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Full Length Research Paper

Characterisation of gully formed in built up area in southwestern Nigeria

Ibitoye, M. O.[1], Ekanade, O.[1], Jeje, L. K.[1], O. O. Awotoye[2] and Eludoyin, A. O[1*]

[1]Department of Geography, Obafemi Awolowo University, Ile-Ife, Nigeria
[2]Ecology and Environmental Studies, Obafemi Awolowo University, Ile-Ife, Nigeria.

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This study was carried out in one of the local government areas in the southwestern part of Nigeria. Its aim is to highlight the causes and characteristics of gullies, and their effects in the area. Gullies in the local government headquarter; the most developed area, and three other rural areas; with varying degree of rurality were studied. Measurements were done in the dry season, at intervals of 10 m (less where gully length was shorter than 20 m) using convectional surveying equipments. Mean gully depths measured at gully shoulders were obtained at the beginning, middle and end of cross-sections. A total of 14 gullies were studied; 8 at Ode Irele (LGA Hq), 4 at Akotogbo, and 1 each from Ajagba and Lipanu. The gullies at Ode-Irele were significantly different from others, especially in terms of the length and width (p< 0.05). In addition while Order 1 gully system dominated study area, an Order 3 and two Order 2 gullies were cited in Ode – Irele. The study concluded that unsustainable development is a complementary agent of erosion in the built up area, in addition to the soil characteristics that has been identified by similar study in the southeastern Nigeria. The study attributed the aggravation of gully process in built – up environments.

Key words: characterization, gully, local administrative headquarter, sustainable development, soil characteristics, Nigeria.

INTRODUCTION

Gullies are antecedents of the removal of soil by running water. 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). When formed, gullies could be sufficiently large enough to disrupt farming operations and too large to be filled during normal cultivation (Kirchhof, 2000). Gullies are a problem in the humid tropics, especially when the communities affected are in the developing world, which generates a significant amount of its Gross Domestic Product (GDP) from agriculture related activities. Their occurrence have caused severe loss of soils, particularly for agricultural productivity in many parts of Nigeria (Okagbue and Uma, 1987; Jeje and Agu, 1982) and resulted in economic, human and social losses in many of the cities. Nearly 1000 million ha of vegetated land in developing countries are subjected to various forms of degradation; including gully erosion resulting in moderate erosion, resulting in moderate or severe decline in productivity (Hudec et al., 2006) Some 9 million ha of land, worldwide, have had their original biotic function fully destroyed and have reached the point that rehabilitation is probably uneco-nomic (Nabhan, 2000). Other effects of gully erosion include (1) deterioration in soil physical properties such as structure, aeration, infiltration and water holding capacity, brought about by reduced organic matter, erosion and loss of vegetation cover; deterioration in physical properties such as structure, aeration, infiltration and water holding capacity, brought about by reduced organic mater, erosion and loss of vegetation cover; (2) adverse changes in soil nutrient resources, including reduction in availability of macro and micro nutrients (nutrient mining) and development of nutrient imbalance, and (3) build-up of toxicities due to acidification and pollu-tion in the downstream.

Several studies have been carried out on soil erosion in different parts of southern, especially southeastern Nigeria, among which are those by Lal (1981), Ofomata (1965) and Jeje and Agu (1990). Common to most of these studies are that gullying in the southern Nigeria is

*Corresponding author. E-mail: oaeludoyin@yahoo.com. Tel +234 8067281611.

caused by one or more of soil characteristics (Ofomata, 1965), human activities (Floyd, 1965), geologic set up (Ogbukagbu, 1976), groundwater conditions (Egboka and Nwakwo, 1985; Okagbue and Uma, 1987). These studies have also showed that gullies would develop in a progressive series of activities, in the succession of (a) formation of rills, (b) development of incipient gullies, formation of shallow gullies (<15m deep) and (c) development of deep gullies (>15 m deep).

