ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

THE EFFECT OF GULLY EROSION IN ILARA-MOKIN, ONDO STATE, NIGERIA

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ABSTRACT
Soil erosion has been a serious concern to the formation and development of gully sites. The study was centered on the causes, effects and control to stabilize this recurrent menace. The gully classification based on shape in this study area is described in terms of V-shaped and U-shaped, the gully classification based on size ranges from medium to large gully. The findings garnered from different sites revealed that the factor that influence gully formation along the flood prone areas are the amount of heavy rainfall, the overland flow, the soil properties and also as a result of human intervention by the burning of bushes and felling of trees owing to the fact that Ilara-Mokin the study area is an agrarian community. The soil samples were subjected to laboratory and data analyses which include the Particle size analysis, liquid limit, plastic limit, direct shear test, organic matter content, exchangeable bases, soil pH and its conductivity. The uniformity index, U.I of the particle size analysis carried out revealed that the soil along the gully bed has more of coarse sand in the ratio 5:3:2 of the soil sample which hasten gully formation. The values obtained for the liquid limit and plastic limit are 27.00 and 6.67 of the soil sample which falls below the standard limit for low compression (<35) that hasten the process of gully formation. The result for direct shear shows that the soil strength is not well compacted as obtained in the experiment carried-out based on the fact that the shear stress is considered weak and subjected to failure, owing to the fact that the soil samples are cohesion less thereby causing it to be easily eroded. The result shows that soil organic matter contents on the surface of the gully erosion sites are very high with values ranges from 6.90 - 19.30. This thereby increased the extent of surface run-off encroaching deeply into the sub-soil; the cation exchangeable capacity contributes to this course as well as a result of their higher and lower concentration in the soil properties at the gully erosion sites. The gully erosion can be stemmed through the construction of check-dam, re-vegetation of trees and plants on the gully floor and side walls and also by diverting surface water above the gully head.

Keywords: Soil, Soil properties, Erosion Control Measures, Gully erosion, Ilara-Mokin.

I. INTRODUCTION
Erosion is one of the surface processes that sculpture the earth's landscape and constitutes one of the global environmental problems. Soil erosion is perhaps the most serious mechanism of land degradation in the tropics [1]. However, gully is visually the most impressive of all types of erosion. Gully erosion is a well-defined water worn channel. It is a recently extended drainage channel that transmits ephemeral flow, steep side, steeply sloping or vertical head scarf with a width greater than 0.3 m and a depth greater than 0.6 m [2;3]. It is a V or U-shaped trench in unconsolidated materials with a minor channel in the bottom, but not necessarily linked to a major stream. Similarly, Onu [4] and Scheingross and Lamb [5] defined gully as a relatively deep, vertical-walled channel recently formed within a valley where no well-defined channel previously existed.

Gully erosion is an advanced stage of rill erosion where surface channels have been eroded to the point where they cannot be smoothened over by normal tillage operations. Gullies can be active or inactive. The former, according to Poesen *et al*. [6] and Abdulfatai *et al* [3] can occur where the erosion is actively moving up in the landscape by head-cut migration. The causes of gully erosion are poorly understood but the processes and factors involved in its growth and degradation are well-known. The research has shown that gully processes had happened in the past even without human interference. Thus, the phenomenon of gully erosion is either naturally-induced or artificially-induced, or both. Like in other parts of the world, gully erosion is one of the major environmental threats facing Nigeria [3].

Extensive soil erosion problems occur especially in areas with deep sand plains, high stream banks or sloping valleys of which Ilara-Mokin area of Ondo State is not an exception. Large quantities of valuable agricultural soils are lost each year to soil erosion, especially gullies. Consequently, this menace in this region is liable to attract the attention of both the state, federal and international agencies. This is in bid to proffering meaningful solutions to the problem. The effort made by the State Government to cope with the menace includes measures such as hydraulic regulatory works that integrate a network of drainage with storage ponds to cut off flood crest, lower hydraulic loads of interceptor canals, wicker-work fences and hedges at the inner gully slopes and also the positioning of check dams on the main channels of gullies. There is speculation that the surface regulation of surface waters through engineering measures is effective in controlling only shallow (< 15 m deep) gullies that have not cut through a saturated zone. These measures tends to fail when used for deep gullies that are mostly affected by ground water especially when such gully floors are located in non-cohesive and very permeable sands [7;8]. The objectives of this study include the identification of areas affected, determination of the soil properties of the gully sites and suggesting possible engineering remedies.

II. MATERIALS AND METHODS

2.1 The study Area

Ilara-Mokin, the study area, is located in Ifedore Local Government Area of Ondo State, Nigeria. It lies between the geographic co-ordinates of Latitude $7^0$21"16"N and 7^0 22" 20"N, Longitude $5^0$05"58"E and $5^0$07"12"E as shown in figure 2.1 given below [9]. Generally, slopes gently from the north towards the southern part. The area has a climate characterized by two seasons; the wet season and the dry season. The wet season starts from around mid-March and ends in October with an average rainfall of 1500 mm to 2000 mm while the dry season starts around November and ends in March with an average maximum temperature of about 33˚C [10].

