Pedality And Soil Moisture Retention Characteristics In Relation To Erodibility Of Selected Soils

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Abstract: Research on the pedality and soil moisture retention properties as they influence susceptiblity to soil erosion was conducted in the onset of 2006 rainy season in selected sites of Southeastern Nigeria. Minipedons were sampled for the in situ analyses. Soil data were subjected to analysis of variance, correlation and regression analyses. Results indicate that pedality is influenced by management type, with soils under bush fallow having higher pedality values. Variation in pedality attributes were significant ($p \leq 0.05$) in soils under bush fallow and conventional tillage. Some pedality attributes and soil moisture retention characteristics had significant correlation with erodibility factor: Available soil data showed that soil texture and organic carbon greatly influenced pedality and soil moisture retention characteristics in the site. However, more parameters and intensive soil sampling may be needed to improve the certainty of prediction. [Nature and Science. 2007;5(1):1-7].

Keywords: Degradation, hydraulic properties, morphology, tropical soils, soil structure.

Introduction

Variability in soil structure due to agricultural management practices has been studied using different techniques (Coughlan *et al.,* 1991; Boersma and Kooistra, 1994). However, description of some visible features is a rapid approach that can be used for an initial global evaluation of soil structure (Eynard *et al.,* 2004). Pedality is used to describe soil structure in terms of strength, size, shape and arrangement of aggregates Eynard *et al.* (2004) calculated pedality as a product of grade, size and type of structure.

The concept of pedality has been developed as it relates to hydraulic properties (Bouma, 1992; Lin *et al.,* 1999) especially as they influence soil moisture retention characteristics. Soil moisture content which is a variable amount of water contained in a unit mass or volume of soil and the energy state are important factors influencing plant growth (Igwe *et al.,* 1997). Soil moisture content influences wettability (Dekker *et al.,* 2001; Doerr *et al.,* 2002) and repellency (Hallet and Young, 1999). Measurement of stability of soil peds to water is used to estimate structural changes due to cultivation, since water is a major agent of aggregate breakdown but these attributes can be quantified using morphological features of a soil structure. These changes due to effects of human use and management were referred to as dynamic soil quality (Seybold *et al.,* 1998) and they influence vulnerability of soils to erosive forces.

Land use types cause differences in soil properties (Geeves *et al.,* 1995). In Southeastern Nigeria, Akamigbo (2001) reported marked differences in soil properties due to two different land uses, with intensive cropping of most productive soils leading to gully formation. Attempts have been made to quantitatively assess near surface soil quality using the soil quality morphological index (SQMI) (Grossman *et al.,* 2001). The SQMI combines information about soil texture, soil structure, moist rupture resistance, dry crust strength, thickness of surface horizon, surface connected macropores and cracks in determining soil quality. Soil texture influences plasticity, compatibility and consistency (Hillel 1998).

Changes in near-surface morphology due to land use and management are not substantially recognized in soil survey (Seybold *et al.,* 2004) and have not been considered in soil quality assessments (Grossman *et al.,* 2001).

Southeastern Nigerian soils have been subjected to intensive cropping with little or no additional soil fertility inputs. Soil fertility regeneration depends on natural bush fallow whose length has been shortened due to high population pressure (Onweremadu, 1994). Slash-and-burn system of clearing is still a farming practice. All these have heightened the spate of land degradation through soil erosion. However, there is current desire to acquire soil data, and such acquisition through soil survey might be too expensive considering the low socio-economic status of farmers in the area. Based on the foregoing, the study aimed at investigating the pedality and moisture retention characteristics of soils while relating them to erodibility and soil texture under three tillage practices.

Materials and Methods

Study area: Southeastern Nigeria lies between latitudes 4^{o}30' and 7^{o}30^{o}N, and longitudes 6^{o}45' and 9^{o}00'. The major geological materials in the area include shale, cretaceous sandstones, upper coal measures, lower coal measures, coastal plain sands and basement complex rocks (Orajaka, 1975). The area is predominantly a lowland with highlands above 200 metres above sea level (Ofomata, 1975). It is characterized by a bimodal annual rainfall about 1700 to 2500 mm. Daily temperatures are generally high ranging from 28 to 35^{o}C. The area has a rainforest vegetation. Farming is a major socio-economic activity in the area.

Field studies: Thirty soil samples from surface horizons were collected from selected parts of southeastern Nigeria for the study in the beginning of rainy season in 2006. The choice of sampling points was guided by the geological map of the area, such that all soil groups were represented. Soil samples were air-dried, crushed and sieved using 2-mm sieve.

