

Organic Carbon Sequestration Capacity of Soils of Akwa Ibom State, Nigeria

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Abstract: - Organic carbon sequestration capacity of soils in Akwa Ibom State was assessed. The aim was to identify the organic carbon sequestration capacity of different parent materials and landuse types in the state. Based on the satellite imageries, geological and topographic maps, the study area (Akwa Ibom State) was grouped into four major mapping units to reflect the parent materials, namely: coastal plain sand, sandstone, shale and beach ridge sand. Also, four land use types namely; cultivated farmland, oil palm plantation; homestead and secondary forest of 3 years and above were selected for the study. In each parent material and land use type, three representative locations were selected for sampling. In each sampling location, profile pit was dug and soil samples were collected at a designated depth of 0-20, 20-60, 60-100cm. The core samples were also collected at the same depth for bulk density and hydraulic conductivity-determinations in the laboratory. The study revealed that beach ridge sand soils had the highest organic carbon sequestration capacity, followed by coastal plain sand, followed by sandstone while shale soils had the least in the order: beach ridge sand > coastal plain sand > sandstone > shale. In term of landuse types, homestead or compound farmland had the highest organic carbon sequestration capacity, followed by oil palm plantation and secondary forest of 3-5 years while cultivated farmland had the least in the order: homestead > oil palm plantation > secondary forest > cultivated farmland. Among the organic matter fractions, silt + clay fraction had the highest organic carbon storage capacity, followed by encapsulated POM while free POM had the least storage capacity. In term of soil depth, 60-100 cm soil depth had highest organic carbon storage capacity, followed by 20-60 cm while 0-20 cm had the least. Therefore, in the choice and management of the soil for efficient and sustainable organic carbon source and sink, beach ridge among parent materials and homestead or compound farmlands among landuse types have higher organic carbon sequestration potentials than others.

I. INTRODUCTION

Soil organic carbon has a negative impact on the environment due to emission of CO₂ which has effect on global climate change. Among the emitted greenhouse gases (CO₂, methane, nitrous oxide) that caused global warming, carbon dioxide contributed about 72% of the total emitted greenhouse gases while methane and nitrous oxide contributed 18% and 9% respectively to global warming that resulted in climate change (IPCC, 2007). Hence, to reduce atmospheric CO₂ and create balance between the elements of the greenhouse gases, the existing atmospheric carbon must be captured and stored.

The most simple and economic way of reducing the level of atmospheric CO₂ is through carbon sequestration in soil (Abdi, 2005). The carbon pool in soils is approximately twice as that in the atmosphere. The atmospheric CO₂ concentration is influenced by the balance between soil organic carbon (SOC) inputs and output (IPCC, 2007).

The amount of organic carbon (SOC) in the soil is controlled by many factors. Firstly, parent material is the main compound in the accumulation and decomposition of soil organic carbon (Parton *et al.*, 1987). Soil aggregates play a crucial role in the sequestration of organic carbon through several stabilization mechanisms (Oades, 1993 and Sollins *et al.*, 1996). Organic compounds such as COOH can adsorb cations and anion through various mechanisms such as hydrogen bonds, cationic and anionic exchange, ligand exchange, (columbic), van der waals (non-columbic) which provide a bridges between negatively charged organic functional groups and negatively charged clay surfaces (formation of organic metallic complexes). Soil aggregates are capable of physically protecting soil organic matter against mineralization, by encapsulating or trapping organic matter between packets of clay particles or interlayer spaces of layer silicate clay minerals or clay coating of organic matter particles resulting in much longer residence times for soil carbon. Absorption of organic materials by minerals has been suggested as an important way to maintain and stabilize organic carbon. Organic compounds with minerals reduce microbial mineralization. Parton *et al.* (1987) reported that amorphous and non-amorphous iron oxides and hydroxide have preserved 50-70 % of total solved OC adsorption and the remaining was absorbed by other minerals, especially kaolinite clay particles.

Secondly, the landuse type is another important factor that control SOC levels. Changes of landuse and management practices influence the amount and rate of soil carbon losses (Guggenberger *et al.*, 1995). Landuse types affect the amount of soil carbon emission. Han *et al.*, (2010) reported increase in soil carbon when arable soils were converted to grass land in China. Soil organic carbon is lost when trees are felled and when soils are ploughed (tillage) (Wu *et al.*, 1998). Soil organic carbon accumulation varies with soil depth. Goulding and Poulton (2005) reported about 18 ton ha⁻¹ increases in SOC in topsoil over a 35 years period after conversion of arable land to permanent grass. Increases

in soil organic carbon were recorded in soil horizons to a depth of at least 40-69 cm in Rothamsted soils (Poulton, 2003).

Soil organic carbon on the other hand, enhances soil macro-aggregate formation by its action as a binding agent (Tisdall and Oades, 1982). Soil organic carbon plays an important role in supplying plant nutrients (N, P, S), enhancing cation exchange capacity, improving soil water retention and supporting soil biological activity (Dudal and Deckers, 1993). Soil organic carbon is not only a major regulator of various processes underlying the supply of nutrients and the creation of a favourable environment for plant growth but also regulates various processes governing the creation of soil-based environmental services. Therefore, this study was conducted to identify organic carbon sequestration capacity of commonly practice land use types and parent materials in Akwa Ibom State so as to select, preserve and improved the area as measures of climate change mitigation and land degradation reduction.

II. MATERIALS AND METHODS

The study area

The study was conducted in Akwa Ibom State, located in south eastern Nigeria. It lies between latitudes 4⁰30' and 5⁰30'N and longitudes 7⁰ 30' and 8⁰20'E, and underlain mainly by coastal plain sands, beach ridge sands, sandstone / shale and alluvial deposits parent materials. The climate is humid tropical, annual rainfall ranges from more than 3000 mm along the coast to about 2250 mm at the extreme north, with 1 – 3 dry months in the year. Mean annual temperature varies between 26 and 28⁰C, while relative humidity varies between 75 – 80 %. The original natural vegetation which comprised lowland rainforest, mangrove forest and coastal vegetation, has given way to a mosaic farmland, riparian forest and oil palm forest (Petters *et al.*, 1989).

