GEOPHYSICAL AND GEOTECHNICAL EVALUATION OF EROSION SITES IN EBEM-OHAFIA AREA OF ABIA STATE, SOUTHERN NIGERIA.

ABSTRACT

This work is an integrated evaluation of the external and internal structures of an erosion site in Ebem-Ohafia area of Abia state, Nigeria using the geophysical and geotechnical methods of investigation. The geophysical method used was the electrical method which employed the Schlumberger electrode configuration with maximum half current electrode spacing of AB/2 = 165m, and 4 vertical electrical sounding (VES) data were acquired. Results show that the top soil resistivity values vary from 58.8 Ωm – 886.6 Ωm, that of the weathered layer vary from 100 Ωm - 3586.6 Ωm; and the maximum depth of each sounding location varies from 33.4 m - 59.6 m. In the geotechnical approach, four soil samples from each of the sounding locations were used for the study. The geotechnical results show that the soil has relatively high clay content with plasticity index ranging from 6.0% -12.0%. The consistency limits of the soils generally indicate low to medium plasticity. The natural moisture content varies from 5.3% to 9.4%; while the liquid limit ranges from 27.4% - 41.1%. By using the resistivity values together with plasticity index in the evaluation, it is established that the higher the value of layer resistivity, the lower the plasticity index of the layer. This indicates that the vicinity of VES 1 is the most erosion-prone locality in the study area, while the vicinity of VES 4 remains stable. The plastic index of the soils within the area is adjudged to be of low to medium plasticity (, 20 %); hence, the soils are expected not to exhibit high cohesion potential. It was however concluded that geomorphologic and anthropogenic factors are the major causes of the erosion menace in the area. Subsequently, good agricultural practices and regulars monitoring of the area is recommended.

Keywords: *Geo-electrical data; plasticity index; geomorphology, erosion menace.*

1.0 INTRODUCTION

Soil erosion is a geo-morphological process which results in the gradual or quick removal of the surface layer of weathered rock or sediments by agents of denudation and the subsequent transportation to another depositional environment.

It is a natural process, but human (anthropogenic) activities significantly contribute to activities stimulating erosion.

Soil erosion is caused by climatic factors such as wind, storm, temperature and precipitation. Water (rainfall) and wind are responsible for over 80% of the natural causes of erosion (Blanco and Lal, 2010), therefore given similar vegetation and ecosystems, areas with high-intensity precipitation, more frequent rainfall, more wind, or more storms are expected to have more erosion. While on the other hand, incessant cultivation of land on steep slopes, mechanized agriculture, deforestation, roads, anthropogenic climate change and urban sprawl are amongst the most significant human activities stimulating erosion (Julien, 2010). Also, the tillage of agricultural lands which breaks up soil into finer particles increases wind erosion rates because the smaller particles are easily picked up by the wind. For the fact that most of the trees are mainly removed from agricultural fields, winds travel at higher speeds in such an open area (Whitford, 2002).

It can also be caused by geological factors such as sediment rock type and its porosity and permeability. The composition, moisture, and compaction of soil are all major factors in determining the erosivity of rainfall. Sediments containing more clay tend to be more resistant to erosion than those with sand or silt, because the clay helps bind soil particles together (Nichols, 2009). The topography of the land also determines the velocity at which surface runoff will flow, which in turn determines the erosivity of the runoff.

47　There are four types of erosion resulting from rainfall: splash, sheet, rill, and gully erosion.
48　Splash erosion which is generally seen as the first but least severe stage in the soil erosion
49　process is followed by sheet erosion, then rill erosion and finally gully erosion being the most
50　severe of the four (Zachar, 1982; Toy. et al, 2002).
51　Erosion rates dictate the morphology of landscapes, and therefore quantifying them is a critical
52　part of many geomorphic studies. Geomorphology pertains to the study of the physical features
53　(landscape) of the surface of the earth in relation to their geological structures. Since the
54　topographic form of landscapes reflects interplay between geology and climate-driven surface
55　processes; therefore these interactions dictate erosion rates and control topography.
56　Geologic factors generally determine topography while climatic factors modify the efficiency of
57　the erosional processes. Therefore, an understanding of relationships between erosion rates and
58　landscape morphology becomes essential to geomorphic studies (Yoo and Mudd, 2008a; Tucker
59　and Hancock, 2010). Thus areas susceptible to extreme gully erosion processes owe their
60　vulnerablity to a combination of distinct geological, geo-morphological, and pedological
61　characteristics (Ogbonna et. al 2011, John et.al, 2015).
62　Methods to directly measure erosion rates are expensive and time consuming (Hurst et.al, 2012),
63　therefore causes of erosion are better studied and erosion-prone areas highlighted for
64　precautionary and remediation actions. Since it is established that geologic factors play crucial
65　role in geomorphology of an area; then the use of geophysical and geotechnical methods in the
66　evaluation of geologic processes of an area therefore comes to play.

67　For the fact that soil comes from a complex interaction between earth materials, climate, and
68　organisms acting over time, soil characterization by sampling and in-situ testing will always face
69　perturbation effects.
70　Alternatively, near surface site characterization using geophysical methods yields important
71　information related to the soil characteristics, and can also provide insight into the processes that
72　control the geomorphic evolution of landscapes (Santamaria et al., 2005; John et.al, 2015).
73　In soil stratification, bulk density, texture (clay content), and water content have been identified
74　as parameters of interest for developing indicators dealing with compaction, decrease in organic
75　matter, erosion and shallow landslides (Grandjean et. al, 2007).
76　Bulk density can be determined from S-wave velocity, electrical conductivity and, to a lesser
77　extent by magnetic susceptibility and viscosity.
78　Clay content can be determined from electrical conductivity, reflectance and, to a lesser extent
79　by S-wave velocity.
80　Water content can be determined from dielectric permittivity, and, to a lesser extent from
81　electrical conductivity and reflectance.
82　From the above indications, soil electrical conductivity integrates several factors, this allows for
83　a more detailed characterization of the soil properties with repeated measurements at the same
84　site, as well as by combining data with other sources of information (John et.al, 2015).
85　In addition to that, Vertical electrical conductivity profiles have lesser soil perturbation effects,
86　and are able to retrieve corresponding variations of soil characteristics with depth by performing
87　measurements with different sensor configurations. Hence, the choice of using vertical electrical
88　sounding (VES) technique of Electrical resistivity method in this study.

