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Research Article

Assessment of Gully Erosion Characteristics and Soil Depth Effect on Clay Mineralogy in Coastal Plain Sands, Akwa Ibom State, Nigeria

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Abstract
A study was conducted in nine gully sites in coastal plain sands Akwa Ibom State, Nigeria. The gullies were group into three broad categories and at three gully slope positions, with a control site. Soil samples were collected with a spade at 0–20 cm and 20–50 cm depths. Data generated were analysed using the analysis of variance. Results revealed that clay minerals on gully categories shows there was no significant effect on the content of minerals. Assessment of clay minerals on gully slope position shows that hematite, magnetite, quartz, K-feldspar, calcite, dolomite, K_20, gibbsite had significant difference among gully slope positions. Clay minerals on soil depth indicated that topsoil content of quartz (39.80 gkg^{-1}) and K_20 (1.09 gkg^{-1}) were significantly higher than the 29.55 and 0.64 gkg^{-1}, respectively, obtained in the topsoil.
Keywords: Soil Erosion, Gully Categories, Gully Slope Position, Soil Depth, Clay Mineralogy.

Introduction

The dislodged, transported and deposited of materials in the landscape are caused by wind or water erosion and the severity of erosion processes are determined by the soil particle size, field slope and water flow velocity (Essien and Ogban, 2018; Simeon and Essien, 2024). In furrow irrigation maximum flow velocity is realized close to the inlet and gradually declines over the furrow length. Hence, the sediment load generally increases throughout the first quarter of the field length and steadily declines over the second half of the field (Trout, 1996; Essien *et al.*, 2023a). Soil erosion from the upstream end can be up to six times (Ogban *et al.*, 2022; Fernandez–Gomez *et al.*, 2024) or 20 times greater (Trout, 1996) than the furrow average.

In the field, erosion is often observed as alterations in furrow cross section (Horst *et al.,* 2005). Furrows are typically formed into a V–shaped cross–section at the start of the season. A combination of soil erosion and slumping causes the channels to widen and become shallower with a flat bottom (Segeren and Trout, 1991; Essien, *et al.*, 2024a). Furrows in fields with steeper slopes tend to become deeper and narrower (Trout and Kemper, 1983). The alteration in cross section is also affected by the flow regime as surge inflow was found to remove greater amounts of material from the side walls compared to continuous inflow (Horst *et al.,* 2007), and thus lead to gully erosion.

Gully erosion usually represents a permanent loss of soil, where agricultural production proceeds without appropriate protective measure and recultivation. This phenomenon is critical and the most damaging in the soils of southeastern part of Nigeria. Gully erosion is a relatively deep, vertical–walled channel recently formed within a valley where no well–defined channel previously existed (Bettis III, 1983). 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 operation (Essien *et al.*, 2023b; Essien *et al.*, 2025b). Gullies can be active (actively eroding) or inactive (stabilized). Active gullies, according to Poesen *et al.*, (2003), can occur where the erosion is actively moving up in the landscape by head–cut migration. Ogban and Edoho (2011) viewed active gully as a young and head ward erosion with incision actively occurring at the rate of 3.30 meters per year. In their studies the meta–stable gully (Ms–2) was an old gully, stabilized by vegetation (Ogban and Edoho, 2011).

Gully erosion triggered by human exploitation of natural ecosystems in different from such as forest clear cutting, tillage, range land change to rainfed farm, urban development, road construction in recent century in different parts of the world (Croke and Mockler, 2001; Nachtergaele, 2001; Essien, *et al.,* 2019; Essien *et al.,* 2024b).

