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Gully Morphological Assessment and Anthropogenic Determinants in Urban and Rural Settlements of Upper Imo River Basin (UIRB) South Eastern Nigeria

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Abstract: Gully erosion have been proven to vary both in terms of size and number in urban and rural settlements and is caused by factors related to both human and natural phenomenon. This study assessed the gully morphological development in an urban and rural settlement with the view of finding the settlement that is more vulnerable to gully erosion development. It investigated gully development in the urban and rural settlements of UIRB; gully morphological features in settlements; and the anthropogenic factors of gully development in urban and rural settlements. A reconnaissance survey was carried out in 2016, while a detailed field survey on the sampled locations and gully sites was carried out from 2017 till early 2019. Two types of data were employed in this study. They were primary and secondary (archival) data. The secondary data set used for this study was obtained from maps (topographical and lithological) and satellite imageries obtained from USSG. Primary data used for the study were grouped into two-gully morphological data and anthropogenic data. The two data sets were obtained through field measurement, digital image analysis, and a questionnaire survey. The morphological data considered are gully length, width, depth, area slope, and elevation, while anthropogenic data involves human economic activities. The sampling technique employed was randomized systematic sampling. Three major factors considered in the course of sampling were settlement type, the number of second-order basins located within the various settlements of the upper Imo River basin, and several gullies located in the settlements of UIRB. Considering these factors 18 gully sites were randomly sampled from gullied second-order basins. Data analysis makes use of percentages, measures of variations, t-tests, and levene statistics. Results of the analysis showed that gully erosion in UIRB develops both in urban and rural settlements. 61.1% of the gullies develop in rural settlements, while 39.9% 0f the gullies develop in urban settlements. The total length, width, and area of the sampled gully sites in Upper Imo River were 6213.2 m, 1931.1, and 330,005.6 m^2 (330 km^2) respectively. Out of these values, the total length, width, and area found in the rural area was 3,539.2, 863.5 m, and 91,767 m^2 (91.8 km^2) respectively, while the total length, width, and area in the urban area was 2,674, 1,067.9 and 238,238.4 m^2 (238.2 km^2) respectively. The slope where gullies are located in rural areas ranges between 84.4-89.8%, while the slope where gullies are located in urban areas of UIRB ranges between 89.4-89.7%. The elevation where gullies develop in rural areas falls between 55-142 m, while the elevation where gullies are located in urban areas ranges from 55-89.9 m. In terms of number, more gullies are fun in rural settlements than in urban settlements, but in terms of intensity and threat, they are higher in rural areas than in urban areas. Failed road construction was the major factor of gully erosion initiation and development in the urban areas, while sand mining was the major factor of gully erosion in the rural areas of the upper Imo River basin. The two major contributors to gully erosion development in the urban area were failed road construction and sand mining, while the two least contributing factors of gully erosion in the urban areas of the study area were stone mining and farming activities.

Keywords: Upper Imo River Basin, Settlement, Morphological, Gully

Introduction

Gullying is one of the landscape evolutions processes which in no small measure contributes to shaping the earth's landscape. Its development is largely associated with numerous negativities, as in some cases, it involves the loss of soil and the deposition of a great amount of soil (Billi and Dramis, 2003). For many parts of South Eastern Nigeria in general and UIRB in particular, this environmental problem has been observed both in rural and urban centers. This has resulted in the loss of soil mass leading to the depletion of natural resources. This research investigated and assessed gully morphological parameters in urban and rural areas to find out if variations exist in these variables and the extent of these variations in these settlements. Results of various research conducted showed that gully erosion formation and development is caused by two major factors- physical and anthropogenic factors, though the anthropogenic factors is been exaggerated while the physical factors are been estimated (Ezedike and Chibo, 2019; Iro, 2020a). Gully erosion is caused by factors relating to both human (anthropogenic) and natural phenomena, although the human factor has been found to have a more dominating tendency than the natural factors, especially in developing nations (Noori *et al.*, 2016). The causes of gully erosion identified in the literature have been generic, hence this research examined these causes as it relates to an urban and rural environment, thereby identifying factors that are more pronounced in the various settlements. Despite achievements made due to technological advancements such as land use planning mechanical methods (Wu and Cheng, 2005) and drainage channel constructions and expansions, gully erosion and its impacts remain on the increase in both urban and rural areas of Southeastern Nigeria.

