Structural stability of Dystric Nitisol in Relation to Some Edaphic Properties under Selected Land Uses

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Abstract: We conducted this study before the rains in 2005 to assess the aggregate stability of soils of a toposequence as affected by soil properties under six land uses, namely cassava cultivation polluted with crude oil (CP), rubber plantation (RP), non polluted cassava cultivation (NCP), forest (F), oil palm plantation (OPP) and bare fallow (BF).Target soil sampling technique was used to collect soil samples based on physiography and land use. Routine laboratory analyes were conducted on soil samples and data generated were analyzed using simple mean (descriptive statistic) and correlation coefficient (inferential statistic). Results show differences in selected soil properties due to land use. Total porosity, organic matter (OM) water stable aggregates and mean weight diameter of soil peds varied due to land use and topography. Mean weight diameter increased with declining slope gradients while aggregates were more stable under CP, F, BF and RP. Mean weight diameter had significant relationship with OM (r=0.52), total nitrogen (r =0.51), exchangeable Ca (r =0.39), exchangeable Na (r = 0.34), pH(r =0.32), and exchangeable H (r =-0.21) at 1% level of probability. [Nature and Science. 2007;5(4):7-13].

Keywords: Land use, Nitisols, pedality, physiography, tropical soils.

Introduction

Aggregate stability of a soil has a great influence on crop performance, soil erosion, runoff and transport of contaminants from farmlands to water bodies (Rasiah and Kay, 1994). A good soil structure is important in sustaining long term crop production on agricultural soils (Eneje *et al., 2005)* because it influences water status, workability resistance to erosion, nutrient availability, crop growth and development (Piccolo and Mbagwu, 1999). Aggregate stability is one of such measures used in determining structural suitability of soils for agricultural and non-agricultural uses.

Aggregate stability of soils is influenced by quality and quantity of organic matter (Piccolo, 1996; Spaccini *et al., 2001;* Adesodum *et al., 2004),* cations content (Dexter and Chan, 1991; Levy and Torrento, 1995), soil texture (Boix-Fayos *et al.*,1992). These were classified into biotic and abiotic factors (Brady and Weil, 1999). In addition to these, anthropogenic activities influence aggregate stability. Spaccini e*t al.* (2001) observed that cultivation reduced aggregate stability and increased proportions of the small size aggregate relative to forest soils. Labile pool of organic matter which enhances aggregate stability is highly affected by land use (Cambardella and Elliott, 1992). Mbagwu and Auerswald (1999) reported that forest, bush fallows, mulched and minimum-tilled plots had higher percolation stability when compared with paddy rice fields, unmulched, and continuously cropped plots. Eynard e*t al.*(2004) reported high water stable aggregates in grassland than cultivated soils.

There is a death of information on the relationship between aggregate stability and land use types in soils of the Southeastern Nigeria. 5cantiness of soil information as it pertains aggregate stability could be responsible for the increasing spate of soil structural breakdown and development of a variety of rills and gullies on a once beautiful landscape, leading to soil loss, displacement of homes loss of farmlands, poor nutrient reserve and declining yield of crops. The major objective of this study was to investigate the relationship between aggregate stability and soil properties while relating these to land use types.

MATERIALS AND METHODS

Study Area: The study was conducted before rains in 2005 in six sites of Owerri Agricultural Zone lying between latitudes 5^{o} 25' and 5^{o} 45' N and longitudes 6^{o} 45' and 7^{o}05'E. Soils are derived from Coastal Plain Sands (Benin formation) of the Miocene-Oligocene geologic era. Earlier, soils of the area were classified as Dystric Nitisols (Onweremadu, 2006).

The area has a lowland geomorphology. Mean annual rainfall is about 2400mm while mean annual temperature ranges from 26-29^{o}C. Rainforest vegetation predominates in the area. Farming is a major socio-economic activity of the area.

Field studies: Target soil survey sampling technique was used with emphasis on land use and topography. Soil samples were collected at a depth of O-15cm with an auger from six sites. The six sites include Asaa, Obitti, Ihiagwa, Eziobodo, Etekwuru and Emebiam, all in Imo State. Six land use practices used were used and include cassava cultivation polluted with crude oil (CP), cassava cultivation not polluted with crude oil (NCP), forest (F), oil palm plantation (OP), rubber plantation (RP) and bare fallow (BF). All these land uses were of the same topography (0-1%; 3% and 5%). A total of nine bulk samples were collected from each study site with 3 samples from each slope gradient. Nine core samples were also collected from each land use type. The composite soil samples were air-dried and sieved through 4.76mm sieve for water stable aggregate analysis and the remaining soil particles were passed through 2-mm sieve for soil characterization. Core samples were used for bulk density and total porosity determinations.

