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PARTICLE SIZE AND QUICK UNDRAINED TRIAXIAL ANALYSIS OF SOIL SAMPLES FROM MAJOR GULLIES SITES IN EDO STATE

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ABSTRACT: *The issue of gully erosion is of major concern in Nigeria. The study was carried out in Edo state, Southern Nigeria. Edo State was chosen as the study area due to the fact that the magnitude of gully erosion has resulted in loss of lives and properties, destruction of arable lands and wastage of large areas of usable land. In the study* particle test and *quick undrained triaxial* analysis of soil sample *from the major gullies sites were determined. The analysis of soil samples collected from Edo South are more sand, this also explain why the areas are susceptible to gully erosion*. This can also be attributed to the high volume of soil that is wash away in the area. *The compressive strength of these soil samples collected from the area are in the ranges of 163Kn/m at Ambrose Ali University in Edo Central to 232 Kn/m at Igueben also Edo Central. The bulk density in the area ranges from 1.70Mg/m^3 at Ambrose Ali University Ekpoma in Edo Central to 2.66Mg/m^3 at Oka in Edo South and the moisture content ranges from 26.7% at Oka in Edo South to 32.0% at Ambrose Ali University Ekpoma in Edo Central*

KEY WORDS: Gully, Erosion, Particle, Undrained, Triaxial

INTRODUCTION

Soil is one of the most vital earth's natural resources. It sustains both plant and animal for their growth and development and as such threats to the soil poses danger to both human and animal life. Gully erosion is one of the most fatal threats and hazard to the environment. It constitutes a clear form of soil degradation and destruction. It occurs where surface water flow has become trapped in a small concentrated stream, and begins to erode channels in the ground surface, making it wider and deeper.

The Food and Agriculture Organization (FAO) of United Nations in [8] estimated that the global loss of productive land through erosion is 5-7 million hectares per year. According to the United Nations Environment Programme UNEP, [15] 24 billion tones of fertile soil and 15 billion trees are being lost annually to land degradation. Soil erosion either by water or wind affects agriculture and natural environment, this prompted a worldwide concern. Soil loss and its associated impacts is one of the most important but probably the least recognized environmental problems, especially

in developing countries. According to [11] accelerated soil erosion is a serious problem and will remain so during the 21st century especially in the tropics and subtropics.

Although soil erosion is most devastating in south eastern states of Nigeria, however there are significant evidences that the problem is one of the main ecological problems in Edo State. Several studies including Ehiorobo and Osadolor [5], Eseigbe and Ojeifo [6], Aderemi and Iyamu [2], Okonofua and Uwadia, [12], Afegbua, Uwazuruonye and Jafaru [3] and Eseigbe and Gbakeji [7], have been conducted on the magnitude of soil erosion in the study area. The major targets of these scholars were to examine the main causes and types of soil erosion, assess the risk of accelerated soil erosion and identified the management techniques that will help to ameliorate them. Their specific objectives were to determine the moisture content of soils in the exposed gully, determine the degree of firmness or physical state of the soils and particle size analysis of the soils samples collected from some of the gullies. These researchers concluded that there are evidences of accelerated gully erosion and all past attempts at solving the problem have proved ineffective and thus constituting risk to the people living around the gullies in the area.

Most of these studies have been centered on the causes and the devastation resulting from soil erosion. The dimensions of the gullies were not stated, the particle test and quick undrained triaxial analysis of soil sample from the major gullies sites were not done and such information constitutes the problem of the research. This study will fill the research gap by providing these necessary information about the gully erosion in the area to the concerned bodies and institutions.

Study Area Description

Edo State is located in the South-South Zone of Nigeria. Its capital town is Benin-city. The State *geographical* coordinates are Latitudes 05° $44^{\prime}$ to 07° $34^{\prime}$ $00^{\prime\prime}$ N and longitude 05° $04^{\prime}00^{\prime\prime}$ and 06° $45^{\prime}$ $00^{\prime\prime}$ E. It has a land mass of 19,794km square and it is bordered by Kogi State to the north, Delta State to the East and South and Ondo State to the West.