Soils were morphologically described using the Natural Resources Conservation Services (Soil Survey Staff, 2003). The morphological description of soil structure was quantified in relation to hydraulic properties of soils, based on the scale of Lin *et al.* (1999) (Table 1). Pedality was calculated as a product of grade, size and type of soil structure. Ped size was rated independently of type (fine <10 mm, medium 10-50 mm, coarse > 50 mm). The scale for platy structures was one-tenth less than other structure types and only very thin plates received maximum points because the orientation of platy structures is unfavourable to vertical flow and root penetraction.

Laboratory study: Particle size distribution was determined hydrometer method (Gee and Or, 2002). Bulk density was evaluated using the core method (Grossman and Reinsch, 2002). Total carbon was determined by a Leco CS444 analyzer (Leco Corp., St. Joseph, M. I). Soil samples were placed in a furnace overnight at 475^{o}C temperature to estimate inorganic carbon, and organic carbon was measured after subtraction from the total carbon content (Yang and Kay, 2001).

Soil moisture retention characteristics were determined by soaking disturbed soil samples for 48 hours to allow the samples get saturated. The saturated soil samples were put in the pressure plate extractor and pressure applied at 0.01, 0.05, 0.1 and 1.5 Mpa suction until water ceased to drain-out. The soil samples were weighed and oven-dried at 105^{o}C for 24 hours. The volumetric moisture content (θ_v), values obtained were multiplied by their corresponding bulk density. Available Water Capacity (AWC) was calculated as the water retained between suction 0.01 and 1.5 Mpa. Atterberg limits were determined according to the procedure of Sowers (1965). The liquid limit was estimated with the aid of Casagrande apparatus while the plastic limit was obtained by kneading and rolling the soil on a glass plate. Plasticity index (PI) was calculated as the difference between liquid limit and plastic limit (Grieve, 1980).

The Wischmeier erodibility factor (K) was computed using the Nomograph (Wischmeier *et al.,* 1971) and the Slaking index (SI) was calculated as liquid limit divided by water retained at 0.01 MPa (De Boodt, 1967).

Statistical analysis: Soil data analyses were carried out using statgraphics (STSC Inc/Statistical Graphics Corporation, 1987). The software was also used to perform correlation and regression analyses on the data. Variability in soil properties was ranked according to the procedure of Aweto (1982).

Results

Soil properties: Value ranges in selected soil properties are shown in Table 2. High values of coefficient of variation were recorded in Atterberg limits, sand and organic carbon contents while moderate variations occurred in erodibility factor, silt and clay content. Bulk density showed slight variation (CV=15%).

Pedality: Pedality was better developed in a 5 – year old bush fallow fields on the surface soils when compared with both the conventional and minimum tillage management practices. But predality of minimum tillage was better than of conventional tillage. At depths greater than 20 cm, structural changes due to tillage management practice were less marked. There were non-significant pedality attributes in soils under minimum tillage. Granular aggregates and fine wedges predominated in the 0-20 depth of soils in bush fallow whereas blocky structures were common in conventionally tilled soils. Very large lumps or blocks dominated below 20 cm of conventionally tilled soils. In soils with high clay content, wedge formation was observed and pedality rating tended to be greater, especially under bush fallow. In line with the findings of Sparrow *et al.* (1999), ped type was not primarily responsible for the differences in pedality.

Soil moisture retention characteristics: Values of volumetric moisture retention characteristics as shown in Table 4 show that soils do not retain much water at high suctions. Amount of available water varied and decreased as soil texture changed from finer materials to more coarse forms. Soils with more clayey textures retained highest level of water at 0.01 Mpa and this water influenced availability of soil moisture. Soils of Awgu with relatively high sand content had very high AWC. The more clayey soils had least slaking index values while sandier textures were more slakeable.

Relationship between pedality, soil moisture retention characteristics, slaking index and erodibility: Table 5 presents correlaton coefficient values between erodibility factor and pedality attributes in addition to slaking index. Grade had the greatest relationship with erodibility factor while it related weakly with slaking index. Unlike in pedality attributes, soil erodibility factor had a better relationship with soil moisture contents (Table 6). Highly significant negative correlation coefficients (p=0.01; 0.05) were obtained between erodibility factor and soil moisture content at different pressures, namely 0.01, 0.05, 0.1 and 1.5 Mpa.

