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Assessment of Gully Erosion in Selected Settlements in Akoko South West Local Government Area of Ondo State, Nigeria

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Abstract

The study assessed gully erosion in selected settlements in Akoko South West. 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 10 gullies were studied. Soil samples were also taken from the studied gullies for the determination of the particle size distribution. Descriptive statistics were such as mean and standard deviation used to achieve clarity. The mean values of 97.98m, 2.81m and 8.56m were recorded for gully length, depth and width respectively while the mean value of soil loss was 3394.30. There was spatial variability in soil properties as indicated by the high coefficients of variation in soil. These variations suggest differential sensitivity of these properties to change under erosion. There is need to regulate soil loss through the use of preventive measures such as mulching, terracing and planting of cover crops so as to enhance soil productivity.

Keywords: Gully erosion, Soil properties, Gully dimensions

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Background to the Study

Soil is a fundamental resource that provides a number of ecosystem services and it is the dynamic medium on which we produce 99 per cent of our food in addition to fodder, fibre, raw materials and biofuels (Brevik, Cerda, Mataix-Solera, Pereg, Quintan, Six, & Vanoost 2015; Smith et al., 2015). Soils contribute to basic human needs like food, clean water and clean air and are major carrier for biodiversity (Keesstra, Bouma, Wallings, Tittonell, Smith, Cerda & Fresco 2016). Soils have critical relevance to current global issues such as food and water security, climate regulation, land degradation and desertification (Montanarella, Pennock, McKenzie, Badraoui, Chude, Baptista, & Vargas, 2016). The loss of this resource through land degradation processes such as wind and water erosion, is one of the most serious environmental problems. 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 formation is one of the greatest environmental disasters facing the world. 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). 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). The aim of this research was to assess the rate and factors of gully system in the area.

Materials and Method

Akoko South West Local Government Area is located north-east of Ondo State and South-West of Nigeria. The region lies within longitude 5°41' E and latitude 7°23'N. 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, the study area 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 South West Local Government Area 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).

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:

$A = w \times d$

Laboratory Analysis

Soil sample was taken from the studied gullies for the determination of soil particle size distribution. Ten 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.

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.

Results and Discussion

From the morphological parameters of gullies studied shown in Table 1, the gully lengths varied from minimum of 41.16m at Ayepe-Iwaro Akoko to maximum of 168.23 at Ayegunle Akoko with mean value of 97.98 and standard deviation of 45.62. Gully depths ranged from 0.83m at Ayepe-Iwaro Akoko to 6.91m at Supare Akoko. It has a mean value of 2.81m and standard deviation of 2.44. 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, 1 was small gully, medium gullies were 3 and large gully was 1. Gully widths ranged from 3.77m at Ayepe-Iwaro Akoko to 13.35 at Supare Akoko, with mean value of 8.56m and standard deviation of 3.95. 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. All these values of gullies dimensions suggest that gullies in the study area are moderate similar to the observations of Ofomata (2000) in part of southeastern Nigeria.

Volumetric estimate of soil loss in the five gullies shown in Table 1 revealed that gully system at Supare Akoko recorded the highest soil loss of 8580.6 tonnes followed by Ayegunle Akoko, Akungba Akoko and Oba Akoko with 6090.85 tonnes, 1169.3 tonnes and 1003.1 tonnes respectively. The lowest soil loss of 127.65 tonnes was obtained in the gully at Ayepe-Iwaro Akoko. Altogether, a sum of 16,971.5 tonnes of soils was lost to gully erosion in the entire study area. All the gullies studied are located within the slope gradient of between 2°–14°. Ordinarily, under vegetation cover, these slope gradients would not enhance erosion processes but due to exposure to raindrop impact and human activities, gully has become pronounced.

Table 1: Morphometric Attributes of the Studied Gullies

Gully location	Length	Width	Depth	Slope gradient	Cross Sectional Area	Soil Loss
Akungba	85.42	7.58	1.7	2°21'41"	12.98	1169.3
Ayegunle	168.23	11.78	3.10	2°26'58"	35.90	6090.85
Ayepe-Iwaro	41.16	3.77	0.83	4°08'45"	2.78	127.65
Supare	98.78	13.35	6.91	6°21'05"	58.61	8580.6
Oba	96.29	6.26	1.51	2°32'41"	9.63	1003.1
Mean	97.98	8.56	2.81		23.98	3394.30
Standard Deviation	45.62	3.95	2.44		23.01	37.25.20

Source: Researcher's Fieldwork, 2018.

