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Implications of the Particle Size Characteristics of Nanka Sands Geological Formation on the Agulu/Nanka Gully Erosion Menace

***Onuoha, D. C.; Ogbo, O. G. & Aso, C. J.**
*Environmental Management Department, Nnamdi Azikiwe University,
P.M.B. 5025 Awka, Nigeria.

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ABSTRACT: *Gully erosion is one of the major environmental menace defacing the physical environment of the southeastern Nigeria. The geology and soil characteristics of the area has been reported to be amongst the causes of gullying. This study therefore considered some of the physical properties of the Agulu/Nanka gully erosion sites and their implication to gully erosion in the area. Two samples were collected from Agulu and Nanka as sample 1 and 2 respectively. The particle size distribution analyses and plots shows that there is 0% gravel, 98.00% sand particles and 1.94% of silt in sample 1; while we have 0% gravel; 98.50% of sand particles and 1.50% of fine particles in the sample 2. For sample 1, the coefficient of uniformity is 5.6 thus well graded and poorly sorted. While the coefficient of curvature is 0.457 showing that it is moderately graded and sorted. Sample 2 has the coefficient of uniformity as 8 thus well graded and poorly sorted; with the coefficient of curvature as 0.6 showing a moderately graded and sorted sample. From the plots, both samples are predominantly sandy soil with low silt content. The study recommends improved farming techniques, cultural method of soil erosion control and enactment of laws against any activities which will promote erosion growth. Also bioremediation through continuous planting of trees and advanced methods of chemical remediation like grouting would be recommended to stabilize the area against the massive landsliding and continued gully expansion witnessed presently.*

KEYWORDS: particle size analysis; gully erosion; geologic formation; grading and sorting.

INTRODUCTION

Soil erosion is the denudation or wearing away of the upper layer of soil. It is a form of soil degradation. Agulu-Nanka formation is composed of sandstones, of which the formation found in this area is called the Nanka Sandstone/Nanka Sands. Agulu-Nanka area gully erosion covers an area of about 1100 km. The gullying started around 1850 and the rate of gully growth is estimated at 20-50 m year. The British Colonial Office and the local inhabitants attempted to control the gullying by constructing small dams and planting trees, but the measures failed. The area lies in the humid tropical rainforest belt of Nigeria. The landscape is a cuesta within the Awka-Orlu uplands formed by the Nanka formation (early Eocene) and the Imo Shale formation (Palaeocene). Both the geological, hydrogeological, geotechnical and hydrogeochemical characteristics of the area and human activity have contributed to gully development and growth. Major aquifers and aquitards form multiaquifer systems and heavy rainfall causes a rise in the water table. The increase in hydraulic head produces rapid flow rates that enhance the gullying process. Expansion and contraction of the clays and shales in the rainy and dry seasons respectively lead to slumping and landslides.

The formation of Nanka and Agulu erosion site is formed from Ameki formation.The Ameki Formation is a Lutetian to Bartonian geological formation located in Nigeria. It belongs to the Bende-Ameki Group. The Nigerian Eocene sediments are well dated marine deposits and unfossiliferous beds of terrestrial origin, referred by inference based on stratigraphic position, to the Eocene (Reyment, 1965). These Eocene rocks that outcropped in South-eastern Nigeria have been classified under the Ameki Group and comprises of Ameki Formation; whose maximum thickness ranges from 1,200 to 1,500m.

The Ameki Formation exhibits deeper marine formations that progress seaward due to the abundance of shale in the stratigraphy. The size class is macrofossils and the preservation is originally phosphate.

The Agulu-Nanka gully is the most prominent erosional feature in East-Central Nigeria. It probably originated from horizontal compression beneath the crust aided by the presence of a large volume of unconsolidated formation. The control of the gully erosion has been a source of nightmare to successive agencies concerned over the years. Their Sands formation consist of successions ranging from unconsolidated to poorly consolidated sands (310m thick), thin intercalation of claystone and siltstone bands, lenses and flaser beds, cross-bedded, poorly sorted and medium to coarse-grained.

