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# GULLY MORPHOMETRY AND MORPHOLOGY IN THE IYI-UKWU BASIN, SOUTH-EAST, NIGERIA

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**ABSTRACT:**
*The characteristics of gullies in the Iyi-Ukwu catchment in Isiala Ngwa, Nigeria were studied and classified as class 2 and 4 gullies using standard classification methods. Mean gully width ranged from 1.07m to 5.17m, while the mean depth ranged from 1.0 to 6.36. Three (3) out of the ten gullies were in the continuous stage of development while others were in their discontinuous stage. All the gullies had a rectangular shape with a gully shape factor of 1.0. Gullies were also found to be long and narrow with the major direction of advancement being southwest wards following the direction of the face of the Enugu-Okigwe-Arochukwu Cuesta. Also morphometric analysis revealed that slope was a major causative factor of gully formation as slope angles ranged between $5^0$ and $14^0$. A statistical analysis of the relationship between gully fall, slope angle and the difference in gully cross sectional areas revealed a significant difference between the cross sectional area of gullies and a significant relationship between gully depth and gully side slope angle implying that as gully channel down-cuts or deepens, the gully side became steeper. This study finally concludes that gullies in the study area were initiated by a combination of steep slopes, high rainfall, soil characteristics, and human activities. Precautionary measures and soft control methods are recommended.*

**Key words:** gully erosion, gully classification, morphometry, morphology, Iyi-Ukwu basin

## INTRODUCTION

Landscape morphology and the processes that bring them into being have always been of interest to scholars. These attempts have created frameworks for interpreting the interaction between impressed forces (external pressure in form of stress and strain from rain and wind power, ice movement and biological activities) and the resistance forces of nature which depends mostly on the patterns of physical cohesion and chemical bonding in matter. Landform evolution is therefore a product of the balancing of these forces in the presence of climatic and endogenic factors, which include rainfall, temperature, relief, soil type and geology. Energy for these geomorphic interactions is provided by the sun, geothermal and gravitational energy.

Land degradation arising from the relationship between landscape features, forms, processes and anthropogenic influence has created erosional hazards in various regions of the world by unbalancing physical environmental systems thereby making it necessary to incorporate sustainability in land-use systems. Land geometry provides the initial pull and drag effect for erosion especially water induced soil removal. Other influential factors in the systematic removal of soil and organic materials from the surface of the earth include wind, water, ice and the activities of man (Egboka, 2004).

Water and wind are responsible for 84% of degraded acreage of land in the world, thereby making soil erosion one of the significant environmental problems we face today (Blanco *et al*, 2010). Approximately, 40% of the world's agricultural land is seriously degraded (Sample, 2007); and it has been established that by 2025, the African continent will only be able to feed just 25% of its population as a result of soil degradation due to uncontrolled human activities (Wikipedia, 2013; ttp://en.wikipedia.org/wiki/Food_security).

Within the humid tropical environment, water induced erosion caused by high rainfall on the land geometry or gradient tilt results in three primary types of soil erosion which include; sheet, rill and gully erosion. Gully erosion is the most severe of the three and has been defined as an advanced and destructive form of soil erosion. When rills or other erosion channels become "so deep that it cannot be crossed by a wheeled vehicle or eliminated by plowing" (Peterson, 1950; Young, 1975). Although there has not been a specific upper limit to the size of gullies, they typically range in size from 0.5m to as much as 30m deep (Soil Science Society of America, 1996).

The main causes of gully erosion are natural as well as anthropogenic. Ruhu (1975), Miller *et al* (2008) and Tarbuck *et al* (2000) have acknowledged the impact of gradient in gully development. The gradient index can increase runoff production on hill slopes and or reduce the erosive resistance of soil surface. The natural, physical or geological causes include; climate, surface configuration (relief/slope), surface material and vegetation. Thus the human components comprise of agricultural practices and other land use activities which cause great change in the relative proportions of infiltration and runoff. Once the rate of rainfall is faster than infiltration rate into the soil, surface runoff occurs and rapidly carries the loosened soil particles down slope (FAO, 1965).

