Spatial Analysis of Geotechnical Properties and Morphological Characteristics of Gullies in Land Covers (LC) and Lithologies of Upper Imo River Basin (UIRB), Southeastern Nigeria

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ABSTRACT

Globally, gully erosion have been identified as one of the major hazards that inhibits the functions of both the land and the soil. Gully initiation and development increases runoff, enhances flooding and aids sedimentation. This research investigated and spatially analyzed the morphological and geotechnical parameters of gullies across land covers, investigated the changes that were observed in the LC between 2003 and 2018; and assessed morphological and geotechnical variables across the land covers. Landsat 8 and topographical maps were processed to identify the extent of UIRB boundary. Considering LC and Lithology, 18 gully sites were randomly and systematically sampled. Six gullies were sampled for soil sample collection for laboratory analysis. Thirteen geotechnical variables were generated through standard soil test and four morphological variables were also generated through field measurement and digital image. Gully morphological and geotechnical variables were analyzed using spatial, descriptive and inferential statistics. Five important LCs were observed UIRB between 2003 and 2018. There is a substantial change experienced in all the identified land covers. The greatest gain was observed in build up area with 6.99% gain, and farm land with a loss of 12.77% experienced the highest cover loss. Five lithological units in the area has three of them affected by gully. The lithology identified to be greatly affected was the coastal plain sands with 71.83%, 78% and 79.29% of the gully length, width and area respectively in UIRB, found within the lithology. 8 out of the 13 geotechnical variables were found to be higher in coastal plain sands than other lithologies. Gully morphological and geotechnical characteristics showed significant variation across the lithologies and land covers, with built-up area and farmland being mostly under gully attack and coastal plain lithology being the lithology with greatest gully erosion vulnerability

Keywords: Upper Imo River Basin, Lithology, Morphological, Geotechnical, Land Cover.

1. Introduction

The outcome of the activities between man and his surroundings is seen in different manifestations. These manifestations is made visible through various environmental degradations bedeviling different locations of world especially the developing countries. Gully erosion is one of such environmental problems which is seen as one of the processes that shapes the landscape in no small measure. This environmental problem have been identified in all areas of the universe, and the outcomes is not limited to soil removal, sediment generation, land depletion and change in the shape of the landscape [1], [2], [3]; [4], [5]; [6]. The loss of soil by gully also resulted in the reduction of natural resources. Once initiated, gully erosion develops rapidly and becomes quite difficult and impossible to stop or halted by a natural process and the result is substantial damage to the environment, economy and social livelihoods. Man plays an important part in the processes that leads gully formation and this starts from the removal of the vegetation cover [7]. In the humid tropics, expansion of farm land and tree felling removes soil cover, while and in the semi arid areas, overgrazing is the major means of vegetal removal. These two removal activities favor gullying [8].

Both natural and antropogenic (human) factors have been found to cause gully erosion, although human factors were believed to be more important than natural factors [9]; [10]; [11].. The determination of the specific gully causing in different areas have been made very difficult because of the variability and many factors of gully erosion

Gully occurs when running water accumulates in a channel and removes great quantity of soil from the rill over a certain period of time [12]. [13] views the phenomenon in terms of erosion in a linear form which produces a form that continuously cuts its head, unstable walls, and is also vulnerable to movement of materials supported by gravity, and non graded longitudinal profile with ephemeral movement of water. According to [14], it is a continuous long valley resulting from accumulation of water flowing down slope which triggers the removal of materials from the land surface. According to [15], the gully sites in Imo and Abia State Southeastern Nigeria alone were more than 1970 in number. [16], identified 450, and [17], observed that in Imo State alone, about 2500 gullies that are still expanding.. Research from [18] exposed that well above 1.6% of the Southeastern land were covered by gully erosion. From 1980 which is over forty years ago, the most visible gully sites were those located in Oko (Agulu-Nakna) in Aguata Local

Government Area of Anambra state, Isuikwuato and Ozuitem in Abia State and locations around Orlu in Imo state. Presently, these gully sites have extended beyond these area, and the rate at which they are increasing are so rapid that if adequate control measures and steps are not put in place, the entire zone will be threatened. Majority of the gullies, especially the larger ones that receives high volume of water are now seen as a threat within Upper Imo River Basin that constitutes both urban, suburban and rural locations, like Owerri, Okigwe, Umuahia, Nekede, Ihitte Uboma, etc [19]. The reason for this extension is not far from due to ineffective and most times lack of control measures.

There are so many evidences in in published works from different parts of the word that supports that gully development is caused by factors which relates to soil (geology) and environment. Notable among these factors are geotechnical, geomorphological, hydrological, climate and land use/land cover [20]; [2]; [21]. Studies and researches conducted in gully ha taken various dimensions. These include causes, impacts and possible solution [22]; morphology and rehabilitation with agro-ecological environment [23]; Geotechnical investigations of gully around drainage basin [24]; morphometry and morphology [25]; land use change and gully formation [26]; gully vectorization and quantification [27]; controlling factors of gully morphology [2] among other studies. Various aspects of gully have been investigated, and efforts have been made to identify the factors and processes and also describing its morphology [28]; [29]; [30]; [31], [32]; [33]; [34] and [35].

Specifically, this study is an attempt to link lithology and land cover in gully erosion development with the aim of investigating the roles played by each in gully development of Upper Imo River Basin Southeastern.

