Estimation of Annual Soil Loss over Queen Ede Gully Site in Ogbeson Community, Benin City, Nigeria

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Supported by tetfund

Received: March 20, 2022 **Accepted:** June 18, 2022

Abstract: The annual soil loss from gully site in Ogbeson area of Benin City was assessed using the Revised Universal Soil Loss Equation (RUSLE) coupled to an ArcMap 10.4. The study utilised monthly rainfall data for 19 years (2000-2018) from the Nigerian Meteorological Agency, Digital elevation model DEM and soil samples. The soil samples were collected along the chainage points of the gully to a depth of 0.3m using soil auger at 150-metre (m) distance apart. The dominant soils are sandy soils mostly sandy-loam and loamy-sand. The soil of the area is friable and highly erodible due to low soil organic matter content. The erodibility factor (K) is nearly uniform over the area at 0.002 ton $\text{ha}^{-1}\text{MJ}^{-1}\text{mm}^{-1}$. The mean annual soil loss rate was 0.71 tons/ha/year which is a lesser volume when compared to the rate of 0.541 $\text{tonha}^{-1}\text{yr}^{-1}$ estimated for the study area in 2012. The low rate might be due to the current intervention measures to stabilize the gully under the Nigeria Erosion and Watershed Management Project (NEWMAP). However, the study still reveals an increasing rate of soil loss especially when compared with values from previous studies in other agro-climatic zones. The growing rate might be due to loss of vegetation associated with rising urbanization in the area. Therefore, further and consistent intervention and conservation measures are required to arrest the gully's expansion. Such measures include reforestation, conservation of vegetation, creation of retention trenches and other engineering structures including regular maintenance of existing structures.

Keywords: Gully erosion, RUSLE, Soil loss, soil texture, soil erodibility

Introduction

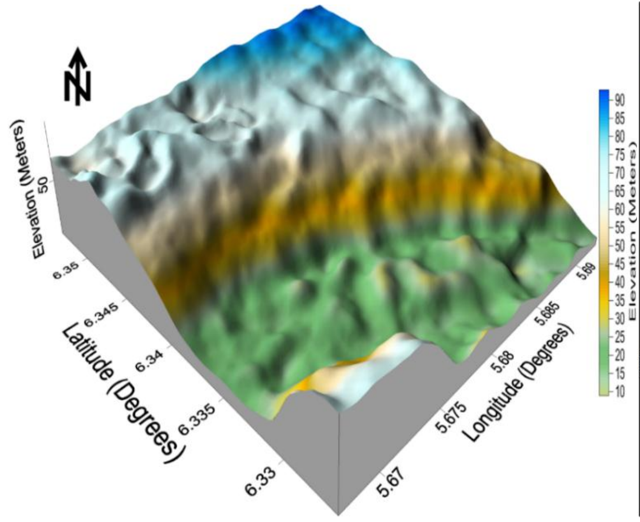
Soil erosion is a severe land degradation with both on-site and off-site effects. The detachment and movement of the soil is the on-site effect while sedimentation constitute the off-site effect (Morgan, 2005). A significant amount of soil is lost annually from soil erosion all over the world (Sekercioglu, 2010). Thus, it is a major environmental hazard as it reduces soil nutrient and even causes pollution and climate change (Morgan, 2005; Mondal et al., 2018). It washes away the top soil thereby reducing soil depth and the associated organic matter (Wardle *et al*., 2004; Mondal *et al.*, 2018). The loss of soil nutrients then leads to low agricultural yield due to poor soil fertility (Bakker *et al.*, 2007) or even total destruction of the given land in the case of gully erosion (Morgan, 2005; Kirkby and Bracken, 2009; Mondal *et al.*, 2018). The poor agricultural yield of the Sub-Saharan African region has been attributed to the problem of soil degradation by erosion(Lal, 1990). The accelerated soil loss in the tropics has been linked to the extensive deforestation going on in the area and other unsuitable agricultural practices (Lal, 1990, 2003; Walling, 2013; Wainwright and Mulligan, 2013). The increasing rate of urbanization and the associated deforestation has exacerbated the problem of soil erosion. For instance, in Nigeria it affects nearly 80% of the land and the southern part of the country is a hotspot for most of the eccentric gullies (Team and Centre (Canada), 1991). The dimensions of some have continued to increase unabated in most locations often cutting off communities thereby making it difficult for some to have access to market (Egede and Donatus, 2013). The gravity of the problem of soil erosion notwithstanding, most of the studies have been reactive; focusing on the review, causes and effects of gully erosion (Ofomata, 1980; Odemerho and Sada, 1984; Ofomata, 1987; Jeje, 2005; Ajaero and Mozie, 2010; Abdulfatai et al., 2014). However, only a few have attempted to estimate amount of soil loss (Tekwa and Usman, 2006; Fagbohun et al., 2016). Yet, the only study that quantified the soil loss in the study area is Ehiorobo and Izinyon (2013) who estimated about 0.541 $\text{tonha}^{-1}\text{yr}^{-1}$soil loss. Other studies were on the causes and review of soil erosion in the region (Audu and Ehiorobo, 2012; Omon and Ojeifo, 2012; Ehiorobo and Ogirigbo, 2013; Okoli, 2014; Ikhile, 2015). Nonetheless, none has recently been done especially following the intervention by the World Bank assisted project (NEWMAP) in the area in 2016/2017. Such study is necessary not only to estimate the amount of soil loss but equally to evaluate the performance of the intervention measures in stabilising the gullies.