Gully erosion is not peculiar to Nigeria or its South Eastern region. It is a global problem that has numerous effects both on the natural environment and socio-economic life. Impacts include loss of farmlands, siltation of rivers, destruction of roads, bridges, communities and even in some cases loss of human life. For instance in Umuchiani village in Anambra State of Nigeria, inhabitants were forced to vacate their ancestral home due to gully erosion and gully induced landslides in 2005. Also in Isiukwuato Local Government area of Abia State, gullies are now the major land feature. As at 2002, the Isuikwuato Local Government documented over 39 gully sites which occupied about 26.4% of the local government's land area (Umunnakwe *et al,* 2010). Also, in Umuaka Imo State, it was noted ( Akpokodje, e*t al,* 2010), that the depth, width and length of the gullies are over 50m, 500m and 2000m respectively. In 1994, one of the major gullies advanced by

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over 60m within one rainy season. The gullies mainly originated from poorly constructed side drains and termination of culvert at unsafe points at the Njaba River valley along the abandoned old Owerri – Orlu road. It is in this light that the present study sets out to investigate the gully development and the morphology of gullies within the Iyi-Ukwu catchment.

While it is true that gully erosion is a major striking land-feature in the south eastern part of Nigeria, there have not been enough significant control measures applied both by the Federal and the State governments to remedy this environmental challenge. In Isiala- Ngwa North as shown in Table 1, gully formation has been identified within most of its communities. At present, the only work (Kalu, 2000, Alozie, 2005) that has been done is the identification of gully sites in the Local Government Area without any mention of gully processes and characteristics.

**Table 1: Newly Identified Gully Sites in Abia State**

| L G A | Affected Area |
|---|---|
| Umunneochi | Isuochi, Ovim, Mbala, Lokpanta, Ugwu |
| Isukwuato | Leru, Obinaga, Uturu, Ogwugwunta etc(MacWilson, 1994) |
| Isiala Ngwa North/South | Ihie, Eziama Ntigha, Avor Ntigha, Umuala, Umuosu, Umuode, Nvosi, Umuakwu, Ohuhu Nsulu, Aro-achara etc. |
| Umuahia North/South | Ubakala, Nsirimo, Olokoro, Amzuu, Ohia, Umuokpara, Nkwo egwu etc |
| Ohafia | Igbere. Abiriba, Ebem Ohafia etc. |

**(Kalu, *2000; Alozie, 2005)***

This study therefore aims to present the process and nature of gully development within the Iyi-Ukwu catchment, with objectives of establishing the spatial patterns of gully development in the area, analysing gully morphometric parameters and classification within existing frameworks.

**Study Area**

The study area is located within Isiala Ngwa North Local Government Area of Abia State in South Eastern Nigeria. Isiala Ngwa North Local Government Area lies within Latitude $5^o$ 10’ and $5^o$ 30’ North, and Longitude $7^o$ 25’ and $7^o$ 35’ East. According to the 2006 census records, the population of Isiala Ngwa North is 153,734 and covers an area of about 283 $km^2$.

The topography of the Iyi-Ukwu basin is characterized by hills and valley with peak elevationaround 120m above the sea level. Using the Koppen’s climatic classification scheme, the Iyi-Ukwu basin falls within the tropical wet and dry (Aw type) climate, with two seasons in the year, namely: the rainy season and the dry season.