The mechanical characteristics of clay minerals such as liquid limit, plasticity limit and specific surface area exert strong influence on crack tension and slab failure in gully erosion, when clay content reaches more than 30% (Frydman *et al.,* 2007; Ogban and Essien, 2016). Soil minerals such as smectite, vermiculite, shale and mudstone are the dominant minerals in some tropical soils (Owliaie *et al.,* 2006; Essien *et al*., 2025a). Smectite is important clay minerals in terms of erosion, sedimentation and land slide occurrence it also contributes to the high cation exchange capacity (CEC) and causes high erodibility to the soils due to its unique characteristics mainly weak inter–layer bonding, high swelling and cracking potential and high-water adsorption capacity. It can expand up to 30% in volume for water adsorption contributing to creeping pipe–ping, landslide and gully erosion (Lutengger and Cerato, 2008). Vermiculite minerals affect gully erosion in the arable lands. The low occurrence of vermiculite in the calcareous soil is mainly related to its lower stability under high pH, low aluminum (Al) activity and the presence of large amounts of silicon (Si) and magnesium (Mg) in soils (Khomali and Abtahi, 2003). The non –phyllosilicate soils contained expandable minerals such as calcite, dolomite and feldspar and other common minerals in the semi–arid region. In this region, unlike smectite and vermiculite do not contribute to piping, gully and sliding phenomena. The surface charge of these minerals are close to zero, resulting in a soil with intermediate aggregate stability and also contribute to the intermediate soil losses (Lado and Ben Hur, 2004). Illite, kaolinite quartz and feldspar are also other minerals in the soil and rock in the religion affecting soil erosion, due to their specific properties. Low crystalline illite, kaolinite, fine quartz and feldspar in the sedimentary rocks are found in these areas (Baioumy and Gharaie, 2008). In this religion, the occurrence of kaolinite, illite and chlorite in the soil is due to their origin from the surrounding cretaceous parent rocks (Khormali and Abtahi, 2003). Mudstone is the common intermediate among sedimentary rocks in most parts of the area and induces a soil with low porosity, high run–off potential and erosion hazard.

Gully erosion is the worst stage of all types of soil erosion and remains one of the most challenging environmental problems in the globe, moreover, there is dearth information regarding gully erosion on coastal plain sands in Akwa Ibom State, Southeastern Nigeria. Therefore, there is need to assess clay mineralogical effect on gully erosion soils on coastal plain sands in Akwa Ibom State, southeastern, Nigeria.

Materials and Methods

Environment of the Study Area

The study was conducted on soils of coastal plain sands areas in Akwa Ibom State, southeastern Nigeria. Akwa Ibom State is situated between latitudes $4°30^1$ and $5°30^1$N and longitudes $7°30^1$ and $8°20^1$ E. The state has a total land area of 8,12 km^2 and a shoreline of 129 km long (Petters *et al.,* 1989). The climate of the area is characterized by two seasons, dry and rainy seasons. The dry seasons lasts from November to March, while rainy season occurs between the months of April and October. Rainfall is heavy ranging from over 3,000 mm along the coast to 2,000 mm on the northern fringes. Temperatures are uniformly high throughout the year with slight variation between 26° and 28°C. High relative humidities are common, with a mean of 75% while solar radiation ranges from 6–15 KJ per day (Petters *et al.,* 1989). The soils of the area are derived from sandy parent materials and are highly weathered and dominated by low activities of clays. Sands and clays from river deposition cover a greater part of the state and constitute the Benin formation, also known as the coastal plain sands (Petters *et al.,* 1989). The soils have excellent physical conditions for seed bed preparation but are fragile because of the sandiness of the surface soils (Ogban *et al.,* 2022; Mark *et al.,* 2024; Sam *et al*., 2025).

The soils in the nearly flat floodplain and depressional areas are clayey throughout; poorly to very poorly drained. Alluvial is the most common profile feature (Ogban and Essien, 2016; Akata *et al*., 2024a). Akwa Ibom State is situated in the humid region of the southeastern Nigeria. The natural vegetation is mainly savannah with some relicts of rainforest distributed in patches (Jungerius, 1964). The native vegetation has been almost completely replaced by secondary forest of perdommantly wild oil palms, wood shrubs and various grass undergrowth (Petters *et al.,* 1989). The predominant land use practice in the area as in most of the south–east includes arable crop production, cash crop production and non–agricultural uses such as industrialization, residential, commercial and road construction. The major crops grown are cassava, yam, maize, cocoyam, potato and vegetables (Akpan *et al.,* 2023; Akata *et al.,* 2024b; Ben *et al.,* 2024; Akpan *et al.,* 2025).

