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APPLICATION OF AHP AND GEOSPATIAL TECHNIQUES FOR EVALUATING GULLY EROSION VULNERABILITY IN BENIN CITY, EDO STATE, NIGERIA

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Abstract

This paper assessed gully erosion using Remote Sensing and GIS methods as well as Analytical Hierarchical Process (AHP) method to determine areas vulnerable and susceptible to gully erosion and Analysed qualitatively the perception of city dwellers, their coping mechanisms to (and the causative factors of) Gully Erosion in Benin City. Five essential criteria (Lithology, Land-use/Landcover (LULC), Drainage Density (DD), Slope and Soil) were identified based on literature. AHP was used to determine weights for each of the Pairwise Comparison Matrix (PCM) obtained. Consistency of generated weights obtained was not above 0.07 reflecting a valid result. Field work was also conducted to establish the people's perception and identify the causes and control measures for the gully erosion problem in the area, 100 questionnaire was distributed using purposive systematic sampling methods to inhabitants around identified gully sites. The gully erosion vulnerability model developed in this study revealed that as high as 44.4% of the total area was highly vulnerable to gully erosion, 52.1% (488.69Km^2) of the area is vulnerable to gully erosion, while 3.4% (32.37 Km^2) was found to be less vulnerable to gully erosion. Findings on the major contributing factor that leads to the gully erosion formation showed that lack of drainage system account for 56.25%, improper land use practice account for 25% and bad road construction (18.75%). About 50% of the respondents are of the view that adequate drainage system would go a long way to mitigate the gully erosion. This study has provided information on the state of gully erosion vulnerability in Benin City through mapping of vulnerable areas and we recommend that planning and urban development in Benin-City be based on the informed decision making, we also recommend the construction of proper and efficient drainage systems and suggest that collaborative and integrated land-use practices be upheld in the city of Benin.

Keywords: Geospatial techniques, Gully erosion, AHP, vulnerability

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L'APPLICATION DES TECHNIQUES PHA ET GEOSPATIALES POUR L'EVALUATION DE LA VULNERABILITE A L'EROSION DES RAVINS DANS LA VILLE DE BENIN, DANS L'ETAT D'EDO, AU NIGERIA.

RESUME

Cet article a évalué l'érosion des ravins à l'aide des méthodes de télédétection et de SIG ainsi que la méthode du processus hiérarchique analytique (PHA) pour déterminer les zones vulnérables et sensibles à l'érosion en ravins et analyser qualitativement la perception des habitants de ladite ville, leurs mécanismes d'adaptation à l'érosion du ravin (et leurs facteurs causatifs) dans la ville de Benin. Cinq critères essentiels (la Lithologie, l'Utilisation des terres/Couverture des terres, la Densité de drainage (DD), les Pentes et sols) ont été identifiés sur la base de la littérature. La méthode du processus hiérarchique analytique (PHA) a été utilisé pour déterminer les poids pour chacune des matrices de comparaison par paires. La cohérence des poids générés n'était pas supérieure à 0,07 reflétant ainsi, un résultat valide. Un travail de terrain a également été mené pour établir la perception des gens et identifier les causes et les mesures de contrôle du problème d'érosion en ravins dans la région, 100 questionnaires ont été distribués en utilisant des méthodes d'échantillonnage systématique aux habitants autour des sites de ravins identifiés. Le modèle de vulnérabilité à l'érosion en ravins développé dans cette étude a révélé que jusqu'à 44,4% de la superficie totale était très vulnérable à l'érosion en ravins, 52,1% (488,69Km2) de la zone est vulnérable à l'érosion en ravins, tandis que 3,4% (32,37 km2) s'est avéré moins vulnérable à l'érosion en ravins. Les résultats sur le principal facteur contributif qui conduit à la formation d'érosion en ravine ont montré que le manque de système de drainage représente 56,25%, les pratiques inappropriées d'utilisation des terres représentent 25 % et la mauvaise construction des routes (18,75 %). Environ 50 % des répondants sont d'avis qu'un système de drainage adéquat contribuerait grandement à atténuer l'érosion des ravins. Cette étude a fourni des informations sur l'état de vulnérabilité à l'érosion des ravins dans la ville de Bénin par la cartographie des zones vulnérables et nous recommandons que la planification et le développement urbain dans la ville de Benin soient basés sur la prise de décision éclairée, nous recommandons également la construction de systèmes de drainage appropriés et efficaces et nous suggérons que des pratiques collaboratives et intégrées d'utilisation des terres soient maintenues dans la ville de Bénin.

Mots clés: Techniques géospatiales, Érosion en ravins, PHA, vulnérabilité

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Introduction

Soil erosion is a worldwide phenomenon which ravages large areas of land particularly in high rainfall (Murck, Skinner,& Porter, 1995). Soil-gully erosion has been known as one of the major challenges to global environmental and socio-economic sustainability (Noori, Siadatmousavi, & Mojaradi, 2016). Soil erosion is one of the indicators of land quality due to the destructive effect it has on land and its effect of reduced productivity of land (Marzolff and Poesen, 2009; Onu, Osahon, & Ukonu, 2020). The formation of gullies has become one of the greatest environmental disasters facing many towns and villages in Southern and Eastern Nigeria (Adekalu, Olorunfemi, & Osunbitan, 2007; Nwilo, Olayinka, Uwadiegwu, & Adzandeh, 2011; Odjugo, 2012). Erosion affects the sustainability of agricultural production on a global scale (Bouaziz, Leidig, & Gloaguen, 2011). The definitions of erosion and its consequent problems has been explained in the work of (Abdulfatai, Okunlola, Akande, Momoh, & Ibrahim, 2014; Onu et al., 2020; Saini, Jangra, & Kaushik, 2015). Erosion is one of the surface processes that sculpture the earth's landscape and constitutes one of the global environmental problems. Erosion has been described as a well-defined water worn channel (Monkhouse & Small, 1978); Soil erosion is perhaps the most serious mechanism of land degradation in the tropics (El-Swaify, Dangler, & Armstrong, 1982; Nwilo, Olayinka, Uwadiegwu, & Adzandeh, 2011; Odjugo, 2012). However, gully erosion is visually the most impressive of all types of erosion (El-Swaify, 1990 as cited in Abdulfatai et al., 2014), highly visible and affects soil productivity, restricts land use and can threaten roads, fences, buildings and human life (Afegbua, Uwazuruonye, & Jafaru, 2016).

