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Full Length Research Paper

Carbon Storage in Tropical Agricultural Soils of South Eastern Nigeria under different Management Practices

CN Mbah* and FI Idike

Department of Soil Science and Environmental Management Ebonyi State University, P.M.B. 053, Abakaliki-Nigeria.

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Changes in agricultural practices influence how much and at what rate carbon is stored in or released from soils. We examined the carbon storage at two soil depths (0-5cm and 5-20cm) in four agricultural practices namely: natural undisturbed forest, Gmelina *arborea* forest, alley crop farming and sewage sludge dumpsite in southeastern Nigeria. At both depths the soil ph, bulk density, total porosity, water holding capacity and sand fraction (gkg-^{1}) showed low variation while silt + clay fraction was observed to vary moderately. Total carbon stored in soil was highest in natural uncultivated forest with 37%, 62% and 27% increase relative to alley cropping, sewage sludge dump and Gmelina *arborea* forest, respectively. Results also showed that forests and alley cropping can store large quantities of C in soils while sewage sludge is not effective in storing large quantities of C

Keywords: Agricultural practices, soil depth, forest, alley cropping, carbon storage.

INTRODUCTION

Organic carbon in agricultural soils contributes positively to soil fertility, soil tilth, crop production and overall soil sustainability (*Lal,* 1997). Soil organic carbon (SOC) is a large and active pool, containing roughly twice as much carbon as the atmosphere and 2.5 times as biodata. Carbon storage or sequestration is the facilitated redistribution of carbon from the air to other parts. This would reduce the rate of atmospheric carbon increase thereby mitigating global warming (Tieszer, 2000).Changes in agricultural management can increase or decrease soil organic carbon (SOC). Carbon enters the soil as roots, litter, harvest residues and animal manure. It is stored primarily as soil organic matter (SOM). Agronomists have long recognised the benefits of maintaining and increasing SOM which adds to soil fertility, water retention and crop production (Mbah and Mbagwu, 2003). Similarly, much interest has been shown in the role of organic matter in soil fertility and formation and stabilization of both macro and micro-aggregates. According to Six *et al.*,(2000)soil attributes such as aggregates type, aggregate size and stability (Eynards et al., 2004) and pedality (Limn et al ., 1999) influences SOM. Studies by Angers *et al*.(1997), Gale *et al,(*2000) and Paustion *et al* .(2000) showed a positive influence of aggregation on the accumulation of SOM.

In soils of Northern Nigeria, Adamu *et al.* (1997) found that smaller aggregates were enriched with SOC. In Southeastern Nigeria, Mbah and Ngwu (2008) reported that finer soil particles retain more water and accumulate more OM than macro-aggregates. Onweremadu *et al*. (2010) observed differences in the distribution of carbon fractions in soil aggregate with concentrations of colloidal organic materials being higher in water-stable aggregates. Elliot and Bethany (1995) observed that the ability of a soil to capture and secure storage of carbon is a function

*Corresponding author: Email cnmbah10@yahoo.com

of texture and structure while other researchers attributed it to texture, farming system and management (Lal, 2004), irrigation and tillage (Del-grosso *et al.* 2005), tillage technique (Allmaras *et al*., 2004), cropping intensity (Ortega *et al*. 2002) and nitrogen inputs to soil (Potter *et al*., 1997).

Carbon has higher density (w/v) near the surface but SOM decomposes rapidly releasing CO_2 to the atmosphere. Some carbon becomes stabilized especially in the lower part of the profile. However, in many areas agriculture and other land use activities have upset the natural balance in the soil carbon cycle, contributing to an alarming increase in carbon release (Schlesinger and Litcher, 2001). Soils differ in their response to different management. It is important to investigate more closely the influence of different agricultural management practices on a range of soil properties. Similarly, researches on quantification of C stored in soils in most African countries including Nigeria is proceedingly slow .This study investigated the soil carbon storage of tropical Ultisols of south eastern Nigeria as influenced by differences in agricultural management practices.

MATERIALS AND METHODS:

Site Description

South eastern Nigeria stretches from 04^o 75'N to 07^o 00' N and between 05^o 34' E and 09^o 24' E, has a total area of approximately 78, 612 km (Unama *et al*., 2000). The mean annual temperature ranges between 27 – 32^{o}C. The soils of the zone have isohypethermic temperature regime and receive average annual rainfall of between 1600mm – 4338mm (Unama et al. 2000).

The sites and their land use history are described as follows;

Site 1: Artificial Gmelina arborea forest established by the forest department at Abakaliki about 30 years ago. Abakaliki (Ebonyi state) falls within longitude 08^0 3^1 E and latitude 06^0 25^1 N in the derived savannah region of the southeast agro-ecological zone of Nigeria. Geologically, the area is underlain by sedimentary rocks derived from marine deposits of the crutaceous and tertiary periods. The soil belongs to the order Ultisol and classified as Typic Haplustult(FDALR,1985).

