Relating Urban Parameters To Gully Development In Southwestern, Nigeria

Matthew IBITOYE and Aderemi ADEDIJI, Nigeria

Keywords: Impervious surface, Drainage density, gully catchment, Total station

SUMMARY

This study examined the contributions of urban parameters to gully development in Southwestern Nigeria. It identified various parameters that contributed to urban gully development with a view to develop a predictive model for monitoring accelerated gully erosion in this part of the humid tropics.

Twenty (20) towns were randomly selected for this study from where thirty (30) gully systems comprising forty (40) 1^{st} order and five (5) 2^{nd} order gullies were measured using Total Station (TS). Global Positioning System (GPS) receivers was used to extend controls (XYZ coordinates) to gully catchment and also in the determination of spot heights within the gully catchment. Google Earth images (2.5m spatial resolution) were used to extract catchment characteristics such as area, drainage lengths, number of houses in the catchment and the impervious surface area. Soil samples taken from gully shoulders (soil tops) and floor were analyzed for textural characteristics and bulk density. Data were analyzed using descriptive statistics, analysis of variance, multiple regression (stepwise) and geospatial techniques.

The result showed that impervious surface (X_1) and bulk density (X_2) contributed 89.8% ($R^2 = 0.898$; $\beta = 0.557$; $P<0.05$) to the soil loss variance in the study area. The study showed that urban gully development was largely caused by large volume of runoff on mainly steep earth roads and unpaved drains coupled with poor engineering work and drains maintenance. Hence, there is need to grass open surfaces within urban built-up areas in order to reduce the rate of imperviousness of the surfaces as well as the rate of occurrence of accelerated soil erosion.

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1. INTRODUCTION

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 river channel morphology in the humid tropics (Meijerink et al, 1994). Gullying could become even more severe in areas of high population growth and high rainfall intensity (Marker and Sidorchuk, 2003). Gullies assume (diverse) destructive dimensions in many parts of the world particularly in the urban environment. The exposure of tree roots, building foundations, utilities (e.g. electric and tele-communication poles, water pipes) and other structures are evidence of erosion problems in most of Nigerian towns and villages. In fact, Jeje (2005) observed that accelerated erosion in form of gullying was to a large extent an urban phenomenon in Southwestern Nigeria.

Several studies exist on the effects of urbanization on soil and sediment loss in both the temperate and tropic regions. For instance, Harvey (1974), Gregory (1977), Hollis (1975), Walling (1979), Hooke (1980), Sawatsky and Tuttle, (1996), as well as Lei (2008) among others carried out several studies on the effects of urbanization on soil erosion and sediment loss in the temperate regions and Heede, (1970), Rapp, (1975), Akintola, (1978), Gupta, (1984), Oyegun, (1987), Okoye, (1988), Ebisemiju, (1989a and 1989b), Jeje and Ikeazota, (2002), Jeje, (2005), Aziegbe, (2006), Ionita, (2006), Jimoh, (2008) among others carried out several studies on accelerated erosion in urban environment in the tropics. Also, the conference of International Association of Geomorphologists (IAG) in 1986 focus attention on urban erosion and local organizing committee (LOC) led an excursion to several eroded areas particularly gullies in the city of Manchester. The focus of the meeting by SCOPE – IUG in 1999 was also on sediment loss from cities. Since these conferences, the issue of urban erosion has been on the front burner among geomorphologists.

In many of these studies, attention was focused mostly on the contributions of climate, soil characteristics and anthropogenic factors to gully development, neglecting the contributions of catchment parameters such as urban soil, impervious surface, drainage density and other urban land use characteristics. Therefore, this present study attempts to examine the various parameters influencing urban gully development in this part of humid tropics. In other words, the study will evaluate the effects of all the various characteristics of urban land surface on gully development with the aim to identifying which of the parameters is most important in predicting urban gully growth. This is very important if urban gullying is to be controlled and remediated.

2. STUDY AREA

The former Ondo State (now Ondo and Ekiti) of Southwestern Nigeria constituted the study area. The study area is underlain by the sedimentary formation to the south and Basement Complex rock to the north. The choice of the study area was as a result of its true representation of Southwest Nigeria (excluding Lagos State) in terms of geology and physiographical characteristics. The study area which is part of the eastern section of Southwest Nigeria, lies between latitude 5^o 57` N and $9^o$ 12` N and longitude 2^o 40` E and $6^o$ 03` E (Figures 1).

The population of the study area is 5,825,236 (Ondo – 3, 441,024 and Ekiti – 2,384,212) (NPC, 2006). The people of the region are predominantly Yorubas comprising sub groups such as, Akures, Ekitis, Ondos, Ikales and Ilajes and settled in various sized villages and urban centres. As observed by Jeje (1988), the development of most of these towns and villages occurred without any systematic planning. Buildings sprang up without recourse to physical planning particularly during the evolution of traditional urbanization which took place after the Yoruba civil wars at the end of the 19th and early 20^{th} centuries. Some of these towns had a modicum of planning during the colonial period, with the result that high density residential areas adjoined low density fairly laid out residential areas which was joined to the traditional areas and they are high density urban cores. The poor execution of planning policies (residential layout design and implementation), often result in accelerated soil erosion in the study area and thus making the problem an urban phenomenon in contrast to gullying in Southestern Nigeria which is both rural and urban.