Hence, the study employed the Revised Universal Soil Loss Equation (RUSLE) to assess the soil loss in the area. The RUSLE is adjudged to be one of the best models for assessing soil erosion in diverse climate zones (Demirci and Karaburun, 2012; Prasannakumar *et al.*, 2012; Pan and Wen, 2014; Chadli, 2016a; Mondal *et al*., 2018). It is widely used across diverse climate zones (Balasubramani et al., 2015; Samanta et al., 2016; Chadli, 2016b; Bekele and Gemi, 2020; Khademalrasoul and Amerikhah, 2020; Bagwan and Gavali, 2020; Tadesse and Tefera, 2020; Chatterjee, 2020). Bekele and Gemi (2020) find that low erosion severity dominates the Dijo watershed of Ethiopia. Khademalrasoul and Amerikhah (2020) find that erosion is lowest at locations with high NDVI at border areas of Khuzestan and Chaharmahal Province of Iran. The study estimated the annual soil loss of the Ogbeson area of Benin city and offered recommendations on the best management approaches to curtail further soil loss in the area.

Materials and methods

Study Area

The study focused on the Queen Ede gully erosion site that traverses Ogbeson town in Ikpoba-Okha L.G.A of Edo State Nigeria. The area is tropical rainforest with high mean annual rainfall of about 2200mm (NIMET, 2018). It has dense forests with diverse tree species. However, it is undergoing massive deforestation due to urban expansion, mining and other industrial activities. Hence, most of the original rainforests are giving way to secondary forest. The area is underlain by sedimentary formations marked by reddish earth comprising ferrogenised and laterised clayey sand (Reyment, 1965).



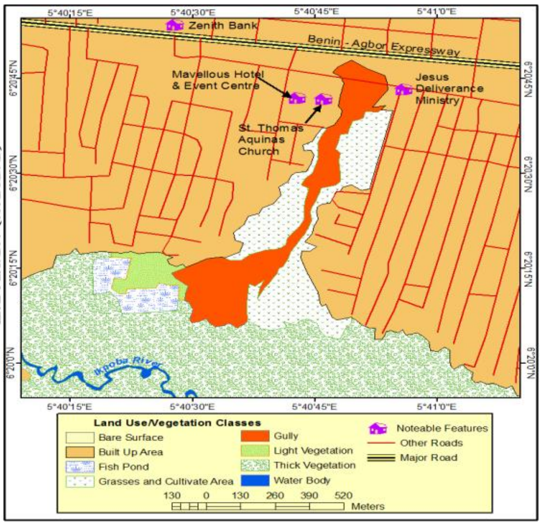


Fig. 1. 3D Imagery of configuration of the study area. Fig. 2. The study area and the Gully Site

The monthly data of the area was collected from the Nigerian Meteorological Agency (NIMET) from 2000 – 2018. The data was used to compute the erosivity (R) value for the area. Soil samples were also collected along the chainage points of the gully site to a depth of 0.3m at an interval of 150m. They were collected with soil auger. The samples were put in cellophane bags and taken to the Geotehnical Laboratory of the Civil Engineering Department of University of Benin for soil analysis. A total of 15 samples were taken, 3 at each chainage point. The geographic locations of the chainage points were recorded which were used in generating the geospatial map of the area (Figure 1, Table 1.). The width of the gullies at each chainage point was measured.