Objectives and hypotheses

The general consensus on sustainable development as aptly reflected in the World Commission on Environment and Development (1988) is that ecological interactions do not respect the boundaries of individual ownership and political jurisdiction." Nor has the local nature of human interaction with the environment been confined, as the result of the creation of ever more sophisticated technologies, to local environmental effects. The enforcement of common interest often suffers because areas of political jurisdiction and areas of impact do not coincide. Although many countries agree to this in principle, situations have shown that the concept may not be effective, after all, especially in the developing countries. One important characteristic of these countries is rapid urban population growth, causing overpopulation and over-utilization of the resources at the region of highest population concentration (Onakerhoraye and Omuta, 1994). Many of these areas may consequently experience unsustainable utilization their land resources. For examples, overuse of land surface may cause loss of soil fertility and reduces its compactness.

The impact land use of gully formation in Nigeria has not been well documented. Many of the previous studies in Nigeria have actually attributed gully formation largely to soil properties (Orabuchi, 2006; Hudec et al., 2006). Little is however known about the effect of land use, on the characteristics of these gullies in parts of the Southwestern Nigeria. This knowledge is however of importance if generalizations are to be made about the attributes of gullies in the humid tropical zone of the southern Nigeria, especially in the context of sustainable development. The objective of this study is to characterize the gully erosion in rural areas at different stage of growth. All conclusions on the effect of land use were based on the hypothesis that ecological destruction increases with increasing living standards of those living in developing countries. When compared with Agenda 21 Principle 1 that 'human beings are at the centre of concerns for sustainable development; they are entitled to a healthy and productive life in harmony with nature, the conclusions are based on the idea of unsustainable development, especially in developing countries.

Study area

The four settlements (Ode – Irele, Akotogbo, Ajagba, Lipanu) selected for this are local built – up areas in Irele LGA in the Southwestern Nigeria. The total land area is approximately 400 km^2. The population of Irele LGA was 145, 166 in 2006 (Ibitoye, 2006), when the study was conducted. This is projected to increase by 5% based on estimation of the National Population Census (Nigeria) for the State (Ibitoye, 2006). Other settlements in the periphery are however, likely to worse off due to envisaged backwash effect of urbanization in the 'core' (headquarters) of the LGA, especially as induced by migration. As at the time of the study, about 33% of the total population resides in Ode–Irele, 8% in Akotogbo, 7% in Ajagba and 3.4% in Lipanu.

The LGA lies on 6°18' N, 4° 49'E and 6° 43'N, 5°10' E (Figure 1), within the tropical rainforest region. The mean annual rainfall in a 10 – year meteorological data (1995 – 2005) collected from the Ondo State Agricultural Development Programme's meteorological station cited in Ode – Irele is 2300 mm. The distribution is bimodally distributed with peaks in June and September. The dry season occurs in November to March. The mean annual evaporation is 2.1 mm while mean annual temperature ranges from minimum 22.3°C and maximum 31.4°C. The onset and cessation of the rainy season are usually marked by high intensity thunderstorms. The general elevation is about 45m above mean sea level. The ground slopes imperceptibly in an N - S direction (deduced from the flow direction of the drainage systems). The soils of the studied settlements are predominantly sandy (Table 1). Compared to the results of Evans (1980), which showed that soils greater than 30% clay may be susceptible to erosion, the study area may be vulnerable if adequate conservation efforts are not in place. This is because; the clay content of the study area exceeded the limit of 30% at the time of study.

All the gullies studied are located within the built up area, where the building density is up to 45 / ha. Gullies in Ode–Irele became pronounced since 1999 those of other settlements became obvious since 2001. All the settlements studied were also poorly provided with drainage systems. Lipanu was hardly provided with any. Significant proportion of the overland flow therefore flows along the untarred roads and the unpaved drains. Surface runoff often flows along the untarred roads and unpaved drains. In some areas, where concrete drains and culverts are constructed, runoff hardly flows through them. Drains in other areas are often blocked with debris and sands. The few unblocked drains and culverts could not accommodate the volume of surface runoff generated during heavy rainstorms. Improved wooden bridges were constructed over some of the gullies to link some of the streets and allow pedestrians to pass. As at the period of fieldwork, some of the wooden bridges at Akotogbo and Idogun in Ode Irele were already weak. Observations showed that some buildings in the gully affected area have, and have been abandoned, and many of those still occupied were at the verge of collapsing into the channels (Figure 2a –c).