The geology of the study area reveals that the entire area is underlain by sedimentary rocks. It consists of the crystalline basement rocks in the hilly and dissected zone in the north followed southwards by residual lateritic soils of the well drained dry lands at Auchi, Agbede and Afuze. [2] observed the area is underlain by sedentary rock of the Pleistocene age often referred to as the Benin formations. The sedimentary rock contains about 90 percent of sandstone and shale intercalation. It consists of over 90% sandstone, clay, shale and lignite coarse fine grained in some areas. The nature of the underlying geology contributes significantly to the origin and spread of gullies Afegbua, Uwazuruonye and Jafaru [3]. The relief of the area is mainly characterized by swamping creeks and dissected plateau such as the Esan Plateau, Orle valley and the dissected uplands of Akoko-Edo Local Government Area.

According to Aderemi and Iyamu [2], there are six types of physical features which constitute the landscape of the area. Sandy coastal plain and alluvium clay are found in the Benin lowlands area with some hills in the east. Slopes are tilled in the southwest direction. River Osse, River Orihionmwon and lkpoba are the major drain in the area. With the exception of River Osse that has a wide flood plain, [6], observed that other rivers in the area are characterised by steeply incised

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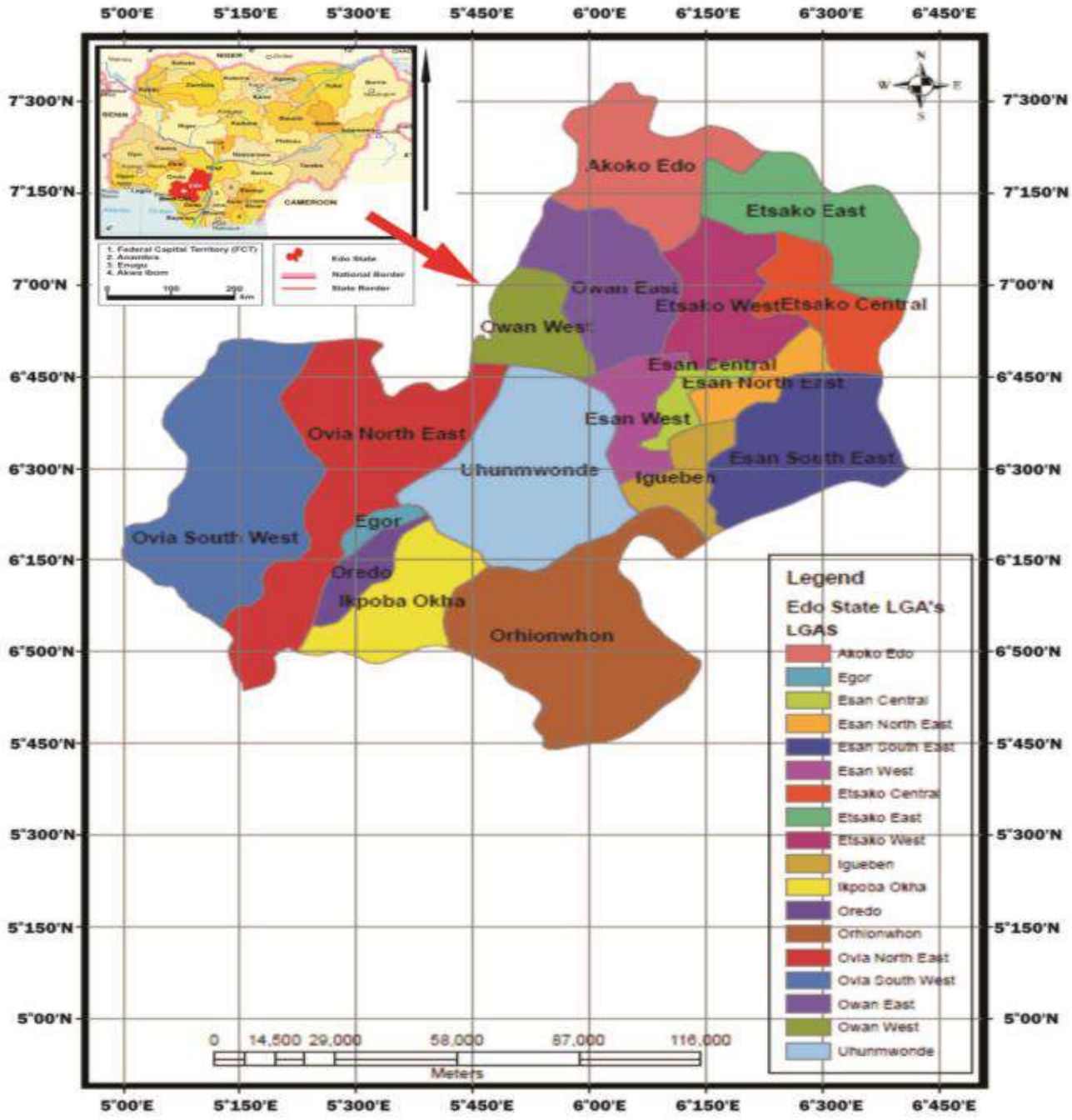
valleys in their upper courses and they become broad as they enter River Ethiope in Delta State. According to [6], the state has land mass that is relatively flat terrain in the southern part with an average height above the sea level of about 500metres except towards the northern axis where the Northern and Esan plateaus range from 183 metres at the Kukuruku Hills and 672 metres at the Somorika Hills.

