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Aggregate Stability of Soils on a Sloppy Terrain in Owerri, Southeastern Nigeria

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ABSTRACT

The study was conducted to assess the aggregate stability of soils on a sloppy terrain in Owerri, Southeastern Nigeria. The study area was cut into three physiographic positions: top slope, mid slope and foot slope. Transect survey technique was used to guide field sampling. Soil samples were collected at 0-15 cm and 15-30 cm depths on each physiographic position. Core samples were collected for bulk density determination. The samples were taken to the laboratory for laboratory analysis. Data obtained were subjected to analysis of variance (ANOVA) to partition the total variability in the observations made. The means were separated using least significant difference (LSD). Results showed that the land was generally stable. The soils at the foot slope were more stable than soils at the top and mid slope. The foot slope had %water stable aggregates of 28.09%. The mid slope had a %WSA of 19.50% while that of the top slope was 17.83%. These were for their top soils. The sub soils had lower values than the top soils. The %WSA was 12.27%, 13.40% and 19.83% for the subsoil of the top slope, mid slope and foot slope respectively. There were also clear variations in the physical and chemical properties of the study area.

Keywords: Aggregate stability, percent water stable aggregates (%WSA), soil degradation, slope.

INTRODUCTION

Aggregation affects erosion, movement of water and plant root growth. Desirable aggregates are stable against rainfall and water movement (USDA, 1996). Some aggregates readily succumb to the beating of rain and the rough and tumble of ploughing and tilling the land while some others resist disintegration (Brady and Weil, 1999). Aggregate stability is largely influenced by the binding action of microorganisms and the cementing action of stable humus components (Savalia et. al. 2008). Soils are characterized by high degree of spatial variability due to the combined effects of physical, chemical and biological processes that operate with different intensities and at different scales (Priyabrata et. al. 2008). Soil properties also vary in sloping soils (Okon et. al. 2014). As the steepness of slopes increases, there is greater run-off and erosion, soil creep, less water infiltration and less water available for chemical and biological activity (Foth, 1984). The net effect is retardation in soil genesis. Erosion in steep slopes commonly result in thin soils especially where soils are underlain by bedrock. Erosion is a major cause of soil degradation leading to reduction in soil's productivity. It leaches out of the soil organic matter and other soil cementing agents which bind the soil particles together. Southeastern Nigeria is characterized by pronounced soil degradation due to poor aggregation (Onweremadu et. al. 2010). Therefore, this study was aimed at determining the aggregate stability of soils of a sloppy terrain in Owerri, Southeastern Nigeria.

MATERIALS AND METHODS

Study Area

The study was carried out on sloping terrain in the Otamiri river water shed in the Teaching and research farm of Federal University of Technology, Owerri, Imo State. Owerri is located between latitude $5^0$25'N and $5^0$30'N and longitude $7^0$00'E and $7^0$10'E. The area has minimum and maximum ambient temperatures of 20^0C and 32^0C respectively and mean annual rainfall of about 2500mm (Igbozuruike, 1975). The soils of the area are derived from coastal plain sands known as acid sands (Benin formation). The soils are ultisols that are rich in free iron, but have low mineral reserve (Ofomata, 1975).

Field Study

Prior to soil sample collection, reconnaissance visit was made to the study site. The site was cut into three physiographic positions: top slope, mid slope and foot slope using transect survey techniques. Sampling points were located within the slope segments at 10m intervals along the transect.

Soil sample collection and Preparation: soil samples were collected randomly at 0-15cm and 15-30cm depth within each 10m interval at the three physiographic positions. The soil samples were air dried and prepared for laboratory analyses. Core samples were also collected for bulk density determination.

LABORATORY ANALYSES

Aggregate stability was studied at the macro level using percent water stable aggregates (Kemper and Chepil, 1965). Bulk density was determined using core method (Grossman and Reinsch, 2002). Particle size analysis was done using Bouyoucos hydrometer method (Gee and Or, 2002). Soil pH was determined using 1:2.5 soil-water ratio with a pH electrode and values were read out from a pH meter (Hendershot et al., 1993). Total Nitrogen was determined by kjeldahl digestion method (Bremner, 1996). Organic carbon was determined using the chromic wet oxidation method (Nelson and Sommers, 1982). Exchangeable Ca and Mg were determined by the EDTA versanate titration method (Thomas, 1982). Exchangeable Na and K were determined by the flame photometer method. Exchangeable acidity was measured by leaching the soil with 1N KCl and titrating with 0.05N NaOH (Mclean, 1982). Available Phosphorus was determined using Bray 2 method and exchangeable acidity (IITA, 1982).