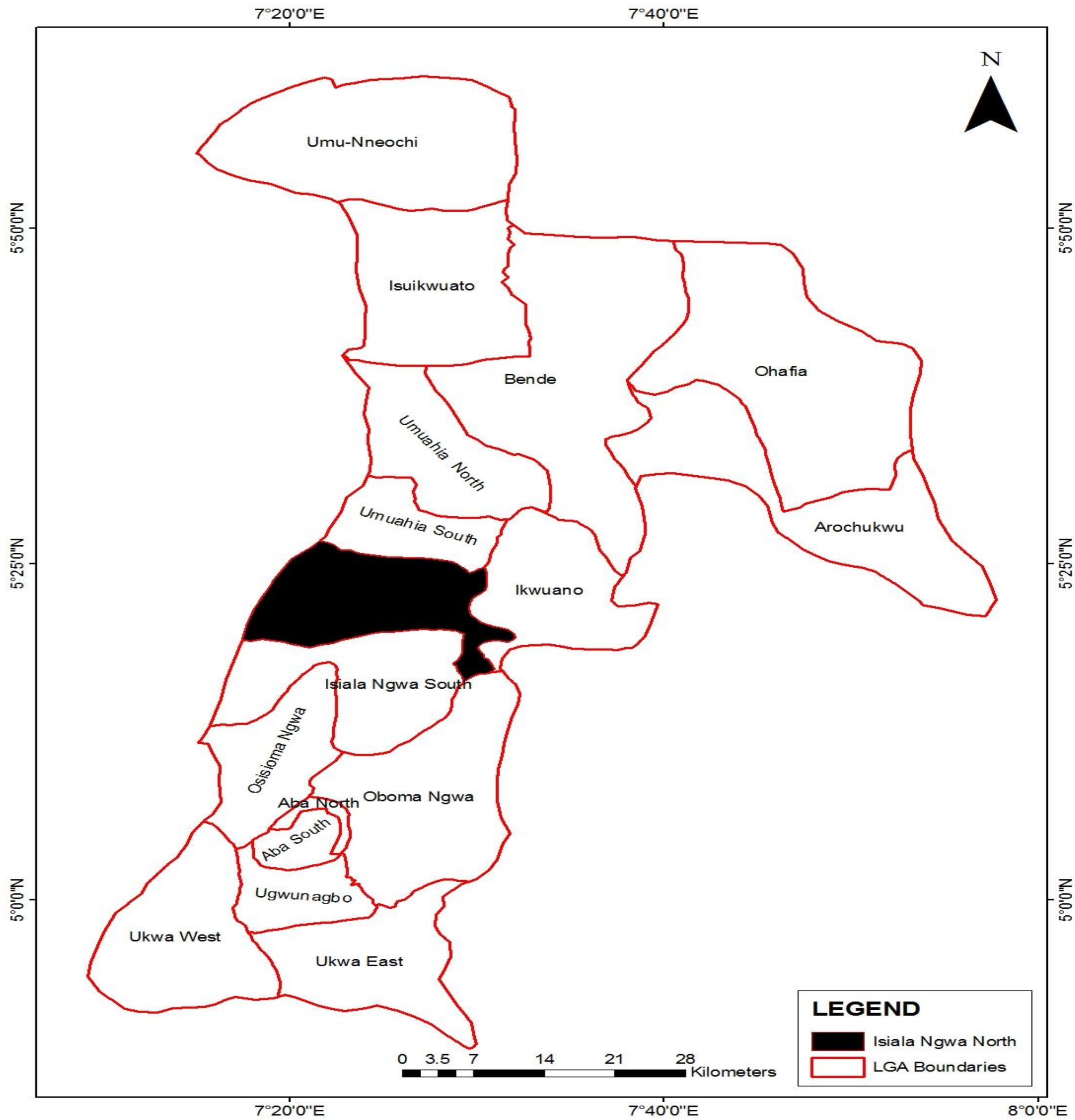


**Fig 1: Map** ***of Abia State showing Isiala Ngwa North Local Government Area*****.**

The rainy season begins in March with characteristic thunderstorms that mark the onset of the rainy season and ends in October with two peaks in June and September. The hottest months are from January to March when the mean temperature is above 27°C with the North East trade winds or the Tropical continental wind (cT) dominating the area. The relative humidity is usually high throughout the year, reaching a maximum during the rainy season when values above 90% are recorded.

The study area falls within Umuahia ecozone. Table 2 shows the mean annual and monthly rainfall of the zone between 2002 -2006 as recorded by Metrological Division, National Root Crops Research Institute, Umudike, Nigeria.

