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Research Paper

Determination of the Effects of Soils Shear Strength and Stuctural Defects Ongully Developments in Imo State Nigeria.

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ABSTRACT: *The Shear Strength, Erodibility Indices, and Cohesive Strength of the soils from the Twenty-seven Local Government Areas (Three Geopolitical zones) in Imo State the south eastern part of Nigeria, were determined using the static laboratory method. The values of the shear strength for Owerrri zone, Orlu zone and Okigwe zone averaged 84.0KN/m^2, 83.3KN/m^2 and 82.5KN/m^2. For the Erodibility Indices, its values averaged 0.22 for Owerri zone, 0.23 for Orlu zone and 0.22 for Okigwe zone, also the Cohesive Strength values for the three zones averaged 4.2KN/m^2, 5.5KN/m^2 and 4.6KN/m^2. The obtained values were used in determining the correlation(R)/relationship that existed between the soil properties in the zones using statistical method (penman's formula) which shows that the Shear Strength against the soil loss for Owerri zone, Orlu zone and Okigwe zone, R is -0.44, 0.100 and -0.01 respectively. The obtained correlation(R) values of Shear strength against soil loss for the three zones shows that Owerri zone and Okigwe zone have very low correlation/relationship, therefore has little or no effect on the gully developments, while Orlu zone strongly correlates and contributes immensely to the gully development in the zone thereby making the zone to be highly erodible and requires good conservational structures to check the attendant effect.*

Keywords: *Soil, gully erosion, shear strength, erodibility, Nigeria.*

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I. INTRODUCTION

Gully erosion development in Imo state is on the increase. The number increases yearly and usually after the rainfall regime.UNDP (1996), reports that about three hundred and fifty-five (355) active gully sites exist in Imo state and four other states in the south east Nigeria. Gully erosion is defined as a relatively deep vertical walled channel which occurs when water is channeled across the unprotected land. The concentrated water washes away the unprotected soils along the drainage line. Gully erosion is associated with high rainfall intensity, topography and slope. Otherfactors include concentrated runoffs, surficial developed area runoffs, poor road maintenance, faulty construction of culverts and drains as well as fluvial processes. Sango doyin. (1994) was of the opinion that rainfall characteristics, flow rates, runoff volumes and land slopes affects the rates of particle detachment, breakdown, transportation, dispersion and deposition.

Onu (2012) states that gully erosion in Nigeria is more predominant in the sedimentary terrains and perhaps in the basements/sediments contact areas. He added that gully development takes the advantage of the loosely consolidated and sometimes friable rocks and sandstones. Imo state has a weak geological formations that are characterized with silty sands, low plasticity clay group and consolidated sands that render the soil/sediments vulnerable to erosion. (UNDP 1996). Shear strength of a soil isthe maximum shear resistance which the materials (soils) are capable of developing. Shear strength of the soil depends on the cohesive strength (C) and the angle of internal friction (Φ). The values of the shear strength (Ʈ); cohesive strength (C) and angle of internal friction (Φ) determine how vulnerable soil samples are to detachment and transportation of the soils.

Objectives of the study

The objectives of this study is to determine the nature of the relationship between the soils shear strength (SS) and the erodibility Indices (EI).

II. LITERATURE REVIEW

The shear strength of the soil is the ability of the soil to resist sliding along the internal surfaces within the soil mass (Murthy Smith, 2009). It is the maximum shearing resistance which soils are capable of developing. The stability of a structure existing on the surface soil or the impacts of rain drops, depends on the shearing resistance offered by the soils. If the shearing force is given as F_a and the normal load represented as P_n. Then the shearing force that is usually proportional to the normal load P_n can be represented as

$F_a = P_n \tan \Phi$ -- 1

The shear strength which is the maximum resistance to shearing stress, can be stated as follows