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

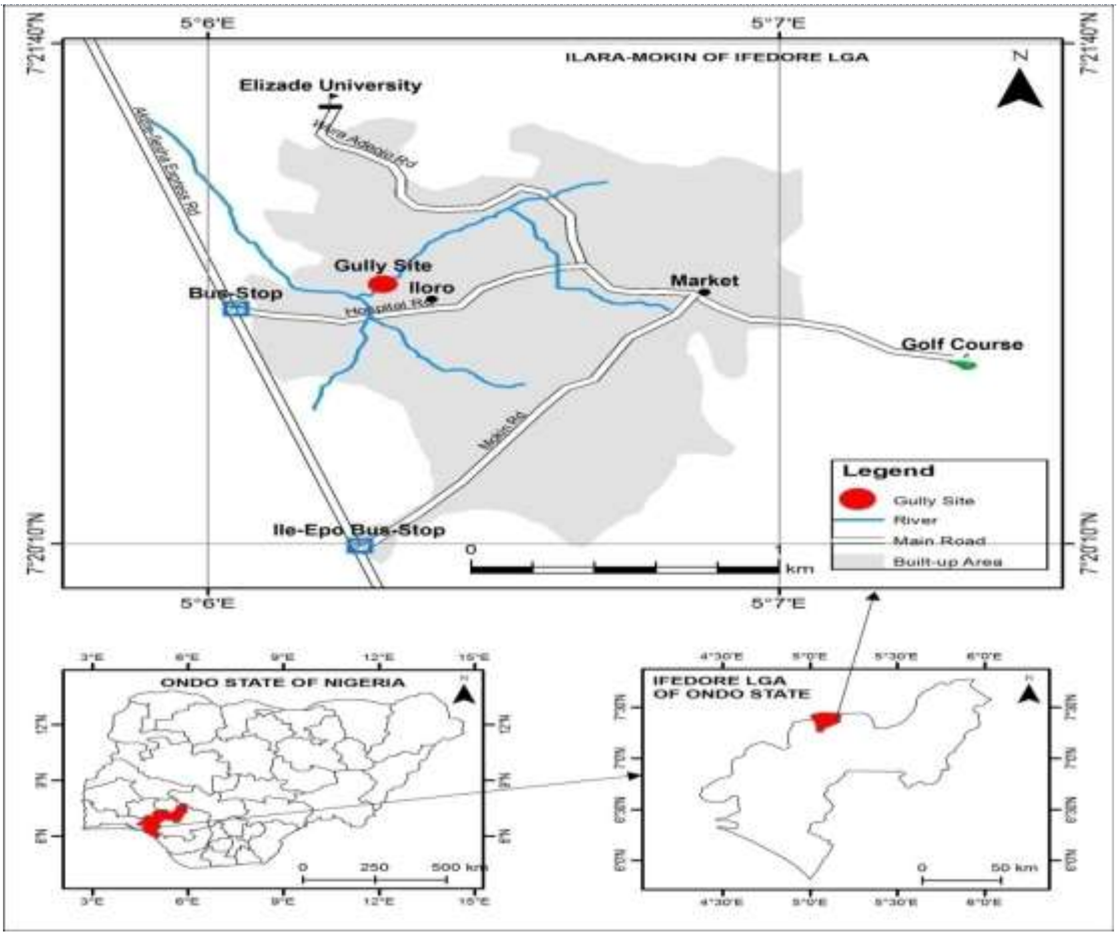

Figure 2.1:The Map of the Study Area

Source: Department of Remote Sensing and GIS FUTA (2016)

2.2 Sample Collections

Sixteen (16) soil samples were collected with the use of soil auger at the depth of 0-20 m at different locations of the gully sites, concealed in a polythene bag and, transported to the laboratory which was then subjected to particle size analysis, liquid limit, plastic limit, direct shear test, organic matter content, exchangeable bases (Ca^+, K^+, Na^+ and Mg^+), soil pH and its conductivity.

2.3 Laboratory Analysis

2.3.1 Soil Particle Size Analysis and Textural Class

Undisturbed sample was collected from the surface of the gully erosion sites with the aid of soil auger at five different locations. The sample was air-dried for three weeks. This was poured on a set of sieves being arranged in descending size of aperture for separating the particle according to size on a mechanical sieve shaker. This was shaken vigorously by the sieve shaking machine for a few minutes. The weight of soil particles retained in each sieve was recorded and the corresponding weight of particle passing through in reference to cumulative retained in each sieve was determined. Their percentage was calculated as well. A plot of percentage passing through particles against sieve size was done.

$$\text{Percent of Material Retained} = \text{Sieve no} \times \frac{\text{weight retained}}{\text{Total weight}} \times 100$$

$$\text{Percent of Material finer than} = \frac{\text{Percent of Material Retained}}{100}$$

$$\text{Average Particle size} = (0.135)(1.366)^{F_m}$$

Where; F_m = Fine modulus

$$\text{Percent Finer than} = \frac{\text{Weight retained}}{\text{Total weight}} \times 100$$

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2.3.2 Liquid Limit Test

It was determined using Cassagrande Apparatus method. Before any appreciable experiment is carried out in determining the soil liquid limit and plastic limit, the soil sample from the surface of the gully erosion sites was collected and air dried. It was purified with mortar and its pestle by losing it from crumb sieve through a 425µm sieve and 200g of sieved soil sample was placed on the glass sheet and mix with a distilled water, reserve a little portion of it (in hard form) for plastic limit test. The cup was half-filled with the prepared wet soil using spatula and leveled up, using a 2 mm grooving tool the soil was then cut into two halves. The handle of the machine was rotated to 2rev/sec (1 revolution represents 1 blow) record the number of blows required to close the gap over 13mm (the normal blow must be known 10 and 50) a portion of the soil just tested was collected and its moisture content was determined. The test was repeated five (5) times by adding more water on each occasion. A graph of moisture content against number of blows was plotted where the value of the moisture content corresponding to 25 blows is the liquid limit (to the nearest whole number).

2.3.3 Plastic Limit Test

The reserved 20g portion of the sample was taken and re-mixed properly on the glass sheet with moderate water to make it sufficiently plastic or roll it into ball roll it between the hand and the glass sheet to form a thread of about 3 mm diameter. The thread was prepared in two rows and moisture content of each was determined. The average value of the moisture contents derived in percentage was taken to be the plastic limit. The range of the plastic limit of soil is given in table 2.1 as given below.

PI = LL – PL
Where,
PI = Plasticity Index
LL = Liquid Limit
PL = Plastic Limit

Table 2.1:Plasticity constant (standard)

Plastic limit of soil	Plasticity
< 35%	Low
35% - 50%	Intermediate
>50%	High

Source: [11]

2.3.4 Direct Shear Test

Undisturbed soil sample was collected with the aid of core sampler, the soil sample collected was carefully inserted in between the two porous stones of the shear box placed on ball bearing and then itwas covered with the lid.The lowerand upper halves of the box were tightened with the screw firmly ensuring the leveling of the machine by setting the spirit level at the center of the lever. The dial ring was properly set and fixed by making contact with the shearing box, as the dial guage inside it remained at mark zero. Normal load was applied and it was tightened a little, the vertical load was applied as the spirit levels remained balanced, the nuts holding the box firmly was unscrewed as the soil was set for shearing, the horizontal load was applied by turning the machine wheel known as the compressive arm creating an impact on the dial guage deflection. This was maintained until its further turning caused no further deflection on the guage. This was noted and recorded as the shearing point and converted to standard unit. The experiment was repeated five times by varying soil samples and loads. A graph of Shear Stress against Normal Stress was plotted, the intercept on shear axis was determined as it corresponded to the soil cohesion value.

