

SOIL AGGREGATE STABILITY INDICES AS INFLUENCED BY LAND UTILIZATION TYPES IN SELECTED SOILS OF AKWA-IBOM STATE, NIGERIA

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ABSTRACT

This study investigated soil aggregate stability indices as influenced by land utilization types (LUT) in selected soils of Akwa-Ibom State, Nigeria. The main objective was to determine the effect of land use on stability of soils under different use in the study area. The different land uses considered were forest land use (FOR), agricultural waste dump sites (AWS), continuous cultivated land (CUL) and fallowed land system (FAL). In each land use type, one (1) profile pit was dug 0-20, 20-40, 40-60, 60-80 and 80-100cm respectively. The samples were analyzed for particle size, bulk density, total porosity, saturated hydraulic conductivity and aggregate stability. The results showed mean values of stable aggregate of 17.92, 18.41, 16.70 and 18.40% for AWS, CUL, FAL and FOR land use types. There was no significant difference in 2mm water stable aggregates among the four land use types ($P > 0.05$). However, FOR and CUL had higher 2mm aggregate than FAL and AWS. Next to 2mm water stable aggregates was 0.25mm water stable aggregates with mean values of 60.21, 62.71, 61.92 and 61.29% in AWS, CUL, FAL and FOR respectively. Continuous cultivated land recorded the highest 0.25mm water stable aggregate among the four land use types, but the difference was not significant ($P > 0.05$). The forest type vegetation is highly recommended because it has high stable aggregates. Secondly regrowth of forest should be raised to increase soil organic pool for improved structural stability.

Keywords: Aggregate stability, land use types, stability indices.

INTRODUCTION

Soil aggregate stability is a major factor of importance regarding many aspects of soil management. How farmers use and manage their land can have profound changes in aggregate stability. Oades (1993) noted that the main disruptors of aggregate stability are tillage, traffic from equipment, and traffic from livestock. Using reduced tillage or zero tillage practices had been shown to improve soil aggregation compared to conventional tillage methods (Six *et al.*, 2000). The use of cover crops increases soil aggregation (Liu *et al.*, 2005), due to the increase of soil organic matter and soil cover that is provided. Perennial crops typically prevent aggregate disruption and allow plants to develop an extensive root system which promotes aggregate stability.

Kay (1990) remarked that favourable soil structure and high aggregate stability are important in improving soil fertility, increasing agronomic productivity, enhancing porosity and decreasing erodibility. Soil aggregation results from the interaction of many factors including the environment, soil management, plant influences and soil properties (Xie, 2015). Soil aggregation can be directly altered by management strategies that

disturb the soil, including land use or management (Noellemeyer *et al.*, 2008), tillage practices (Fernandez *et al.*, 2008) or fertilization (Sodhi *et al.*, 2009), which can impact on biotic and abiotic cementing agents (Bartoet *et al.*, 2010).

Land use or management types that enhance soil aggregation by reducing soil disturbance while increasing soil organic stocks in the form of biological factors that include roots, fungal hyphae, and by-products of microbial synthesis and decay (Sodhi *et al.*, 2009). Land use does not only disturb soil structural indices but also plays a significant role in soil textural characteristics which is key in stability of soil aggregates. Onofioke (2002) asserted that texture is an important property contributing to soil aggregation. Bybordi (2003), noted that different land use practices exert unique changes on the soil erodibility which in turn affects the detachment of primary soil aggregate, transportability and deposition of particles during run-off. Vegetation cover is frequently the most important factor affecting site resistance to soil aggregation. Large scale removal of vegetation exacerbates soil stability problems (Udosen, 2008).

Many parcels of land in the study area are under varying land use types without adequate management. Hence most crop lands are seriously eroded, exposed to flood hazard due to excessive bush burning, others are decreasing in size as a result of planting on slopes without any contour while the productivity of the soils is declining significantly. The impact of some of these land uses is quite amazing. It does not only result in poor yield, but may also lead to food insecurity, environmental pollution and other vices including environmental degradation. In order to ensure sustainable soil conservation and environmental protection, this study with the objectives of determining the effect of land use on stability of soil under different uses in the study area became pertinent.