DATA ANALYSIS

Results and data obtained were presented in tables and analyses done using analysis of variance. The means were separated using least significant difference (LSD).

RESULTS AND DISCUSSION

The results of the physical properties of the study area are shown in Table 1. Results showed that the land was generally stable. Mbagwu et al. (1993) pointed out that higher values of %WSA indicate higher stability. Aggregate stability increased towards the foot slope. The soils at the foot slope were more stable than soils at the top and mid slope. This can be attributed to the higher content of organic matter at the foot slope which is a good soil binding agent. The foot slope had %water stable aggregates of 28.09%. The mid slope had a %WSA of 19.50% while that of the top slope was 17.83%. These were for their top soils. The sub soils had lower values than the top soils. The %WSA was 12.27%, 13.40% and 19.83% for the subsoil of the top slope, mid slope and foot slope respectively. These values were not significantly different at (P=0.05). There was a preponderance of sand-sized fractions over the other sizes. This is in corroboration with (Onweremadu *et al*. 2010) that soils of Southeastern Nigeria are characterized by pronounced soil degradation due to poor aggregation. Okon *et al*., (2014) discovered that sand fraction dominates other soil fractions. Akamigbo (1999) attributed sandiness and changes in most soil properties to influence of parent materials, excruciating climate, land use and land use history. Sandiness of soils varied significantly (P=0.05) among physiographic positions. Significant (P=0.05) difference was also recorded in silt sized fractions. The textural class for soils at the top slope and mid slope ranged from loamy sand to sand while that of the foot slope ranged from sandy loam to loamy sand. The result also showed that the landscape had low bulk density values which were significant at (P=0.05). The values were not up to the critical level of 1.85 indicating a low compaction level. Silt/clay ratio also varied significantly at (P=0.05) among physiographic positions. The mean values of the silt/clay ratio ranged from 0.25g/kg to 0.83g/kg for the top soil and 0.32g/kg to 0.70g/kg for the sub soil. Results of silt/clay ratio showed very low values in the entire landscape indicating that the soils are formed from parent materials that are at a more advanced stage of weathering.

Table1. *Physical Properties of the Study Area*

Physiographic Positions	Depth (cm)	Sand (g/kg)	Silt (g/kg)	Cla (g/kg)	Textural class	Bulk density g/kg	SCR	Total porosity(%)	Aggregate stability %WSA
Top slope	0 – 15	895.73	42.33	61.93	sand	1.45	0.68	45.67	17.83
	15 – 30	916.47	34.53	49.00	sand	1.42	0.70	46.67	12.27
Mid slope	0 – 15	890.00	49.90	60.40	sand	1.31	0.83	50.67	19.50
	15 – 30	904.00	34.83	61.17	sand	1.40	0.57	47.33	13.40
Foot slope	0 – 15	789.90	43.33	170.13	sandy Loam	1.34	0.25	49.33	28.09

	15 – 30			108.87	Loamy	1.39	0.32	47.33	19.83
$LSD_{(0.05)}$	18.85*	21.01*	569.1^{NS}		sand	0.091*	0.2957*	3.387*	2.261^{NS}

Table 2 shows the results of the chemical properties of the study area for each physiographic position. There were clear variations in the chemical properties, as the foot slope had higher content of organic carbon, total nitrogen and available phosphorus than the top slope and mid slope, but the mid slope had the highest ECEC and total exchangeable bases. Results showed that the pH was moderately acidic. This is typical of a humid tropical soil and it can be attributed to climate and the parent material from which the soils are formed which are coastal plain sands.