Modelling: Results of stepwise regression analysis conducted in the study are shown on Table 7. Soil organic carbon and textural parameters contributed highly to variability in pedality and volumetric moisture retention characteristics.

Table 1: Scores for quantifying morphological features of soil structure in relation to water retention (Adapted from Lin *et al.,* 1999).

Morphological feature	Class	Score
Structure grade	Massive	0
	Weak	1
	Moderate	5
	Strong	25
	Single-grained	50
Aggregate size	>50 mm (>5 mm if platy)	1
	10-50 mm (1-5 mm if platy	3
	<10 mm (< 1 mm if platy)	10
Structure type (shape)	Massive	0
	Platy	1
	Prismatic, blocky, wedge >10 mm	10
	Granular, single grained wedge <10 mm	30

Table 2: Selected soil properties of studied soils

Soil property	Range	Mean	CV	Ranking
Liquid limit (%)	10-62.0	39.0	109	HV
Plastic limit (%)	10-45.0	26.0	67	HV
Plasticity index (%)	0.0-17.8	0.4	120	HV
Wischmeier Erodibility (K)	0.1-0.8	0.4	35	MV
Bulk Density (g cm^{-3})	1.2-1.7	2.0	15	LV
Clay (%)	7.0-57.0	25.0	48	MV
Silt (%)	2.0-30.0	19.0	31	MV
Sand (%)	43.0-90.0	54.0	52	HV
Organic carbon (%)	0.5-1.6	16.0	60	HV

HV=High variation, MV=moderate variation, LV=little variation

Table 3: Differences between soil samples (N=30) in means of pedality, and structural type, grade and size averaged over 0-20 cm in the study site.

Management type	Pedality property	Soils samples scores	Level of significance
Minimum Tillage	Pedality	880.0	NS
	Type	8.3	NS
	Grade	6.8	NS
	Size	5.0	NS
Conventional Tillage	Pedality	286.0	**
	Type	5.2	**
	Grade	4.8	**
	Size	5.3	**
5-year old bush fallow	Pedality	1960.0	**
	Type	11.0	**
	Grade	8.9	**
	Size	7.6	*

** significant at $p \leq 0.01$, * significant at $p < 0.05$, NS = not significant

Table 4: Volumetric moisture retention characteristics and slaking index values of studied soil (%)

	MPa					
Location	0.01	0.05	0.1	1.5	AWC	SI (%)
Agulu	18.3	13.8	11.9	11.6	6.7	1.0
Ihiala	12.4	9.7	6.6	6.5	5.9	2.2
Opi	20.1	14.0	15.3	13.9	6.2	0.1
Izzi	38.0	18.1	15.1	14.0	24.0	0.2
Ezzamgbo	44.1	30.2	28.0	20.3	23.8	0.4
Ezzikwo	39.1	18.1	15.2	14.3	24.8	0.8
Mgbidi	13.5	9.4	6.7	6.4	7.1	2.4
Agbani	33.7	21.0	17.9	18.1	15.6	0.8
Afikpo	36.5	17.2	14.8	13.1	23.4	0.7
Owerri	10.0	8.1	6.1	5.9	4.1	2.3
Mbaise	9.8	7.6	7.0	5.3	4.5	2.2
Ukehe	24.2	15.6	11.6	11.4	12.8	0.2
Ehamufu	27.1	16.4	13.1	12.8	14.3	0.1
awkuzu	16.2	8.9	8.0	7.3	8.5	1.8
Obosi	12.2	10.1	8.8	6.8	5.4	2.1
Obolloafo	21.3	15.1	14.1	14.9	7.2	0.1
Oguta	10.6	9.2	7.8	4.7	5.9	2.0
Egbema	11.2	9.5	8.2	5.7	5.3	1.9
Okigwe	19.6	13.4	12.6	10.2	9.4	1.2
Ibeku	60.2	50.1	47.2	29.1	21.1	0.6
Uturu	25.6	19.6	16.7	11.9	13.7	0.9
Amakama	29.2	17.1	14.6	10.2	19.0	1.8
Anuro	64.8	46.7	43.8	30.0	34.8	0.7
Lokpanta	44.1	29.5	25.4	9.9	34.2	0.7
Awgu	33.2	22.8	21.8	8.3	24.9	0.8
Aguata	15.9	11.7	11.8	9.1	6.8	1.3
Awka	17.0	9.0	8.0	7.2	9.8	1.2
Nenwe	31.6	19.0	11.3	10.4	21.2	0.7
Aninri	32.7	22.7	22.0	19.0	13.7	0.8
Akidi	64.0	54.0	48.1	39.1	24.9	0.6