MATERIALS AND METHODS

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 $4^{\circ} 30'$ and $5^{\circ} 30'N$ and longitude $7^{\circ} 30'$ and $8^{\circ} 30'E$. 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 $27^{\circ}C$. 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 (Petterset *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 Fallowed 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:

$$\rho_b = \frac{M_s}{V_t} \dots\dots\dots(4)$$

where,

ρ_b = Bulk density (Mg m⁻³)
 M_s = dry soil mass (mg)
 V_t = total volume of soil (m³)

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:

$$f = \left[1 - \left(\frac{\rho_b}{\rho_s} \right) \right] \dots\dots\dots(5)$$

where f = Total porosity
 ρ_b = bulk density (Mg m⁻³)

ρ_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:

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

where,

Q = discharge rate (cm³ 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 (cm²)
 t = time (min)

Aggregate stability:

The wet sieving method of Kemper and Rosenau (1986) with a set of sieves of 2, 1, 0.5, and 0.25, 0.05 mm diameter was used. After passing the soil samples through a 8 mm sieve, approximately 50 g of the soil was put on the first sieve of the set and was gently moistened to avoid sudden rupture of the aggregates. After moistening, the set was sieved in water at 50 oscillations per minute. After 10 min of oscillation, soil remaining on each sieve was dried, then sand and aggregates were separated. The mean weight diameter was calculated by the relationship:

$$MWD = \sum(X_i, W_i) \dots\dots\dots(8)$$

Where X (in millimeter) is the average diameter of the openings of two consecutive sieves, and W the weight ratio of aggregates remained on the *i*th sieve. For determination of aggregate size distribution

(ASD) the weight ratio of aggregates of each sieve (>2 , 2 ± 1 , 1 ± 0.5 , 0.5 ± 0.25 , and < 0.25 mm) to the total weight of aggregates was calculated.

RESULTS AND DISCUSSION

The percent water stable aggregates are presented in Table 1-5. Values of 2mm sieve aggregates showed means of 17.92, 18.41, 16.70 and 18.40 % in AWS, CUL, FAL and FOR respectively (Table 1). There was no significant difference in 2mm water stable aggregates among the four land use types ($p>0.05$). However, FOR and CUL had higher 2mm aggregates than FAL and AWS. Next to 2mm water stable aggregate was 0.25 mm water stable aggregates. Values obtained in the study ranged showed means of 60.21, 62.71, 61.92 and 61.29 % in AWS, CUL, FAL and FOR respectively. From the result, CUL recorded the highest 0.25 mm water stable aggregates among the four land use types but the difference was not significant ($p>0.05$). Considering 0.05 mm water stable aggregates, values obtained showed means of 17.27, 14.29, 16.27 and 16.25 % in AWS, CUL, FAL and FOR. The highest 0.05 mm aggregates were obtained in AWS followed by FOR and FAL while CUL had the least but the difference was not significant ($p>0.05$). For 0.01 mm aggregates, result obtained revealed that AWS recorded a mean of 7.96 % while CUL, FAL and FOR recorded means of 7.45, 7.26 and 7.55 %. Result showed that aggregate stability to water in the four sieve diameters was greatest in 0.25 mm sieve size. This might be responsible for the low total porosity recorded in the study (Porosity less than 50 %). This agrees with Baveret *al.* (1972) cited in Edem (1997) that total porosity and the dominance of large pores increases with soil aggregation and size of the aggregates.

There was no definite pattern in the distribute of water stable aggregates with depth except

except 0.25 mm and mean wet diameter (MWD). For instance, wet season recorded 15.49 % for 2mm aggregates in the wet season while dry season had a mean of 20.22 % and the difference was significant ($P<0.05$). Wet season also recorded a mean of 74.13 % for 0.25 mm aggregates significantly higher than 48.94 % obtained in dry season. For 0.05 mm aggregates, mean of 8.28 was obtained in wet season significantly lower than 23.72 % obtained in dry season while a mean of 1.41 % obtained in wet season for 0.01 mm aggregates was significantly lower than 13.69 % obtained in dry season.