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**Table 2: Mean Monthly and Annual rainfall of Umuahia ecozone**

| Year | Monthly Mean(mm) | Annual Mean(mm) |
|---|---|---|
| 2002 | 210.4 | 2,525.0 |
| 2003 | 229.2 | 2,750.9 |
| 2004 | 169.9 | 2,039.3 |
| 2005 | 165.5 | 2,701.0 |
| 2006 | 225.1 | 2,030.0 |
| Overall Mean | 200.0 | 2,400.4 |

***(Metrological Division, National Root Crops Research Institute, Umudike, Nigeria; 2007)***

In Abia state, there are two principal geological Formations namely Bende-Ameki and the Coastal Plain Sands which is also known as the Benin Formation (Igboekwe *et al* 2011) of which the Iyi-Ukwu catchment falls within. The soils of the study area fall within the broad group of ferrallitic soils of the Coastal Plain Sand and escarpment which is also affected by the climatic and topological variables. Agriculture is the major occupation of the people of Isiala Ngwa North Local Government area, thus subsistence farming is prevalent and about 80 per cent of the population is engaged in it. Farming activity in the study area is determined by the seasonal distribution of rainfall and dominated by multi cropping and the bush fallowing agricultural systems. However, due to increase in population, farmlands are no longer allowed to fallow for long periods and most farms are now cultivated continuosly.

## MATERIALS AND METHODS

The methods described in Young (1975) were applied in this study. Ten gully erosion sites were identified for this study and measurements were taken at intervals of 10m in Sites 1, 5, 6 and7 which gave us 14, 8, 10, and 14 sampling points respectively, interval of 20m in Site 2 which gave us 13 sampling points and in an interval of 5m each for gullies in Site 3, 4, 8, 9 and 10 which gave us 17, 11, 13, 11 and 10 sampling points respectively. The intervals are dependent upon the length of the gully.

Field observation method was adopted to determine the class of gullies in the study area, their shapes, and stages of development, shape factor and direction of flow.

Soil data was obtained from the field (depth, 70cm) by the use of a hand auger and was used to assess the relationship between gully development and soil type. Soil physical properties such as soil particle size distribution was analysed by using the sieve pipette method (Soil Science Society of America (1996). Other soil parameters that were determined include; bulk density which indicates how dense the soil is and how tightly it is packed according to the shape of the soil peds and the percentage of air space or pores. It is directly related to the compaction level of the soil. The bulk density indicator is measured with the dry mass per volume in g/cm3 or g/ml. Sandy textured soils have higher bulk density than clayey soils. The bulk density of sandy soils is higher than 1.6, the value for loam type soils are generally between 1.2 and 1.6 and clayey soils have a bulk density less 1.2. When soil's bulk density value is less, the available water and water holding capacity of the soil is higher. Sandy textured soils have higher bulk density than clayey soils (USAID Soil Test manual, 2008).

Also 30 years Rainfall data of the study area was obtained from National Root Crop Research Institute (NRCRI) Umudike, which is the closest weather station to the study area. Physical parameters such as the length, width and depth of gullies were measured using measuring tape. The gully elevation, the coordinate of gully sites was measured in the field, with the use of a hand held Global Positioning System (GPS) device (GARMIN 72 Model). Photographic methods using (Samsung ES65 digital camera) and other field observation methods were also adopted.

Physical gully parameter measurement was carried out towards the end of the rainy season, during which the gullies are not undergoing any form of reformation. From the ten sites, measurements were taken at an interval of 5m, 10m and 20m intervals depending on the length of gully. Measuring tape, rope tied with a dead weight and levelling staffs, were used to measure the gully length, width and depths respectively

Fourteen (14) Gully morphometric properties were derived from each site, and are defined as stated in table 4. The morphometric properties chosen are those which are the most characteristics of the gully form.

