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Gully Morphometric and Soil Physical Properties in Selected Settlements in Akoko Region of Ondo State, Nigeria

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Abstract:
The study was carried out in Akoko Region of Ondo State, Nigeria. The study examined gully characteristics and soil physical properties. The mean values of 76.36m, 1.81m and 8.17m were recorded for gully length, depth and width respectively. Measurements of gully characteristics were done in the dry season using conventional surveying equipment. The gully dimensions measured include: gully length, width, depth and cross section areas. A total of 20 gullies were studied. Soil samples were also taken from the studied gullies for the determination of the soil bulk density and particle size distribution. Descriptive statistics were such as mean and standard deviation used to achieve clarity.
The mean values of 76.36m, 1.81m and 8.17m were recorded for gully length, depth and width respectively while the mean value of sediment loss was 2,577.59. The value of depth suggested that the gullies in the study area are predominantly shallow and exhibited V-shaped cross section area. The mean cross sectional area was 16.72m². Findings show that the soil in the study area is predominantly sandy clay loam with 48.50% sand, 12.51% silt and 30.25% clay at the upper soil horizon while it was predominantly clay (42.60%) at the gully floor. These results further confirmed that along the depth of soil profile, proportion of clay content increases thereby increasing the soil cohesiveness and resistant to detachment. Significant relationship was observed between sediment loss and gully width, gully depth, gully length and cross sectional area. This study recommended that preventive measures such as planting of cover crops and mulching should be put in place.

Keywords: *Gully erosion, sediment loss, soil physical properties, gully attributes.*

1. Introduction

Gully resulting from accelerated soil erosion has been an issue of growing concern not only in the humid tropics but in many parts of the world (Adediji et al., 2009). Gullies have been recognized as an important environmental threat in many parts of the world (Ionita, 2006). This phenomenon has been identified as a major factor in soil degradation, water quality deterioration and changes in channel morphology in the humid tropics (Meijerink et al, 1994). A gully is formed when running water erodes sharply into soil, typically on a hillslope. Gullies are antecedents of the removal of soil by running water (Ibitoye et al., 2008) and the amount of erosion depends on a combination of the power of the rain to cause erosion and the ability of the soil to resist the rain impact (Hudson, 1957). Soil erosion is a geomorphic process whereby the surface layer of weathered rock is loosened and carried away by wind, running water, wave, ice and a lower horizon in the soil or rock is exposed (Okwu-Delunzu et al., 2018). Soil erosion is continuously triggering the land degradation and expansion of wastelands in many areas of world (Mekonnen et al., 2015; Erkossa et al., 2015). Soil erosion is a severe geomorphic hazard traditionally associated with livelihood in the tropical and semi-arid areas, influencing long-term effects on soil productivity and sustainable agriculture (Dai, et al., 2015; Prosdocimi et al., 2016; Novara et al., 2016). Gully erosion is a highly noticeable form of soil erosion and can affect soil productivity and impair roads and water ways (Worrell, 2007).

Gully is the worst stage of all types of soil erosion and it is a highly visible form of erosion (Abdulfatai et al., 2014), which affects several soil functions (food and other biomass production, water storing, filtering and transformation, habitat and gene pool, physical and cultural environment for mankind, and source of raw materials) and hence soil quality (Poesen, 2011). Gully erosion begins when runoff concentrate into channels and result in the development of rills that enlarge into deep trenches on the land surface over time (Asghari Saraskanrond et al., 2017).