Field work

The study area (Akwa Ibom State) was grouped into four major mapping units based on geological formation and parent material namely coastal plain sand, sandstone, beach ridge sand and shale. Mini soil profile pit was dug at representative location within each parent material within depths of 0-100 cm. Soil samples were collected from designated depths of 0-20, 20-60 and 60-100 cm. Core samples using core rings were also collected from the same depths for saturated hydraulic conductivity and bulk density determination. A total of 144 soil samples were generated and taken to the laboratory for analysis.

Laboratory analysis

The following analyses were carried out using appropriate standard procedures: Particle size analysis was carried out using the bouyoucos hydrometer method as described by Udo *et al.* (2009). Bulk density was determined by the method described by Udo *et al.* (2009). Saturated

hydraulic conductivity was determined using the constant head permeameter method. Soil pH was determined in water using a 1:2.5 soil to water suspension and the soil pH was read using a glass electrode. Organic carbon was determined by the dichromate wet-oxidation method as described by Nelson and Sommers (1996). The value was multiplied by 1.732 to obtain organic matter content. Available phosphorus was determined using the bray P1 extractant. The phosphorus in extract was measured by the blue method of Murphy and Riley (1962). Total nitrogen was determined by kjeldahl digestion and distillation method as described by Udo *et al.* (2009). Exchangeable bases: Ca, Mg, Na, K. were extracted using normal ammonium acetate (Thomas, 1986). The exchangeable K and Na were determined by flame photometer while Ca and Mg were determined using atomic absorption spectrometer. Effective cation exchange capacity (ECEC) was determined by summing up exchangeable cations and exchangeable acidity. Percentage base saturation was calculated using the formula:

$$\% \text{ base saturation} = \frac{\text{Summation of exchangeable bases} \times 100}{\text{CEC}}$$

Organic Matter fraction

A 100g air dried soil sample (sieved through a 2mm screen) was weighed into a stirring cup, and then calgon (Sodium hexametaphosphate) was added for dispersion. Deionized water was added to the soil sample to achieve a soil: water ratio of 1:5(v:v). The content in the stirring cup was thoroughly mixed using the mechanical stirrer for 15minutes. Each sample was then transferred into a set of sieves (0.25mm and 0.10mm). The soil sample was separated into different particle size fractions under slowly running water. The sample was washed until the water flowing out of the 0.10mm sieve was clear. The soil sample in the <0.10mm was recovered by allowing the soil particle to settle out; after the top clear solution was decanted. Three size fractions were obtained: the coarse fractions (>0.25mm) fraction with non-protected particulate organic matter (free particulate organic matter), the fine sand fraction (0.25-0.10mm) which is the occluded particulate organic matter and the silt +clay fraction (<0.10mm). All fractions were dried in a 60⁰c oven. The carbon concentration in each fraction was determined (Cambardella and Elliott, 1993). (Cambardella and Elliott, 1993).

III. RESULTS

Soil properties of the study area

The range, mean and median of soil properties of the study area are presented in Table 1. In soils developed from beach ridge sand parent material, the mean sand fraction was 94.17 %, silt fraction was 3.08 % while clay fraction was 6.99 %. In soils developed from coastal plain sand parent material, mean sand fraction was 86.27%, silt was 4.33 % while clay fraction was 9.77 %. In sandstone soils, sand fraction was 91.09 %, silt was 3.17 % while clay fraction was 6.70 %. In

soils developed from shale parent material, mean sand fraction was 80.56 %, silt was 9.03 % while clay fraction was 10.59 %. Based on the USDA textural classes, the mean soil texture of the study area ranged from moderately coarse to coarse sand within 1m soil depth. Within 1m soil depth, soils of beach ridge sand and sandstone parent materials were of coarse texture while soils of coastal plain sand and shale parent materials were moderately coarse. The mean bulk density of beach ridge sand soils was 1.4 g/cm³, coastal plain sand soils was 1.2 g/cm³, sandstone soils was 1.4g/cm³ while

shale soils was 1.3 g/cm³. The mean bulk density in all the parent materials under consideration was within the limit that does not affect root growth (Arshad *et al.*, 1996). The mean saturated hydraulic conductivity of beach ridge sand soils was 34.60 cm/hr, coastal plain sand soils was 19.3 cm/hr, sandstone soils was 61.47 cm/hr while shale soils was 29.73 cm/hr. The mean rate of water flow was moderately rapid in coastal plain sand and shale soils and rapid in sandstone and beach ridge sand soils within 1m soil depth (Arshad *et al.*, 1996).