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2.0   MATERIALS AND METHODS

2.1 LOCATION AND PHYSIOGRAPHY OF THE STUDY AREA

The study area is located within Ohafia Local Government Area of Abia State which lies between latitude 5°30´ N to 5°45´ N, and longitude 7°45´ E to 7°55´ E. It is part of the tropical rainforest characterized by dry and rainy season with a total annual rainfall of over 1400 mm and an annual temperature range of 23°C to 32°C (Fig. 1).
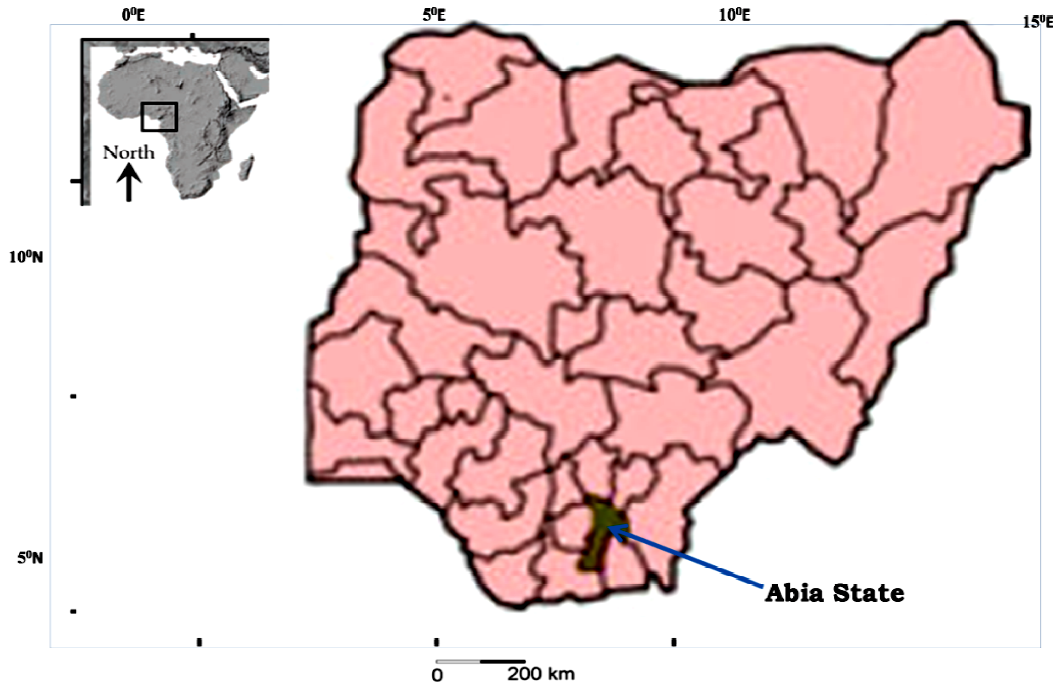
Abia state is characterized by a great variety of landscapes ranging from rolling hills to dissected escarpments, and has major geomorphologic regions (plains and lowlands) such as the Niger River Basin and the Delta; the Coastal plain and the Cross River basin; and the plateau and the escarpment (John et.al, 2015).

This study is necessary because gully erosion is considered a major cause of geo-environmental degradation in the Southeastern part of Nigeria whereby a greater percentage of lands are devastated annually during the rainy season. This also necessitated the study during the rainy season when all major agricultural activities are taking place.

Ohafia local government area falls within the south-eastern part of the Anambra basin. The south-eastern part of the Anambra basin is a part of the scarplands of south Nigeria. The north-south trending of Enugu escarpment forms the major watershed between the lower Niger drainage system to the west, and the Cross-River and Imo drainage systems to the east (Ibe et al., 1998).

2.2 GEOLOGICAL SETTINGS OF THE STUDY AREA

The geology of Ohafia local government area falls within the Deltaic marine sediment of Cretaceous to Recent age. There are three major geologic Formations in the area: the Nkporo Formation, Mamu Formation (Lower Coal Measures) and the Ajalli (false-bedded sandstones) Formation which is the study locality (Fig. 2).