The study area is underlain especially to the southern part by Post-jurassic Sedimentary and quartzite, quartz-schist, magnetite, gneisses, granite gneisses, charnockites and coarseporphriti-biotite granite rocks of Precambrian Basement Complex (Anifowose, 1989). Specifically, Oke Imesi, Ijero, Efon, Ilawe axis of the study area was underlain by major rocks of the Ife-Ilesa Schist belt which comprises of Amphibolite Complex Schists and Quartzite sequence (Elueze, 1988). The rocks constitute parent materials of the Oke Messi Soil Association which comprised of different soil series. The most important are the gravelly, sandy and hill drift series (Jeje, 2005). The study area is underlain by the Ferruginous Tropical soils at the northern part, Ferralitic soils at the central and hydromorphic soils formed on fluvial and lacustrine alluvium in the southern part (Smyth and Montgomery, 1962). The most important are the gravelly, sandy and hill drift series (Jeje, 2005). The study area is characterized by humid tropical climate (Am Koppen's climatic classification) with mean annual temperature of 27 ^{o} C and a mean annual rainfall ranging between 1250mm and 1400mm, distributed between the months of March and October with peaks in July and September, and short dry spells in August, whose occurrence however varies from year to year. (Akinbote et al, 2008). The rainfall effectiveness is between 6-9 months in the year (Udo, 1978) but in recent years the rains started much earlier in February in some parts of the study area (Odekunle, 1997, Omogbai, 2010). From November through February, the area experiences the dry season due to the prevalence of the dust laden north-east trade winds (cT air masses) that blow across the region, loaded with fine dust from the Sahara with short periods of haze weather, locally referred to as harmattan.. The onset and withdrawal of the rains are marked by thunderstorms accompanied by high rainfall intensity (Odekunle, 1997).

3. MATERIAL AND METHODS

Both primary and secondary data were used for this study. The values of existing Ground Control Points (GCPs) were collected from Survey Sections of the States Ministry of Lands and Housing in Akure and Ado Ekiti, respectively. Where the points were found to be insufficient or too far from the gully sites, a single frequency geodetic Global Positioning System (GPS, South H66 and H68) was used to provide more control points. The positional coordinates (Easting and Northing and Elevations) obtained through this method were later used for correction and geo-referencing of the Google Earth imageries (2.5m spatial resolution) used in the study area. Population data of selected settlements in the study area were collected from the Federal Office of Statistics while rainfall data were collected from the Agro-climatological and Ecological Project Office, Ministry of Agriculture, Forest Resources, Akure and Ado Ekiti, respectively.

Twenty (20) towns were randomly selected from a list of 25 towns with cases of serious gully erosion problem. Thirty (30) gully systems comprising forty (40) 1^{st} order and five (5) 2^{nd} order gullies were selected for the study. The gully catchments were delineated on the ground and from Google Earth imageries. Spot heights (terrain configuration) of the catchment was determined using GPS receivers in a 'track-and-go' method at approximately 50m grid interval. For each gully, the information stored in the memory compartment of GPS was downloaded and processed with the aid of the manufacturer's software to get the X, Y, Z values of each point. The processed data were stored in the Notepad of Microsoft Office.

The dimension (length, width, depth and gully surface area) of each gully was measured using Total Station (TS) with angular and linear accuracy of 2 seconds and ±2mm + 2ppm (see Ibitoye, 2012). With the hard copies of Google Earth imageries, the entire area routing runoff into the gullies (catchment area) was identified physically in the field and delineated along the catchment or drainage divide. Infill developments (developments after the imageries have been captured) such as buildings, drainages, roads and impervious surface were also identified in the field. The Google Earth imageries were geo-referenced with the values of well dispersed and well distributed Ground Control Points (GCPs) that are identifiable on the imageries using AutoCAD Land Development version 2007. All features of interest (buildings, drainages, roads and impervious surfaces) were later digitized on screen and their values estimated using geostatistical tool of the software. The summation of all the drainage lengths, both macro and micro channels, were made and divided by area of catchment to produce drainage density for each catchment.

Soil samples were taken from gully shoulders (tops) and floors. The number of samples from each gully depends on the length and slope gradient of gully catchment (U.S.Dept. of Agric, 2009). Based on this principle 45 samples were collected for textural analysis. In addition, core sample were also taken using McCauley sampler for the determination of soil bulk density which was used to estimate the weight of sediment loss (tonnes). The details of the methods adopted in the study is documented elsewhere (Ibitoye, 2012). Data collected was analyzed using descriptive statistics, Analysis of Variance, multiple regression (stepwise) and geospatial techniques The level of contribution of each variable in the overall gully development in the study area was determined using Factor Analysis (FA) and multiple (stepwise) regression analysis in order to determine the most important parameter for predicting sediment loss from studied gullies in the study area. The factor Analysis was used in order to remove multicollinearity in the data. These statistical analyses were done using SPSS statistical packages.