Distribution of mean wet diameter (MWD) among land use showed means 0.99, 0.98, 1.01 and 1.16 % in AWS, CUL, FAL and FOR respectively. MWD is the summation of the four sieve diameter. The highest value is obtained in FOR followed by FAL while CUL had the least. This implies that forest

that there was a decrease with depth in the distribution of 2 mm and 0.25 aggregates with increasing depth. The highest proportion of 2mm water stable aggregates was obtained in 60 – 80 cm with 18.88 % followed by 80 – 100 cm with 18.50 % while 20 – 40 cm had the least (17.58 %) but the difference was not significant ($p>0.05$). Interactive effects were not also significant ($p>0.05$) but the trend decreased with depth in all land use types except FAL (Figure 4.25). Also, the highest mean 0.25 mm aggregates were obtained in 40 – 60 cm with 62.28 % followed by 20-40 cm with 61.56 % while 50 – 80 cm had the least with 59.78 % and the difference was not significant ($p>0.05$). Interactive effects were not also significant ($p>0.05$) for 0.25 mm water stable aggregates but the trend showed mixed pattern. It decreased with depth in CUL and FAL and increased with depth in FOR and AWS (Figure 2). Distribution of 0.05mm aggregates with depth showed that 0 – 20 cm recorded the highest (17.57 %) followed by 20 – 40 cm with 16.43 % while 80 – 100 cm had the least (15.11 %) and the difference was not significant ($p>0.05$). Interactive effects were not also significant ($p>0.05$) but the trend showed decrease with depth in all the land use types (Figure 3). For distribution of 0.01 mm aggregates with depth, the highest was obtained in 60 – 80 cm with 7.99 % followed by 80 – 100 cm with 7.70 % while 0 – 20 cm had the least (7.29 %) and the difference was not significant ($p>0.05$). Interactive effects were not also significant ($p>0.05$). It decreased in FAL and CUL with depth but increased in AWS and FOR with depth (Figure 4). This shows that aggregate stability of soils varies both with land use types and diameter of the aggregate.

Seasonal distribution of the water stable aggregates showed that wet season had lower content of the stable aggregates than dry season

soil (FOR) have the highest stability of the primary aggregate followed by fallowed land (FAL) while cultivated land (CUL) had the least. The high stability of forest and fallowed land than cultivated land suggests that organic matter is highly responsible for stability of the primary aggregates. Hence, land use types that build organic matter in the soil is likely going to have higher stability of the primary aggregates to water than land use types that use up or destroy organic matter. Cultivation reduces organic matter and as shown in the results, it does not support aggregation of the primary particles. Such soil is prone to water erosion and other degrading forces.

Table 1: Distribution Of 2mm Aggregate Among Season, Land Use And Depth

Season	Depth	Land Use				Mean	Sub Mean
		AWS	CUL	FAL	FOR		
Wet	0-20	21.19	19.89	8.45	15.83	16.34	15.49
	20-40	14.54	20.58	18.21	17.02	17.59	
	40-60	13.85	17.20	13.36	12.30	14.18	
	60-80	15.22	19.65	16.36	15.05	16.57	
	80-100	10.46	15.17	11.46	14.10	12.80	
Dry	0-20	20.13	15.43	22.30	22.59	20.11	20.22
	20-40	19.87	19.51	15.47	15.47	17.58	
	40-60	19.18	19.46	22.64	25.87	21.79	
	60-80	24.49	17.08	20.05	23.14	21.19	
	80-100	20.27	20.16	18.73	22.60	20.44	
		17.92	18.41	16.70	18.40		
Depth	0-20cm	20-40cm	40-60cm	60-80cm	80-100cm		
	18.23	17.58	17.98	18.88	18.50		
CV(%)					22.08	Fcal	P-value
LSD _(0.05) for	Season				2.751	4.366	0.04*
LSD _(0.05) for	Land Use				2.838	0.108	0.979
LSD _(0.05) for	depth				2.849	0.128	0.943
LSD _(0.05) for	Season*	Land Use			2.792	0.379	0.823
LSD _(0.05) for	Season*	depth			2.818	0.537	0.658
LSD _(0.05) for	Land Use*	depth			3.032	0.086	1.0
LSD _(0.05) for	Season*	Land Use*depth			3.198	0.197	0.998

