo State
mikedchosen@yahoo.com

Abstract: *The study was concluded to evaluate the influence of physiographic positions of acatenary landscape on soil organic carbon storage in an Ultisolin Southeastern Nigeria. The study area was cut into three physiographic positions: top slope, mid slope and foot slope. Transect survey technique was used to guide field sampling. Soil samples were collected at 0-15 cm and 15-30 cm depths on each physiographic position. Core samples were collected for bulk density determination. The samples were taken to the laboratory for laboratory analysis. Data obtained were subjected to analysis of variance, correlation and regression analysis. Results showed that soil organic carbon storage washigher in the top soil than in the subsoil. The values increased down the slope towards the foot slope with values of 90.48 g/m^2, 99.43 g/m^2 and 281.80g/m^2 respectively for the top soil of the top slope, mid slope and foot slope while the values for their sub soils were 136.75g/m^2, 137.34g/m^2 , and 331.93g/m^2 respectively. Soil organic carbon storage correlated positively with percent clay (r= 0.8), organic matter (r=0.7503), pH (r=0.4099), total nitrogen (r=0.9203) and Available P (r=0.7817) but negatively with percent sand (r= -0.7423) and bulk density (r=-0.2191).*

Keywords: *carbon storage, catena, topography, tropical soils.*

1. INTRODUCTION

Soil is one of the most important natural resources in the world and plays a central role in terrestrial ecology. It is an important reservoir of active carbon and plays a major role in the global carbon cycle. Research has shown that soil is the largest terrestrial sink for carbon on planet earth. It contains about three times more carbon than vegetation and twice as much as that present in the atmosphere (Batjes and Sombrock, 1997). According to (EPA, 2008a), forests and stable grasslands are referred to as carbon sinks due to their vegetation and root systemsfor long period of time. Therefore, deforestation will lead to loss of soil organic carbon in plant biomass and increase in CO_2 level in the atmosphere. Soil organic carbon plays a major role in crop production. It helps to sustain soil productivity by contributing to the physical, chemical and biological properties of soils. Hence, restoration of soil quality through soil organic carbon management is a major concern for tropical soils.

Foth (1984), defined catena as a sequence of soils about the same age, derived from similar parent materials and occurring under similar climatic conditions but having different characteristics because of variations in relief and drainage. Related soils differ in their properties primarily because of the influence of a catena. Soil properties vary with physiographic positions and parent materials. Lower slope positions are sites of accumulation resulting in deep colluvial soils while the upper soils have residual components (Satoh et al, 1990; Sobecki and Karathanasis, 1992).

Soils of southeastern Nigeria formed on unconsolidated coastal plain sands are characterized by the dominance of sandy textured fragments comprising larger quantities of coarse over fine textured materials, have low physical and chemical fertility due to dominance of low activity clays and inherent low organic matter contents (Ojanuga et al., 1981; ofomata, 1981). There is rapid degradation of arable soils due to anthropogenic factors leading to the depletion of organic matter content and the antecedent decline in soil productivity.

Recent concerns about green house gases and damage to the ozone layer have resulted in more concerned studies on the inputs, outputs and storage of carbon in different terrestrial systems. Thus this study aimed at determining the amount of soil organic carbon stored on the different physiographic positions on a catenary landscape and its relationship with some soil physicochemical properties.

2. Materials and Methods

Study Area: The study was carried out on an eroded catena in the Otamiri river water shed in the Teaching and research farm of Federal University of Technology, Owerri, Imo State. Owerri is located between latitude $5^0$25'N and $5^0$30'N and longitude $7^0$00'E and $7^0$10'E. The area has minimum and maximum ambient temperatures of 20^0C and 32^0C respectively and mean annual rainfall of about 2500mm (Igbozuruike, 1975). The soils of the area are derived from coastal plain sands known as acid sands (Benin formation). The soils are ultisols that are rich in free iron, but have low mineral reserve (Ofomata, 1975).