The climate of the study area is humid sub-tropical indicating that it is basically within the tropical rain forest zone dominated by broadleaved trees that form dense layered stands which usually are above 50m (165 ft) in height. It is typically tropical with two major seasons- the wet and the dry seasons. Ikhile [10], highlight that the seasons correspond to the periods of dominance of the wet tropical continental air masses and the seasonal distribution of rainfall follows the direction of the Inter-Tropical Divergence (ITD) which varies almost proportionally with distance from the coast. The temperatures across the state is relatively high with a very narrow varies in seasonal and diurnal ranges 22-36 range with an average annual rainfall of about between 2000mm-2500mm. The wet season comes between April and November and the dry season between December and March. According to [13], there is a marked dry season, with duration of increases from three months in south, northwards, while the rainy period decreases inland from nine months in the south to five months in the northeast.

The vegetation zones of Edo State coincide with the political zones in the state. Edo South is in the moist rainforest, Edo Central in the dry rainforest and derived savanna and Edo North is characterized with derived savanna and southern guinea savanna. The magnitude of devastation as a result of flooding and erosion has resulted in loss of lives and properties, destruction of arable lands and wastage of large areas of usable lands. The State Strategic Health Development Plan also suggested need for re-afforestation, regulated construction and provision of drainage facilities in urban areas as well as attitudinal change on the part of the people.



Local Government Areas in Edo State
Source: Edo State Ministry of Lands and Surveys

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METHODOLOGY

Direct field observation and measurement of gully length, depth and width was done with the help of research assistants using simple survey equipments (measuring tape, Camera and 3percent accuracy Global Positioning System (GPS). The numbers of gullies chosen for the study were determined using the Taro Yamane formula. $n = \frac{N}{1+N(e)^2}$ ----------*Equation 1*

Where

n = sample size
N = total number of gullies in the state
e = is the margin of error assumed (0.05)
1 = is the theoretical constant

The formula was chosen because it has 95% confidence level and the total number of gullies in the study area is within ranges of hundred which fit into the basic assumption of the formula.

$$n = \frac{110}{1+110\ (0.05)}\ 2$$

$$= \frac{110}{111\ (2.5)}$$

$$= 0.396$$

Basic Assumption

If the population is a few hundreds, a 40% sample will do, if many hundreds, a 20% sample will do. If a few thousands, a 10% sample and if several thousands, a 5% or fewer sample will do Ezeigw (2014) [8]

$$n = 0.396 \text{ X } 40$$

$$= 16$$

The random sampling technique was used in selecting the 16 gullies sites across the study area.