$Ʈ = C + \tilde{V} \tan \Phi$ --2

where

$Ʈ$ = Shear Strength in KN/m^2

C = Cohesive Strength in KN/m^2

$\tilde{V}$ = Normal Stresses in KN/m^2

Φ = angle of internal friction indegrees

Fugason (2004), stated that the shear resistance of soils is as a result of the angle of internal friction and the interlocking particles that hold or cement the soils particles together. The cohesive strength determines the resistance due to the forces holding the soils particles together. The angle of internal friction is the resistance due to the interlocking of the soils particles. Erodibility is the vulnerability of the soils to erosion (Moore 2020). Erodibility indices (EI) vary significantly from soil to soil. The vulnerability and susceptibility of soils to erosion depends on the physical characteristics of the soils (Moore 2020); Amanze*et al* (2015). Consequently the lower the value of the cohesive strength (C) and angle of internal resistance (Φ), the more vulnerable and susceptible the soils samples to detachment, deformation, slumping and transportation. Soil erosion depends on the shear strength of the soil. Al Derah and Bradfod (1982), stated that the quantity of soil detached through a single water drop impact, decreases as the soil shear strength increases. Rainfall events provides the discharge, runoffs and surface flows that can induce erosion. Roose(1997) provided a rainfall factor (R) that can be used to predict erosion and soil losses. He provided an expression as

$R = 0.5H$ -- (3)

where

R = The rainfall factor

H = The mean annual rainfall (2000 – 2500mm/yr).

The value of H can be used with Hudson (1995) Universal soil loss equation (USLE) for estimating the total annual soil loss in tons/hectare/year. The USLE can be expressed as follows

$A = 2.24RK$ -- (4)

where

A = Annual soil loss in tons/hectares

R = Rainfall factor in mm

K = Erodibility factor.

Eqn (4) is used where the crop and slope factors are taken as one. Rainfall events that provides raindrops impact, concentrated runoffs and surface flow encourage erosion processes such as detachments and transportations. Two energy sources – impacts of raindrops on the soil surface and shearing actions of the overland flow/surface flow, are responsible for the wearing away of the earth's surface – processes that induce erosion and soil losses.

III. MATERIALS AND METHODS

Study area: This study was carried out in Imo state Nigeria. Imo state belongs to the south eastern part of Nigeria, andhas twenty seven local government areas, which are grouped into three major geo-political zones. Itbelongs to the rainforest region of Nigeria, and lies within latitudes $04^0 52^1$N and 05^0 47^1N and longitude 07^0 02^1E and 07^0 26^1E. It receives an annual rainfall depths of between 2000 and 2500mm. There are two main seasons – the rainy (wet season) that starts in April and end in October, and the dry season, which starts from November and ends in March. The intensity of rainfall is generally high during the rainy season. Rainfall intensity and the amount/depth of rainfall are largely responsible for soil erosion in Imo state.

Soil sampling: Soil samples were collected from one identified gully site in each local government area of Imo state (from the twenty-seven local government areas). The soil samples were air-dried for about five days before the laboratory analysis. Samples were subjected to combined hydrometer and mechanical sieve analysis. Shear strength tests were conducted for each sample using the triaxial shear test apparatus in order to determine shear strengths of sample soils from all the twenty-seven local government areas/three geopolitical zones where different sizes of gully were identified.

The correlation coefficient (R) of the soils shear strength and erodibility was determined using equation 5: i.eR

$$= \frac{n(\sum XY) - (\sum X)(\sum Y)}{\sqrt{[(n\sum X^2 - (\sum X))^2)(n\sum Y^2 - (\sum Y)^2)]}} \quad \text{equ 5}$$

Source :Peamans equation

IV. RESULTS AND DISCUSSIONS

Results of the sample tests for cohesive strengths (C), angle of internal friction (Φ), shear strengths (Ʈ), erodibility indices (EI) were presented on tables 3, 4, 5, and 6. Tables 1 and 2, were seen as standard yardstick for results comparism. Soils from Owerri zone have an average shear strength of 84KN/m^2, samples from Orlu zone as 83.3KN/m^2, while samples collected from Okigwe zone have an average shear strength of 82.5KN/m^2. Average erodibility indices for Owerri zone was 0.22; Orlu zone 0.225 and Okigwe zone 0.215, and were-presented on table 6. Regression and correlation analysis were carried out on the variables (shear strength anderodibility indices) in order to determine the linkage between the two variables and the nature of the relationship existing between them which will show the results for soil losses.