Soil Properties

Soil properties are key indicators of soil quality and are commonly assessed as an index to soil erosion (Lufafa, 2000). Because of their relevance to the soil erosion process, soil properties were characterized in regard to landscape and soil depth in Akoko region. The soil properties considered in this study include soil organic matter content (OM), soil pH, exchangeable calcium (Ca), magnesium (Mg), sodium (Na), cation exchange capacity (CEC), potassium (K), sand, silt and clay.

Soil Chemical Properties

The soil chemical properties were evaluated. At the depth of 0-20cm, the soil organic matter content was highest (0.41%) at Supare Akoko and lowest (0.14%) at Oba Akoko. The highest amount of calcium (3.11ppm), magnesium (1.40ppm), sodium (1.23ppm) and potassium (0.81ppm) were recorded at Ayepe-Iwaro, Ayepe-Iwaro Akoko, Supare Akoko and Supare Akoko respectively. CEC was highest (5.95ppm) at Ayegunle Akoko and lowest (3.11ppm) at

Supare Akoko while soil pH was highest (6.37) at Supare Akoko and lowest (5.67) at Akungba Akoko. At the depth of 20-50cm, the soil organic matter content was highest (0.30%) at Supare Akoko and lowest (0.14%) at Ayepe-Iwaro Akoko. The highest amount of calcium (3.12ppm), magnesium (1.35ppm), sodium (1.33ppm) and potassium (0.81ppm) were recorded at Ayepe-Iwaro Akoko, Ayepe-Iwaro Akoko, Supare Akoko and Supare Akoko respectively. CEC was highest (5.65ppm) at Ayegunle Akoko and lowest (3.01ppm) at Supare Akoko while soil pH was highest (7.52) at Supare Akoko and lowest (4.50) at Ayepe-iwaro Akoko. The observed soil chemical properties with soil depth positions are presented in Table 2.

Table 2: Soil Chemical Properties

Location	Depth (cm)	OM	pH	Ca	M	K	Na	CEC	Altitude
Akungba	0-20 20-50	0.17 0.15	5.67 5.87	2.09 2.19	0.41 0.38	0.47 0.47	0.70 0.67	4.86 4.66	377.7
Ayegunle	0-20 20-50	0.20 0.17	5.97 5.55	1.96 1.56	0.40 0.37	0.26 0.16	0.56 0.58	5.95 5.65	323.5
Ayepe-Iwaro	0-20 20-50	0.17 0.14	5.60 4.50	3.11 3.12	1.40 1.35	0.41 0.21	0.99 0.99	4.82 4.65	359.3
Oba	0-20 20-50	0.14 0.12	5.70 7.70	2.11 2.20	0.72 0.64	0.61 0.71	0.79 0.82	4.49 4.77	288.6
Supare	0-20 20-50	0.41 0.30	6.37 7.52	1.62 1.64	1.14 1.09	0.81 0.81	1.23 1.33	3.11 3.01	342.1

Source: Researcher's Fieldwork, 2018.

Coefficient of variations were computed for the chemical properties at the different depth and classified according to Wilding et al. (1983) in which CV less than15 percent (CV<15%) was classified as homogenous (least), 15 to 35 percent as moderate and greater than 35 percent as heterogenous. Following this categorization, organic matter, magnesium and potassium fitted the heterogenous category. Cation Exchangeable Capacity, calcium and sodium fitted the moderate category while soil pH fitted the homogenous category. In order to compare the variability of the soil properties among themselves across the study area, the coefficient of variability was used and the result was further categorized into four classes in a modified version after Aweto (1982). Less than 20% CV is regarded as low variability; between 21 and 50% is regarded as moderate variability; while between 51 and 100% CV is regarded as high variability. Any CV above 100% is regarded as very high variability. The soil chemical properties across the study area showed considerable variation for each element. In the topsoil, soil pH has low CV of 5.46%; soil calcium, sodium, potassium, organic matter and CEC varied moderately at 25.09%, 30.59%, 41.18%, 50% and 21.94% (Table 3). High CV was recorded for magnesium.50.35%. In the subsoil, organic matter, pH, calcium, sodium and CEC varied moderately at 38.89%, 21.83%, 28.97%, 34.09% and 21.10%. Very high CV was recorded for magnesium (57.14%) and potassium (61.70%). There was spatial variability in soil properties manifested through the high coefficient of variation values. These variations suggest differential sensitivity of these properties to change under erosion. The observed difference in soil properties with landscape are attributed to pedogenetic-geomorphic factors like eluviations and illuviation which differ in the respective landscapes. Salako et al. (2006), observed that geomorphic processes and parent materials do have different influences in the concentrations of chemical properties. Olowolafe (2002) also established some variation in soil properties due to the influence of soil parent materials in a study of two separate catchment areas of Jos, Nigeria.