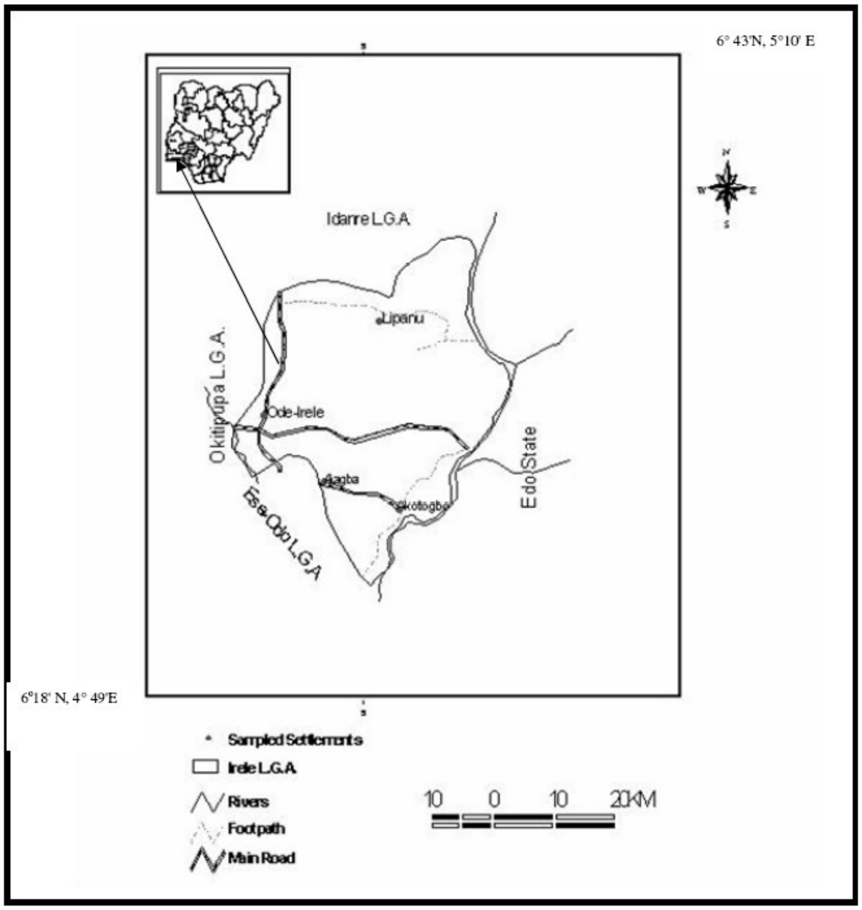

Figure 1. Study area.

Table 1. Morphometry of the studied gullies based on sites.

Variables		Ode –Irele	Akotogbo	Ajagba	Lipanu
Length (m)		186.9±168	84.1±59.6	105.2±65.2	30.1±21.8
Depth (m)		4.2 ± 1.9	3.3 ± 2.4	2.4 ± 4.4	3.0 ± 1.8
Width (m)		5.6 ± 4.5	5.4 ± 2.6	3.3 ± 2.1	2.3 ± 0.5
Cross-sectional area (m^2)		25.7 ± 29.1	24.0 ± 29.5	5.6 ± 5.1	2.3 ± 0.7
Soil texture composition (in %)	Sand	63	56	63	54
	Silt	7	3	7	14
	Clay	30	41	30	32

MATERIALS AND METHODS

The LGA was purposely selected for this study because of its recent and increasing but unheard record of gully erosion. 14 gullies were identified in all the selected settlements; and their characteristics (depth, length, width) of all were measured. The gullies in Lipanu and Ajagba were mainly 1st order. A 2nd order was identified in Akotogbo (with three 1st order), five 1st order, and two 2nd and one 3rd order systems in Ode-Irele during the course of the investigation. Some aspects of the morphometry of these gullies are shown in Tables 1 and 2. Measurements were done in the dry season for accuracy, considering the type of instruments and approach available for use.

Measurements were done at intervals of 10 m (except gully with less than 20 m length) using measuring tape and leveling staff, for length and depths, respectively. Mean gully depths measured at gully shoulders were obtained at the beginning, middle and end of cross-sections. GPS (GERMIN 12 Model) was used to measure the coordinates from which averaged area for each catchment was computed. The catchment of each gully was delineated in the field based on the slope gradient and the gully pattern. The values of depths and widths with widths of gully were plotted against the measured length intervals to show gully profiles. For each gully, the measured cross sectional areas were calculated. 34 soil samples; 2, 6, 8 and 12, respectively from Lipanu, Idogun, Ajagba, Akotogbo and Ode-Irele, were collected for the analysis of physical properties such as sediment loss, bulk density, moisture content, soil texture

Table 2. Morphometry of the studied gullies based on type (order).