TABLE 1: STANDARD SOILS STRENGTH AND EROSIONAL STATUS.

S/NO	SHEAR STRENTGTH (KN/m^2)	STATUS/INTERPRETATIONS
1	0 ----------------- 100KN/m^2	SEVERE
2	101 ----------------- 200KN/m^2	HIGH
3	201 ----------------- 300KN/m^2	MODERATE
4	301 ----------------- 400KN/m^2	SLIGHT
5	401 ----------------- 500KN/m^2	RARE

Source: (UNDP, 1996)

TABLE 2: STANDARD SOILS AND COHESIVE STRENGTH STATUS

S/NO	SOILS	SHEAR STRENGTH
1	STIFF BOULDER CLAY	400 ---------------------- 600KN/m^2
2	STIFF CLAY	200 ---------------------- 400KN/m^2
3	FIRM CLAY	100 ---------------------- 200KN/m^2
4	SOFT CLAY	50 ---------------------- 100KN/m^2

Sources: (Smith, 1982)

TABLE 3: SAMPLE SOILS FROM OWERRI ZONE

S/NO	SAMPLES	C KN/m^2	$Φ^0$	Ʈ KN/m^2	EI (K)	EI (K)	SOIL LOSS (frost/ha/yr)
1	A	4	24^0	56.4	31	0.31	68.4
2	B	3	28^0	65.5	33	0.33	73.9
3	C	4	21.5^0	74	24	0.24	53.7
4	D	5	25^0	57.7	31	0.31	68.4
5	E	6	25^0	88.9	11	0.11	24.6
6	F	4.1	21^0	74	11.3	0.11	25.3
7	G	4	25^0	59	31.6	0.32	70.7
8	H	5	26^0	91	31	0.31	68.4
9	I	4	20^0	68.7	11.4	0.11	25.5

TABLE 4: SAMPLE SOILS FROM ORLU ZONE

S/NO	SAMPLES	C KN/m^2	$Φ^0$	Ʈ KN/m^2	EI (K)	EI (K)	SOIL LOSS (frost/ha/yr)
1	A	4.1	21^0	74	19	0.19	42.56
2	B	4	22.4^0	77.3	19	0.19	42.56
3	C	4	27^0	94.6	24	0.24	53.76
4	D	3	26^0	89.7	32.3	0.32	72.35
5	E	3	28^0	65.5	31	0.32	69.44
6	F	4	24^0	83	19	0.19	42.56
7	G	5	29^0	84	32	0.32	71.68
8	H	3	26^0	89.7	29	0.29	64.96
9	I	4	27^0	94.6	24	0.24	53.76
10	J	6	25^0	84.4	12.8	0.13	28.67
11	K	6	24^0	85.2	22.5	0.22	50.54
12	L	3	12^0	78	18.2	0.18	40.76

TABLE 5: SAMPLE SOILS FROM OKIGWE ZONE

S/NO	SAMPLES	C KN/m^2	$Φ^0$	Ʈ KN/m^2	EI (K)	EI (K)	SOIL LOSS (frost/ha/yr)
1	A	4	22.4^0	77.3	11.2	0.11	25.088
2	B	4	24^0	83.2	19	0.19	42.56
3	C	5	24^0	84	22.0	0.22	49.28

4	D	6	25^0	88.9	15	0.15	33.6
5	E	7	20.8^0	84.5	18	0.18	40.3
6	F	4	22.4^0	77.3	22.5	0.225	50.4

TABLE 6: SUMMARY OF THE RESULTS OF THE SOIL ANALYSIS

S/NO	ZONES	C KN/m^2	Φ^0	Ʈ KN/m^2	K - VALUE	SOIL LOSS (frost/ha/yr)
1	OWERRI	4.2	24^0	84.0	0.22	53.0
2	ORLU	5.5	24.5^0	83.3	0.23	48.6
3	OKIGWE	4.6	23^0	82.5	0.22	40.2

Key: C cohesive strength of the soil KN/m^2
Φ Angle of internal friction in degrees
Ʈ Shear strength of the soil KN/m^2
EI Erodibility Indices
SL Soil loss ton/hectares/yr.