Laboratory Analyses: Particle size distribution was determined by Bouyoucos hydrometer method (Gee and Or, 2002) while bulk density was measured by core method (Grossman and Reinsch, 2002). Soil aggregate stability was estimated by wet-sieving techniques (Kemper and Rosenau, 1986). Mean weight diameter (MWD) was computed as:

$$\mathrm{MWD} = X_iW_i \sum_{i=1}^{n}$$

Where MWD = mean weight diameter of water –stable aggregates
X_i = Mean diameter of each size fraction (MM)
W_i = Mean Proportion of the total sample weight in the corresponding size fraction.

Soil pH was determined potentiometrically in soil-water ratio of 1:2.5 as described by Hendershot e*t al.* (1993). Soil organic carbon was measured by wet digestion (Nelson and Sommers, 1996) while total nitrogen was estimated by microkjeldahl method (Bremner, 1996). Exchangeable acidity and exchangeable bases determined by potassium chloride extraction method (Juo, 1981). Available phosphorus was measured by Olsen method (Emteryd, 1989). Soil cation exchange capacity was estimated by a method described by Rhoades (1982).

Calculations: Exchangeable Sodium Percentage (ESP) was computed as

$$\mathrm{ESP} = \frac{\text{Exchangeable Sodium (meq/100g)}}{\text{Cation exchange capacity (meg/100g)}} \times 100\%$$

Sodium Adsorption Ratio (SAR) was calculated as follows:

$$\mathrm{SAR} = \frac{\text{Exchangeable Sodium}}{\frac{(\text{Exchangeable Calcum + Magnesium})^{1/2}}{2}}$$

Statistics: Results were subjected to mean of values. Correlations and multiple regression analyses were also conducted to relate changes in aggregate stability (MWD) and soil properties using SPSS(1999).

Results

Soil properties: Selected properties of soils studied are shown in Table 1.Coarse sand predominated over other size fractions irrespective of land use. While percent silt was low in line with Igwe *et al.* (1995), textural class ranged from sand to sandy loam. Also low clay content was observed in studied soils.Forest and oil palm plantation soils had the lowest bulk density value of 1.29 g/cm3 with highest value recorded in soils under cassava cultivation polluted with crude oil (CP) and this corresponded to high and low total porosity values for the former and latter land uses, respectively. Organic fractions were highest in soils under CP and rubber plantations (RP) and least in soils under cassava cultivation non polluted (NCP) and bare fallow (BF). Available phosphorus was highest in RP and least in oil palm plantation (OP). Highest value of base saturation (BSat) was found in soils under RP while least value was recorded in forest soils. Soils under NCP and CP recorded highest exchangeable sodium percentage (ESP) and sodium adsorption ratio (SAR). Soils were generally strongly acidic irrespective of land use type with soils under forest exhibiting highest value of exchangeable aluminium (1.1 meg/100g soil).

An introduction of slope factor gave differences in some soil properties (Table 2). Average coarse sand content decreased with slope decrease irrespective of land use and this contrasted with the trend in fine sand and clay distribution Total porosity and organic matter increased downslope irrespective of land use type. Conversely bulk density decreased downslope, ranging from 1.47 to 1.24 g/cm3 (mean values). Highest bulk density values were recorded in RP, CP and NCP in all the physiographic positions.

Aggregate Stability: Aggregate stability varied among physiographic position (Table 3). Highest percentage of water-stable aggregates were recorded in the less than 0.25 mm diameter water-stable aggregates at each slope type. The 4-2 mm water-stable aggregates increased in the downslope direction for all the land use types. Organic matter (OM) increased downslope with RP having highest mean OM at the bottomslope. Very sharp increased in OM occurred in CP from 5 to 3 % slope gradient while BF exhibited the least OM increased.

Mean weight diameter (MWD) increased with declining slope gradient, having 0.41 mm (5% slope), 0. 54 mm (3%) and 0.66 mm (0-1%). Aggregates were most stable in CP, jointly followed by F and OP, then BF, RP and NCP in a decreasing order. The NCP followed the general trend of decreasing upslope as in other treatments but values not as comparable with others. Surprisingly; BF did not show least stability despite its exposure to climatic and anthropogenic forces.

Relationship between Aggregate Stability and Soil Properties: Results of correlation analysis between aggregate stability (MWD) and some soil properties are shown in Table 4. There were very significant (P =0.01) positive relationship between OC, pH T.N., exchangeable calcium and exchangeable and sodium MWD while exchangeable hydrogen related very significantly (P-0.01) but negatively related with the aggregate stability index. However, exchangeable potassium has a significant (P=0.05) with MWD while exchangeable magnesium, total exchangeable acidity, BD, ESP and SAR showed no significant relationship with MWD. Of the variables assessed organic fractions (OC and TN) had the best relationship with MWD. These results show consistency with the studies of Rachman *et al.* (2003) which reported greater aggregate stability as OM increased in long-term cropping systems.

