JASEM ISSN 1119-8362
All rights reserved

Full-text Available Online at
www.ajol.info and
www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage. *June,* 2012
Vol. 16 (2)174 - 179

Soil Carbon Characteristics of a Fluvisol Affected by Aggregates from Two Tillage and Crop Regimes

[1]*EMMANUEL ONWEREMADU; [1]FRANK AKAMIGBO; [2]CHIGOZIE ASIABAKA

[1]*Department of Soil Science and Technology, Federal University of Technology, Owerri, Nigeria*
[2]*Department of Agricultural Extension, Federal University of Technology, Owerri, Nigeria*

ABSTRACT: We investigated soil carbon characteristics of a Fluvisol as influenced by different ped sizes and crop types for a period of 10 years in Owerri, Southeastern Nigeria. The experimental design was a split-split plot arranged in a randomized complete block design, with tillage technique serving as main plot; crop regime was the split plot and NPK fertilizer as split – split plot. Tillage techniques used were conventional tillage (CT) and minimum tillage (MT) while maize and soybean were used as crop types. Soil samples were collected at 20 cm depth with soil auger while core samples with cores partitioned 0 – to 10 – and 10 – to – 20 cm depth intervals were used to obtain soil samples for bulk density determinations. Routine laboratory analysis were conducted on soil samples and obtained data on crop and soil were statistically analyzed using analysis of variance (ANOVA) and means were separated using least significant differences (LSD) at $P < 0.05$. Aggregate size distribution was significantly ($P < 0.05$) influenced by tillage and crop type at 0 – 10 cm depth and soil carbon varied significantly ($P < 0.05$) with aggregate–size forms, tillage technique and crop species. Prediction of carbon behaviour in floodplain soils should take into consideration variability in ped forms, tillage method and crop types. @JASEM

Carbon sequestration potential of soils may be influenced by tillage technique and crop type. Tillage encourages loss of soil organic matter through disruption of macroaggregates, physical breakdown of plant residues and incorporation of crop residues into the soil (Six *et al*, 2000; Six *et al*., 2002). Soil management practices such as zero-tillage; minimum tillage, conventional tillage and cropping systems influence the distribution of soil organic carbon and soil organic nitrogen as well as the stability of soil aggregates (Onweremadu *et al*., 2007a). Zero tillage promotes soil aggregation through binding of soil particles by high soil organic matter content (Paustian *et al*., 2000). Formation of macroaggregates around particles of undecomposed soil organic matter protects them from decomposition (Six *et al*., 2002), and this enhances carbon storage. Whereas zero tillage promotes aggregation and carbon storage (Hendrix *et al*., 1998), conventional tillage disrupts macro-aggregates are more stable than macroaggregates (Cambardella and Elliot, 1993).

Cropping systems have great impact on soil carbon storage and evolution. Crop types play profound roles in carbon sequestration and carbon storage varies due to differences in quality and quantity of crop resides (Martens, 2000). Very high soil organic matter content was reported in multiple cropping systems where crops are grown annually (Ortega *et al*., 2002; Wright and Hons, 2004).

In Southeastern Nigeria, land degradation is widespread and soils are mined (Onweremadu, 2006) resulting from increasing population, reduced fallow length, excruciating climate, erodible soils and conflictive land use practices. Studies on soil organic matter dynamics and soil aggregates as influenced by tillage technique and crop type become necessary in assessing soil quality especially as it affects carbon sequestration and climate change. The major objective of this study was to investigate the behaviour of soil carbon under different aggregate sizes, tillage techniques and crop types.

MATERIALS AND METHODS

Study Area: The study was carried out at Otamiri River watershed soil at Federal University of Technology Owerri, Nigeria (Latitudes $5^0 30'$ and $6^0 00'$ N, Longitudes $7^0 00$ and $7^0 30^0$ E). Soils of the study area are derived from Coastal Plain Sands (Benin formation) of the Oligocene–Miocene geologic era (Orajaka, 1975) and were classified as Fluvisols in an earlier study (Onweremadu et al., 2007). Owerri belongs to the lowland area of Southeastern Nigeria with an altitude of about 50 – 100 metres above mean sea level (Orajaka, 1975). The climate is humid tropical having a mean annual rainfall ranging from 2250 to 2500 mm and with a mean annual temperature range of 26 – 29 ^{0}C. It has depleted rainforest vegetation due to demographic pressure. Farming is a major socio-economic activity of the area.