TABLE 7: PRAXIS OF STATISTICS

VALUE OF R	DEGREE OF CORRELATION
± 1	Perfect correlation
± 0.90 or more	Very high degree of correlation
± 0.75 to ± 0.90	Sufficiently high degree of correlation
± 0.60 to ± 0.75	Moderate degree of correlation
± 0.30 to ± 0.60	Only the possibility of a correlation
Less than ± 0.30	Possibly no correlation
	Absence of correlation

Source: Onuoha and Ngome (2022)

DETERMINATION OF THE COEFFICENT OF CORRELATION (R) FOR SHEAR STRENGTH AGAINST SOIL LOSS FOR OWERRI ZONE

Using the formular(equ 5)

$$R = \frac{n(\sum XY) - (\sum X)(\sum Y)}{\sqrt{[(n\sum X^2 - (\sum X))^2)(n\sum Y^2 - (\sum Y)^2)]}}$$

Where X = Values for Shear Strength
Y = Values for Soil Loss

SAMPLES	**X(ƮKN/m^2)**	**Y(Soil/Loss)**	**XY**	**X^2**	**Y^2**
A	56.4	68.4	3857.8	3180.9	4678.6
B	65,6	73.9	4847.8	4303.4	5461.2
C	74	53.7	3973.8	5476	28883.7
D	51.7	68.4	3536.3	2672.9	4678.6
E	88.9	24.6	2186.9	7903.2	605.2
F	74	25.3	1872.2	5476	640.1
G	59	70.7	4171.3	3481	4998.5
H	91	68.4	6224.4	8281	4678.6
I	68.7	25.5	1751.9	4719.7	650.3
	∑X=629.3	**∑Y=478.9**	**∑XY = 32422.4**	**∑X^2 = 45494.1**	**∑Y^2 = 29274.8**

To Determine the R for Shear Strength against Soil Loss for Owerri Zone

$$R = \frac{n(\sum XY) - (\sum X)(\sum Y)}{\sqrt{[(n\sum X^2 - (\sum X)^2)(n\sum Y^2 - (\sum Y)^2)]}}$$

Where X = Values of Shear Strength for the 9 Local Government Area
Y = Values of Soil Loss for the 9 Local Government Area
n = The total number of Local Government Areas in Owerri zone = 9

$$R = \frac{[9*(32422.4) - (629.3)(478.9)]}{\sqrt{[(9*45494.1 - (629.3)^2)(9*29274.8 - (478.9)^2)]}}$$

$$R = \frac{[291801.6 - 301371.77]}{\sqrt{[(409446.9 - 396018.5)(263473.2 - 229345.2)]}}$$

$$R = \frac{-9570.17}{(13428.4)(34127.99)}$$

$$R = \frac{-9570.17}{\sqrt{458284.30}}$$

Therefore $R = \frac{-9570.17}{21,407.58} =$ **-0.44**

Therefore correlation R for Shear strength against Soil loss for the 9 (nine) Local Government Areas in Owerri Zone is = **-0.44**
From the result obtained, it shows that there is no relationship between the Shear strength and the Soil loss in Owerri Zone, therefore it is said to lack correlation.

DETERMINATION OF THE COEFFICENT OF CORRELATION (R) FOR SHEAR STRENGTH AGAINST SOIL LOSS FOR ORLU ZONE
Using the formular (equ 5)

$$R = \frac{[n(\sum XY) - (\sum X)(\sum Y)]}{\sqrt{[(n\sum X^2 - (\sum X)^2)(n\sum Y^2 - (\sum Y)^2)]}}$$

SAMPLES	X(Ʈ KN/m²)	Y(Soil/Loss)	XY	X²	Y²
A	74	42.56	3,149.44	5,476	1,811.3536
B	77.3	42.56	3,289.888	5,975.29	1,811.3536
C	94.6	53.76	5,085.696	8,949.16	2,890.1376
D	89.7	72.35	6,489.795	8,046.09	5,234.5225
E	65.5	69.44	4,548.32	4,290.25	4,821.9136
F	83	42.56	3,532.48	6889	1,811.3536
G	84	71.68	6,021.12	7056	5,138.0224
H	89.7	64.96	5,826.912	8,046.09	4,219.8016
I	94.6	53.76	5,085.696	8,949.16	2,890.1376
J	84.4	28.67	2,419.748	7,123.36	821.9689
K	85.2	50.4	4,294.08	7,259.04	2,540.16
L	78	40.76	3,179.28	6084	1,661.3776
	∑X=1000	**∑Y=633.46**	**∑XY = 52,922.455**	**∑X² = 84,143.44**	**∑Y² = 35,652.1026**