These units are interbedded by shale-siltstone and fine sand layers (25cm thick) in a few of the gully sites.

The Agulu-Nanka area gully erosion covers an area of about 1100 km. The gullying started around 1850 and the rate of gully growth is estimated at 20-50 m year. The area lies in the humid tropical rainforest belt of Nigeria.

The study areas where the two main sedimentary formations Nanka and Agulu cropped out have continued to witness incipient gullies in recent times. The genesis and continued expansion of gully erosion in the area is mainly linked to the geology, topography, human activities that are poorly planned, and geotechnical properties of the soils. The soil surface is also accessible to rainfall and run-off due to scanty vegetation/plant cover in the areas of study. The geotechnical properties of these areas determine their susceptibility to gully erosion (gorges) which are advancing into canyon proportions. Detailed mapping, plastic limits, low liquid limit, low plasticity, the high proportion of sands, high permeability, the shear strength, and the very loose compactness of soils from the Nanka Formation and Agulu Formation shows that the geological conditions and geotechnical composition of the soils were responsible for the initiation and propagation of the gully erosion in the study areas.

Time Formed, Deposited and Geologic Sequence.

The Nanka and Agulu sand was formed at the Epoch time of Eocene Age. Underlain it, is the thick Imo Formation of Paleocene age and overlain by the Oligocene of Ogwashi-Asaba Formation. Towards the northwest part of the study area, the Nanka and Agulu sand is overlain by the Nsugbe Formation of Oligocene age and underlain by the Ameki Formation of the Eocene age towards the southeastern part.

Environment of Deposition

The geometry of the Nanka Sand belongs to the sheet sand bodies type with great horizontal extent in relation to its thickness. This is possible because of lateral sedimentation of the formation which means that their boundaries transect laterally at a low angle and time plane. Sheet sands are typical of quartz arenites as in the Nanka Sand which occurs as a series of coalesced bodies of linear deposits. The Nanka Sand is compositionally matured with very close heavy mineral suite which have been interpreted as abrasion due to prolonged tidal circulation.

General Description of Sandstone

Sandstone is a clastic sedimentary rock composed mainly of sand-sized silicate grains. Sandstones comprise about 20–25% of all sedimentary rocks. Most sandstone is composed of quartz or feldspar because they are the most resistant minerals to weathering processes at the Earth's surface. Sandstone is a very common mineral and can be found all over the world. There are large deposits found in the United States, South Africa (where eight different varieties of the stone can be found), and Germany holds the most locations of sandstone deposits in the world. Sandstone has natural variations in colour, tone, shade and grain. Some stones have oxidising properties and others have unchanging banding. it has a very high quartz content, it might be crushed and used as a source of silica for glass manufacturing.

Formation of Sandstone

The first stage involves layers of sand amassing due to the process of sedimentation, when particles settle in the fluid they sit in and rest against a barricade; this can either be from water or air. The stone then becomes cemented by the pressure of the suspended stone being precipitated between grains. The stone is formed from the sand of older, fragmented rocks. This then forms the stone that is typically said to contain sand ranging in size from 1/16th of a millimetre to 2 millimetres.

Sand is the most common element found in sandstone (hence the name), other materials found in it such as cement and matrix. Cement located within the stone is usually comprised of quartz, calcium carbonate or iron oxide. When it holds too much cement material, it is thought of as poorly formed stone.

Physical Characteristics

Location

Agulu and Nanka are towns in Anambra State, Nigeria. Agulu and Nanka lie between latitude 6^03'N-6^07'N and longitude 7°04'E-7^05'E. The area of Agulu and Nanka are bounded on the north by Nise and mbaukwu, on the south by Ekwulobia, on the East by Oko,Amaokpala and Ogbu(Awgbu) and on the west by Akwaeze, Neni and Adazi. A major tarred road running from Awka-Amawbia to Ekwulobia with other minor untarred roads and footpaths which help to connect the gully complex.