## RESULTS AND DISCUSSION

### General Gully and Climate Characteristics

All the gullies studied are located within the slope angles of between > $5^{o}$ (8.84%) - 14 (25%) with an average of $10.9^{o}$ (19.3%). This is in tandem with Ofomata, (1985) who stated that an increase in slope increases runoff, which facilitates soil erodibility rate thus initiating gully formation. Studies (Hashim, 1995) at the Mardi research station, southern Terengganu in Malaysia concluded that soil erosion was prominent on terrains with slopes of $10^{o}$ to $25^{o}$ and that soil loss increased from 5 to 104 t $ha^{-1}$ with increasing slope and that soil loss was substantially increased when large flow pathways were present. Roose (1996) has stated that the influence of slope on the development of hillsides is well known to geomorphologists and that increases in gradient may not necessarily affect the kinetic energy of rainfall, but transport accelerates toward the foot of the slope as the kinetic energy of the runoff increases and outweighs the kinetic energy of the rainfall when the slope (S) exceeds 15% ($8.5^{o}$). He stated further that Zingg (1940) had shown that soil loss increases exponentially with the slope gradient in the United States of America and that erosion and runoff increase very quickly with minor variations in slope as small as 0.5% in Senegal.

Our study area is permanently under the influence of the Tropical Maritime Air Mass, and thus has hot and wet conditions all year round. An R-Factor (rainfall-runoff factor) of 84.88 and a soil erodibility coefficient (K-Factor) of 0.32 were calculated for the study area using the Revised Universal Soil Loss Equation (RUSLE) of (Wischmeier and Smith, 1978) indicating a high level propensity towards gullying. Also, the soils in this area have a high percentage of sand (> 64%) and high sand to clay ratio (1:2.3) and this type of

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soil belongs to the 'irrigable' class of the Modified US Bureau of Reclamation Land Suitability Class specifications (FAO, 1976; Adepetu et al., 2000). They are thus highly erodible (Ibitoye *et al*, 2008).

## Gully Width and Depth

In this study, a total of ten gullies from the Iyi-Ukwu catchment were studied and parameters analysed. A total of fourteen (14) morphometric parameters were derived from each of the gully site. The major impact of gullying in the study area is the erosion of arable land and the cutting off of roads leading to the area (plates 1 and 2). The mean gully width in the study area ranges from 1.07m to 5.17m, while the mean depth ranges from 1.0 to 6.36. The finding from the morphometric parameters shows that one of the major reasons for the gully formation within the study area is the slope. The morphometric data for each of the gullies are as shown in Table 6.

## Gully Shape and Stage

Gullies in the study area are long-narrow linear to rectangular shaped. The methods of Ireland, *et al* (1939) and (Leopold *et al*, 1964) were used in classifying the gullies. In sites 1, 2 and 3 the gullies are classified in class 4, while gullies in sites 4,5,6,7,8,9 and 10 are in class 2 ( Ireland, *et al*, 1939), while using (Leopold *et al*, 1964), three (3) out of the ten gullies are grouped into the continuous stage of development while the others are in their discontinuous stage. Since all the studied gullies have a rectangular shape, they are generally grouped into the gully shape factor of 1.0 (Heede, 1970).

**Table 3: Soil/gully physical parameters tested**

| Location | Soil Moisture Content (%) | Porosity | Bulk Density | Void Ratio | % Sand | % Silt-Clay | Slope Angle |
|---|---|---|---|---|---|---|---|
| **Site 1** | 14.69 | 0.54 | 1.347 | 1.15 | 68 | 23 | 14° |
| **Site 2** | 18.56 | 0.61 | 1.422 | 1.13 | 73 | 16 | 5.75° |
| **Site 3** | 17.72 | 0.72 | 1.489 | 1.17 | 62 | 32 | 11° |
| **Site 4** | 32.89 | 0.52 | 1.711 | 1.10 | 72 | 21 | 9.0° |
| **Site 5** | 12.00 | 0.52 | 1.450 | 1.15 | 64 | 30 | 9.0° |
| **Site 6** | 10.17 | 0.57 | 1.721 | 1.14 | 58 | 32 | 14° |
| **Site 7** | 19.44 | 0.60 | 1.652 | 1.12 | 59 | 32 | 11° |
| **Site 8** | 12.42 | 0.55 | 1.891 | 1.16 | 67 | 23 | 10° |
| **Site 9** | 24.34 | 0.52 | 1.532 | 1.10 | 58 | 30 | 11° |
| **Site 10** | 15.30 | 0.54 | 1.432 | 1.18 | 55 | 35 | 14° |
| **Total** | **179.53** | **5.69** | **15.647** | **11.4** | **636** | **274** | **108.75** |
| **Average** | **17.95** | **0.57** | **1.565** | **1.14** | **63.6** | **27.4** | **10.9** |