Site 2: A natural undisturbed forest located at Federal University of Technology, Owerri. The forest is over 32 years old. Owerri (Imo State) is bounded by latitude 04^0 $4^1$and 08^015^1N and longitude 06^040^1 and 08^015^1E . The predominant parent material underlying Imo state from which most of the soils are formed are the costal plain sands popularly known as "Acid soil" (Orajaka, 1975). The soil is classified as Pinthic Tropodult/ Plinthic Acrisol (FDALR.1985).

Site 3: An alley crop farm established about 10 years ago at the Teaching and Research farm of Faculty of Agriculture and Natural Resources Management, Ebonyi State University Abakaliki. The alley consist of *glicidia sepium* and *Pannicum Maximum* , prunned yearly and used for maize and vegetable cultivation

Site 4: Sewage sludge dumpsite located at University of Nigeria, Nsukka. The dumpsite has existed for over 40 years. The dumpsite is continuously tilled yearly and planted with maize, Okra, vegetables, cassava, etc by the staff of the University. Nsukka -06^0 52^1N, 07^0 24^1E- (Enugu state) is characterized by a tropical climate with marked wet and dry seasons and deep, well drained and red to brownish-red in colour and derived from sandy deposits of false- bedded sandstone (Orajaka,1975). It is a sandy clay loam and classified as Typic kandistult in the soil taxanomy (Nwadialo, 1989) which is equivalent to Dystric Nitisol in the FAO classification (FAO/UNESCO, 1988)

Soil Sample Collection

Between mid October and early November 2009, soil samples were collected from four sites (with different agricultural management practices) in different parts of south eastern Nigeria. Soil samples were collected from two depths of 0-5cm and 5-20cm in each of the site. Four undisturbed core samples and four auger samples were collected from each depth in all the sites. The auger samples were composited, air dried at room temperature and sieves through a 2mm sieve preparatory for analysis.

Laboratory Methods

Particle size analysis was carried out by pipette method of Gee and Or, (1994). Bulk density was analysed by core method according to Doran and Mielke, (1984) while organic carbon was determined by the Walkley and Black procedure (Nelson and Sommers, 1996). Soil pH was determined in soil electrolyte (0.001m) $Cacl_2$ suspension using a glass electrode pH meter (Digital pH meter Accumet model AR15, Fisher Scientific). Water holding capacity was determined using the method of Mbagwu and Mbah (1998).

Total porosity was calculated as follows:

$$Tp = \left(1 - \frac{bd}{pd}\right) \times \frac{100}{1} \quad \text{--------------------------------------}1$$

where

Tp = Total porosity, bd = bulk density and Pd = particle density assumed to be 2.70gcm^{-3}).

The carbon stock in each depth was calculated as follows: C%/100 x soil bulk density x area (1ha) x soil depth.

Data Analysis

Soil data were subjected to simple means and co-efficient of variation (%). Variability was ranked as follows: Little variation (CV % <20), moderate variation (CV % = 20 - 50)

Table 1: Selected characteristics of the soil

	pH		Sand gkg^{-1}		Silt +clay gkg^{-1}		BD gcm^{-3}		TP %		OC gkg-1		WHC	
Depth (cm)	0-5	5-20	0-5	5-20	0-5	5-20	0-5	5-20	0-5	5-20	0-5	5-20	0-5	5-20
Site 1	5.5	5.2	718	700	282	300	1.38	1.45	40.3	39.6	14.2	13.0	410	430
Site 2	4.9	4.7	882	864	118	136	1.61	1.63	49.0	46.0	16.7	15.6	400	442
Site 3	5.4	5.2	650	647	350	353	1.50	1.62	62.0	63.0	10.5	10.0	380	405
Site 4	5.4	5.1	801	800	199	200	1.20	1.23	55.6	53.7	1.23	6.90	400	425
Mean	5.3	5.1	763	753	237	247	1.42	1.48	51.7	50.6	12.9	11.4	398	426
CV%	7.3	8.9	13	13	42	39	12	13	18	20	7	9	3	4

Site 1 = Artificial Gmelina arborea forest at Abakaliki
Site 2 = Natural undisturbed forest at owerri
Site 3 = Alley crop farm at EBSU, Abakaliki
Site 4 = Sewage sludge dumpsite at Nsukka.

and high variation (CV % > 50) according to Aweto, (1982).

RESULTS

Variability in soil characteristics of the agricultural management practices ranged between 3-42% (Table 1). Moderate variation was observed in silt + clay contents while the soil characteristics of pH, OC, WHC, **B**d, and Tp showed low variability at both depths. Organic C content ranged between 10.5–16.7 and 6.9–15.6 (gkg^{-1}) at 0–5cm and 5–20cm soil depths, respectively. Table 1 also showed that OC concentration was higher at 0-5cm depth relative to 5-20cm depth in all the management practices. Soil bulk density was observed to be higher in the top 0-5cm compared to 5-20cm soil depths. In contrast to the observed higher bulk density values in the top 0-5 cm table 1 showed that higher amount of water was retained at 5-20cm depths compared to 0-5cm.