Topography

The dominant topographic feature in the study area is the North - South Awka-Orlu escarpment, which runs from Awka in Anambra State through Ekwulobia to Orlu in Imo State. Agulu and Nanka lies in the minor escarpment of the uplands revealing steep slope through these places. Terrain observation reveals a ravine complex with hanging hills, slopes and valleys as plains of weakness that trigger off gully erosion in the East.

Climate

Climate in the study area is characterized by two main seasons namely the rainy (wet) and Dry seasons respectively. The rainy season which lasts between the month of April and October is characterized by thunderstorms. The dry season (harvest season) extends from November to March annually. This is typically an equatorial tropical rainforest climate type. Rainy (wet) season is characterized by relatively high temperature (33°c) and high relative humidity. Chilly and dry harmattan wind is experienced in dry season. This lowers environmental temperature appreciably, especially in the month of December and January. It's main features are excessive evaporation,low relative humidity, low rainfall and general dryness. The effect is the drying of vegetal covers and shedding of leaves by deciduous trees. It also ushers in harvest of farm produce. Some of which are sun dried. The study area records average maximum and minimum temperature of about 32°C and 25°C respectively and annual mean rainfall of about 2000mm.

Vegetation

The study area falls within the rain forest belt and characterized by growth of tall trees amidst thick undergrowth. Climbers and epiphyte forming complex tangles are common and trees have luxuriant foliage. Oil palm trees are common while swampy areas have thick cover of raffia palm. Lowlands are thickly vegetated with forest trees, while the highlands consist mainly of grasses with trees and shrubs sparsely distributed typical of derived Guinea Savannah. In some areas, only isolated stands of few forest emergent trees remain as evidence of the original forest. This is due to high rate of human activities in form of deforestation as lands are cleared for purpose of farming and construction.

Drainage

The drainage is mainly dendritic pattern. Agulu lake occupies the southwest facing part of the minor escarpment while Atama lake in Nanka occupies the south-eastern part. The pattern formed by streams in the area is as a result of the bedrock lithology. All streams flows Northeast with 4th order Odo (Awdo) and ota-Alu rivers as the major drainages.

Geology of the Study Area

The geology of the area exposes two main lithologic formations. They are Imo Shale (Paleocene-Eocene) and Nanka. Sandstone (Eocene) a lateral equivalent of Ameki Formation. Imo Shale the older of the two geological formations cover about twenty five (25) percent of the study area. Light grey coloured Imo Shale is characteristically fissile and fine grained. Three sandstone units of about 25-40 meters thick separated by 2-3 meters thick Clay/Shale beds were observed in Enugwu-Nanka erosion site. The Sandstone Units consists of poorly sorted unconsolidated sand of variegated colour; yellow to brown to iron stained on weathered surface and white to milky white on fresh surface. The Clay/Shale beds are dark grey to grey with specks of mica and pyrite. Sandstone consists of quartz arenites with predominantly monocrystalline quartz. This is evidence of long transportation and mineralogical and textural maturity.

Description of Gully Complex

Lateritic soil overburden measuring up to 18 meters in Enugwu-Nanka erosion site has been dissected, exposing beds of unconsolidated sands. Most of the gully sections consist of this upper fairly homogenous and cohesive reddish brown soil unit and a lower cohesion less unit having this Shale/Mudstone interbeds. The walls of gullies stand like cliffs reaching 110 meters. Depth and 350 meters width in places. Outcropping interbedded layers of shale (2-3m thick) form resistant ledges creating abrupt changes in slopes hence showing a bench likes structure

Chemical Characteristics

The study area has high infiltration capacity with lower amount of organic matter. Expansion and contraction of the clays in the shale intercalations during the rainy and dry seasons respectively lead to slumping and landslides. Slightly acidic waters produced by redox reactions decompose cementing materials, thereby disaggregating the sand grains and facilitating gullying.