Many gullies grow initially rapidly to large dimensions making effective control technically difficult (Thomas et al., 2004; Valentin et al.,2005). Gully processes has for sometimes been neglected because gully processes are difficult to study and control. This is why studies in gully processes and their modeling are scarce (Gomez et al., 2003; Sidorchuk, 2005). Gully erosion is an important sign of land degradation (Poesen et al., 2003). Studies have been carried out in different part of the world by researchers such as Szabó et al. (1998) and Nwilo et al. (2011), in the southern Nigeria states like Abia, Anambra by Nwilo et al. (2011), they were able to identify the distribution of gullies in the study area and also examine the cause of erosion and spotting affected areas. The impact of gully erosion has attracted the attention of many scholars including: Conoscenti et al.(2014), Dube et al.(2014), Torri et al.(2014), Boardman (2014), Casali et al.(1999), Baets, et al.(2014), and Paolo et al.(2014) with emerging views that gully erosion causes a significant soil and water, decreases crop yield, raises degradation of ecosystem, destroys roads and bridges, farmlands as well as settlements. Ehiorobo and Audu (2012) investigated gully erosion in an Urban Area and reported that gully erosion occurs due to extreme overflow of fluid with a very high speed and energy to remove and transmit soil particles downhill slope. Shit and Maiti (2012) argued that gully erosion is one of the major devastating catastrophes that speed up soil erosion. The incidence of this hazard signifies a severe type of land degradation that deserves a very exceptional consideration.

Over the years, tremendous contributions have been recorded in understanding the behavior of gully erosion and its controlling factors by many scholars such as Casali et. al. (2009), Valentin et. al. (2005), Poesen et. al. (2003), Marzolff and Poesen (2009), James et al. (2007), Li et al. (2003) and Casasnovas (2003) using different criteria. Poesen (2011) observed that gullies are among the morphological indications of long periods of soil erosion revealing the effects of atmospheric adjustments, for example, heavy rain fall and land use practices in the landscape. This phenomenon is the principle geomorphic features to loosen human environment relations brought about by particular socio-economic circumstances. Gully erosion is the most important factor responsible for generating of sediments; approximately about 10 and 95% of the overall sediments were produced at catchments level while a reduced amount of 5% of the entire catchments area is often occupied by gully channel.

Soil erosion is a common phenomenon in Akoko Region, where it causes widespread soil degradation. The pressure on arable land in the area is growing and this forces people in the region to convert more marginal, available forest and grazing lands to arable lands. Unsustainable and exploitative land use practices due to an increasing demand for food, fiber and fodder by growing human and livestock populations are responsible for accelerated soil erosion in many parts of Akoko Region. There are little or no known studies on gully morphometry in Akoko Region of Ondo State, Nigeria. This study, therefore, examines the relationship between gully morphometry and soil physical properties in some selected settlements in Akoko Region of Ondo State, Nigeria.

1.1. Materials and Method

Akoko region is located north-east of Ondo State and South-West of Nigeria. The region lies within longitude 5031' E to 6006'E and latitude 7018'N to 7045'N. Akoko region covers an area extent of about 2465.6km^2(Fig. 1). Akoko region is situated at an altitude between 270m and 2750m above sea level. Most parts of the region have undulating terrain, which in many cases are almost completely encircled by high rugged rock outcrops, rising to a height of over 2750m in some places.

Geologically, Akoko region is a physiographic region characterized by two major crystalline basement rocks of the main African Precambrian shield. These are magmatite and granite gnesis, with quartz and pegmatite veins. These rocks belong to the migmatite-gnesis sub-classification of the basement complex of Nigeria. Akoko region is located within the humid tropical climate of the forest region, which experiences two climatic seasons namely the rainy season (April – October) and the dry season (November – March).

