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## Spatial Variability of Soil Carbon in Floodplain Soils of Southeastern Nigeria

E.U. Onweremadu  
Department of Soil Science and Technology,  
Federal University of Technology, Pmb 1526 Owerri, Nigeria

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**Abstract:** Variability of soil carbon in 5 floodplain soils at landscape scales were studied. Transect technique was used in soil sampling at 0, 25, 50, 75 and 100 m sampling points. Results showed that some measured soil properties varied among floodplain soils although all locations belong to the rainforest agro-ecology. The Oa horizons accounted for the highest variability in thickness (CV = 26%) in some locations. There was significant variation in total soil carbon in 60% of the floodplain soils. It is concluded that intensive soil sampling from landscape delineations will provide more accurate and reliable representation of soil carbon for scaling at regional levels.

**Key words:** Distribution, lowland, organic matter inventory, tropical soils, variation

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### INTRODUCTION

Periodic assessments of the distribution of soil carbon within and among soils are critical to developing an understanding of the cause and effect relationships between climate or land use change and release of carbon (IV) oxide to the atmosphere (Schimel *et al.*, 1994). In addition to understanding the cause and effect relationship, knowledge of soil organic carbon spatial variability is critical when developing carbon budgets for basic ecosystem characterization (Davis *et al.*, 2004).

The magnitude of Soil Organic Carbon (SOC) pool is a product of complex interactions among climate, topography, texture and land-use practices (Penmook and Kessel, 1997; Tan *et al.*, 2003). Because of the strong influence of climate on SOC dynamics, a greater precision may be achieved if monitoring is conducted within the region containing similar climate conditions (Brejda *et al.*, 2001).

Geospatial and temporal changes occur in soil carbon distribution in floodplains. Variabilities are attributed to changes in temperature, precipitation, plant succession or local depositional factors (Marion and Oechel, 1993). Bockheim *et al.* (2004) reported spatial variability of SOC pools with relative basin age class and attributed this to increased variability in hydrological enrichments.

In USA, some regional studies on estimation of SOC pools using pedon data have been conducted as a part of the USDA-NRCS Progressive Soil Survey (Kern, 1994; Grossman *et al.*, 1998; Homann *et al.*, 1998). Although the national soil survey database in USA is quite comprehensive, additional data on the of O horizons and subsoils of forest soils to the carbon pool were reported (Eswaran *et al.*, 1993). Such regional studies are scanty in developing countries and where available consider too many soil properties. This study is aimed at investigating the degree of variation occurring in floodplain soils in lowland areas of southeastern Nigeria.

### MATERIALS AND METHODS

#### Study Site

The research was focused on 5 floodplain soils along Imo River, Mmahu Egbema River and Oguta Lake in southeastern Nigeria. The watershed area is over 14500 km<sup>2</sup> and dominated by alluvial landforms, especially levee, backswamp, terrace and crevasse splay of recent neocene age

(Ofomata, 1975). This formation is partly marine, partly deltaic, partly estuarine, partly lagoonal and fluviolacustrine in origin (Orajaka, 1975). The site has a bimodal rainfall pattern with a mean annual rainfall greater than 2500 mm (Obi and Salako, 1995). Mean monthly temperature is about 28°C. Rainforest vegetation predominates in these lowland areas although altered slightly by anthropogenic activities. Farming, hunting and fishing are the major socioeconomic activities of the area. Farmers raise mounds to avoid seasonal waterlogging.

Studies conducted at a scale of 1:500,000 classified soils of the area as Typic Udipsamments (Akvette), Typic Hapludults (Egbema), Typic Paleudults (Mbaise), Arenic Paleudults (Oguta) and Arenic Paleudults (Owerinta) with an altitude below 100 m in all locations (Onweremadu, 2006).

### **Field Sampling**

Land units were delineated based on the 5 physiographic features, namely near upland hillwash, terrace, levee and backswamp. Soils were collected along two randomly chosen transects within each of the 5 delineations according to the procedure of Young *et al.* (1991). Sampling locations were spaced at 25 m intervals for a total of five sampling points, that is, 0, 25, 50, 75 and 100 m per transect. Samples for each location were collected by horizon to a depth of 100 cm. Organic horizon samples were collected from a 15 by 15 cm area intact and separated into fibric (Oi), hemic (Oe) and sapric (Oa) horizons using peat samples. Composite samples were produced by bulking collected samples from each pedogenic horizon for each floodplain. Mineral soil samples were collected using a 4.7 cm diameter split core sample.

