

INFLUENCE OF ORGANIC MATTER ON AGGREGATE STABILITY OF SELECTED SOILS UNDER DIVERSE LAND USE SYSTEMS IN AKWA-IBOM STATE, NIGERIA

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ABSTRACT

A study on the influence of organic matter on aggregate stability of selected soils under diverse land use systems in Akwa-Ibom state, Nigeria was carried out. The land use systems considered were forest land use (FOR), agricultural waste dump sites (AWS), continuous cultivated land (CUL) and Fallow land system (FAL). The samples were collected at depth 0-20, 20-40, 40-60, 60-80 and 80-100cm. a total of twenty (20) core and bulk samples were obtained in each land use system. indices of aggregation that mean organic matter content in AWS was 4.19%, 5.38% in CUL, 3.75% in FAL and 5.22% in FOR. The highest mean organic matter was obtained in FOR and the difference was significant ($P < 0.05$). organic matter status of these soils belong to low fertility class. The low organic matter status impacted negatively on the nutrient status and structural stability of the soils in the study area. The highest organic matter was obtained at depth 0-20cm and decreased down the profile. Interactive effects of land use and depth was not significant ($P < 0.05$). The study recommends the addition of organic materials like agricultural wastes or crop residues, organic mulch and green manuring as means of increasing organic pools of these soils which will enhance the soil's physical condition and make them structural stable.

Key words: Organic matter, aggregate stability, landuse.

INTRODUCTION

Soil aggregation refers to any stable association of individual's particles of the same or different nature, as a result of granulometric composition, soil biology and physic-chemical properties. Romkens *et al.* (2007) categorized factors affecting aggregate stability as abiotic (soil organic matter, activities of plant roots, soil fauna and flora), and the environment (soil temperature and moisture content). The concept of aggregate stability depends on both the factors that bind particles together and the nature and magnitude of the disruptive stress (Kosters *et al.*, 2013). Soil aggregate stability is of major importance in regard to many aspects of and Sposito (1993) reported that soils high in aggregate structure due to varying degree of soil organic matter are friable, well aerated,

Soil aggregate is improved by organic matter and so increased organic matter will reduce degradation and enhance soil productivity. Mismanaged land use world wide had become a global concern because of the associated negative impacts. Different land

soil management. It is directly and indirectly related to the soil conservation and degradation (Bonanomi *et al.*, 2011). Onofiok (2002) noted that aggregate stability is important in evaluating the ease with which soils erode by water or wind, the potential of soils to crust/seal, soil permeability quasi-steady state infiltration rates, seedling emergence and in predicting the capacity of soils to sustain long term crop production.

Soil organic matter pools is an important component of soil quality and aggregate stability. Different land use (forestry, pasture and crop cultivation etc) poses varying impact on soil organic matter and soil physical stability (Igwe, 2004). Heil rich in nutrients, easily penetrated by plant roots, poses high water holding capacities and are considered agriculturally superior.

uses had altered and severely impacted the land's nutrients and hydrological cycles as well as the earth's climate. Intensive crop cultivation of land without adequate supplementation of lost organic matter had destroyed structural characteristics of most

soils with increased severity of erosion (Thrner, 2001). Other human activities such as devegetation, unregulated tillage activities, urbanization etc. had significantly impacted on our carbon stocks and impacted negatively on aggregate stability of soils. There and other concerns necessitated the present study on influence of organic matter on aggregate stability of four land use types of selected soils in Akwa-Ibom state with the objectives of determining the relationship between soil organic matter pools and soil stable aggregates under four land use practices.

Materials and Method

The study area

The study was carried out in three Local Government Areas in Akwa Ibom State namely Ibeno, Itu and Ini Local Government Areas representing Beach Ridge Sands (BRS), Coastal Plain Sands (CPS) and Sand Stone (STN) landforms of the State. Akwa Ibom State is located between latitude 4° 30' and 5° 30'N and longitude 7° 30' and 8° 30'E. It is one of the nine states of Niger Delta region of Nigeria situated around the tributaries of the Niger River, into the Southern Atlantic Ocean and the core South-South of Nigeria. The region is about 20,000 sq/km as it is the largest wetland in Africa and among the third largest in the world (Anifowose, 2008; Chinweze and Abiola-Oloke, 2009).

Climate

Akwa Ibom State lies in the humid tropics which are characterized by two distinct seasons: dry and wet seasons. The dry season starts from November to March while the wet season lasts from April to October.

In the month of August, there is a period of 2-3 weeks of little or no rain which is referred to as the August break. This period marks the end of the first planting season and the beginning of the second planting seasons mostly for cereal and vegetable crops in September.