Table 1: Range, mean and median of soil properties in the study area

Soil property		Parent material			
		Beach ridge sand	Coastal plain sand	Sandstone	Shale
Sand (%)	Range	86.00-97.99	75.00-93.50	84.50-94.70	60.50-94.70
	Mean	94.17	86.27	91.09	80.56
	Median	94.84	87.35	91.60	85.75
Silt (%)	Range	0.00-19.99	0.00-9.00	0.7-7.0	1.10-37.00
	Mean	3.08	4.33	3.17	9.03
	Median	0.01	5.00	2.95	4.8
Clay (%)	Range	5.00-15.20	6.50-18.70	6.50-10.70	2.10-22.70
	Mean	6.99	9.77	7.93	10.59
	Median	5.17	8.60	6.70	7.85
Bulk density (g/cm ³)	Range	0.9-1.7	0.09-1.5	1.0-1.7	0.9-1.7
	Mean	1.4	1.2	1.4	1.3
	Median	1.4	1.3	1.4	1.3
Ks (cm/hr)	Range	2.64-186.0	0.09-54.57	12.39-141.80	8.22-95.23
	Mean	34.60	19.3	61.47	29.73
	Median	27.33	15.3	63.89	12.45
pH (H ₂ O)	Range	3.0-5.6	2.9-5.7	2.9-4.9	3.3-5.4
	Mean	4.8	4.0	4.0	4.4
	Median	4.9	3.9	4.2	4.4
EC(dsm ⁻¹)	Range	0.03-0.92	0.03-0.4	0.02-0.24	0.027-0.19
	Mean	0.11	0.1	0.09	0.11
	Median	0.05	0.1	0.05	0.11
OC (%)	Range	2.06-9.05	1.9-5.8	0.96-5.56	2.68-5.53
	Mean	4.8	0.09	3.62	4.0
	Median	4.2	0.09	3.89	4.0
TN (%)	Range	0.05-0.99	0.00-0.2	0.023-0.19	0.058-0.14
	Mean	0.19	0.09	0.09	0.098
	Median	0.13	0.09	0.10	0.097
Av.P (mg/kg)	Range	0.00-23.99	0.8-26.7	0.49-37.31	0.00-18.66
	Mean	6.44	13.3	7.3	2.54
	Median	1.75	16.7	2.5	1.34
Ca (cmol/kg)	Range	6.3-23.3	2.3-25.7	7.1-30.5	1.59-24.1
	Mean	14.63	12.98	14.1	17.27
	Median	14.4	14.00	13.6	18.0
Mg (cmol/kg)	Range	2.12-7.74	0.7-8.5	2.3-10.1	5.32-15.21
	Mean	4.7	4.3	4.7	10.37
	Median	4.8	4.6	4.5	10.34
Na (cmol/kg)	Range	0.03-0.7	0.04-0.29	0.03-0.12	0.00-0.66
	Mean	0.14	0.09	0.06	0.1
	Median	0.07	0.06	0.05	0.06
K (cmol/kg)	Range	0.04-0.75	0.04-1.16	0.03-0.38	0.06-0.43
	Mean	0.16	0.24	0.09	0.15
	Median	0.12	0.10	0.05	0.09
EA (cmol/kg)	Range	1.2-4.8	1.2-3.5	0.9-11.1	0.6-8.9
	Mean	2.1	2.6	3.1	3.33
	Median	1.5	2.8	2.7	2.15
ECEC (cmol/kg)	Range	9.87-32.61	6.7-36.5	12.6-44.8	24.3-71.9
	Mean	21.8	20.5	22.0	38.0
	Median	21.4	22.1	20.1	31.0
BS (%)	Range	81.7- 99.6	49.3-94.5	62.4-94.1	71.2-98.2
	Mean	90.9	83.9	85.4	89.6
	Median	93.0	87.0	89.8	93.6

The mean soil pH in water of beach ridge sand soils was 4.8, coastal plain sand soils was 4.0, sandstone soils was 4.0 while

shale soils was 4.4. The mean hydrogen ion concentration (pH) indicated that beach ridge sand soils were very strongly

acid while others were extremely acid. The mean electrical conductivity of the soils of beach ridge sand parent material was 0.1 ds/m , coastal plain sand soils was 0.1 ds/m, sandstone soils was 0.09 ds/m while shale soils was 0.1 ds/m within 1m of soil depth. The values indicated that the study area was salt free (non-saline) (Smith and Doran, 1996). The mean soil organic carbon of beach ridge sand soils was 4.8 %, coastal plain sand soils was 3.4 %, sandstone soils was 3.9% while shale soils was 4.0 % within 1m soil depth. The values indicated that organic carbon was very high in all the parent materials in the study area (Enwezor *et al.*, 1989). However, organic carbon was higher (4.8 %) in beach ridge sand soils compared with others. The mean total N of beach ridge sand soils was 0.2 %, coastal plain sand soils was 0.09 %, sandstone soils was 0.09 % while shale soils was 0.1 % within 1m of soil depth. Mean total N was low in coastal plain sand and sandstone soils, moderately low in shale soils and medium in beach ridge sand soils within 1m soil depth (Enwezor *et al.*, 1989). The mean available P of beach ridge sand soils was 6.4 mg/kg, coastal plain sand soils was 13.3 mg/kg, sandstone soils was 7.3 mg/kg while shale soils was 2.5 mg/kg within 1m of soil depth. Mean available P was moderate in coastal plain sand and sandstone soils, and low in beach ridge sand and shale soils within 1m soil depth (Enwezor *et al.*, 1989). The mean exchangeable Ca of beach ridge sand soils was 14.6 cmol/kg, coastal plain sand soils was 13.0 cmol/kg, sandstone soils was 14.1 cmol/kg while shale soils was 17.3 cmol/kg within 1m of soil depth. The mean exchangeable Mg of beach ridge sand soils was 4.7 cmol/kg, coastal plain sand soils was 4.3 cmol/kg, sandstone soils was 4.7 cmol/kg while shale soils was 16.0 cmol/kg within 1m of soil depth. The mean exchangeable Na of beach ridge sand soils was 0.1 cmol/kg, coastal plain sand soils was 0.09 cmol/kg, sandstone soils was 0.06 cmol/kg while shale soils was 0.1 cmol/kg within 1m of soil depth. The mean exchangeable K of beach ridge sand soils was 0.2 cmol/kg, coastal plain sand soils was 0.2 cmol/kg, sandstone soils was 0.09 cmol/kg while shale soils was 0.2 cmol/kg within 1m of soil depth. Mean exchangeable Ca and Mg were high while exchangeable Na and K were low in the study area. The mean effective cation exchange capacity (ECEC) of beach ridge sand soils was 21.8 cmol/kg, coastal plain sand soils was

20.5 cmol/kg, sandstone soils was 22.0 cmol/kg while shale soils was 38.0 cmol/kg within 1m of soil depth. The mean exchangeable acidity of beach ridge sand soils was 2.1 cmol/kg, coastal plain sand soils was 2.6 cmol/kg, sandstone soils was 3.1 cmol/kg while shale soils was 3.3 cmol/kg within 1m of soil depth. The mean base saturation of beach ridge sand soils was 90.9 %, coastal plain sand soils was 83.9 %, sandstone soils was 85.4 % while shale soils was 89.6 % within 1m soil depth. The values indicated that base saturation was very high in all the parent materials in the study area (Enwezor *et al.*, 1989).