The Ajalli Formation of Cretaceous age consists of red earth sands which form the false sandstones. These in turn consist of great thickness of friable but poorly sorted sandstones. It is overlain by Nsukka Formation.
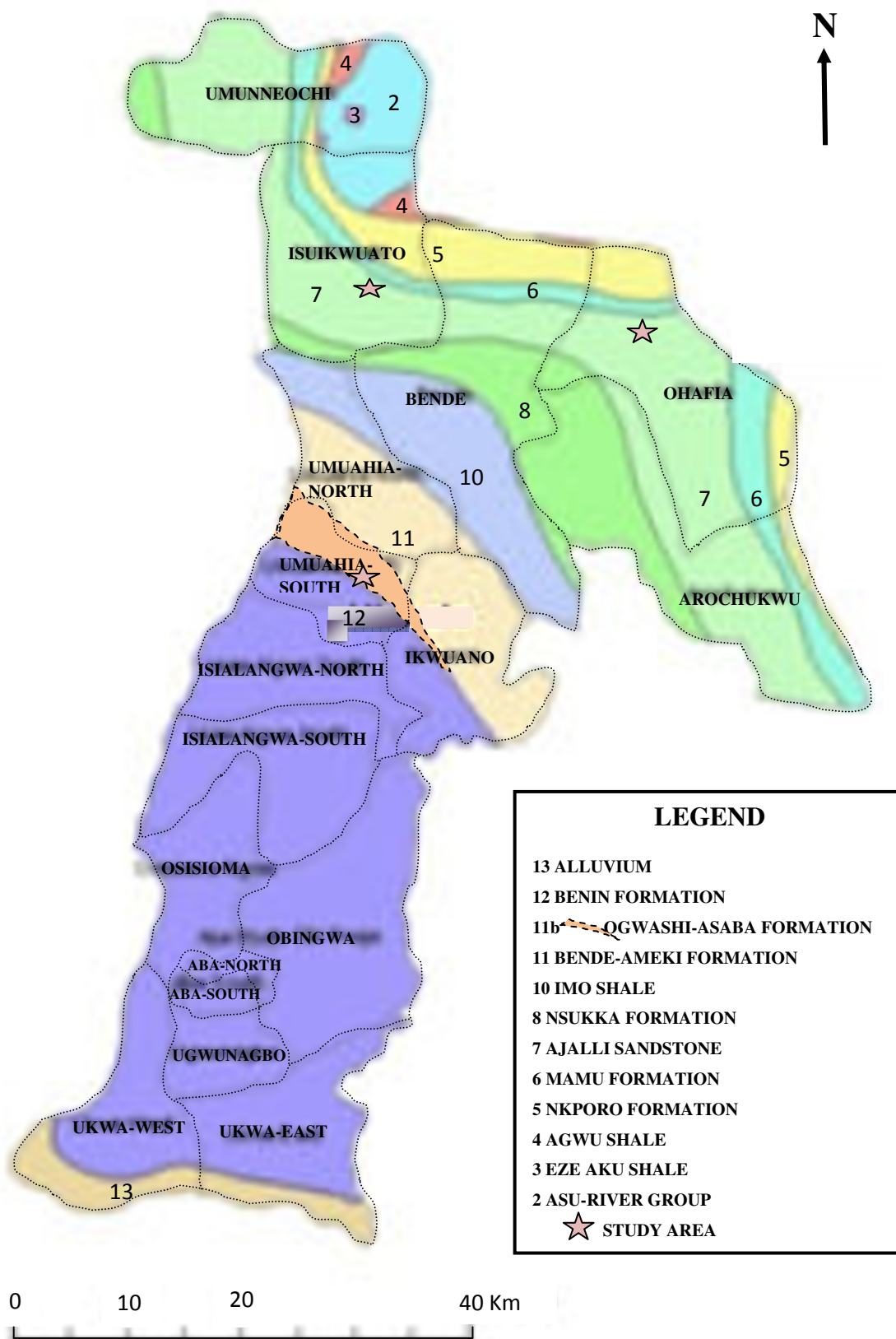
Fig. 2: Geologic map of Abia State showing the Local Government Areas and the study area (Modified after Geological Survey of Nigeria (GSN), 1985).

2.3 GEOPHYSICAL INVESTIGATION OF THE SITE

Four (4) Vertical Electrical Sounding (VES) stations were carried out in proximity to the chosen erosion sites using the Schlumberger configuration (Fig. 3). The Garmin GPS 72 was used in determining the coordinates in longitude, latitude and elevation above mean sea level of each of the sounding point.
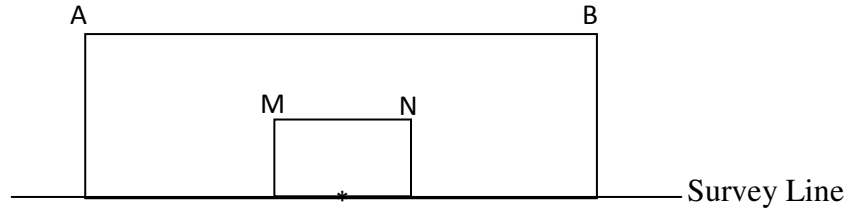
Fig. 3: Schematic diagram of the Schlumberger electrode configuration used in the study.

Then the ABEM Terrameter SAS 4000 which was used in the data acquisition was deployed to the position where a direct current (DC) from a 12V battery linked to the Terrameter was passed into the ground using two metal stakes (current electrodes 'AB/2') linked by insulated cables. The current developed a ground potential difference whose voltage was determined using two other electrodes 'MN/2', which were kept in line with the pair of current electrodes. For each VES profile, the distance between the potential electrodes (MN/2) was varied gradually from 0.5 m to 14 m to obtain a measurable potential difference. The half current electrode separation (AB/2) was also correspondingly varied from 1.5 m to 165 m.

The observed field data which is the ratio of the resulting voltage to the imposed current is only a measure of resistance of the subsurface (ground resistance). This is read off directly from the Terrameter and is used to compute the corresponding apparent resistivity in Ohm-meters by multiplying with the geometric factor (values as functions of electrode spacing), which then gives the required apparent resistivity results as functions of depths of individual layers as shown

below: $$\rho a = \pi R \left(\frac{L^2 - a^2}{2a}\right) \qquad \text{... (1)}$$

Where ρ_a = Apparent resistivity, L = 'AB/2' = Half current electrode spacing (m).

a = MN/2 = Half potential electrode spacing (m), R = Resistance in ohms.

$\pi \left(\frac{L^2 - a^2}{2a}\right)$ = Geometric factor (K).

The sounding curves for each point was obtained by plotting the computed apparent resistivity against the half current electrode spacing (AB/2) on a log-log graph scaled paper and initial estimates of the resistivities and thicknesses of the various geoelectric layers were obtained and used for computer iteration using RESIST software package.

The final interpreted results were used for the preparation of geoelectric sections and histograms.

2.4 GEOTECHNICAL INVESTIGATION OF THE SITE

Soil samples at each erosion study site were collected from the surface to a depth of 1 m and preserved in airtight polythene bags upon collection, then thereafter transported to the laboratory for some geotechnical and soil physical analyses in accordance with British Standard 1377.

The determination of some of the parameters was done after air drying of the samples by spreading them out on trays in a fairly warm room for four days, while that of natural moisture content was done immediately upon reaching the laboratory.

162 The parameters determined include natural moisture content, void ratio, grain-size analysis,
163 liquid limit, plastic limit and plasticity index.