Table 2: Distribution of 0.25mm Aggregate among season, Land use and Depth

Season	Depth	Land Use				Mean	Sub Mean
		AWS	CUL	FAL	FOR		
Wet	0-20	67.49	75.90	78.58	75.22	74.30	74.13
	20-40	72.97	70.44	72.93	71.66	72.00	
	40-60	69.96	73.39	79.24	78.07	75.16	
	60-80	69.69	72.32	71.18	74.86	72.01	
	80-100	83.01	73.32	73.24	79.07	77.16	
Dry	0-20	42.98	53.21	45.93	42.52	46.16	

	20-40	52.63	51.61	50.12	50.12	51.12	
	40-60	47.97	52.56	49.33	47.69	49.39	
	60-80	44.47	53.32	48.66	43.76	47.55	
	80-100	50.97	51.02	50.01	49.94	50.48	48.94
		60.21	62.71	61.92	61.29		
Depth	0-20cm	20-40cm	40-60cm	60-80cm	80-100cm		
	60.23	61.56	62.28	59.78	61.25		
CV(%)					21.54	Fcal	P-value
LSD _(0.05) for		Season			2.494	161.362	0.000**
LSD _(0.05) for		Land Use			4.154	0.537	0.709
LSD _(0.05) for		depth			4.162	0.304	0.822
LSD _(0.05) for		Season*	Land Use		2.511	0.284	0.887
LSD _(0.05) for		Season*	depth		2.537	0.872	0.459
LSD _(0.05) for		Land Use*	depth		4.415	0.375	0.969
LSD _(0.05) for		Season*	Land Use*depth		2.811	0.127	1

Table 3: Distribution of 0.05mm Aggregate among season, Land use and Depth

Season	Depth	Land Use				Mean	Sub Mean
		AWS	CUL	FAL	FOR		
Wet	0-20	10.81	3.79	8.40	8.04	7.76	8.28
	20-40	11.82	6.20	6.94	10.40	8.84	
	40-60	13.94	7.92	6.28	8.17	9.08	
	60-80	9.30	6.63	10.31	9.01	8.81	
	80-100	5.64	5.85	10.40	5.71	6.90	
Dry	0-20	30.15	25.34	25.94	28.11	27.39	23.72
	20-40	22.25	21.35	26.25	26.25	24.02	
	40-60	22.71	22.32	21.65	22.32	22.25	
	60-80	22.37	22.98	24.77	23.95	23.52	
	80-100	23.71	20.57	21.79	19.57	21.41	
		17.27	14.29	16.27	16.15		
Depth	0-20cm	20-40cm	40-60cm	60-80cm	80-100cm		
	17.57	16.43	15.67	16.16	15.11		
CV(%)					51.38	Fcal	P-value
LSD _(0.05) for	Season				1.225	317.557	0.000**
LSD _(0.05) for	Land Use				2.367	1.752	0.147
LSD _(0.05) for	depth				2.376	2.094	0.108
LSD _(0.05) for	Season*	Land Use			1.215	1.58	0.188
LSD _(0.05) for	Season*	depth			1.194	0.458	0.712
LSD _(0.05) for	Land Use*	depth			2.501	0.765	0.684
LSD _(0.05) for	Season*	Land Use*depth			1.233	0.521	0.895