### **Laboratory Analysis**

Particle size distribution was determined by hydrometer method (Gee and Or, 2002). Bulk density was estimated by core method (Grossman and Reinsch, 2002). Organic matter was determined by loss on ignition (Nelson and Sommers, 1996) while total soil carbon was measured using an automated C and N analyzer (Carlo-Erba, Milan, Italy) (Nelson and Sommers, 1996).

### **Statistical Analysis**

Descriptive statistics such as means and coefficients of variation and comparative analysis (Analysis of variance-ANOVA) were performed on soil data in SPSS version 10 (SPSS Inc., 1999).

## **RESULTS AND DISCUSSION**

### **Site**

Table 1 shows a brief description of the locations studied. All location belong to the lowland area of southeastern Nigeria (Ofomata, 1987). Although the landforms are of Neocene era (Ofomata, 1975), 4 locations have highly weathered soils (Ultisols). This could be attributed to rainfall and temperature characteristics of the site which promote rapid weathering (Eshett, 1989). Trees dominated other plant types although this trend varied geospatially within these floodplains. The nature and distribution of the plant types have obvious pedogenic implications on the floodplain soils. Earlier biosequence studies show that trees influence litter layer thickness (Johnson-Maynard *et al.*, 2004), activities of soil organisms (Coleman and Crossley, 1996), C and N accumulation (Ulery *et al.*, 1995) and rates of decomposition (Feng *et al.*, 1999; Quideau *et al.*, 2000, 2001).

### **Soil Properties**

Generally soils are sandy in all the locations with silt-sized fraction being most stable while clay content formed a bulge in all pedons except at Akvette (Table 2). Sandiness of these soils can be explained by the lithology coupled by climate and peculiar pedogenesis. Particle size fractions varied intra-pedally. Using Coefficient of Variation (CV), Aweto (1982) classified tropical soils as of little

Table 1: Brief description of the study sites

Location	Dominant plant type	Source	Soil taxonomy	Geographic		Coordinates
				X	Y	Z
Akwette	Trees	Fluvial	Typic Udipsamments	5°3'13 <sup>11</sup> .540	7°39'45 <sup>11</sup> .310	50 m
Egbema	Trees	Fluvial	Typic Hapldults	5°49'10 <sup>11</sup> .965	7°21'51 <sup>11</sup> .500	55 m
Mbaise	Trees	Fluvial	Typic Paleudults	5°48'33 <sup>11</sup> .010	7°37'10 <sup>11</sup> .040	90 m
Oguta	Mixed	Lacustrine	Arenic Paleudults	5°53'16 <sup>11</sup> .148	7°120'32 <sup>11</sup> .400	66 m
Owerrinta	Mixed	Fluvial	Arenic Paleudults	5°42'46 <sup>11</sup> .906	7°38'39 <sup>11</sup> .180	62 m

(Source: Onweremadu, 2006), X = Latitude, Y = Longitude, Z = Elevation

Table 2: Weighted means and coefficient of variation (CV) for particle size distribution of soils in the study site

Location	Horizon	n	Sand (g kg <sup>-1</sup> )		Silt (g kg <sup>-1</sup> )		Clay (g kg <sup>-1</sup> )	
			mean	CV (%)	mean	CV (%)	mean	CV (%)
Akwette	Oie	5	-	-	-	-	-	-
	A	5	860	12	40	8	100	6
	AB	5	820	6	40	15	140	8
	Bt <sub>1</sub>	5	810	9	40	4	150	3
Egbema	Bt <sub>2</sub>	5	810	13	40	2	150	5
	Oie	5	-	-	-	-	-	-
	Oa	5	-	-	-	-	-	-
	A	5	810	21	30	16	160	9
Mbaise	Bt <sub>1</sub>	5	800	10	30	5	170	3
	Bt <sub>2</sub>	5	790	11	30	6	160	5
	Oie	5	-	-	-	-	-	-
	A	5	840	6	20	8	140	14
Oguta	AB	5	830	9	20	10	150	11
	Bt <sub>1</sub>	5	800	15	20	4	180	4
	Bt <sub>2</sub>	5	800	19	30	-	170	5
	Oie	5	800	-	-	5	-	-
Owerrinta	Oa	5	-	-	-	-	130	-
	A	5	-	5	90	-	240	8
	Bt <sub>1</sub>	5	780	18	70	19	140	9
	Bt <sub>2</sub>	5	690	22	70	23	-	3
Owerrinta	Oa	5	790	-	-	6	130	-
	Oa	5	-	11	40	-	-	6
	A	5	830	4	60	15	130	15
	AB	5	840	16	20	17	100	6
	Bt <sub>1</sub>	5	800	-	50	5	180	8
Bt <sub>2</sub>	5	820	25	-	7	130	-	