Soil Sampling

The study was conducted in nine gully erosion sites on the coastal plain sands in Akwa Ibom State southeastern Nigeria. The nine gullies were selected for the study based on their stages of gully evolution and were grouped into three broad categories based on their dynamics, namely, active gullies (AcG), meta–stable gullies (MsG) and stabilized/old gullies (SoG). The longitudinal section of each gully was partitioned into upper (US), middle (MS) and lower (LS) gully slopes positions for this study. The gully face/side was reconditioned and soil samples collected. Soil samples were collected with a spade at 0–20 cm and 20–50 cm depths and at a control site of 50 cm away from the gully area. The study was therefore a 3 x 3 x 2 factorial experiment in randomized complete block (RCB) design, with gully category in main plot, gully slope position in subplot and soil depth in sub subplot. In the field geographic positioning system (GPS) were used to obtain the coordinates of the sampling position (Table 1 to 3). Morphological features of the gully and the gully parameters like gully length and width, gully depth, dominant vegetation, land use were determined. The gully volume/size: -The gully volume/size was calculated as follows:

$$GV = GL \times GW \times GH \text{ (m)}$$

Where,
GV = gully volume (m^3),
GL = gully length (m),
GW = gully width (m),
GH = gully height (m)

Laboratory Analysis

The bulk soil samples were air dried and sieved through 2 mm mesh to obtain the fine earth used for chemical analysis. Clay minerals were determined by X–ray diffractrometry (XRD) with a SIEMENS D500 diffractrometer, using Ni–filtered CuKa–radiation after various pretreatments. The geochemical composition of the total elements in the fine earth fractions (< 2. 00 mm soil fraction) were determine using SIEMENS SRS 200 X–ray fluorescence (XRF) equipment. Fe and Al were obtained through this determined represented as Fe_2O_3 (Fet) and Al_2O_3 (Alt), respectively (McKeaque and Day, 1966).

Statistical Analysis

The data generated were fitted into a 3 x 3 x 2 factorial in randomized complete block (RCB) design and subjected to analysis of variance and multiple regression analysis. Significant differences were tested at probability level of 5%.

Results

Morphological properties of the gullies elevation, height and width of the gullies are presented in Table 1. Active gullies had mean elevation of 33.67±17.62m at the upper slope (US), 31.33±16.26m at the middle slope (MS) 30.00±14.93m at the lower slope (LS), 34.67±18.01m at the control area and 25.00±14.53m at the stream area. For the meta–stable gully, mean elevation were 54.67±29.50m, 54.00±28.16m, 51.67±27.54m. 57.33±31.18m and 31.18m and 31.67±11.06m for US, MS, LS, control and the stream area, respectively. Mean elevsations of stabilized/old gullies were 44.00±17.06m, 41.33±16.44m, 31.00±4.58m, 52.33±15.01m and 19.00±6.08m for US, MS, LS, control and the stream area, respectively. For all gully categories the highest elevations were obtained at the control side, followed in the order by US, MS, LS and the stream area. The elevations of the gullies varied highly (CV = 35%) across the study area.

The height of active gullies were 0.70±0.10m at the US, 0.88±0.13m at the MS and 0.35±0.09m at the LS. Meta–stable gullies were 2.17±1.15m, 3.32±1.44m and 2.33±2.14m in height at the US, MS and LS, respectively, while those of stabilised gullies were 11.55±4.05, 6.67±2.25m and 4.40±2.65m for US, MS and LS, respectively. Active gullies were small gullies (<1.5m), while meta–stable gullies were all medium gullies and old/stailished gullies were large gullies, expect the lower gullly slope position, which was a medium gully. The width of active gullies were 1.07±0.61m, 0.98±0.46m and 1.28±0.29m at the US, MS and LS. Width of meta–stable gullies were 6.33±6.82m, 9.23±7.39m and 7.73±11.06m at the US, MS and LS, respectively. Gully width increased width the age of gully as follows: Active gully > meta–stable gully > stabilized gully.

The length of the studied gullies are presented in Table 2. Total gully length of active gully, meta–stable gully and stabilized gully were; 275.67±32.65m, 21.67±99.29m and 484.83±319.53m. Stabilized gully had the highest total length of gully, followed by active gully and lastly by meta-stable gully. Gully length from the gully head to the point of termination was greater than from the point of termination to the stream area.

Table 1. Elevation, height and width of the studied gullies.

