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EFFECT OF PARTICLE SIZE DISTRIBUTION ON GULLY EROSION GROWTH IN A WATERSHED IN ENUGU STATE

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ABSTRACT

A trial was conducted to evaluate the effect of particle size distribution on gully erosion growth in Nsukka in 2004. The soil physical characteristics (Sand, Silt and Clay fractions) of the topsoils of segments A, B, and C of the gully were 49.6 to 93.6% (mean, 71.6%), 4 to 10% (mean, 6.7%) and 2.4 to 40.4% (mean, 21.7%) respectively. For the subsoil, ranges and mean values of Sand, Silt and Clay for segments A, B, and C were 51.6 to 95.6% (mean, 71.6%) 2.0 to 6.0% (mean, 3.3%) and 2.4 to 42.4% (mean, 25.1%) respectively. The ranges and mean values of gully width for segments A, B and C were 3.36 to 4.72m (mean, 3.86m), 2.96 to 5.73m (mean, 3.98m) and 2.25 to 4.03m (mean, 3.41m) respectively, while range and mean values for gully depth for segments A, B and C were 1.95 to 2.6m (mean, 2.36m) 2.21 to 2.34m (mean, 2.27m) and 1.85 to 2.08m (mean, 2.93m) respectively. Segment B with particles tending towards coarse fraction had the greatest gully width. Segments A and C with particles tending towards the fine fraction were deeper. This pattern is premised on the fact that detachability increases with increase in particle size and transportability increases with decrease in particle size.

KEYWORDS: Particle size distribution; Detachability; Transportability; Land Use; Degradation.

INTRODUCTION

Gully erosion is an advanced stage of rill erosion. The difference between gully and rill erosion is that gullies cannot be obliterated by tillage operations unlike rills. Ezechi (2000) observed that gully erosion is a serious form of land degradation that can produce badlands, endanger roads, habitation, agriculture and pollute streams. Descroix et al (2000) reported that soil characteristics were major contributory factors to gully erosion growth. According to Ofomata (1965), Nigeria had long been experiencing soil erosion problems due to both unstable lithological materials and ill advised land use practices.

Egboka (2000) contended that the present day soil and gully erosion meance ravaging Southeastern Nigeria should not be viewed superficially in terms of causative factors. He opined that the underlying physico-chemical characteristics of the soils and rocks, the joints, faults and ravines with potential movements along them as a result of imposed stresses in place and time tends to be of more importance and hence must be considered.

Soil particle size is the effective diameter of a particle and is usually less than 2mm in diameter. While particle size distribution is the amount of the various soil separates in a soil sample usually expressed as weight percentage (Obi, 2000). The separates are made up of sand (2.00 to 0.05mm), silt (0.05 to 0.002mm) and clay (<0.002mm). Parent material greatly influences the particle size distribution of soils (Esu, 1990).

The soil type or texture in turn influences erosion and those properties of the soil important in determining intensity of erosion. These are particle size distribution, structure, organic matters content, content of polyvalent metals and permeability (Descroix *et al* 2000). The particle size distribution of soils determines to a large extent the physical and chemical behaviour as well as the microbiological population of the soil and hence the biological and biochemical reactions taking place in the soil (Esu, 1990). Particle size distribution is therefore a major determinant of other soil factors that influence the extent of erosion. Sand for instance, because of its small specific surface contribute very little to the water and nutrient retention capacity of the soil. Also because of lack of cohesion in sand, it facilitates sand shearing. Therefore soils that are predominantly sand tend to be highly erosive because of ease of detachment and transportation of the particles. Silt have large specific surface than sand and therefore a faster weathering rate and release of soluble nutrients for plant growth than sand (Garland and Broderick, 1994). Silts also have a larger capacity for holding water by virture of large specific surface. Clay has greatly increased specific surface compared with silt and sand. Therefore, clay contributes a lot more to the physical reactivity of the soil than sand and silt combined (Obi, 2000). The significance of this study is predicated on the fact that the ability to change particle size distribution to suit desired land use is limited and therefore the need to adjust land use to soil physical conditions to prevent erosion. The objectives of this study were therefore (i) to analyse the particle size distribution of the soils (ii) determine the dominant soil particle size fraction and the texture of the soils so as to adjust land use to the soil physical condition to mitigate soil degradation by erosion. The use to which a particular land is put is referred to as the land use of that tract of land (Akamigbo, 1999). Agricultural land use in Nigeria are categorized as Forestry, arable crop production, fish ponds and tourism (FDALR, 1999). The land use types have different land and soil requirements and therefore, knowing the soil physical conditions, one can select appropriate land use types that match the soil properties.