2. Methodology
2.1 Description of the Study Area
UIRB) is found in South Eastern Nigeria (figures) on latitude $4^{0}38N - 6^{0}01N$ and longitude $6^{0}40E - 8^{0}00E$ with an area of about 8100km^{2}. Three States of Imo, Abia and some parts of Rivers can be found within the study area.
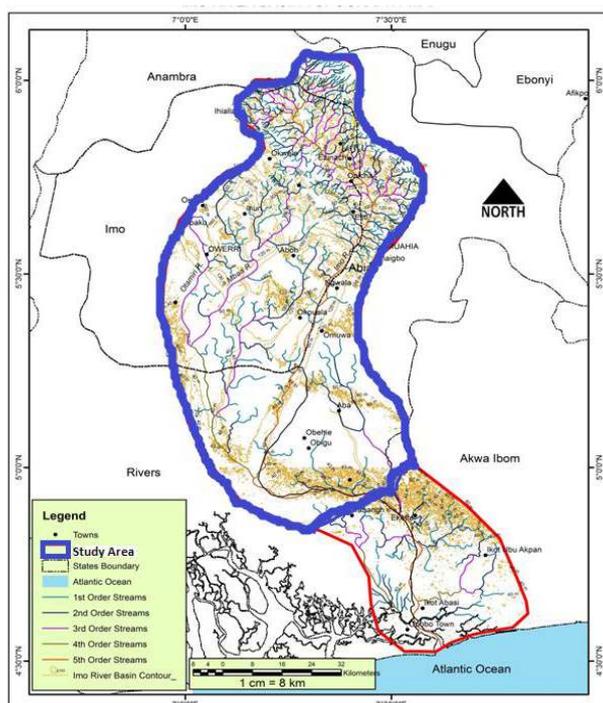

Figure 1: Imo River Basin indicating Upper Imo River Basin

The area is richly endowed with water resources of rainfall. Mean annual rainfall ranges from 2250mm to 250mm in areas lying between 5°40'N to 5°49'N. This decreases to mean annual value of 2000mm to 225mm between 5°49'N to 5°55'N and further inland 5°55'N to 6°03'N, mean annual value decreased to 1750mm – 2000mm. It was observed that within the 15year period, that the highest annual amount of rainfall observed in the study area was 3250.8mm of rainfall, and this amount was observed in the year 2006. The least annual amount of rainfall recorded in the location was recorded in the year 2004, and the amount of rainfall recorded was 1530.5mm of rainfall (figure 2).
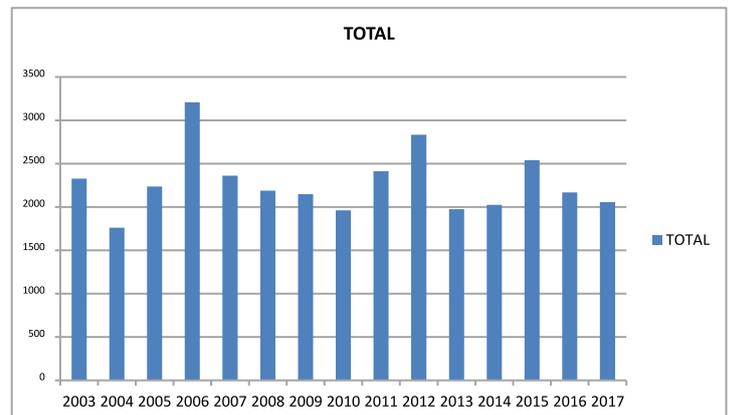
Figure 2: Total Rainfall in UIRB from 2008 – 2017

Source: Anambra Imo River Basin Development Authority, 2017

Geologically, the area is underlain by sedimentary rocks of about 5480m thick and their ages ranges from upper cretaceous to Recent. This sedimentary deposit covered about fifty percent of the total surface of Nigeria [36]. These rocks were derived from pre-existing igneous or metamorphic or even sedimentary rocks. These rocks were found to be deposited within the depressions in the earth surface crust. The study area is located within the Cretaceous sediment of the Anambra Basin. Generally, Coastal Plain Sands which constituts abot 80% of the basin and sedimentary deposits which constitutes the other 20% are the two major geological formations of the basin. The lithology of UIRB is divided into four, and they are, the lignite, Imo clay-shale/bende ameki, false bedded sandstone, and coastal plain sands (Fig. 3).

Figure 3: Geological Map of Upper Imo River Basin

2.2. Data collection

The smaller gullies identified in the study area are Okohia Isiama (OKI), Umudurugo Obowo (UMO), Amuzu Okwuohia (AMZ), Umueze- Ezi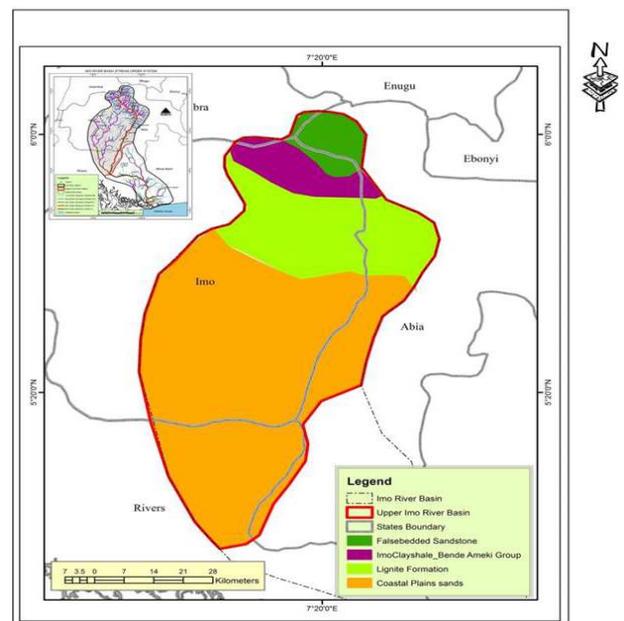ala – Obizi (UEO), Amakohia Owerri (AMO), and Umueze 2 (UMZ),and field measurement were used to obtain their morphological features Field measuring instruments used were tapes, ranging poles, and the measurement was done at 5 meters intervals as outlined by Ehiorobo and Audu (2012). Topographical map (Sheet 312) and Landsat 8 were used to extract the features of the bigger gullies studied. The bigger gullysies studied were located Aba site 1, Aba 2 (AB2), Umuduru (UMD), Okigwe (OKG), Emekuku (EME), Isiebu (ISB), New Owerri (NEO), Amainyi Ihitte Uboma (AMI), Nekede (NEK), Ibeku (IBE), Umuahia (UMU) and Isinweke (ISI). In general 18 gully sites were selected and studied from UIRB. Gully length, width, depth and area are the four morphological characteristics investigated and