The annual rainfall ranges from 2,000 mm on the northern fringe to over 3,000mm along the coast. This is why the study area is always characterized by heavy flooding and severe erosion in some areas. These incidences of erosion and flooding are aggravated by land use changes in the area. The mean relative humidity is 75% while solar radiation ranges from 6 - 15 mm per

day. The temperature is constantly high with a mean monthly value of approximately 27 °C. Relative humidity is at a constant high value of between 70 and 90 % all year round (Udosen, 2008).

Geology and Soils

The soils in Akwa Ibom State developed from sedimentary geological formation (Petters *et al.*, 1989). The soil is developed from sandy parent materials, highly weathered and dominated by low clay activities (Udo and Sobulo, 1981).

Vegetation and Land use

The State is located within the humid forest zone of Nigeria. There is a drastic transformation of the natural vegetation due to the population pressure and urbanisation. Traditional subsistence crops like plantain, cassava, maize, okra, vegetables, yam, cocoyam etc, are typical features in the study area. The native vegetation has been completely replaced by secondary forest of predominantly oil palms, woody shrubs such as *Chromolaena* and grasses. Peters *et al.* (1989) observed that human population pressure coupled with poor management and improper land use has led to forest depletion with the attendant soil degradation and low productivity.

Field Studies

Four (4) land use systems namely Forest land use system (FOR), Agricultural wastes dump sites (AWS), Continuous Cultivated Land (CUL) and Fallow Land System (FAL) were selected within the three Local Government Areas namely Uyo, Ibeno and Ini Local Government Area. In each land use system, one profile pits measuring 1m x 2 m and about 1 m depth was sunk giving a total of four profile pits per local Government area and twelve (12) profile pits for the study. Each profile pit was demarcated into five designated depths of 0 – 20, 20 – 40 and 40 – 60, 60 – 80 and 100 cm. Core samples were collected using core cylinder measuring 7.2cm height and 6.8cm width for determination of hydraulic conductivity and bulk density while auger sample was collected using soil auger, all at five designated depths of 0 – 20, 20 – 40 and 40 – 60, 60 – 80 and 80 - 100 cm depths for auger samples respectively. A total of twenty (20) core and bulk samples were obtained in each land use system giving a total of sixty (60) core and auger samples for the study per

cycle and one hundred and twenty samples for the two cycles. Indices of aggregation that were determined include liable, active fraction and humic acid while soil properties determined included; bulk density, total porosity, macro porosity and saturated hydraulic conductivity

Laboratory Analysis

The bulk samples were air-dried and sieved through a 4 mm sieve and further sieved through a 2mm sieve. Thereafter, these samples were stored in a labelled polyethylene bags then analysed for the following properties:

Particle size distribution was determined using the Bouyoucos (Hydrometer) method described in Udo *et al.*, (2009).

Bulk Density

Bulk density was determined by the method described by Landon (1984). Soil samples were oven-dried at the temperature of 105°C to a constant weight. Bulk density was calculated from the mass volume relationship as:

$$\ell_b = \frac{M_s}{V_t} \quad (4)$$

where,

ℓ_b = Bulk density (Mg m^{-3})
 M_s = dry soil mass (mg)
 V_t = total volume of soil (m^3)

The total volume of soil was calculated from the internal dimension of the core cylinder.

Total Porosity

Total porosity was calculated from particle - bulk density relationship as follows:

$$f = \left[1 - \left(\frac{\ell_b}{\ell_s} \right) \right] \quad \dots (5)$$

where f = Total porosity

ℓ_b = bulk density (Mg m^{-3})

ℓ_s = Particle density assumed to be 2650 Mg m^{-3}

Saturated Hydraulic Conductivity

The core samples were used for the determination of hydraulic conductivity as described by Dane and Topp (2002). The samples were placed in a basin of water and allowed to saturate for 24 hours. Hydraulic conductivity was determined by the constant head method. This involved placing each cylinder in a funnel and constant water head maintained throughout the determinations, the water passing through the soil column was collected and measured. Saturated hydraulic conductivity was calculated using the equation below:

$$K_{sat} = \frac{QL}{\Delta hAt} \quad (6)$$

where,

Q = discharge rate ($\text{cm}^3 \text{ hr}^{-1}$)

L = length of soil column (cm)

Δh = change in hydraulic head (cm)

$L + h$ (L = length of soil – containing cylinder, h = height of water above soil – containing cylinder)

A = Cross sectional area of the Cylinder (cm^2)

t = time (min)