4. RESULTS

The physical characteristics of soils in the studied gullies are shown in Table 1. The values for both the gully top and floor are presented in the Table 1. As evident from Table 1, the values of bulk density obtained at the top soil, ranged between 1.29 g/cm^3 at Ijero and 1.82 g/cm^3 at Oke Ibedo, Ilawe with a mean of 1.53±0.112 g/cm^3 while the gully floor has values ranging from 1.49 g/cm^3 at Odo Owa to 1.96 g/cm^3 at Usin, Ikole and a mean of 1.72± 0.135 g/cm$^{3.}$ As shown in the table, all the soil sampled irrespective of depth, exhibited high bulk density values which are far above 1.0 – 1.3 g/cm^3 considered for well aggregated forest or grassland vegetation (Babalola, 1988, Hagan et al, 2010). The soil moisture values at the upper soil level ranging from 7.3% at Odo Iro, Oke Imesi to 20.89% at Odo Osun, Igbara Oke and a mean value of 14.56%. On the gully floor, the values varied from 10.38% at Ita Osun to 21.94% at Osinle and have a mean value of 16.32%. The soils in the study area are predominantly sandy clay with mean percentage of sand (53.43%), while clay and silt were 32.45% and 14.12%, respectively at the top soil layer. On the gully floor, clay content exhibits highest mean percentage of 44.88%, followed by sand (42.64%) and silt (12.48%). The table also revealed that the proportion of sand decreases with soil depth while clay content increases with soil depth. This showed that soil would be more resistant to gullying process and thus, the V-shaped profiles observed in most of the gullies. At the gully top, the values of clay ratio ranged between 1.00 and 3.60 at Oke Ibedo, Ilawe and Ayeka, Okitipupa, respectively with a mean value of 2.30. The value at the gully floor was between 0.49 at Ikalako, Aramoko and 4.06 at Odo Osun, Igbara Oke with a mean value of 1.48.

Table 2 shows some physiographic attributes of catchment area of individual gully systems. The catchment area ranged from 1.18 hectare at Osinle in Akure to 77.265 hectares at Eddy Hotel, Ilutitun. A total sum of 1075878.151m drainage channel lengths conducted runoff over a total catchment area of about 501.248 ha, out of which 439.177 ha (88%) formed the primary catchment (areas that primarily conducted surface runoff that initiated gully formation). The drainage density ranged from 0.100 at Owo to 0.380 at Odo Osun, Igbara Oke. The table further reveals that about 420.993 ha (84%) of the catchment was impervious being covered with 6094 houses. The catchments had housing density which ranging from 4.11 per hectare at Methodist, Ikole to 34.233 at Oke Ibedo, Ilawe. The generalized catchment slope gradients range from approximately 1^0 04’ 21’’ at Odo Osun in Igbara Oke to 8^0 24’ 40’’ at Agbangudu, in Ijero. Based on slope characteristics, the catchments can generally be regarded as flat. As expected, Eddy gully catchment with the largest area (62.358ha) produced the highest volume of runoff (1,544,419.74 m^3 per annum), followed by AUD, Ikare (53.04 ha) and Apata, Okitipupa (33.49 ha) with the runoff volume of 831639.69 m^3 and 829,411.34 m^3 per annum, respectively.

Table 3 shows the relationship among catchment attributes. The result shows that catchment area (Y_1) is significantly and positively correlated with four other attributes namely, impervious surface (Y_2) channel length (Y_3), runoff ((Y_7) and number of houses (Y_8) within the catchment ($r \geq 0.84$; $p \leq 0.05$). Impervious surface (Y_2) also correlated significantly and positively with channel length (Y_3), runoff (Y_7) and No of houses (Y_8) within the catchment ($r \geq 0.86$; $p \leq 0.05$). Channel length (Y_3) correlated positively and significantly with runoff (Y_7) and houses within the catchment (Y_8) ($r \geq 0.74$; $p \leq 0.05$). It also has a positive but weak correlation ($r=0.40$; $p \leq 0.05$) with rainfall (Y_6). Surprisingly, rainfall (Y_6) maintained positively but rather weak relationship with runoff ($r=0.42$; $p \leq 0.05$) while runoff (Y_7) on its own correlated positively and significant with houses (Y_8) within the catchment ($r=0.77$; $p \leq 0.05$). Slope gradient (Y_5) have negative relationship with bulk density (X_1) ($r=-0.63$; $p \leq 0.05$). Also %sand have strong negative relationship with %clay and %silt, respectively ($r \geq -0.67$; $p \leq 0.05$). It is also worth to mention that drainage density (Y_4) and %clay (X_3) has no significant relationship with any of the variables. The results of factor analysis (FA) performed to determine the important explanatory variables for gullies growth and development in the study area showed, total catchment area, impervious surface area, channel length, number of houses, and slope gradient load highly on component1. Sand and clay load highly on component 2 but with negative value for sand. Drainage density and housing density load highly on component 3 while silt and erosivity load highly on component 4 (see Table 4). A critical examination of the four components revealed that component 1 was a gully catchment parameter factor while component 2 was regarded as earth material factor. The contribution of each component to the variance explained was shown in Table 5. From the table, the eigenvalues of the 14 variables (earth materials and environmental parameters) were summarized into four factors. The retention of four factors out of 14 principal components obtained for the factor analysis was based on the choice of components with eigenvalues greater than 1.0. Components 1, 2 and 3 in Table 5, accounted for 75.44% variance in the original data. In the table, component 1 explains 38.23% of the variance while component 2 and 3 accounted for 21.44% and 15.76% of the variance, respectively. The sums of square loadings (Table 5) also confirmed a cumulative variance of 64.86% from the three components (1, 2 and 3)which further explained the contributions of some gully variables. The stepwise regression analysis performed on the earth materials and environmental parameters showed that impervious surface area and soil bulk density contributed 89.8% ($R^2 = 0.898$) of the total variance with adjusted R^2 value of 0.741 ($p=0.024$), F-cal 12.462 ($p=0.007$) and standardized coefficient (β) 0.557 ($p=0.024$) (see Table 6). The table further shows impervious surface area as the most important predictor of sediment loss in the study area by accounting for 71.2% ($R^2 = 0.712$) (β 0.595; $p=0.020$) of the soil loss variance. The contributions of other factors are shown in the table (see Table 6) and their t ($p \geq 0.37$) values showed that they were not significant. The