To Determine the Correlation for Shear Strength against Soil Loss for Orlu Zone

$$R = \frac{[n(\sum XY) - (\sum X)(\sum Y)]}{\sqrt{[(n\sum X^2 - (\sum X)^2)(n(\sum Y^2) - (\sum Y)^2)]}}$$

Where X = Values of Shear Strength for the 12 L.G.A. in Orlu Zone
Y = Values of Soil Loss for the 12 L.G.A. in Orlu Zone
n = Total number of Local Government Areas in Orlu zone = 12

$$R = \frac{[12(52922.40) - (1000)(633.46)]}{\sqrt{[(12*84143.44 - (1000)^2)(12*35652.10 - (633.46)^2)]}}$$

$$R = \frac{[635069.52 - 633460]}{\sqrt{[(1009721.28 - (1000000))(427825.2 - 401271.57)]}}$$

$$R = \frac{1609.52}{\sqrt{(9721.28)(26553.63)}}$$

$$R = \frac{1609.52}{\sqrt{258135272.2}}$$

$$R = \frac{1609.52}{16066.58} = \mathbf{0.100}$$

Therefore R = **0.100**
Therefore, the correlation R for Shear Strength against Soil Loss for the 12 L.G.A. in Orlu zone is**0.100**From the result gotten, it can be deduced that there is a strong relationship between the two soil properties in the zone, therefore the propertiescorrelatesstrongly.

DETERMINATION OF THE COEFFICENT OF CORRELATION (R) FOR SHEAR STRENGTH AGAINST SOIL LOSS FOR OKIGWE ZONE
Using the formular (equ 5)

$$R = \frac{n(\sum XY) - (\sum X)(\sum Y)}{\sqrt{[(n\sum X^2 - (\sum X)^2)(n\sum Y^2 - (\sum Y)^2)]}}$$

Where X = Values for Shear Strength
Y = Values for Soil Loss

SAMPLES	X(ƮKN/m^2)	Y(Soil/Loss)	XY	X^2	Y^2
A	77.3	25.08	1938.7	5975.3	629.0
B	83.2	42.56	3540.9	6922.2	1811.4
C	84	49.28	4139.5	7056	2428.5
D	88.9	33.6	2987.04	7903.2	1128.9
E	84.5	40.3	3405.4	7140.3	1624.1
F	77.3	50.4	3895.9	5975.3	2540
	∑X=495.2	**∑Y=241.22**	**∑XY = 19907.44**	**∑X^2 = 40972.3**	**∑Y^2 = 10162.1**

To Determine the Coefficent of Correlation (R) For Shear Strength against Soil Loss for Okigwe Zone

$$R = \frac{n(\sum XY) - (\sum X)(\sum Y)}{\sqrt{[(n\sum X^2 - (\sum X)^2)(n\sum Y^2 - (\sum Y)^2)]}}$$

Where X = Values for Shear Strength for the 6 L.G.A. Okigwe Zone
Y = Values for Soil Loss for the 6 L.G.A. Okigwe Zone
n = Number of Local Government Areas in Okigwe Zone

$$R = \frac{[6*(19907.44) - (495.2)(241.22)]}{\sqrt{[(6*40972.3 - (495.2)^2)(6*10162.1 - (241.22)^2)]}}$$

$$R = \frac{[119,444.64 - 119,452.14]}{\sqrt{[(245,833.8.8 - 245223.04)(60972.6 - 58187.08)]}}$$