164 The natural moisture content of the samples collected from the field was determined in the
165 laboratory within a period of 24 hours after collection.
166 The field soil samples that were collected and preserved in airtight polythene bags were labelled
167 'm_{wet}'.
168 The wet samples 'm_{wet}' were put in an oven pan and weighed on a scale. The weighed wet
169 samples 'm_{wet}' were heated in an electric oven at a uniform temperature of 110ºC for about
170 100minutes, and then allowed to cool.
171 Upon cooling, the samples are re-weighed on the scale and labelled 'm_{dry}'.
172 The moisture content especially in geotechnics is expressed as a percentage of the sample's dry
173 weight: (% moisture content = u * 100)
174 $\qquad$ where $u = \dfrac{m_{wet} - m_{dry}}{m_{dry}}$ $\qquad$ …2
175 While, porosity is expressed as a percentage of the sample's wet weight: (% moisture content = u
176 * 100)
177 $\qquad$ where $u = \dfrac{m_{wet} - m_{dry}}{m_{wet}}$ $\qquad$ …3
178 Porosity is the ratio of the volume of voids (containing air, water, or other fluids) in a soil to the
179 total volume of the soil expressed as void fraction usually between 0 and 1, or as a percentage
180 between 0 and 100.

181 In order to conduct the sieve analysis, the soil samples were first oven-dried and then all lumps
182 broken into smaller particles. The soil is then shaken through a stack of sieves ranging from BS
183 2.00mm to BS 0.075mm with a pan below the stack.
184 After sieving, the mass of soil retained on each sieve is determined and expressed in percentage:
185 Mass of soil retained $= \left(\dfrac{total\ weight - mass\ of\ weight\ retained}{total\ weight} \right) * 100$ $\qquad$ …4
186 The soil particles that passed through the 0.075mm sieve were subjected to Atterberg limits tests
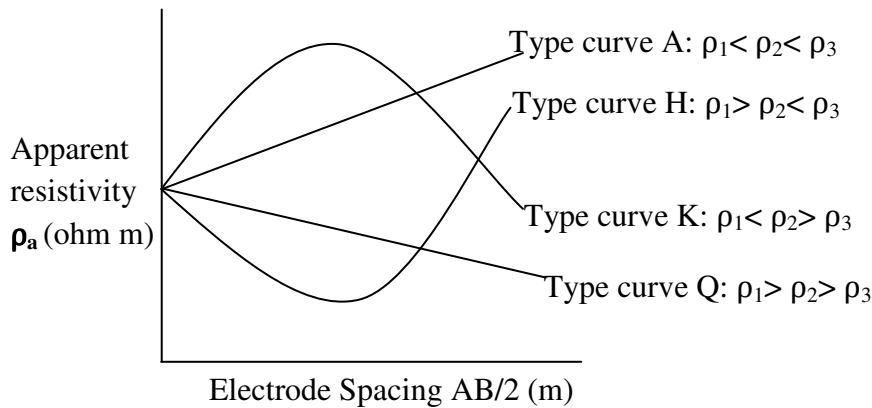187 inorder to determine the consistency of the soils.
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203 **3.0**   **RESULTS AND DISCUSSIONS**
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205 **3.1 GEOPHYSICAL RESULTS**
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207 **3.1.1 Analysis of Sounding Curves**
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209 Sounding curves obtained over a horizontally stratified medium is a function of the resistivities
210 and thicknesses of the layers as well as the electrode configuration. The calculated apparent
211 resistivity is plotted against the corresponding half current electrode separation (AB/2) to
212 construct the VES curves, and the letters Q,A,K and H are used in combination to indicate the
213 variation of resistivity with depth (Fig. 4).
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Type curve A: $\rho_1 < \rho_2 < \rho_3$

Type curve H: $\rho_1 > \rho_2 < \rho_3$

Apparent resistivity ρ_a (ohm m)

Type curve K: $\rho_1 < \rho_2 > \rho_3$

Type curve Q: $\rho_1 > \rho_2 > \rho_3$

Electrode Spacing AB/2 (m)

222 **Fig. 4: Schematic diagram of resistivity type curves for layered structures.**
223
224 Four type curves were identified within the study area. They are AAK of VES 1, KQH of VES 2,
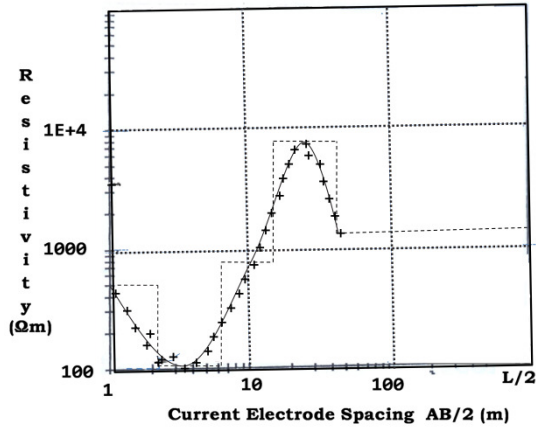225 HQK of VES 3, and KQQ of VES 4 type (Fig. 5, Fig. 6, Fig. 7 and Fig. 8).
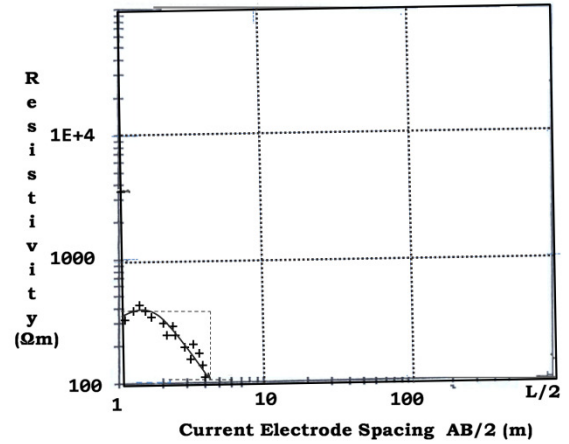226
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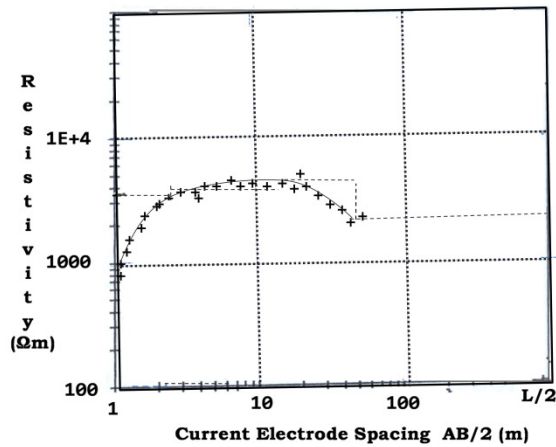
Fig. 5: Typical curve of VES 1
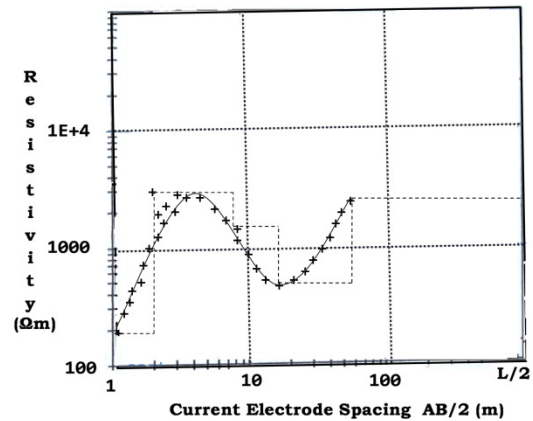