Influence of parent material and organic matter fraction on Organic carbon sequestration capacity of soils in the study area

The influence of parent material and organic matter fraction on the organic carbon stock ($t\ C\ ha^{-1}$) is shown in Figure 1. In beach ridge sand soils, mean soil organic carbon stock was 361.9 $t\ C\ ha^{-1}$ in free POM, 325.3 $t\ C\ ha^{-1}$ in encapsulated POM and 390.3 $t\ C\ ha^{-1}$ in silt + clay fraction. In coastal plain sand soils, mean soil organic carbon stock was 175.9 $t\ C\ ha^{-1}$ in free POM, 167.6 $t\ C\ ha^{-1}$ in encapsulated POM and 297.6 $t\ C\ ha^{-1}$ in silt + clay fraction. In sandstone soils, mean soil organic carbon stock was 123.3 $t\ C\ ha^{-1}$ in free POM, 189.5 $t\ C\ ha^{-1}$ in encapsulated POM and 243.4 $t\ C\ ha^{-1}$ in silt + clay fraction. In soils developed from shale parent material, mean soil organic carbon stock was 155.6 $t\ C\ ha^{-1}$ in free POM, 157.1 $t\ C\ ha^{-1}$ in encapsulated POM and 236.9 $t\ C\ ha^{-1}$ in silt + clay fraction. The mean organic carbon stock in soils developed from beach ridge sand ($359.2\ t\ C\ ha^{-1}$) was significantly ($p < 0.05$) higher than that of soils developed from coastal plain sand ($207.7\ t\ C\ ha^{-1}$), soils developed from sandstone ($185.4\ t\ C\ ha^{-1}$) and that of soils developed from shale ($183.2\ t\ C\ ha^{-1}$) within 1m of soil depth (Fig.2). The trend was as follow: beach ridge sand > coastal plain sand > sandstone > shale. Among the organic matter fraction (Fig.1), mean organic carbon stock was significantly ($p < 0.05$) higher in silt + clay fraction than encapsulated POM and free POM in all the parent material under consideration. The trend was: silt + clay > free POM > encapsulate POM.

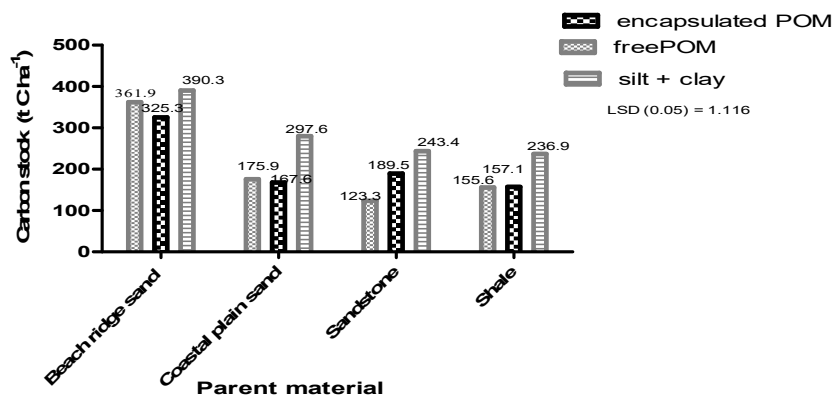


Fig.1: Influence of parent material and organic matter fraction on organic carbon sequestration capacity of soil of the study area

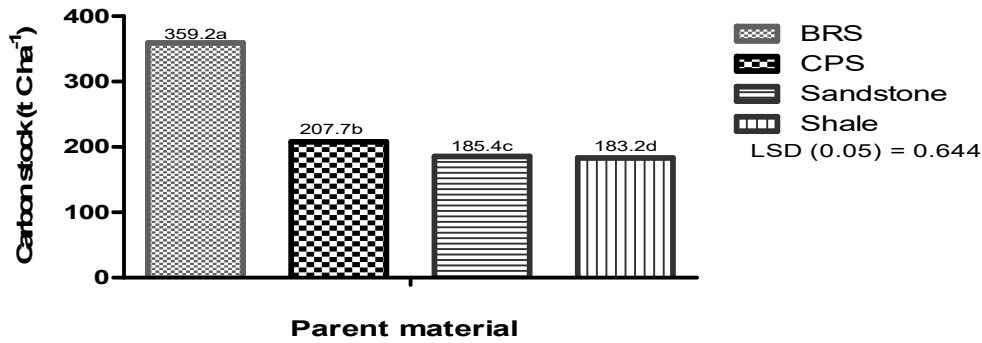


Fig.2: Influence of parent material on organic carbon sequestration capacity of soils

Influence of landuse types and organic matter fractions on the organic carbon sequestration capacity of soils in the study

The influence of landuse types and organic matter fractions on organic carbon sequestration capacity of soils of the study area is presented in Figure 3. In cultivated farmland, mean soil organic carbon stock was 206.9 t C ha⁻¹ in free POM, 193.6 t C ha⁻¹ in encapsulated POM and 263.5 t C ha⁻¹ in silt + clay fraction. In secondary forest of 3-5years, mean soil organic carbon stock was 183.2 t C ha⁻¹ in free POM, 231.3 t C ha⁻¹ in encapsulated POM and 287.8 t C ha⁻¹ in silt + clay fraction. In homestead, mean soil organic carbon stock was 208.8 t C ha⁻¹ in free POM, 186.3 t C ha⁻¹ in encapsulated POM and 325.9 t C ha⁻¹ in silt + clay fraction. In oil palm plantation, mean soil organic carbon stock was 217.7 t C ha⁻¹ in free POM, 228.3 t C ha⁻¹ in encapsulated POM and 273.0 t C ha⁻¹ in silt + clay fraction. The mean soil

organic carbon stock of homestead (240.4 t C ha⁻¹) was significantly ($p < 0.05$) higher than that of oil palm plantation (239.7 t C ha⁻¹), secondary forest (234.1 t C ha⁻¹) and cultivated farmland (221.4 t C ha⁻¹) (Fig.4). The trend was as follow: homestead > oil palm plantation > secondary forest > cultivated farmland. The results showed that homestead had the highest capacity to sequester carbon than oil palm plantation and secondary forest while cultivated farmland had the least. Among the organic matter fractions (Fig. 3), secondary forest and oil palm plantation, the organic carbon stock was (sequestration capacity) significantly ($p < 0.05$) higher in silt + clay fraction than encapsulated POM and free POM, in the order: silt + clay > encapsulate POM > free POM. But in homestead and cultivated farmland, the organic carbon stock was highest in silt + clay fraction, followed by free POM, while encapsulated POM had the least, in the order: silt + clay > free POM > encapsulate POM.