2.3. Laboratory Analysis

Soil samples were collected from 6 sampled gullies taking cognizance of lithology and land cover. Two samples were collected from each of the 6 gullies at a depth of 2m and 4m and a total of 12 samples were collected. Samples were kept on organic cellophane bags before they were taken to the laboratory for analysis. Two major tests carried out were Atterberg or consistency test for geotechnical and geophysical properties, and Sieve Analysis for particle size distribution. The parameters generated are for the plastic limit (PL), liquid limit (LL), plasticity index (PI) relative consistency (CR) maximum dry density (MDD), bulk density (BD), optimum moisture content (OMC), organic carbon (OC), water-stable aggregate (WSA), organic moisture (OM), Sand, Silt and Clay.

2.4. Land Cover Analysis

Landsat 8 imageries were classified into different land covers for land cover analysis, and this was done through geo-referencing to WGS84 EPSG 4326. After geo-referencing, a clipping tool in QGIS platform were used to the product of the geo-referenced imageries A post classification comparison was used to identify the change in the 2003 and 2018 imageries. ERDAS imagine software was used for image. An unsupervised classification was performed, and the two imageries were classified into different land.

2.5. Data Processing and Statistics

Some gully morphological and geotechnical variables include the computation of gully area and some geotechnical variables using the following equations.

$A = w \times d$ ....Equation (3.1)
A = Gully area measured in square meters
W= width of gully at specific point (m)
$PI = LL – PL$ .... Equation (3.2)
Where PI = Plasticity index, LL = Liquid Limit and PL = Plastic Limit
$L I = Wn-PL/PL$ .... Equation (3.3)
Where Wn = natural moisture, PL = Plasticity Index
$Cr = LL- Wn/PL$ .... Equation (3.4)
Moisture content, $W = M_2 –M_3/ M_3 – M_1 * 1000 \ (mg/m^3)$....Equation (3.5)
M_1 = mass of container, M_2 = mass of wet soil + container, M_3 = mass of soil + container
Gully density was derived by the ratio of total length of gullies found in a given land cover to the total area occupied by the land cover [37].

The variability and homogeneity of the gully morphological and geotechnical characteristics was obtained using Analysis of Variance (ANOVA), Post-Hoc test and Levene's statistics. These tests were done in Statistical Package for Social Sciences (SPSS) version 22.0

3.0. Results and Discussion of Findings

3.1. Change in Land Cover between 2003 and 2018 in UIRB

Land cover of an area determines the rate and extent to which various types of erosion can develop and expand. Land cover analysis of the study area showed that 5 different types were discovered in UIRB in 2013 and 2018. They are - forests, built-up areas, farm land, wetland, and water bodies.

The extent of change of the identified land cover in UIRB is seen in figure 4. As evident in figures 4, the five land covers showed different patterns of change.
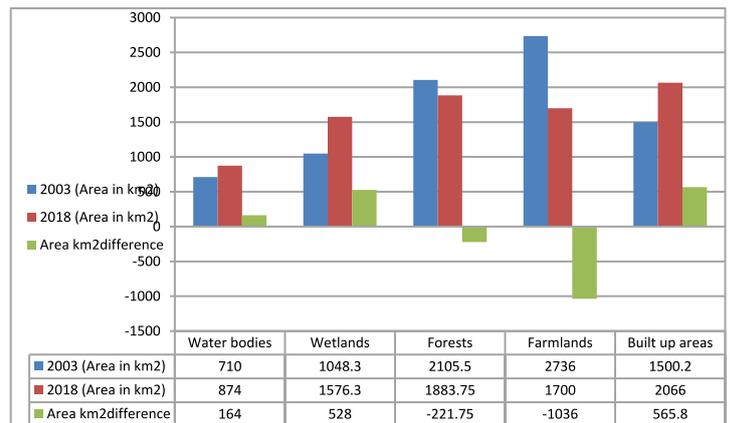

	Water bodies	Wetlands	Forests	Farmlands	Built up areas
2003 (Area in km2)	710	1048.3	2105.5	2736	1500.2
2018 (Area in km2)	874	1576.3	1883.75	1700	2066
Area km2difference	164	528	-221.75	-1036	565.8