Table 5: Correlation coefficients between erodibility factor (K), pedality, type, grade size and slaking index of soils studied (n=30)

Soil property	Correlation coefficient (r)	Level of significance
Pedality	0.516	*
Type	0.166	NS
Grade	0.774	*
Size	0.623	*
Slaking index	0.296	NS

Table 6: Correlation coefficient between erodibility factor (K) and moisture retention characteristics of soil (n=30)

Moisture content (MPa)	Correlation coefficient	Level of significance
0.01	-0.612	*
0.05	-0.635	**
0.10	-0.648	**
1.50	-0.608	**
AWC	-0.498	*

AWC=available water capacity
** significant at p = 0.01, * significant at P=0.05

Table 7: Stepwise regression models of pedality and soil moisture retention characteristics with selected soil properties (n=30)

Department variable	Regression equation	r2
Padality	Y=17.79+0.62(clay)-0.76(sand)+6.1(OC)	0.77
Size	Y=40.25+0.31(clay)-0.43(sand)+5.5.(OC)	0.81
Grade	Y=30.15+0.36(clay)+4.55(OC)	0.85
0.01 Mpa	Y=19.21+0.29(clay)44(sand)+4.7(OC)	0.80
0.05 Mpa	Y=33.23+0.47(clay)-0.42(sand)+1.22(OC)	0.78
0.10 Mpa	Y=2.36-0.28(sand)	0.82
1.50 Mpa	Y=2.16+0.33(clay)+0.81(OC)	0.72
AWC	Y=47.21-0.33(sand)	0.58

OC=organic carbon, AWC=available water capacity
** significant at $p \leq 0.01$

Discussion

Differential pedality in soils of the study site is a result of variation in aggregation due to land use. Below 20 cm depth, there was almost a homogenous pedality in all soils under study. As granular aggregates dominated 0-20 cm in bush fallow, blocky soil structures were found at the same depth at Conventional and Minimum tillage soils, suggesting the influence of tillage and traffic on pedality. In a similar study, Akamigbo (1999) reported marked differences between virgin forest and cultivated soils of a humid tropics in morphological properties.

Pedality and pedality attributes of grade and size significantly ($p \leq 0.05$) influenced erodibility of soils (Table 5). Weaker soil structures are more vulnerable to erosive forces than stronger grades just as large ped sizes resist easy transportability by runoff water. However, these peds are modified by alternate wetting and drying (Caron *et al.,* 1992) and slaking occurs on these soils when wet moisture status reverses upon drying (Igwe, 2001) during the dry season.

Variation in soil moisture retention characteristics suggests differential transmissivity of soil water in these soils. Significant negative correlation coefficients between erodibility and soil moisture retention characteristics, implies that they could be used to detect the level of susceptibility to soil erosion. Earlier, Hardley *et al.* (1985) observed that detachment of soil peds by impacting rain drops responds to various levels of soil wetness, suggesting that alternate drying and wetting promotes soil erosion. However, hydraulic properties of soils are influenced greatly by human management with Ley *et al.* (2002) affirming that soil immediately after tillage is highly unstable and undergoes dynamic changes in the interaggregate stability. However, this study did not assess the soil moisture characteristics under different management practices considering the report of Blanco-Canqui *et al.* (2004) that residual effects of tillage diminish within 21 to 28 days.

Modelling using the available soil data confirms the significance of particle size distribution and organic carbon (organic matter) in the aggregation of soils and in pedality, especially as they relate to the susceptibility of soils to erosion. But the relevance of organic carbon in soil structural formation is at macroagregation in tropic soils (Igwe *et al.,* 1999). Gantzer *et al.* (1990) observed that soil erodibility was related to soil texture, stating that long-term productivity of clayey soils increases their erodibility. High r^2 values in the study implies that the associating parameters are good predictors of pedality and soil moisture retention characteristics. Determination of soil texture and soil moisture rententivity is cheap when compared with highly expensive and sophisticated probing sensors, suggesting the use of these parameters in low-input agriculture of the study area.

Conclusions

Pedality varies due to management practice, with soils under bush fallow exhibiting higher values when compared with conventional and minimum tillage practices. Soil moisture retention characteristics varied due to management practice in the site. Both pedality and soil moisture retention characteristics influenced erodibility of soils.

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Received: 2/20/2007

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