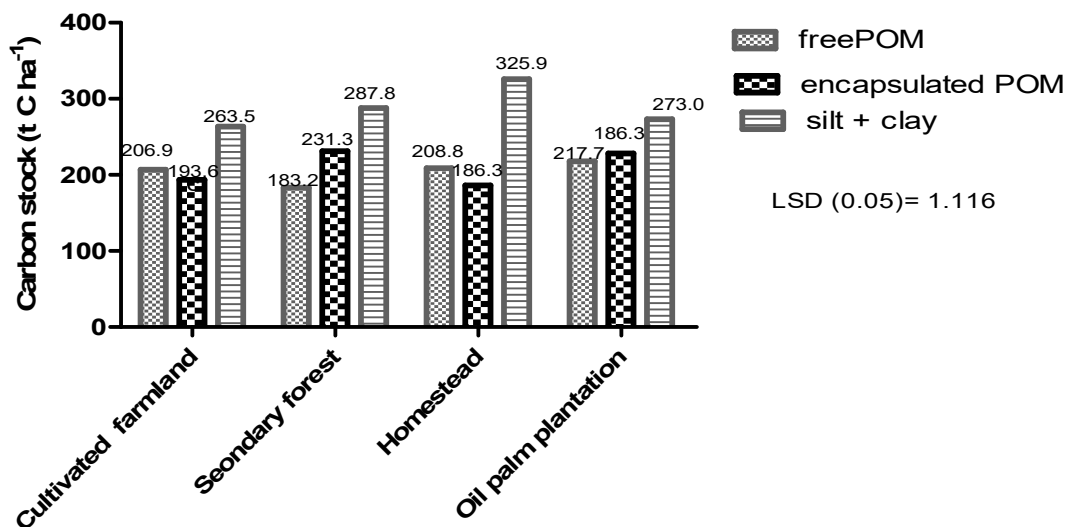


Fig. 3: Influence of landuse types and organic matter fraction on organic carbon sequestration capacity of soils in the study area

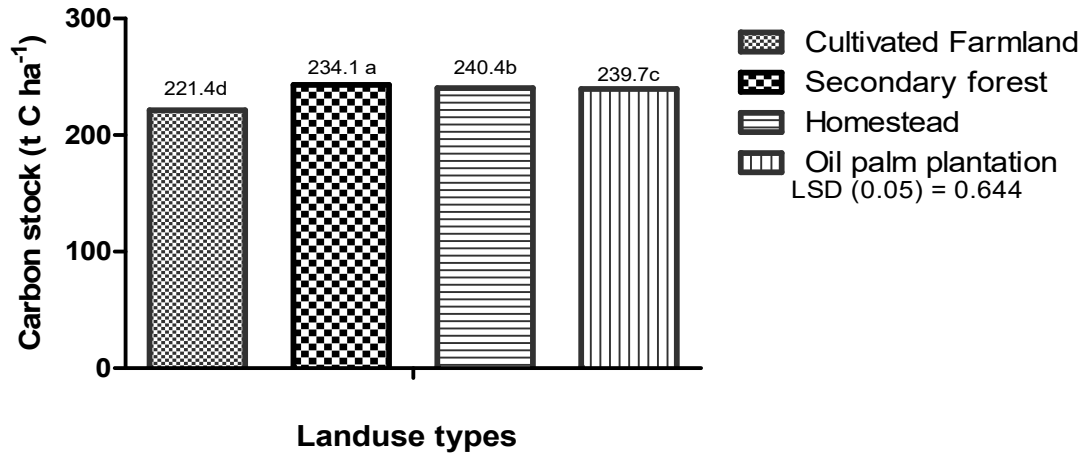


Fig. 4: Influence of landuse types on organic carbon sequestration capacity of soils in the study area

Influence of soil depth on organic carbon sequestration capacity

The influence of soil depth on organic carbon sequestration capacity of soils of the study area is presented in Figures 5 and 6. Among parent materials (Fig.5), in beach ridge sand soils, mean soil organic carbon stock was 93.1 t C ha⁻¹ in 0-20 cm depth, 373.1 t C ha⁻¹ in 20-60 cm and 611.3 t C ha⁻¹ in 60-100 cm. In coastal plain sand soils, mean soil organic carbon stock was 84.8 t C ha⁻¹ in 0-20 cm depth, 259.5 t C ha⁻¹ in 20-60 cm and 278.7 t C ha⁻¹ in 60-100 cm. In sandstone soils, mean soil organic carbon stock was 63.5 t C ha⁻¹ in 0-20 cm depth, 199.7 t C ha⁻¹ in 20-60 cm and 293.0 t C ha⁻¹ in 60-100 cm. In soils developed from shale parent material, mean soil organic carbon stock was 81.7 t C ha⁻¹ in 0-20 cm depth, 193.0 t C ha⁻¹ in 20-60 cm and 274.9 t C ha⁻¹ in 60-100 cm depth.