	Elevation					Height			Width				
Location	**US**	**MS**	**LS**	**CT**	**Stream area**	**US**	**MS**	**LS**	**US**	**MS**	**LS**	**Dominant landuse**	**Vegetable active gully**
Active gully													
Nsit Ibom	39	37	36	43	24	0.6	0.75	0.25	0.4	0.65	0.95	Cassava, maize plantation	Arable cropping
Etinan	14	13	13	14	11	0.7	1.0	0.4	1.6	1.7	1.5	*Chromolaena odorata* and shrubs	Fallow land
Ibesikpo	48	44	41	47	40	0.8	0.9	0.4	1.2	1.3	1.4	*Chromolaena odorata* and shrubs	Fallow land
Mean	33.67	31.33	30.00	34.67	25.00	0.70	0.88	0.35	1.07	0.98	1.28	-	-
SD (±)	17.62	16.26	14.93	18.01	14.53	0.10	0.13	0.09	0.61	0.46	0.29	-	-
CV (%)	52.33	51.89	49.78	51.95	58.10	14.29	14.24	24.74	57.28	47.14	22.83	-	-
Meta-stable gully													
Ibiono Ibom	76	75	70	81	42	1.5	4.2	1.2	2.2	7.3	1.5	*Chromolaena odorata* and shrubs	Fallow plant
Uyo	67	65	65	69	33	3.5	4.1	4.8	14.2	17.4	20.5	Maize, cassava, melon plantation	Arable cropping
Nistatai	21	22	20	22	20	1.50	1.65	1.00	2.6	3	1.2	*Chromolaena odorata* and shrubs	Fallow land
Mean	54.67	54.00	51.67	57.33	31.67	2.17	3.32	2.33	6.33	9.23	7.73	-	-
SD (±)	29.50	28.16	27.54	31.18	11.06	1.15	1.44	2.14	6.82	7.39	11.06	-	-
CV (%)	53.97	52.15	53.30	54.39	34.93	53.29	43.54	91.65	107.62	80.06	142.98	-	-
Stabilized/old gully													
Abak	63	60	36	61	26	16.15	4.2	1.5	31.3	7.5	15.5	*Chromolaena odorata* and shrubs	Fallow land
Itu	39	35	30	61	16	10	8.6	6.7	20.8	23.6	2	Cassava plantation	Arable cropping
Nsit Ubium	30	29	27	35	15	8.5	7.2	5.0	46	34	55	*Chromolaena odorata* and shrubs	Fallow land
Mean	44.00	43.33	31.00	52.33	19.00	11.55	6.67	4.40	32.70	21.70	24.17	-	-
SD (±)	17.06	16.44	4.58	15.01	6.08	4.05	2.25	2.65	12.66	13.35	27.54	-	-
CV (%)	38.77	39.78	14.78	28.68	32.01	35.10	33.72	60.26	38.71	61.53	113.97	-	-
US = Upper slope, MS = Middle slope, LS= Lower slope, CT: Control area.													

Table 2. Length of the studied gullies.

Location	Length of gully from head of gully to termination point	Length of gully from termination point to the stream bank	Total length of gully from gully height to the stream bank
Active gully			
Nsit Ibom	152	120	272
Etinan	245	Control erosion channel	245
Ibesikpo	285	25	275.67
Mean	227.33	72.50	275.67
SD (±)	68.24	67.18	32.65
CV (%)	30.02	92.66	11.85
Meta-stable gully			
Ibiono Ibom	150	Control erosion channel	150
Uyo	335	Control erosion channel	335
Nistatai	175	5	180
Mean	220.00	5.00	21.67
SD (±)	100.37	Not comparable, due to one location	99.29
CV (%)	45.62	Not comparable, due to one location	44.79
Stabilized/old gully			
Abak	127	95	222
Itu	430.5	410	840.5
Nsit Ubium	257	135	392
Mean	271.50	213.33	484.83
SD (±)	152.27	171.49	319.53
CV (%)	56.08	80.39	65.91

Assessment of Clay Mineralogy on Gully Categories

Mean value of clay minerals on gully category are presented in Table 3.

The mean value of quartz (SiO_2) in soil of AcG was 36.30 gkg^{-1}, that of MsG was 32.02 gkg^{-1} while that of SoG was 35.69 gkg^{-1}. There was no significant effect of gully category on the composition of quartz. The mean value of K–feldspar (Al_2SiO_8) in soil of AcG was 14.96 gkg^{-1}, that of MsG was 15.86 gkg^{-1}, while that of SoG was 16.09 gkg^{-1}, there was no significant effect of gully category on the content of K–feldspar. The mean value of calcite (CaO) of gully category in the soil of AcG was 3.11 gkg^{-1}, that of MsG was 4.42 gkg^{-1}, while that of SoG was 4.53 gkg^{-1}, there was no significant effect of gully category on the content of calcite.