Table 4: Distribution of 0.01mm Aggregate among season, Land use and Depth

Season	Depth	Land Use				Mean	Sub Mean
		AWS	CUL	FAL	FOR		
Wet	0-20	0.51	0.43	2.76	0.64	1.09	1.41
	20-40	1.00	2.78	1.60	0.80	1.55	
	40-60	2.26	1.50	1.09	1.17	1.50	
	60-80	2.46	1.41	1.68	1.00	1.64	
	80-100	0.89	2.32	1.15	0.83	1.30	

Dry	0-20	15.86	14.29	11.45	12.38	13.50	
	20-40	11.13	13.13	15.39	15.39	13.76	
	40-60	16.27	12.86	10.88	12.38	13.10	
	60-80	15.60	13.02	14.01	14.75	14.34	
	80-100	13.59	12.72	12.59	16.16	13.76	13.69
		7.96	7.45	7.26	7.55		
Depth	0-20cm	20-40cm	40-60cm	60-80cm	80-100cm		
	7.29	7.65	7.30	7.99	7.70		
CV(%)					84.08	Fcal	P-value
LSD _(0.05) for	Season				1.384	112.108	0.000**
LSD _(0.05) for	Land Use				2.125	0.05	0.995
LSD _(0.05) for	depth				2.134	0.065	0.978
LSD _(0.05) for	Season*	Land Use			1.413	0.026	0.999
LSD _(0.05) for	Season*	depth			1.431	0.213	0.887
LSD _(0.05) for	Land Use*	depth			2.277	0.158	0.999
LSD _(0.05) for	Season*	Land Use*depth			1.632	0.153	1

Table 5: Distribution of Mean Weight Diameter (MWD) among season, Land use and Depth

Season	Depth	Land Use				Mean	Sub Mean
		AWS	CUL	FAL	FOR		
Wet	0-20	1.42	1.43	1.10	1.26	1.30	
	20-40	1.22	1.44	1.44	1.40	1.38	
	40-60	1.22	1.35	1.25	1.24	1.26	
	60-80	1.43	1.36	1.36	1.34	1.38	
	80-100	1.24	1.36	1.30	1.35	1.31	1.33
Dry	0-20	0.57	0.45	0.54	2.41	0.99	
	20-40	1.34	0.54	1.01	1.01	0.98	
	40-60	0.47	0.72	0.44	0.51	0.54	
	60-80	0.47	0.65	0.74	0.58	0.61	
	80-100	0.51	0.52	0.90	0.48	0.60	0.74
		0.99	0.98	1.01	1.16		
Depth	0-20cm	20-40cm	40-60cm	60-80cm	80-100cm		
	1.15	1.18	0.90	0.99	0.99		

CV(%)			42.56	Fcal	P-value
LSD _(0.05) for	Season		0.148	30.981	0.000**
LSD _(0.05) for	Land Use		0.168	0.946	0.442
LSD _(0.05) for	depth		0.167	0.506	0.679
LSD _(0.05) for	Season*	Land Use	0.150	0.741	0.567
LSD _(0.05) for	Season*	depth	0.149	0.813	0.49
LSD _(0.05) for	Land Use*	depth	0.170	0.991	0.465
LSD _(0.05) for	Season*	Land Use*depth	0.149	1.15	0.334

On the whole, the result of aggregate stability analysis has shown 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. This indicates that these soils were stable or less erodible because Bryan (1974) cited in Ekerete and Ogban (2001) had reported that the proportion of

water stable aggregate <0.5 are good index of soil erodibility. That is, 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 and clay particles.