Amangabara (2015) defined gully as the erosive process whereby runoff water concentrates in a narrow channel and cuts a considerable amount of soil from the narrow channel over a short period. Nnamdi and Ujiro (2022) sees a gully as a linear deep erosion feature with active head cut, unstable side walls, subject to mass movement, and a nongraded longitudinal profile with temporal water flow. Kumar *et al.* (2020) sees a gully as a continuous depression created from the concentration of surface runoff under the influence of gravity which encourages the removal of earth material. Bradstock *et al.* (1990) define a gully as a steep-sided channel, often with steeply sloping and actively eroding head scarp caused by erosion due to intermittent flow of water, usually during and immediately following heavy rain. From all these definitions, it is clear that gully represents depressions that are larger and more pronounced than rills, and once developed; it is difficult to be controlled by natural means or by normal tillage operations (Bradstock *et al*., 1990).

Evidence abounds in literature in different climatic zones that the evolution and development of gully erosion are influenced by so many geological, environmental factors and anthropogenic factors. Notable among these factors are geotechnical, geomorphological, hydrology, climate and land use/land cover (Amare *et al.*, 2021; Fashae *et al.*, 2022). Research study on gully erosion has taken various perspectives and dimensions. Having noted the above point, this research was narrowed down to an assessment of only the anthropogenic factors in an urban and rural environment. The anthropogenic factors generally identified in the literature include land use/land cover, agricultural activities, road and other infrastructural development, sand mining and stone quarrying, etc., (Okereke *et al*., 2013; Nwogu *et al*., 2018, Oparaku *et al*., 2014).

Gully erosion is widespread in various settlements of Nigeria and it has been documented as a serious environmental threat in almost all states of the country (Oparaku *et al.*, 2014). It is among the erosive processes that mostly contribute to shaping the earth's surface (Billi and Dramis, 2003). Pimentel (1993) estimated that, globally, about 6 million hectares of land are lost per year in urban and rural settlements to erosion-related land degradation. Therefore, gully erosion and its control deserve the attention of environmentalists, individuals, communities, and governments (Iorkua, 1999), being one of the most conspicuous forms of accelerated erosion which occurs under widely different climates, geologic and land use conditions (Bocco *et al*., 1990; Udosen, 1991; Osadebe *et al*., 2014). The incidence of soil erosion especially one of the devastating types (gully) is not new, as it has formed a subject for serious consideration since the beginning of the 20th century. Various aspects of the phenomenon have been studied and attempts made to identify the factors and processes as well as describe the morphology of the same. These can be seen in the works of many scholars including (Faniran and Areola, 1974; Jeje, 1978; 1988; Igwe *et al*., 2012). Most of the reports in the literature on gullies in Nigeria came from the Eastern state. These studies have shown that population density, high relief, steep slopes, deforestation, infrastructure development, humid tropical climate, and deeply weathered friable sandstones and shale operate to predispose the soil to the rapid process of gulling.

Okoro *et al*. (2013), observed that over 1.6% of the entire land of Eastern Nigeria is occupied by gullies. Over the past forty decades, precisely about 1980, the notable gully sites in the region were the Agulu, Nanka, Ozuitem, Oko in the Aguata area, Isuikwuato, and Orlu. Recently in 2014, channels in some parts of the Imo River basin were noticed to have developed into valleys. These channels generally eroded into red earth and unconsolidated geologic materials establishing prominent gullies with nearly vertical slopes (Chikwelu and Ogbuagu, 2014). Increased erosion activities around the early gullies have continued to expand these gullies into a complex system. Most of the gullies especially those with high discharge values are now of canyon proportion and constitute the most threatening environmental hazard with the basin which covers many metropolises and rural settlements, like Owerri, Okigwe, Umuahia, Nekede, Ihitte Uboma, etc.

Gully erosion has been proven to vary both in terms of size and number in urban and rural settlements (Ezedike and Chibo, 2019). Gully erosion has been proven to be caused by factors related to both human and natural phenomena, although the human factor has been found to have a more dominating tendency than the natural factors, especially in developing nations (Noori *et al*., 2016). Some of the direct primary effects of gully erosion in an environment have been inadequacy in water supply, declining productivity in agricultural yield, loss of cultivable arable farmland, vegetation cover loss, as well as facilities and infrastructure destruction (Nwaogu *et al*., 2018). Furthermore, they ranged from climatic, land use land cover, topographic, and lithological features as well as human factors. The variability as well as the enormity of these contributing factors have resulted in the complexity in the determination of specific factors of gully erosion development on the surface of the earth. However, in terms of monitoring, the introduction of a Geographic Information System (GIS) in conjunction with Remote Sensing (RS) in combination with both physical and empirical models have been more reliable and effective (Adediji *et al*., 2010; Pechanec *et al*., 2015; Seutloari *et al*., 2015; Noori *et al*., 2016). This research, therefore, tends to assess gully morphological variables to determine their intensity and variability in urban and rural settlements of the upper Imo River basin of southeastern Nigeria.