Figure 4: The Extent of change observed in the Land cover in 2003 and 2018

The information in figure 4 showed that built up area experienced the highest gain from other land covers. In 2003, built up area covers 1500km^2 of the of 8100km^2 basin area, and this value increased in 2018 to 2066km^2 representing 565.8km^2 (6.99%) increase. Farmland experienced the greatest loss decreasing from 2736km2 to 1700km2.This represents a total of 1036 (12.99%) loss. The result is supports the results of similar work done in Nanka area from 2003 and 2015 [11]. By implication, this will make the area vulnerable to different types of erosion. [9], [7]

3.2. Gully Morphological Assessment and Soil Loss

Assessment of gully morphological parameters and locations were made under various identified land covers. Gully assessments in various land cover helps to provide the required information on the status of gullies found in the various land cover. The gullies under the various land cover were examined by identifying the land cover that contain both the gully head and the larger part of the gully area. This was taken to be the land cover where the gully is located. Table 1 showed that none of the gullies originated from the water bodies, hence those gullies that were found in the water bodies were as a result of encroachment from other land covers. This simply means that none of the sampled gullies has its head located in the water bodies. This is the reason why despite that the water bodies cover an area of 874 km^2(10.79 %) of the total land mass of the study area, the calculated values of average length, width, depth, area and even the densities of gullies were all zero.

Table 1: Gully Morphological Assessments and Soil Loss under various Land Cover in 2018 in UIRB

Land Cover	No. of gully	Av. Gully Length (m²)	Av. Gully Width (m²)	Av. Gully Depth (m²)	Av. Gully Area (km²)	Gully Density (m²)	Soil loss (m³)
Water bodies	0	0	0	0	0	0	0.0
Wetland	2	283.5	17.27	116.95	0.80	0.13	$1.45*10^6$
Forest	2	336.4	195.1	79.7	0.82	0.12	10^7
Farmland	7	344.9	83.1	102.3	24.17	0.41	$1.93*10^7$
Built up area	7	360.31	118.4	110.3	22.55	0.34	$3.2*10^7$

The minimal human activities around water bodies as well as its association with thick forest cover was adduced to be the reason why none of the gullies in the study area originated from water bodies [39], [40]. . Built-up areas and farmlands are the land cover that has the greatest gully locations since both of them contain 14 (7 each) out of the 18 gullies sampled for this study. The two land covers contained about 77.8 % of the gullies in UIRB. Both have the highest density as the density of gullies in farmland was 0.41, while gully density in the built-up areas is 0.34. This suggests that gully in the farmlands are closer more than gullies in the built-up areas and other land uses. The density of gully erosion across the land cover in UIRB was observed to be higher than the gully density across land covers obtained by [38] in the Eastern Nile watershed. It also indicated that farmland has the highest vulnerability to gully attack (this is due to tillage encourages the unconsolidation of the land top soils, the loose nature allows for easy detachment), followed by built up areas. The land cover with the least gully density in the study area is forested areas. This land cover has a gully density of 0.12, an indication that forested areas are not easily vulnerable to gully attack.

In terms of gully sizes, farmlands and built-up areas have their areas mostly attacked by gully erosion. Same pattern was identified in the gully area, length, width and depth. The most affected gully areas are the farmlands (24.17 km²), followed closely by built-up areas (22.55km²), then forest (0.82 km²) and the least land cover affected by gully is wetland (0.80km²). Invariably, it is the gully depth where the vulnerability of gully is highest in the wetlands. This showed the power of water as a factor of soil erosion through softening and dissociation of the materials that held the soil particles together. The average depth of gullies in the study area is highest in the wetland because the presence of water in these areas has made the soil in the area vulnerable to erosion. There was a massive loss of soil experienced in all the land covers affected by gully. The greatest soil loss was experienced in the built up area with $3.2*10^7$m³ sediment loss. $1.93*10^7$m³ was experienced in farmland, while 10^7m³ and $1.14 * 10^6$m3 of soil was lost in forest and wetland respectively. These values were large compared to soil loss in from gully sites in South Western Nigeria [41].

3.3. Gully Morphological and Geotechnical Characteristics in Land Covers

Table 2 presents the descriptive statistics of morphological and geotechnical variables of the gullies. Built up area has the greatest gully length (99.9m),and forest has the highest gully width (195.06m), while wetland has the least gully length (60.2m) and width (18.58m). farmland and built up areas are suggested as the covers that are at highest vulnerability risk to gully erosion as suggested by the values of morphological variables obtained from them.

The geotechnical result also showed that the least liquid limit of 3.10% was found in the built-up areas while the highest value of 20.40% was found in the forest land cover. The same trend was observed in atterberg or consistency test, except for the relative consistency where the opposite is the case.

For relative consistency, the least value (0.00%) was obtained in the forest land cover and the highest (2.00 %.) was found in the built-up area. This result shows that built-up area is among the land cover most vulnerable to gully erosion mainly because the cover protecting the land have been removed, while forest land cover is the least vulnerable since the presence of forest still provide the shield which the land needs from raindrop impact. The least bulk density value (1.92gm⁻²) was observed for farmland and the maximum bulk density value (2.16gm⁻²) and the highest mean value of bulk density was found in the built-up area. The high bulk density of soils in the built-up area causes leaching of organic content which helps to binds the soil particles together [24]. This factor can also be attributable to the high vulnerability of the built-up area to gully erosion

A test of homogeneity for variance values for the variables to ascertain the level of disparities at a 95% confidence interval shows none statistically significant difference in the variance values for all the morphological variables. As such, the observations taken on gully length, gully width, gully depth and gully area for all the locations across land cover types are assumed to be approximately the same across the locations.