2.0 Literature Review

According to Obi and Okekeogbu (2017), in their study on erosion problems and their impacts in Anambra state of Nigeria:(a case of nanka community), identify the erosion sites in the study area, to analyze its soil nature and to assess the overall effects. To achieve the stated objective, both primary and secondary data were adopted using both statistical and descriptive techniques. The study identified serious erosion problems some of which are the following: Existence of prominent gully erosion in the study area. Considerable loss of soil structure leading to loss of agricultural productivity and disruption of socio-economic activities in the area. The Vertical Electrical Sounding (VES) was performed at different locations in the study area. This was used to determine apparent resistivity tests and the resultant data which was used to obtain different geoelectric units of the area (Okoro, et al, 2010). The geoelectric results were compared with lithologic data obtained from drilled sites and these were combined to identify subsurface lithology. Lithologically, the result from tests indicates that Nanka soil consists mainly of sandy soil, sharp-siltstone and finely laminated shale. Sand submits comprised un-cemented medium to coarse grained and pebbly quartz sand, with thickness ranging from 50-90m (Nwajide and Hoque, 1979).

Onwuka, S. U. And Onuoha, D. C. (2020), in their study on the evaluation of the pre-grouting and post-grouting erodibilities of Nanka sand geologic unit causing gully in Anambra state, evaluated grouting using some selected Chemicals to ascertain if erodibility of the soil is being affected (lowered) by grouting and to what extent. The study adopted the laboratory research method in analyzing the samples collected from the selected gully erosion sites to determine their various erodibilities using an artificial rainfall simulator. To achieve this, the following steps were taken: to determine the erodibilities of the formation samples collected, to determine the relationship between pre-grouting and post-grouting erodibilities of the samples of the formation collected and to infer whether or not grouting reduces erodibility. The study postulated and tested the hypothesis: there is no significant difference between the pre-grouting and the post grouting erodibilities of the samples collected. It was found that there is reduced erodibility with the application of each grouting chemical. The erodibility before grouting was higher than the erodibility after grouting and the test of hypothesis showed that there is significant difference between the pre-grouting and post grouting erodibilities of samples collected.

Ajaero and Mozie (2011) in their study of assessment of gully erosion menace in Agulu-Nanka area reported that Agulu-Nanka gully erosion area represents a wide area being eaten away gradually and continuously by landslide cum gully advancement processes covering the entire Aghori basin, which covers many communities in the region. Their work has also shown that, landslide resulted from floods and gully erosion in Nigeria cause death, loss of properties, and population displacement when they occur in densely populated area.

Adekalu et al. (2007) and Okpala (1990) in their study, says the formation of gullies has become one of the greatest environmental disasters facing many towns and villages in Southeastern Nigeria. They further emphasized that the region is fast becoming hazardous for human habitation and that hundreds of people are directly affected every year and have to be relocated. Increased migration of inhabitants as well as degradation of agricultural fertile land.

Ocheli, Ogbe and Aigbadon (2021), in their study on the Geology and geotechnical investigations of part of the Anambra Basin, Southeastern Nigeria: implication for gully erosion hazards. The Geologic and geotechnical conditions of soils where Nanka and Ajali Formations outcropped in Anambra Basin, Southeastern Nigeria were investigated and accessed. This was done using detailed mapping and mechanical soil laboratory tests to unravel the genesis and continued expansion of gully erosion in the study areas. The result carried out in the Field study revealed that gully erosions are more pronounced in the study area with poor vegetation cover and a high degree of slope steepness. Grain size analysis revealed that the soils of the Nanka Formation have an average sand content value of 90.90% (sandy) and silt content value of 3.0% (low fine portions). The plasticity index of the fine portions indicates that the soils are weak plastic, with a mean value of 5.29%. The soils have an average cohesion value of 0.30