Among landuse types (Fig.6), in cultivated farmland, mean soil organic carbon stock was 69.4 t C ha⁻¹ in 0-20 cm depth, 248.7 t C ha⁻¹ in 20-60 cm and 346.0 t C ha⁻¹ in 60-100 cm. In secondary forest of 3-5 years, mean soil organic carbon stock was 86.6 t C ha⁻¹ in 0-20 cm depth, 247.3 t C ha⁻¹ in 20-60 cm and 368.3 t C ha⁻¹ in 60-100 cm. In homestead, mean soil organic carbon stock was 89.4 t C ha⁻¹ in 0-20 cm depth, 269.9 t C ha⁻¹ in 20-60 cm and 361.7 t C ha⁻¹ in 60-100 cm. In oil palm plantation, mean soil organic carbon stock was 77.6 t C ha⁻¹ in 0-20 cm depth, 259.4 t C ha⁻¹ in 20-60 cm and 381.9 t C ha⁻¹ in 60-100 cm. The mean organic carbon stock in 60-100 cm soil depth of both landuse types and parent material (364.5 t C ha⁻¹) was significantly ($p < 0.05$) higher than that of 20-60 cm (256.3 t C ha⁻¹), and that of 0-20 cm (80.7 t C ha⁻¹) soil depth. The trend was as follow: 60-100 cm > 20-60 cm > 0-20 cm.

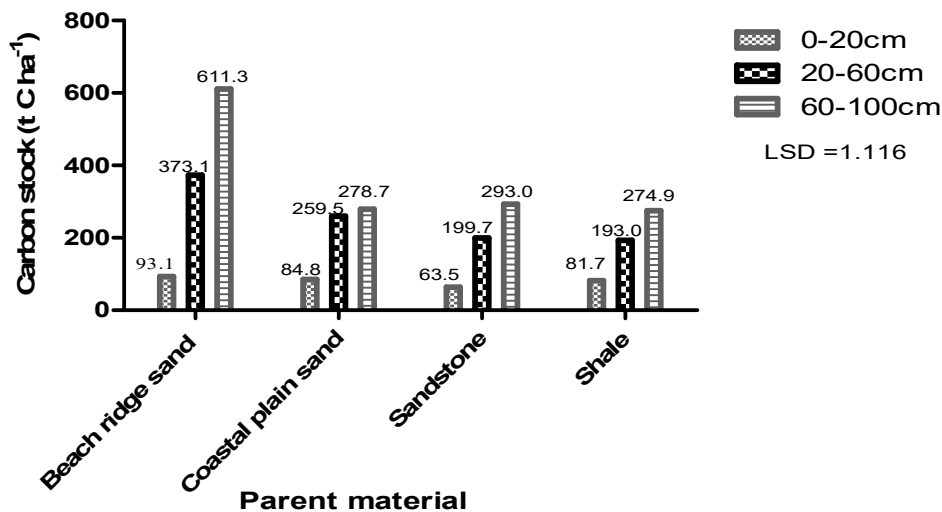


Fig. 5: The influence of parent material and soil depth on organic carbon sequestration capacity of soils

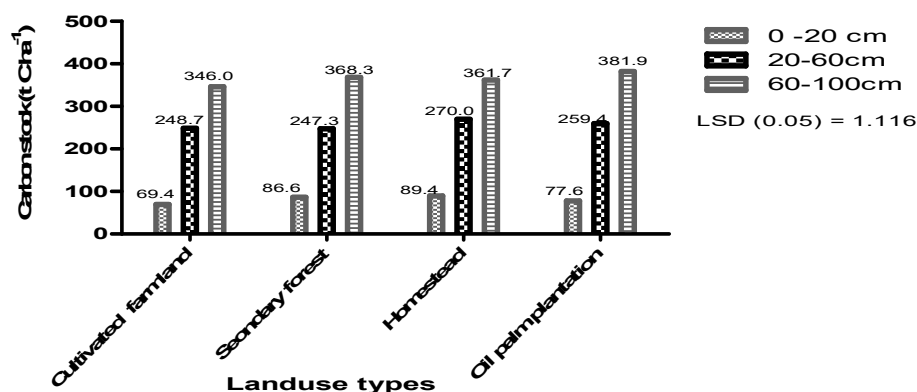


Fig. 6: The influence of landuse and soil depth on organic carbon sequestration capacity of soils

IV. DISCUSSION

Soil properties of the study area

The coarse texture of soil of the study area could be attributed to influence of parent material (coastal plain sand, beach ridge sand, sandstone /shale) (Soil Survey Staff, 2006). The general high acidity in the study area could be attributed to high rainfall in the area and as well as high agricultural activities. In humid environment, soil pH decreases over time in a process called acidification due to leaching caused by high amount of rainfall. Also, the moderately coarse to coarse texture soil with low buffering capacity could be responsible for the high soil acidity. Soils with high clay and organic matter content are more able to resist a drop or rise in pH (have greater buffering capacity) (Whitebread *et al.*, 1998). The high organic carbon content in beach ridge sand than others could be attributed to poorly drained soil (water table close to the soil surface) of beach ridge sand soils. Poorly drained soils typically accumulate more organic carbon than well drained soil, due to decline in oxygen concentration. Many micro-organisms involved in organic matter decomposition are aerobic (oxygen requiring) and will not function well under anaerobic conditions (oxygen limiting) (Solomon *et al.*, 2002). The medium total N of beach ridge sand soils compared with others could be attributed to high organic matter, increased mineralization rate due to adequate moisture content and warm temperature within 1m soil depth compared with other parent materials (Herridge, 2011). The low available P in shale and beach ridge sand soils compared with others could be attributed to high fixation in the form of Al-P and Fe-P due to high content of organic matter (humus fraction) and soil pH compared with others. As soil pH increases, the carboxyl or hydroxyl or phenolic hydroxyls groups in humus fraction (organic matter) ionise or dissociate to form negatively charge sites which are available for cation exchange. In acid soils (pH < 5.5), the sum of Ca, Mg, K and Na is often less than the total exchange capacity of the soil, the remaining being filled by Al, H and Mn, which when Al is in solution react with P to form Al-P precipitate

(insoluble P) (Stevenson, 1982). The high contents of mean exchangeables Ca and Mg in the study area could be attributed to effect of landuse rather than parent material. The high ECEC of shale soils compared with others could be attributed to high content of clay and organic matter. Soils low in clay (< 15 %) are much more dependent on soil organic matter to provide CEC and biotic processes dominate, whereas soils high in clay (>35 %), biotic processes are minimal (Oades, 1993). The high potential acidity of shale soils compared with others could be attributed to high degree of ionisation or dissociation of organic matter to form negatively charge sites which are available for Al and H cation exchange (acid soil) (Stevenson, 1982).