Gully order	Mean gully length (m)	Mean gully depth (m)	Mean gully width (m)	Mean cross-sectional area (m^2)
1^{st} Order (n = 10)	211.8±213.5	3.1±2.4	4.6±4.1	19.4±29.1
2^{nd} Order(n = 3)	51.9 ± 42.6	3.2 ± 1.8	4.3 ± 4.1	13.1 ± 8.8
3^{rd} Order (1)	171.2 ± 101.3	5.9 ± 2.8	7.7 ± 4.5	39.3 ± 26. 8
Mean (n = 14)	**193.6 ± 195.9**	**3.5 ± 2.6**	**5.1 ± 4.2**	**22.2 ± 28.7**

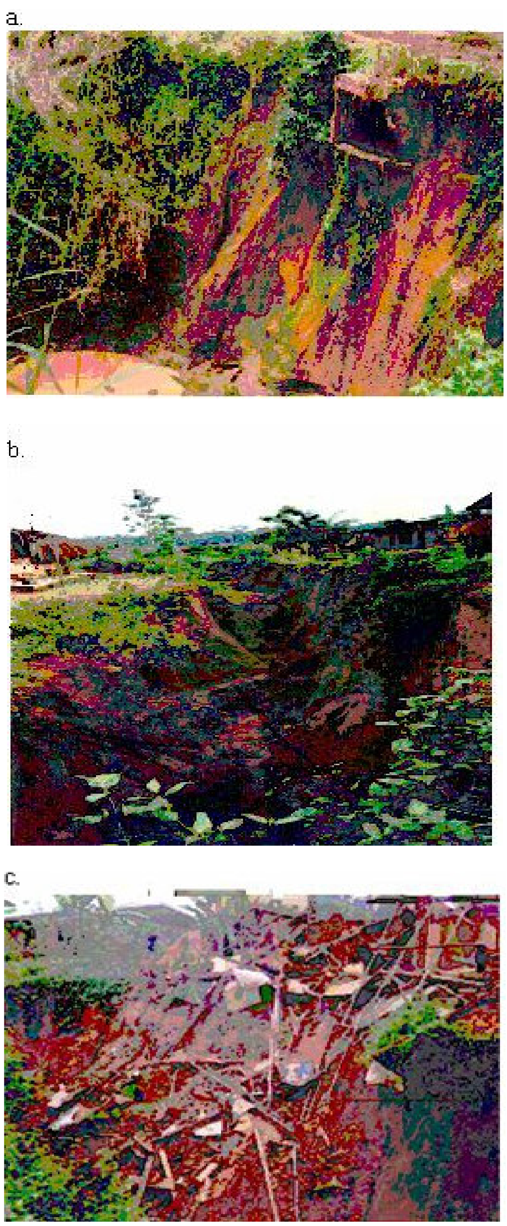

Figure 2 (a, b, c). Some instances of destruction caused by gullies in the Irele LGA.

and permeability using standard laboratory methods (Brown, 1987). The data obtained for each location was compared with that of others for the parameters observed using the Analysis of Variance (ANOVA) technique. This was with the view of obtaining significant relationship(s) among the locations. The height distributions in the locations were described using isolines while the characterization of the gullies in the study area was performed using appropriate graphs. These methods have been adjudged adequate methods of data representations (Zar, 1992).

RESULTS AND DISCUSSION

Figure 3 a–c shows the contour maps and the corresponding digital elevation model (DEM) for studied gullies in the study area. Not only outcrops of hard rock are responsible for the formation of different gullies, but also local control measure put in place to hold back the eroded materials where a level ground was observed. For instance, the gully at Ode - Irele exhibited more or less uniform widths and depths that were not more than 5 m for the greater length of the gully until it suddenly increased in both dimensions. This sudden change may be a consequent of increased surface runoff on the unconsolidated bare earth below a culvert constructed over the gully. At Ajagba, similar shape was observed with sudden increase in gully widths between 50 and 80 m. This perhaps could be attributed to the runoff. On the average, the gully erosion process took place more in lateral than vertical direction, except at Idogun, where the situation was converse. In addition, it is observed that towards the dying out points, gully widths generally increased while gully depths decreased.