Table also shown a t- values of 3.160 ($p < 0.20$) for impervious surface and 3.011 ($p < 0.24$) for bulk density. The implication of these values is that any positive unit change in the two predictors (impervious surface and bulk density) will further aggravate the impact on the sediment loss from the gullies through increase in volume of runoff.. A predictive equation was generated for sediment loss from the study gullies in the study area. The equation is expressed as;

$$Y=-45798.82+352.51X_1 + 27694.24X_2$$

Where;

Y= Soil loss (m^3), X_1= Impervious surface (Ha), X_2= Bulk density (g/cm^3)

5. DISCUSSION

The high bulk density value (1.5 g/cm^3 and 1.8 g/cm^3 at the topsoil and gully floor respectively) obtained for this study indicated that the soils in the study area are highly compacted due to urban activities such as human and vehicular traffic, construction for engineering purpose such as roads and other civil works. These values are far above the 1.0 -1.3g/cm^3 considered for well aggregated forest land (Babalola, 1988). By comparison, the values of bulk density obtained in the study area was in the same range for the values obtained for urbanized city of Miami-Dade and Gainesville in Florida which were averaged at 1.63 g/cm^3 and 1.52 g/cm^3, respectively (Gregory, et al 2006, Hagan, et al 2010). The implication of high values of bulk density in the study area is that there would be reduction in the infiltration capacities of the soils, thus making the soil prone to greater runoff and soil loss. When this happens, more water would be generated as surface runoff in the case of a steep slope terrain and flooding as in the case of lowland area. As runoff flows down slope, there is tendency for it to create rills which may later converge down slope, especially if it is concentrated, to form gullies. The above process explains the gully formation and pattern observed at Idogun and Orunbemiku in Ode Irele, Adu in Akure and Odo Ese 1st order gullies II and III in Oke Imesi where the greater proportion of the surface runoff flows over heavily compacted urban roads upslope of the gully catchments. The result of stepwise regression analysis also showed bulk density as a significant predictor of sediment loss from the studied gullies. With the value of $R^2 = 0.182$ (see Table 6), bulk density contributed 18.2% of the soil loss variance in the study area. The implication of this is that an increase in the proportion of compacted soil will decrease soil infiltration and consequently generate more runoff and sediment removal from slopes in a urbanized gully catchment .

As evident from Table 1, the soil in the study area is predominantly sandy with 53.43% sand, 32.45% clay and 14.12% at the upper soil horizon while it was predominantly clay (44.88% clay, 42.64% and 12.48%) at gully floor. These results further confirmed that the proportion of clay content increases with depth and thus, increases soil cohesiveness and resistance 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 channels. Ordinarily, the high proportion of sand at the upper top soil could not have supported gully initiation but other factors such as high volume of runoff as a result of increase in impermeable surfaces and other anthropogenic factors, most of the urban bare soils easily susceptible to action of running water (runoff). The soil analysed in this study exhibited higher clay content and higher bulk density at the gully floor. The result thus confirmed the finding of Guerra *et al.* (2006) in their study of urban gullies in Sao Luis City, Brazil, where it was observed that soil with higher proportion of sand content associated with lower bulk density value while soil with higher clay content have higher bulk density. The mean values of 12.93% and 17.7% of moisture content at top soil and gully floor, respectively (see Table1) indicated that the soil pore spaces that are supposed to accommodate soil water and air had been seriously reduced or compressed as a result of soil compaction and consequently decreasing the energy of water (Michael, 1985). When such soil condition happens, infiltration rate becomes very low and thus enhancing runoff and erosion. At low moisture contents, the soil behaves as a solid and fractures under stress but with increased moisture content it becomes plastic and yields by flow without fracture (Morgan, 1996). It is worth mentioning that despite the fact that the soil samples were collected in June/July when the rainfall intensity in the study area was at its peak, the soil moisture was still low which indicate that the soil was highly compacted. The mean porosity values of 19.04% at top soil and 37.24% at gully floor were indications of highly compacted soil which is one of the characteristics of urban soil.

The process of urbanization in the study area increases due to intent and desire for more housing and other socio-economic activities. A great deal of the urban terrains were altered either directly in the form of buildings encroaching into the upper slope, or indirectly by re-routing runoff water unto them. Other activities of man such as the use of heavy machinery during building and road constructions further help to compact soil of the immediate environment (Pickering and Owen, 1997). This situation, leads to reduction in infiltration rate and thus, increases runoff. The footpaths created as a result of trekking from one house to another not only further compact the catchments, but served as micro channels for runoff. In this regard, typical examples were observed at the upper section of gully head at Oni Close in Aramoko and Idogun quarter in Ode Irele and as well as Ita Osun in Efon Alaaye.