$$\text{Shear stress} = \frac{5.25}{3.00} \times \text{Dial guage}$$

$$\text{Normal stress} = \frac{\text{Weight (KN)}}{\text{Area}}$$

2.3.5 Organic Matter Content

Organic Carbon was carried out by weighing 0.5g of grounded soil sample into 250ml conical flask. 10 ml of 0.167M of $K_2Cr_2O_7$ (potassium dichromate) was added. Also, 20 ml of concentrated H_2SO_4 was immediately added and swirled gently until soil and reagent were mixed. The mixture was allowed to settle for 30minutes and after then 100ml of distilled water was added. This solution was titrated against 0.5M Ferrous Ammonium Sulphate with 3 drops of Ferroine indicator to brownish red end point. The blank was also prepared and treated as sample (no soil sample in the blank but other reagents were present).

$$\% organicCarbon = (B - T) \times M \times 0.003 \times 100 \div Weightofsoil$$

Where, B = Blank titre value
T = Sample titre value
M = Molarity of ferrous ammonium sulphate.
Organic Matter was calculated from Organic carbon.

$$\% OrganicMatter = \% OrganicCarbon \times 1.724$$

2.3.6 Exchangeable Bases

Exchangeable Ca^+, K^+, Na^+ and Mg^+ in the soil sample were determined as described by [12]. 10g of air dried soil which has been passed through a 2 mm sieve was transferred into a centrifugal tube. To this was added 100 ml of 1M of Ammonium Acetate (NH_4OAC) and shake on a mechanical shaker for 2hrs then centrifuge at 2000 revs per minutes for 5 minutes. The clear supernatant was decanted into a 100ml volumetric flask after it has been soaked overnight and another Ammonium Acetate (NH_4OAC) solution was added to the residue, shaken for 30 minutes and centrifuged. The supernatant was transferred into the same volumetric flask and steps repeated again before the flask was made to mark with NH_4OAC solution (Ca^{2+}), K^+ were determined from the supernatant with the aid of flame photometer, while magnesium (Mg^{2+}) was determined by atomic assumption spectrophotometer.

2.3.7 Electrical Conductivity

The Conductivity was carried out by instrumentation method of analysis. 5g of soil sample was weighed into 100 ml beaker and 10 ml distilled water was added, agitated and allowed to stand for 30 minutes. The conductivity was determined by the Lastech Conductivity Meter which has been calibrated with 0.01M of KCl.

2.3.8 Determination of pH

In the pH meter, the glass indicator was connected to the amplifier input while the reference electrode was connected to the amplifier output. The Electrical part was completed when both electrode was immersed in the test solution which acted as electrical cell thereby generating a cell potential, E^+ cell. 10g of 2mm sieved air dried soil sample was weighed into 100ml beaker.20ml of distilled water was added to it. The suspension was stirred several times over a 30minutes interval with a glass rod. The pH of the soil in the beaker was measured. The pH was the soil in the beaker containing the sample was measured by immersing the glass electrode into the partly settled suspension and the electrode just deep enough into the clear solution on top of the suspension. This was evaluated with the result recorded soil pH is a measure of the acidity or alkalinity of the soil.

III. RESULTS AND DISCUSSION

3.1 Identification of Areas Affected by Gully Erosion in Ilara-mokin, Ondo State.

The foremost objective of this work is to identify erosion prone areas affected severely by gully erosion in Ilara-Mokin, where two areas with prominent gully site were cited. The study areas were located in Iloro Street and Owode quarters in Ilara-Mokin area of Ondo State. The gully classification based on size found in this region are the medium and large size gully as classified by Akpan *et al.* [13]. For medium gully, the depth of the gully sites ranges from 1.5 m to 3.0 m, gully drainage area ranges from 10 ha to 30 ha and with the discharge rate ranging from 0.1 to 1 (m^3/s). For large gully, the depth of the gully sites is greater than 3 m, gully drainage area is greater than 30 ha and its discharge rate is greater than 1. The possible reasons for gully formation in this region which is an agrarian town are the peak runoff rate as a result of heavy rainfall, overgrazing, bush clearing and burning and the improper design and lack of maintenance of erosion controlled structure which agreed with the results of Valentin et al. [14] and Aminu [15] who reported similar finding in a study of gully erosion.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

3.2 Uniformity Index of Particle Size of the Sample Soil

The result of uniformity index, (U.I) shows that the coarse soil from all samples collected ranges from 7 to 5, medium was 2 in all the samples while the fine particle contents varies from 1 to 3 as shown in Table 3.1 below. The result shows that we have more of coarse soil particles in the soil sample taken along basement of the gully erosion site which is similar to the result of Obasi, [16]. This implies that sediments with high sand or silt contents with less clay particle erode easily under a flat terrain as illustrated with Figure 3.1 to Figure 3.5 for all the sample locations. Based on the soil texture, the soil of Ilara-Mokin area is dominantly sandy and is therefore vulnerable to erosion.