TABLE 1. Selected properties of soils studied (0-15 cm)

Properties	Unit	CP	RP	NCP	F	OP	BF
CS	%	55	49	70	76	63	62
Fs	%	28	28	17	16	24	18
Silt	%	7	12	2	1	7	9
Clay	%	10	11	11	7	6	11
TC		LS	SL	Ls	S	L	SL
BD	g/cm3	1.53	1.43	1.36	1.29	1.29	1.36
TP	%	42	46	48	51	51	52
$pH_{(1:2.5/H20)}$		4.8	4.7	4.8	1.4	4.7	4.5
OC	%	2.2	2.2	1.1	1.7	1.9	1.7
TN	%	0.20	0.20	0.10	0.16	0.18	0.11
Av.P	ppm	8.1	26.6	9.5	10.2	7.6	7.9
Ca^{2+}	meq/100g	0.8	1.8	0.4	0.6	1.6	0.8
Mg^{2+}	meq/100g	0.5	0.6	0.6	0.5	0.9	0.5
K^{+}	meq/100g	0.1	0.2	0.1	0.1	0.1	0.1
N^{a+}	meq/100g	0.8	0.7	0.7	0.6	0.5	0.6
H+	meq/100g	0.2	0.2	0.3	0.3	0.2	0.2
AI^{3+}	meq/100g	0.7	0.5	0.8	1.1	0.2	0.8
CEC	meq/100g	4.9	5.6	3.8	5.2	5.9	4.5
Bsat	%	44	59	47	34	50	44
ESP	%	16	12	18	11	8	13
SAR		3.2	2.4	3.3	2.8	1.5	2.4

CP = Cassava cultivation polluted with crude oil
RP = rubber plantation, NCP = Cassava Cultivation not polluted, F = forest, OP = oil palm plantation, BF = Bare Fallow, LS = Loamy Sand, S = sand,
SL = sandy loamy
CS = Coarse sand, FS = fine sand, TC =textural class,
BD = Bulk density, TP = total porosity, OC = organic carbon,
TN = Total nitrogen, AVP = available phosphorus, CEC = cation Exchange capacity, BSat = base saturation, ESP = exchangeable Sodium percentage, SAR = sodium absorption ratio.

Table 2. Properties of soils under 6 land uses in relation to slope (0-15cm)

Land use	CS (%)	FS (%)	Silt (%)	Clay (%)	TP (%)	BD (%)	OM (%)
5 % slope							
CP	54.5	30.0	6.5	9	41	1.56	2.0
RP	55.5	29.0	7.5	8	38	1.64	1.8
NCP	72.5	15.0	2.5	10	43	1.50	1.5
F	75.0	18.5	0.5	6	48	1.38	3.1
OP	67.0	21.5	6.5	5	47	1.40	1.9
BF	65.5	14.0	12.5	8	49	1.35	1.8
Mean	65.0	21.3	6.0	7.6	44.3	1.47	2.0
3% Slope							
CP	54.0	29.5	6.5	10	42	1.53	4.5
RP	55.0	28.5	7.5	9	42	1.54	2.7
NCP	70.0	16.5	2.5	11	50	1.32	2.0
F	76.0	15.5	1.5	7	52	1.25	2.6
OP	64.0	23.5	7.5	5	52	1.26	3.7
BF	60.5	20.0	8.5	11	49	1.24	1.9
Mean	60.8	22.2	5.6	8.3	48.0	1.35	2.9
0 –1% slope							
CP	56.5	25.0	7.5	11	43	1.52	4.8
RP	38.0	25.5	20.5	16	58	1.12	6.6
NCP	67.0	18.5	5.2	12	52	1.25	2.2
F	76.5	13.0	2.5	8	53	1.24	2.8
OP	57.0	26.5	8.5	8	54	1.22	4.0
BF	58.5	23.0	6.5	14	58	1.10	2.2
Mean	58.9	22.2	8.4	11.5	53.0	1.24	3.8

CS = Coarse sand, FS = fine sand, TP = Total porosity,
BD = Bulk density, OM = organic matter