Field Study: Prior to soil sample collection, reconnaissance visit was made to the study site. The site was cut into three physiographic positions: top slope, mid slope and foot slope using transect survey techniques. Sampling points were located within the slope segments at 10m intervals along the transect.

Soil sample collection and Preparation: soil samples were collected randomly at 0-15cm and 15-30cm depth within each 10m interval at the three physiographic positions. The soil samples were air dried and prepared for laboratory analyses. Core samples were also collected for bulk density determination.

Laboratory Analyses: Soil organic carbon stock was computed by calculation using the formula below;

Soil organic carbon stock= organic carbon x bulk density x soil depth (Batjes, 1996). Bulk density was determined using core method (Grossman and Reinsch, 2002). Particle size analysis was done using Bouyoucos hydrometer method (Gee and Or, 2002). Soil pH was determined using 1:2.5 soil-water ratio with a pH electrode and values were read out from a pH meter (Hendershot et al., 1993). Total Nitrogen was determined by kjeldahl digestion method (Bremner, 1996). Organic carbon was determined using the chromic wet oxidation method (Nelson and Sommers, 1982). Exchangeable Ca and Mg were determined by the EDTA versanatetitration method (Thomas, 1982). Exchangeable Na and K were determined by the flame photometer method. Exchangeable acidity was measured by leaching the soil with 1N KCl and titrating with 0.05N NaOH (Mclean, 1982). Available Phosphorus was determined using Bray 2 method and exchangeable acidity (IITA, 1982).

Data Analysis

Results and data obtained were presented in tables and analyses done using analysis of variance, correlation and regression analysis. The means were separated using least significant difference (LSD).

3. Results and Discussion

Results of the soil organic carbon storage of the catenary landscape are shown in Table 1. The result showed that soil organic carbon storage was generally higher in the top soil than in the subsoil in all the physiographic positions in the landscape which can be as a result of the deposition of organic materials on the soil surface. The values increased down the slope towards the foot slope with values of 90.48g/m^2, 99.43g/m^2 and 281.80g/m^2 respectively for the topsoils of the top slope, mid slope and foot slope, while the values for their subsoils were 136.75g/m^2, 137.34g/m^2 and 331.93g/m^2 respectively. This can be attributed to erosion and washing away of organic materials from the top slope towards the foot slope. The low levels of soil organic carbon storage in the catenary landscape can be attributed to the low organic matter content of the soils. This is in corroboration with Ofomata (1981) that soils of Southeastern Nigeria have low physical and chemical fertility due to the dominance of low activity clays and inherent low organic matter content. The higher content of organic carbon at the foot slope which is about three times that of the top slope can be attributed to erosion and washing away of organic matter from the top slope and deposition on the foot slope.

Table 1. *Soil carbon stock in the studied catenary landscape*

Physiographic positions	**Depth (cm)**	**Soil carbon stock (g/m^2)**
Top slope	0-15cm	90.48
	15-30cm	136.75
Mid slope	0-15cm	99.43
	15-30cm	137.34
	0-15cm	281.80
Foot slope	15-30cm	331.93

The results of the physical properties of the study area are shown in Table 2. The result showed a preponderance of sand-sized fractions over the other sizes. This is in corroboration with (Ojanuga et al., 1981) that soils of Southeastern Nigeria formed on unconsolidated coastal plain sands are characterized by the dominance of sandy textured fragments. The textural class for soils at the top slope and mid slope ranged from loamy sand to sand while that of the foot slope ranged from sandy loam to loamy sand. The result also showed that the landscape had low bulk density values which were not up to the critical level of 1.85 indicating a low compaction level.