Fig. 6: Typical curve of VES 2

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239 **Fig. 7: Typical curve of VES 3**
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244 **Fig. 8: Typical curve of VES 4**
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247 **3.1.2 Geoelectric Sections**
248 Due to the fact that the electrical resistivity of subsurface materials are at times dependent on the
249 physical conditions of interest such as lithology, porosity, water content, clay content and salinity
250 (Zohdy, 1965; Choudhury and Saha,2004; Amos-Uhegbu et al., 2012). Therefore; electrical
251 resistivity measurements determine subsurface resistivity distributions by differentiating layers
252 based on resistivity values, thus geoelectric sections are presented in connection with the
253 resistivity and thickness of the individual layers (Fig. 9).

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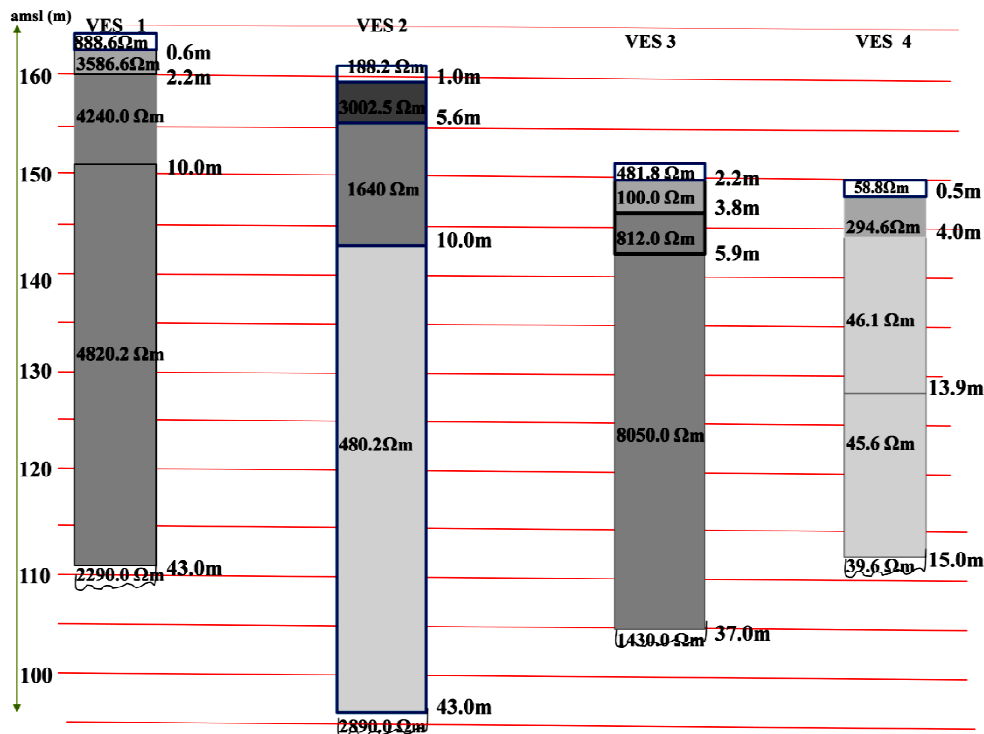
255
256 **Fig. 9: Geoelectric sections of VES 1, 2, 3 and 4**

3.1.3 Geoelectric Parameters

The summary of the VES interpretation shows that there are five geoelectric layers (Table 1). The top soil is composed of resistivity values ranging from 58.8 Ωm – 886.6 Ωm and thicknesses between 0.5 m – 2.2 m. While the weathered layer resistivity values ranges from 100 Ωm - 3586.6 Ωm with their corresponding thicknesses of ranging from 2.2 m – 5.6 m. Also total thickness of each VES station ranged from 33.4 m – 59.6 m.