**Plate 1:** ***Gullies in the Study area*** **Site 1**

**Plate 2:** ***Gullies in the study area Site 4***

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**Table 4: Gully Morphometric Parameters**

| Parameters | Description |
|---|---|
| **W** | Mean gully width |
| **D** | Mean gully depth |
| **W/D** | Ratio of mean gully width to mean gully depth |
| **Θ** | Mean gully side slope angle |
| **θT** | Thalweg slope angle defined as rise over run |
| **F** | Total gully fall (defined as the difference in elevation between the gully head and terminus of the gully channel) |
| **L** | Gully Length |
| **A** | Gully drainage basin area |
| **a** | Mean gully cross-sectional area |
| **V** | Mean gully volume (defined as gully length times mean gully cross-sectional area) |
| **%G** | Percentage Gravel |
| **%S** | Percentage Sand |
| **%S-C** | Percentage Silt-Clay |
| **α** | Hill slope angle = % slope |

Also, the direction of advancement of the four gullies was also studied. Generally gully advancement direction is southwest wards following the direction of the face of the Enugu-Okigwe-Arochukwu Cuesta while only Site 1 was advancing to the North east direction. The gullies in this area are deeper than they are wider; this explains the rectangular nature of the gully channel. Deeper and wider gullies would tend to develop on surface materials containing high percentage of silt and clays as in this case.

**Table 5: Site 3D GPS coordinate and elevation**

| Location | Coordinates | Elevation (at gully head) | Elevation (at gully tail) | Gully Length |
|---|---|---|---|---|
| Site 1 | $05^0$ 20’ 24.4’’N<br>$07^0$ 30’49.4’’E | 92.6m | 54.1m | 149.7m |
| Site 2 | $05^0$ 20’43.8’’N<br>$07^0$ 30’ 52.7’’E | 85.9m | 63.4m | 262.2m |
| Site 3 | $05^0$ 20’ 17.1’’N<br>$07^0$ 30’ 34.3’’E | 115.4m | 98.6m | 86.4m |
| Site 4 | $05^0$ 20’ 27.9’’N<br>$07^0$ 30’ 51.3’’E | 74.4m | 65.2m | 56m |
| Site 5 | $05^0$ 20’ 30.8’’N<br>$07^0$ 30’ 52.2’’E | 70.3m | 58.7m | 78m |
| Site 6 | $05^0$ 20’ 40.3’’N<br>$07^0$ 30’ 52.9’’E | 77.0m | 53.7m | 89.7m |
| Site 7 | $05^0$ 20’ 20.5’’N<br>$07^0$ 30’ 46.5’’E | 92.6m | 65.8m | 132m |
| Site 8 | $05^0$ 21’ 01.7’’N<br>$07^0$ 28’ 43.9’’E | 101.9m | 90m | 62m |
| Site 9 | $05^0$ 21’ 18.5’’N<br>$07^0$ 27’ 46.5’’E | 108.6m | 97.6m | 52.6m |
| Site 10 | $05^0$ 20’ 35.4’’N<br>$07^0$ 30’ 48.6’’E | 79.3m | 68.1m | 44.6m |