Organic Carbon and Organic matter

Organic carbon content of the soil was determined using Walkley and Black (1934) Wet Oxidation Method described in Udo *et al.*, (2009). Soil samples were ground to pass through 0.5 mm sieve. One gramm (1 g) of the sieved sample was weighed into a 250 ml Erlenmeyer flask in duplicate. 10 ml of 1 N $\text{K}_2\text{Cr}_2\text{O}_7$ solution was pipetted into each flask and swirled gently to disperse the soil. Also, 20 ml conc. H_2SO_4 was rapidly added using an automatic pipette, directing the stream into the suspension. The flask was swirled gently until soil and reagents were mixed, then swirled more vigorously for 1 minute. The flask was rotated and allowed to stand on a sheet of asbestos for 30 minutes. 3 – 4 drops of indicator were added and titrated with 0.5 N ferrous sulphate solution till the end point approached where the solution took a greenish to dark green colour. Then the ferrous

sulphate was added drop by drop until the colour changed sharply from blue to red. A blank titration was also prepared in the same manner but without soil to standardize the dichromate. Organic carbon (C) was calculated as follows:

$$\% \text{ Organic C} = \frac{N(V_1 - V_2)0.3f}{w}$$

(9)

% organic matter in the soil sample was determined by multiplying organic C by 1.729.

where,

N = Normality of ferrous sulphate solution

V₁ = quantity of ferrous ammonium sulphate required for the blank (ml)

V₂ = quantity of ferrous ammonium sulphate required for the sample (ml)

W = Mass of sample (g)

f = Correction factor (1.33)

Nitrogen

Nitrogen (N) concentration was determined using macro-kjeldahl method as described in Udo *et al.*, (2009). 10 g of air-dry sieved sample (passed through 2mm sieve) was weighed into a 500 ml macro-kjeldahl flask and 20 ml of distilled water was added. The flask was swirled for few minutes and allowed to stand for 30 minutes. 50 ml of H₃BO₃ indicator solution was added into a 500 ml Erlenmeyer flask then placed under the condenser of the distillation apparatus. About 150 ml of the distillate was collected then the distillation was stopped. Nitrogen in the distillate was obtained by titrating with 0.01M standard HCl using a 25 ml burette graduated at 0.1 ml intervals till the color changed from green to pink. Nitrogen content (N) was calculated as follows:

RESULTS AND DISCUSSION

Organic Carbon and Organic Matter (OM)

Tables 1 and 2 shows organic carbon and organic matter content of the soils. Distribution of organic carbon among land use types shows means of 2.42, 3.10, 2.16 and 3.01 % in AWS, CUL, FAL and FOR respectively. The highest organic carbon was obtained in CUL followed by FOR while FAL had the least but the difference was not significant (p>0.05). The distribution of

organic matter with depth showed that the highest organic carbon was obtained in 0 – 20 cm depth with 3.0 % followed by 40 – 60 and 20 – 40 cm with 2.83 and 2.76 % while 80 – 100 cm had the least (2.39 %) and the difference was significant (p<0.01). Interactive effect of land use and depth was not significant (p>0.05) but season and depth interacted significantly (p<0.01). Other interactive effect was not significant (p>0.05). Seasonal distribution of organic carbon showed that wet season organic matter was significantly higher than dry season organic matter (p<0.05). A mean of 3.01 % was obtained in wet season, significantly higher than 2.35 % in dry season. This suggests that organic carbon is highest in the soil during the wet season.

Mean organic matter in AWS was 4.19 %, 5.38 % in CUL, 3.75 % in FAL and 5.22 % in FOR. The result shows that the highest mean organic matter was obtained in FOR and the difference was significant (p<0.05). According to soil fertility classification by FFD/FMARD (2012), organic matter < 4.0 is classified very low, 4 – 10 % is low, 10 – 14 % is medium, 14 – 20 % is high while 20 – 24 % is very high. Hence, organic matter status of these soils belong to low fertility class. The low organic matter may be attributed to rapid mineralization under the high temperature and moisture conditions of the tropical climate. However, the low level of organic matter may be linked to high rainfall which preferentially removes plant and animal residue including the humified organic fraction. In line with this, Lal (2001) reported a linear decline in soil organic matter content with cumulative soil erosion. The degradation of organic matter affects the nutrient status and structural stability of the soil, which encourages clay dispersion and susceptibility of the soil to erosion. It also influences the nature of the soil reaction. The low content of organic matter implies that these soils may have inadequate supply of N, P and S among other nutrient elements. Organic matter is known to supply most of the N and S and almost half of the P taken up by unfertilized crops (Edem, 2007).