Table 3.1: Particle Size Analysis Values of the Soil Sample

SAMPLES	S_A	S_B	S_C	S_D	S_E
Coarse	5	7	6	6	7
Medium	2	2	2	2	2
Fine	3	1	2	2	1

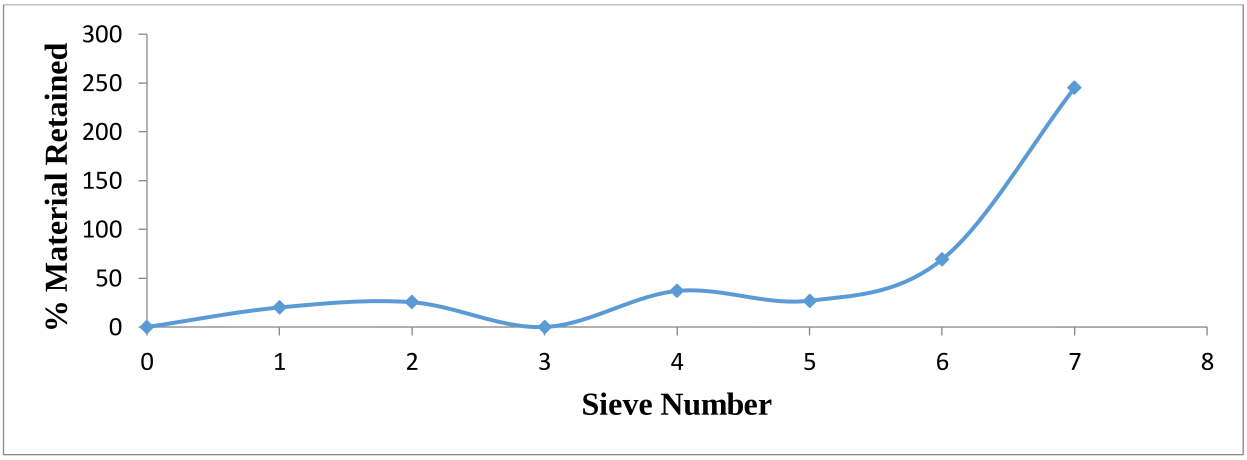

Figure 3.1: The graph of % material retained against sieve size for sample, S_A

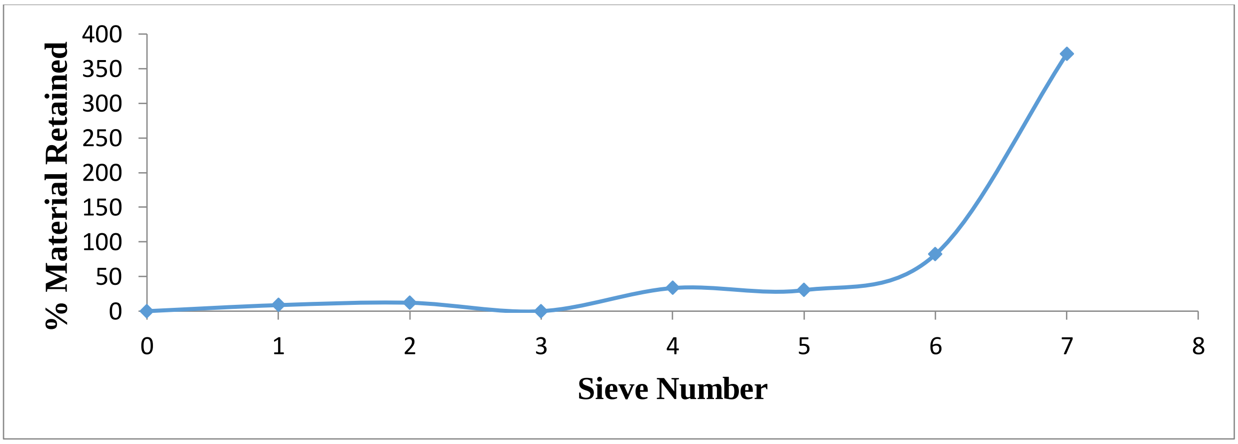

Figure 3.2: The graph of % material retained against sieve size for sample, S_B

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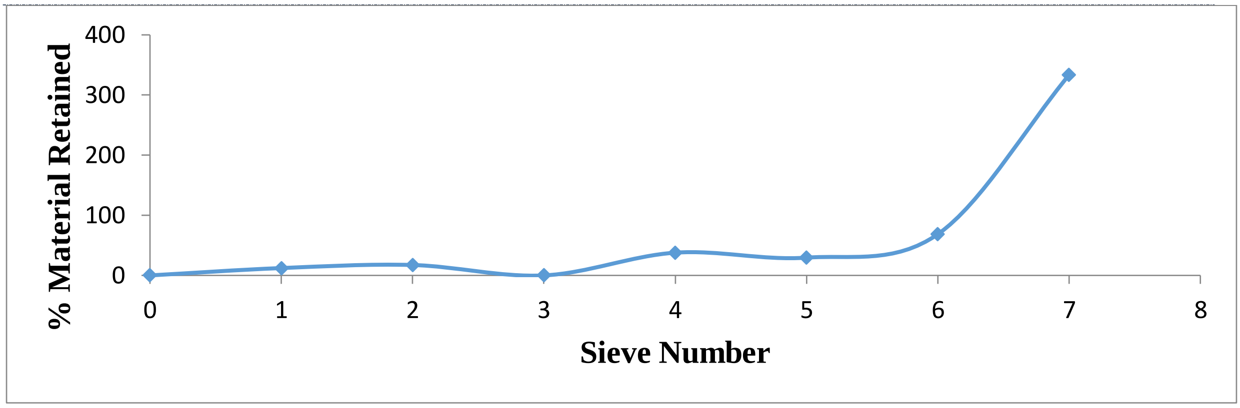