kg/cm^2 indicating a very weak cohesion. The soils are highly permeable; with an average value of 2.67×10^{-3} cm/s. The compaction test further revealed that the soils are loosely compacted. The soils for the Ajali Formation have an average sand content value of 95.10% (sandy) and silt content value of 1.43% (low fine portions). The plasticity index of the fine portions indicates that the soils are weak plastic, with a mean value of 2.70%. The soils have an average cohesion value of 0.30 kg/cm^2 indicating a very weak cohesion. The soils are highly permeable; with an average value of 2.70×10^{-3} cm/s. The compaction test revealed that the soils are loosely compacted. After field surveys and laboratory analyses, it was found that the gully erosions have been developing respectively on steep slopes and non-vegetated areas, and their genesis facilitated by the cohesionless and very permeable nature of the sandy formations. The potential implications of these gully erosion include damaging of buildings, residential houses, bridges, and roads, loss of farmland and vegetation, isolation of village.

Procedure for the Laboratory Analysis

Step1: The cleaning of the separation plate and setting it according to their sieve size.

Step 2: Scaling of the sand size (in grams). We used 500grams of the sand.

Step 3: After scaling of the sand, you pour it into the separation plate for sieving. We used an electronic sieving method and the machine is called Mechanical Sieve Shaker. During the sieving, you leave it for up to 5-10 minutes. For the two samples, we used 5 minutes each.

Step 4: After sieving the sand, you scale the sand again to get the mass retained.

Step 5: Calculation of the mass retained. Here all you do is to sum up the mass retained you got when scaling the sand, the second time.

Step 6: You calculate for the Percentage of mass retained by dividing the mass retained by 500 and multiply with 100.

Step 7: You calculate for the cumulative percentage retained by adding up the first number of the percentage mass retained to the second one, continue with the same for the other to the last number. It is said that in calculating for the cumulative percentage retained the last number should be 100.

Step 8: You calculate for the percentage cumulative finer, to get this you have to subtract the first number of the percentage mass retained from 100, what you get will then be first number for the percentage cumulative finer, then to get the others you have to subtract the first number that you got from the second percentage mass retained then apply it to the rest to get your answers. It is said that the last answer or number to get when calculating for percentage cumulative finer should be 0.

Step 9: After calculating for the table, you now see what you get to draw you graph.

PARTICLE SIZE DISTRIBUTION

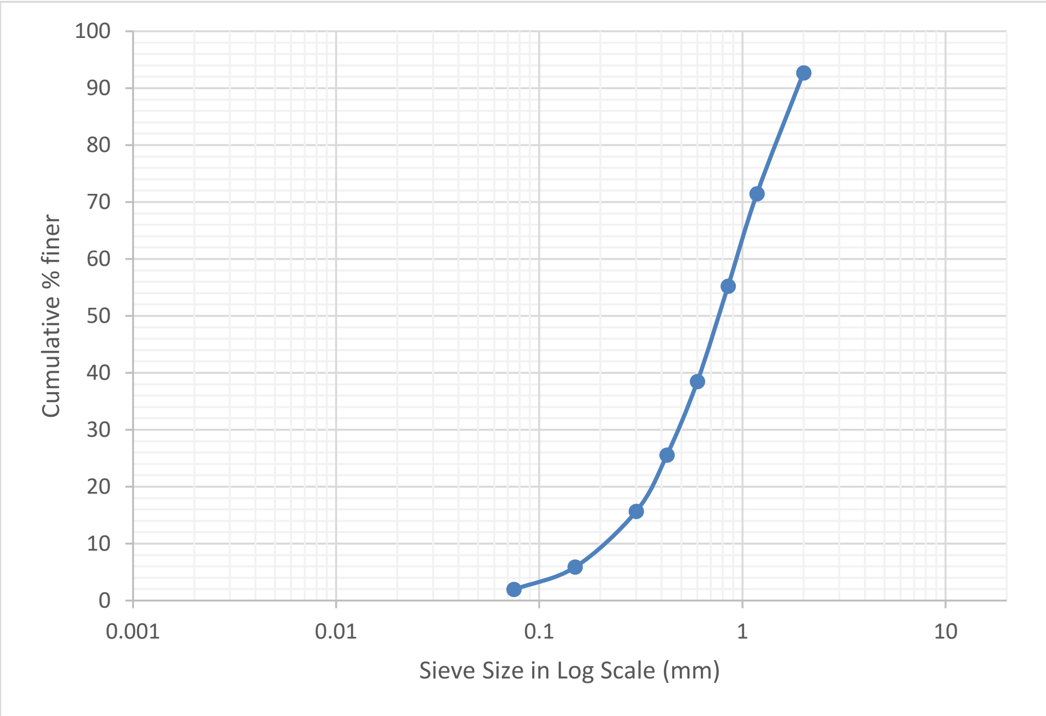
FOR SAMPLE 1 (AGULU SAND)