**Table 1: A summary of the VES interpretation results**

VES Station	Location	GPS Reading		Type curve	Number of layers	Resistivity of layers (Ωm)	Thickness of layers (m)	Total thickness (m)	Fitting error (%)
		Elevation (m) m.s.l	Co-ordinates						
1	Ebem Ohafia 1	164.7	$5^0 38.214^! $ N $7^0 49.409^! $ E	AAK	5	ρ_1=888.6 ρ_2=3586.6 ρ_3=4240.0 ρ_4=4820.2 ρ_5=2290.0	t_1 = 0.6 t_2 = 2.2 t_3 = 10.0 t_4 = 40.9 t_5 = ?	53.7	2.0
2	Ebem Ohafia 2	164.3	$5^0 37.888^! $ N $7^0 49.709^! $ E	KQH	5	ρ_1=188.2 ρ_2=3002.5 ρ_3=1640.0 ρ_4=480.2 ρ_5=2890.0	t_1 =1.0 t_2 = 5.6 t_3 = 10.0 t_4 = 43.0 t_5 = ?	59.6	2.3
3	Ebem Ohafia 3	153.6	$5^0 37.862^! $ N $7^0 49.696^! $ E	HQK	5	ρ_1=481.8 ρ_2=100.0 ρ_3=812.0 ρ_4=8050.0 ρ_5=1430.0	t_1 = 2.2 t_2 = 3.8 t_3 = 5.9 t_4 = 37.0 t_5 = ?	48.9	2.5
4	Ebem Ohafia 4	149.9	$5^0 37.428^! $ N $7^0 49.527^! $ E	KQQ	5	ρ_1=58.8 ρ_2=294.6 ρ_3= 46.1 ρ_4=45.6 ρ_5= 39.6	t_1 = 0.5 t_2 = 4.0 t_3 = 13.9 t_4 = 15.0 t_5 = ?	33.4	2.7

3.2 GEOTECHNICAL RESULTS

Geotechnical characteristics of soils determine their structures which relates to the physical state of the soil complex. The parameters that make up the soil structure include properties such as soil texture and grain-size distribution, bulk density and moisture content, porosity and permeability etc. These parameters in turn aid in determining the stability of soils, thus influencing the resultant arrangement/re-arrangement of soil structures.

3.2.1 Soil texture and Mechanical sieve analysis

Soils that are largely made up of fine particle are likely to have more chemical reactions and exchangeable cations, but a reduction in the silt and clay fractions tends to lower the reaction thus leading to the loss of top soil. Based on particles size, finer particles are defined as particles less than 0.075 mm in diameter (Fig. 10).
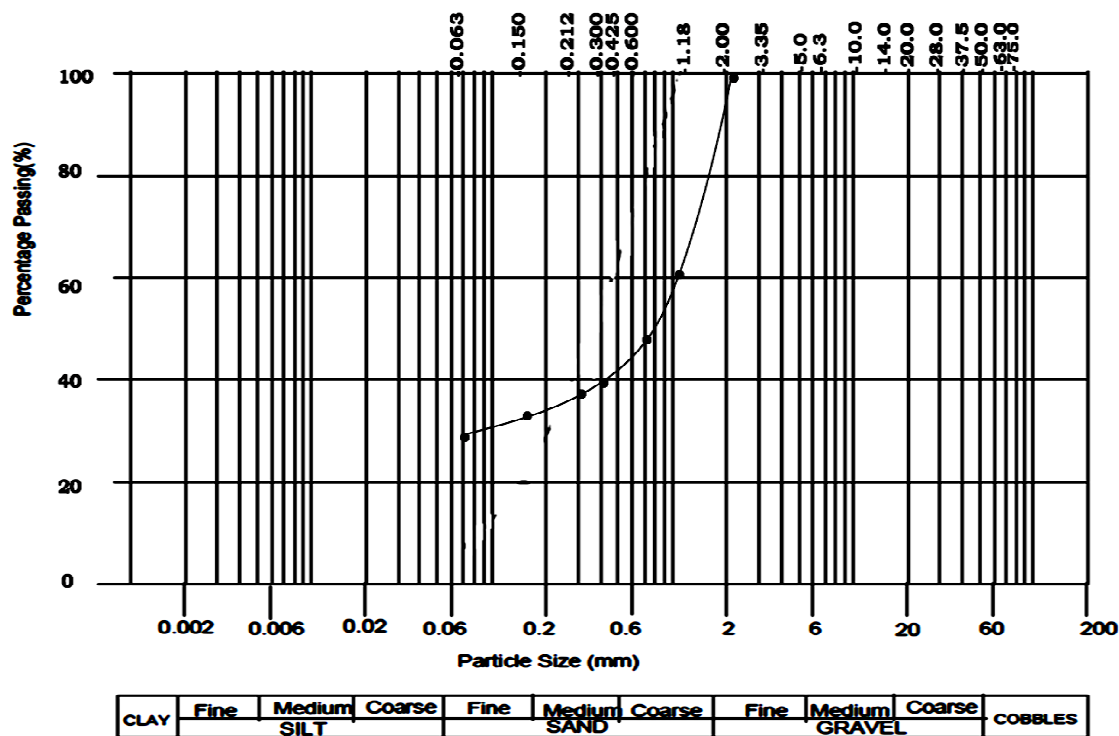
Fig. 10: The grain size distribution curve of OHAFIA 1 soil sample

Grain size distribution analyses show that the tested soils range from 30 - 35% passing the 0.075 mm sieve (Table 2). The finer particles that passed through the 0.075mm sieve were subjected to Atterberg limit tests.

Table 2: Soil textural analysis of the top soils of the erosion sites in the study area

Sample Location	Textural characteristics	Percentage passing the sieve diameter (%)			Remarks
		0.075mm sieve	0.6mm sieve	2.00mm sieve	
VES 1	Loose gritty medium to fine grained sands	30.0	48.4	100.0	Brownish-red silty-sand
VES 2	Loose gritty fine grained sands	32.0	49.0	100.0	Brownish-red silty-clay sand
VES 3	Sticky medium to fine grained silty sands	33.0	49.0	100.0	Brownish-red silty-clay sand
VES 4	Malleable fine grained clayey sands	35.0	46.1	100.0	Brownish-red clayey sand

285 **3.2.2 Water content and void ratio**
286 The natural moisture content of the tested soil samples ranges from 5.3% - 9.4% (Table 3).
287 Sandy soils fall within the range of 5 to 15% (Terzaghi et al. (1996). Therefore tested soil
288 samples are adjudged to be sandy deposits.