The mean value of dolomite (MgO) in soil of AcG was 1.36 gkg^{-1}, that of MsG was 1.89 gkg^{-1}, while that of SoG was 1.95 gkg^{-1}, there was no significant effect of gully category on the content of dolomite. The composition mean value of K_2O in soil of A_CG was 0.67 gkg-^{1} , that of MsG was 0.95 gkg-^{1}, while that of SoG was 0.97 gkg-^{1}, there was no signifcant effect of gully catergory on the composition of K_2O. Mean value of gibbsite (Al $(OH)_3$ in soil of AcG was 0.79 gkg-^{1}, that of MsG was 0.86 gkg-^{1}, while that of SoG was 0.79 gkg-^{1}, there was no significant effect of gully category on the composition of gibbsite.

Mean contect of hematite (Fe_2O_3) of gully categories indicated that hematite in soil of AcG was 1.22 gkg-^{1}, that of MsG was 1.03 gkg-^{1}, while that of SoG was 1.13 gkg-^{1}, these was no significant effect of gully category on the composition of hematite. The mean composition of magnetite in soil of AcG was 0.86 gkg-^{1}, that of MsG and SoG were 0.92 gkg-^{1}, there was no significant effect of gully category on the composition of magnetite.

Content of crystalline and amorphous Fe of gully catergories shows that mean value of crystalline Fe in soil of AcG and SoG were 0.94 gkg^{-1}, while that of MsG was 0.93 gkg^{-1}. Amorphous Fe composition of AcG, MsG and SoG were 1.42, 1.21 and 1.38 gkg^{-1}, respectively, there was no significant effect of gully category on the composition of crystalline and amorphous Fe.

Content of crystalline and amorphous Al of gully categories shows that the mean of value of crystalline Al in soil of AcG was 0.26 gkg-^{1}, while those of MsG and SoG were 0.24 gkg-^{1} each. Amorphous Al composition of AcG, MsF and SoG were 0.30, 0.28 and 0.29 gkg-^{1}, respectively, there was no significant effect of gully category on the composition of crystalline and amorphous Al.

Table 3. Mean content of clay minerals on gully categories.

Gully type	SiO_2 quartz	Al_2SiO_8 K-feldspar	CaO calcite	MgO dolomite	K_2O	Al $(OH)_3$ gibbsite	Fe_2O_3 hematite	Fe_3O_4 magnetite	Fe (Crys)	Fe (Am)	Al (Crys)	Al (Am)
	gkg^{-1}											
AcG	36.30	14.96	3.11	1.36	0.67	0.79	1.22	0.86	0.94	1.42	0.26	0.30
MsG	32.02	15.86	4.42	1.89	0.95	0.86	1.03	0.92	0.93	1.21	0.24	0.28
SoG	35.69	16.09	4.53	1.95	0.97	0.79	1.13	0.92	0.94	1.38	0.24	0.29
Sig	0.75	0.51	0.05	0.06	0.06	0.46	0.67	0.76	1.00	0.28	0.43	0.58
LSD	14.45	1.18	1.18	0.52	0.26	0.07	0.48	0.22	0.15	0.27	0.31	0.33

Note: LSD: Least significant difference; Crys: Crystalline; Am: Amorphous

Assessment of Clay Minerals on Gully Slope Positions

The mean value of composition of Clay minerals under different gully Slope positions are presented in Table 4.

The result shows that in CT soil quartz was 32.66 gkg^{-1}, US soil was 33.63 gkg^{-1}, MS soil was 35.65 gkg^{-1} and LS soil was 36.74 gkg^{-1} (Figure 1), there was no significant effect of gully slope position on the composition of quartz in the soil. The composition mean value K–feldspar indicated that CT soil had 15.19 gkg^{-1}, US soil had 16.51 gkg^{-1}, MS soil had 16.62 gkg^{-1}, while LS soil had 14. 23 gkg^{-1} (Figure 2), there was no significant effect of gully slope position on the composition of K–feldspar in the soils. The mean composition of calcite (CaO) in the soils was 3.08 gkg^{-1} in CT soil, 4.10 gkg^{-1} in US soil, 4.59 gkg^{-1} in MS soil and 4.30 gkg^{-1} in LS soil (Figure 3), there was no significant effect of gully slope position on the composition of calcite in the soil.