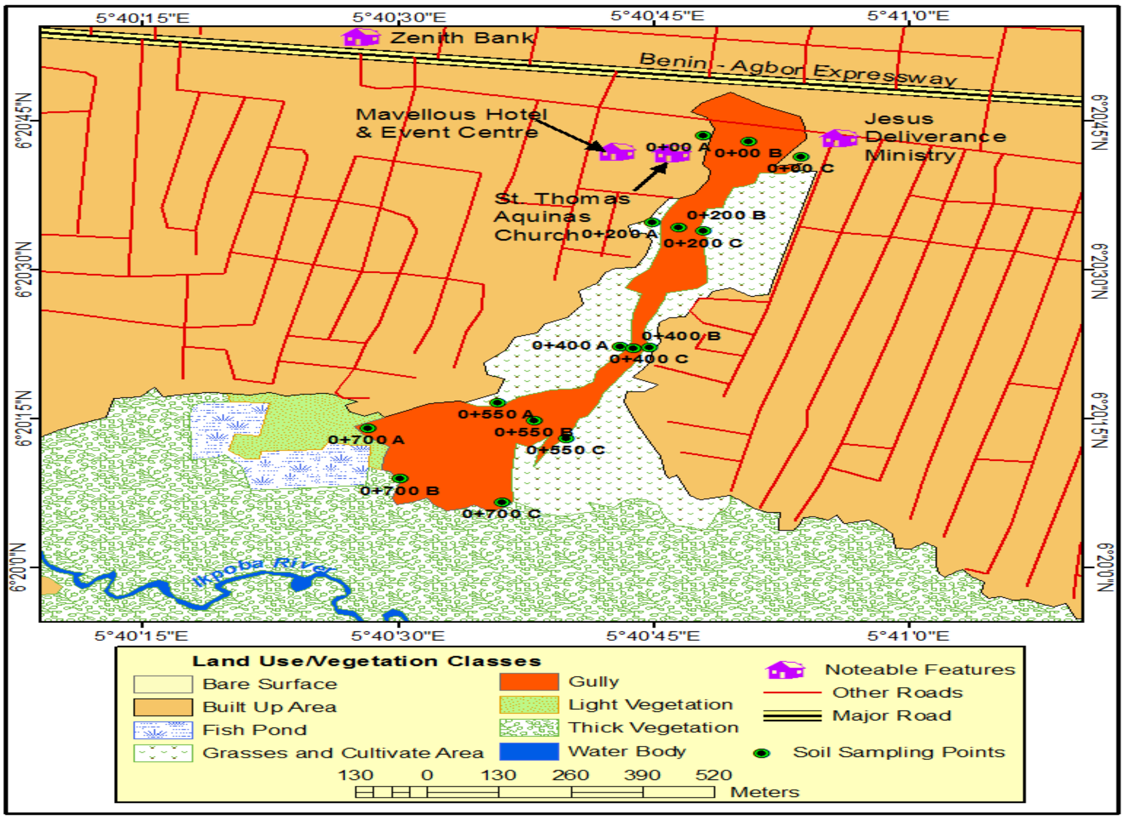


Figure 3. Soil sample collection points

Table 1 Geospatial attributes of Soil Samples sites

CHAINAGE	POINTS	DISTANCE BETWEEN POINTS (m)	NORTHINGS	EASTINGS	LATITUDE	LONGITUDE
	A		06°20'30.564"	05°40'45.294"	6.34182	5.67925
		33.1				
0+000	B		06°20'30.198"	05°40'46.516"	6.34172	5.67959
		33.1				
	C		06°20'30.09"	05°40'47.742"	6.34169	5.67993
	A		06°20'24.21"	05°40'43.716"	6.34006	5.67881
		10.3				
0+200	B		06°20'24.144"	05°40'43.872"	6.34004	5.67885
		10.3				
	C		06°20'24.114"	05°40'44.382"	6.34003	5.679
	A		06°20'16.603"	05°40'41.238"	6.33794	5.67812
		14.5				
0+400	B		06°20'16.428"	05°40'41.532"	6.3379	5.67812
		14.5				
	C		06°20'16.278"	05°40'41.988"	6.33786	5.67833
	A		06°20'14.322"	05°40'38.82"	6.33731	5.67745
		25				
0+550	B		06°20'13.686"	05°40'38.328"	6.33714	5.67731
		25				
	C		06°20'13.038"	05°40'37.698"	6.33696	5.67714
	A		06°20'12.642"	05°40'34.056"	6.33684	5.67613
		12				
0+700	B		06°20'12.468"	05°40'34.44"	6.3368	5.67623
		12				
	C		06°20'12.246"	05°40'34.806"	6.33674	5.67634