Edo state is no exceptions to gully erosion problem in Nigeria as land degradation due to flooding and erosion ranked first and second in the ranking of environmental problems in Edo state (Edo State Government, 2010). The magnitude of devastation as a result of flooding and erosion has resulted in loss of lives and properties, destruction of arable lands and wastage of large areas of usable lands. Gully erosion within settlements requires peculiar attention because of the threat it poses to buildings and other structures that endanger human lives. The gully in Auchi and other areas of Edo State has posed numerous threats to inhabitants of the area and has caused many residential buildings and worship centers to collapse, destroying road networks and other infrastructure, and degrading land for commercial and agricultural purpose, with more buildings perching precariously on the edge of the stream channels.

Several studies have been carried out over the decades on the problems of gully erosion in south eastern Nigeria (Nwilo et. al., 2011; Odjugo, 2012; Abdulfatai et al., 2014). The spatial distribution of gully erosion sites on false bedded and stone geologic formation in Eastern Nigeria has been studied and explained in the work of (Nwilo et al., 2011) who showed settlements at risk and the level of vulnerability of settlements and infrastructure using GIS. The review of literatures on gully erosion in Nigeria has been provided in the works of (Abdulfatai et al., 2014), who iterated on the effects of gully erosion on lives and properties, including seclusion of villages and communities in areas where major roads are divided by huge gullies, especially in the south-eastern parts of Nigeria. Odjugo (2012) monitored climatic changes over a period of 70 years (1940-2010) and analysed flood and erosion characteristics in the city of Benin., using both qualitative and quantitative methods to assess the damages caused by flood and erosion in the area, with a focus on the financial implications. Rural community efforts in controlling gully erosion has also been examined in the works of (Onu et al., 2020), the qualitative study revealed poor or low performance of communities participation in gully erosion control. Saini et al., (2015) assessed the sites vulnerable to gully erosion usinge Multi Criteria Evaluation (MCE) to assess the sites vulnerable to gully erosion in Markanda River catchment area in India. Anejiounu, Nwido, & Ebinne (2013) pointed out that mapping of areas of soil erosion risk is important as an erosion control measure, and from the foregoing, it has been established that erosion is a major threat to soil and water resource conservation in South-eastern Nigeria of which Edo state is inclusive.

Various attempts made at controlling erosion in the region is yet to yield desired result.

The introduction of Remote Sensing and GIS technologies and their combination with the empirical models have made the soil erosion monitoring more efficient, effective, reliable, faster and easier with sustainable results and low cost (Gelagaya & Minale, 2016; Noori et al., 2016). For instance, the derived data from normalized differentiate vegetation index (NDVI) and digital elevation model (DEM) generated from the multi-temporal satellite imageries provides vital information on the vegetation cover, topography and management which boosts spatial estimation of soil erosion at various scales using C-factor, LS-factor and P-factor (Noori et al., 2016; Seutloali, Dube, & Mutanga, 2016). These geospatial methods have made the potential effects of land use/landcover (LULC) and its changes on soil-gully erosion to be successfully achieved, and modelling and prediction of the relationships between land use/landcover (LULC) and soil-gully erosion has become easy and interesting. Several erosion models including the physical (WEPP, ANSWERS, AGNPS, SHE), and empirical models (USLE, RUSLE, AHP, MUSLE, FAO, Fournier, PSIAC, Modified PSIAC, EPM) have been developed and successfully applied in many soil-gully erosions assessments (Adediji, Tukur, & Adepoju, 2010; Seutloali, Dube, & Mutanga, 2016; Saaty & Vargas, 2001). Analytic Hierarchy Process (AHP) is a decision approach designed to aid the solution of complex multiple criteria problems and has been explained in (Drake, 1998; Saaty & Vargas, 2001). AHP is a widely accepted statistical method and a very popular means of calculating the needed weighting factors with the help of a preference matrix where all identified relevant criteria are compared against each other with reproducible preference factors (Saini et al., 2015). Assessment of erosion in an area is vital in order to evaluate land management and to provide a basis for land users and decision makers with regards to land conservation efforts and environmental monitoring. This paper is therefore aimed at 1. Assessing gully erosion using Remote Sensing and GIS methods as well as Analytical Hierarchical Process (AHP) method to determine areas vulnerable and susceptible to gully erosion; and 2. Analysing qualitatively the perception of city dwellers, their coping mechanisms to (and the causative factors of) Gully Erosion in Benin City, Nigeria.

Study Area

The study area is Benin City in Southern Nigeria. Benin City is located in Southern Nigeria within latitudes 60 20” 01’ N and 60 58” 01’ N and longitudes 50 35” 01’ E and 50 41” 01’ E. It broadly occupies an area of approximately 112.552 km. This extensive coverage suggests spatial variability of weather and climatic elements. As Buchanan & Pugh (1955) observed, Benin City lies visibly in the southern most corner of a dissected margin: a prominent topographical unit which lies north of the Niger Delta, west of the lower Niger Valley, and south of the Western Plains and Ranges. The study area map is shown in Figure 1. The city serves as the principal administrative and socio-economic center for both Oredo Local Government Area and Edo State in Nigeria. Benin City is a humid tropical urban settlement which comprises three Local Government Areas namely Egor, Ikpoba Okha and Oredo.