Table 3: Descriptive Statistics of Soil Chemical Properties

Chemical Properties	Depth (cm)	Mean	Standard Deviation	Coefficient of Variation
Organic Matter	0-20 20-50	0.22 0.18	0.11 0.07	50 38.89
pH	0-20 20-50	5.86 6.23	0.32 1.36	5.46 21.83
Ca	0-20 20-50	2.18 2.14	0.56 0.62	25.09 28.97
M	0-20 20-50	0.81 0.77	0.45 0.44	55.56 57.14
Na	0-20 20-50	0.85 0.88	0.26 0.30	30.59 34.09
K	0-20 20-50	0.51 0.29	0.21 0.29	41.18 61.70
CEC	0-20 20-50	4.65 4.55	1.02 0.96	21.94 21.10

Source: Researcher's Fieldwork, 2018.

Soil Physical Properties

The range of sand, silt, and clay at the topsoil were 49 to 68%, 12 to 24%, and 19 to 29% while at the subsoil, sand, silt and clay were 45 to 75%, 9 to 34% and 16 to 38% were observed for sand, silt and clay respectively. The mean values for sand, silt and clay at the top were 57%, 19% and 23% respectively while at the subsoil, the mean values for sand, silt and clay were 57%, 16.8% and 26.2%(Table 4 and Table 5). The soils were classified sandy loam clay following the USDA textural classification system.

Table 4: Soil Physical Properties

Location	Depth (cm)	Sand	Silt	Clay
Akungba	0-20 20-50	56 61	20 17	24 22
Ayegunle	0-20 20-50	68 75	12 09	19 16
Ayepe-Iwaro	0-20 20-50	56 50	24 12	20 38
Oba	0-20 20-50	56 54	15 12	29 30
Supare	0-20 20-50	49 45	24 34	27 21

Source: Researcher's Fieldwork, 2018.

Physical Properties	Depth (cm)	Mean	Standard Deviation	Coefficient of Variation
Sand	0-20 20-50	57 57	6.86 11.64	12.04 20.42
Silt	0-20 20-50	19 16.8	5.39 10.03	28.37 59.70
Clay	0-20 20-50	23 26.2	4.32 9.34	18.78 35.65

Source: Researcher's Fieldwork, 2018.

The coefficients of variations were comparatively greater at the bottom soil than at the top soil. The CV at the top horizon was 12.04% for sand, 28.37% for silt and 18.78% for clay (Table 4), while at the lower horizon; the CV was 20.42% for sand, 59.70% for silt and 35.65% for clay (Table 4).

Conclusion

Gully initiation and development in the study area have contributed immensely to environmental degradation in many of the settlements studied. Also, the values of gully dimensions (widths, depths and lengths) indicated that the development has not reached a disaster level, but the restoration of damage done require assistance from the outside especially from the government and Non-Government Organizations (N- GOs). Spatial variation of soil properties in Akoko South West Local Government Area had been examined. It was concluded that due to variability of soil properties, soil erosion rate varied from one location to another in the region. There is need to regulate soil loss through preventive measures such as mulching, terrace and planting of cover crops so as to reduce the existing rate of soil loss and enhance agricultural productivity. Long term preventive measures such as re-vegetation with trees and perennial grasses, introduction of agro-forestry programme that is compatible with crop, livestock and forestry development and short term soil and water conservation measures are put in place will assist in reducing soil loss and triggers of gullying in the study area.

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