Materials and Methods

Study Area

The Imo River basin is located in South Eastern Nigeria. The basin covers three states of the region: Abia, Imo, and Rivers. It is located within latitude $4^0$38N-$6^0$01N and longitude $6^0$40-$8^0$00E of the Greenwich meridian and covers an area of about 8100 km^2 (Fig. 1). This study was carried out in the upper section of the basin generally referred to as the Upper Imo River Basin (UIRB). UIRB is located within latitude 5^{o}19N-6^{o}01N and longitude $6^0$40E-$8^0$00E. The study area has a plain topography generally in the south but consists of gentle to high undulating ridges in the north. Imo River is the major river that drained the study area. The Imo River basin is characterized by a bedrock of a sequence of sedimentary rocks of about 5480 m thick and with ages ranging from upper cretaceous to recent. Generally, two formations underlie the Imo River basin. The coastal plain which consists of about 80% of the basin is made up of non-indurated sediments; the second form which constitutes the remaining 20% is underlain by a series of sedimentary rocks. Generally, the lithology of the upper Imo River basin is basically of sedimentary deposit and is divided into five lithological formations, namely lignite, Imo Clay-shale, Bende Ameki formation, False bedded sandstone, and Coastal plain sand. The UIRB consists of 5 stream orders and 603 stream channels (1st order = 419; 2nd order = 121; 3rd order = 41; 4th order = 11; and 5th order = 1). The river also flows through many settlements comprising both urban and rural settlements (Fig. 2)

The area consists of about 20 urban locations and 15 rural areas covering parts of two states of South Eastern Nigeria, Abia and Imo.

Methodology

A reconnaissance survey was carried out in 2016, while a detailed field survey on the sampled locations and gully sites was carried out from 2017 till early 2019, and the details of the fieldwork were defined subsequently. Two types of data were employed in this study. They were primary and secondary (archival) data. The secondary data set used for this study was obtained from maps (topographical and lithological) and satellite imageries Landsat 2003 and 2018 obtained from USSG. Primary data used for the study were grouped into two-gully morphological data and anthropogenic data. The two data sets were obtained through field measurement and digital image analysis and a questionnaire. The morphological data considered are gully length, width, depth, and area, while anthropogenic data were human economic activities. The UIRB is made up of 529 stream channels comprising 369 first-order, 112 sec order, 37 third-order, ten 4th order, and one 5th order. It also comprised 20 urban and 15 rural locations. The target population for the study is the second-order basin. This basin was chosen to afford comparison with previous studies and also is based on the assumption that: Second-order basins are most likely to provide the needed replication of the entire study area; they provide a good reflection of the entire basin and are better accessible compared to higher orders; they are large enough to be geomorphologically significant, yet small enough to provide a statistically sufficient sample without excessive effort. The sampling technique employed was the randomized systematic sampling. Three major factors considered in the course of sampling were settlement type, the number of second-order basins located within the various settlements of the upper Imo River basin, and several gullies located in the settlements of UIRB. Considering these factors 18 (26.9%) gully sites were randomly sampled from18 (16%) gullied second-order basins. This formed the sample size and this sample size is considered large enough for generalization for the total population of the study

Field measurement was adopted for the measurement of morphological parameters of the selected six smaller gullies. This involves the measurement of the morphological parameters of the sampled gullies in different parts of the rural and urban sites as well as in the different lithological compositions within the basin. The morphological properties measured were the gully length, width, depth, area, elevation, and slope gradient. The instrument used for primary data acquisition includes Global Positioning Systems (Garmin GPS 60), cameras, measuring tape, leveling staff, measuring tape, and so on. The GPS was used to collect spatial data of the locations coordinates of the gully mouth, tail, and specific locations where attribute data were collected (such as the location where the depth of the gully was taken). Cameras were used to take the pictorial image of the gullies visited during reconnaissance surveys and fieldwork. Measuring tapes were used to measure gully length, width, and depth at 10 m intervals because of visibility problems in some locations. Aerial photos/satellite imageries and topographical maps were used to generate morphological data for the twelve (12) larger gullies that have gone into advanced stages of development to stability.