Source: Fieldwork 2018

Analysis

The RUSLE was used to estimate the soil loss in the area (Renard et al., 1991; Renard, 1997) which is based on equation 1.

$$\boldsymbol{A = R \cdot K \cdot LS \cdot C \cdot P} - - - - - - - - - - - - - \quad 1$$

Where A is the computed soil loss, K is the soil erodibility factor, R is the erosivity factor, L is the slope length factor, S is the Slope steepness factor, C is the cover management factor and P is the support practice factor.

2.2.1. Soil sample analysis

The laboratory tests were based on the general guidelines according to the British Standard Specifications B.S 1377:1990;'Method of Test for Soils for Civil Engineering Purposes'. The following components were analysed; the particle size, soil permeability and organic matter content (OM). The particle size test was done to determine the soil texture. The procedure involved the wet/dry sieve test and the hydrometer test. For lack of necessary equipment, soil permeability was determined indirectly using the Allen Hazen equation (Eq. 2)

$$P_o = \left(d_{10}{}^2\right) \quad - \quad 2$$

Where P_o is the coefficient of permeability of the soil (m/s), C is a constant (0.01), $d_{10}{}^2$ is the particle size for which 10% of the material is finer. The materials and equipment used in the determination of the soil permeability include soil samples, weighing Scale, British Standard (BS) Sieves No. 8, No. 10, No. 16, No. 30, No. 40, No. 50, No. 70, No. 100 and No. 200 (of sizes 2.36mm, 2.00mm, 1.18mm, 0.60mm, 0.425mm, 0.30mm, 0.212mm, 0.015mm and 0.075mm respectively), Sample Containers of Known Weights, and Pan. The soil organic matter content was determined using measuring equipment, potassium Dichromate, concentrated tetraoxosulphate (vi) acid, Ammonium Ferrous Sulphate, Diphenylamine indicator, Distilled water, Deionised water, Tap water, Conical flask, Beaker, Mortar and Pestle and Ortho-Phosphoric acid.

Determination of Soil Erodibility Factor (K)

Soil Erodibility factor K was then estimated for each soil sample using the modified Wischmeier and Smith (1978) equation. They developed a monograph which relates K to soil properties based on equation 3.

$$\boldsymbol{K} = \frac{2.1 \text{ x } 10^{-4}(12 - \text{OM})\text{M}^{1.14} + 3.25(s-2) + 2.5(\text{p}-3)}{100} - 3$$

Where K is soil erodibility factor which is multiplied by 0.137 when converting to metres, M is the portion of silt and very fine sand given as the product of the primary particle size fraction. M is the percentage of organic matter, OM is the percentage of organic matter, S is soil structure and P is soil permeability or soil infiltration index (Wischmeier and Smith, 1978). The structure and permeability classes and groups of classes were determined from the Soil Survey Manual (USDA 1951) Fig. 4, Tables 2 and 3 (USDA 1951).

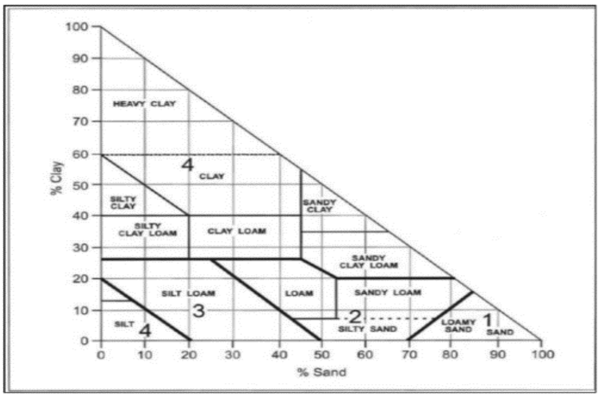


Figure 4 Percentage Clay Vs Percentage Sand Textural Triangle. (USDA). (1951). ***National soil Handbook)***

Table 2: Categories of Soil Structure Index

STRUCTURE CATEGORY	SOIL STRUCTURE	PARTICLE SIZE (mm)
1	Very Fine Particles	<1.0
2	Fine Particles	1.0~2.0
3	Medium or Coarse Particles	2.0~10.0
4	Blocks, Shale or Coarse Particles	>10.0

(Source: United States department of Agriculture (USDA). (1951). *National soil Handbook)*

Table. 3: Categories of Soil Permeability Class/Infiltration Index.