Generally, distribution of organic matter with depth showed that the highest organic matter was obtained in 0 – 20 cm depth followed by 40 – 60 and 20 – 40 cm depth while 80 – 100 cm had the least and the

difference was significant ($p < 0.01$). Interactive effect of land use and depth was not significant ($p > 0.05$). It showed that CUL soil recorded the highest organic matter at 0 – 20 cm, 20 – 40 and 80 – 100 cm. FOR recorded overall highest organic matter at 40 – 60 cm followed by 60 – 80 and 80 – 100 cm. Generally, organic matter decreased with depth (Figure 4.11). These two land use types had exceptional high organic matter distribution down the profile. The least land use in term of organic matter content was FAL followed by AWS and their low organic matter was observed down the profile. The high organic matter at 0-20 cm and 40-60 and low organic matter at 60 – 80 and 80 – 100 cm is expected indicating that organic matter decreased with depth. High content of organic matter in CUL and FOR may be attributed to manure applied on the cultivated soil and accumulation of organic material on forest soil. Low organic matter in AWS suggests that proportion of decomposable organic carbon obtained from the accumulated organic carbon

is low. In other word, it has not been effectively mineralized. Hence, it is not the amount of organic materials heap on the soil that matters but proportion of mineralized organic material released from the accumulated organic materials. So agaric waste should not just be heaped at a point but should be spread as manure on other soils. It should be noted that rate of mineralization or decomposition of organic materials is attributed to so many factors including higher activities of living organisms and availability of air. Though irregular distributions of organic matter with depth have been reported by Rosenzweig *et al.*, (2016); the decrease of organic matter from top to sub soil implies that organic matter is higher at the top soil than the sub soil. This may be attributed to accumulation of litter and other organic materials on the top soil than sub soil, higher root activities at the top soil than sub soil and micro flora and fauna activities at the top soil than the subsoil. Hence, it could be inferred that organic matter decreased with soil depth.

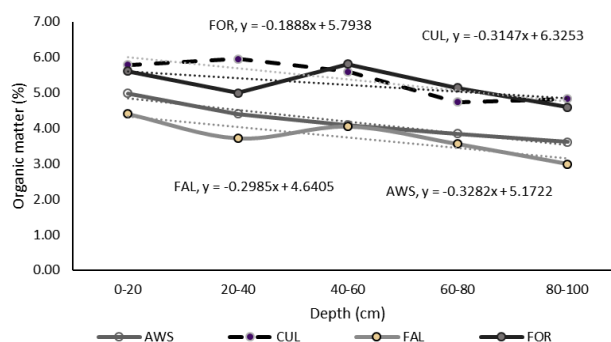


Figure 1: Interactive Effect of Land use and Depth on the distribution of organic matter in the soils

Seasonal distribution of organic matter showed that wet season organic matter was significantly higher than dry season organic matter ($p < 0.05$). A mean of 5.20 % was obtained in wet season, significantly higher than 4.06 % in dry season. This suggests that organic matter is highest in the soil during the

wet season. Of course, water is very essential in mineralization of organic matter. So much organic materials is mineralized in the wet season than dry season leading to higher organic matter in the wet season than dry season.

Table 1: Distribution of Organic Carbon among Season, Land use and Depth

Season	Depth	Land Use				Mean	Sub Mean
		AWS	CUL	FAL	FOR		
Wet	0-20	2.99	3.86	1.61	3.21	2.92	
	20-40	3.39	4.44	1.49	2.93	3.06	
	40-60	2.93	4.58	1.75	3.40	3.17	
	60-80	3.15	4.03	1.65	3.38	3.05	
	80-100	2.82	4.18	1.32	3.03	2.84	3.01

Dry	0-20	2.77	2.84	3.45	3.28	3.09	
	20-40	1.70	2.45	2.82	2.82	2.45	
	40-60	1.81	1.91	2.94	3.33	2.50	
	60-80	1.38	1.46	2.48	2.56	1.97	
	80-100	1.29	1.29	2.12	2.20	1.73	2.35
		2.42	3.10	2.16	3.01		
Depth	0-20cm	20-40cm	40-60cm	60-80cm	80-100cm		
	3.00	2.76	2.83	2.51	2.39		
CV(%)					34.06	Fcal	P-value
LSD _(0.05) for	Season				0.299	13.909	0.000**
LSD _(0.05) for	Land Use				0.297	2.023	0.099
LSD _(0.05) for	Depth				0.308	6.599	0.000**
LSD _(0.05) for	Season*	Land Use			0.235	1.687	0.161
LSD _(0.05) for	Season*	depth			0.296	16.815	0.000**
LSD _(0.05) for	Land Use*	depth			0.309	0.157	0.999
LSD _(0.05) for	Season*	Land Use*depth			0.250	0.145	1.0