For the gully geotechnical variables, the Levene's homogeneity test (Table 3) was used to test for homogeneity of variance between the groups measured, at the ninety-five (95%) percent confidence interval. A result showed that the variances observed for each of the land cover types showed significantly different within variance result. Consequently, Post HOC test was used for investigating the disparities i.e. the ANOVA result of 0.034 observed between the forest cover types. From the Post HOC result presented in Table 4, the liquid limit (%) values observed for each land cover type, though different, were not so statistically significant from one another. The ANOVA result for relative consistency, sand, silt, clay, bulk density, optimum moisture content, maximum dry density, organic carbon, water-stable aggregate and organic moisture were observed to be non-statistically significantly different from one another. By implication, the differences observed in the mean values of each of these geotechnical properties for each land cover type were not statistically significantly different at the 95% confidence interval. Though no statistically significantly different mean result was observed for the plastic limit values for land cover type, values measured at the built-up area, wetland and forest were observed to be more similar than that observed on the farmland. On the other hand, however, the ANOVA result presented on the plasticity index for the land cover types was observed to be statistically significantly different from one another. The Levene's test for these values for each factor was observed to be homogenous to one another. From the Post HOC test (Table 4), the mean plasticity index value observed at the built up area was not statistically significantly different from the mean plasticity index value measured on the farmland cover area. These two mean values (that is, values measured on built up area and farmland) were observed to be statistically significantly different from the mean plasticity index value that was observed on the Wetland cover type and Forest cover type.

It is important to note that the mean plasticity index value observed on Wetland and forest cover types were also not statistically significantly different from each other. The result of the analysis of the geotechnical variables by implication mean that while forest and wetland are not under serious threat to gully erosion, built-up areas and farmland covers are in serious attack to gully erosion.

Table 2: Summary of Descriptive Statistics of Gully Morphological Properties under Land Cover in UIRB

Land Cover	Gully Morphological and Geotechnical Variables																			
	Liquid limit					Plastic limit					Plasticity Index					Relative Consistency				
	M_1	M_2	M_3	Std.er	Std dev	M_1	M_2	M_3	Std.er	Std dev	M_1	M_2	M_3	Std Er	Std dev	M_1	M_2	M_3	Std Er	Std dev
Farmland	17.00	22.20	19.55	1.08	2.16	12.40	13.80	12.80	0.33	0.67	4.50	9.80	6.75	1.11	2.22	0.00	2.00	1.03	0.56	1.13
Built-up area	3.10	20.00	11.33	4.61	9.23	2.00	14.10	7.63	3.16	6.32	1.10	5.90	3.20	1.21	2.43	0.15	2.00	0.32	0.08	0.16
Wetland	25.00	27.30	26.15	1.15	1.63	2.30	3.50	2.90	0.60	0.85	21.50	25.00	23.25	1.75	2.47	0.00	0.46	1.00	1.00	1.41
Forest	26.50	29.40	27.95	1.45	2.05	4.20	4.30	4.25	0.05	0.07	22.30	25.10	23.70	1.40	1.98	0.00	0.00	0.00	0.00	0.00

M_1 = Minimum, M_2= maximum, M_3 = mean, Std. er = standard Error, Std dev = Standard deviation

Table 2: Continued

Land Cover	Gully Morphological and Geotechnical Variables																			
	Length (m)					Width(m)					Depth (m)					Area(km²)				
	M_1	M_2	M_3	Std. er	Std dev	M_1	M_2	M_3	Std. er	Std dev	M_1	M_2	M_3	Std. Er	Std dev	M_1	M_2	M_3	Std.er	Std dev
Farmland	63.70	601.70	308.70	82.27	201.53	19.30	233.96	95.67	41.71	102.16	63.30	420.00	155.30	54.13	132.60	160.80	10000.00	2792.91	1782.93	4365.08
Built-up area	99.90	980.00	374.70	105.84	280.03	23.60	441.20	131.75	54.89	145.23	56.00	144.50	99.15	12.32	32.61	582.40	10000.00	2255.57	1382.9.02	3658.14
Wetland	60.20	506.10	283.15	222.95	315.30	15.90	18.58	17.24	1.34	1.90	92.50	141.00	116.75	24.25	34.29	62.01	1538.39	800.20	738.19	1043.96
Forest	65.80	609.98	337.89	272.09	384.79	4.30	385.81	195.06	190.76	269.77	76.00	95.00	85.50	9.5.44	13.44	15.80	1628.70	822.25	806.45	1140.49

M_1 = Minimum, M_2= maximum, M_3 = mean, Std. er = standard Error, Std dev = Standard deviations

Table 2: Continued

Land Cover	Gully Morphological and Geotechnical Variables																			
	Sand					Silt					Clay					Bulk Density				
	M_1	M_2	M_3	Std.er	Std dev	M_1	M_2	M_3	Std.er	Std dev	M_1	M_2	M_3	Std. Er	Std dev	M_1	M_2	M_3	Std. Er	Std dev
Farmland	73.60	91.40	80.55	4.00	7.99	2.00	2.40	2.10	0.10	0.20	6.40	22.40	16.90	3.77	7.55	1.92	2.13	2.07	0.05	0.10
Built-up area	75.60	88.60	81.35	2.95	5.91	2.00	4.00	2.60	0.48	0.95	9.40	22.40	16.15	2.78	5.56	2.01	2.29	2.16	0.06	0.13
Wetland	89.60	91.60	90.60	1.00	1.41	2.00	2.00	2.00	0.00	0.00	6.40	6.40	6.40	0.00	0.00	2.01	2.11	2.06	0.05	0.07
Forest	65.60	77.60	71.60	6.00	8.49	2.00	6.00	4.00	2.00	2.83	20.40	28.40	24.40	4.00	5.66	2.02	2.14	2.08	0.06	0.08