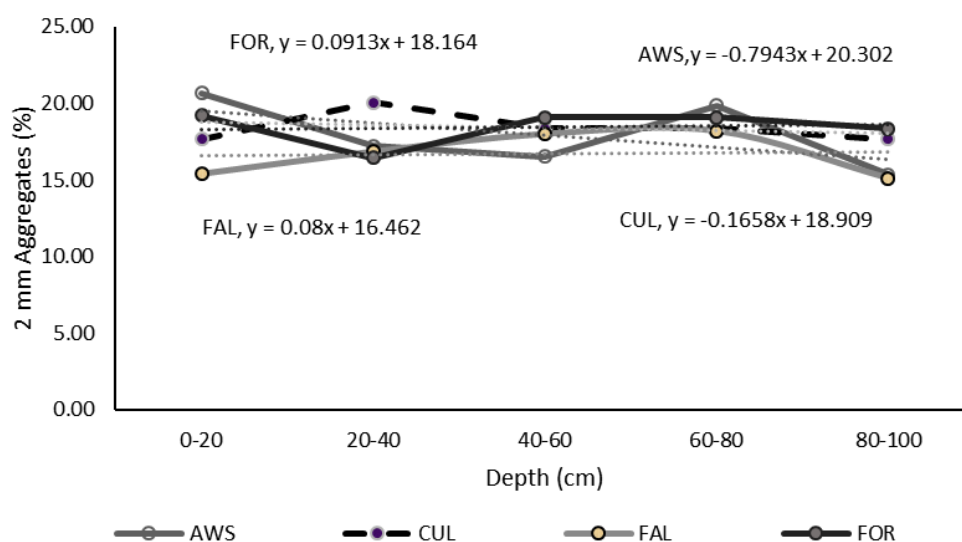


Figure 1: Interactive Effect of Land use and Depth on the distribution of 2mm Aggregates in the soils

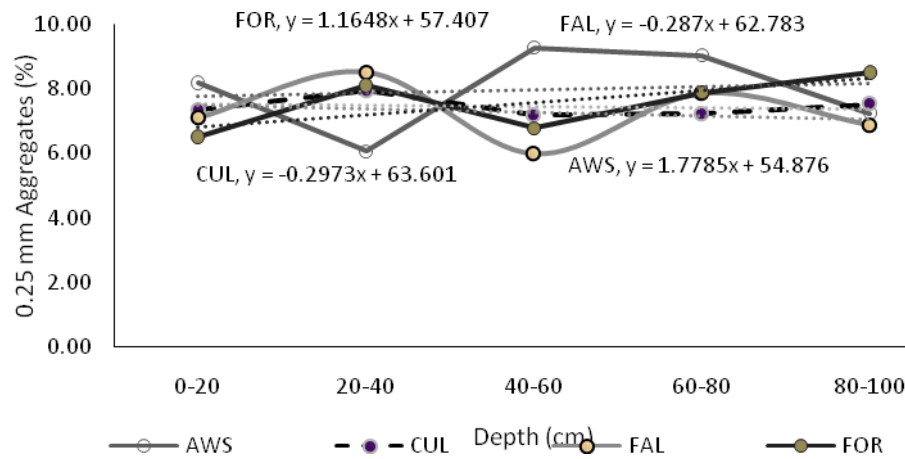


Figure 2: Interactive Effect of Land use and Depth on the distribution of 0.25mm Aggregates in the soils

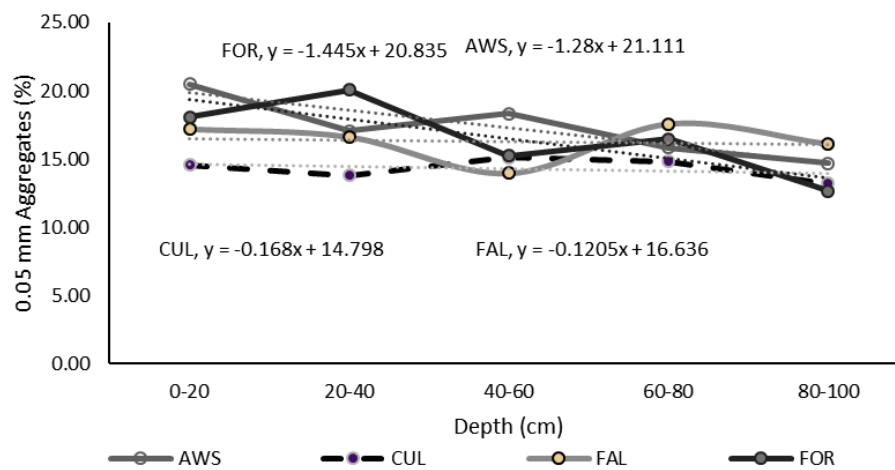


Figure 3: Interactive Effect of Land use and Depth on the distribution of 0.05mm Aggregates in the soils