Figure 3.3: The graph of % material retained against sieve size for sample, S_C

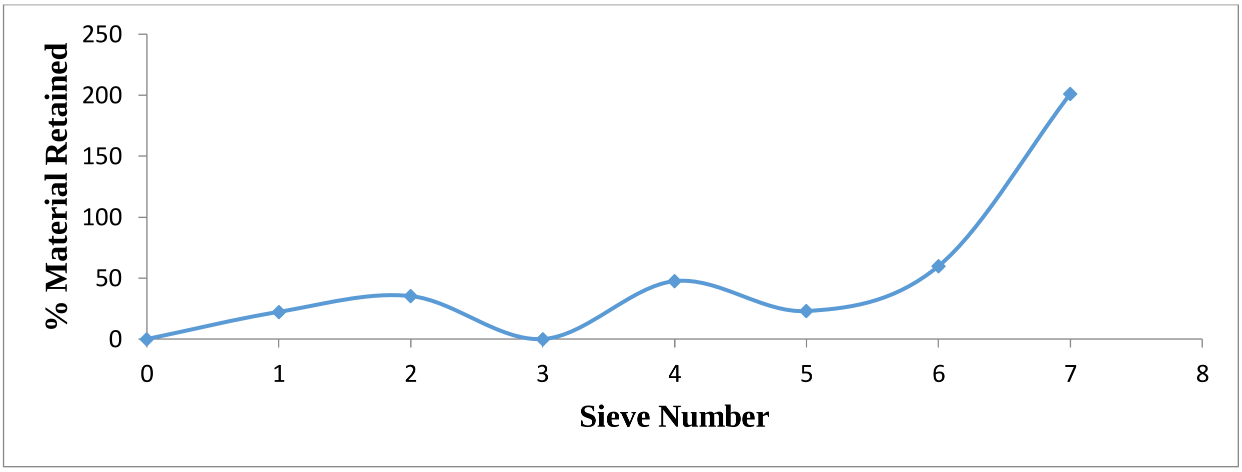

Figure 3.4: The graph of % material retained against sieve size for sample, S_D

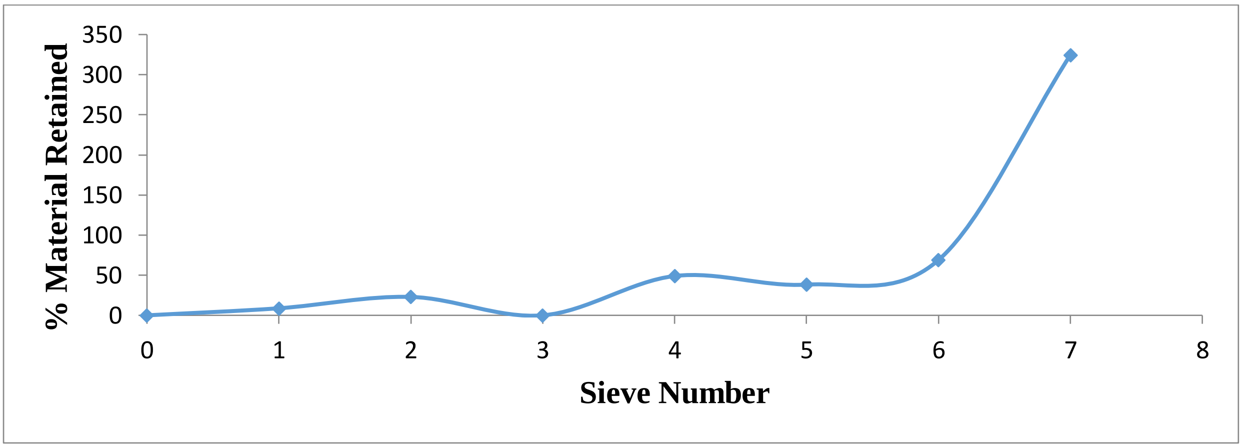

Figure 3.5: The graph of % material retained against sieve size for sample, S_E

3.3 Liquid and Plastic Limit Test

The Liquid limit, (LL) of the soil sample from all sampling location ranged from 6.65 to 13.5 while its Plastic limit (PL) ranged from20.5 to 27.00 as shown below in Table 3.2. The plasticity index of the soil properties is low because it is less than 35 percent (Table 2.1). Hence, it is non-plastic (NP). The plasticity index ranged from 7% to 20.33%. The implication was that the gully erosion soils are loose, friable and unconsolidated which hasten the gully formation process. Comparing this result with the result of Amangabara [1], it shows that the result is similar; therefore, soil can be described as either sandy clay or sandy silt. Figure 3.6 to 3.10 show the regression graph of moisture content (%) against number of blow for all the five sample locations.

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***Table 3.2**: Liquid and Plastic limit*

Sample	Parameters Determined		
	Plastic Limit	Liquid Limit	Plasticity Index
S_A	27	6.67	20.33%
S_B	17.5	6.65	10.85%
S_C	23	12.5	10.50%
S_D	20.5	13.5	7.00%
S_E	21	6.65	14.35%