M_1 = Minimum, M_2= maximum, M_3 = mean, Std. er = standard Error, Std dev = Standard deviations

Table 2: Continued

Land Cover	Gully Morphological and Geotechnical Variables																			
	Optimum Moisture Content					Maximum Dry Density					Organic Carbon					Water Stable Aggregate				
	M_1	M_2	M_3	Std.er	Std dev	M_1	M_2	M_3	Std.er	Std dev	M_1	M_2	M_3	Std. Er	Std dev	M_1	M_2	M_3	Std. Er	Std dev
Farmland	6.30	19.40	12.18	2.95	5.90	1.81	1.95	1.86	0.03	0.06	0.04	0.48	0.25	0.11	0.22	0.30	0.76	0.51	0.10	0.20
Built-up area	14.30	18.70	16.70	0.94	1.88	1.78	2.10	1.96	0.07	0.14	0.06	0.32	0.14	0.06	0.12	0.28	0.82	0.55	0.15	0.30
Wetland	14.00	17.60	15.80	1.80	2.55	1.76	1.79	1.78	0.02	0.02	0.02	0.02	0.02	0.00	0.00	0.52	0.58	0.55	0.03	0.04
Forest	15.90	19.10	17.50	1.60	2.26	1.69	1.76	1.73	0.04	0.05	0.02	0.20	0.11	0.09	0.13	0.52	0.61	0.57	0.05	0.06

Table 2: Continued

Land Cover	Gully Morphological and Geotechnical Variables				
	Organic Moisture				
	M_1	M_2	M_3	Std.er	Std dev
Farmland	0.07	0.60	0.31	0.12	0.25
Built-up area	0.10	0.55	0.22	0.11	0.22
Wetland	0.03	0.03	0.03	0.00	0.00
Forest	0.03	0.34	0.19	0.16	0.22

M_1 = Minimum, M_2= maximum, M_3 = mean, Std. er = standard Error, Std dev = Standard deviations

Table 3: Levene's test of homogeneity of variance

Geotechnical property	Levene statistic	df1	df2	p-value	Remark
LL (%)	55.323	3	8	< 0.001	Significant
PL (%)	68.433	3	8	< 0.001	Significant
PI (%)	0.337	3	8	0.799	Not significant
RC (KNM2)	1017.256	3	8	< 0.001	Significant
Sand (%)	1.530	3	8	0.280	Not significant
Silt (%)	18.520	3	8	0.001	Significant
Clay (%)	1.557	3	8	0.274	Not significant
BD (gcm-3)	0.890	3	8	0.486	Not significant
OMC (%)	4.045	3	8	0.051	Not significant
MDD (gcm-3)	1.705	3	8	0.243	Not significant
OC (%)	7.424	3	8	0.011	Significant
WSA (%)	8.926	3	8	0.006	Significant
OM (%)	2.730	3	8	0.114	Not significant

Table 4: Post HOC test for the ANOVA tables

Geotechnical property	Land cover type			
	Built up area	Wetland	Farmland	Forest
LL (%)	11.33 ± 9.23[a]	26.15 ± 1.63[a]	19.55 ± 2.16[a]	27.95 ± 2.05[a]
PL (%)	7.63 ± 3.16[ab]	2.90 ± 0.85[ab]	12.80 ± 0.67[a]	4.25 ± 0.07[ab]
PI (%)	3.20 ± 1.21[a]	23.25 ± 1.75[bc]	6.75 ± 1.11[a]	23.70 ± 2.72[c]
RC (KNM2)	0.32 ± 0.08[a]	1.00 ± 1.00[a]	1.03 ± 1.13[a]	0.00 ± 0.00[a]
Sand (%)	81.35 ± 2.95[a]	90.60 ± 1.00[a]	80.55 ± 4.00a	71.60 ± 6.00[a]
Silt (%)	2.60 ± 0.48[a]	2.00 ± 0.00[a]	2.10 ± 0.10[a]	4.00 ± 2.00[a]
Clay (%)	16.15 ± 2.78[a]	6.40 ± 0.00[a]	16.90 ± 3.77[a]	24.40 ± 4.00[a]
BD (gcm-3)	2.16 ± 0.06[a]	2.06 ± 0.05[a]	2.07 ± 0.05[a]	2.08 ±0.06[a]
OMC (%)	16.70 ± 0.94[a]	15.80 ± 1.80[a]	12.18 ± 5.90[a]	17.50 ± 1.60[a]
MDD (gcm-3)	1.96 ± 0.07[a]	1.78 ± 0.02[a]	1.86 ± 0.03[a]	1.73 ± 0.04[a]
OC (%)	0.14 ± 0.06[a]	0.02 ± 0.00[a]	0.25 ± 0.11[a]	0.11 ± 0.09[a]
WSA (%)	0.55 ± 0.30[a]	0.55 ± 0.04[a]	0.51 ± 0.20[a]	0.57 ± 0.06[a]
OM (%)	0.22 ± 0.11[a]	0.03 ± 0.00[a]	0.31 ± 0.25[a]	0.19 ±0.22[a]

Cells in rows with same superscript are not statistically significantly different

3.4. Gully Distributions and Variations of its Morphological and Geotechnical Properties across Lithological Formations

Result obtained on the analysis of the distribution of the cumulative sizes of the gully morphological properties in

various lithologies was computed. Table 5 presents the information.