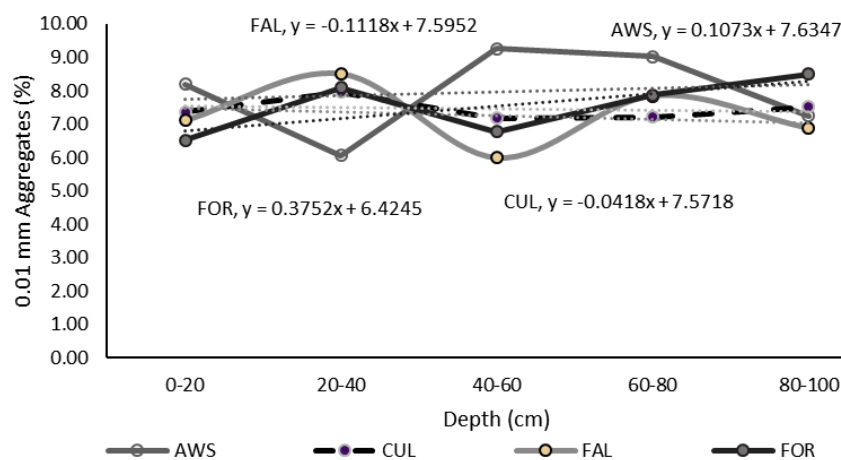


Figure 4: Interactive Effect of Land use and Depth on the distribution of 0.01mm Aggregates in the soils

SUMMARY AND CONCLUSION

Considering water stable aggregates, there was no significant difference in the distribution of 2mm aggregates among the four land use types. However, FOR and CUL had higher proportion of 2mm aggregates than FAL and AWS. Next to 2mm aggregate was 0.25 mm aggregates. CUL recorded the highest proportion of 0.25 aggregates among the four land use types. The highest proportion of 0.05 mm aggregates was obtained in AWS followed by FOR and FAL while CUL had the least. For 0.01 mm aggregates, result obtained revealed that AWS recorded the highest followed by FOR to CUL while FAL had the least. Result showed that aggregate stability to water in the four sieve diameters was greatest in 0.25 mm in the four land use types than 2 mm diameter. There was no significant difference ($p>0.05$) in the distribute of aggregates with depth. On the whole, the result of aggregate stability analysis has shown 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. This indicates that these soils were stable in water or less erodible.

RECOMMENDATIONS

- i In relation to soil conservation and stability,

the forest type of vegetation (Agro-forestry) is highly recommended because it has high stable aggregates down the profile with a lots of spaces or pores between aggregates with evidence of good root growth and biological activity such as earthworms. Fallowed and secondary regrowth or forest should be raised to increase soil organic matter pool for improved structural stability of the soil. This could be done through planting of trees in the farmland along with annual or perennial crops. Hence, perennial crops should be planted in the farm land typically to require a halt in tillage, which prevents aggregate disruption, and allows plant to develop an extensive root system which can promote aggregate stability.

- ii Soils with few pores and fissures like the continuous cultivated soil will be easily prone to compaction. Compacted soil is much more prone to soil erosion and run-off. Hence, the use of heavy equipment like tractor on CUL soil should be minimized because the structure of these soil can be easily damaged by this operation. As such, reduced tillage or zero tillage practice should be adopted over conventional tillage practices to check porosity and stability of the soil aggregates. Higher stocking rate of livestock such as cattle can decrease the aggregate stability of soil due to compaction of soil and loss of vegetation and therefore should be minimal.