The Geologic structure of Benin City consist of crystalline rock formation of Precambrian basement complex and sedimentary rock of cretaceous tertiary and quaternary formation (Balogun & Okoduwa, 2000; Prichard, 1985). According to Odjugo (2012), Benin city is characterized as a tilted plain with slope positioned in a South-West direction, with the Eastern edge tilting towards Ikpoba river which drains the North-Eastern part of the city, while the western edge slopes towards Ogba river in a gentle slope formation. According to Odjugo (2012) Benin city has a highest elevation of 85m above sea level situated around Esan Plateau; the city is classified climatically under the rainforest belt with an annual rainfall of above 2000mm and a mean monthly temperature of 28^0C and relative humidity of 80% (Odjugo, 2012), reflected by the ever green and deciduous nature of the vegetation in the area, such vegetation as (ferns, mosses, mushrooms in the muddy and swampy areas of Benin, found during the peak period of rainy season; these lower grasses and plant species gives way to higher order plants as Mahogany, Walnut, Cedar as well as oil palm trees.

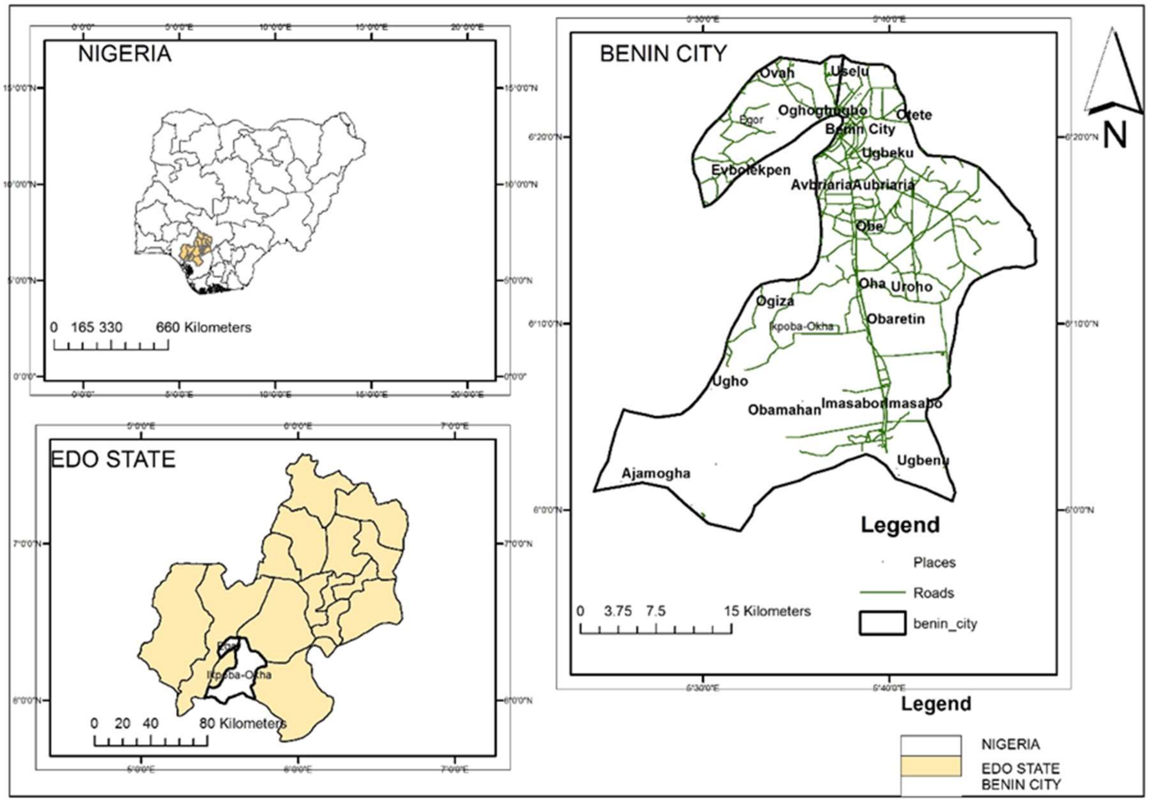

Figure 1: The Study Area Map

Methodology

Data was collected and used in this study. Primary data used in this study includes coordinate of four (4) gully erosion sites obtained with a GPS device and selected based on the physical occurrence of know gullies in the area of interest, photographic shots of the areas affected was collected as well using of digital camera, field interviews conducted with residents living near the affected areas and the administration of questionnaires. Secondary data used in this study includes; soil map, high-resolution imagery obtained from Google Earth, Digital Elevation Model (DEM) using SRTM was downloaded from ALOS PALSAR for the purpose of slope extraction. Landsat 8 OLI & TIRS was downloaded from Global Land Cover Facility (GLCF) and used in classifying Land use/Landcover (LULC). Idrisi was used to create color composites and classify the LULC of the area, ArcMap was used to digitize and also for the map layout production.

Analytic Hierarchy Process (AHP) was used to reclass each factor into different level of vulnerability; this was achieved via the use of pair wise comparison for each sub-class of 3, ranking means of decreasing order of impact (highly vulnerable, vulnerable and less vulnerable), this was done to produce the five (5) required factor maps. The factors which were considered for the creation of the vulnerability map is based on relevant literature (Vaidyanathan, Shanna, Sinha, & Dikshit, 2002). The five required factors used in this study are: slope, lithology, drainage density, soil and land use/land cover. Assigning weights to the selected factors is usually a complex decision problem that involve multiple criterion function. In such a situation, preference can arise if a logical, well-structured decision-making process is not followed (Saini et al., 2015). Multi Criteria Evaluation (MCE) methodology can objectively solve complex decision problem using multiple criteria. AHP method introduced by Saaty & Vargas (1991) was used in this study. All factors considered relevant for a decision were compared against each other in a pair-wise comparison matrix which is a measure to express the relative preference among the factors. Therefore, numerical values expressing a judgment of the relative importance of one factor against another was assigned to each factor. Since it is known from psychological studies that an individual cannot simultaneously compare more than 7 ± 2 elements, a scale for comparison consisting of values ranging from 1 to 9 which describe the intensity of importance (preference/dominance) was adopted as presented in Table 1.