Table2. *Chemical Properties of the Study Area*

Physiographic Positions	Depth cm	pH	OC g/kg	TN g/kg	Avail P mg/kg	TEB	TEA	ECEC
						cmol/kg		
Top slope	0 – 15	5.28	4.16	0.63	3.52	1.32	3.33	4.65
	15 – 30	4.58	3.21	0.30	1.91	0.56	2.76	3.32
Mid slope	0 – 15	5.29	5.06	1.03	0.10	6.76	3.47	10.23
	15 – 30	4.90	3.27	0.60	0.06	3.91	3.01	6.92
Foot slope	0 – 15	5.79	14.02	6.73	6.73	3.19	4.03	7.22
	15 – 30	5.20	7.96	5.33	5.33	1.75	3.13	4.88
LSD(0.05)		0.5369*		0.1244^{NS}	1.021*			0.705*

Table 3 shows the descriptive statistics of the study area, while Table 4 shows the correlation between aggregate stability and other selected soil physical properties. It showed that the means were similar are the range not very different, revealing that the soils were from the same parent material (Coastal plain sands). The sand and day contents in the study area were highly variable (>100% variation) while the aggregate stability varied moderately (CV ≥ 15% ≤ 35%). The silt clay ratio, bulk density and total porosity had low variations (CV ≤ 15%).

The standard deviation (SD) indicated that clay in the top soil deviated mostly from the mean (97.49 ± 62.92g/kg).

Aggregate stability correlated negatively and significantly with %sand (r = -0.948, P = 0.01), but positively and significantly with %clay (r = 0.901, P = 0.05). It also correlated negatively and non-significantly with bulk density (r = -0.573) and silt/clay ratio (r = -0.623) at (P = 0.05) but positively and non-significantly with silt (r = 0.518) at (P= 0.05).

Table3. *Descriptive statistic of the soil properties*

Soil Properties	Depth	Range	Min	Max	Mean	Std. Dev.	CV	Skewness
Sand	Top Soil	105.83	789.00	895.73	858.54	60.03	3604.18	-1.71
	Sub Soil	59.74	856.73	916.47	892.4	31.51	993.14	-1.43
Silt	Top Soil	7.57	42.33	49.90	45.19	4.11	16.91	1.62
	Sub Soil	0.43	34.40	34.83	34.59	0.22	0.05	1.08
Clay	Top Soil	109.73	60.40	170.13	97.49	62.92	3958.38	1.73
	Sub Soil	59.87	49.00	108.87	73.01	31.64	1001.30	1.45
Silt/Clay	Top Soil	0.58	0.25	0.83	0.59	0.30	0.091	-1.26
	Sub Soil	0.38	0.32	0.70	0.53	0.19	0.04	-0.89
Total	Top Soil	5.00	45.67	50.67	48.56	2.59	6.70	-1.225
Porosity	Sub Soil	0.66	46.67	47.33	47.11	0.38	0.15	-1.73
Bulk	Top Soil	0.14	1.31	1.45	1.37	0.07	0.01	1.415
Density	Sub Soil	0.03	1.39	1.42	1.40	0.02	0.00	0.94
Aggregate	Top Soil	10.26	17.83	28.09	21.81	5.51	30.31	1.55
Stability	Sub Soil	7.56	12.27	19.83	15.17	4.08	16.63	1.58

Table4. *Correlation of Aggregate Stability with selected soil physical properties*

Soil Properties	r
Sand	-0.948**
Silt	0.518
Clay	0.901*
Silt/Clay	-0.623
Total Porosity	0.535
Bulk Density	0.573

SUMMARY, CONCLUSION AND RECOMMENDATION

Results showed that the land was generally stable. Mbagwu et al. (1993) pointed out that higher values of %WSA indicate higher stability. Aggregate stability increased towards the foot slope. The soils at the foot slope were more stable than soils at the top and mid slope. This can be attributed to the higher content of organic matter at the foot slope which is a good soil binding agent. The foot slope had %water stable aggregates of 28.09%. The mid slope had a %WSA of 19.50% while that of the top slope was 17.83%. These were for their top soils. The sub soils had lower values than the top soils. The %WSA was 12.27%, 13.40% and 19.83% for the subsoil of the top slope, mid slope and foot slope respectively. These values were not significantly different at (P=0.05). The textural class for soils at the top slope and mid slope ranged from loamy sand to sand while that of the foot slope ranged from sandy loam to loamy sand. The result also showed that the landscape had low bulk density values which were significant at (P=0.05). The silt/clay ratio showed that the soils were at an advanced stage of weathering. The values ranged between 0.25 and 0.83 in the entire landscape. Silt/clay ratio was significant at (p=0.05). There were also clear variations in the chemical properties, as the foot slope had higher content of organic carbon, total nitrogen and available phosphorus than the top slope and mid slope, but the mid slope had the highest ECEC and total exchangeable bases. Results showed that the pH was moderately acidic. This work reveals that the landscape was relatively stable and needs proper soil conservation management practices to maintain its stability.

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