Sieve size (mm)	Mass retained (g)	% mass retained	Cumulative retained	Cumulative %finer
2	36.2	7.28	7.28	92.72
1.18	105.8	21.27	28.55	71.45
0.85	80.9	16.27	44.82	55.18
0.6	83.5	1.79	1.61	38.39
0.425	4.3	12.93	74.54	25.46
0.3	49.1	9.87	84.41	15.49
0.15	48.7	9.72	94.13	5.87
0.075	19.4	3.90	98.03	1.97
Tray	9.4	1.89	99.92	0.08
Total	497.3			

X	Y
2	92.72
1.18	71.45
0.85	55.18
0.6	38.39
0.425	25.46
0.3	15.49
0.15	5.87
0.075	1.97
Tray	0.08

The x variables are the sieve size figures and the y variables are the cumulative % finer.

It was from this x and y variables that the graph was plotted.



By grading,

Gravel	0.00%
Sand	98.0%
Fine(silt and clay)	1.94%

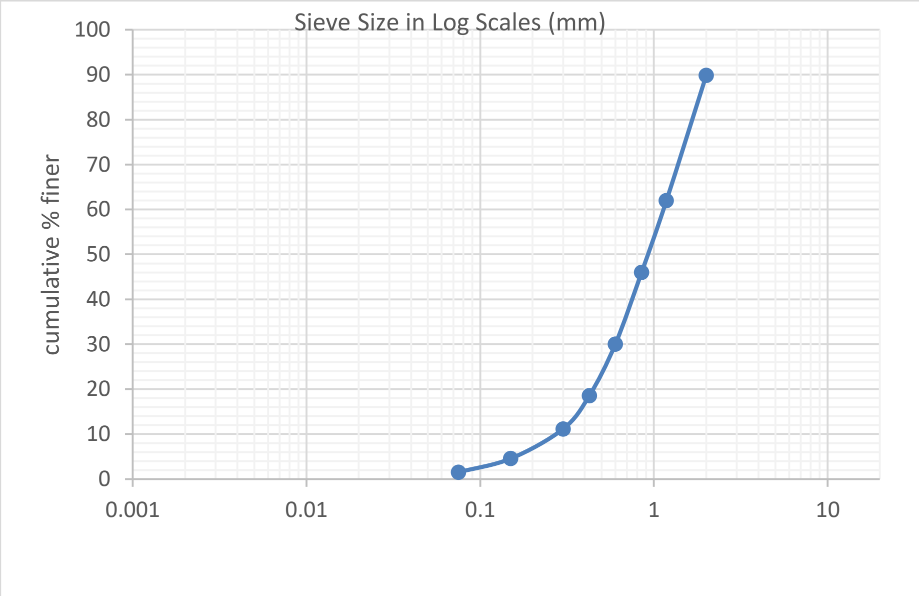
The gravel sand and silt classification show that there is no gravel in the sample @0.00%, and 98.00% of sand particles and 1.94% of fine particles.