Table 2. *Physical properties of the study area*

Physiographic Positions	Depth (cm)	Sand (g/kg)	Silt (g/kg)	Clay (g/kg)	Textural class	Bulk density g/kg
Top slope	0-15	895.73	42.33	61.93	sand	1.45
	15-30	916.47	34.53	49.00	sand	1.42
Mid slope	0-15	890.00	49.90	60.40	sand	1.31
	15-30	904.00	34.83	61.17	sand	1.40
Foot slope	0-15	789.90	43.33	170.13	sandy	1.34
	15-30	856.73	34.40	108.87	Loam	1.39
$LSD_{(0.05)}$	18.85*	21.01*	569.1^{NS}		Loamy	0.091*

Table 3 shows the results of the chemical properties of the study area for each physiographic position. There were clear variations in the chemical properties, as the foot slope had higher content of organic carbon, total nitrogen and available phosphorus than the top slope and mid slope, but the mid slope had the highest ECEC and total exchangeable bases.

Table 3. *Chemical properties of the study area*

Physiographic Positions	Depth cm	pH	OM g/kg	TN g/kg	Avail P mg/kg	TEB	TEA	ECEC
						←	*Cmol/kg*	→
Top slope	*0-15*	*5.28*	*7.17*	*0.63*	*3.52*	*1.32*	*3.33*	*4.65*
	15-30	*4.58*	*5.53*	*0.30*	*1.92*	*0.56*	*2.76*	*3.32*
Mid slope	*0-15*	*5.29*	*8.73*	*1.03*	*0.10*	*6.76*	*3.47*	*10.23*
	15-30	*4.90*	*5.63*	*0.60*	*0.06*	*3.91*	*3.01*	*6.92*
Foot slop	*0-15*	*5.79*	*24.17*	*6.73*	*6.73*	*3.19*	*4.03*	*7.22*
	15-30	*5.20*	*13.73*	*5.33*	*5.33*	*1.75*	*3.13*	*4.88*
LSD(0.05)	*0.5369**	*0.134^{NS}*	*0.1244^{NS}*	*1.021**			*0.705^{NS}*	

OM= Organic matter TN=Total Nitrogen Avail P= Available Phosphorus TEB= Total Exchangeable Bases

TEA= Total Exchangeable Acidity ECEC= Effective Cation Exchange Capacity

The relationship between soil organic carbon storage and other selected soil properties are shown in Table 4. Soil organic carbon storage correlated positively and significantly with Total nitrogen (r=0.9203) at (P=0.01) and also with pH (r=0.7740), Avail P (r=0.7817) and clay (r=0.8)and organic matter (r=0.7503) at (P=0.05). This can be attributed to the decomposition of litter falls. As carbon was sequestered, nitrogen and phosphorus were also sequestered. Increased clay content down the slope also increased carbon because clay has high adsorptive capacity and can retain sequestered carbon and other nutrients more than other soil separates. Its correlation with Total Porosity was also positive but non significant with (r=0.1183). Soil organic carbon storage correlated negatively and non-significantly with sand (r=-0.7423), silt (r=-0.3271) and ECEC (r=-0.1485).

Table 4. *Correlation and Regression between Soil Organic carbon stock and selected soil properties*

Soil properties	r	r^2	Regression equation
Organic matter	*0.7503*	*0.563*	y=0.053x + 1.273
pH	*0.7740*	*0.599*	y=0.026x + 1.779
Total Nitrogen	*0.9203*	*0.847*	y=0.025x – 2.16
Available P	*0.7817*	*0.611*	y=0.021x – 0.860
ECEC	*-0.1485*	*0.022*	y=-0.003x + 6.86
Bulk density	*-0.2191*	*0.048*	y=-0.000x + 1.405
Sand	*-0.7423*	*0.551*	y=-0.339x + 936.4
Silt	*-0.3271*	*0.107*	y=-0.020x + 43.57
Clay	*0.8000*	*0.640*	y=0.366x + 19.46

Y=soil organic carbon stock, x=each soil property correlated with soil organic carbon stock.

4. CONCLUSION

The research work shows that different physiographic positions on a catenary landscape affect soil organic carbon storage. The footslope had higher amounts of soil organic carbon storage than the top slope and mid slope. This can be attributed to erosion and washing away of organic matter from the top slope towards the footslope. Therefore, based on the result of this work, it is recommended that agro forestry practices like alley cropping can be practiced on the top slope and mid slope to protect the soil from erosion and reduce the velocity of run-off. Furthermore, due to low fertility status of the area, practices involving the use of surface ameliorants such as compost manuring, green manuring and mulching should be incorporated into the farming system of the area to increase organic matter build up and subsequently soil organic carbon storage.