Table 5: Total Sizes of morphological properties of gullies in various Lithologies of UIRB

Lithological Formations	Total Sizes of Morphological features					
	Length (m)	%	Width (m)	%	Area (km²)	%
False Bedded Sandstone	0.0	0.0	0.0	0.0	0.0	0.0
Lignite formation	1,157.27	18.93	447.98	21.5	67.07	20.31
Coastal plain Sand	4,390.18	71.83	1,625.26	78.00	261.91	79.29
Imo Clay Shale	0.0	0.0	0.0	0.0	0.0	0.0
Bende Ameki	565	9.24	10.5	0.5	1.32	0.40
Total	6,112.45	100	2083.74	100	330.30	100

A total length of 6,112.45m, width of 2083.74m, and area of 330.30 km² was obtained from the gullies in UIRB. From the total length, 71.83% (4,390.18m) computed fot the coastal plain sands, 28.17percent (1157.27m) found in lignite and 18.98% (56m) found in Bende-Ameki lithology. 78% (1,625.26m) of gully width were in the coastal plain sands, 21.5% (447.98m) were in lignite and 0.5% (10.5m) found in the Bende-Ameki formation. 261.91 km² (79.29%) of the gully area are in the Coastal plain sands, Lignite has 67.07 km² (20.31%) and Bende-Ameki contains only about 0.4 percent (1.32km²) of the total areas covered by gully in UIRB. [42] reported similar results in Idah – Ankpa Plateau of Anambra River Basin where discovery made showed that the total length of gullies in Ajali sandstone was 16,700m while the length in upper coal was 1808m, gully width in Ajali sandstone was 294.04m, while the width in upper coal was 29.82m, and the total gully area in Ajali sandstone was 2,300m², while the width in upper coal was 324.04m². The research identified that the intensity and severity of gully in UIRB ere most in the coastal plain sands formations.

Table 6 presents is the summary of the descriptive statistics of gully morphological and geotechnical features in the identified lithologies. There is a statistically significant variations in the average length, width, depth and area of the gullies in the coastal plain sands and lignite lithological formations. The coastal plain sands has an average gully length of 350.42m, width of 125.02m, mean depth of 119.45m and average area of 20.12km². the Lignite has an average length of 290.44m, width of 73.90m,depth of 119.38mand an area of 16.77km². these values were observed to be higher in coastal plain sands lithology than the lignite.

For the 13 geotechnical variables, the mean values also vary between the coastal plain sand and lignite geology. These values also prove that the intensity and effect of gully erosion in the Upper Imo River Basin were more in the coastal plain sand lithology than other lithologies of the UIRB. This calls for efforts to minimize the rate of exposure of the soil underlain by coastal plain sand lithology. The mean values for 8 of the 13 geotechnical variables were higher in coastal plain lithology than in the lignite geology. The variables with the higher mean values for coastal plain lithology were the liquid limit, plasticity index, silt, clay, bulk density, optimum moisture content, water-stable aggregate, and organic moisture. The proportion of sand clay and silt disagrees with that was reported by [43] in the highland of Ethiopia. In the study, the soil particle was distributed with clay component having the largest proportion, while the sand particles constitute the least proportion. This result is at variance what obtains in UIRB. The percentage liquid limit, plastic limit, plasticity index, optimum moisture content and maximum dry density were also not in agreement with what was recorded by [24].

The reason for the deviation in the geotechnical properties is because the study was done on Ameki formation, while this research was done on a combination of coastal plain, Bende-Ameki, false bedded sandstone and lignite formations.

Table 6: The Descriptive Statistics Morphological Characteristics of gullies in the Lithological Formations in UIRB

Variable	Lithological formation					
	Coastal plain sand			Lignite		
	Mean	Std. Error	Std. Deviation	Mean	Std. Error	Std. Deviation
Gully length (m)	350.42	70.56	254.42	290.44	113.24	226.48
Gully width (m)	125.02	40.11	144.63	73.90	48.80	97.60
Gully depth (m)	119.45	26.07	93.99	119.38	14.57	29.13
Gully area (km²)	20123.79	10232.71	36894.56	16769.00	16028.74	32057.48
LL (%)	24.47	1.74	4.27	19.55	1.08	2.16
PL (%)	6.73	2.04	4.99	12.80	0.33	0.67
PI (%)	17.40	3.89	9.53	6.75	1.11	2.21
RC (KNM2)	0.39	0.32	0.79	1.03	0.56	1.13
Sand (%)	79.60	3.93	9.63	80.55	4.00	7.99
Silt (%)	3.00	0.68	1.67	2.10	0.10	0.20
Clay (%)	17.07	3.64	8.91	16.90	3.77	7.55
BD (gcm-3)	2.14	0.05	0.11	2.07	0.05	0.10
OMC (%)	16.40	0.82	2.02	12.18	2.95	5.90
MDD (gcm-3)	1.83	0.05	0.13	1.86	0.03	0.06
OC (%)	0.11	0.05	0.12	0.25	0.11	0.22
WSA (%)	0.64	0.06	0.14	0.51	0.10	0.20
OM (%)	0.23	0.08	0.20	0.17	0.08	0.17

Result of Levene Test on lithological formation show no statistically significant result for the gully length, gully depth, liquid limit, relative consistency, sand, clay, bulk density, maximum dry density, water-stable aggregate and organic moisture, while there is a statistically significant result for gully width, gully area, plastic limit, plasticity index, silt, optimum moisture content and organic carbon across the lithological formation (Table 7). A further investigation to ascertain the difference in mean for the variables across the lithological formation using an independent sample T–test showed the same result for the mean values of the variables.