For Sample 2: Nanka Sand

Sieve size (mm)	Mass retained (g)	% mass retained	Cummulative retained	Cumulative %finer
2	50.5	10.17	10.17	89.83
1.18	139.1	28.02	38.19	61.81
0.85	79.2	15.95	54.14	45.8
0.6	79.6	1.04	70.18	29.82
0.425	57.0	11.48	81.66	18.34
0.3	36.6	7.37	89.03	10.97
0.15	32.5	.55	95.58	4.42
0.075	14.8	2.98	98.56	1.44
Tray	7.1	1.43	99.99	0.01
Total	496.4			

X	Y
2	89.83
1.18	61.81
0.85	45.8
0.6	29.82
0.425	18.34
0.3	10.97
0.15	4.42
0.075	1.44
Tray	0.01

The x variables are the sieve size figures and the y variables are the cumulative % finer. It was from this x and y variables that the graph was plotted.



Gravel	0.00%
Sand	98.50%
Fine (siltt and clay)	1.50%

The gravel sand and silt classification show that there is no gravel in the sample @0.00%, and 98.50% of sand particles and 1.50% of fine particles.

Using Engineering Geology

We used engineering geology to classify the soil samples. The shape of the grain size distribution curve can indicate the type of soil. Thus, uniformly or poor graded soil will be represented by nearly vertical lines, and a well graded soil by a line of a uniform slope passing through all sizes.

Coefficient of Uniformity and Coefficient of Curvature

In order to describe the shape of the grain size distribution curve with a single number, two coefficients are generally used.

$$C_u = \text{coefficient of uniformity} = \frac{D_{60}}{D_{10}}$$

C_{cr}= coefficient of curvature = $\frac{D_{30}^2}{D_{60}.\,D_{10}}$

A uniformly or poorly graded soil will have its coefficient of uniformity (C_u) of less than 2.0 (nearly 1.0) and a well graded soil will have its coefficient of curvature (C_{cr}) more than 1.0, but less than 3.0. Moreso over, C_u is greater than 4 for gravels and 6 for sands (USBR 1960).

For sample 1 (AGULU SANDS)

C_u $= D_{60}/ D_{10} = 5.6$

C_{cr} $= D_{30}^2 / D_{60}.\, D_{10} = 0.457$

This result shows that the sand in sample 1 based on the coefficient of uniformity, @ 5.6 is well graded and poorly sorted. While the coefficient of curvature @0.457 shows that it is moderately graded and sorted.

For sample 2

C_u $= D_{60}/ D_{10} = 8$

C_{cr} $= D_{30}^2 / D_{60}.\, D_{10} = 0.6$

This result shows that the sand in sample 2 based on the coefficient of uniformity, @8 is well graded and poorly sorted. While the coefficient of curvature @0.6 shows that it is moderately graded and sorted.

Both samples indicates that the sands in this area are predominantly sandy soil with low fine sand content.

CONCLUSION AND RECOMMENDATION

South – east geopolitical zone of Nigeria suffers from the havocs of soil erosion, which are caused by both natural and anthropogenic sources and also the natural geology and terrain of the area. Soil erosion reduces soil quality and diminishes the productivity of natural, agricultural and the forest ecosystem. Most of our activities affects the soil adversely.

There is need to adopt measures required to sustain the soil from the menace of soil erosion. If there is commitment to attain population stabilization and resources conservation, the world would be better to meet the challenges of sustainable development.

Adopting sustainable development requires adopting improved farming techniques, cultural method of soil erosion control and enactment of laws against any activities which will promote erosion growth. The governmental and non-governmental environmental agencies should also sensitized Nigerians on the causes, impacts and problems of soil erosion. Seminars and conferences should be organized locally and internationally to showcase the importance of sustaining our soil against soil erosion so as to avoid its continuous challenges and threat.

The study recommend Bioremediation and continuous planting of trees as this will reduce soil erosion. Finally considering the high level of porosity, permeability, friability and loose nature of the formation underlying the study area which is key to its high erodibility, advanced methods of chemical remediation like grouting is also recommended to stabilize the area against the massive landsliding and continued gully expansion witnessed presently.

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