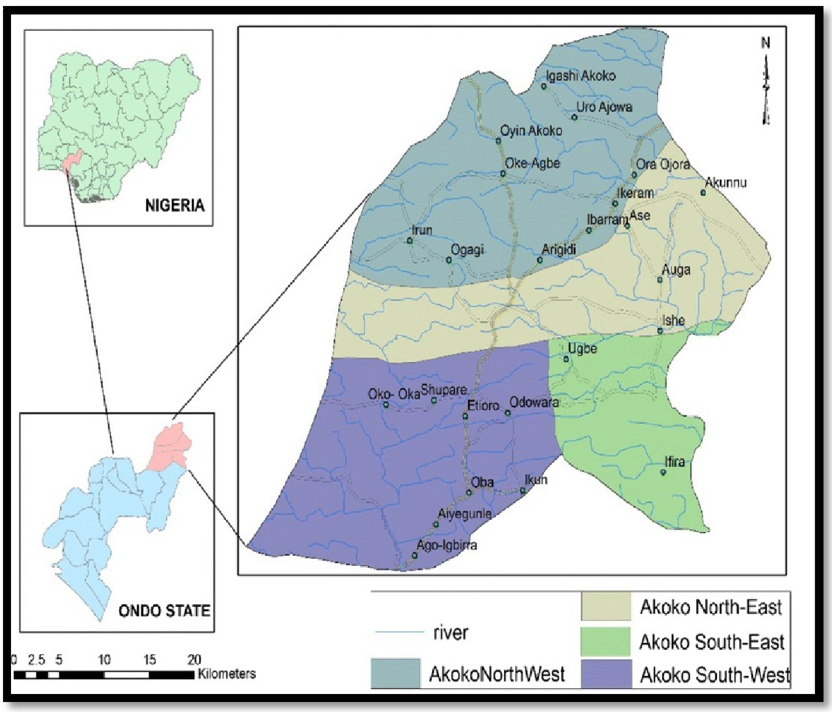

Figure 1: Map of Akoko Region
Source: Ondo State Ministry of Land Survey 1993 (Updated by the Researcher, 2018)

1.2. Measurement of Gully Attributes

Fieldwork was embarked upon to obtain the physical characteristics of erosion surface through direct measurement. Each of the erosion surface was measured in the field for dimensions (that is length, width, depth and gully surface areas) using Total Station while terrain configuration of the catchment was determined using GPS receivers. Twenty gully sites were discovered in the selected communities. The processed data from GPS and Total Station were exported into AutoCAD environment from which gully length, gully width and surface area were determined using geo statistical tool of the software. From the value of Z coordinate and corresponding Z coordinate, gully depths (D_1) was determined by subtracting the value of gully floor (center of the gully) from the half of the summation of the values of the gully shoulders. Cross-sectional area for each point along the gully length was calculated using the approach described by Ofomata (2000) and later summed up:

$A = w \times d$

The volume of sediment lost from the gully was determined using the formula:

Volume of soil sediment = volume of soil lost ÷ surface area.

1.3. Soil Sampling

Soil sample was taken from the studied gullies for the determination of soil bulk density and particle size distribution. Forty soil samples were collected for laboratory analysis. To determine the soil particle size distribution, a dispersing agent was mixed in distilled water until it completely dissolved. A dried soil sample weighing 50kg was poured into a container, a quantity of the dispersing solution and distilled water was then poured into the container and mixed thoroughly using a spoon which was rinsed off with distilled water after stirring. A meter stick was used to measure the distance of the base of the graduated cylinder and the 500ml was marked by putting the stick inside the cylinder. The initial temperature and hydrometer were obtained. The corrected hydrometer reading of the first reading was subtracted from the initial 50kg total soil in the sample and multiplied by 2 to obtain the exact percentage of sand. Similarly, the corrected hydrometer reading was subtracted from the second reading and multiplied by 2 to obtain the exact percentage of clay. The difference in percentage between the sum of percentage of sand and clay were subtracted from 100 to give the exact percentage of silt. This was done for each sample of soil to determine the percentage of sand, clay and silt in them.

1.4. Statistical Analysis and Data Presentation

Descriptive statistics was employed to analyse the data collected for gully parameters and soil samples. Inferential statistics such as correlation was used to determine the relationship between gully parameters and soil parameters. The Statistical Package for Social Sciences (SPSS) version 16.0 was used for analysis and interpretation of the data collected. The findings of the study were presented in tables.