As shown in Table 2, all the gully catchment areas were highly developed with total housing units of about 6094 and more than 70% of the catchment areas were impervious. This implies that greater percentage of the catchment surfaces supported the generation of high volume of runoff. This relationship agrees with the observation of Paul and Mayer (2001) that increases in impervious surface has direct effect on water movement in the system. The study also confirmed the observation by Junior et al (2010) in Gama, Brazil where it was observed that imposition of houses, streets and other impervious surfaces altered runoff generation and thus triggered gully formation. The result of stepwise analysis (Table 6) confirmed impervious surface area as the most important predictor of sediment loss in the study area and thus accounts for 71.2% (R^2 = 0.712) (β 0.595; p=0.020) of the soil loss variance from the studied gullies. The implication is that out of 13 variables considered in this study, impervious surface alone contributed more than 70% to sediment loss while 12 other variables accounted for less than 30% of the soil loss variance. Also shown in Table 2, is the total drainage length of 1075878.151m (micro and macro channels) with mean drainage density of 0.240 which networked the entire catchment area of 5012480m^2 (501.248 Ha). However, the value of drainage density obtained in this study is far below the typical drainage density of 1.5 -6.0 considered for urban catchment (Watershed Characteristics, 2000). Table 2 also showed that slope gradients of the studied gully catchments ranged from 1^0 10' to 8^0 25', ordinarily under vegetal cover, these slope gradients would not enhance erosion processes but due to exposure to direct raindrop impact and human activities coupled with poor Civil Engineering work to control the runoff, gullying has become pronounced virtually in all the catchments.

Building of drains along urban streets and concrete channels is a deliberate attempt to control surface runoff but the improper handling of the projects often accelerated or triggered gully formation and growth at the receiving locations. Many of the channels and drains constructions are at times abandoned or terminated half way before reaching the natural drainage channels (stream/ river). Some drains were constructed without any consideration for the slope pattern of the road and amount of runoff to be generated, thus providing avenue for the runoff to overflow the drains during heavy rainfalls. Drainages were not even provided along some roads or provided and not serve the purpose of conducting runoff due to blockage and as a result, uncontrolled runoff flows along the roads/streets and unpaved drains and thus lead to development of incipient gullies as observed along a street, off old Benin Road, in Ore. The annual rainfall in the study area reflects typical characteristics of tropical region rainfall with high amount which ranged from 1249mm to 2,567mm per annum. The result of linear regression analysis between runoff and catchment area shows that there is strong positive correlation between the two variables (F=316.78; P=0.00) (see Ibitoye, 2012). This further confirm the observation by Gregory and Walling (1973) in Exeter and Pathak et al (2005) that the larger the catchment area, the greater the runoff generated. The situation becomes worse in the study area when greater percentage of the runoff routed through long paved steep drains as was the case in Ita Osun in Efon Alaaye, Oke Ila in Ado Ekiti, Odopupa in Igede, Ose in Owo, Eddy Hotel in Ilututun, Aduwo Street, Ode Aye, Odo Ese in Oke Imesi, Ayeka and Apata in Okitipupa. The steepness and the smooth surface of the paved drains in the entire gully locations mentioned above facilitated an increase in both the volume and the velocity of the runoff. This is in accordance with the observation made by Hudson (1995) in Zimbabwe. These factors coupled with unconsolidated nature of soil beneath the concrete channel made it possible for the runoff to severely cut deeper and faster into the earth surface at the termination points. This scenario is similar to the earlier observations made by Jeje (2005) in Efon Alaaye and Auchi as well as Ibitoye (2006)'s findings in some selected towns in Irele Local Government of Ondo State, Nigeria.

6. CONCLUSION

This study examined the various urban parameters that contributed to gully erosion in parts of the Southwestern Nigeria. Catchment area, impervious surface, channel length, number of houses, slope gradient, % sand and % clay accounted for the largest proportion (38.2%) of the total variance in the gully catchment characteristics in the study area. It was further established that combination of impervious area and bulk density contributed 89.8% of all the soil loss variance while impervious area alone contributed (71.2%) of the variance. The study showed that urban gully development was largely caused by large volume of runoff on mainly steep earth roads and unpaved drains coupled with massive impervious surface and poor engineering work and drains maintenance. Therefore, there is need to reduce imperviousness of urban built-up area through grassing of open surfaces within urban environment in this part of the humid tropics.