Permeability Class/Infiltration Category, P	Infiltration	Permeability, P_o (Infiltration Rate) mm/hr.
1	Very Fast	>125.00
2	Fast	62.50~125.00
3	Medium	20.00~62.50
4	Medium to Slow	5.00~20.00
5	Slow	1.25~5.00
6	Very Slow	<1.25

(Source: adapted from USDA 1951

Determination of Rainfall Intensity and Erosivity Index (EI_{30}):

The erosivity index was derived using Arnoldus model in equation 4 (Arnoldus, 1980), as data on rainfall intensity is unavailable in the area. The equation is given as follows;

$$\text{RI} = \sum_{i=1}^{12} \frac{MR^2}{AR} - - - - - - \quad 4$$

Where MR is monthly rainfall and AR is the annual rainfall. RI is the rainfall intensity which is substituted in equation 5 to estimate the EI_{30}.

$$E1_{30} = 0.0302 \text{ x } RI^{1.9} - - - - - - - - \quad 5$$

Generation of spatial maps

Landsat imagery of January 2017 was downloaded from Google earth and exported to ArcMap 10.3 environment and georeferenced using Latlon geographic coordinate system. This was followed by shapefile creation. Dem was also downloaded from the United States Geologic Survey website (www.earthexplorer.usgs.gov). It has a spatial resolution of 30x30m. Raster clip was used to clip off the area of interest. The image was then classified to obtain land use land cover classes. ASTER DEM data with 30 x30m resolution was acquired from the USGS website. From the DEM, several parameters were derived such as relief, contour, slope and sloe length among others. They were extracted using the 'Spatial Analyst Tool' in ArcMap 10.3.

NDVI Extraction

A Normalised Difference Vegetation Index (NDVI) was extracted from the Landsat images in ERDAS imagine 9.2. Also, the evaluated soil texture values were exported to ArcMap environment and interpolated to produce a smooth surface using the Inverse Distance Weighted (IDW) tool. The generated smooth surface was reclassified into 9 classes using the equal interval classification. The slope length was extracted from the DEM which is a combination of hillslope length and gradient.

Determination of Topographic Factor, LS Values

The effect of topography on soil erosion is determined by the LS factor in RUSLE. It combines the effects of slope-length factor, L, and slope-gradient factor, S. To calculate the LS factor; Slope Length, $\boldsymbol{\ell}$, Slope Angle, $\boldsymbol{\theta}$ and Percentage Slope, **s** were considered. To estimate them, the highest point and the lowest point of the slope were identified and chosen from the Relief Map. The highest point which is close to the gully head was considered as **A** and the lowest point close to the gully tail as **B**. The difference in the elevation which is the difference between the two points (**A** and **B**) was considered as **|AB|**. The point **C** was taken as the horizontal distance of the lowest point of the slope from the highest point of the slope (**BC**). The horizontal distance of the lowest point from the highest point was then given as **|BC|**. The Slope Length, $\boldsymbol{\ell}$ was then **|AC|** and the Slope Angle, $\boldsymbol{\theta}$ $\mathbf{A\hat{C}B}$. Where **|AB|** was the Rise and **|BC|** the Run as shown in Figure 5.

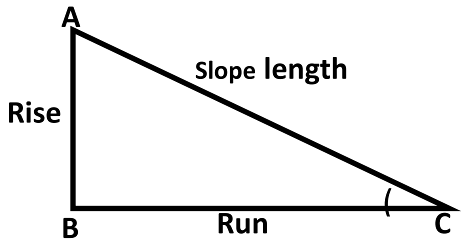


Fig 5. A hypothetical representation of the slope of the study area.