Table 2: Distribution of Organic Matter among Season, Land use and Depth

		Land Use				Mean	Sub Mean
Season	Depth	AWS	CUL	FAL	FOR		
Wet	0-20	5.18	6.68	2.79	5.55	5.05	
	20-40	5.86	7.69	2.57	5.07	5.30	
	40-60	5.07	7.93	3.03	5.88	5.48	
	60-80	5.46	6.97	2.85	5.85	5.28	
	80-100	4.88	7.24	2.28	5.24	4.91	5.20
Dry	0-20	4.79	4.90	6.02	5.66	5.34	
	20-40	2.94	4.22	4.86	4.86	4.22	
	40-60	3.11	3.27	5.07	5.74	4.30	
	60-80	2.24	2.51	4.27	4.41	3.36	
	80-100	2.35	2.41	3.71	3.94	3.10	4.06
		4.19	5.38	3.75	5.22		
Depth	0-20cm	20-40cm	40-60cm	60-80cm	80-100cm		
	5.20	4.76	4.89	4.32	4.19		
CV(%)					33.94	Fcal	P-value

LSD _(0.05) for	Season		0.516	13.786	0.000**
LSD _(0.05) for	Land Use		0.510	1.899	0.119
LSD _(0.05) for	Depth		0.532	6.75	0.000**
LSD _(0.05) for	Season*	Land Use	0.403	1.659	0.168
LSD _(0.05) for	Season*	depth	0.511	16.961	0.000**
LSD _(0.05) for	Land Use*	depth	0.533	0.161	0.999
LSD _(0.05) for	Season*	Land Use*depth	0.431	0.146	1.0

Total Nitrogen (TN)

Total nitrogen (TN) reflects pattern of soil organic carbon. Means obtained in respective land use were 0.11, 0.14, 0.10 and 0.13 % for AWS, CUL, FAL and FOR. The highest TN was obtained in CUL followed by FOR and the difference was not significant ($p>0.05$). Nevertheless, the values were low and it suggests that there may be Nitrogen problem (Nitrogen deficiency) in these soils falling within the low fertility range according to FFD/FMARD (2012) soil fertility classification. This suggests that the high organic matter is not well mineralized to release all its available nutrients to plants. The partial decomposition of organic materials suspected may be attributed to high acidity of the soil as most soil bacterial that carry out decomposition process do not

thrive well in high acidic soil. The low total nitrogen indicates that the soils are poorly buffered and consequently has low fertility status which could affect the suitability of these soils for certain crop production.

Effect of depth on the distribution of TN showed that the highest total nitrogen of 0.13 % was obtained at 0 – 20 cm followed by 0.12 % in 20 – 40 and 40 – 60 cm respectively. It declined at 60 - 80 cm and 80 – 100 cm depth recording the least values and the difference was significant ($p<0.05$). The trend also confirms that total nitrogen decreased with depth in all the land use types (Figure 4.12). Interactive effect of land use and depth showed that CUL had the highest total nitrogen down the profile followed by FOR to AWS and FAL all of them decreasing with depth but it was not significant ($p>0.05$).

Table 3: Distribution of Total Nitrogen Among Season, Land Use and Depth

		Land Use				Mean	Sub Mean
Season	Depth	AWS	CUL	FAL	FOR		
Wet	0-20	0.13	0.17	0.07	0.14	0.13	
	20-40	0.15	0.20	0.07	0.13	0.14	
	40-60	0.13	0.20	0.08	0.15	0.14	
	60-80	0.14	0.18	0.08	0.15	0.14	
	80-100	0.12	0.19	0.06	0.14	0.13	0.13
Dry	0-20	0.12	0.12	0.15	0.14	0.13	
	20-40	0.07	0.11	0.12	0.12	0.11	
	40-60	0.08	0.08	0.13	0.14	0.11	
	60-80	0.06	0.07	0.11	0.10	0.09	
	80-100	0.05	0.07	0.09	0.10	0.08	0.10
		0.11	0.14	0.10	0.13		
Depth	0-20cm	20-40cm	40-60cm	60-80cm	80-100cm		
	0.13	0.12	0.12	0.11	0.11		
CV(%)					34.00	Fcal	P-value