Table 3. Structural stability of studied soils

Land Use	Water-stable aggregates (mm)					MWD(mm)	OM
	4-2	2-1	1-0.5	0.5-0.25	<0.25		
CP	11.2	10.9	16.9	19.7	32.9	0.75	1.9
RP	2.1	1.1	4.8	21.3	69.8	0.28	1.8
NCP	1.3	2.1	8.1	20.5	64.0	0.29	1.5
F	3.5	4.9	13.2	24.9	50.8	0.44	3.1
OF	1.6	1.4	5.1	34.1	55.3	0.31	1.9
BF	4.1	3.5	9.7	27.5	53.7	0.42	1.8
Mean	3.96	4.00	9.63	24.66	54.91	0.41	2.0
3 % Slope							
CP	13.2	13.2	11.5	14.0	46.9	0.79	4.5
RP	4.6	5.2	12.9	23.7	50.1	0.47	2.7
NCP	2.2	2.5	8.6	27.5	58.2	0.35	2.0
F	4.8	10.8	17.3	25.4	39.1	0.58	2.6
OP	8.7	6.6	9.2	23.8	49.2	0.58	3.7
BF	6.0	4.3	10.5	29.1	48.2	0.49	1.9
Mean	6.58	7.10	11.66	23.91	48.61	0.54	2.9
0 – 1% Slope							
CP	16.3	17.5	17.8	17.6	26.9	0.99	4.8
RP	11.1	12.1	12.1	6.8	46.7	0.69	6.6
NCP	2.3	2.9	6.8	31.9	55.3	0.35	2.2

F	6.3	12.1	15.7	23.5	39.7	0.63	2.8
OP	9.7	12.5	20.8	15.9	38.7	0.74	4.0
BF	5.3	8.5	13.6	21.1	39.7	0.55	2.2
Mean	8.50	10.93	14.46	19.46	41.16	0.66	3.7

MWD = Mean weight diameter

Table 4. Relationship between MWD and some soil properties (N=90)

Variable	r	r^2	Level of Significance
OC	0.52	0.270	* *
pH(water)	0.32	0.100	* *
TN	0.51	0.260	* *
Ca^{2+}	0.39	0.150	* *
Mg^{2+}	-0.03	0.001	NS
K^+	0.22	0.050	* *
N^{a+}	-0.34	0.110	* *
BSat	0.34	0.110	* *
H	-0.21	0.040	* *
TEA	-0.13	0.010	NS
BD	-0.07	0.005	NS
SAR	0.05	0.003	NS
ESP	0.13	0.02	NS

MWD = Mean weight diameter, OC = organic carbon, TN = total nitrogen, TEA= exchangeable acidity, BSat = base saturation, BD =bulk density, SAR = sodium Adsorption Ratio ** Significant at P = 0.01, * Significant at P = 0.05 NS = not significant, r =correlation coefficient, r^2 = coefficient of Determination.

Discussion

Sandiness, acidity and low organic matter content of soils could be attributed to a combination of influences from parent materials climate, land use type and land use history. The presence of Coastal Plain Sands as a parent material resulted in the formation of sand-sized fractions with little clay content and clayiness affects aggregate stability (Kay and Angers, 1999). It implies that the predominance of sand-sized particles promotes aggregate instability, and this is characteristic of studied soils of the study site. Instability of aggregates is worsened by high rainfall duration, amount and intensity which heighten erosivity of these disaggregated soils. Also, low content of organic matter in these soils especially those on 5% slope enhances disaggregation of macroaggregates. It has been reported that a positive relationship exists between organic matter and aggregate stability (Spaccini *et al.* 2001; Adesodum *et al.,* 2004). Despite a good value of OC recorded in CP, it still has the highest value of bulk density (1.53 g/cm^3), and this is attributable to effect of cultivation and crude oil pollution of these soils. Foth (1984) reported that crude oil spillage increases bulk density due to aggregate disintegration as tillage operations break down aggregates, reduce structural stability while increasing bulk density (Eynard *et al.,* 2004). In Southern Brazil, Viera *et al.*(2002) reported changes in bulk density resulting from cultivation.

Exchangeable calcium strongly correlated with MWD (r =0.39; p = 0.01, N = 90) possibly due to the ability of the basic cation to promote flocculation of soil colloids (Curlin *et al.,* 1994; Dontsova and Norton, 2002). Exchangeable potassuim had the same effect while Na^+ significantly decreased as MWD increased (r = 0.34; P =0.01). Earlier, Dontsova *et al.* (2004) reported that exchangeable cations significantly influence soil-water relations and this may have affected structural stability. Exchangeable Na and Mg enhance dispersion and clay swelling in the soil exchange complex. Cationic hydrogen had a significant negative correlation (r = -0.21; p = 0.01) with MWD, which could be attributed to its preponderance after intensive leaching of basic cations in the tropical rainforest agroecology. In the same study, values of exchangeable Na were low and exhibited insignificant relationship with ESP and SAR, suggesting that exchangeable sodium is not a principal factor influencing MWD and consequent erodibility of soils of the study area.

Conclusions

The study revealed that properties of soils varied due to land use practices. Rubber plantation and CP soils exhibited highest BD values while RP and CP soils were high in OM. While BD decreased downslope, OM increased towards 0-1% slope. Structural stability of aggregates also varied with land use, with CP showing highest MWD in all the physiographic positions. However,in all land use types, MWD was very strongly related with OC and TN. There is a great need to use other aggregate stability indices in soils of the study site for increased knowledge and for purposes of comparisons.

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