The mean composition of dolomite (MgO) in the soils was 1.33 gkg^{-1} in CT soil, 1.76 gkg^{-1} in US soil, 1.99 gkg^{-1} in MS soil and 1.85 gkg^{-1} in LS soil, there was no significant effect of gully slope position on the composition of dolomite in the soils. K_2O mean value composition of gully sope position in the soils was 0.67 gkg^{-1} in CT soil, 0.87 gkg^{-1} in US soil, 1.00 gkg^{-1} in MS soils and 0.93 gkg^{-1} in LS soil, there was no significant effect of gully slope position on the composition of K_2O in the soil.

Gibbsite (Al $(OH)_3$) composition of gully slope positions shows that there were significant differences in soil content of gibbsite among the different gully slope positions with the composition of gibbsite in CT (0.87 gkg^{-1}) being equal with that of LS (0.85 gkg^{-1}), but significantly higher than those of US (0.78 gkg^{-1}) and MS (0.70 gkg^{-1}). Hematite (Fe_2O_3) composition of gully slope positions indicated that soil content was 1.20 gkg^{-1} in CT soil, 1.03 gkg^{-1} in US soil, 1.14 gkg^{-1} in MS soil and 1.15 gkg^{-1} in LS soil, there was no significant effect of gully slope position on the composition of hematite in the soil.

The result of magnitite (Fe_3O_4) compsition of gully slope positions shows that the mean value of the soil content was 0.86 gkg^{-1} in CT soil, 0.94 gkg^{-1} in US soi, 0.97 gkg^{-1} in MS soil and 0.86 gkg^{-1}in LS soil, there was no significant effect of gully slope position on the composition of magnetite in the soil. Crystalline and amorphous Fe composition of gully slope positions revealed that crystalline Fe in the soil content was 1.00 gkg^{-1} in CT soils, 0.95 gkg^{-1} in US soil, 0.89 gkg^{-1} in MS soil and 0.91 gkg^{-1} in LS soil, while that of amorphus Fe were 1.25 gkg^{-1} in CT soils, 1.33 gkg^{-1} in US, 1.25 gkg $^{-1}$ in MS soil and 1.52 gkg^{-1} in LS soil. Crystalline Al recorded 0.24 gkg^{-1} in CT soil, 0.25 gkg^{-1} in US, MS and LS soils, while amorphous of Al recorded 0.28 gkg^{-1} in CT soil, 0.29 gkg $^{-1}$ in US soil, 0.31 gkg^{-1} in MS soil and 0.29 gkg^{-1} in LS soil.

Assessment of Clay Minerals on Soil Depth

The results of the clay mineralogy of the top and subsoil are presented in Table 5.

The mean contents of some clay minerals in the topsoil (0–20 cm) and subsoil (20-50 cm), revealed that the topsoil content of quartz (39.80 gkg^{-1}) (Figure 2) and K_2O (1.09 gkg^{-1}) were significantly higher than the 29.55 and 0.64 gkg^{-1}, respectively, obtained in the subsoil. The reverse was the case for K–feldspar, calcite, dolomite, gibbsite, hematite and magnetite, in which the content of 13.34, 2.54, 1.27, 0.64, 0.90 and 0.81 gkg^{-1}, respectively, were obtained in the topsoil and was significantly lower than the 17.93, 5.50, 2.20, 0.96, 1.36 and 0.99 gkg^{-1}, respectively, obtained in the subsoil. Crystalline and amorphous Fe and Al were not significantly affected by soil depth. The soils were dominated by quartz and K–feldspar while the content of other minerals were low.

Table 4. Mean content of clay minerals on gully slope positions.

Gully slope positions	SiO_2 quartz	Al_2SiO_8 K-feldspar	CaO calcite	MgO dolomite	K_2O	Al $(OH)_3$ gibbsite	Fe_2O_3 hematite	Fe_3O_4 magnetite	Fe (Crys)	Fe (Am)	Al (Crys)	Al (Am)
	gkg^{-1}											
CT	32.66	15.19	3.08	1.33	0.67	0.87	1.20	0.86	1.00	1.25	0.24	0.28
US	33.63	16.51	4.10	1.76	0.87	0.78	1.03	0.94	0.95	1.33	0.25	0.29
MS	35.65	16.62	4.59	1.99	1.00	0.70	1.14	0.97	0.89	1.25	0.25	0.31
LS	36.74	14.23	4.30	1.85	0.93	0.85	1.15	0.86	0.91	1.52	0.25	0.29
Sig	0.93	0.20	0.13	0.14	0.15	0.01	0.89	0.54	0.60	0.29	0.85	0.44
LSD	16.68	2.71	1.36	0.60	0.30	0.09	0.56	0.25	0.17	0.31	0.04	0.04
Note: LSD: Least significant difference; Crys: Crystalline; Am: Amorphous												

Table 5. Means of some clay minerals based on soil depth.