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290 **3.2.3 Atterberg limits**
291 The result of the finer soil samples subjected to Atterberg limit tests shows that the lowest value
292 for Liquid limit is that of Ohafia 3 which is 27.4%; while the highest value is that of Ohafia 4
293 which 41.1%.
294 On the other hand, Ohafia 3 also recorded the lowest Plastic limit which is 19.2%, while Ohafia
295 4 of 29.1% has the highest (Table 3).

296 **Table 3: A summary of the results of the soil geotechnical characteristics**

	Natural Moisture Content (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity index (%)
VES 1	5.3	32.0	26.0	6.0
VES 2	7.8	30.3	20.1	10.2
VES 3	7.0	27.4	19.2	8.2
VES 4	9.4	41.1	29.1	12.0

297

298 But since soil consistency is a measure of the degree and kind of cohesion and adhesion between
299 the soil particles in relation to its resistance to deformation; and varies with moisture content, and
300 soil minerals. Therefore, the difference between the liquid limit and the plastic limit (plasticity
301 index) is of utmost concern (Table 4).

302 **Table 4: Plastic indices and their corresponding state of plasticity (Modified after**
303 **Burmister, 1997)**

Plasticity Index	State of plasticity
0	Non-plastic
<5	Slightly plastic
5-10	Low plastic
10 - 20	Medium plastic
20 - 40	Highly plastic
>40	Very high plastic

304

305 Soils with high plasticity index (PI) tend to be clay, those with a lower PI tend to be silt, and
306 those with a PI of 0 (non-plastic) tend to have little or no silt or clay.
307 Plasticity index is reported as NP (non-plastic) when either the liquid limit or plastic limit cannot
308 be determined especially when the soil sample is extremely sandy, or when the plastic limit is
309 equal to or greater than the liquid limit.
310 The plasticity index gives an indication of, among other things, an increase in moisture content
311 required to convert a soil from a semisolid to a liquid state. It is the range in moisture at which a
312 soil is in a plastic state, and therefore may be considered as a measure of the cohesion possessed
313 by a soil.

314 From the result of the laboratory analysis, Ohafia 1 has the lowest value of plasticity which is
315 6.0%, while Ohafia 4 has the highest plasticity index of 12.0%.
316 The plasticity index of soil samples from Ohafia 1 and Ohafia 3 fall between 5.0% and 10.0%,
317 and are therefore of low plasticity, while Ohafia 2 and Ohafia 4 are of medium plasticity
318 (Burmister, 1997).

319
320 **3.3 INTEGRATED EVALUATION OF THE EROSION SITES**

321 Lithology influences the rate at which erosion occurs. Friability, transportability, infiltration,
322 permeability of different horizons, aggregate stability, surface scaling, top soil depth and water
323 holding capacity are inherent depositional parameters of sediments. Areas overlain with sands
324 are prone to erosion menace than areas overlain with clay; this is because clays are stiff and
325 sticky.
326 Since the electrical resistivity of sediments depends on lithology, water content, clay content and
327 salinity; a correlation of VES data with the lithological information of same erosion site is
328 imperative (John et. al, 2015).
329 From the lithologs derived from the erosion sites and geoelectric sections generated from the
330 VES survey; including other lithologs and geoelectric sections sourced from previous studies, a
331 better subsurface understanding of the lithological sequence of the area was obtained.

332 Amos-Uhegbu et.al (2012) lithologically deduced from drill-hole and geoelectric data that
333 Cretaceous sediments within the study area having resistivity < 100Ωm are clays, 100Ωm -
334 500Ωm are silts, 500Ωm - 1500Ωm are fine-grained sands, 1500Ωm - 3000Ωm are medium-
335 grained sands, 3000Ωm - 5500Ωm are coarse-grained sands, and > 5500Ωm as sandstone. Thus,
336 the higher the resistivity of under-compacted / unconsolidated sediment, the lesser clay (fines) it
337 contains; and also less cohesive (sticky) it is in behaviour.
338 From the above indication and also from in-situ observations, the topsoils of VES 1, VES 2, VES
339 3 and VES 4 are sands, silts, silts and clays respectively.
340 The interpreted results were used to prepare a geoelectric cross-section (Fig. 11). The geoelectric
341 cross-sections delineated a maximum of five geoelectric layers comprising the top soil, coarse-
342 grained sands, medium-grained sands, flne-grained sands, silts, clays and sandstone. The top soil
343 is composed of fine-grained sands, silts and clays with resistivity values varying from 58.8 Ωm –
344 886.6 Ωm and thickness of between 0.5 – 2.2 m. The weathered layer ranges in composition

345 from coarse-grained sands to clays and silts with resistivity values that vary between 100 Ωm
346 and 3586.6 Ωm.
347 The primary cause of erosion A (between VES 2 and VES 3) is probably anthropogenic (land
348 cultivation) thus leading to the loss of soil cover (topsoil) of silty origin, and subsequently
349 exposing the sandy weathered layer. This triggered the gully erosion A and the rate of the
350 menace was checkmated by the silty topsoil of VES 3, after the loss of sediment thickness of
351 about 10.7 m along a distance of about 140 m (Fig. 11).