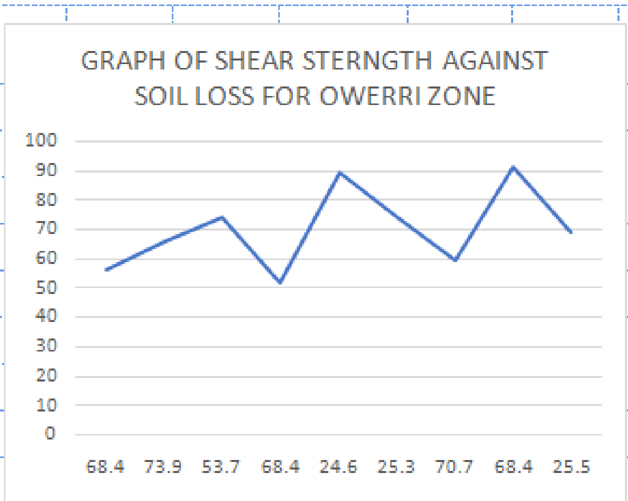
$$R = \frac{-7.5}{\sqrt{(610.76)(2785.52)}}$$

$$R = \frac{-7.5}{1304.33} = \mathbf{-0.0058}$$

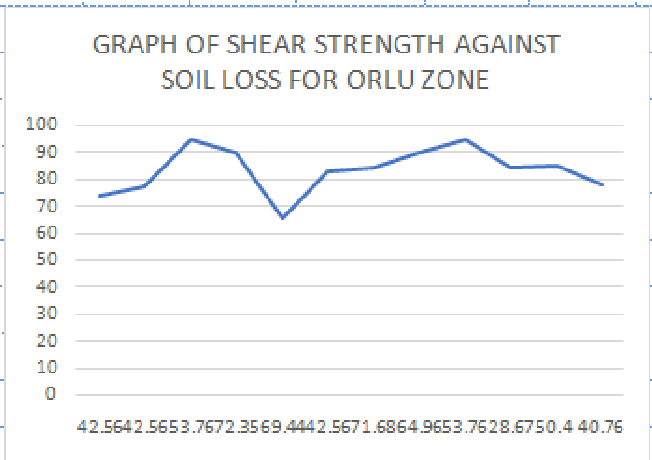
Therefore the correlation R for Shear Strength against Soil Loss for the 6 Local Government Areas in Okigwe zone is = **-0.0058**
From the result obtained, it shows that the Shear Strength has no relationship that the Shear Strength has no relationship with the Soil Loss, therefore the soil lacks correlation in that zone.

GRAPHS

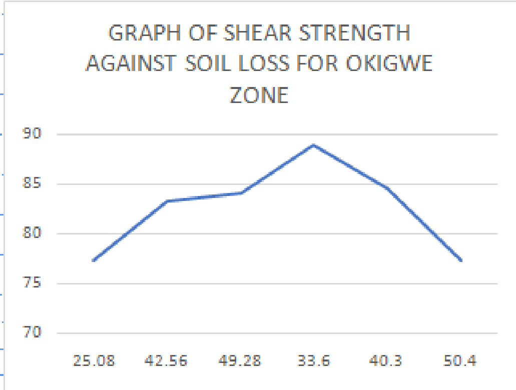
X SHEAR STRENGHT	Y SOIL LOSS
56.4	68.4
65.6	73.9
74	53.7
51.7	68.4
88.9	24.6
74	25.3
59	70.7
91	68.4
68.7	25.5



X SHEAR STRENGTH	Y SOIL LOSS
74	42.56
77.3	42.56
94.6	53.76
89.7	72.35
65.5	69.44
83	42.56
84	71.68
89.7	64.96
94.6	53.76
84.4	28.67
85.2	50.4
78	40.76



X SHEAR STRENGTH	Y SOIL LOSS
77.3	25.08
83.2	42.56
84	49.28
88.9	33.6
84.5	40.3
77.3	50.4



V. **CONCLUSION**:

The present correlation (R) result for the twenty-seven local government areas in the three geopolitical zones in Imo State Nigeria, shows that the shear strength and soil loss for Owerri and Okigwe zones correlates slightly and may have little or no effect in the gully development in the two zones. Invariably, the gully in these two zone must be caused by other factors; but for Orlu zone, the result strongly correlates which indicates that the soil properties contributes immensely to the gully development in the area.

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