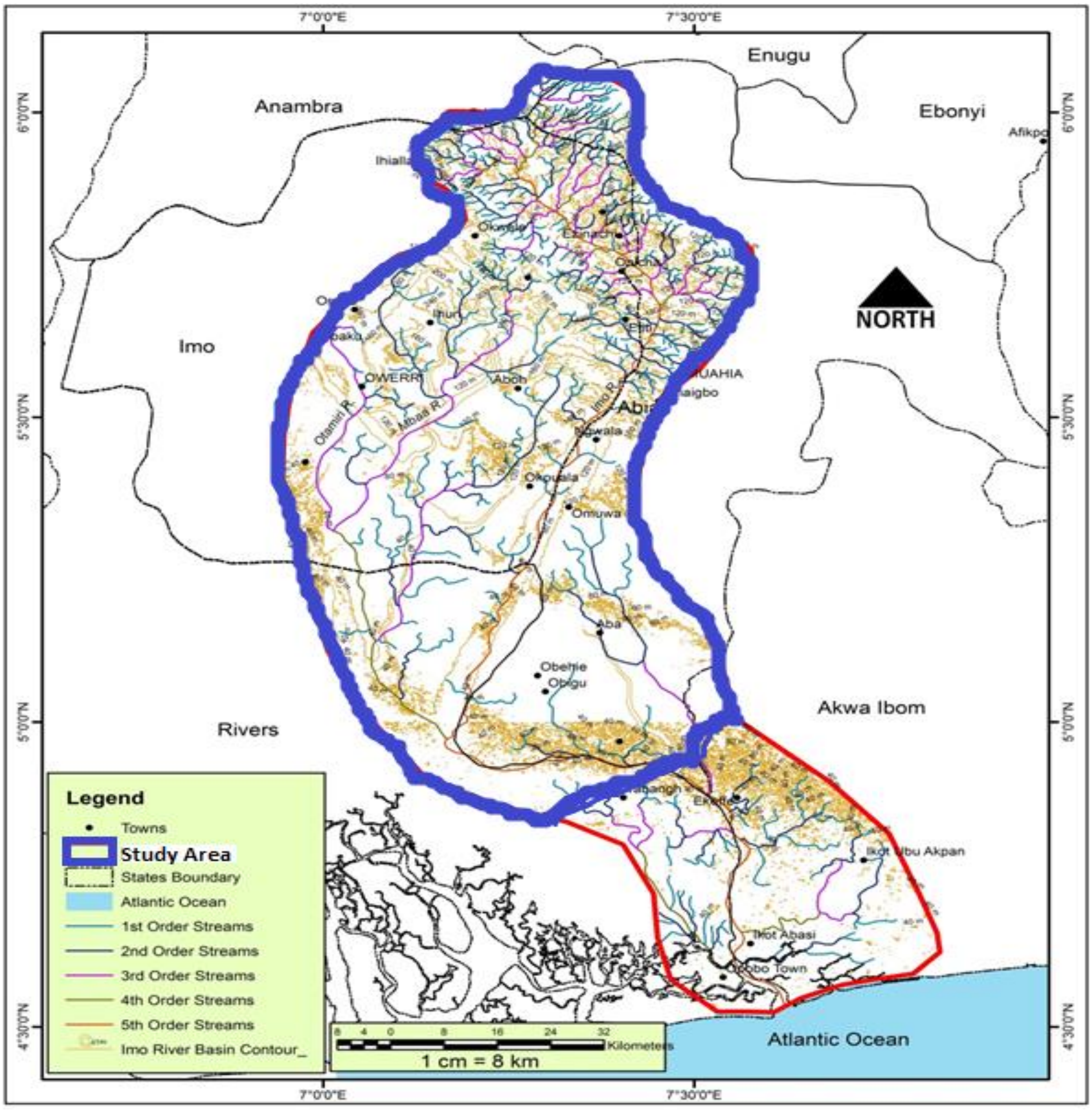

Fig. 1: Nigeria showing the upper Imo River basin

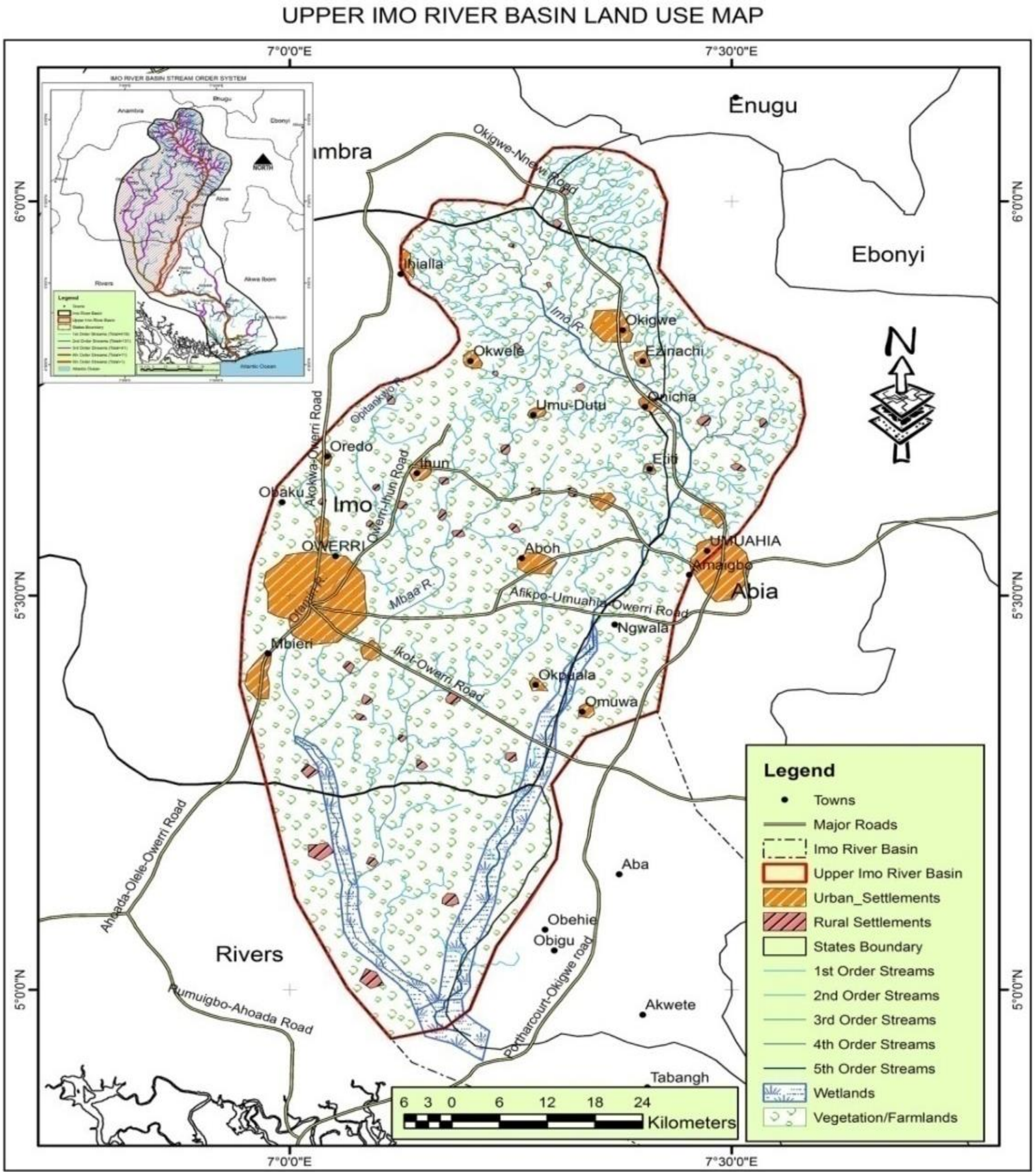

Fig. 2: Settlement Map of upper Imo River basin

Questionnaire survey and administration were used to generate data on anthropogenic factors of gully development. Data involved here are data on land use type and vegetation. Well-structured copies of the questionnaire were distributed to individuals living around the sampled gully sites within the basin. A total of 514 respondents were systematically selected from residents of the sites sampled. These were distributed with copies of the questionnaire and at the end, 494 copies were retrieved and used for the research The sample size was obtained by taking a sample of 0.2% of the 2018 population census of the areas where the sampled gully site is located.

