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Percent Clay, Aggregate Size Distribution and Stability with Depth along a Toposequence Formed on Coastal Plain Sands

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Abstract: We studied the distribution of clay and its effects on aggregate size distribution and stability along a toposequence formed from coastal plain sand in a tropical ecosystem, the distribution of percent clay with depth; 0-15, 15-30, 30-45 and 45-60cm was related to changes in soil aggregation. Results showed that topo position, and depth of soil significantly alone and interactively affected percent clay distribution and soil aggregation at $p<0.01$. Topo position explained about 80% of the differences in clay content at shallow soil depth (0-30cm), while deeper in the soil profile (30-60 cm) it explained between 50-70% of the differences in clay content. Topo position explained over 70% of the trend in aggregate size distribution deeper in the soil profile (30-60 cm), but contributed less than 50% in affecting the trend in aggregate size distribution at the shallow depth. The effect of topo position was higher (about 70%) in influencing aggregation at micro aggregate level (<0.6 mm), than (50%) in the macro aggregate level (>1mm) irrespective of soil depth.

Key words: Toposequence, aggregation, percent clay, soil profile, coastal plain sand

INTRODUCTION

The Southwestern Nigeria landscape is generally characterized by an undulating land form features that ranges from nearly level at the crest sharply sloping hillsides, gently sloping low lying areas, sharply gradient V-shape valleys and flats flood plains. According to Smyth and Montgomery (1962) Oluwatosin *et al.* (2001) soils frequently occur in a well defines and fairly regular sequence. These sequences have been referred to as Catena (Ahn, 1983). Soils along a toposequence can be with or without uniform lithology. Odenerho (1980) reported that the distribution of individual soil series on a toposequence as well as the spatial distribution of the toposequence itself has considerable influence on the land use pattern of an area, result in morphological changes and horizonation thus relating hydrology to topographic positions. Clay-sized particles play a dominant role in the storage of inorganic chemicals and supplying nutrients to plants. Quirk (1978) observed that a lot of interest shown in the study of soil structure is predicated upon its role in soil productivity and these studies relate the organization of primary particles into aggregate and their resistance to water. The stabilizing effect of clay particles even at very small quantities in association or combination with microbial polysaccharides has also been emphasized (Foster 1981). Soils having a clay texture at some depth within the profile are very common, even in similar physiographic positions (David and Mohammed 1995).

According to Bourma and Loveday (1988) clay soils develop in-situ by weathering of the parent rock, as well as from transported material. While mass-wasting processes are responsible for the deposition of colluvial clays, clays transported by water are deposited as alluvium in river valleys and as marine deposits in coastal plains (on which some of the most densely populated parts of the world are found). They reported that commonly distributed groups of clay minerals are the kaolinites, the montmorllonites and the illites.

Research reports of Dudal and Eswaran (1988) indicated that soil formation in vertisols is mainly conditioned by the parent materials; therefore, vertisols also occur under a wide range of climates and occupy over 320 million ha, or 2.4% of the global land area. The typical physiographic position of the vertisols is usually a rather flat plain, but they are also found in depressions, valleys and on slopes. However, vertisols are clayey soils with high shrinkswell potential that have wide, deep cracks when dry. Most of these soils have distinct wet and dry periods throughout the year. They occur where the climate features dry periods of several months. Ray *et al.* (1999) reported that the main soil-forming process affecting vertisols is the shrinking and swelling of clay as these soils go through periods of drying and wetting. They stressed that vertisols have a high content (>30%) of sticky swelling and shrinking - type clays to a depth of iron more.

Several studies have been conducted to evaluate the effect of topography on soil physical, chemical a well as the biological properties (Oluwatosin *et al.*, 2001; Ibia and Udo, 1993 and Hall, 1983) however, no detailed study on the clay distribution along a topographic positions have been done especially in the humid tropical ecosystem.