Particle Size Analysis

Particle size distribution analysis is a necessary classification test for soils especially coarse soils. It presents relative portions of different sizes of particles. The international pipette method was used to perform particle size analysis for soil textural classification. The method employs the Stock's law in order to determine the size of particles. The procedure involves preparation of the soil sample by wet sieving to remove silt and clay particles while the remaining coarse material is dry sieve. The data were analyzed to address the research questions and the specified objectives.

Procedure

i. Weigh the air-dried test sample to 0.1% of its total mass
ii. Place the sample and sieve through a 20mm sieve with wirebrush until the individual particles are finer material
iii. Sieve the fraction retained on the 20mm test sieve on the appropriate larger test sieve and weigh the amount retained on each test sieve
iv. Weigh the material passing 20mm test sieve
v. Riffle the sample to get a convenient fraction of about 0.5kg and weigh that fraction
vi. Spread the riffle fraction in the large tray or bucket and cover with water

vii. If the soil is cohesive add sodium hexametaphoshate to water first at a concentration of 2g per litre. Stir the mixture well to wet the soil, allow the soil to stand for at least 1 hour in this solution stirring frequently.
viii. Wash the material through a 75 µm sieve, allowing the material passing sieve 75um to run to waste. Ensure that neither test with material or water
ix. Transfer all the material retained on the sieve into a tray or evaporating dish and dry in an oven at 105ºC to 110ºC. Allow it to cool and weigh
x. Sieve the dried fractions through the appropriate sieve down to the 75 µm test sieve. Weigh the amount retained on each sieve and any fines passing the 75µm test sieve and record.

Compressive Strength Using Undrained Triaxial Analysis

Compressive strength is a term used in soil mechanics to describe the magnitude of the shear stress that a soil can sustain. The shear resistance of soil is a result of friction and interlocking of particles and possibly cementation or bonding at particle contacts. It is often measured in Kilonewton per Meters (Kn/m).

The compressive strength (q_u) is the load per unit area at which the cylindrical specimen of a cohesive soil falls in compression and it is determine using this formulae Q_u=P/A-----Equation 2
Where
P= axial load at failure

A= corrected area = $\frac{A_0}{1-\varepsilon}$ ----------Equation 3

A_0 is the initial area of the specimen

ε = axial strain = change in length/original length.

Procedure:

i. Place the sampling soil specimen at the desired water content and density in the large mould.
ii. Push the sampling tube into the large mould and remove the sampling tube filled with the soil. For undisturbed samples, push the sampling tube into the clay sample.
iii. Saturate the soil sample in the sampling tube by a suitable method.
iv. Coat the split mould lightly with a thin layer of grease. Weigh the mould.
v. Extrude the sample out of the sampling tube into the split mould, using the sample extractor and the knife.
vi. Trim the two ends of the specimen in the split mould. Weigh the mould with the specimen.
vii. Remove the specimen from the split mould by splitting the mould into two parts.
viii. Measure the length and diameter of the specimen with vernier calipers.
ix. Place the specimen on the bottom plate of the compression machine. Adjust the upper plate to make contact with the specimen.

x. Adjust the dial gauge and the proving ring gauge to zero.
xi. Apply the compression load to cause an axial strain at the rate of ½ to 2% per minute.
xii. Record the dial gauge reading, and the proving ring reading every thirty seconds upto a strain of 6%. The reading may be taken after every 60 seconds for a strain between 6%, 12% and every 2minutes or so beyond 12%.
xiii. Continue the test until failure surfaces have clearly developed or until an axial strain of 20% is reached.
xiv. Measure the angle between the failure surface and the horizontal, if possible.
xv. Take the sample from the failure zone of the specimen for the water content determination.

Soil bulk density is a weighted average of the densities of its components. It is the weight of dry soil divided by the total soil volume. The total soil volume is the combined volume of solid and pores which may contain air and water. The International System of Units (SI) for bulk density is megagrams per cubic meter (Mg m^{-3}), which is numerically equivalent to grams per cubic centimeter.