MATERIALS AND METHODS

The gully site studied is located within the University of Nigeria – Nsukka Campus between latitude $6^{o}52'$ N and longitude $7^{o}24'$ E on a mean elevation of 400m. The rainfall distribution is bimodal (May to July and September to early November with a short dry spell in August). The average rainfall is about 1,600mm (Mbagwu and Salako, 1984). The gully length studied is about 1,378 long. Three segments, A, B and C, each 458m long, of the active gully were identified and demarcated for the study. Segment A was on the west of 0 – 2% slope, segment B was on a slope of about 4 – 8% whicle segment C was on a slope of about 2 – 4%. The deep, porous red soils are derived from sandy parent materials of coastal plain sands (Mbagwu and Salako, 1984). Three segments A,

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B, and C, each 458m long, of the active gully were identified and demarcated for the study. The depth and width of the gullies were measured by a tape at three sections as of each gully and recorded in a field notebook. Surface (0-15cm) and subsurface (15-30cm) samples were collected with a auger into well labeled sample bags.

Particle size distribution was determined by the hydrometer method of day (1965). Sand, Silt and Clay were determined with the aid of the Boyoucous hydrometer using sodium hexametaphosphate as dispersing agent. Sizes and amounts of particles settling were determined by employing the progressive time interval of 40sec, and 2 hours. The texture was determined by using the soil separates percentage and the textural triangle.

RESULTS AND DISCUSSIONS

The data on particle size distribution and texture are presented in Table 1.

TABLE 1:The soil particle size distribution of segments A, B, and C of a gully in Nsukka

Gully	Soil Depth	Sand	Silt	Clay	Textural
Segments	(cm)	%	%	%	Class
Segment/A1	0 – 15	71.6	6	22.4	Sandy clay loam
Segment/A2	15 – 30	67.6	2	30.4	Sandy clay loam
Segment/B1	0 – 15	93.6	4	2.4	Sand
Segment/B2	15 – 20	95.6	2	2.4	Sand
Segment/C1	0 – 15	49.6	10	40.4	Sandy clay
Segment/C2	15 – 30	51.6	6	42.4	Sandy clay
Top soil	Range	49.6 – 93.6	4 – 10	2.4 – 40.4	
Sub soil	Range	51.6 – 95.6	2 – 6	2.4 – 42.4	
Top soil	Mean	71.60	6.70	21.73	
Sub soil	Mean	71.60	3.30	25.10	

The table shows the ranges and mean values for sand, silt and clay for topsoils as 49.6 to 93.6% (mean, 71.6%), 4.0 to 10% (mean, 6.70%) and 2.4 to 40.4% (mean, 21.7%) respectively. For the subsoil, the ranges and mean values for sand, silt and clay were 51.6 to 95.6% (mean, 71.60%), 2.0 to 6.0% (mean, 3.30%) and 2.4 to 42.4% (mean, 25.10%) respectively. The dominant soil fraction for topsoils and subsoils was sand > clay > silt. Segment B had the highest sand fraction with the texture being predominantly sand, followed by segment A with a texture of sandy clay loam and segment C with a texture of sandy clay.

Thus the particle size ranges were tending towards the finer range from segment B to segment A and segment C as seen in their textures of sand, sandy clay loam and sandy clay respectively.