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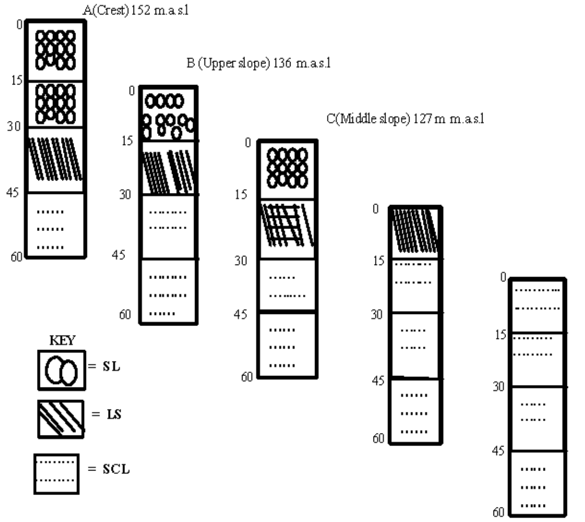
Therefore, the objective of this study is to examine clay distribution along a toposequence with depth as well as relate percent clay to aggregate size and aggregate stability of soils formed from coastal plain sand in southeastern Nigeria.

MATERIALS AND METHODS

Site description: The study site is located at Amaoba-Ime in Ikuano Local government area of Abia State,, Nigeria. Amaoba-Ime falls within latitude $05^{0}27^{1}$N and longitude 07^{0} 32^{1}E. The toposequence is 582m long, with elevation ranging from 152m above sea level to 109m above sea level which terminates at the streams. A schematic representation of the toposequence under study is shown in Fig. 3. The climate of the study area is characterized by heavy precipitate of over 2,000 mm per annum with high temperature and relative humidity. The mean annual temperature wind, sunshine and relative humidity o the area 22.3°C, 02, 5km/dday, 31 h and 69%, respectively. Five topounits (Fig. 1) characterized by fallow and cultivation were chosen for sample collection.

Sample collection: The toposequence was marked into five topographic levels A-E, as follows: crest, upper slope, middle slope, lower slope and the valley bottom. Soil sample were collected from 4 depths as follows: 0-15, 10-30, 30-45 and 45-60 cm depth. Auger samplers were used to collect the soil samples in triplicate from each depth making a total of twelve samples from each topounit and a grand total of sixty auger samples each from the toposeqence were collected and used for laboratory analysis.

Sample preparation for laboratory analysis: The auger samples collected from each of the 5 topographic levels were air dried sieved through a 2 m mesh and labeled before laboratory analysis.



Note: SL=SandyLoam, LS=Loamysand, SCL=Sandyclayloam

Fig. 1: Schematic representation of the toposequence under study showing the different topographic units and textural class with depth

Laboratory analysis: The clay percent were calculated after particle size analysis (Bouyoucuos, 1951) as follows: 51g of air-dried soil was weighed into a 500 mL dispersing cup. The cup was filled within 5cm of the top with distilled water and 20 mL of sodium hexameta-phosphate (calgon) was added and allowed to soak for about fifteen min. The content was stirred for 10 min. The suspension was poured into a special one-liter cylinder and made up to one liter mark with distilled water. The top of the cylinder was covered with hand and inverted several times. It was placed on the table and the time noted. After about 30 sec, the hydrometer was slowly and carefully placed into the suspension. At exactly fourty sec, the hydrometer reading was taken. The hydrometer was removed and the temperature of the suspension taken. After 2 h, the hydrometer reading and temperature reading of the suspension was taken. Correction for the hydrometer reading was made by subtracting 2 from every hydrometer reading to compensate for the added dispersing agent. The different particle size was calculated thus:

% Sand = $100.0 - (H_1 + 0.2\,(T_1 - T) - 2.0)\,2$
% Clay = $(H_2 + 0.2\,(T_2 - T) - 2.0)2$
% Silt = 100 (% sand + % clay).

Where

H_1 = First hydrometer reading.
H_2 = Second hydrometer reading.
T_1 = Temperature (°F) after 40 sec.
T_2 = Temperature (°F) after 2 hrs.
T = Calibration temperature (°F) of the hydrometer.