It is calculated using this formula:
$r_b = f_a r_a + f_p r_p + f_o r_o +$..... Equation 4

Where

f= is the volume fraction of a component

a = air (pores)

p = soil mineral particles

RESULTS AND DISCUSSION

Particle Size Analysis of Soil Samples in Edo North

Particle test analysis of soil sample from the gully site at Ikabigbo in Edo North has 72.80 % of sand, 15.92% of clay and 11.28% of silt. The sample collected from Jatu road, has 68.80% of sand, 18.64% of clay and 12.56% of silt. The sample collected from Egelessor gully site has 70.80% of sand, 19.92% of clay and 9.28 of silt. In Gaz Mohmoh, the soil sample has 68.08% of sand, 19.92% of clay and 12.0% of silt. This shows that the soil in the area is more *sandy*, making it more erodible and dispersible on exposure to rainfall. It is also an indication that there is a great tendency for the gullies to get widening especially during the rainy season. This *also* explains why the areas are prone to gully erosion.

Table 1 Particle Size Distributions of Soil Samples in Edo North

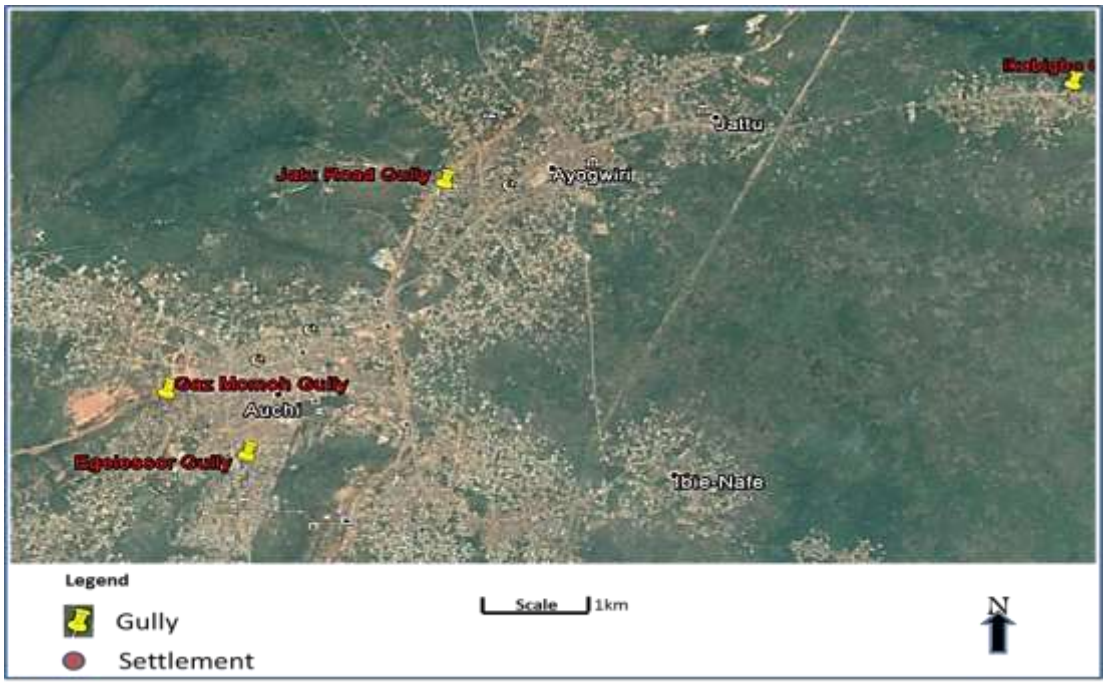
Sample ID	**% Sand**	**% Clay**	**% Silt**	**Total in %**
Ikabigbo	72.80	15.92	11.28	100
Jatu Road	68.80	18.64	12.56	100
Egelessore	70.80	19.92	9.28	100
Gaz Mohmoh	68.08	19.92	12.0	100

Quick Undrained Triaxial of Soil Samples in Edo North

Laboratory analyses of soil samples from gullies in Edo North have the following results as shown in Table 5.14. Sample from Ikabigbo has a bulk density of 2.02Mg/m^3, moisture content of 28.8% and compressive strength of 179kn/m. Jatu road sample has bulk density of 2.42Mg/m^3, moisture content of 28.9% and compressive strength of 181kn/m. Sample from Egelessor has bulk density of 2.23Mg/m^3, moisture content of 29.2% and compressive strength of 180kn/m. Gaz Mohmoh has bulk density of 2.42Mg/m^3, moisture content of 28.5% and compressive strength of 185kn/m.