Table 2 below, shows a pairwise comparison matrix of order 5 where the five (5) criteria earlier described (C1, C2, C3, C4, and C5) were compared against each other. In the direct comparison of the criteria C1 and C2, criterion C1 is regarded equal to moderate importance and similarly relative importance are assigned to the remaining criterion. The transpose position automatically gets a value of the reciprocal; it is 1/5 which equals 0.2.

The assigned preference values were synthesized to determine a numerical value which is equivalent to the weights of the factors. Therefore, the Eigen values and Eigen vectors of the square preference matrix revealing important details about patterns in the data matrix were calculated. The above square matrix of order five (5) gives five (5) Eigen values with which five Eigen vectors - each having five vector components - can be calculated as shown in Table 3 below. It is regarded sufficient to calculate only the Eigen vector resulting from the largest Eigen value since this Eigen vector contains enough information to provide – by its Eigen vector components - the relative priorities of the factors being considered (Saaty & Vargas, 1991).

Table 1: Example of scale for comparison

Intensity of Importance	**Description**
1	Equal importance
2	Equal to moderate importance
3	Moderate importance
4	Moderate to strong importance
5	Strong importance
6	Strong to very strong importance
7	Very strong importance
8	Very to extremely strong importance
9	Extreme importance
Reciprocals	Values for inverse comparison

Source: (Saaty & Vargas, 2001)

Table 2: Pairwise Comparison Matrix

Criteria		**LULC**	**Lithology**	**DD**	**Slope**	**Soil**
		C1	C2	C3	C4	C5
LULC	C1	1.00	0.33	0.2	0.14	0.11
Lithology	C2	3.00	1.00	0.33	0.2	0.14
DD	C3	5.00	3.00	1.00	0.33	0.2
Slope	C4	7.00	5.00	3.00	1.00	0.33
Soil	C5	9.00	7.00	5.00	3.00	1.00
Total		25.0	16.33	9.53	4.67	1.78

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Table 3: Normalized Pairwise Comparison Matrix

Criteria		LULC	Lithology	DD	Slope	Soil	Row total (c1 to c5)	Priority Vector (row sum/5) Criteria w.	Weight (%)
		C1	C2	C3	C4	C5			
LULC	C1	0.04	0.02	0.02	0.03	0.06	0.17	0.04	3.5
Lithology	C2	0.12	0.06	0.04	0.04	0.08	0.08	0.08	6.8
DD	C3	0.2	0.18	0.11	0.07	0.11	0.67	0.13	13.5
Slope	C4	0.28	0.31	0.32	0.21	0.18	1.3	0.25	26.2
Soil	C5	0.36	0.43	0.52	0.64	0.56	2.5	0.50	50.0
		1.00	1.00	1.00	1.00	1.00	4.72	1.00	100.00

Source: Authors (Modified from Saaty, 1991).

Consistency ratio (CR) was calculated to measure how consistent the judgments have been relative to large samples of purely random judgments. AHP always allows for some level of inconsistencies which should not exceed a certain threshold as shown in Table 4.

The Random inconsistency indices (RI) (Table 4) developed by (Saaty & Vargas, 1991) was used to determine the consistency ratio (CR), which measures the degree of consistency. If the value of CR is smaller or equal to 0.1, the inconsistency is acceptable or else the pair-wise comparison may be revised if the CR is much in excess of 0.1 the judgments are unreliable because they are too close for comfort to randomness. Therefore, the weights can be accepted as the calculated CR is equal to 0.07 as shown in equation (1) – (2) below;

Table 4: Calculating Consistency Ratio (CR)

Criteria		LULC	Lithology	DD	Slope	Soil	Weight criteria sum	Weight criteria	Consistency Ratio (R)
		C1	C2	C3	C4	C5			4.5
LULC	C1	0.04	0.026	0.026	0.04	0.06	0.18	0.04	
Lithology	C2	0.12	0.08	0.043	0.05	0.07	0.36	0.08	4.54
DD	C3	0.2	0.24	0.13	0.083	0.1	0.75	0.13	5.79
Slope	C4	0.28	0.4	0.39	0.25	0.17	1.5	0.25	5.94
Soil	C5	0.36	0.56	0.65	0.5	0.5	2.82	0.50	5.64
Total								26.464	26.464/5 = 5.293

Source: Authors (Modified from Saaty & Vargas, 1991).

Table 5: Random Indices for matrices of various sizes

N	2	3	4	5	6	7	8	9	10
RI	0.00	0.52	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Source: Saaty & Vargas (1991).

Consistency Ratio, $CR = \frac{\text{CI}}{\text{RI}}$ equation (1)

Where;

$\text{CI} = \frac{\text{max}-\text{n}}{\text{n}-1}$……….. equation (2)

RI = Random consistency index (The random indices for matrices of various sizes are shown in Table 5.), n = Number of criteria, and max = priority vector multiplied by each column total (see Table 4).

n (no. of criteria) = 5, max = 5.293, RI = 1.12 (from Table 5)

From (2) $\quad \text{CI} = \frac{5.293 - 5}{5 - 1} = 0.07325$

From (1) $\quad$ Consistency Ratio, $CR = \frac{\text{CI}}{\text{RI}} = \frac{0.07325}{1.12} = 0.07$

An analysis for inconsistencies is performed and the value of CR= 0.07 falls little below the threshold value of 0.1 and it indicates a high level of consistency. Therefore, the weights can be accepted. To determine the vulnerability to gully erosion in the area the combination of all the causative factors was done as follows; all the rating classes was multiplied by their weights calculated using AHP method. This weight is a relative percentage, and the sum of the percentage influence weights for all the raster maps will be equal to 100. Ranks were also assigned to all classes considered based on their relevance to gully erosion as shown in Table 6.