## Table 6: Gully Morphometric Parameters

| Parameters | Computed Values | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Site 1** | **Site 2** | **Site 3** | **Site 4** | **Site 5** | **Site 6** | **Site 7** | **Site 8** | **Site 9** | **Site 10** |
| **Mean gully width (W) in metres (m)** | 5.17 | 3.46 | 3.16 | 1.9 | 1.83 | 2.73 | 3.21 | 1.40 | 2.25 | 1.07 |
| **Mean gully depth (D) in metres (m)** | 6.36 | 4.18 | 2.73 | 1.7 | 3.56 | 2.87 | 3.17 | 2.62 | 1.10 | 1.0 |
| **Ratio of W/D in metres (m)** | 0.81 | 0.83 | 1.16 | 1.12 | 0.51 | 0.95 | 1.01 | 0.53 | 2.08 | 1.07 |
| **Slope side angle (θ)** | $14^0$ | $5.75^0$ | $11^0$ | $9.0^0$ | $9^0$ | $14^0$ | $11^0$ | $10^0$ | $11^0$ | $14^0$ |
| **Thalweg slope angle (θT)** | 0.25 | 0.10 | 0.19 | 0.15 | 0.15 | 0.25 | 0.20 | 0.19 | 0.21 | 0.25 |
| **Total gully fall (F) in metres (m)** | 38.5 | 23.4 | 16.8 | 9.2 | 11.6 | 23.3 | 26.8 | 11.9 | 11 | 11.2 |
| **Gully length (L)in metres (m)** | 149.7 | 262.2 | 86.4 | 58 | 78 | 87.7 | 132 | 62 | 52.6 | 44.6 |
| **Drainage basin area (A)** (in $km^2$) | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 |
| **Mean gully cross-sectional area (a) in** $m^2$ | 32.88 | 14.46 | 8.62 | 3.23 | 6.52 | 7.84 | 10.18 | 3.67 | 2.48 | 1.07 |
| **Mean gully volume (V)** | $4924.43m^3$ | $3791.41m^3$ | $744.77m^3$ | $184.34m^3$ | $508.15m^3$ | $702.80m^3$ | $1343.m^3$ | $227.43m^3$ | $130.19m^3$ | $47.72m^3$ |
| **Percentage Gravel (%G)** | 9% | 11% | 6% | 7% | 6% | 10% | 9% | 10% | 12% | 10% |
| **Percentage sand (%S)** | 68% | 73% | 62% | 72% | 64% | 58% | 59% | 67% | 58% | 55% |
| **Percentage Silt-Clay (%S-C)** | 23% | 16% | 32% | 21% | 30% | 32% | 32% | 23% | 30% | 35% |
| **Hill slope angle (α)** | 25% | 10% | 19% | 15% | 15% | 25% | 20% | 19% | 21% | 25% |

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The relationship between gully fall and gully slope angle and the difference in the cross sectional area of the gullies was also tested statistically using the Pearson's Correlation Coefficient and the Chi-square respectively. The calculated Chi-square value was 85.31 (Table 7). Adjusting this value at 95% probability level with N-1 degree of freedom yielded 16.92, necessitating the rejection of the null hypothesis (0.05 probability levels). We therefore conclude that a significant difference between the cross sectional area of gullies formed within the Iyi-Ukwu catchment.

Pearson's Correlation Coefficient value obtained between gully fall and gully slope angle was 0.53 (Table 8), while the significance of this correlation coefficient obtained using the student 't' distribution at 8 degrees of freedom at the 95% probability was 1.7 while the value for critical 't' was 2.31. The coefficient of determination revealed that only 28.09% of variation in gully fall was explained by variation in gully slope angle.

There is a relationship that exists between the gully depth and the mean gully side slope angle, in most of the gullies in the study area, and this implied that as gully channel down-cuts or deepens, the gully sides become steeper. This has a strong implication for gully development, because if gully sides become steeper independent of the gully depth, it may signify that the gullies have attained some equilibrium stage where erosional forces are concentrated upon widening rather than deepening the gully floor. The gullies studied within the Iyi-Ukwu catchment are both continuous and discontinuous gullies where the gullies are wider than they are deep and deeper than they are wide respectively, according to (Leopold *et al*, 1964).

The $27km^2$ Iyi-Ukwu catchment shows little or no variation in climate and soil characteristic and has a strong relationship between morphometric parameters and gully formation. The morphometric parameters show a kind of uniformity as gullies are mainly of the linear type but in various stages of development. The geomorphology of the area is therefore influenced by mainly surface materials of mostly silt-clay with steep slopes and a cohort of high precipitation.