Table 2 showed the differences in C storage at both depths in the four agricultural management practices. Highest value of total stored C was observed in site 2 (Natural undisturbed forest). At the depth of 0-5cm stored carbon ranged from 738±5 – 1344±17 **gCm^{-2}** while store d C was between 1697.4±4 – 5085.6±6 **gCm^{-2}** at 5-20cm depth. Total carbon stored in site 2 was higher than those in sites 1, 3 and 4 by 27%, 37% and 62%, respectively. Higher values of stored carbon were observed at 5-20cm depth compared to 0-5cm depth in all the agricultural management practices studied

DISCUSSION

Variation in soil bulk density values (Table 1) could be as a result of compaction resulting from a combination of factors such as ; human and animal trafficking, rain drop impacts and wetting and drying cycles in soil (Anikwe *et al.,* 2003). Soil compaction may have been responsible for the low CV% of bulk density since soil samples were collected at the end of the harvest when re-compaction after tillage may have occurred. Bulk density values are important for calculating the total quantities of carbon stored at particular time and soil depth. According to Krull *et al*. (2001) all organic C in soil is located within the pores between mineral particles either as discrete

Table 2: Total organic carbon (gCm^{-2}) storage of the soils at different depths (cm).

	Depth (cm)		
	0 – 5	5-20	Total
Site 1	979.8± 4	3770±18	4719.8
Site 2	1344±17	5085.6 ±6	6429
Site 3	795±6	3240±5	4035
Site 4	738±5	697.4±4	2435.4

Site 1 = Artificial Gmelina arborea forest at Abakaliki
Site 2 = Natural undisturbed forest at **Owerri**
Site 3 = Alley crop farm at EBSU, Abakaliki
Site 4 = Sewage sludge dumpsite at Nsukka.

particles or as molecules adsorbed onto the surface of these mineral particles.

The difference observed in total C stored in the soil (table 2) could be attributed to either the agricultural management practices or the variability in the silt+ clay content of the soil. According to Sundermier *et al*. (2004) forests sequester 10.6% as much as carbon dioxide as was released in the United States by combustion of fossil fuel. Study by Birsley (1996) showed that pine plantation can accumulate almost 100 metric tons of C per acre after 90 years. Similarly, Smith *et al*. (1999) observed an increase in soil organic C during a 6 year experiment with corn. Ismail *et al*. (1994) found a sequestration of 1250 grams of C per square meter (gC/m^2) in soils under conventional tillage and 1740 (gC/m^2) under no – till practices. In another study Hassink (1997) reported a relationship between silt – and – clay associated C and texture while Feller and Beare ,(1997) noted that silt + clay particles protect SOM. Buyamosky and Wagner, (1998) showed increasing OM as a function of increasing C content from residue and manure.

Table 2 also showed that natural undisturbed forest stored the highest quantity of carbon while the least quantity was stored in sewage sludge dumpsite. The low quantity of C stored in sewage sludge dumpsite could be as a result of continuous cropping. Previous studies showed that tillage adversely affects carbon storage in soils (Anikwe *et al*., 2003). Similarly, Bationo *et al.* (2007) in a study soil organic carbon dynamics, functions and management in West African agro-ecosystems reported rapid decline of SOC levels with continuous cultivation. For sandy soils they found that average annual losses may be as high as 4.7% where as with sandy loam soils, losses were lower, with an average of 2%. Similarly low value of SOC observed in sewage sludge dump site could be as a result of the inability of organic manures to act as net carbon sink in agricultural lands in line with the observation of Schlesinger, (2000).

At about 10years alley crop farm stored 4035 gCm^{-2} carbon compared to 2435.4 gCm^{-2} observed in sewage sludge dumpsite at 40 years. The value (4035 $gCm\text{-}^{2}$) represents 166% increase compared to the value of stored C in sewage sludge dump site. Similarly, at 10 years stored carbon in alley crop farming practice represent 60% and 80% of total C stored in natural undisturbed forest and Gmelina *arborea* forests, respectively. The high quantity of stored carbon in alley crop farm could be as a result of pruning which adds manure to the soil. Smith *et al*. (1997) showed that addition of organic matter to the soil increase C sequestration. Again, the age of the alley crops may have also contributed to the high C capture and storage since young plants sequester more C than older ones.

CONCLUSION

Carbon storage in soils can be influenced by agricultural management practices. Forests and alley cropping can store large quantities of C in soil. Sewage sludge is not effective in storing large quantities of C in soil in line with the observation of Schlesinger (2000) that no net sink of carbon is likely to accompany the use of organic manures on agricultural lands**.**

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