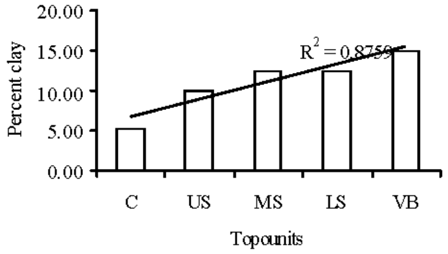
Soil aggregation: The procedure of Van Bavel (1953) was used with little adjustment. The 50 g of pre-sieved soil was placed on the topmost of 3 sieves of 2mm diameters, 1 and 0.6 mm and was pre-soaked in water for five min. The sieves were vertically oscillated 25 times at one oscillation per minute. At exactly two min, the various sieves were slowly and carefully removed from water. The soils from the various sieves were removed into weighing dishes. Oven dried at 105°C for 24 h and then weighed. Aggregate size distribution was monitored at micro aggregate (WSA < 0.6mm) and macro aggregate (WSA>Imm) levels and were expressed as a percentage weight of aggregate in the various size fraction over that of the original soil. The percentage aggregate stability of soil samples was calculated using the Mean Weight Diameter (MWD), expressed as:

Table 1: Percent clay distribution with depth along the toposequence

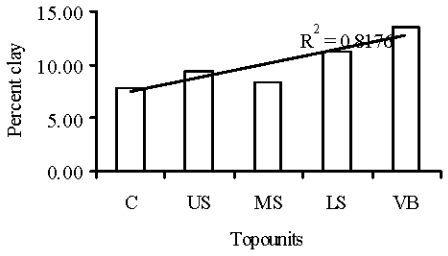
	Depth (cm)			
Topolevel	0-15	15-30	30-45	45-60
Crest	5.09	7.76	9.76	14.43
Upper Slope	10.07	9.40	12.07	11.40
Middle Slope	12.43	8.43	11.76	10.43
Lower Slope	12.48	11.15	12.08	24.48
Valley Bottom	14.81	13.48	18.15	22.81

SE Topolevel (T) = 0.786 SE Depth (D) = 0.703 SE (TXD) = 1.573

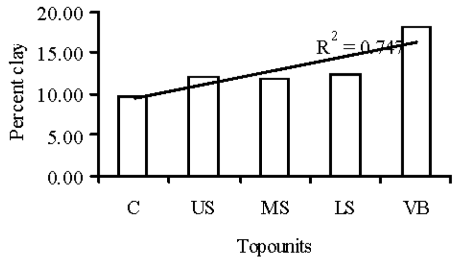
(a) 0-15cm depth



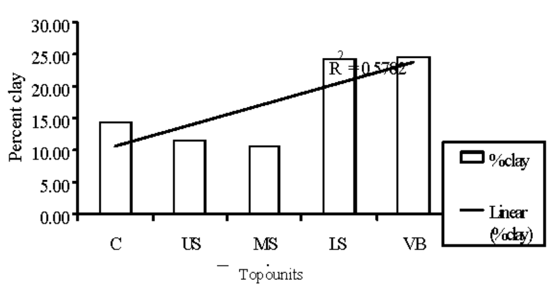
(b) 25-30cm depth



(c)30-45cm depth



(d) 45-60cm depth



Note: C=crest, US= Upper Slope, MS= Middle Slope, LS= Lower Slope, VS= Valley buttom

Fig. 2 a-d: Percent clay distribution with depth along the toposequence

$$MWD = \sum_{i=1}^{n=i} X1W1$$

Summation method suggested by Yonker and McGuiness (1956)