Experiment: A long term field experiment (10 years) conducted in the University Teaching and Research farm. The experimental design was a split–split plot arranged in a randomized complete block design, with tillage techniques serving as main plot, crop type was the slit plot and NPk fertilizer was the split–split plot. Field plots measured 12 m x 4 m each, and treatments were replicated four times. Two crop species were grown annually under conventional tillage (CT) and minimum tillage (MT). The crop

---

* E-mail: uzomaonweremadu@yahoo.com

species were maize (*Zea mays* L.) and soybean (*Glycine max* L. Merrill). In the MT plots, only planting holes were opened with a dibble whereas in CT, raised beds, 20 cm deep were prepared manually using traditional hoes. Fertilizer (NPK 15:15:15) was applied manually using a band application method at 5 cm depth and 10-15 cm radius at the rate of 150 Mg ha-^{1}. All treatments were repeated in the relevant plots annually throughout the duration of the experiment.

Field Sampling and Laboratory Analyses: Soil samples were collected from soils after crop harvest using soil auger, with 25 cores taken to a depth of 20 cm depth. Soil cores were partitioned 0-to 10 – and 10- to 20 – cm depth intervals. Soil samples from respective depths in each plot were bulked and air–dried for 7 days before passing them through a 4.75–mm sieve. Another triplicate core sample was obtained using a 7.5 cm core sample for bulk density determinations (Grossman and Reinsch, 2002). Also soil samples from different treatments were collected for incubation studies Soil aggregates were fractionated by wet–sieving (Cambardella and Elliot, 1994). Soil samples were immersed in water on a net of sieves, namely 2 mm, 250 µm ad 53 µm after capillary wetting of 90 g of oven-dried soil to field capacity. The set up was vertically shaken 3 cm for 50 times during a 120-second period. Backwashing of water-stable aggregates were oven-dried at 50 ^{o}C for 72 hours and weighed. Soil particles that passed through the 53-µm sieve were determined by calculating the difference between whole soil and the sum of the three aggregate-size fractions (> 2 mm, 250 µm-2 mm, 53 µm –250 µm). These aggregate sizes represented macroaggregates (>2mm), small macroaggregates (250 µm – 2 mm), Microaggregates (53 µm – 250 µm) and silt plus clay associated particles (<53 µm). Subsamples of aggregate size fractions were ground to pass a 0.5-mm sieve and analyzed for soil organic carbon (SOC). The SOC was determined by wet digestion (Nelson and Sommers, 1982). In this procedure, 0.5 g of soil was digested with 5 ml of 1N $K_2Cr_2O_7$ and 10 ml of concentrated H_2SO_4 at 150 ^{0}C for 30 min. This was followed by titration with standardized $FeSO_4$.

Soil microbial respiration was measured by CO_2 evolution and obtained by back titration with 1.0 M HCl after precipitating the carbonates with 3 ml, 1.0 M $BaCl_2$ as described by Blom and Eddhausen (1955). Three hundred grams of soil were wetted to field capacity, put in flasks and tightly covered after inserting 0.01M NaOH solution. The evolved Co_2 was trapped in the NaOH solution and then titrated with 1.0 M HCl solution.

Data Analysis: Statistical analysis (means and analysis of variance: ANOVA) were performed using PC SAS Version 8.2 (SAS INSTITUTE, 2001). A one-way ANOVA model was used for individual treatment comparisons at P<0.05 and means separated by the Least Significant Difference. The determination of difference in SOC between aggregate sizes was done using a three-way ANOVA with factors being crop type, tillage technique and proportion of aggregate fractions.

RESULTS AND DISCUSSION

Properties of studied soils are shown on Table 1, indicating preponderance of sand-sized fractions, strong acidity and low cation exchange capacity. Bulk density increased with depth and was higher in soils under maize than soybean irrespective of tillage technique (Table 2). Maize yield was higher in MT than CT while the reverse was the case in soybean (Table 2).

Table1. Some properties of soils of the study site

Soil Property	Unit	Value
Total sand	g kg^{-1}	900 ± 4
Silt	g kg^{-1}	20 ± 4
Clay	g kg^{-1}	80 ± 3
pH KCl	-	4.1 ± 0
Cation exchange capacity	cmol g kg^{-1}	2.5 ± 0.2

(Source: Onweremadu *et al.,* 2007)

Aggregate-size distribution was significantly (P < 0.05) influenced by crop type and tillage technique at 0 – 10cm depth (Table 3) with maize under CT producing 43% of macroaggregates of size 250 µm – 2 mm at 0 – 10 cm depth while soybean cultivation resulted in 38 % of the same size fraction and tillage method. Generally, in both crop types, MT gave rise to largest aggregate-size fraction (>2 mm) while CT resulted in greater proportion of silt + clay associated fractions (<53 µm).