2. Results and Discussion

2.1. Gully Morphometry and Sediment Loss in the Selected Settlements

The characteristics of the gullies studied are shown in Table 1. In this table, gully lengths ranged between 37m at Ikun Akoko and 171.69m at Ugbe Akoko with mean length of 76.42 and standard deviation of 34.63. The main causes of the initiation and development of gullies were noted. Rainfall was the primary reason identified as cause of gully. Gully depths ranged from about 0.82m to 6.56m at Oyin Akoko and Supare Akoko respectively. It has a mean value of 1.81m and standard deviation of 1.25. The value of depth suggested that gullies in the study area are predominantly shallow and thus exhibited V-shaped cross section in most of the gully lengths thus similar to observation of Jeje (2005) in Efon Alaaye. Based on gully depth, gullies were classified as small gully (less than 1m), medium gully (between 1-5m) and large gully (greater than 5m) (Pathak et al., 2006). In terms of gully depth measurement, 5 were small gullies, medium gullies were 14 and large gully was 1. Gully widths ranged from 2.29m at Afin Akoko to 13.35 at Supare Akoko, with mean value of 8.17m and standard deviation of 3.33. All of the gullies exhibited higher values of width than depth. The implication is that erosion processes in the gullies are more lateral than vertical. Some gullies such as gullies in Ayegunle Akoko, Ifira Akoko, Ikaram Akoko, and Oyin Akoko exhibited relatively uniform values of depths throughout their lengths. It is to be noted that some gullies like the ones in Ajowa Akoko, Auga Akoko, Ayegunle Akoko, Ayepe-Iwaro Akoko, Erusu Akoko, Ifira Akoko and Oyin Akoko exhibited larger values of widths at their heads than at the exits.

The cross sectional areas for the gullies ranged from 2.64m^2 at Arigidi Akoko to 85.40m^2 at Supare Akoko. It has a mean value of 16.72m^2. Table 2 shows the estimated sediment loss. As evident from the table, gully system at Supare Akoko recorded the highest sediment loss of 14,157.99 tonnes followed by Ayegunle Akoko and Ikare Akoko with 9684.45 tonnes and 4566.18 tonnes respectively. The lowest sediment loss of 217.01 tonnes and 293.15ctonnes were obtained in the gully at Ayepe-Iwaro Akoko and the gully at Afin Akoko respectively. Altogether, a sum of 51,551.82 tonnes of soils was lost to gully erosion in the entire study area.

	Mean	Standard Deviation
Width	7.66	3.2
Depth	1.80	1.27
Length	90.39	38.24
Cross-Sectional Area	16.39	18.24
Slope	4.95	2.61

Table 1: Gully Morphometric
Source: Researcher's Fieldwork, 2018

Gully Location	Sediment Loss (Tonnes)
Afin	293.15
Ajowa	1290.33
Akungba	1566.86
Arigidi	445.23
Auga	2670.87
Ayegunle	9684.45
Ayepe-Iwaro	217.01
Epinmi	545.03
Erusu	947.76
Ifira	1254.46
Ikaram	1023.40
Ikare	4506.18
Ikun	796.26
Ipe	1929.89
Isua	1683.33
Oba	1524.71
Oke-Agbe	2018.84
Oyin	712.35
Supare	14157.99
Ugbe	4283.72
Total	51,551.82