LSD _(0.05) for	Season		0.014	18.1	0.000**
LSD _(0.05) for	Land Use		0.013	1.492	0.212
LSD _(0.05) for	Depth		0.014	6.532	0.001**
LSD _(0.05) for	Season*	Land Use	0.010	1.617	0.178
LSD _(0.05) for	Season*	depth	0.013	15.632	0.000**
LSD _(0.05) for	Land Use*	depth	0.014	0.266	0.993
LSD _(0.05) for	Season*	Land Use*depth	0.011	0.143	1.0

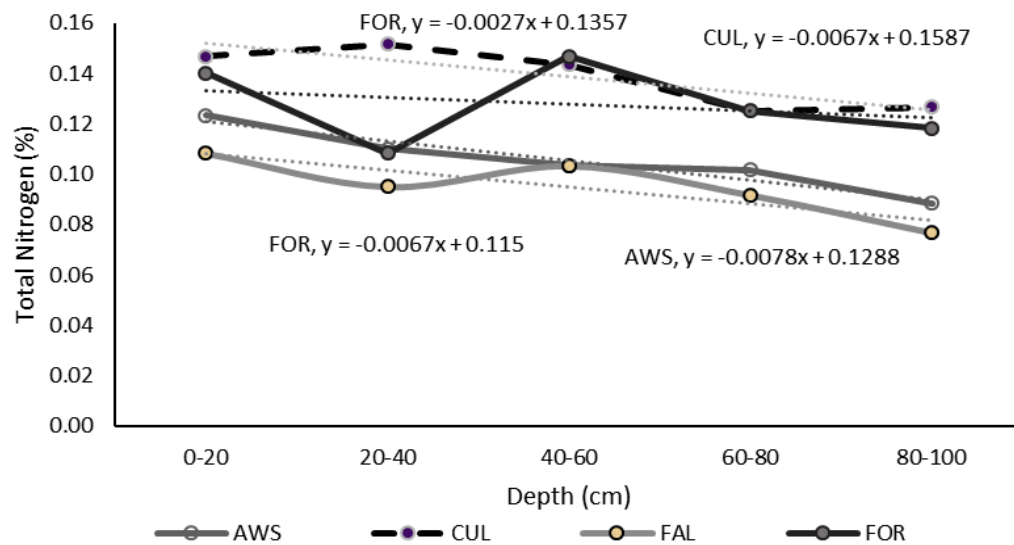


Figure 2: Interactive Effect of Land use and Depth on the distribution of Total Nitrogen in the soils

Seasonal distribution of total nitrogen showed that wet season had mean total nitrogen of 0.13 significantly higher than 0.10 obtained in dry season. This is attributed to level of organic matter in the wet and dry season. It could be established therefore, that wet season favour higher accumulation of total nitrogen in the soil than dry season irrespective of land use types. Interactive effect of season and depth was significant ($p < 0.01$) indicating that the sub soil may have nitrogen deficiency in the dry season than wet season.

Seasonal changes in stable aggregates and organic matter pools in soils under the four land use systems

Table 4.30 shows mean seasonal changes in water stable aggregates under the four land use types. 2 mm aggregates were 15.05 % in wet season but 20.79 % in dry season in AWS. In CUL, 2mm was 18.50 % in

wet season and 18.33 % in dry season, in FAL, wet season recorded mean of 13.57 % for 2mm aggregates lower than 19.84 % in dry season whereas in FOR had mean of 14.86 % lower than 22.02 % in dry season. The results showed that values of 2mm aggregates in wet season under different land use types were higher than values in dry season but the difference was not significant ($p > 0.05$). The distribution of 0.25 mm aggregates showed that the means were higher in wet season than dry season. Specifically, AWS had mean of 72.62% in wet season higher than 47.80 % in dry season, CUL had mean of 73.07 % in wet season higher than 52.35 % in dry season, FAL had a mean of 75.03 % higher than 48.81 % while FOR had a mean of 75.78 % higher than 46.03 %. But the difference was not significant ($P > 0.05$).

Table 4: Season changes in Stable Aggregates under different Land use type

Season	LUS	2mm	0.25mm	0.05mm %	0.01mm	MWD
		←—————→				
Wet	AWS	15.05	72.62	10.30	1.42	1.31
	CUL	18.50	73.07	6.08	1.69	1.39
	FAL	13.57	75.03	8.47	1.66	1.29
	FOR	14.86	75.78	8.27	0.89	1.32
Dry	AWS	20.79	47.80	24.24	14.49	0.67
	CUL	18.33	52.35	22.51	13.20	0.58
	FAL	19.84	48.81	24.08	12.86	0.73
	FOR	22.02	46.03	24.73	14.21	0.97
	Lsd (0.05)	2.792	2.511	1.215	1.413	0.150
	Fcal	0.379	0.284	1.580	0.026	0.751
	Pvalue	0.943ns	0.887ns	0.188ns	0.999ns	0.567ns