Table 2. Mean values of soil and crop attributes

Attributes	Conventional Tillage	Minimum Tillage
	Maize	
Bulk density (Mg m $^{-3}$)		
0 – 10 cm depth	1.41	1.32
10 – 20 cm depth	1.58	1.43
Crop (Grain yield (tha-1)	7.6	9.7
Crop residue production (g m -2)	326.2	438.5
	Soybean	
Bulk density (Mg m $^{-3}$)		
0 – 10 cm depth	1.30	1.26
10 – 20 cm depth	1.36	1.32
Crop yield (tha^{-1})	2.13	1.91
Crop residue production (g m $^{-2}$)	511.0	426.0

Table 3. Distribution of soil aggregates in maize and Soybean under conventional and minimum tillage at 0-10 and 10- 20 cm depths

Depth (cm)	> 2mm	250 µm-2mm	53-250µm	<53 µm
0-10	2	43	13	20
10-20	3	31	12	27
	Maize			
0-10	34	38	11	17
10-20	32	33	14	21
	Soybean (CT)			
0-10	12	38	20	30
10-20	22	35	20	23
	Soybean (MT)			
0-10	26	20	20	24
10-20	24	26	27	23

CT = conventional tillage, MT = Minimum tillage

The distribution of SOC was significantly (P = 0.05) affected by crop type and tillage method (Table 4) at 0 – 10 cm depth. While at 0 – 10 cm depth, SOC under MT was higher for maize than soybean with SOC value under maize in CT higher than its counterpart in Soybean. At 10 – 20 cm depth, tillage effect was not significant. There were significant (P = 0.05) variations in SOC content of aggregate-size fractions as influenced by crop type and tillage techniques (Table 5).

Minimum tillage increased SOC in 250 µm – 2.0 mm and >2 mm size fractions in maize. In the same tillage technique, SOC values were higher in aggregates >2 mm and 250 µm – 2.0 mm. Higher values of SOC were recorded in 10 – 20 cm depth under CT in both crops when compared with values obtained in 0 – 10 cm depth. Carbon dioxide evolution varied in both crops under CT and MT at the investigated depths (Table 6). Mean values of evolved CO_2 were greater in CT than MT in both crops at 0 – 10 and 10 – 20 cm depths. Values of CO_2 were generally higher in maize than soybean at 0 – 10 and 10 – 20 cm depths. In addition, CO_2 evolution increased with incubation time.

Properties of studied soils reflect the nature of parent materials (Akamigbo and Asadu, 1983), land use (Nnaji *et al.*, 2002; Akamigbo, 1999) and a combination of these factors including climate (Onweremadu *et al.* 2007b). Crop type and tillage significantly (P = 0.05) impacted on the distribution of aggregate-size fractions at 0 – 10 and 10 – 20 cm depths with 250 µm to 2 mm predominating in both tillage regimes. Significant tillage effect at both depths could be attributed to incorporation of organic materials into the soil while crop effect is attributed to rooting pattern, total number and quality of crop residues.

Higher values of aggregates < 250 µm could be traced to the combined effect of organic matter and thixotropic processes (Igwe and Stahr, 2003). It could be that N-content of maize (gramineae) and soybean (leguminoseae) affected quality of crop residue (Franzluebbers *et al.*, 1995) and this influenced aggregation (Spaccini *et al.*, 2001). Greater carbon sequestration in maize than soybean may due to biochemical nature of their residues and differences in soil aggregate sizes. In both crops, pattern of C-storage with depth differed in CT and MT, probably due differences in intensity of tillage.

Table 4. Distribution of SOC (g kg^{-1}) in maize and soybean under CT and MT at 0-10 and 10-20 cm depths

Depth (cm)	Maize		Soybean	
	CT	MT	CT	MT
0-10	9.8	18.8	8.6	13.6
10-20	8.6	8.8	8.8	9.0

SOC = soil organic carbon, CT = Conventional tillage, MT = Minimum tillage

Table 5. Distribution of SOC (g kg-1) content of aggregates in maize and soybean under CT and MT at 0-10 and 10 – 20 cm depth