Hence, Slope Length, $\ell = |AC| = \sqrt{[(|AB|)^2 + (|BC|)^2]}$, --6

The Slope Angle, $\boldsymbol{\theta} = A\hat{C}B = \tan^{-1}\left(\frac{RISE}{RUN}\right) = tan^{-1}\left(\frac{|AB|}{|BC|}\right) - - - - - - - - - - - - - - - - \quad 7$

The Percent Slope, $\mathbf{s} = \left(\frac{\text{RISE}}{\text{RUN}} \times 100\right)\% - - - - - - \quad 8$

The slope length (L) factor for the RUSLE was then computed after McCool *et al*., (1989) equation (Eq.9)

$$Slope\ Length, L\ Factor = \left(\frac{\ell}{22.13}\right)^m - \quad 9$$

Where $\boldsymbol{l}$ is Slope Length, in metres (m), m is 0.5 if the percent slope is 5 and more; 0.4 if the percent slope is between 3 and 5; 0.3 if the percent slope is between 1 and 3, and 0.2 if the percent slope is less than 1. LS is calculated by multiplication of L and S.

$\boldsymbol{m}$ is given as

$$\text{m} = \frac{\beta}{\beta+1} \text{------} \quad 10$$

and

$$\beta = \left[\frac{\left(\frac{\sin\theta}{0.0896}\right)}{3(\sin\theta)^{0.8} + 0.56}\right] \quad - - - \quad 11$$

Now,

$Slope\ Steepness, S\ Factor = 10.8 \sin\theta + 0.03,$ if $s < 9$

$Slope\ Steepness, S\ Factor = 16.8 \sin\theta - 0.5, \text{if } s \geq 9$

The management cover factor can be estimated from the NDVI according to De Jong, (1994) (Eq.12).

$$\text{C} = 0.431 - 0.805(\text{NDVI}) \quad 19$$

Where

$$\boldsymbol{NDVI} = \left(\frac{\text{RASTERVALUE}}{1000}\right) - - - \qquad 20$$

The support practice factor (P) value was derived using the relationship between the land cover and support practices factor shown in Table 4.

Table 4. Relationship Between Land Cover type and Support Practice Factor, *P*.

Land	P-Factor
Agricultural Land	0.4
Built-up land	1
Tree clad area	0.1
Waste land	1
Water bodies	0.5

Source: Devatha *et al.* (2015)

Results

The soil particle test shows that the particles sizes range from 0.002 - 0.1 (Table 5, 6). It can be seen that the soil samples have more amount of fine particles than coarse particles, being that more weight is recorded from 2.0mm sieve and below. Sample QE 0+200 A is observed to have the highest amount of very fine sand particles, as it has more particle weight in the range of 0.002- 0.1mm. In Table 6, the structural class, for all sample points is seen to be 1.00. This maybe as a result of the textural properties of the soil, since more of the particles are less than 1mm in diameter.

Table 5: Weights of dry soil samples retained on British Standard (BS) sieves.

SIEVE SIZE (mm)	WEIGHT OF DRY SOIL SAMPLES RETAINED ON SIEVES (g) SOIL SAMPLES														
	0+00 A	0+00 B	0+00 C	0+200 A	0+200 B	0+200 C	0+400 A	0+400 B	0+400 C	0+550 A	0+550 B	0+550 C	0+700 A	0+700 B	0+700 C
2.360	4.11	1.75	2.51	0.00	1.30	1.03	2.33	3.08	5.52	0.67	0.70	6.00	1.27	0.78	0.00
2.000	0.84	0.62	1.07	0.16	0.30	0.35	0.78	1.38	1.30	0.57	0.28	1.78	0.55	0.31	0.07
1.180	5.99	4.41	7.13	2.54	3.03	3.60	5.57	10.35	4.95	3.34	2.09	10.37	4.55	3.14	1.12
0.600	28.69	22.17	24.33	11.84	20.90	23.14	26.33	38.47	16.22	15.04	8.63	25.03	25.98	13.48	8.94
0.425	11.10	8.70	10.60	1.84	12.01	10.46	13.19	11.58	8.40	8.11	4.91	10.00	11.21	7.14	8.10
0.300	25.22	32.63	27.53	20.09	36.32	35.43	33.18	22.76	27.04	31.09	32.09	26.77	33.45	28.31	30.67
0.212	9.65	16.14	12.30	13.62	16.91	16.35	11.90	5.00	16.92	22.90	28.07	11.15	15.18	17.36	19.70
0.150	2.80	5.35	4.01	5.95	3.40	4.00	2.86	1.06	5.98	7.50	9.42	2.88	4.21	7.86	7.62
0.075	3.05	3.94	3.46	7.90	1.73	1.53	1.55	0.92	6.01	4.98	6.27	2.37	1.81	5.30	5.23