Results and Discussion

Gully Development in Settlements in Upper Imo River Basin

This section examined and investigated the relationship between gully erosion development and settlement type in the study area. It investigated whether the severity of gully erosions was found more and develops faster in a rural area than urban area and vice versa. Investigations were also made to examine the intensity and effect of gullies in these settlements. To do this, the gully numbers in various settlements were investigated and their morphological variables in the two settlements were analyzed. The rate of gully expansion in the settlements was also studied and various factors that cause gully development were also analyzed.

Number of Gullies Located in Various Settlements in Upper Imo River Basin

In the upper Imo River basin, it was observed that gully erosions were found both in urban and rural areas. The information in Table 1 shows the summary of several gullies located in both rural and urban settlements of the study area.

Analysis of the information in Table 1 shows that out of the18 gullies sampled, more gullies were located in rural areas than we have in urban areas. The reason for this as gathered from the research was because the urban land surfaces are planned, most of the areas are tarred, and runoff is provided with channels. Therefore, the impact of raindrops on the soil does not have direct contact with bare soil. Hence, we have fewer gullies in urban areas than we have in rural areas (Iro, 2020a). But the case is different in rural areas where the land surfaces are unplanned; most of the surfaces are not tarred; the majority of the people still depend on the exploitation of the land for survival, hence exposing the soil surfaces; the impact of raindrops has direct contact with bare soils; runoffs were not provided with any channel; hence it follows the slope, thereby wearing off the surface of the earth and causing erosion (Igwe, 2012; Iro, 2020b). Therefore, it was discovered that in the upper Imo River basin, 61% of the gully sites were found in rural areas while 39.9% can be found in urban areas.

Gully Morphological Features in Settlements of Upper Imo River Basin

Gully morphological features and annual rates of gully expansions in urban and rural areas were investigated and analyzed. Information on the gully morphological features in rural and urban settlements were presented in Table 2.

Information in Table 2 showed the total length, width, and area of the sampled gully sites in upper Imo river were 6213.2 m, 1931.1, and 330,005.6 m^2 (330 km^2) respectively. Out of these, the total length, width, and area found in the rural area was 3,539.2, 863.5 m, and 91,767 m^2 (91.8 km^2) respectively, while the total length, width, and area in the urban area was 2,674, 1,067.9 m and 238,238.4 m^2 (238.2 km^2) respectively. These morphological features and descriptive statistics are high compared with those obtained in some parts of the globe (Nachtergaele *et al*., 2001; Zhang *et al*., 2007; Whitford *et al*., 2010; Addis, 2015). This means that in terms of area, 27.8% of the total areas covered by the gully in the upper Imo River basin were in rural areas, while 72.2% were in urban areas. 57% of the gully lengths in UIRB were in the rural area while about 43. 0% was in an urban area. 44.7% of the gully width was located in a rural area while 55.3% was found in urban areas. The information in the table also shows that the slope where gullies were located in rural areas ranges between 84.4-89.8%, while the slope where gullies are located in urban areas of UIRB ranges between 89.4-89.7. The implication is that higher slopes in rural areas favor' the development of gullies than the higher slopes of urban settlements. The elevation where gullies develop in rural areas falls between 55-142 m, while the elevation where gullies are located in urban areas ranges from 55-89.9 m. This by implication means that gullies in rural areas of UIRB develop in higher elevations while the gullies in urban areas of the basin develop in relatively lower elevations.

The research showed that there was more number (61.1%) gullies in rural areas than were found in urban areas (38.9%). In terms of intensity, effect and threat, they are greater in urban areas than in rural, because the gully area, width, and length were greater in urban areas than in rural areas. It can be adduced that gullies in UIRB expand faster in urban areas than in rural areas.

To further ascertain the intensity of gully erosion in the two settlements, the gully morphological variables in the two settlements were subjected to further statistical analysis. The information in Table 3 shows the descriptive statistics of gully morphological variables in the two settlements type, while those in Tables 4-5 showed the analytical statistics of the gully morphological variables in the settlements.

The mean gully length, width, depth, and the area of gullies in the urban settlement of UIRB were 314.36, 164.68, 73.60 m, and 27.38 km^2 respectively, while their respective standard deviations were 31.77, 163.12, 17.58 m and 43.14 km^2. For the rural areas in the UIRB, the respective mean gully length, width, depth, and area were 345.45, 91.45, 138.53, and 15.98 km^2, and standard deviations of 291.42, 121, 44, 91.67, and 32.40 km^2. The information showed that urban settlements have higher mean gully width (164.64 m) and gully area (27.38 km^2) compared with mean gully width (91.45 m) and mean gully area (9.34 km^2) values for rural settlements. On the other hand, the mean gully length (345.45 m) and mean depth (138.53 m) for the rural settlement was observed to be higher compared with the mean length (314.36 m) and mean depth (73.60 m) values for the urban settlement. This showed that the intensity of the gully is high both in urban and rural settlements of UIRB but higher in the urban settlements since the mean gully area and width are higher in the urban settlements than in rural settlements.