Soil depth	SiO_2 quartz	Al_2SiO_8 K-feldspar	CaO calcite	MgO dolomite	K_2O	Al $(OH)_3$ gibbsite	Fe_2O_3 hematite	Fe_3O_4 magnetite	Fe (Crys)	Fe (Am)	Al (Crys)	Al (Am)
	gkg^{-1}											
0-20 cm	39.80	13.34	2.54	1.27	1.09	0.64	0.90	0.81	0.91	1.28	0.25	0.30
20-30 cm	29.55	17.93	5.50	2.20	0.64	0.96	1.36	0.99	0.97	1.40	0.24	0.29
Sig	<.001	<.001	<.001	<.001	<.001	<.001	0.00	0.01	0.33	0.28	0.7	0.41
LSD	3.47	1.26	0.88	0.35	0.18	0.06	0.25	0.12	0.12	0.22	0.03	0.03
Note: LSD: Least significant difference; Crys: Crystalline; Am: Amorphous												

Figure 1. Comparison of SiO_2 across slope position and depth.

Figure 2. Al_2SiO_8 across slope positions.

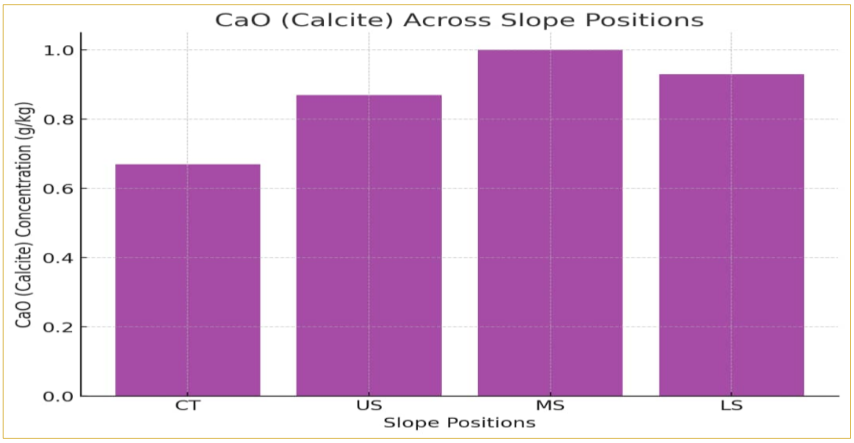

Figure 3. CaO (calcite) across slope positions.

Discussion

In all the gullies control had the highest mean values, may be as a result that certain measures (vegetation cover) were taken into consideration to control as to reduce some of the erosion activities in the area (Essien *et al.,* 2022). In considering the height of gullies, the result shown that middles had the high mean values in active and meta–stable gullies, while upper slope had high value in stabilized/old gully. Consequently, may be because of the stabilized/old gully that resisted the break down of soil aggregate and the other two (active and meta–stable gully), high value in the middle slope was that, the upper slope aggregate break down letter accounted for the middle slope after deposition.

Quartz was dominant in the topsoil than the subsoil because the content of sand in the topsoil was generally higher than that of the subsoil. This is so because sand deposits are made mainly of the mineral quartz and the weathering of any quartz–bearing rock creates sand. Quartz is the most common mineral in the crust of the earth comprising an estimated 35% of all rocks. The oxides of Fe (gibbsite and hematite) were more in the subsoil than in the topsoil comparably, because the subsoil accumulates leached minerals like iron and aluminum oxides. The oxides of Fe are actually what give the reddish colour of the subsoil.

Conclusion

The menace of gully erosion is quite alarming on soil of coastal plain sands Southestern Nigeria, thereby militaling against food production, since hectares of land that would have been used for agricultural purposes are being washed away. Consequent upon this assessment of clay mineralogyal on the gully erosion soils on coastal plain sands in Akwa Ibom State, Southeastern Nigeria were studied. The three gully categories studied showed that clay minerals are washed down (towards the lower slope) left the upper and middle slope with low content of minerals, while the lower gully slope positions dominated with some clay minerals. The subsoil had more of accumulated oxides of Fe, while quartz was lower compared with the topsoil.

Declarations

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