Table 2 Quick Undrained Triaxial of Soil Samples in Edo North

Sample ID	**Bulk Density (Mg/m^3)**	**Moisture Content %**	**Compressive Strength Kn/m**
Ikabigbo	2.02	28.8	179
Jatu Road	2.42	28.9	181
Egelessore	2.23	29.2	180
Gaz Mohmoh	2.42	28.5	185



Google Earth Map Showing Locations of Major Gullies in Edo North

Photo of Jatu Road Gully Site in Edo North

Particle Size Analysis of Soil Samples in Edo South

Soil sample collected from Oka Gully site in Edo South has 64.08% of sand, 23.92% clay and 12.00% of silt. That of Ikpoba slope has 66.08% of sand, 21.92% of clay and 12.00% of silt. The soil sample from Queen Eden gully site has 72.08% of sand, 20.64% of clay and 7.28% of silt. That of Ogiso gully site has 73.36% of sand, 17.92% of clay and 8.72% of silt. The analysis of soil sample from Evbotubu gully site has 66.08% of sand, 22.64% of clay and 11.24% of silt. The sample collected from University of Benin gully site has 67.36% of sand, 21.92% of clay and 10.72% of silt. Again the analysis of soil samples collected from Edo South are more sand, this also explain why the areas are susceptible to gully erosion.

Table 3 Particle Size Distributions of Soil Samples in Edo South

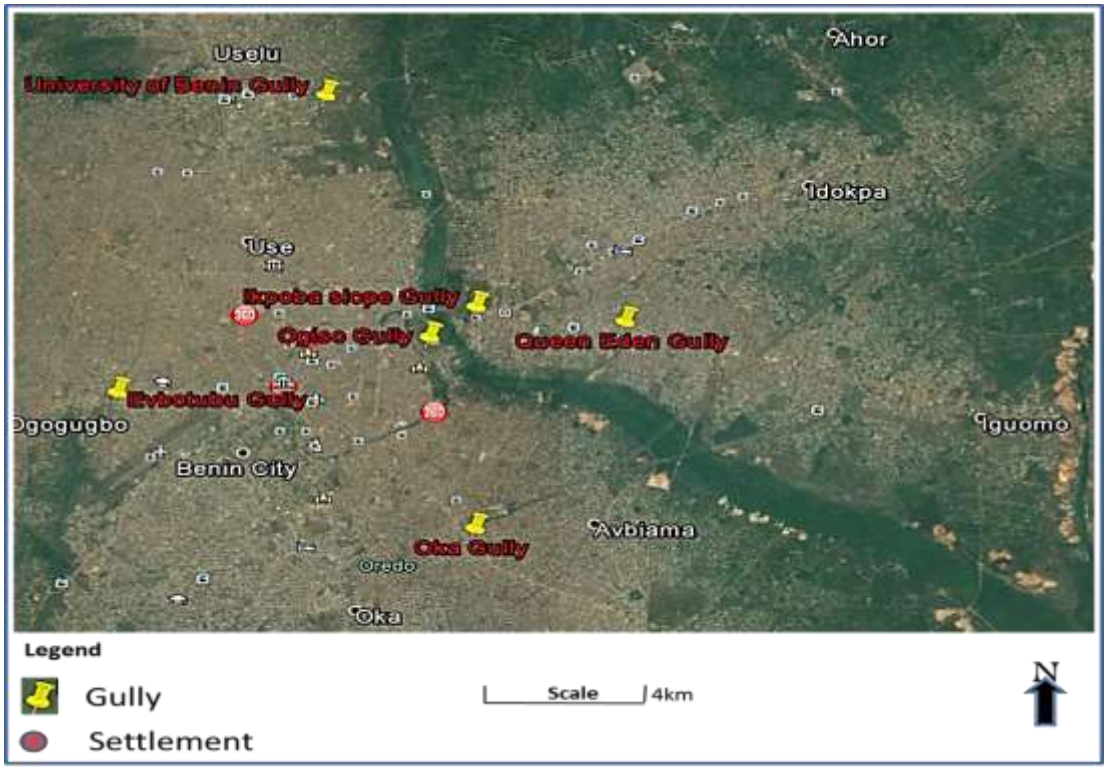
Sample ID	**% Sand**	**% Clay**	**% Silt**	**Total in %**
Oka Gully	64.08	23.92	12.00	100
Ikpoba Slope	66.08	21.92	12.00	100
Queen Eden	72.08	20.64	7.28	100
Ogiso	73.36	17.92	8.72	100
Evbotubu	66.08	22.66	11.26	100
Uniben Site	67.36	21.92	10.72	100