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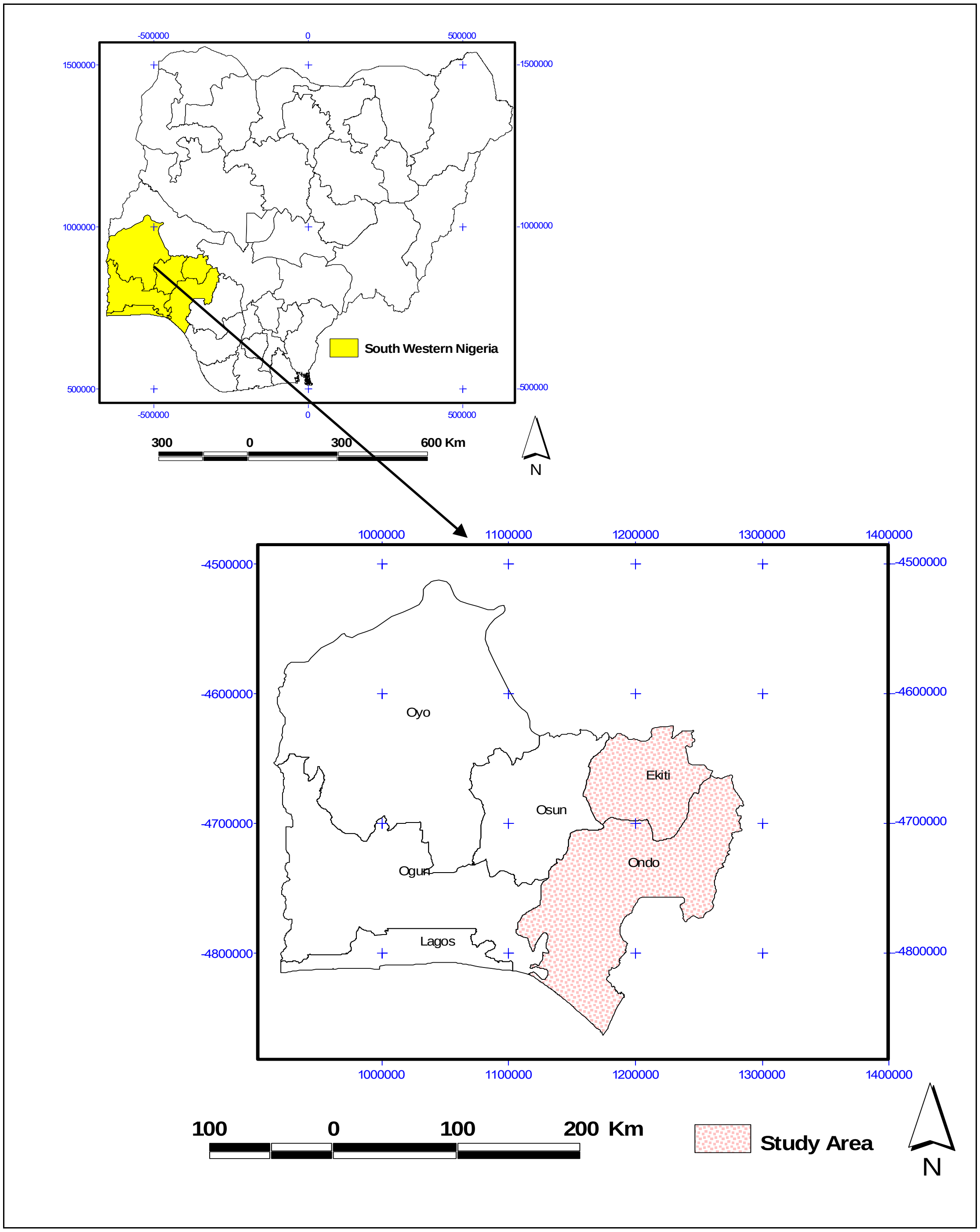

Figure 1: Map of Southwestern Nigeria showing the Study Area (Ondo and Ekiti States).

Table 1: Descriptive Analysis of Soil Physical Characteristics of the Study Gullies.

	Sample depth	Min.Value	Max. Value	Mean	Std. Deviation
Bulk Density(g/cm^3)	Top Floor	1.29 1.49	1.82 1.96	1.53 1.72	0.112 0.135
Moisture Content (%)	Top Floor	7.30 10.38	20.89 21.96	14.56 16.32	3.02 3.35
Sand (%)	Top Floor	32.24 20.80	71.68 75.68	53.43 42.64	10.35 15.68
Clay (%)	Top Floor	21.76 19.76	51.20 65.76	32.45 44.88	7.36 13.81
Silt (%)	Top Floor	6.56 0.56	20.00 24.00	14.12 12.48	4.48 5.67
Clay Ratio	Top Floor	1.00 0.49	3.60 4.06	2.30 1.48	0.64 0.99

N = 45

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Table 2: Catchment Characteristics of the Studied Gullies

S/N	Gully locations	Catchment area. (Ha)	Impervious surface (Ha/%)	Total drainage length (m)	Drainage density (Σch./area)	Catchment slope gradient	Number of houses in the catchment	Housing density (no houses/ catchment)	Runoff (m^3)
1	Oke Ila, Ado	10.064	8.631(85.76)	30192.619	0.300	3^0 52' 24''	146	14.507	135768.18
2	Ibaka, Akungba	27.540	25.883 (93.98)	34149.949	0.124	1^0 48' 52''	284	10.31	366975.65
3	Adu, Akure	4.065	3.681(90.54)	6570.639	0.162	2^0 13' 52''	53	13.038	58243.88
4	Osinle I, Akure	6.718	5.667 (83.35)	10343.09	0.154	$2^0$20'26''	57	8.485	95316.70
5	Osinle II, Akure	1.182	1.118 (94.62)	1746.54	0.148	2^0 11' 18''	13	10.998	17687.77
6	Ikalako, Aramoko	18.331	14.905 (81.31)	35379.513	0.193	4^0 12' 49''	378	20.621	186307.04
7	Oni Close, Aramoko	1.725	1.674 (97.04)	4046.956	0.235	3^0 19' 17''	43	24.928	20928.59
8	Ita Osun, Efon Alaye	21.193	17.939 (84.65)	52975.45	0.250	4^0 19' 09''	307	14.486	224226.82
9	Olofin Str., I/Odo	9.971	7.638 (76.60)	28417.721	0.285	2^0 14' 12''	132	13.238	119866.28