Table 7: Levene Test for Gully Morphological and Geotechnical Variables across Lithologies of UIRB

Geotechnical property	Levene statistic	df1	df2	p-value	Remark
LL (%)	3.415	2	9	0.079	Not significant
Gully length (m)	0.04	3	15	0.84	Not statistically different
Gully width (m)	0.80	3	15	0.04	Statistically different
Gully depth (m)	0.05	3	15	0.84	Not statistically different
Gully area (km²)	0.51	3	15	0.039	Statistically different
PL (%)	10.690	2	9	0.004	Statistically Significant
PI (%)	10.455	2	9	0.004	Statistically Significant
RC (KNM2)	4.095	2	9	0.054	Not statistically significant
Sand (%)	0.826	2	9	0.468	Not statistically significant
Silt (%)	5.468	2	9	0.028	Statistically Significant
Clay (%)	1.015	2	9	0.401	Not statistically significant
BD (gcm-3)	0.406	2	9	0.678	Not statistically significant

OMC (%)	6.499	2	9	0.018	Statistically Significant
MDD (gcm-3)	4.152	2	9	0.053	Not statistically significant
OC (%)	8.334	2	9	0.009	Statistically Significant
WSA (%)	2.556	2	9	0.132	Not statistically significant
OM (%)	2.689	2	9	0.121	Not statistically significant

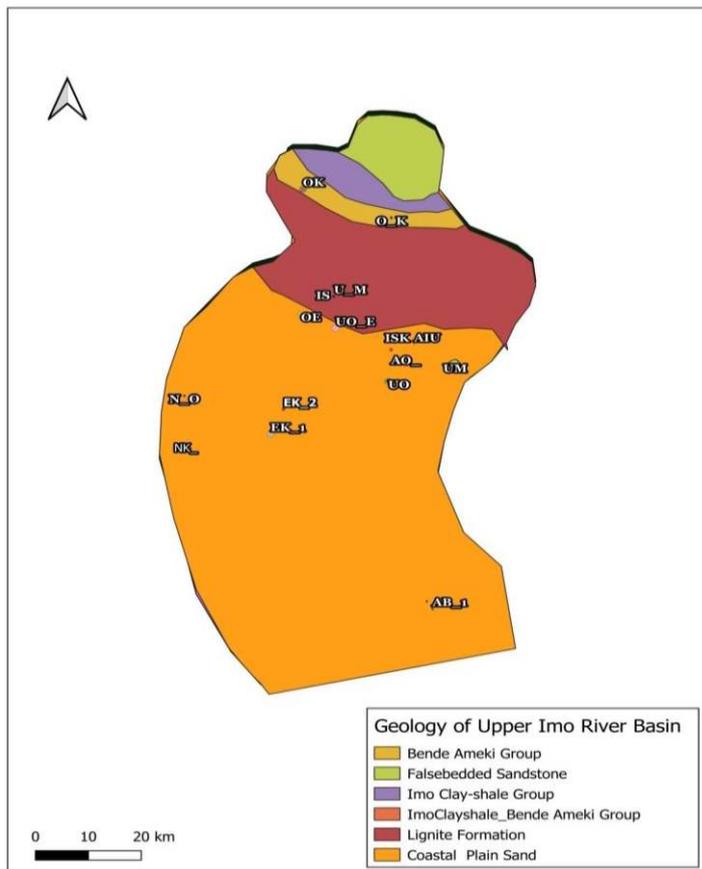The Location of the gullies across the various lithologies is seen in figure 4.

Figure 4: Gully Location across Lithologies of UIRB

Conclusion

The study area is located in two states of Southeastern Nigeria. The two states are Imo and Abia The geology of the area consist of the basement complex rock of Precambrain, which is made of five lithological. In the UIRB, five major land covers were classified for the study area, and all were found that have experienced different types of changes within the study period. Water bodies, wetland and built up areas has positive changes (gain) of 6.99%, 6.52% and 2.02% respectively. water. In one year, water body was observed to gain 37.7km^2, wetland gained 35.2km^2 and built-up area gained 10.9km^2. Forest and farmland experienced negative change (loss) in their area. Within the period under study, forest cover lost 2.99% (69.1km^2), and farmland lost 2.74%(2.74%) of its area. Gully intensity was observed to vary across the various lithological compositions. Three lithological compositions were identified to have been affected by gullying in UIRB. Ofomata (1985), was of the view that the state of earth's material has a tremendous influence on the rate of infiltration, and thereby of slumping and or sliding. Lithological field studies in South-Eastern Nigeria revealed that

gullying remained active over the lithological landscape.

Gully intensity in UIRB was revealed to be highest in the coastal plain sand lithology, and least in the Bende-Ameki lithology. The total gully width in UIRB was 2,083m; the value in coastal plain sand lithological composition was 1,625.26m representing 78% of the total gully width. Lignite lithology has 44798m or 21.5% of the total gully width, while the Bende-Ameki lithology has a width of 10.5m, representing 0.5% of the total gully width. This same trend was also observed in the gully area. The gully area in the coastal plain lithology was 79.29% of the entire gully area in UIRB, the area occupied by lignite lithology represents 20.31%, and Bende-Ameki lithology completed the remaining 0.4% of the gully area

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