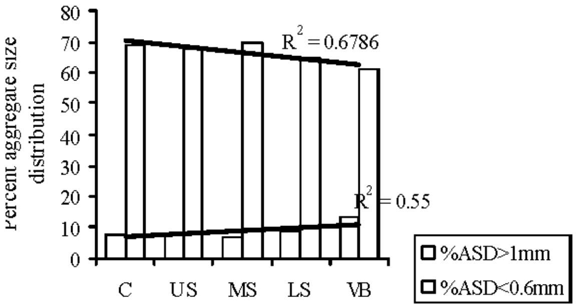
RESULTS AND DISCUSSION

In this study results show that the soil textural class varied along the toposequence and with depth, ranging from sandy loam, sandy-clay-loam and loamy sand textures (Fig. 1). There were also variations in clay, aggregation and aggregate stability with depth along the toposequence under study (Table 1 and 2). These variations were statistically significant at $p<0.001$. There were parallel increases in the magnitude of percent clay, aggregate size and aggregate stability of the soils studied with depth and along the toposequence. The lowest content in both clay percent and aggregation were observed at the crest while the valley bottom gave the highest content in clay, aggregate size distribution (>1mm and <0.6mm) and aggregate stability. The topo positions were able to determine or influence the distribution and contents of percent clay by 80% at 0-30cm depth but contributed only about 50% in determining the percent clay content and distribution deeper in the soil profile (Fig. 2 a-d). The reverse however was the case for MWD with the greater percentage of its distribution attributed to topo position at the lower depth of soil profile (Fig. 3a-d). The observed trend and degree of relationship between clay content, aggregate size and aggregate stability along the toposequence can be explained by the fact that the total clay content of a clay soil is a prominent feature of the soil and most of the other physical properties are affected by this factor especially in the topsoil where clay content is usually lower due to erosion and eluviations which causes a lateral or downward movement of the clay fraction, also David and Mohammed (1995) observed that total clay content is high and rather uniform throughout the profile with minor increases with depth. However, Ogban *et al.* (1991) reported that relationships exist in the studied parameter, as observed in this study; they reported that nutrient status and physical characteristics of soils are related to the topography of the soils area.

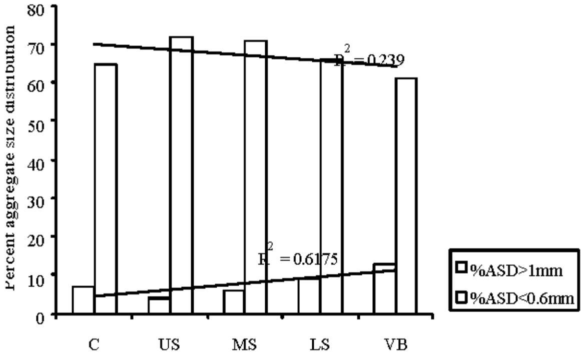
Table 2: Percent aggregate stability distribution with depth along the toposequence

Topolevel	Depth (cm)			
	0-15	15-30	30-45	45-60
Crest	1.341	0.645	1.097	1.281
Upper slope	1.353	2.235	1.264	1.339
Middle slope	1.262	1.243	1.318	1.257
Lower slope	1.376	1.424	1.511	1.418
Valley bottom	1.452	1.403	1.342	2.211

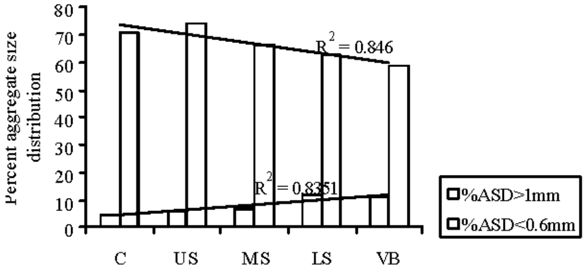
SE Topolevel (T) = 0.0248 SE Depth (D) = 0.0222 SE T X D = 0.0446



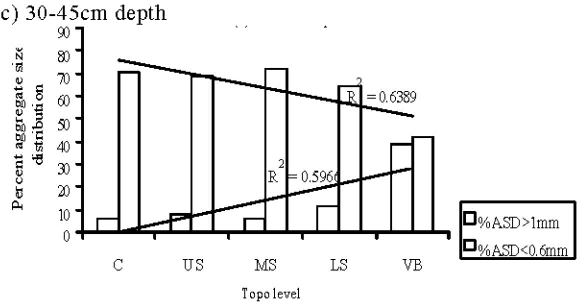
(a) 0-15 cm depth



(b) 15-30 cm depth



(c) 30-45cm depth



(d)45-60cm depth

Fig. 3: a-d: Percent macro and micro size distribution of aggregates with depth along the toposequence

Earlier repots of Probert *et al.* (1987) also indicated that physical properties such as soil structure vary with clay content. These relationships can be explained by the observation of Okusanmi *et al.* (1985) who reported that soil properties morphological, physical and chemical and potential for crop production often varies from the crest to the valley bottom due to differences in soil types. Therefore the soils along the toposequence studied differed as a result of erosion, transportation and deposition of chemical and particulate constituents in the soil. Agricultural and any other use of lands of such physiographic outlay should take care of the differences that may arise from the topographic positions of land to ensure maximum productivity in such lands.

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