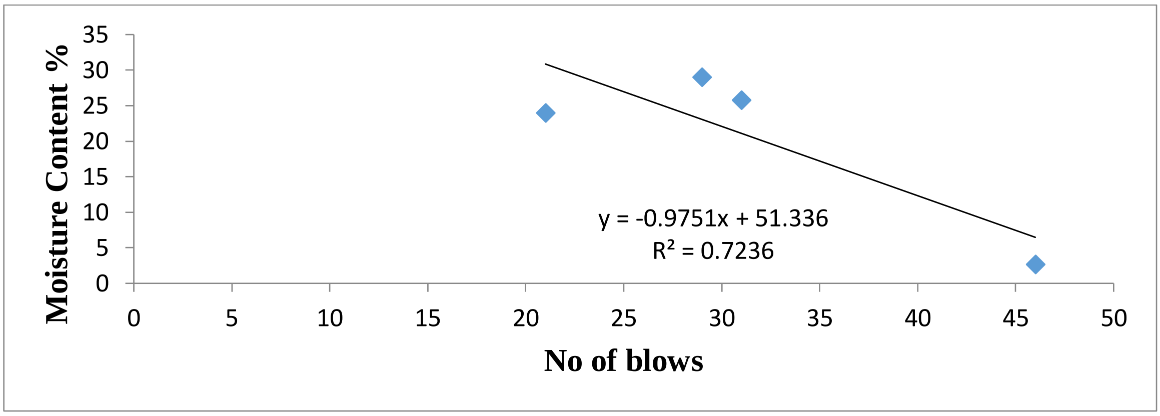

***Figure 3.6:** The graph of Moisture content (%) against No of blow for sample, S_A*

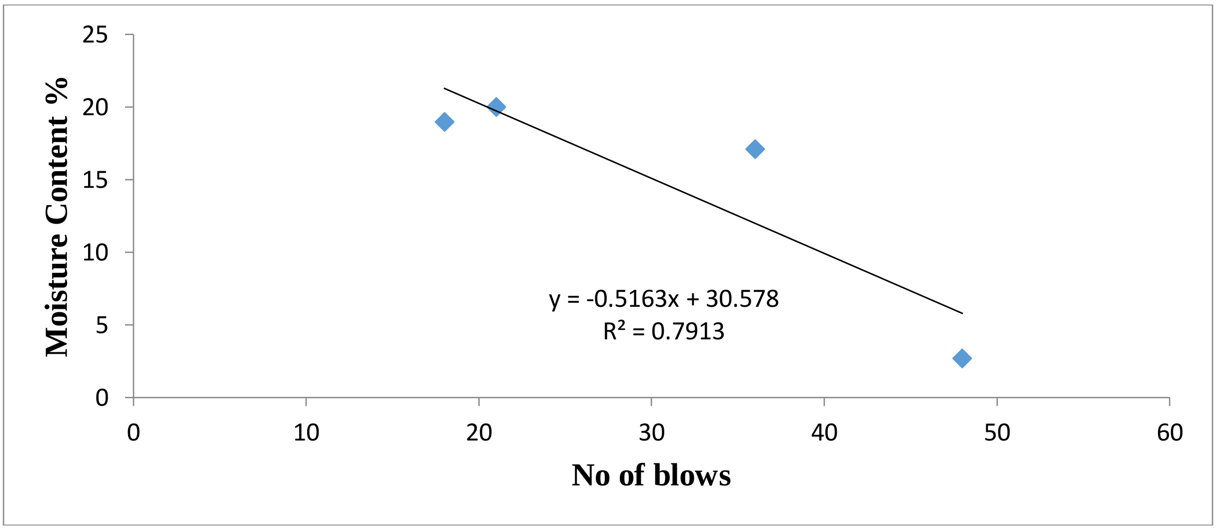

***Figure 3.7:** The graph of Moisture content (%) against No of blow for sample, S_B*

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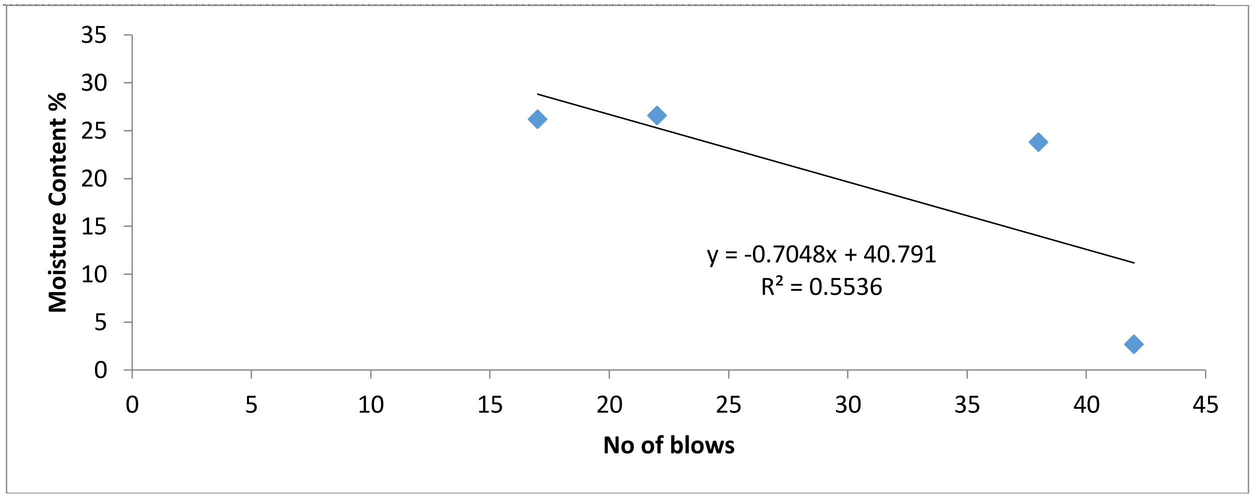

Figure 3.8: The graph of Moisture content (%) against No of blow for sample, S_C

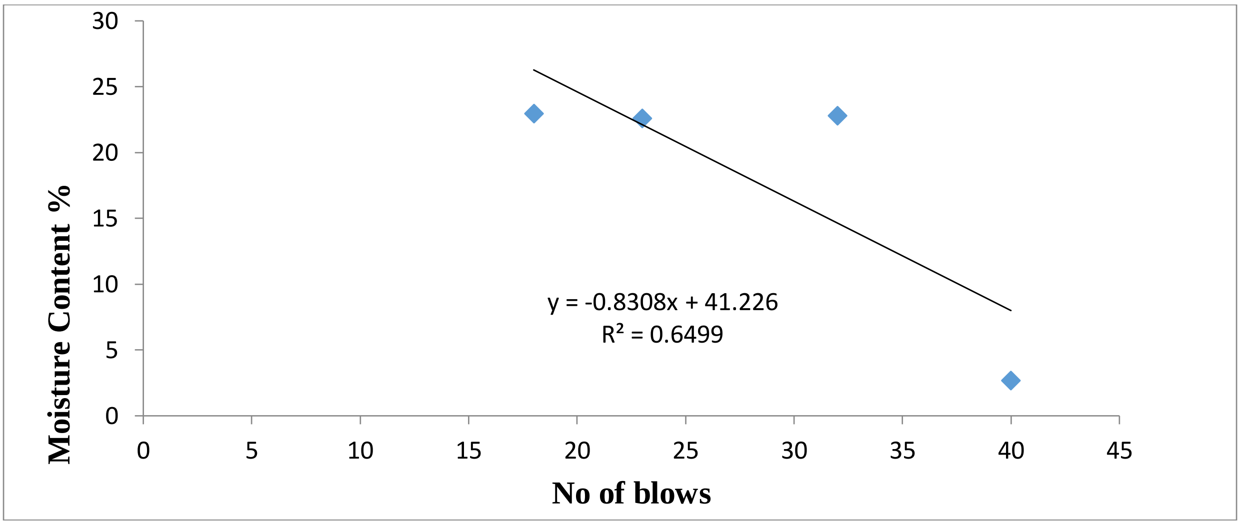

Figure 3.9: The graph of Moisture content (%) against No of blow for sample, S_D

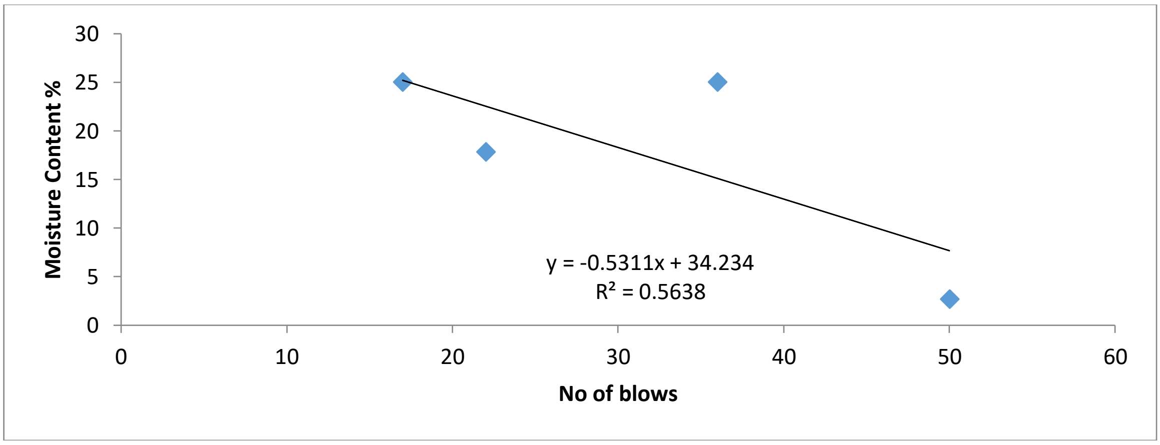

Figure 3.10: The graph of Moisture content (%) against No of blow for sample, S_E

3.4 Direct Shear Test

Table 3.3compared the measured maximum shear stress – normal stress as shown below. It is observed that we have more linear shear stress – normal stress curves beyond the maxima shear stress and expect a tendency to the residual line. With low normal stress, the changing of the direction of the curves is longer. This agreed with findings of Vasarhelyi and Van, [17] that the slopes of the shear stress – normal stress as shown in figure 3.11are independent on the starting normal stress. The slope can depend on the mathematical behavior, shear displacement rate and type of the soil. These expressions in the figures show that when the soil is deposited in a loose state, the normal stress is smaller than the shear stress. Therefore, the compaction density of the deposited soil decreases, the normal stress is lower than the shear stress which is similar to the results of Amangabara, [1]. This result can be interpreted to mean that the soil shear displacement rate in Table 3.3 is weak and can easily be dislodged and transported away by erosive force.