Quick Undrained Triaxial of Soil Samples in Edo South

Laboratory analyses of soil samples from gullies in Edo South. Sample collected from Oka gully site has a bulk density of 2.66Mg/m^3, moisture content of 26.7% and compressive strength of 234kn/m. That of Ikpoba slope bulk density of 2.58Mg/m^3, moisture content of 26.9% and compressive strength of 196kn/m. Sample from Queen Eden has bulk density of 1.81 Mg/m^3, moisture content of 30.2% and compressive strength of 173kn/m. Sample from Ogiso site has bulk density of 1.79 Mg/m^3, moisture content of 31.1% and compressive strength of 169kn/m. Sample from Evbotubu site has bulk density of 2.50Mg/m^3, moisture content of 27.0% and compressive strength of 198kn/m and sample from University of Benin site has bulk density of 2.52Mg/m^3, moisture content of 27.1% and compressive strength of 189kn/m.

Table 4 Quick Undrained Triaxial of Soil Samples in Edo South

Sample ID	Bulk Density (Mg/m^3)	Moisture Content %	Compressive Strength Kn/m
Oka Gully	2.66	26.7	236
Ikpoba /Slope	2.58	26.9	196
Queen Eden	1.81	30.2	173
Ogiso	1.79	31.1	169
Evbotubu	2.50	27.0	198
Uniben Site	2.52	27.1	189



Google Earth Map Showing Locations of Major Gullies in Edo South

Photo of Evbotubu Gully Site in Edo South

Particle Size Analysis of Soil Samples in Edo Central

Particle size test analysis of soil sample from Gully site in Ambrose Ali University (AAU) Ekpoma, has 77.36% of sand, 13.92% of clay and 8.72% of silt. That of Igueben has 65.36% of sand, 22.64% of clay and 12.0% of silt. Sample from Ewohimi gully site has 76.08% of sand, 13.92% of clay and 10.0% of silt. Uromi has 70.08% of sand, 19.92% of clay and 10.0% of silt. Ewu is 75.36% of sand, 15.92% of clay and 8.72% of silt. The sample from Ibore has 66.80% of sand, 25.92% of clay and 7.28% of silt. This also shows that soil samples collected from Edo Central are highly sandy which also explain why the areas are susceptible to gully erosion.