Most severe gully incidence was observed in Ode – Irele, with about 750 m length, 5.5m depth and 9.8m width. Figure 4 also shows that the distributions of the gullies in LGA headquarter outnumber those of other settlements. It also shows a significant difference between the nature of the gullies. This settlement incidentally was the most developed, having 33% of the total population of the LGA. The physical properties of the top soil near the gullies in the study sites are shown in Table 3. The bulk density values ranged between 1.45 and 1.89 gcm^{-3} at different gully sites. These values are far above 1.0 – 1.3 gcm^{-3} considered for a well-aggregated forest or grassland vegetation (Babalola, 1988). The mean moisture content obtained at the upper layer of the area was 11.04 %; ranging between 9.4 in Ajagba and 12.4 in Akotogbo. The average soil loss per catchment area was 38, 299.2, 1224.5, 162.1 and 1882.1 tha^{-1} for Lipanu, Ode-Irele, Ajagba and Akotogbo, respectively. The highest soil loss

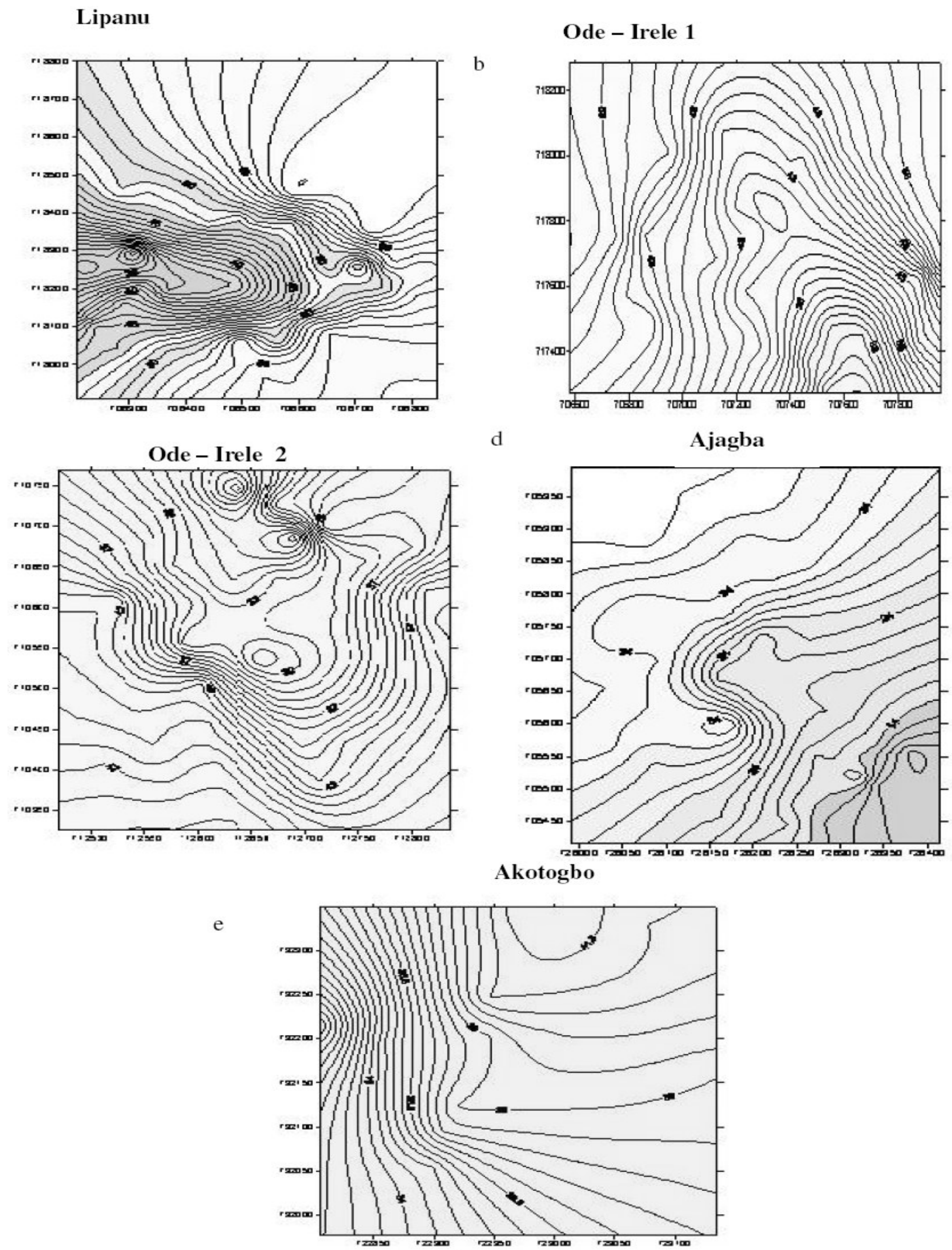

Figure 3 (a – e). Contour maps for the gullies in, respectively.

was measured at Ode –Irele and lowest at Lipanu (Table 4).

The inappropriate construction of drains along urban streets and concrete channels has enhanced the formation of gully in the study area. The termination half way (before getting to the natural drainage channel) of the construction work of the erosion channels being constructed some years back by the government constituted the main factors that have triggered the gully formation erosion observed. Runoff from concretized platforms onto the bare earth below induced the formation of some gullies, from the points where the concrete platforms have terminated. For instance, the runoff that brought about the gully dimension (3.4 (depth)