variation (CV = 20%), moderate variation (CV = 20-50%) and high variation (CV > 50%), showing that there were slight variations in most horizons in particle size distribution. Little variation in particle size distribution in the upper horizons suggests similarity of influencing factors in the pedogenesis of these soils and sand-sized fraction (CV = 22%) in Oguta indicate varying rates of eluviation and illuviation. There is outstanding development of argillic horizon (Bt) in all locations except at Akwette, confirming advanced illuviation and argillation in the floodplain soils.

The average solum thickness of the mineral soils varied among locations and pedons (Table 6). The Oie horizons ranged in thickness from 3 to 9 cm and had lower bulk density values (0.09-0.81 Mg m<sup>-3</sup>) and SOC concentrations (300-408 g kg<sup>-1</sup>) (Table 3). Akwette and Mbaise soils lacked Oa horizons, Oguta soils had the thickest Oie-Oa horizons of 7-9 cm, respectively, but the bulk density values were correspondingly low (0.09-0.10 Mg M<sup>-3</sup>). Bulk density values decreased spatially and with depth, possibly due to changes in organic matter distribution as well as land use pattern. The Oa horizons were thin (3-7 cm) but there is greater likelihood that they mixed with the underlying A-horizons as a result of pedoturbation. Results of coefficient of variation in the organic horizons indicate little to moderate variation, suggesting that a number of factors such as soil type, vegetation type, management history, stand age and micro-climate may also be important in explaining spatial variability in soil carbon.

Table 3: Weighted means and coefficient of variation (CV) for thickness (cm), bulk density ( $M\text{ gm}^{-3}$ ), soil organic carbon (SOC) ( $\text{g kg}^{-1}$ ), total soil C ( $\text{g kg}^{-1}$ ), organic matter (OM) ( $\text{g kg}^{-1}$ ) and total soil organic carbon/area ( $\text{mg ha}^{-1}$ ) of soils in the study site

Location	Horizon	n	Thickness		Bulk density		SOC		Total soil C		OM		Total soil C/area	
			Mean	CV (%)	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)
Akwette	Oie	5	5	3	0.19	9	302	7	386	26	52	7	30.0	6
	A	5	6	11	1.04	3	22	22	31	24	38	21	2.2	22
	AB	5	50	8	1.26	3	6	10	11	8	10	9	0.6	8
	Bt <sub>1</sub>	5	75	7	1.32	2	2	6	4	4	3	6	0.2	6
Egbema	Bt <sub>2</sub>	5	100	-	1.40	1	1	4	3	3	2	3	0.1	3
	Oie	5	6	6	0.11	7	365	5	406	4	629	5	36.0	5
	Oa	5	4	26	0.32	5	26	12	34	23	45	11	2.6	10
	A	5	55	15	1.05	4	20	18	28	17	34	18	2.0	17
Mbaise	Bt <sub>1</sub>	5	78	14	1.26	2	8	9	12	8	14	8	0.8	8
	Bt <sub>2</sub>	5	100	-	1.38	1	2	6	3	5	3	6	0.2	7
	Oie	5	4	10	0.26	7	300	2	402	23	517	3	29.8	4
	A	5	5	6	1.23	4	36	6	50	7	62	6	3.6	5
Oguta	AB	5	80	3	1.28	5	15	21	23	2	26	20	1.5	19
	Bt <sub>1</sub>	5	82	28	1.29	2	5	9	11	10	9	9	0.5	8
	Bt <sub>2</sub>	5	100	-	1.41	3	2	4	3	2	3	4	0.2	5
	Oie	5	9	11	0.09	8	408	6	450	5	703	5	40.5	4
Owerrinta	Oa	5	7	26	0.10	2	86	26	263	20	148	25	8.5	24
	A	5	60	4	1.22	8	40	7	54	8	69	7	3.9	7
	AB	5	80	22	1.30	7	20	2	26	4	34	3	2.0	4
	Bt	5	100	-	1.36	5	6	2	10	2	10	2	0.6	3
Owerrinta	Oa	5	3	22	0.81	7	312	4	375	5	538	4	30.9	5
	A	5	55	11	1.12	5	40	27	56	28	69	27	3.9	26
	AB	5	79	8	1.21	2	26	15	31	16	49	15	2.6	16
	Bt <sub>1</sub>	5	83	26	1.27	1	18	9	23	11	31	9	1.8	10
Owerrinta	Bt <sub>2</sub>	5	100	-	1.34	3	9	3	13	4	15	3	0.9	5