Table 3.3: Maximum shear stress and normal stress test values of the soil samples

Sample	Parameter Determined	
	Maximum shear stress	Maximum normal stress
SA	27	6.67
SB	17.5	6.65
SC	23	12.5
SD	20.5	13.5
SE	21	6.65

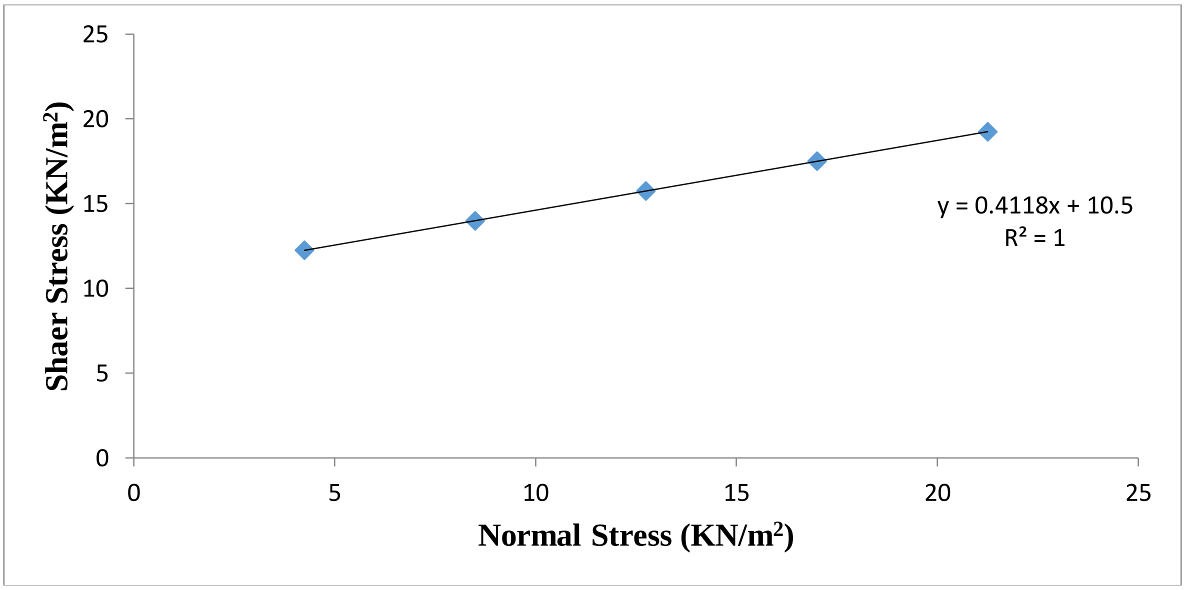

Figure 3.11: Direct shear test graph.

3.5 Organic Matter Content

The Organic matter content and chemical constituents of soils sample have significant effect on erodibility. The Organic matter content of the soil obtained at the six gully points were of the range of (6.90 – 19.30) g/kg decreases down the slope with highest range at sample B, sample C and D at the trench bottom as shown in Table 3.4 and Figure 3.12. Organic matter influences soil erodibility as the stability of the soil aggregates with low organic matter content may be loose and easily detached by running water. [18;12]

Table 3.4: Organic matter content

Samples	Organic Matter(g/kg)
S_A	17.90
S_B	19.30
S_C	18.60
S_D	12.40
S_E	6.90
S_F	7.60

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Impact Factor: 5.164
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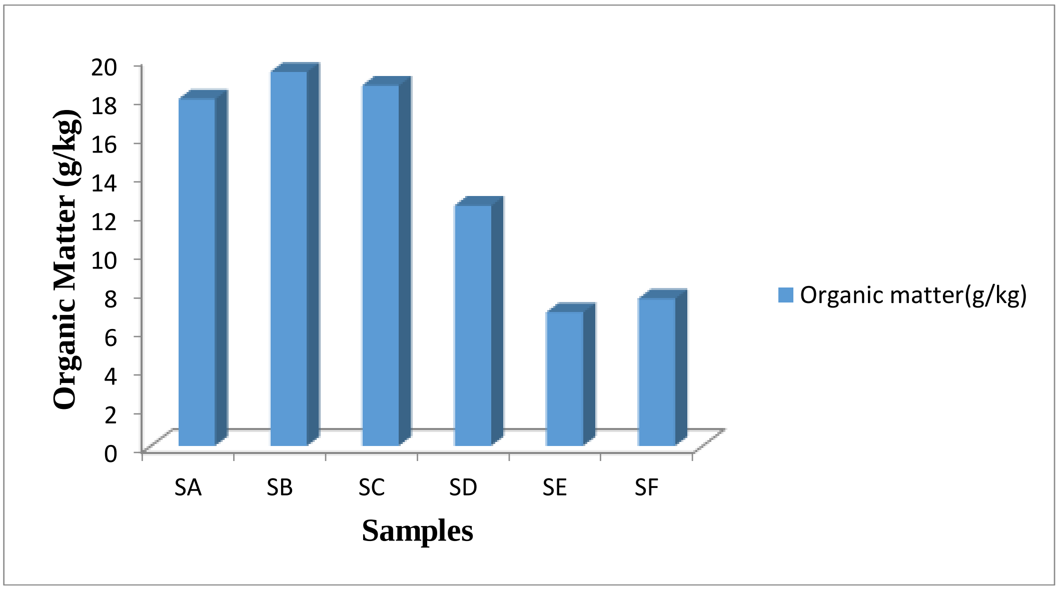

Figure 3.12: Chart showing the various level of organic matter content.