A test of homogeneity of variance for the observations for the urban and rural settlement type (Table 4) shows a different dispersion (or variation values) for gully length and depth between the rural and urban settlements while no statistically significant difference was observed for the dispersion values for gully width and gully area for the rural and urban settlements.

Consequently, an independent sample T-test was carried out to ascertain the similarities or disparities in the mean values for the settlement types (Table 5). From the T-test result, no statistically significant differences were observed between the mean values for types of settlement for gully length and gully area, while there is a statistically significant difference for gully width and gully depth in the urban and rural settlements.

Table 1: Number of gullies located in various settlements of UIRB

Gully settlement	Number of gullies	Percentage
Rural	11	61.1
Urban	7	38.9
Total	18	100.0

Table 2: Sizes of gully morphological features in Rural and Urban settlements

Rural gullies						Urban gullies					
	Morphological features						Morphological features				
Location	Length (m)	Width (m)	Area (km^2)	Slope (%)	Elevation (m)	Location	Length (m)	Width (m)	Area (km^2)	Slope (%)	Elevation (m)
ISB	463.2	219.80	64.90	89.6	107.0	AB1	278.5	43.73	0.6	89.4	55.0
IBK	316.3	19.30	1.40	89.7	124.0	AB2	327.1	173.50	34.5	89.6	55.0
UMD	501.6	18.58	1.50	89.4	124.0	UMU	343.5	441.20	100.0	89.6	89.9
AMA	99.9	23.60	0.80	89.7	89.0	NEO	340.7	52.96	1.3	89.4	72.4
AMO	60.2	15.90	0.10	89.7	142.0	OKG	565.0	10.50	1.3	89.6	89.9
OKI	128.8	36.60	0.50	89.7	124.0	NEK	601.7	233.96	100.0	89.7	55.0
UMG	65.8	4.30	0.02	89.8	89.7	AKO	282.0	112.00	0.6	89.7	55.0
EMK	609.9	385.80	1.60	89.8	55.0						
ISI	249.7	72.00	20.00	89.4	124.0						
UMZ 2	63.7	20.60	0.20	89.8	72.0						
UEO	980.0	47.00	0.80	84.4	124.0						
Total	3,539.2	863.50	91.80				2,674.0	1,067.90	238,2.0		
Percent	57.0	44.70	27.827.17				43.0	55.30	72.2		

Note: ISB = Isiebu: IBK = Ibeku; UMD = Umuduru; AMO = Amuzu Okwuohia;; OKI = Okohia Isiama; UMG = Umudurugo;EMK = Emekuku; ISI = Isinweke; UMZ 2 = Umueze 2; UEO = Umueze-Eziala- Obizi; AB1 – Aba 1; AB2 = Aba 2; UMU = Umuahia; NEO = New Owerri; OKG = Okigwe; NEK = Nekede; AKO = Amakohia Owerri

Table 3: Summary of gully morphological variables for settlement type in UIRB

	Settlement type					
	Urban			Rural		
Variable	Mean	Std. Error	Std. Deviation	Mean	Std. Error	Std. Deviation
Gully length (m)	314.36	14.21	31.77	345.45	84.12	291.42
Gully width (m)	164.68	72.95	163.12	91.45	35.06	121.44
Gully depth (m)	73.60	7.86	17.58	138.53	26.46	91.67
Gully area (sq. km)	27.38	19.29	43.14	15.98	9.35	32.40

Table 4: Test of homogeneity for observations for settlement type

	Levene statistic		
Variable	F-value	p-value	Remark
Gully length (m)	9.51	0.01	Statistically different
Gully width (m)	0.22	0.65	Not statistically different
Gully depth (m)	0.97	0.03	Statistically different
Gully area (sq. m)	0.57	0.46	Not statistically different