REFERENCES

Akamibgo, F.O.R. and Asadu, C.L.A. (1990) The influence of topography on some soil parameters in selected areas of Anambra state. Soil sci. Soc. Of Nig. Journal vol 6.

Batjes, N.H. (1996). Total carbon and nitrogen in the soils of the world.European Journal of Soil Science.Vol 47 Issue 2, Pp 151-163

Bremner, J.M. (1996) Nitrogen total. In: Methods of soil analysis, part 3, chemical method. 2nd edition.Soil science society of American book series. No 5, SSA, Madison W.I. Pp 1085-1121.

EPA, (2008a) Agriculture and food supply.http://epa.gov/climate/effects/agriculture.html.

Foth, H.D., (1984). Fundamentals of soil science (7thed). John Willey and Sons New York.

Gee, G.W., and Or, D. (2002) Particle size Analysis. In methods of soil analysis. Dan D.J., and G.C Topps (Ends), part 4 physical methods. Soil science of America book series No 5, ASA and. SSSA Madison, W.1.Pp.225-293.

Grossman, R.B., and Reinsch, T.G. (2002) Bulk density and linear Expansivity.In methods of soil analysis, Dane J.H. and G.C Topps (Eds) part 4, physical methods. Soil sic soc. Am. Book series No. 5. ASA and SSSA Madison W.1. Pp 201-228/

Hendershot, W.H. Lalande, H., and Duquette. M., (1993) soil reaction and exchangeable acidity, in: soil sampling and methods of soil analysis (Caeter M.R., Ed.), Canadian soc. Soil sci. lewis publishers, London Pp 141- 145.

Igbozurike, M.U. (1975) Vegetation types. In: Ofomata, G.E.K: Nigeria in map Easten states. Ettiope publishing house mid west mass communication co-operation, Benin city, Nigeria Pp30-32.

IITA, (1982).Automated and semi-automated methods for soil and plant analysis. In: D.A and P.V. Raoleds manual series 7. International institute for tropical agriculture (IITA).

Mclean, E.Q. (1982) soil pH and lime requirement. In: methods of soil analysis. R.H. Miller and D.R. keeney (Eds), Part 2, 2ndEdn, agron.Monogr. No 9, SAS abs SSA, Madison WL Pp. 199-234.

Nelson, D.N. and Sommers, L.E. (1982) Total carbon, organic carbon amd matter. In methods of soil analysis part 2 (page A.L, R.H., Miller, and D.K., Keeney Edc) Amer Soc. Agron. D.M. madison W.I. Pp 30-32.

Ofomata, G.E.K. (Ed) (1975) Soil, In: Ofomata, G.E.K. Nigeria in maps. Eastern states.Ettiope publishing house mid west mass communication corporation. Benin city Nigeria. Pp 539-579.

Olsen,S.R. and Sommers, I.E. (1982) Soil available Phosphorus. In: Metods of soil analysis part 2. 2nd edition Agron mono.9.ASA and SSA, Madison, USA.

Satoh, F.,T. Sakuma and H. Okajima (1990). A topsequence of fine textured soil in the hilly area of the nethermost part of Hokaido I. morphology and physicochemical properties. Soil Sci. plant nutr. 36 (1) ; 9 – 21

Sobeck, T.M. and A.D. Karathanasis (1992).Soil on hillslope on acid gray and black shale. Soil Sci. Soc. Am. J. 56: 1218 – 1226.

Thomas (1982) methods of soil analysis, part 2: Chemical and microbiological properties, 2nd edition; Amer. Soc. Agro. Inc. Madison, Wisconsine. USA.

Vomocil, J.A. (1965) Porosity. In: Methods of soil analysis part 1. Agronmonogr. 9:210-220, Am. Soc. Agron. Madison W.I. USA.