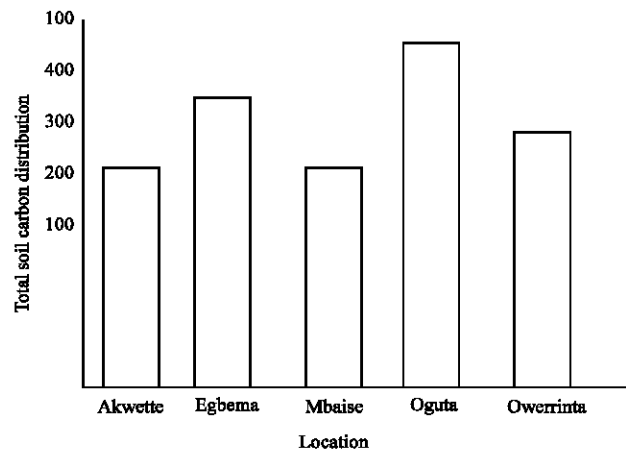


Fig. 1: Proportion of total soil carbon stored in O-A horizons in the 5 study sites

### Total Soil Carbon Distribution

Total soil carbon including the organic horizons ranged from 0.1  $\text{mg C ha}^{-1}$  (deepest mineral horizon in Akwette) to 40.5  $\text{mg C ha}^{-1}$  in Oie horizon in Oguta (Table 3). Higher values of total soil carbon in Oguta soils is attributable to lacustrine origin of soils unlike other locations that under fluvial activities. It is true that organic horizons contain the largest proportion of the soil carbon (Fig. 1), but appreciable quantities are stored in mineral horizons. Torn *et al.* (1997) found 33-70% of soil organic

Table 4: Summary of one way analysis of variance comparing Total soil C (mg ha<sup>-1</sup>) within soils of the study locations

Source	SS	df	MS	F-value	p-value
<b>Akwette</b>					
Model	800	1	800	3.21	0.091
Error	4488	18	249		
Total	5276	19			
<b>Egbema</b>					
Model	15300	2	7650	7.41	0.004
Error	26833	26	1032		
Total	42145	28			
<b>Mbaise</b>					
Model	27700	1	27700	14.60	0.002
Error	34140	18	1897		
Total	61863	19			
<b>Oguta</b>					
Model	130660	1	130660	13.82	0.003
Error	255283	27	9455		
Total	385949	28			
<b>Owerrinta</b>					
Model	900	1	900	3.24	0.092
Error	5000	18	278		
Total	5527	19			

SS = Sum of squares; df = Degree of freedom; MS = Mean squares

carbon in the total soil carbon pool in sub-surface horizons, emphasizing the importance of subsoil horizons in contributing to total soil carbon. This particularly important in shrubby crops which have subsoil as rooting zone.

There was no significant difference at 5% level of probability in total soil carbon in two locations, namely Akwette and Owerrinta despite physiographic differences (Table 4) in the other 3 floodplain, Egbema, Mbaise and Oguta. Total soil carbon stored varied significantly within them at  $p = 0.004$  (Egbema),  $p = 0.002$  (Mbaise) and  $p = 0.003$  (Oguta). Environmental factors determine variation in organic matter contents in tropical soils (Feller, 1993) and these include rainfall, erosion, hydro-morphology and soil texture (Igwe, 2001). The CV results showed that total soil carbon varies greatly at top horizons similar to the findings of Kabrick *et al.* (1997) in Wisconsin.

## CONCLUSIONS

The spatial variability data collected in this study are helpful in estimating soil carbon pools in floodplain soils of southeastern Nigeria. Three of the 5 locations have significantly different pools of total soil carbon, showing that data from a single pedon may not provide reliable data on soil carbon distribution in the area. An input of Geographic Information System (GIS) into similar studies can improve the status by producing customized maps in these floodplain soils. More intensive sampling at series level delineations will certainly yield more reliable data on the distribution and storage of soil carbon which can in turn be used in programming decision support systems in low-input agriculture characteristic of most developing countries. Increased database generation is becoming highly imperative with expansion of farming to floodplains due to heightened demographic pressure.

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