**Table 7: Chi- Square Table**

| **Number of Sites** | **Observed Frequncy** | **Expected Frequency** |
|---|---|---|
| **Site 1** | 32.88 | 9.10 |
| **Site 2** | 14.46 | 9.10 |
| **Site 3** | 8.62 | 9.10 |
| **Site 4** | 3.23 | 9.10 |
| **Site 5** | 6.52 | 9.10 |
| **Site 6** | 7.84 | 9.10 |
| **Site 7** | 10.18 | 9.10 |
| **Site 8** | 3.67 | 9.10 |
| **Site 9** | 2.48 | 9.10 |
| **Site 10** | 1.07 | 9.10 |
| **Total** | 90.95 | |
| **Average** | 9.095 | |

The morphometric parameters such as the cross sectional area shows a significant difference affected by the stages of development. The gully fall which is the difference between the gully head elevation and the gully tail elevation and the gully side slope do not show any relationship because of variation in elevation.

As observed, erosional forces are most active along the bottom portions of the gully channel and sides and less active along the upper portions of most of the gully formed in the Iyi-Ukwu catchment. This implies that the gully depth and side slope increase independently and at a faster rate than increases of gully width.

**Table 8: Pearson's Correlation Coefficient Table**

| Sites | X (gully fall) | y (slope angle) | (x-x) | (y-y) | $(x-x)^2$ | $(y-y)^2$ | (x-x)(y-y) |
|---|---|---|---|---|---|---|---|
| **Site 1** | 38.5 | 14 | 19.8 | 3.6 | 392.04 | 12.96 | 71.28 |
| **Site 2** | 26.4 | 5 | 7.7 | -5.4 | 59.29 | 29.16 | -41.58 |
| **Site 3** | 16.8 | 11 | -1.9 | 0.6 | 3.61 | 0.36 | -1.14 |
| **Site 4** | 9.2 | 9 | -9.5 | -1.4 | 90.25 | 1.96 | 13.3 |
| **Site 5** | 11.6 | 9 | -7.1 | -1.4 | 50.41 | 1.96 | 9.94 |
| **Site 6** | 23.3 | 14 | 4.6 | 3.6 | 21.16 | 12.96 | 16.56 |
| **Site 7** | 26.8 | 11 | 8.1 | 0.6 | 65.61 | 0.36 | 4.86 |
| **Site 8** | 11.9 | 10 | -6.8 | -0.4 | 46.24 | 0.16 | 2.72 |
| **Site 9** | 11.0 | 11 | -7.7 | 0.6 | 59.29 | 0.36 | -4.62 |
| **Site 10** | 11.2 | 10 | -7.5 | -0.4 | 56.26 | 0.16 | 3 |
| **Total** | 186.7 | 104 | | | 844.15 | 60.4 | 74.32 |

Previous studies have shown that gully erosion is caused by soil characteristics and human activities (Floyd, 1965); mainly soil characteristics and less by human activities (Ofomata, 1965); mostly geologic set up and soil characteristics (Ogbukagu, 1976); topography, climate and soil characteristics (Nwajide and Hoque, 1979); groundwater flow conditions (Egboka and Nwankwor, 1985) and mostly groundwater conditions and soil characteristics (Uma and Onuoha, 1987). However, this study concludes that heavy rainfall (R-Factor, 84.88); soil characteristics (64% average sand content), topography and the activities of man are mainly responsible for gullying in the study area. This study is therefore much more in line with the conclusions of Ogbukagu (1976) than any of the previous studies.

Also, that certain attributes of studied gullies (width and length) in Site 1 and 2 are higher than those from other Sites studied suggests that the causes of gullying in the present study are mainly soil characteristics and human activities coupled with heavy rains which initiate high run-off. This is also the case in most parts of eastern Nigeria (Ofomata, 1984). In tandem with the works of Ibitoye *et al*, (2008), it can be safely concluded therefore that gullying is an intermittent erosional phenomenon most active during the rainy season and was found to be the major type of soil erosion active in the study area. It also tallies with the conclusions of Hudec et al, (2006) to the effect that gullying in southern Nigeria is often initiated by rainfall events on surfaces whose vegetation cover has been removed.

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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 Nwankwor (1985). This does not suggest that they are not important.

Precautionary measures which safeguard the land from exposure like protection of land cover especially along slopes and conservation of soil through sound agricultural practices including tree planting, mulching and alley cropping will assist in reducing the triggers of gullying in the study area.

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