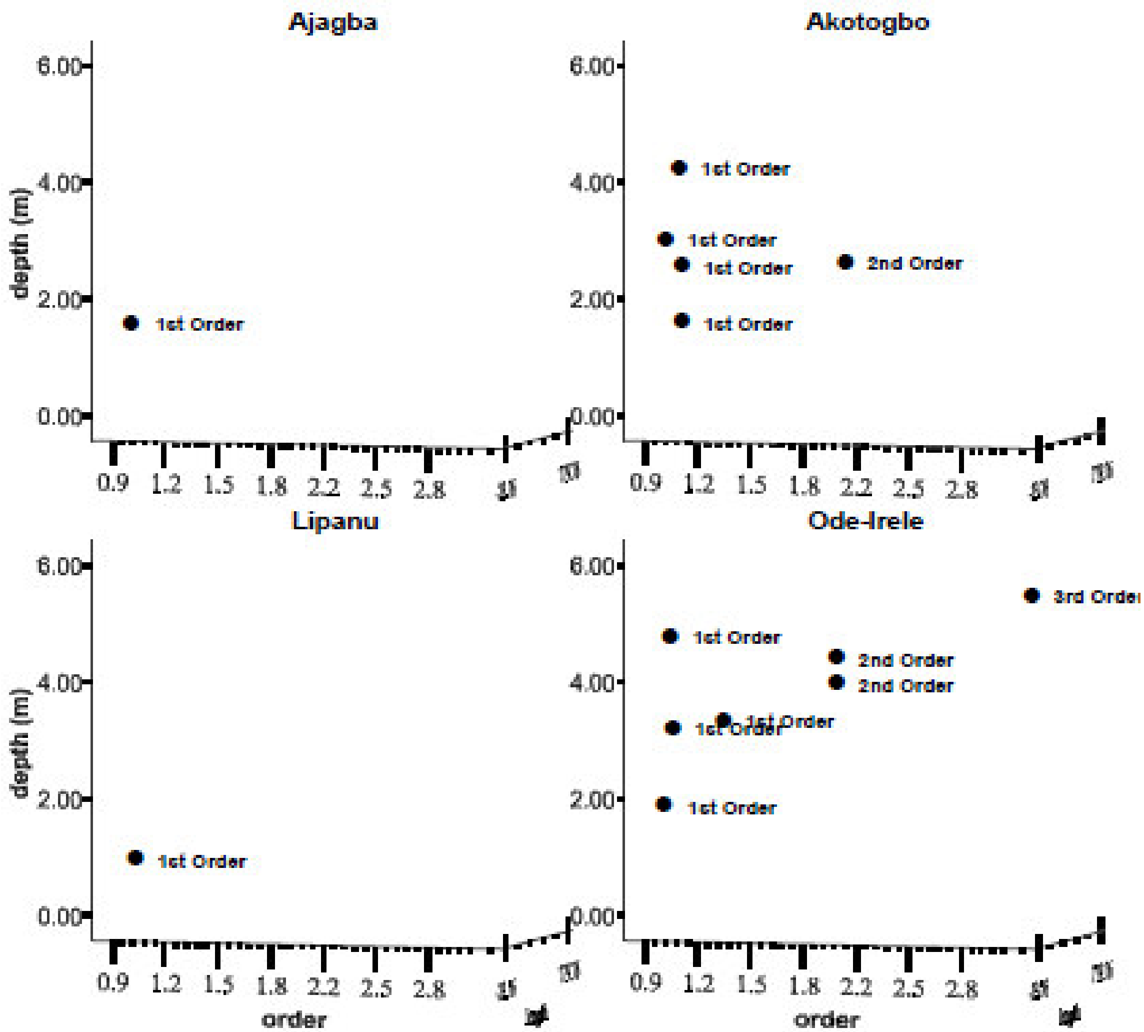

Figure 4. Distribution of the gullies in each settlement.

Table 3: Mean values of some soil physical properties at the studied settlements.

Gully sites	Mean Bulk Density	Moisture (%)	Total Porosity	Sand – clay ratio
Lipanu	1.45	12	18.65	1.45
Ode Irele	1.72	10.17	16.17	1.72
Ajagba	1.65	9.44	15.05	1.62
Akotogbo	1.89	12.43	23.11	1.89

Table 4. Catchment area, annual runoff, soil volume, and sediment loss.

Erosion gully Site	Area of catchment (Ha)	Total annual runoff (m^3)	Total volume of soil loss (m^3)	Sediment loss (tonnes)
Lipanu	5.059	50389.02	132.47	192.08
Ode-Irele	66.39	563042.2	16504.5	28848.5
Ajagba	11.887	118632.26	1167.54	1926.44
Akotogbo	13.269	132424.62	13213.25	24973.04

Table 5. Result of the Analysis of variance performed to investigate significant differences in the morphometric variables.