Ns: Not significant

The distribution of 0.05 mm aggregates was in favour of dry season than wet season. For instance, AWS in wet season was 10.30 % lower than 24.24 % in dry season, CUL had mean of 6.08 % in wet season lower than 22.51 % in dry season, FAL had mean of 8.47 % lower than 24.08 % in dry season while FOR had mean of 8.27 % in wet season lower than 24.73 % in dry season. The trend extended to 0.01 mm aggregates. The values were higher in wet season than dry season. Precisely, AWS was 1.42 % in wet season lower than 14.49 % in dry season, CUL was 1.69 % in wet season lower than 13.20 % in dry season, FAL had a mean of 1.66 % lower than 12.86 % in dry season while FOR had a mean of 0.89 % lower than 14.21 % in dry season and the difference was significant. Similarly, MWD in wet season were higher than values obtained in dry season. AWS had mean of 1.31 % in wet season higher than 0.67 % in dry season, CUL had mean of 1.39 % in wet season higher than 0.59 % in dry season, FAL had mean of 1.29 % in wet season higher than 0.73 % in dry season while FOR had mean of 1.32 % higher than 0.97 % in dry season but the difference was not significant. Seasonal changes in water stable aggregates showed that wet season had lower content of the 2mm, 0.05 mm and 0.01 mm stable aggregates than dry season. The result of also showed that aggregates in the size range of 0.01 – 0.25 mm diameter were more than those in 2.0 mm diameter in all the land use

types both in wet and dry season. This indicates that these soils were equally stable (less erodible) both in wet and dry season as cited by Ekerete and Ogban (2001) that, the greater the proportion of aggregates < 0.5 mm diameter, the greater the erodibility of the soils. So, these soil is very stable in water.

Stability of the soil aggregates is linked to high organic matter content of the soil. Table 31 shows seasonal changes in soil organic matter pool under different land use types. Means total carbon were significantly higher in wet season than dry season in all the land use types. Precisely, AWS had mean of 1.40 % in the wet season higher than 1.24 % in the dry season, CUL had mean of 2.12 % in the wet season higher than 0.97 % in the dry season, FAL recorded mean of 1.48 % higher than 1.19 % in the dry season while FOR showed mean of 1.49 in wet season higher than 1.45 % in the dry season. Also, mean humified acid in AWS was 0.51 % in wet season higher than 0.29 % in dry season, it was 0.72 % in CUL higher than 0.42 % in dry season, FAL recorded mean of 0.47 % higher than 0.41 % in dry season while FOR showed mean of 0.66 % higher than 0.55 % in dry season but the difference was not significant ($p>0.05$). Means of humic acid obtained in the wet season were also higher than means obtained in various land use types in the dry season but the difference was not significant ($p>0.05$). AWS had mean of 0.35 % in wet season higher than 0.21 % in dry season, CUL

recorded mean of 0.45 % in wet season higher than 0.19 % in dry season, FAL showed mean of 0.31 % in wet season higher than 0.30 % in dry season while FOR had a mean of 0.37 % higher than 0.33 % in dry season. Similarly, for the distribution of Felvic acid, AWS had a mean of 0.16 % in wet season higher than 0.08 % in dry season, CUL had a mean of 0.27 % in

Table 5: Season changes in Organic matter pool under different Land use type

Season	LUS	Total carbon	Humified acid	Humic acid	Felvic acid
		←		% →	
Wet	AWS	1.40	0.51	0.35	0.16
	CUL	2.12	0.72	0.45	0.27
	FAL	1.48	0.47	0.31	0.18
	FOR	1.49	0.66	0.37	0.28
Dry	AWS	1.24	0.29	0.21	0.08
	CUL	0.97	0.42	0.19	0.22
	FAL	1.19	0.41	0.30	0.10
	FOR	1.45	0.55	0.33	0.23
	Lsd (0.05)	0.140	0.0669	0.049	0.049
	Fcal	2.819	2.056	2.145	0.268
	Pvalue	0.03*	0.094	0.183	0.898

Ns: Not significant, * Significant at $p<0.05$

Organic matter pool than the dry season. This may be attributed to availability of moisture in the soil during the wet season than during the dry season. The transformation and movement of materials within soil organic matter pools is a dynamic process influenced by climate, soil type, vegetation and soil organisms.