Table 5 Particle Size Distribution of Soil Samples in Edo Central

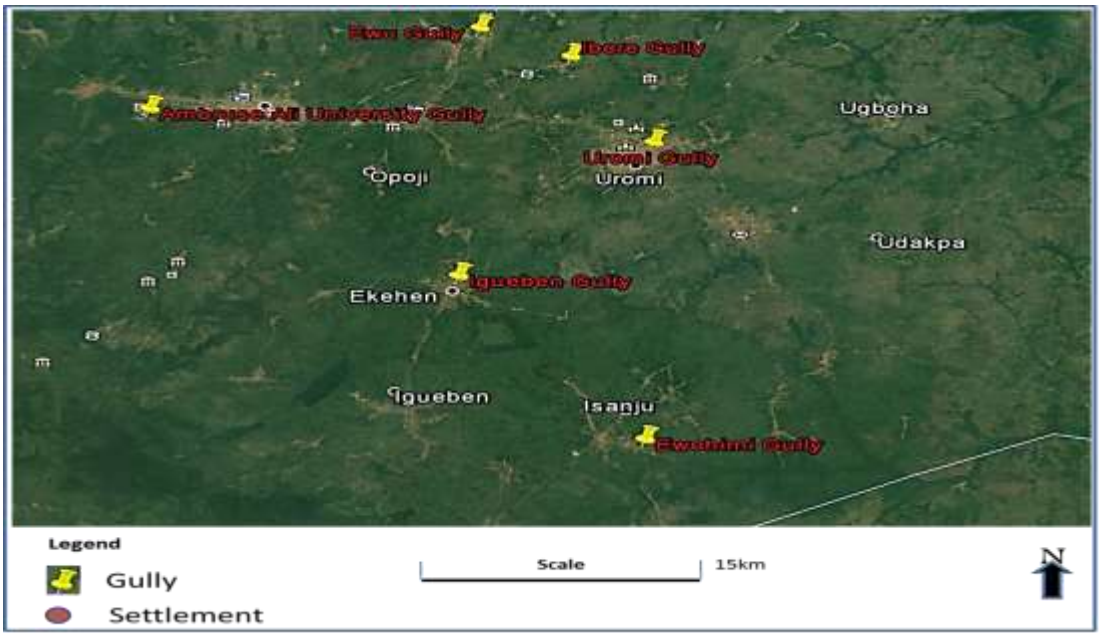
Sample ID	**% Sand**	**% Clay**	**% Silt**	**Total in %**
AAU (Ekpoma)	77.36	13.92	8.72	100
Igueben	65.36	22.64	12.0	100
Ewohimi	76.08	13.92	10.0	100
Uromi	70.08	19.92	10.0	100
Ewu	75.36	15.92	8.72	100
Ibore	66.80	25.92	7.28	100

Quick Undrained Triaxial of Soil Samples in Edo Central

Laboratory analysis of soil samples from gullies in Edo South. The results indicate that the soil sample from Ambrose Ali University site has bulk density of 1.70Mg/m^3, moisture content of 32.0% and compressive strength of 163kn/m. That of Igueben has bulk density of 2.64Mg/m^3, moisture content of 26.8% and compressive strength of 232kn/m. Sample from Ewohimi has bulk density of 1.81Mg/m^3, moisture content of 30.3% and compressive strength of 174kn/m. Uromi has bulk density of 2.27Mg/m^3, moisture content of 28.9% and compressive strength of 182kn/m. Ewu has bulk density of 1.75Mg/m^3, moisture content of 31.3% and compressive strength of 165kn/m. Ibore has bulk density of 2.48Mg/m^3, moisture content of 27.4% and compressive strength of 194kn/m.

Table 6 Quick Undrained Triaxial of Soil Samples in Edo Central

Sample ID	Bulk Density (Mg/m^3)	Moisture Content %	Compressive Strength Kn/m
AAU	1.70	32.0	163
Igueben	2.64	26.8	232
Ewohimi	1.81	30.3	174
Uromi	2.27	28.9	182
Ewu	1.75	31.3	165
Ibore	2.48	27.4	194



Google Earth Map Showing Locations of Major Gullies in Edo Central

Photo of Ewu Gully Erosion Site Edo Central Showing Abandoned Building

CONCLUSIONS

The analysis of soil samples collected from Edo South are more sand, this also explain why the areas are susceptible to gully erosion. This can also be attributed to the high volume of soil that is wash away in the area. The compressive strength of these soil samples collected from the area are in the ranges of 163Kn/m at Ambrose Ali University in Edo Central to 232 Kn/m at Igueben also Edo Central. The bulk density in the area ranges from 1.70Mg/m^3 at Ambrose Ali University Ekpoma in Edo Central to 2.66Mg/m^3 at Oka in Edo South and the moisture content ranges from 26.7% at Oka in Edo South to 32.0% at Ambrose Ali University Ekpoma in Edo Central. This can be attributed to the uniformity in the soil type, causes of the gully, human activities in the area and application of control measure such as cultivation of plantain.

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