Depth (cm)	> 2 mm	250 µm – 2mm	53-250 µm	< 53 µm	Mean
		Maize (CT)			
0-10	5.1	6.8	2.1	5.8	5.0
10-20	5.6	7.5	3.4	9.2	6.4
Mean	5.4	7.2	2.8	7.5	-
		Maize (MT)			
0-10	7.4	9.7	3.6	5.5	6.6
10-20	4.8	8.9	2.8	4.7	5.3
Mean	6.1	9.3	3.2	5.1	-
		Soybean (CT)			
0-10	5.8	3.1	2.3	1.9	3.3
10-20	3.2	2.3	2.1	3.3	2.7
Mean	4.5	3.2	3.2	2.6	-
		Soybean (MT)			
0-10	6.6	7.5	2.6	2.5	4.8
10-20	4.2	4.6	2.0	2.1	5.4
Mean	5.4	5.1	2.3	2.3	-

SOC – Soil organic carbon, CT = Conventional tillage, MT minimum tillage.

Table 6. Carbon (IV) oxide evolution mg/100g soil) during incubation in Maize and Soybean under two tillage techniques at 0-10 and 10 - 20 cm depths

	Incubation time (weeks)					
Depth (cm)	1	2	6	9	12	Mean
		Maize (CT)				
0-10	75	95	125	250	380	185
10-20	50	70	80	105	200	101
Mean	62.5	82.5	102.5	117.5	290	-
		Maize (MT)				
0-10	35	60	90	105	190	96
10-20	20	45	55	90	155	73
Mean	27.5	52.5	72.5	97.5	172.5	-
		Soybean (CT)				
0-10	70	80	120	240	370	176
10-20	60	65	85	115	205	106
Mean	65	72.5	102.5	177.5	287.5	-
		Soybean MT				
0-10	30	55	85	105	205	96
10-20	25	35	65	95	160	76
Mean	27.5	45	75	100	182.5	-

CT = conventional tillage, MT = Minimum tillage

Minimum tillage produced higher percentage values of aggregates > 250 µm and this could explain higher organic matter content in aggregates irrespective of crop species when compared with values of organic matter under CT. Loss of organic matter in form of CO_2 occurs when soil aggregates are broken down thereby exposing the labile pool of soil organic matter. Earlier, Cambardella and Elliott (1992) observed that land use influences aggregate stability which is enhanced by soil organic matter. Higher values of cumulative CO_2 evolution from 0 – 10 cm depth when compared with 10 – 20 cm depth may be arising from higher microbial respiration in response to relatively greater values of organic matter in epipedons irrespective of tillage technique and crop species. Conventional tillage technique led to greater loss of CO_2 in both maize and soybean at both depths (Table 6) since tillage reduces labile soil organic matter and its cessation increases it (Six *et al.*, 2000). Soil aggregates physically protect labile soil organic matter from microbial decomposition (Six *et al.*, 2000; Krull *et al.*, 2003). Carbondioxide evolution in soils under maize was greater than in soils under soybean possibly due to differences in biomass production, land use history and nature of autochthonous soil organisms. High CO_2 evolution under acidic soil conditions characteristic of the study site is detrimental to soil fertility as it leads to unavailability of phosphorus and nitrogen (Boyle and Paul, 1989), availability of ammonium ions, growth of soil microbes and mobility of copper (Ayuso *et al*., 1996).

REFERENCES

Akamigbo, F. O. R.and Asadu, C. L. A. (1983). Influence of parent materials on the soils of Southeastern Nigeria. *East African Agricultural and forestry Journal* 48: 81 – 91

Akamigbo, F. O. R. (1999). Influence of land use on properties of the humid tropical agroecology of Southeastern Nigeria. *Nigerian Agricultural Journal* 30: 59 – 76

Ayuso, M., Paschal, J. A., Garcia, C.and Hernandez, T. (1996). Evaluation of urban wastes for agricultural use. *Soil Science Plant Nutrition* 42: 105 – 111

Blom, L.and Eddhausen, L. (1985). Direct titration of carbon dioxide. *Analytical Chemistry* 13: 120 – 128

Boyle, M., and Paul, E. A. (1989). Carbon and nitrogen kinetics in soil prevcously amended with sewage sludge. *Soil Science Society America Journal* 53:99 – 103

Cambardella, C. A.and Elliott, E. T. (1992). Particulate soil organic matter changes across a grassland cultivation sequence. *Soil Science Society of America Journal* 56: 777 – 783

Cambardella, C. A and Elliot, E. T. (1993). Carbon and nitrogen distribution in aggregates from cultivated and native grassland soils. *Soil Science Society of America Journal* 57: 1071 – 1076