Variables	Settlements	length(m)	depth(m)	width(m)	cross-sectional area
F - distribution		45.92	2.57	10.78	3.9
F - probability		0.00	0.051	0.000	0.06
Ode - Irele	Akotogbo	0.000	ns	0.000	ns
	Ajagba	0.000	ns	0.003	ns
	Lipanu	0.000	ns	0.002	ns
Akotogbo	Ajagba	ns	ns	ns	ns
	Lipanu	ns	ns	ns	ns
Ajagba	Lipanu	ns	ns	ns	ns

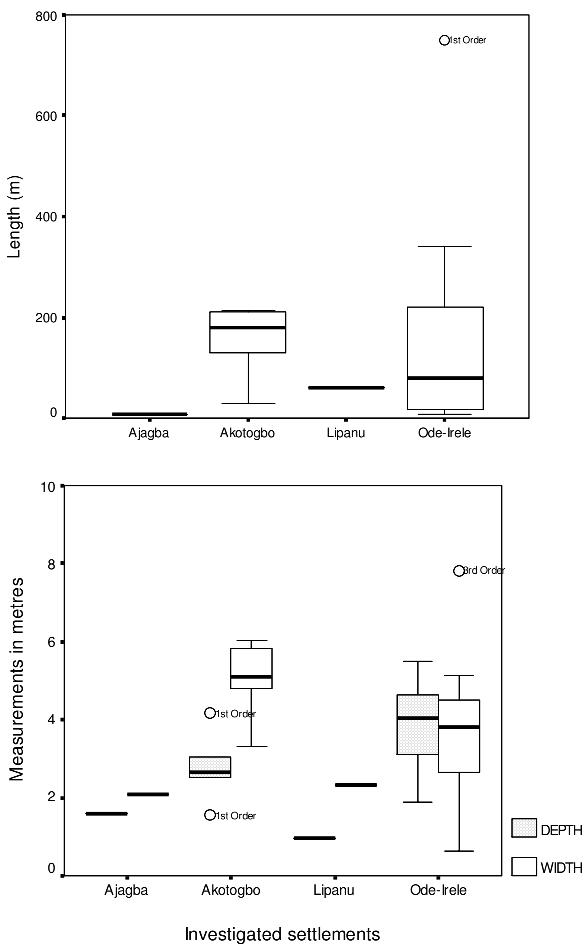

Figure 5. Some characteristics of the gullies in the study settlements, showing outliers and extremes.

by 3.3 m (width)) at the gully head in Idogun was generated form the network of concrete drains that covers just about 8.3 ha (32%) of the total catchment area (86.895 ha). At Ode - Irele, a similar process was observed where runoff plunged into an unpaved drain to scour the soil to a depth of 7 m and a width of 18 m.