Sensitivity analysis was done based on AHP method, weights were calculated as 50.0%, 26.2%, 13.5%, 6.8%, 3.5% respectively for Land Use/Land Cover (LULC), lithology, soils, slope and drainage density of the catchment and consistency ratio (CR) is found as 0.07. This indicated a reasonable level of consistency in the pairwise comparison of the factors. Raster layer in grid format of each of the five (5) selected criteria was multiplied by their given weight(s) and summed together using arithmetic weighted sum overlay tool in ArcGIS software to generate the final gully erosion vulnerability levels in the area (refer to figure 11).

Field observation through interviews/interaction with residence living close to the gullies and the purposive administration of 100 copies of questionnaire for both main street, households and business area within the gully points, was also done to acquire data on causes of the problem, impact of gully erosion, associated difficulties and control measures for gully erosion.

Table 6: Ranking of Influencing Factors and their Sub-Classes

Gully Erosion parameters	Sub-class parameters	Ranking
Land use/landcover	Vegetation	4
	Water bodies	2
	Settlement	1
	Bare ground	3
Lithology	Alluvium	1
	Benin formation	3
	Mangrove swamps	2
Slope	<10%	1
	10.1 – 20%	2
	20.1 – 30%	3
	30.1 – 40%	4
	>40%	5
Soil	Coastal plain sands	2
	Deltaic basins and tidal	3
	Nearly level plains	1
	Recent alluvium	4
Drainage density	< 3km/sq.km	1
	– 6.0km/sq.km	2
	>6km/sq.km	3

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Results and Discussion

The result is presented based on the identified gully sites and the factors influencing gully formation in the study area. These are slope, drainage density, soil and landuse/landcover. It also discussed the people's perception on the challenges of gully formation.

Spatial Distribution of Gully Erosion Sites

Figure 2; shows four existing gullies in the area represented in yellow lines as obtained from direct field measurements. Two of gully erosion lines fall under Aduwawa and Ikpoba hill area in Benin-City, while the other two gully erosion lines fall under Ugbowo and Uselu road area of Benin-City respectively.

Slope

The slope map was derived from DEM and the slopes were grouped in five classes: 0° - 10°, 10° -20°, 20° -30°, 30° -40°, >40° as show in Figure 3 and 4 below, which explains the degree of slope as well as the level of vulnerability associated with each slope class.

Drainage Density

The values obtained from the drainage density map which was prepared after calculating the density of each cell divided by the total area of the basin range from 0 to 168 m-I as discussed in (Saini et al., 2015; Vaidyanathan et al., 2002), and these were finally grouped into 3 classes: high, medium and low drainage density as shown in Figure 5 and 6 below.