Cambardella, C.A. and Elliot, E. T. (1994). Carbon and nitrogen dynamics of soil organic matter fractions from cultivated grassland soils. *Soil Science Society of America* 58: 123 – 130

Franzluebbers, A. J., Hons, F. M.and Zuberer, D. A. (1995). Soil organic carbon, microbial biomass and mineralizable carbon and nitrogen in sorghum. *Soil Science Society of America Journa*l 59: 460 – 466

Gale, J., Cambardella, C. A.and Bailey, T. B. (2000). Root derived carbon and the formation and stabilization of aggregates. *Soil Science Society of America Journal* 64: 201 – 207

Grossman, R. B.and Reinsch, T. G. (2002). *Bulk density*. In: Dane, J.H.and Topp, G. C. (eds.) Methods of soil analysis, physical methods 201 – 228. Soil science society of America Book Series, ASA and SSSA, Madison WI

Hendrix, P. F., Franzluebbers, A. J.and McCracken, D. V. (1998). Management effects on C accumulation and loss in soils of the Southern Appalachian Piedmont and of Georgia. *Soil & Tillage Research* 47: 245 – 251

Krull, E. S., Baldock, and Skemstad, J. O. (2003). Importance of mechanisms and processes of the stabilization of soil organic matter for modeling carbon turnover. *Functional Plant Biology* 30: 207 – 222.

Martens, D. A. (2000). Plant residue biochemistry regulates soil carbon cycling and carbon sequestration. *Soil Biology and Biochemistry* 32: 361 – 369

Nelson, D. W.and Sommers, L. E. (1982). *Total carbon, organic carbon and organic matter*. In Page, A. L., Miller, R. H.and Keeney, D. T. (eds.) Methods of soil analysis, chemical method 1085 – 1121, ASA and SSA, Madison, WI.

Nnaji, G. U., Asadu, C. L. A.and Mbagwu, J. S. C. (2002). Evaluation of physicochemical properties of soils under selected agricultural land use types. *Agroscience* 3: 27 – 33

Onweremadu, E. U. (2006). Assessment of mined soils in erosion – degraded farmlands in southeastern Nigeria. *Estudio Biologia* 28: 59 – 67

Onweremadu, E. U., Onyia, V. N.and Anikwe, M. A. N. (2007a). Carbon and nitrogen distribution in water-stable aggregates under two tillage techniques in Fluvisols of Owerri area, Southeastern Nigeria. *Soil & Tillage Research* 97: 195 – 200

Onweremadu, E. U., Osuji, G. E., Eshett, E. T., Opara, C. C. and Ibeawuchi, I. I. (2007b). Characterization of soil properties of owner-managed farms of Southeastern Nigeria. *Journal of American Science* 3: 28 – 37

Orajaka, S. O. (1975). *Geology*. In Ofomata, G. E. K. (ED.) Nigeria in maps: Eastern states, 5 – 7. Ethiope Publishing House, Benin City

Ortega, R. A., Peterson, G. A.and Westfall, D. G. (2002). Residue accumulation and changes in soil organic matter as affected by cropping intensity in no-till dryland agroecosystems. *Agronomy Journal* 94: 944 – 954

Paustian, K., Six, J., Elliot, E. T.and Hunt, H. W. (2000). Managing options for reducing CO_2 emissions from agricultural soils. *Biogeochemistry* 48: 147 – 163

Six, J., Elliott, E. T.and Paustian, K., (2000). Soil macroaggregate turnover and microagregate formation. A mechanism for C sequestration under no tillage agriculture. *Soil Biology and Biochemistry* 32: 2099 – 2103

Six, J., Paustian, K., Elliot, E. T.and Combrink, C. (2000). Soil structure and organic matter: Distribution of aggregate size classes and aggregate associated carbon. *Soil Science Society of American Journal* 68: 681 – 689

Six, J., Feller, C., Denef, K., Ogle, S. M., De Moraes, J. C.and A, A. (2002). Soil organic matter, biota and aggregation in temperate and tropical soils: Effect of no tillage. *Agronomie* 22: 755 – 775

Spaccini, R., Zena. A., Igwe, C. A., Mbagwu, J. S. C.and Piccolo, A.(2001). Carbohydrate in waterstable aggregates and particle size fractions in forested and cultivated soils in two contrasting tropical ecosystems. *Biogeochemistry* 53: 1 – 22

Wright, A.I,and Hons, F. M. (2004). Soil aggregation and carbon and nitrogen storage under soybean cropping sequence. *Soil Science Society of America Journal* 68: 507 – 513