Influence of parent material and organic matter fraction on organic carbon sequestration capacity of soils in the study area

The high organic carbon stock in soils developed from beach ridge sand parent material than others could be attributed to nearness of water table to the soil surface when compared with other parent materials. Poorly drained soils have high organic matter content due to formation of anaerobic condition which reduces decomposition rate. The optimum moisture content of soils for the growth of aerobic bacteria responsible for organic matter decomposition is usually expressed as its water holding capacity of 50-70%, beyond this moisture level, anaerobic conditions will set-in. Also, it is generally established fact that increasing temperature stimulates microbial activities and therefore decomposition processes. Also, the high organic carbon sequestration capacity of silt + clay fraction of soil may be explained by the fact that soil organic carbon (SOM) is largely physically protected from decomposition due to the fact that SOC is localized in the small pores within soil aggregates or is coated by clay and silt particles (Skjemstad *et al.*, 1996) or encrusted by minerals particles (Oades and Waters, 1991). SOC is also physico-chemically stabilized by adsorption onto the surface of clay minerals (clay- organic matter complexes) (Tisdall and Oades, 1982). Hassink *et al.* (1997) reported that clay and silt

particles of sandy soils preserved much more SOC per unit of weight than fine textured soil. This occurs because clay + silt particles in sandy soils are present as individual particles, while in fine textured soils, clay+ silt particles are coagulated or congealed and less organic carbon are adsorbed per unit weight in fine than coarse textured soils. Congealed soil particles have limited capacity to preserve SOM and, thereby have maximum capacity of saturation with SOC in its clay and silt particles (Hassink, 1997).

Influence of landuse types and organic matter fraction on the organic carbon sequestration capacity of soils in the study

The high organic carbon sequestration capacity of homestead (compound farmland) could be attributed to high biomass input and bulk density. Soil organic carbon losses are primarily due to reduced organic inputs to the soil, although removal by erosion cannot be ruled out. Landuse that results in increased in organic carbon input, increased organic carbon stock (Six *et al.*, 2002). Also, increase bulk density values are primarily associated with organic carbon losses especially in 0-30 cm. Low bulk density is associated with high organic carbon storage. A change in bulk density from 0.1 to 0.2 gcm⁻³ leads to a doubling of losses of soil organic carbon stock and mass. Variation within the range of bulk density typical of mineral soils, for example 1.2 to 1.8gcm⁻³ is less consequential (Six *et al.*, 2002). The high organic carbon stock in silt + clay fraction in all the landuse types under consideration than free and encapsulated POM could be attributed to fine texture (silt and clay fractions) particles of aggregates which form cationic bridging with Ca²⁺, Al³⁺ and Fe³⁺ and the formation of organo-metallic compounds which are more stable. Aggregates containing Al³⁺ and Fe³⁺ and high CEC clay tend to increase SOC incorporation. The interaction of Al³⁺ and Fe³⁺ with kanolinite can synergistically promotes aggregation with limited impact on soil organic carbon (Six *et al.*, 2002).

Influence of soil depth on organic carbon sequestration capacity

The high organic carbon sequestration capacity of 60-100 cm soil depth compared with others could be attributed to high clay content in the 60-100 cm soil depth. Clay concentration affects SOC accumulation. It has been reported that maximum and medium SOC increased with increasing clay content in soil (Nichols, 1984). As clay concentration increases, SOM decomposition decreases. It was found that, if other factors were fixed, as clay concentration increased, SOC accumulated faster (Jenkinson, 1990). Many studies showed that, as the clay constituents' increase, they combine with SOC to form stable aggregates. For this reason, soil texture also plays direct and indirect role in chemical and physical protection mechanisms.

V. CONCLUSION

The study revealed that beach ridge sand soils had the highest organic carbon sequestration capacity, followed by

coastal plain sand, followed by sandstone while shale soils had the least in the order: beach ridge sand > coastal plain sand > sandstone > shale. In term of landuse types, homestead or compound farmland had the highest organic carbon sequestration capacity, followed by oil palm plantation and secondary forest of 3-5 years while cultivated farmland had the least in the order: homestead > oil palm plantation > secondary forest > cultivated farmland. Among the organic matter fractions, silt + clay fraction had the highest organic carbon storage capacity, followed by encapsulated POM while free POM had the least storage capacity. In term of soil depth, 60-100 cm soil depth had highest organic carbon storage capacity, followed by 20-60 cm while 0-20 cm had the least. Therefore, in the choice and management of the soil for efficient and sustainable organic carbon source and sink, beach ridge among parent materials and homestead or compound farmlands among landuse types have higher organic carbon sequestration potentials than others.