EFERENCES

- Barto, E. K., Alt, F., Oelmann, Y., Wilcke, W. and Rillig, M. C. (2010). Contributions of biotic and abiotic factors to soil aggregation across a landuse gradient. *Soil Biology and Biochemistry*. 42, 2316–2324.
- Bouyoucos, G. J. (1935). The clay ratio as a criterion of susceptibility of soils to erosion. *Journal of American Society of Agronomy* 27: 738-741.
- Bybordi, M. (2003). *Soil Physics*, Fifth Ed. Tehran University Publications, 648 pp.
- Edem, S. O. (1997). Characteristics and hydrologic grouping of representative wetland soils of Akwalbom State. Ph. D. Thesis. Rivers State University of Science and Technology, Port Harcourt.
- Fredricksen, R. L., and Harr. R. D. (2008). Soil, vegetation and watershed management. In: P. E. Heilman, H. W. Anderson, D. M. Baumgartner (editors). *Forest Soils of the Douglas fir Region*. Washington State University Co-Op Extension Service.
- Kay, B.D. (1990). *Rates of Change of Soil Structure Under Different Cropping Systems. Advances in Soil Science. Advances in Soil Science. 12: 1–52.*
- Liu, A., Ma, B. L. and Bomke, A. A. (2005). Effects of cover crops on soil aggregate

- stability, total organic carbon, and polysaccharides. *Soil Science Society of America Journal*. 69 (6): 2041–2048.
- Noellemeyer, E., Frank, F., Alvarez, C., Morazzo, G. and Quiroga, A. (2008). Carbon contents and aggregation related to soil physical and biological properties under a land-use sequence in the semiarid region of central Argentina. *Soil and Tillage Research* 99: 179–190.
- Oades, J.M. (1993). *The role of biology in the formation, stabilization and degradation of soil structure*. *Geoderma*. 56 (1–4): 377–400.
- Obasi, A. I., Ekpe I. I., Igwe, E. O. and Nnachi E. E. (2015). The physical properties of soils within major dumpsites in Abakaliki urban, Southeastern Nigeria and their implications to groundwater contamination. *International Journal of Agriculture and Forestry* 5(1): 17–22.
- Ogban, P. I. and Ekerette, I. O. (2001). Physical and chemical properties of the coastal plain sand soils of South – Eastern Nigeria. *Nigeria Journal of Soil Research* 2:6-14.
- Onofiok, O. E. (2002). Lecture note on Introduction to Soil Science. Lecture Note on Soil Physics and Biology, University of Nigeria, Nsukka.
- Petters, W. Usoro, E.J. Udo, E.J., Obot, U.W. and Okpna S.N. (1989). Physical Background soils and landuse and ecological problems, technical report of the task force on soils and landuse survey. Akwa-Ibom State Government Print Office, Uyo 60 3pp..
- Six, J., Elliott, E.T. and Paustian, K. (2000). Soil macroaggregate turnover and microaggregate formation: A mechanism for C sequestration under no-tillage agriculture. *Soil Biology and Biochemistry* 32 (14): 2099–2103.
- Sodhi, G. P. S., Beri, V. and Benbi, D. K. (2009). Soil aggregation and distribution of carbon and nitrogen in different fractions under long-term application of compost in rice - wheat system. *Soil and Tillage Research* 103: 412–418.
- Ude, E.J., Ibia, T.O.; Ogunwale A., Ano, O and Esu, I.E (2009), *Manual of soil, plant and water analysis*, Lagos; Siben Books Limited, Lagos, Nigeria.
- Udo, E., J., and Sobulo, R.A. (1981), *Acid sand of Southern Nigeria*; soil science society of Nigeria special publication monograph, P.1165.
- Udoson, C. E. (2008). *Gully Erosion in IkpaBasin*. Uwana Graphics Press, Uyo. Nigeria.
- Xie, J. Y. (2015a). Soil aggregation and aggregate associated organic carbon and total nitrogen under long-term contrasting soil management regimes in loess soil. *Journal of Integrative Agriculture* 14: 2405–2416