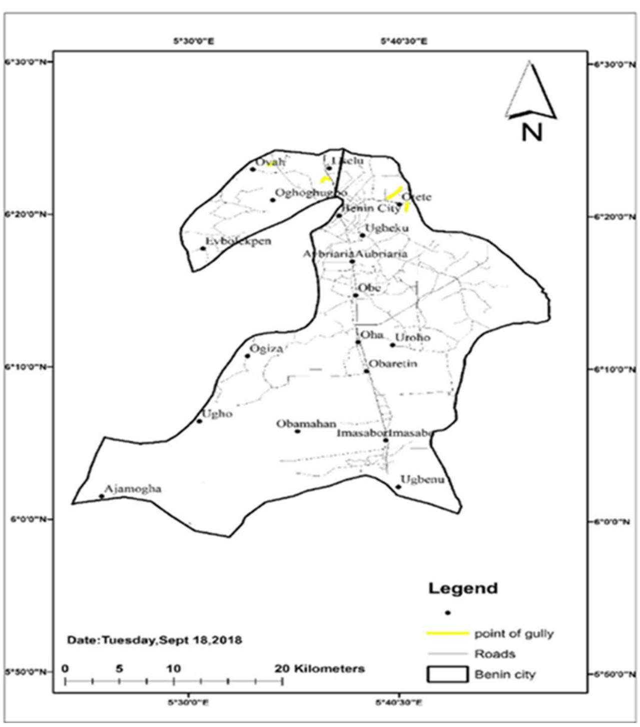

Figure 2: The spatial distribution of gully sites in Benin City

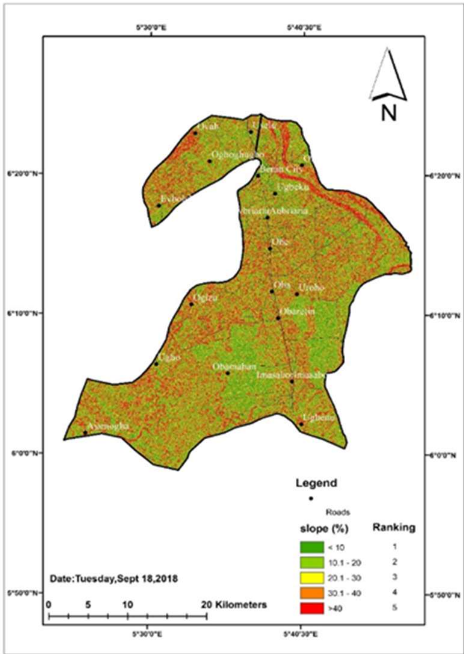

Figure 2: Slope Map

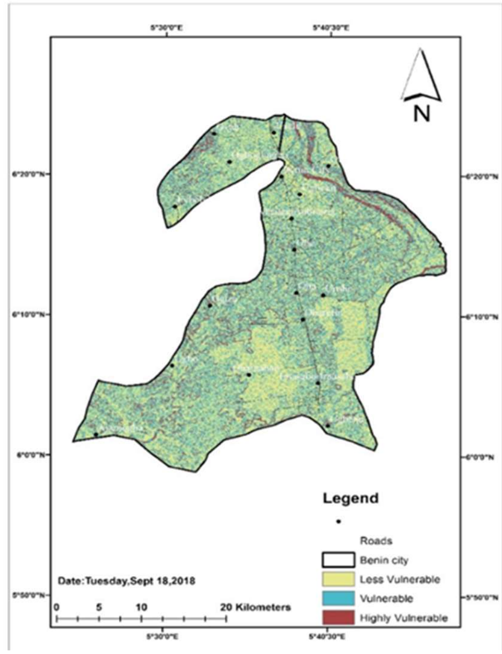

Figure 3: Gully erosion vulnerability map as a result of Slope

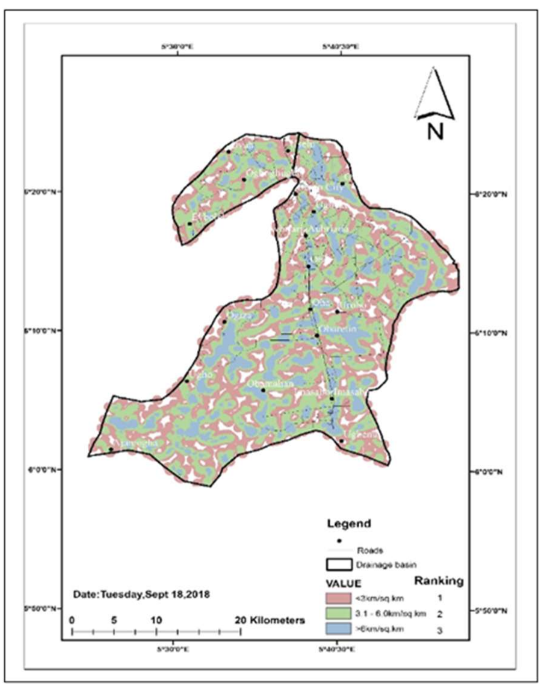

Figure 4: Drainage Density Map

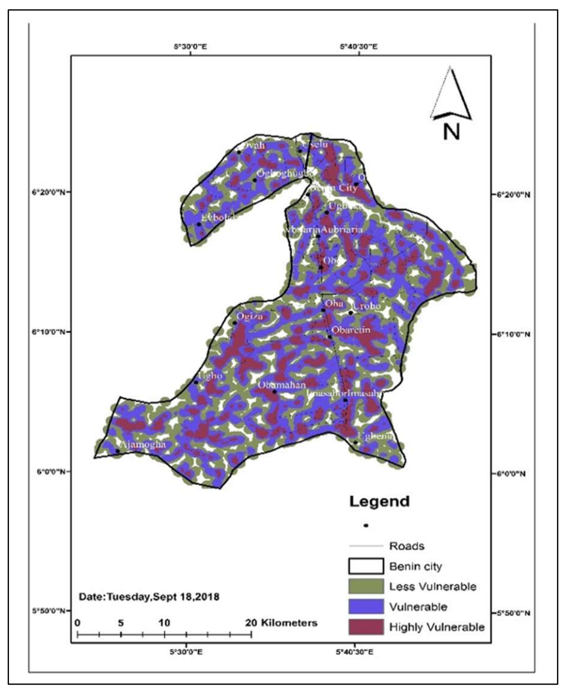

Figure 5: Gully erosion vulnerability map as a result of Drainage Density

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Soil

Soil map as shown in Figure 7 below, was ranked according to the infiltration/retaining characteristics of the soil type. The zone in the study area having soil with low retaining property produced high runoff causing high soil erosion. Thus, higher rank is tagged to the zone with low retaining capacity and vice-versa. (Saini et al., 2015). Four types of soil were obtained namely; coastal plain sands (well drained soils; loamy sand to sandy loam surfaces over sandy clay loam to sandy clay sub-soils), Deltaic basins and tidal (very deep, poorly moderately well drained soils; sandy loam or sandy clay loam surfaces over sand.), nearly level plains (very deep well drained soils; sandy, loamy sand or loamy surfaces over loamy, sand clay) recent alluvium (deep well drained and deep poorly drained soils; sandy clay loam surfaces over sand, sandy clay and sometimes gravelly). Figure 8 below, shows the Gully erosion vulnerability map resulting from the soil type depicted in Figure 7.

Land use/landcover

Different land use types in terms of area, size, features and pattern influences the gully erosion risk. The area with no vegetation covers obviously has the higher risk of soil erosion than areas with vegetation cover. The classes obtained from the classification are; vegetation, water bodies, settlement and bare ground as shown in Figure 9 below, and Gully erosion vulnerability map as a result of Land use/land cover is shown in Figure 10 below.

The combine effect of the five indices together generated a composite map of vulnerability to gully erosion in Benin-City as shown in Figure 1. Results showed that 44.4 per cent of the land mass is highly vulnerable, 52.1 per cent vulnerable and 3.4 per cent less vulnerable to gully erosion respectively, as summarized in Table 7. The gully erosion vulnerability map shown in Figure 11 is strongly related with slope and soil, which was expected due to highest weighting being given to them. The areas that are highly vulnerable are mostly located north east (Aduwawa, Ikpoba hills), and southern parts of the drainage basin of Benin City stream. Highly vulnerable areas are found at the recent alluvium and coastal plain sands. Some isolated zones of highly vulnerable areas are in the southern part of the drainage basin, which are probably attributed to drainage and lineament. The results of the vulnerability map show that barren lands generally found on steep slopes are especially highly vulnerable to gully erosion which is in agreement with (Saini et al., 2015).