Moreover, the result of Analysis of variance performed to distinguish among the selected gullies revealed that the gullies in Ode – Irele differ significantly from those of the surrounding communities, especially in terms of length and width (Table 5). This could suggest a severe impact of growing urbanization rate in most administrative headquarters in Nigeria. Such growth and development are often achieved unsustainably in the country, with a probability of causing environmental problems (Akinbode et al., 2008). Previous studies on gully in southern Nigeria has shown that gully is often initiated by rainfall events on surfaces whose vegetation cover has been removed for agricultural purposes, and sites of uneven compaction of surface soils by human and animal feet, wheeled traffic, in off-road locations. It also takes place, where soils and sediments surround artificial materials, such as poorly designed road culverts and roadside gutters (Hudec et al., 2006). This is true of observations in this study where an attempt to develop an area has resulted into environmental problems (Mukoro, 2005).

The LGA authority is saddled with the responsibilities, which include construction and maintenance of roads, streets, street lighting, drains and other public highways, parks, gardens, open spaces, or such public facilities as may be prescribed from time to time by the House of Assembly of a State and the development of agriculture and natural resources, other than the exploitation of minerals (FGN, 1999). However, guided by the territorial roles performed by LGA headquarter, it is often the ‘core’ of development, which often acquires the lion’s share of the community’s resource while the surrounding villages suffer from inadequate resource allocation, relative underdevelopment and under-population (Onakerhoraye and Omuta, 1994; Obasanjo, 2003). It may therefore not be incorrect to suggest that the gully formation process in the villages of Lipanu, Akotogbo and Ajagba have been initiated by the natural factors of rainfall intensity and soil characteristics. Earlier, it has been shown that the soils here are typically sandy (compare Table 1). However, those of Ode – Irele have been aggravated by human developmental activities, which have been largely unsustainable (compare Figure 5).

Conclusions

The study of Irele LGA highlights the importance of human activities as a factor that could aggravate gully process in an area. The study is based on an area which is likely to express little variation in climate and soil characteristics. Although this was not confirmed in this study, previous studies (Stamp, 1938; Odekunle and Eludoyin, 2008) have shown that the southwest Nigeria is permanently under the influence of the Tropical Maritime air mass, and thus, wet season throughout the whole year. Thus, rainfall was implicated to initiate gully in this region. In addition, the study has shown that the soils in this area have a high percentage of sand (> 55%) and high sand to clay ratio. This type of soil belongs to 'irrigable' class of the Modified US Bureau of Reclamation Land Suitability Class specifications (FAO, 1976; Adepetu et al., 2000). They are thus highly erodable. That certain attributes of the gullies (width and length) in Ode-Irele (the administrative headquarter) is significantly higher than those from other settlements (compare Table 1 and 5) suggests that the causes of gully in the present study are not mainly soil characteristics, less human activities as obtained elsewhere in the southeastern Nigeria (Ofomata, 1965). Gully in the present study was initiated by rainfall, collaborated by 'irrigable' soil characteristics, and aggravated by human activities. This observation is similar to that reported by Floyd (1965) that soil characteristics and human activities caused soil gully. This study however did not consider, explicitly, the contributions of the groundwater conditions, climatic difference and topography as observed by Nwajide and Hogue (1979) and Egboka and Nwakwo (1985). This does not suggest that they are not important. They are however not varying significantly in the present study, probably because of the dimension of the space involved (about 41 km^2).

Nonetheless, based on the findings of this study, it will be concluded that unsustainable development is largely responsible for gully formation in the study area. Irele LGA is typical of most local government administrative headquarters in Nigeria, and other developing countries where rapid growth is anticipated by the nationals, to which the applicability of the findings in this study are anticipated. Thus since the issue of sustainable development has become a World challenge, it has become mandatory to government and non governmental investors in these countries to attempt harmonizing profit priorities with the threshold of the environment

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