Table 2: Sediment Loss
Source: Researcher's Fieldwork, 2018

The soil physical characteristics of gullies studied are shown in Table 3. The highest content of sand (66.68%) at the gully top was observed at Ikare Akoko while the highest content of silt (18%) was observed at Ikun Akoko and Oyin Akoko. The highest content of clay (49.20%) was observed at Epinmi Akoko. The lowest content of sand (30.80%), silt (0.56%) and clay (16.76%) at the gully top were observed at Ikun Akoko, Auga Akoko, Erusu Akoko and Ikare Akoko respectively. At the gully floor, the highest content of sand (72.68%), silt (22%) and clay (67.20%) were observed at Auga Akoko, Ugbe Akoko and Ayegunle Akoko respectively. The lowest content of sand (18.24%), silt (1.52%) and clay (19.76%) at the gully floor were observed at Oba Akoko, Auga Akoko and Epinmi Akoko respectively. The soil classification indicated that the soils in the study area are predominately sandy clay loam with mean percentage of sand (48.50%) while clay and silt were 30.25% and 12.51% respectively at the gully top. At the gully floor, clay content exhibits highest mean percentage of 42.60% followed by sand 35.40% and silt 10.76%. The table also revealed that sand content decreases with soil depth while clay content increases with soil depth.

	Mean (Gully Top)	Mean (Gully Floor)
Sand	48.5	35.40
Silt	12.51	10.76
Clay	30.25	42.60
Bulk Density	1.54	1.68

Table 3: Soil Physical Properties
Source: Researcher's Fieldwork, 2018

The values of bulk density obtained at the gully top ranged between 1.38g/cm^3 at Ikaram Akoko, Oyin Akoko to 1.76g/cm^3 at Auga Akoko with a mean of 1.54g/cm^3 while the gully floor has values ranging from 1.23g/cm^3 at Akungba Akoko to 1.95g/cm^3 at Auga Akoko, Ifira Akoko with a mean value of 1.68g/cm^3. These results further confirmed that along the depth of soil profile, proportion of clay content increases thereby increasing the soil cohesiveness and resistant to detachment. This soil characteristic may partially be responsible for the inability of running water to be active at the vertical cutting of the gully floor and hence, the V-shaped observed at some of the gully. The soil analysed in this study exhibited higher clay content and higher bulk density at the gully floor. The result thus confirms the finding of Guerra et al. (2006) in their study of gullies in Sao Luis, Brazil, where it was observed that soil with high proportion of sand content present lower bulk density value while soil with higher clay content have higher bulk density.

2.2. Relationship between Gully Attributes and Soil Physical Properties

The relationship among gully attributes and soil physical parameters in the study area is shown in Table 4. The result shows that correlation coefficients between the gully attributes and soil physical parameters were low and most of them were inversely proportional. The correlation coefficients among gully attributes showed that gully depth related significantly with gully width (0.641) while gully depth and gully width had a relationship with gully cross sectional area with correlation coefficients of 0.987 and 0.715 respectively. The sediment loss was significantly correlated with gully depth, gully width, gully length and cross sectional area. Except gully depth and gully length; gully width and gully length and between gully length and cross sectional area that had a low correlation, the relationship between other gully attributes were significant. This findings is similar to the result gotten by Ebisemiju (1988) in the southwestern Nigeria whereby the gully length has no effect on gully cross sectional area.

	Depth	**Width**	**Length**	**Cross Sectional Area**	**Bulk Density**	**Sand**	**Clay**	**Silt**	**Gully Slope**	**Sediment Loss**
Depth	1									
Width	.644**	1								
Length	.222	.183	1							
Cross sectional area	.987**	.715**	.232	1						
Bulk Density	.140	.288	-.002	.188	1					
Sand	.165	.150	-.387	.173	.332	1				
Clay	-.145	.082	.340	-.137	-.123	.682**	1			
Silt	.086	.007	-.046	.090	.018	-.336	.001	1		
Gully Slope	.441	.235	-.014	.477*	.403	.479*	-.304	.027	1	
Sediment loss	.938**	.682**	.458*	.953**	.187	.058	-.004	-.028	.427	1

Table 4: Correlation Matrix between Gully Morphometric and Soil Physical Properties

3. Conclusion and Recommendation

Gully formation and development in the study area have been identified as constituting menace on farmlands. However, the values of gully dimension (lengths, depths and widths) indicated that the development has not reached a disaster level. Findings revealed that correlation coefficients between the gully attributes and soil physical parameters were low and most of them were inversely proportional.

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