10	St. Francis, I/Odo	5.333	4.791 (89.84)	16584.991	0.311	1^0 50’ 41’’	157	29.439	75180.05
11	Odo Osun, I/Oke	12.048	11.911(98.86)	45778.758	0.380	1^0 04’ 21’’	359	29.797	186902.39
12	Ijemoji I, II &III, Igede	3.120	2.797 (89.68)	9494.05	0.304	2^0 32’ 49’’	64	20.513	47239.75
13	Odopupa I&II, Igede	26.628	21.683 (81.43)	62544.970	0.235	2^0 56’32’’	467	17.537	366157.15
14	Agbangudu, Ijero	4.256	3.538 (83.13)	10959.917	0.257	8^0 24’ 40’’	51	11.983	53421.02
15	AUD, Ikare	63.551	53.037 (83.46)	65478.365	0.103	4^0 36’ 38’’	714	11.235	831639.69
16	Iyame I&II, Ikare	8.260	6.876 (83.24)	13769.442	0.182	3^0 56’ 10’’	224	27.119	107817.93
17	Usin, Ikole	9.709	9.266 (95.44)	31650.700	0.326	1^0 33’ 02’’	114	11.742	140944.11
18	Methodist, Ikole	19.693	18.848 (95.71)	47263.01	0.240	2^0 7’ 33’’	81	4.113	286706.67
19	Oke Bedo, Ilawe	3.593	3.593 (99.00)	9824.40	0.273	1^0 21’ 42’’	123	34.233	48954.98
20	Eddy Hotel, Ilutitun	77.265	62.358 (80.71)	203981.288	0.264	1^0 59’ 06’	620	8.024	1544419.74
21	Aduwo Str., Ode Aye	16.337	14.543(94.44)	45907.406	0.281	2^0 06’ 36’’	248	15.180	360177.47
22	Idogun, Ode Irele	1.898	1.852 (97.56)	4631.771	0.244	$1^0$12’35’’	63	33.193	47554.84
23	Orunbemiku, Ode Irele	3.808	3.738 (98.17)	10700.666	0.281	1^0 09’ 44’’	86	22.586	9778.20

24	Awiri, Odo Owa	5.327	5.133 (96.36)	1603.427	0.301	3^0 16’ 41’’	107	20.086	77520.35
25	Ikese I, II & III, Oka	14.210	11.022 (77.57)	32825.465	0.231	2^0 49’ 55’’	148	10.415	156269.13
26	Odo Ese I, Oke Imesi	16.654	15.812 (94.94)	46250.587	0.278	3^0 12’ 10’’	209	12.550	197647.75
27	Odo Ese II, Oke Imesi	5.390	4.241 (78.68)	15673.710	0.288	3^0 34’ 51’	79	14.657	53016.59
28	Odo Ese III, Oke Imesi	1.834	1.835 (100.00)	5760.612	0.314	3^0 51’16’’	33	17.993	22931.78
29	Odo Iro I, II&II, Oke Imesi	6.194	6.006 (96.96)	19386.806	0.313	2^0 49’ 41’’	205	33.096	75075.22
30	Ayeka, Okitipupa	19.675	15.418 (78.36)	49385.130	0.251	1^0 56’ 40’’	103	5.235	381858.42
31	Apata, Okitipupa	46.184	33.485 (72.51)	90520.124	0.196	3^0 11’ 46’’	260	5.630	829411.34
32	Idimepen, Owo	7.898	5.534 (70.07)	10438.51	0.132	2^0 25’ 30’’	60	7.597	85954.54
33	Odo Ose, Owo	21.594	16.546 (76.63)	21641.569	0.100	3^0 5’ 57’’	106	4.909	25698.66
	Total	**501.248**	**420.993(83.99)**	**1075878.151**	**7.920**		**6094**	**539.473**	
	Mean	**15.189**		**32602.368**	**0.240**		**184.667**	**16.348**	

Source: Fieldwork, 2012

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Table 3: Results of the Pearson Correlation of Some Soil Properties and Catchments Attributes of Gullies in the Study Area

	X_1	X_2	X_3	X_4	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7	Y_8	Y_9
X_1	1												
X_2	0.038	1											
X_3	0.135	**-0.900***	1										
X_4	-0.318	**-0.668***	0.277	1									
Y_1	-0.225	0.024	-0.146	0.198	1								
Y_2	-0.217	-0.001	-0.138	0.238	**0.994***	1							
Y_3	-0.167	-0.135	0.004	0.292	**0.880***	0.869*	1						
Y_4	0.192	-0.351	0.295	0.271	-0.364	-0.356	-0.007	1					
Y_5	**-0.632***	0.036	-0.214	0.280	0.061	0.047	-0.056	-0.144	1				
Y_6	0.221	0.086	0.075	-0.321	0.259	0.229	0.404*	-0.090	-0.253	1			
Y_7	-0.102	-0.145	0.152	0.062	**0.954***	0.947*	0.951*	-0.070	0.082.	0.452*	1		
Y_8	-0.158	-0.271	0.092	**0.411***	**0.841***	0.857*	0.740*	-0.127	0.088	0.122	0.769*	1	
Y_9	0.206	-0.224	0.278	0.018	**-0.462***	-0.443*	-0.328	0.533*	-0.183	0.028	0.022	-0.012	1