352 Structural stability of the vicinity of VES 3 for about 200 m is observed, but between VES 3 and
353 VES 4, there was loss of sediment thickness (erosion B) of about 3.7 m along a distance of 100
354 m. The primary cause of erosion B (between VES 3 and VES 4) is likely geo-morphological due
355 to facies / terrain change (a change from silty to clayey topsoil along a slope); but could also
356 have been facilitated by anthropogenic activities (land cultivation).
357 For the fact that the slope of VES 1 is towards VES 2, the structural and slope stability of the
358 vicinity of VES 1 is due to the presence of the silty topsoil of VES 2 which is about 1m thick.
359 Any anthropogenic interference on this 1m thick silty topsoil could trigger devastating gully
360 erosion that is likely to erode sediment (sandy) thickness of about 15.6 m of VES 1 and VES 2.
361 On the other hand, the vicinity of VES 4 is totally stable because of the clayey nature of the
362 sediment layers from the topsoil to the depth of the 5th layer which is the limit of the probe.
363 Thus corroborating that the higher the plasticity index of soils, the more cohesive they are; hence
364 the more resistant they are to erosion menace.
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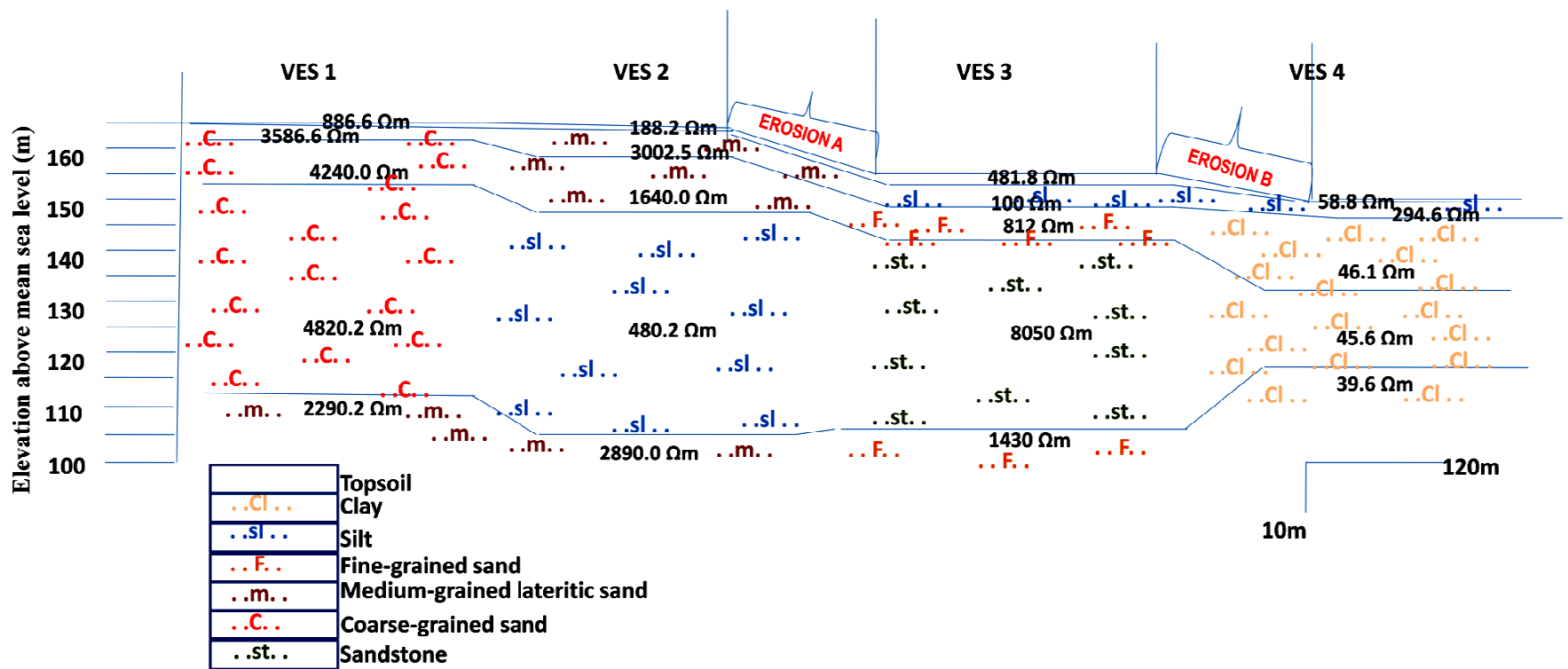
Fig. 11: The geo-electric cross-section of the study area.

4.0 CONCLUSION AND RECOMMENDATION

This study 'Geophysical and geotechnical evaluation of an erosion site in Ebem-Ohafia area of Abia State, Southern Nigeria' which was carried out using geoelectrical surveying method of geophysics, and laboratory geotechnical methods has provided information on the likely causes of erosion menace in the area.

The geophysical results revealed five geoelectric layers within the study area with the resistivity of the topsoils ranging from 58.8 Ωm – 886.6 Ωm; and their thicknesses ranging from about 0.5 m to about 2.2 m.

By using the resistivity values together with plasticity index in the evaluation, it is established that the higher the layer resistivity value, the lower the plasticity index of the layer. Therefore, this indicates that the vicinity of VES 1 is the most erosion-prone locality in the study area; while the vicinity of VES 4 remains stable.

The geotechnical laboratory results show that the natural moisture content ranges from 5.3% to 9.4%.; while the plastic index ranges from 6.0% to 12%. This indicates that the plastic index of the soils within the area is less than 20 % ; therefore can be generally adjudged to be of low to medium plasticity; hence, the soils are expected not to exhibit high cohesion potential.

The vicinity of VES 2 owes its stability to the 1 m-thick silty topsoil layer; therefore any form of interference leading to the removal of the topsoil could trigger another set of devastating erosion menace in the area. Therefore, good agricultural practices should be adopted in the area.

Since erosion menace in the study area is always experienced during the rainy season and unfortunately agricultural practices involving the use of land for cropping is during the rainy season; this involves the removal of vegetative cover and also tillage of lands in the study area. Therefore, re-vegetation should be done to reduce the erosion process such as the planting of deep-rooted perennial grasses and trees in and on the sides of gullies and ephemeral waterways that have the potential to become gullies.

Continuous monitoring of the area and extended investigations to other areas is also recommended.

Finally, the study have shown that by putting into consideration other factors (land use, topography, and lithology); this integrated approach (geoelectrical method of geophysics and geotechnical methods) can aid in identifying areas that are susceptible to gully erosion menace.

It is therefore established that geophysical and geotechnical methods are effective tools in the evaluation of erosion menace.

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