3.6 Exchangeable Bases

The exchangeable Sodium, Na was between 0.08 and 0.29 mM/100g of the sample of soil tested as shown in Table 3.5. Sodium is a dispersing agent that facilitates the dispersion of the soil particles. The higher the rate of sodium content in the soil, the higher the rate of soil erosion in a particular region which is similar to the results of Essien and Okon [18] and Olubanjo [12]

For Magnesium (Mg), the soil along the crest and middle slope had higher values than the soil at the trench bottom, also the values were higher than those of Na. Magnesium is a binding agent that reduces detachment action of running water, thereby reducing the run-off erosion on soils. The Mg content ranges from 0.4 to 1.0 as shown in Table 3.13, the lower the cohesion between soil aggregates, hence it is detached by high rainfall impact which is been eroded by run-off.

But with higher content of Mg, at gully soil (1.00 – 0.4mM/100g) and Ca (3.4 – 2.10mM/100g) against low value of Na as shown in Table 6, the site were saturated and Na could not disperse the compacted soil and clods aggregates. Hence, erodibility was reduced by the cementing action of the base material which is in agreement with the results of Essien and Okon [18].

Table 3.5: Exchangeable bases

Samples	Ca (mM/100g)	Mg (mM/100g)	K (mM/100g)	Na (mM/100g)
S_A	2.10	0.70	2.82	0.23
S_B	2.50	0.80	0.57	0.29
S_C	3.00	0.50	0.90	0.10
S_D	3.00	1.00	0.56	0.12
S_F	2.50	0.70	0.35	0.15
S_F	3.40	0.40	0.28	0.08

ISSN: 2277-9655
Impact Factor: 5.164
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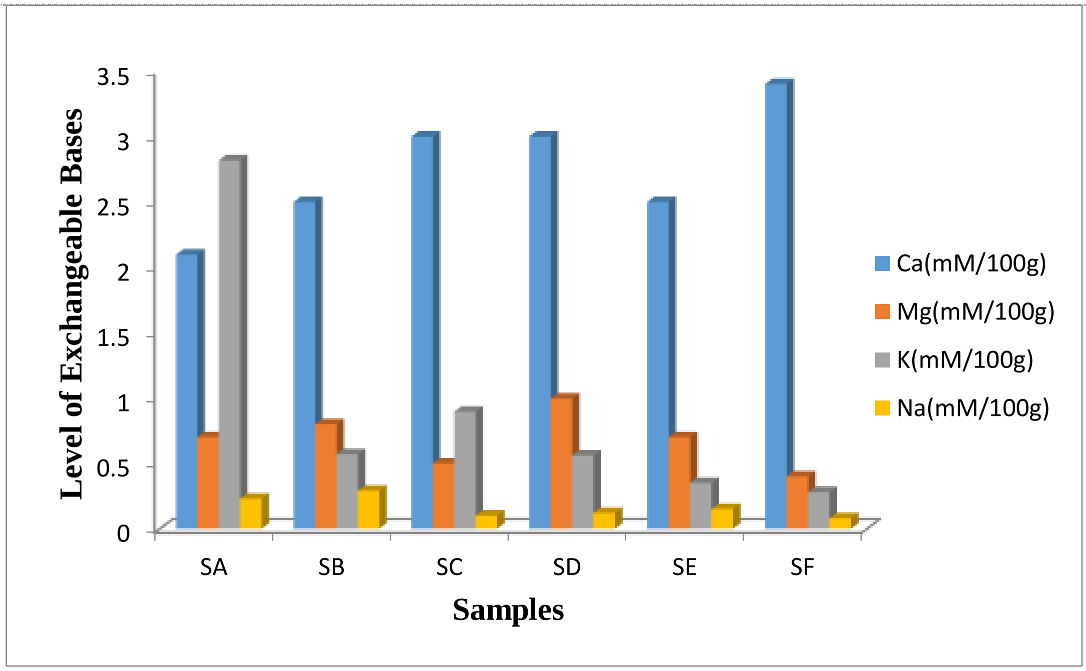

Figure 3.13: Chart showing the level of exchangeable bases.

3.7 Conductivity

The soil sample has the highest conductivity of 584µscm while the lowest conductivity recording was 110µscm of the sample as shown in table 3.6 given below. Most of the samples have higher conductivity hence accelerating dispersion of soil properties under erosive action of water erosion [16].

Table 3.6: Conductivity of soil

Samples	Conductivity (µscm)
S_A	584
S_B	387
S_C	186
S_D	164
S_E	271
S_F	110

3.8 Soil pH

The Table 3.7 below shows the results of pH of acidity and alkalinity of the soil samples at the gully site. This greatly influences the soil erosive action which is similar to the result of Olubanjo, [12].

Table 3.7: Soil pH values

Samples	PH
S_A	8.39
S_B	6.48
S_C	7.36
S_D	7.17
S_E	6.87
S_F	7.55

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IV. CONCLUSION

The physical and chemical properties of the soil at the gully site at different locations were carefully studied. The physical properties of the soil evaluated include particle size analysis, direct shear test, liquid limit, plastic limit, The result shows that the soil strength is not compacted thereby causing it to erode easily, the liquid and plastic limit is low thereby causing the soil properties to erode easily, the particle size analysis obtained has more coarse sand causing the soil to erode easily. The chemical properties of the soil evaluated include soil organic matter, cation exchangeable capacity such as potassium, sodium, calcium and magnesium), the pH and soil conductivity. The result shows that soil organic matter contents on the surface of the gully erosion sites are very high thereby increasing the extent of surface run-off encroaching deeply into the sub-soil, the cation exchangeable capacity contributes to this course as well as a result of their higher and lower concentration in the soil properties at the gully erosion sites. The pH and soil conductivity also plays a vital role in this course of gully erosion formation. To proffer solution to this menace, the construction of check-dams should be encouraged to reduce the velocity of water runoff, the planting of shrubs and trees should be encouraged on the side and floor of the gully in order for lost soil to be reclaimed. Based on the study of the soil physical and chemical properties obtained from the experiment conducted on the ground floor of the gully erosion sites, it is therefore recommended that controlling gully erosion, temporary physical structural measures such as gully reshaping, brushwood, sandbag, loose stone, gabion and arc-weir check-dams are used to dissipate the energy of runoff and to keep the stability of the gully; check-dams are to be constructed across the gully bed to stop channel erosion by reducing the original gradient of the gully channel; planting of vegetative plants and trees on the head, floor and sides of the gully; by construction of reinforced culverts and bridges where prominent run-off is observed.

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ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

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CITE AN ARTICLE

Olubanjo, O. O., & Olubanjo, A. M. (2018). THE EFFECT OF GULLY EROSION IN ILARA-MOKIN, ONDO STATE, NIGERIA. *INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY, 7*(7), 205-218.