Table 5: T-test for the mean difference for settlement type

Variable	Mean difference	Std. Error difference	Df	t-value	p-value	Remark
Gully length (m)	-31.09	133.12	11.61	-0.36	0.72	Not statistically different
Gully width (m)	73.22	71.22	15.00	1.03	0.02	Statistical different
Gully depth (m)	-64.93	42.07	15.00	-1.54	0.04	Statistical different
Gully area (sq. km)	11.40	18.94	15.00	0.60	0.56	Not statistically different

Table 6: Major factors of gully erosion development in various settlements of UIRB

	Urban settlement		Rural settlement		Total	
Major factors	No.	%	No.	%	No.	%
Failed Road Construction	98	19.84	44	8.91	142	28.74
Farming	0	0.00	58	11.74	58	11.74
Sand Mining	68	13.77	174	35.22	242	48.99
Stone Mining	7	1.42	10	2.02	17	3.44
The concentration of runoff channel	09	1.82	14	2.83	23	4.66
Urbanization	12	2.43	0	0.00	12	2.43
Total	194	39.28	300	60.72	494	100.00

Anthropogenic Factors of Gully Erosion in Various Settlements of UIRB

Data obtained through copies of a questionnaire distributed in the course of this research exposes various anthropogenic factors that cause gully erosion in the upper Imo River basin. It was observed that the effect of these factors and activities that initiate gully erosion in the study area varies from one type of settlement to another. This is to say that the activity (ies)/factor(s) that initiated gully erosion in urban areas might not be the same activity that caused gully erosion development in rural areas. Where any of these activities were found to be common in the settlement, their magnitude and intensity were found to vary from settlement to settlement. Results obtained through a questionnaire on the major factors that caused gully erosion in the settlements in the upper Imo River basin are presented in Table 6.

Major factors identified are linked with the loss of vegetation. The principal cause of gully erosion in the study area is related to factors that remove soil cover thereby exposing the soil to various degrees of erosion. Vegetation loss was evident in the study area and this follows a global trend in gully erosion development (Prosser and Slade, 1994; Xu *et al*., 2018). Another factor that initiated gully in both rural and urban settlements of the study area is that which is linked to the topography of the area. topography have observed to have a strong correlation with gully development. Some of the research that established linkages between topography and gully development include (Marquisee, 2010; Igbokwe *et al*., 2008; Boardman and Poesen, 2006). They are all in agreement with the prime influence of topography on gully initiation and development.

Analysis of the information in the Table 6 showed that while failed road constructions were the major factor of gully erosion initiation and development in the urban areas, sand mining was the major factor of gully erosion in the rural areas of the upper Imo River basin. The two major contributors to gully erosion development in the urban area were failed road construction and sand mining, while the two least contributing factors of gully erosion in the urban areas of the study area were stone mining and farming activities. In the rural areas of the upper Imo River basin, the two most contributing factors of gully erosion were sand mining and agricultural activities, while the two least contributing factors were urbanization and stone mining. It was observed from the table that while sand mining is the major factor of gully erosion in the study area, stone mining is the least factor of gully initiation and development in the upper Imo River basin. Four out of the six major factors identified are common in both urban and rural settlements, but their intensity and magnitude in the settlements vary. While the intensity and magnitude of failed road construction are higher in urban areas than in rural areas, the intensity and magnitude of sand mining, stone mining, and concentration of runoff are higher in rural areas than in urban areas. Farming activities are a factor of gully erosion initiation and development exclusively for rural areas, while urbanization is a factor exclusively for urban areas in the upper Imo River basin.

Conclusion

Gully erosion wherever it is found is it rural or urban settlement is a serious environmental threat in many parts of the world. In the process of understanding the nature of the problem and proffering solutions, efforts need to be intensified so that the environment where the gully develops is taken into consideration. This is because no two environments are the same, so the interplay of forces and factors observed in different environments tend to be unique in them. Since gully erosion is observed both in rural and urban settlements, the extent to which these factors caused gully erosion in the settlement of the study area is further explained in this study. Gully erosion has been associated with soil loss, reduction in agricultural yield, destruction of properties, and forced migration due to making the ancestral homes unsafe resulting in abandonment. Gully erosion has been proven to be caused by factors related to both human and natural phenomena, although the human factor has been found to have a more dominating tendency than the natural factors, especially in developing nations (Noori *et al*., 2016). This study has therefore assessed the morphological variables of gullies in the settlements of UIRB and was able to find out if there is a variation that existed in these variables across the urban and rural settlements. Anthropogenic factors of a gully in urban and rural areas, with their magnitudes, were also exposed and the variations of their intensities were determined.

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Ethics

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