REFERENCES

- [1]. IPCC. 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. In Parry, M. L.; Canziani, O.F.; Palutikof, J. P., van der Linden, P. J., Hanson, C.E. (Eds.). Cambridge: Cambridge University Press.
- [2]. Abdi, N. 2005. Estimation of carbon sequestration capacity by *Astragalus* genus (*Subgenus Tragacantha*) in Markazi and Isfaha provinces. Ph.D Thesis, Department of Rangeland Sciences, Islamic Azad University, Tehran, Iran. 601.
- [3]. Parton, W.J., Schimel, S., Cole, D. & Ojiam, D. 1987. Analysis of factors controlling soil organic matter levels in great lains grasslands. *Soil Science Society of America Journal*, 51, 1173-1179
- [4]. Oades, J.M. 1993. The role of soil biology in the formation, stabilization and degradation of soil structure. *Geoderma*, 56, 377-400.
- [5]. Sollins, P., Homann, P. & Caldwell, B.A. 1996. Stabilization and destabilization of soil organic matter: mechanisms and controls. *Geoderma*, 74, 65-105.
- [6]. Guggenberger G., Zech W., Haumaier L. and Christensen B. T. 1995. Land-use effects on the composition of organic matter in particle size separates of soil: II. CPMAS and solution 13C NMR analysis. *European Journal of Soil Science*, 46, 147-158.
- [7]. Han, X., Tsunekawa, A., Tsubo, M., Li, S. 2010. Effects of land-cover type and topography on soil organic carbon stoarage on Northern Loess Plateau, China. *Acta Agric. Scand. Section B-Soil Plant Sci.*, 60, 326-334.
- [8]. Wu, J., O'Donnell, J.K., Syers, M. A., Adey, M.A. & Viyakon, P. 1998. Modelling soil organic matter changes on ley-arable rotation in sandy soils od Northeast Thailand. *Eur. J. Soil Sci.*, 49, 463-470
- [9]. Goulding, K.W.T., Poulton, P.R. 2005. The missing link. *Geoscientist*, 15, 4-7
- [10]. Poulton, P.R., Pye, E., Hargreaves & Jenkinson, D.S. 2003. Accumulation of carbon and nitrogen by old arable land reverting to woodland. *Global Change Biol.*, 9, 942-955.
- [11]. Tisdall, J.M. & Oades, J.M. 1982. Organic matter and water-stable aggregates in soils. *Journal Soil Science*, 33, 141-163
- [12]. Dudal, R., Deckers J. 1993. Soil organic matter in relation to soil productivity. In: Soil organic matter Dynamics and Sustainability of Tropical Agriculture. Mulongoy, K., Merckx, R. (eds.). John Wiley and son, West Sussex, United Kingdom, pp 702.
- [13]. 13. Petters, S.W.; Usoro, E.J.; Udo, E. J.; Obot, U. W. & Okpon, S.N. 1989. Akwa Ibom State Physical Background, Soils and Land Use Ecological Problems. Technical Report of the Task Force on Soils and Land use. Govt. Printer Uyo, pp 602.

- [14]. Udo, E. J., Ibia, T.O., Ogunwale, J.A., Ano, A.A. & Esu I. E. 2009. Manual of Soil, Plant and Water Analysis. Sibon Books Limited, Lagos, pp 82-92
- [15]. Nelson, D.W., Sommers, L. E. 1996. Total organic carbon and organic matter. In: *Methods of Soil Analysis, 2nd Ed.* D. L.Spans; A.L. Page; P.A. Helmke; R.H. Leoppert; P.N. Soltanpour; M.A. Tabatabai & C.I. Johnson, Eds. American Society of Agronomy: Madison, WI, US.A pp. 961-1010.
- [16]. Murphy, J., Riley, J.P. 1962. A modified version for the determination of phosphorus in natural waters. *Anal. Chem. Acta*, 27, 31-36
- [17]. Thomas G. W. 1982. Exchangeable cation. *Methods of Soil Analysis Part 2, Agronomy, Monograph 9* (2nd edition). SSSA Madison, Wisconsin and USA, pp 159-165
- [18]. Cambardella, C.A., Elliott, E.T. 1993. Methods for physical separation and characterization of soil organic fractions. *Geoderma*. 56, 449-457.
- [19]. Arshad, M.A., Coen, G.M. (1996). Characterization of soil quality: Physical and chemical criteria. *Am. J. Alternative Agr.* 7, 25–31.
- [20]. Smith, J.L. & Doran, J.D. 1996. Measurement and use of pH and electrical conductivity for soil quality. *Soil Science Society of American Special Publication* 49, 169-182.
- [21]. Enwenzor, W. O., Ochiri, A. C., Opuwaribo, E. E., Udo, E.J. 1980. A review of fertilizer use on crops in southern zone of Nigeria. In: *Literature Review on Soil Fertility Investigation in Nigeria*. FMANR. Lagos.6.
- [22]. Soil Survey Staff. (2006). Soil Taxonomy. A Basic System of Soil Classification for Making and Interpreting Soil Surveys. USDA Agric. Handbook. No.436, second edition. U.S.Govt. Printing Office, Washington, D.C. 871.
- [23]. Whitebread, A.M., Lefroy, R.D.B. & Blair, G.J. 1998 . A survey of the impact of cropping on soil physical and chemical properties New South Wales. *Aus.J. Soil Res.* 36,669-681.
- [24]. Solomon, D., Fritzsche, F., Tekalign, M., Lehmann, J.& Zech, W. 2002. Soil organic matter composition in the subhumid Ethiopian highlands as influenced by deforestation and agricultural management. *Soil Sci. Soc. Am. J.* 66, 68-82
- [25]. Herridge, D. 2011. Managing legumes and Fertilizer N for Northern Grain Cropping. Grain Research and Development Corporation. DRDC Project UNE00014. GRDC, Kingston ACT, Australia, , pp 54
- [26]. Stevenson, F.J. 1982. Humus Chemistry- Genesis, Composition and Reactions. John and Wiley and Sons, New York, pp 158
- [27]. Oades, J.M. 1993. The role of soil biology in the formation, stabilization and degradation of soil structure. *Geoderma*, 56, 377-400.
- [28]. Skjemstad, J.O., Clarke, P., Taylor, J. A., Oades, J.M., McClure, S.G. 1996. The chemistry and nature of protected C in soil. *Australian Journal of Soil Research*. 34, 251-271
- [29]. Oades, J.M. & Waters, A.G.1991. Aggregate hierarchy in soils. *Australian Journal of Soil Research*. 29, 815-828
- [30]. Hassink, J., Whitmore, A.P., Kubat, J. 1997. Size and density fraction of soil organic matter and the physical capacity of soils to protect organic matter. *European Journal of Agronomy* 7, 189-199.
- [31]. Six, J., Conant, T., Paul, A. & Paustian, K. 2002. Stabilization mechanisms of soil organic matter: implications for C-saturation of soil. *Plant and soil*, 24,1155-176.
- [32]. Nicholas, J.D. (1984). Relation of organic carbon to soil properties and climate in the southern great plains, *Soil Science Society of American Journal*. 48:1382-1384.
- [33]. Jenkinson, D. S. 1990. The turnover of organic carbon and nitrogen in soil. *Trans. Roy. Soc. Ser. B*, 329, 361-368.