Table 7: Vulnerable areas in m^2 (%)

Value	Areas (sqm)	%
Highly Vulnerable	416714800	44.4
Vulnerable	488688100	52.1
Less Vulnerable	32366500	3.4
Total	937769400	100

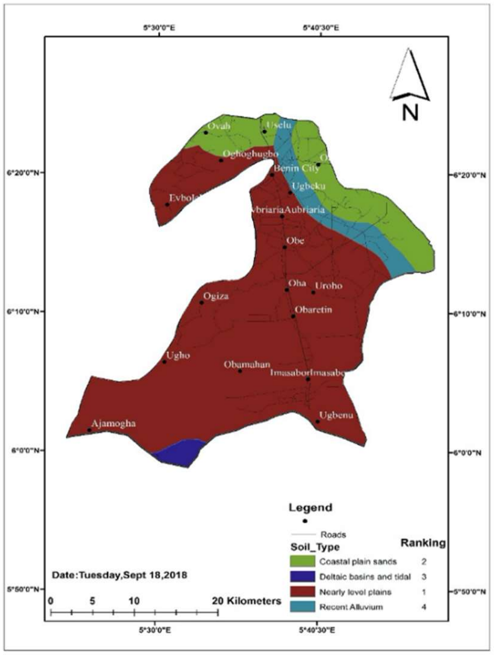

Figure 7: Soil Type Map

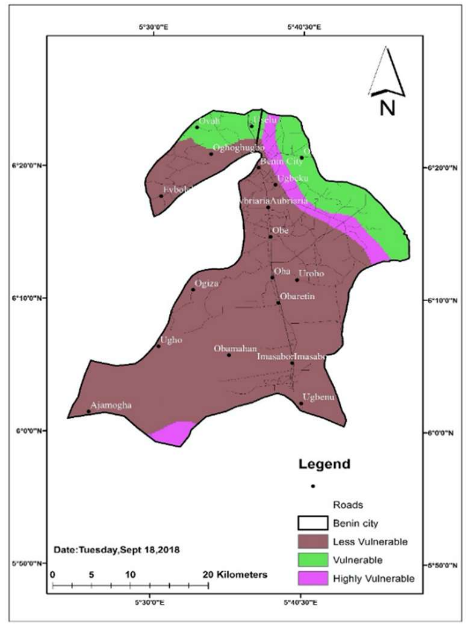

Figure 8: Gully erosion vulnerability map as a result of Soil Type

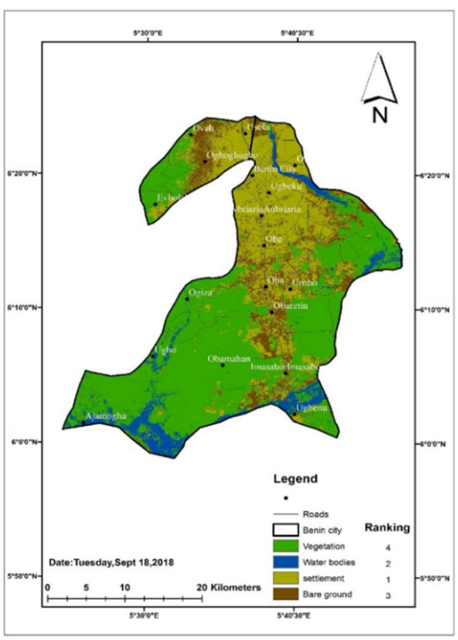

Figure 9: Land use/land cover Map

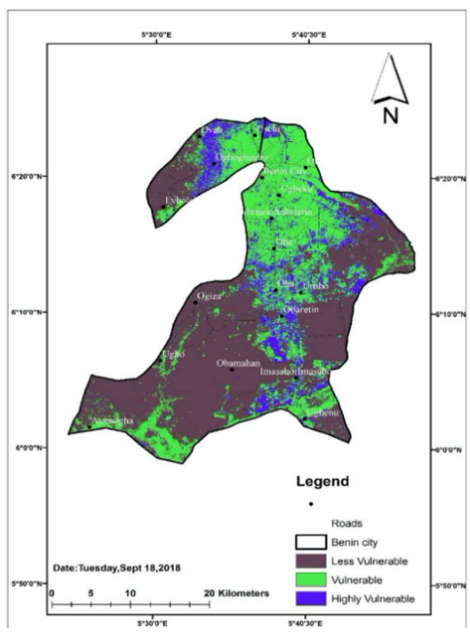

Figure 10: Gully erosion vulnerability map as a result of Land use/land cover

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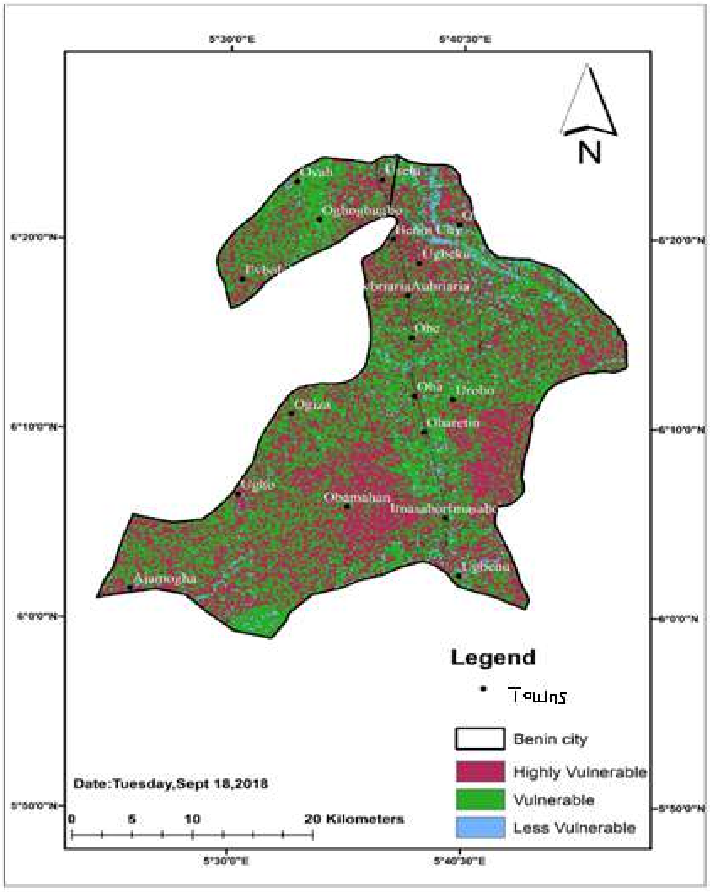