Source: Fieldwork, 2011

* Correlation is significant at the 0.05 level

X_1 = Bulk density, X_2 = Sand, X_3 = Clay, X_4 = Silt, Y_1 = Catchment area, Y_2 = Impervious surface, Y_3 = Total channel length, Y_4 = Drainage density, Y_5 = Slope gradient, Y_6 = Rainfall, Y_7 = Runoff, Y_8 = No of houses per catchment area, Y_9 = Housing density

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Table 4: Results of the Varimax Rotated Factor Loading Matrix for Four Factors

Variables	Components			
	Factor 1	Factor 2	Factor 3	Factor 4
Total catchment area	**0.970**	0.081	0.024	0.090
Impervious surface	**0.977**	-0.011	0.067	0.130
Drainage density	0.242	-0.053	**0.778**	0.434
Channel length	**0.877**	-0.048	0.262	0.297
No of Houses	0**.897**	-0.084	0.398	0.053
Housing density	0.218	-0.276	**0.908**	0.041
Slope gradient	**0.602**	0.456	-0.350	0.390
Bulk density	0.087	-0.129	-0.093	0.266
Sand %	-0.042	**-0.990**	0.078	-0.103
Clay %	-0.037	**0.955**	-0.205	-0.178
Silt %	0.233	0.315	0.348	**0.812**
Rainfall	-0.329	-0.093	0.103	-0.164
Runoff	-0.534	0.484	0.252	0.130
Erosivity	-0.450	0.269	-0.023	**0.885**

Source: Fieldwork, 2012

Table 5: Results of the Factor Analysis Showing Total Variance Explained by the Variables Considered for the Gullies Studied

Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.353	38.234	38.234	4.419	31.562	31.562
2	3.002	21.446	59.680	2.626	18.758	50.320
3	2.206	15.760	75.440	2.036	14.541	64.861
4	1.824	13.028	88.468	1.908	13.627	78.789
5	1.023	7.304	95.775	1.401	10.006	88.495
6	0.453	3.239	99.011			
7	0.115	0.819	99.830			
8	0.024	0.170	100.00			
9	0.00	0.00	100.00			

10	0.00	0.00	100.00			
11	0.00	0.00	100.00			
12	0.00	0.00	100.00			
13	0.00	0.00	100.00			

Source: Fieldwork, 2012

Table 6: Results of the Stepwise Regression of Earth Material and Catchment Parameters of Gullies in the Study area

			ANOVA				
Variables	**R^2**	**Adj.R^2**	**F-cal**	**Sig.**	**β**	**t**	**Sig.**
Impervious area (x_1) only	0.716	0.443	7.368	0.030	0.585	3.16	0.020
bulk density (x_2)	0.182	0.298	5.094	0.024	0.557	3.011	0.024
Impervious area (x_1) & bulk density (x_2)	0.898	0.741	12.462	0.007	-	-	-
Sand (%) (x_3)	0.178				-0.197	0.981	0.372
Silt (%) (x_4)	-0.149				-0.149	0.698	0.516
Clay (%) (x_5)	-0.158				-0.158	0.834	0.442
Catchment area (x_6)	-1.519				-1.519	-1.045	0.344
Drainage length (x_7)	0.429				0.429	0.795	0.463
Drainage density (x_8)	0.029				0.029	0.137	0.896
Slope gradient (x_9)	-0.067				-0.067	-0.246	0.815
Housing density (x_{10})	-0.132				-0.132	-0.668	0.530
Annual rainfall (x_{11})	-0.116				-0.116	-0.498	0.640
Runoff (x_{12})	-0.016				-0.016	-0.172	0.946
Erosivity (x_{13})	-0.127				-0.127	-0.562	0.598

Source: Fieldwork, 2012

Plate1: Plate 2:

Plate 1: Gully formed as a result of poor urban land use management at Ayeka, Okitipupa

Plate 2: Gully formed as a result of half way termination of concrete channel at the back of Gospel Faith Mission Church, Ado Ekiti

BIOGRAPHICAL NOTES

Matthew O. Ibitoye holds B.Sc., M.Sc. and Ph.D degrees in Geography and Environmental Control and Management, respectively from the University of Calabar and Obafemi Awolowo University, Ile Ife, Nigeria. He is an alumnus of the Federal School of Surveying, Oyo where he obtained postgraduate qualifications in Surveying and Geographical Information Systems (GIS). He is a Fellow and Vice President of the Nigerian Institution of Surveyors. A Registered Surveyor and the Managing Director of Geomatt Associates and Environmental Services, Nigeria. He is an adjunct Lecturer at Joseph Ayo Babalola University, Ikeji Arakeji, Nigeria.

Aderemi Adediji is an Associate Professor in the Department of Geography, Obafemi Awolowo University, Ile-Ife, Nigeria. He holds a B.Sc, M.Sc and Ph.D degrees from Obafemi Awolowo University, Ile Ife. He specializes in Hydrology and GIS.

Dr. Matthew IBITOYE
Geomatt Associates and Environmental Services
Oyemekun Commercial Complex,
Akure, Ondo State, Nigeria
+2348034730290
geomattim@yahoo.com

Dr. Aderemi ADEDIJI
Department of Geography,
Obafemi Awolowo University, Ile Ife, Nigeria
+2348034076707
remiadediji2003@yahoo.co.uk

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