The values for depth and width are shown in Table 2.

TABLE 2: **Ranges and mean depth and width of segment a, b, and c of a gully in Nsukka**

Gully Segment	Depth (m)	Width (m)	Textural
Segment A1	2.53	3.36	SCL
Segment A2	2.60	4.72	SCL
Segment A3	1.95	3.49	SCL
Segment B1	2.34	5.37	Sand
Segment B2	2.25	3.62	Sand
Segment B3	2.21	2.96	Sand
Segment C1	2.08	4.03	SC
Segment C2	1.93	2.25	SC
Segment C3	1.85	3.94	SC
Segment A Range Mean	1.95 – 2.60 2.36	3.36 – 4.72 3.86	
Segment B Range Mean	2.21 – 2.34 2.27	2.96 – 5.73 3.98	
Segment C Range Mean	1.85 – 2.08 2.93	2.25 – 4.03 3.41	

The range and mean values of the gully depth for segment A, B and C were 1.95 to 2.60m (mean, 2.36m), 2.21 to 2.34m (mean, 2.27m) and 1.85 too 2.08m (mean, 2.93m) respectively. Segment C had the deepest mean depth, followed by segment A and segment B. The implication of depth is that the deeper the gullies, the greater the risk of collapse of the gully banks. The collapse of gully banks will again depend on the shear strength and particle size distribution of the soils. Transportability of particles increases with decrease in particle size. From the result in Table 1, the proportion of the finer particles (clay) were greatest for segment C followed by segment B in that order. The depth of the gullies equally decreased in that order as particles were tending towards the larger particles (sand) and thereby decreasing transportability. It is the transportation or removal of the finer particles that cause increase in gully depth. The range and mean values of gully width for segments A, B and C were 3.36 to 4.72m (mean, 3.86m), 2.96 to 5.73m (mean, 3.98m) and 2.25 to 4.03m (mean, 3.41m) respectively. Segment B with the greatest amount of sand fraction had the widest gully followed by segment A and segment C in order of decreasing sand fraction. Segment B had the widest mean value of gully width because sand due to lack of cohesion and large particles size facilitates sand shearing and detachment which increases with increase in particles size. The shear strength of soil is related to stability of slopes and foundations and soil behaviour (Obi, 2000). Because of lack of cohesion and little shear strength in segment B, the sides of the gully collapse easily increasing gully width more than the other segments. For segments A and C where the particles tend towards the finer range, in increasing order, shearing and detachability decrease correspondingly and hence the reduction in gully width in proportion to amounts of sand, silt and clay.

SUMMARYAND CONCLUSION

Soil particle sizes increase in equivalent diameter when they tend towards the coarser (sand) particles (2.0 to 0.05mm) and decreased when they tend towards the finer (clay) particles (<0.002mm).

Role of Parent Material. The properties of soils depend on the nature of the parent materials especially the minerals. Texture of the mineral soil determines to a large extent the physical and chemical behaviour as well as the biological potential of the soils. Because the parent materials of the soils are coastal plain sands, the dominant particle size is sand which lacks cohesion and facilitates shearing and detachability and consequently erosion (Russel, 1973).

The process of erosion involves soil detachment and transportation. Soil detachability and transportability are the corresponding soil characteristics that determine the ease with which soil can be detached and transported. Soil detachability increases with increase in particle size and transportability increases with decrease in particle size. Therefore segment B with predominantly sand or larger particles lacks cohesion, facilitating sand shearing and detachment resulting in collapse of gully sides. Gully sides collapse because of little shear strength of the sandy soils (Obi, 2000) leading to the greatest gully width than segments A and C. On the other hand, segment A and C with particles tending towards the finer (clay) are prone to transportation hence their greater depth, with C having the deepest gully in consonance with its higher finer particles. Although particle size distribution is a major contributory factor to gully growth in the site, its effects can be mitigated by adjusting land use to the physical conditions of the soil.

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