All these factors operate within a hierarchical spatial scale. In the case of climate which influences seasons of the year, soil organic matter levels commonly increase as mean annual precipitation increases. Conditions of elevated levels of soil moisture result in greater biomass production, which provides more residues, and thus more potential food for soil biota. Soil biological activity requires air and moisture. Optimal microbial activity occurs at near “field capacity”, which is equivalent to 60-percent water-filled pore space (Prior *et al.*, 2003). With the exception of the hyperhumid regions, the climates of vast areas of the humid, subhumid and semi-arid tropics are characterized by distinct wet and dry seasons. In the wet-dry tropics, large amounts of nitrate often occur in the surface soil during the first

part of the rainy season (Mueller-Harvey *et al.*, 2019). This accelerated nitrogen mineralization caused by a large increase in microbial activity is the result of the first few rains activating the labile soil organic matter. Farmers who practise “slash and burn” agriculture often choose early planting in order to take advantage of this flush of inorganic N before it is lost through leaching and runoff. In these low-input systems, the amount of nitrate present in the soil during the early part of the rainy season is related closely to the organic matter content of the soil. N availability diminishes during the later part of the rainy season.

SUMMARY AND CONCLUSION

Among organic matter pools, the highest total carbon was obtained in CUL followed by FOR while AWS had the least. Considering Humified Acid, the highest mean was obtained in FOR followed by CUL while AWS had the least and the difference was significant ($p<0.05$). Similarly, the highest mean humic acid was obtained in FOR also followed by CUL while AWS had the least. Again, the highest mean fulvic acid was obtained in FOR followed by CUL while

AWS had the least. Generally, FOR soil had the highest concentration of organic matter pool followed by CUL while AWS had the least. Depth distribution of organic matter pool showed that the highest concentration of total carbon was obtained at 0 – 20 cm depth. From 20 – 100 cm, total organic carbon increased steadily with increasing depth. The overall assessment confirmed that organic matter decreased with increasing depth and forest soil contained the highest organic matter pool among the four land use types considered in the study. Seasonal distribution of organic matter pool revealed that wet season had the highest organic matter pool than the dry season and the difference was significant ($p < 0.05$).

Relationship between organic matter pool and water stable aggregates was generally weak in the wet season based on number of significant correlated parameters obtained. Only total carbon had significant correlation with 0.01 mm aggregates. No significant correlation was obtained in CUL and FOR but three significant correlations were obtained in FAL which was the relationship between humified acid with 0.05 mm and 0.01 mm aggregates along with fulvic acid versus 0.05 mm aggregates. The result showed that different organic matter fraction poses a unique influence on each of the water stable aggregates. It also showed that land use has great influence on how organic matter interact with soil aggregates. In dry season, the relationship was stronger than what was obtained in the wet season. For instance, total carbon in AWS had significant correlation with 0.05 mm aggregates, humified acid showed significant relationship with 2 mm aggregates, 0.25 mm and 0.01 mm aggregates. Also, humic acid correlated significantly with 0.25 mm and 0.01 mm aggregates. In CUL, total carbon had significant relationship with 2 mm and 0.25 mm aggregates only while humified acid showed significant correlation with 0.01 mm aggregates only. FOR witnessed the highest significant correlation in the dry season where total carbon correlated significantly with 2 mm, 0.25 mm and 0.01 mm aggregates. Humified acid correlated significantly with 2 mm and 0.05 mm aggregates. Significant correlation was also obtained between humic acid and 0.05 mm aggregates while fulvic acid showed

significant association with 0.05 mm aggregates. This suggests that organic matter pool have greater influence on soil stability when the soil is not saturated.

RECOMMENDATIONS

- i Application of organic materials like agricultural wastes is highly recommended for improved organic matter pool and stability of the soil aggregates. This is because AWS and FOR soils performed better than other land use like FAL and CUL in terms of important physical and chemical properties along with organic matter pool. This should not be animal manure and inorganic fertilizer only, the use of cover crop is also recommended to increase soil aggregation due to the increase of organic matter pool and soil cover that they provide.
- ii Additionally, inputs of organic matter in the form of mulch or manure application can provide a protective cover to the soil during the wet season. This is because the less the soil is covered with vegetation, mulches, crop residues, etc., the more the soil is exposed to the impact of raindrops. When a raindrop hits bare soil, the energy of the velocity detaches individual soil particles from soil clods. Therefore, the soil aggregates should be protected by inputs of organic matter in the form of mulch or manure application.
- iii Organic matter influences the physical conditions of a soil in several ways. Relationship between organic matter pool and aggregates stability was generally weak. Hence, structural stability of the soil should be enhanced by increased plant residues on the soil surface to provide a cover that protects the soil from sealing and crusting not only by raindrop impact, thereby enhancing rainwater infiltration and reducing runoff.

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