Figure 11: Gully erosion vulnerability levels in Benin City,

Edo-State, Nigeria

Perception of People to Gully Erosion in Benin City

The perception of people was sampled specifically with regards to the causes/contributing factors and control measures of gully erosion in the study area was through field questionnaire administration and analyzed. The educational status of respondents in the study area is shown in Figure 12. At least 56.25% of the respondents obtained primary education, 12.5% obtained secondary school education while 31.25% attended tertiary institution. This indicate that most of the people are knowledgeable enough to provide reasonable answers to issues related to gully erosion in the study area. The investigation further shows that 53.125% of the respondents have stayed 1-5 years in the study area, 28.125% of the respondents have stayed 6-10 years, 6.25% of the respondents have stayed 11-15 years and 12.5% of the respondents have stayed 20 years and above (Figure 13). This imply that over 35% are matured enough to give their perception of gully erosion control measures.

Findings on the major contributing factor that leads to the gully erosion formation showed that lack of drainage system account for 56.25%, improper land use practice account for 25% and bad road construction (18.75%), which are all factors taken into consideration in modelling vulnerability to gully erosion in this work and can be seen by the contribution of the drainage density to gully erosion vulnerability as shown in Figure 6 and 11 above. About 50% (Figure 15) of the respondents are of the view that adequate drainage system would go a long way to mitigate the gully erosion problem currently been faced. The respondent's perception attributes the major cause of gully erosion in the area to lack of drainage, with existing drainage systems inadequate to properly channel excess rain-water, the water then washes through the soil and landscape thereby creating its own channels which later forms gullies, this can also be seen by the contribution of LULC and drainage density to gully erosion vulnerability as shown in Figure 6, 10 and 11 above.

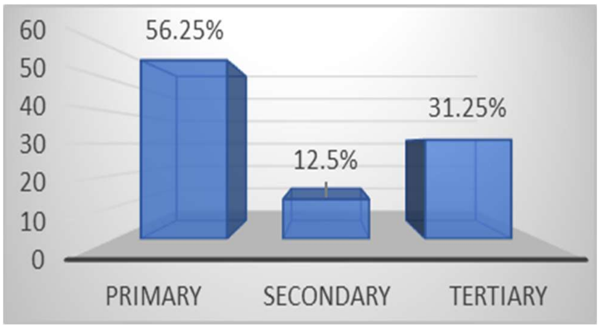

Figure 12: Educational status of respondents in Benin City, Nigeria

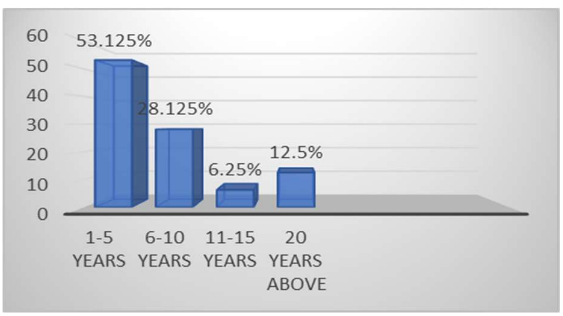

Figure 13: Duration of stay of respondents in the study area

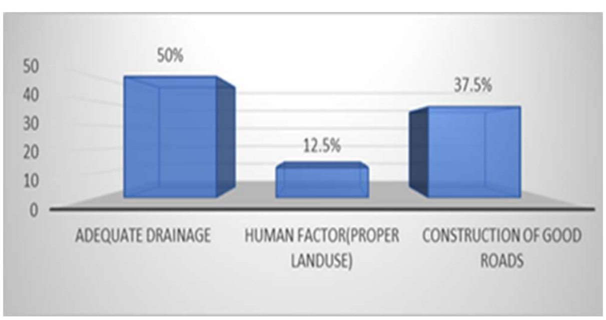

Figure 14: Factors that the development of gully erosion

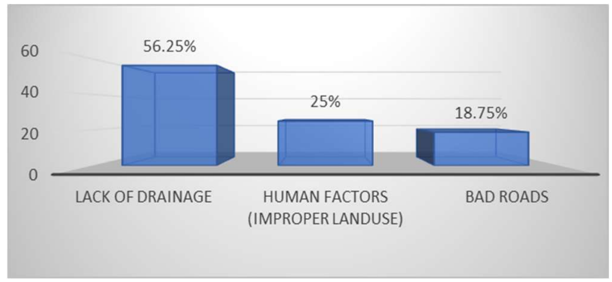

Figure 15: Control measures of gully erosion by the respondents

Conclusions and Recommendation

Benin City is faced with serious environmental threats, particularly gully erosion, this has resulted to inaccessible roads in some parts within the study area, which have made some residence living close the gully to abandon their building. Based on the analysis and results obtained in this study; the area vulnerable to gully erosion will increase over time. Urgent and proper steps is therefore needed to control and prevent the widening progression of existing gullies and formation of new gullies in the area; such steps as timely control of sheet and rill erosion should be taken before it develops into gully erosion to prevent further environment degradation of the environment, we recommend that planning and urban development in Benin-City be based on informed decision making, we also recommend the construction of proper and efficient drainage systems and suggest that collaborative and integrated land-use practices be upheld in the city of Benin. This study has shown how critical gully erosion problem is in Benin City and has provided the government and non-governmental organisations, relevant information required to preserve the environment and reduce/eliminate the level of vulnerability to gully erosion in Benin-city.

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