Table 6: Soil texture and structural class results across the study area

SOIL SAMPLE	%CLAY	%SILT	%SAND	SOIL TEXTURE	STRUCTURE CLASS
0+00 A	0.00	2.21	97.80	Sand	1.00
0+00 B	0.00	1.98	98.02	Sand	1.00
0+00 C	0.00	3.13	96.87	Sand	1.00
0+200 A	12.48	2.73	84.80	Loamy Sand	1.00
0+200 B	0.00	2.08	97.92	Sand	1.00
0+200 C	0.00	2.28	97.72	Sand	1.00
0+400 A	0.00	1.98	98.02	Sand	1.00
0+400 B	0.00	1.98	98.02	Sand	1.00
0+400 C	4.22	1.41	94.37	Sand	1.00
0+550 A	0.00	2.28	97.72	Sand	1.00
0+550 B	0.00	3.28	96.72	Sand	1.00
0+550 C	0.00	2.28	97.72	Sand	1.00
0+700 A	0.00	2.18	97.82	Sand	1.00
0+700 B	0.00	1.98	98.02	Sand	1.00
0+700 C	0.00	1.98	98.02	Sand	1.00

Table 7 shows the d_{10} values, the values of the coefficient of permeability of soil samples in millimetre per hour mm/hr., and their permeability class, using the Hazen Allen method (-Eq 6) in the methodology.

Table 7: D_{10} Values of Soil Samples, permeability class over the study area

SOIL SAMPLES	d_{10} (mm)	HAZEN ALLEN PERMEABILITY(mm/hr) [$= C(d_{10})^2$]	PERMEABILITY CLASS FROM FIG 5.2
0+00 A	0.147	777.924	1
0+00 B	0.074	197.136	1
0+00 C	0.197	1397.124	1
0+200 A	0.122	535.824	1
0+200 B	0.216	1679.616	1
0+200 C	0.228	1871.424	1
0+400 A	0.253	230432.4	1
0+400 B	0.287	2965.284	1
0+400 C	0.084	254.016	1
0+550 A	0.176	1115.136	1
0+550 B	0.122	535.824	1
0+550 C	0.209	1572.516	1
0+700 A	0.262	2471.184	1
0+700 B	0.184	1218.816	1
0+700 C	0.202	1468.944	1

C =0.01

The permeability class for all sample points is 1.00. The results show that the soil samples have very high infiltration rates or permeability. This is in line with the soil Permeability Class/Infiltration standard by United States department of Agriculture (USDA). (1983). In Table 8, the percentage of organic carbon (%OC) and the percentage of organic matter (%OM) in the soil samples are presented.

Table 8: Percentage Organic Carbon and Percentage Organic Matter in Soil Samples

S/N	SOIL SAMPLES DESCRIPTION AND CHAINAGE	DEPTH(M)	% OC	%OM (=%OC × 1.72)
1	QE 0+00 A	0.3	0.58	1.00
2	QE 0+00 B	0.3	0.54	0.93
3	QE 0+00 C	0.3	0.22	0.38
4	QE 0+200 A	0.3	0.86	1.50
5	QE 0+200 B	0.3	0.51	0.88
6	QE 0+200 C	0.3	0.38	0.65
7	QE 0+400 A	0.3	0.06	0.10
8	QE 0+400 B	0.3	0.26	0.45
9	QE 0+400 C	0.3	0.42	0.72
10	QE 0+550 A	0.3	0.26	0.45
11	QE 0+550 B	0.3	0.86	1.50
12	QE 0+550 C	0.3	1.86	3.20
13	QE 0+700 A	0.3	0.48	0.83
14	QE 0+700 B	0.3	0.22	0.38
15	QE 0+700 C	0.3	0.77	1.32

The results for the percentage organic matter content show that the organic matter content in the soil is low, it should increase the erodibility factor. The permeability class for all the samples is 1.00 which implies a high infiltration rate. The result of the organic matter content is low, ranging from 0.10 to 3.20. This shows that the soil is susceptible to erosion as the erodibility factor is high. The erodibility factor is uniformly distributed at 0.002 tonha^{-1}MJ^{-1}mm^{-1}. The erodibility factor distribution is shown in Figure 6.

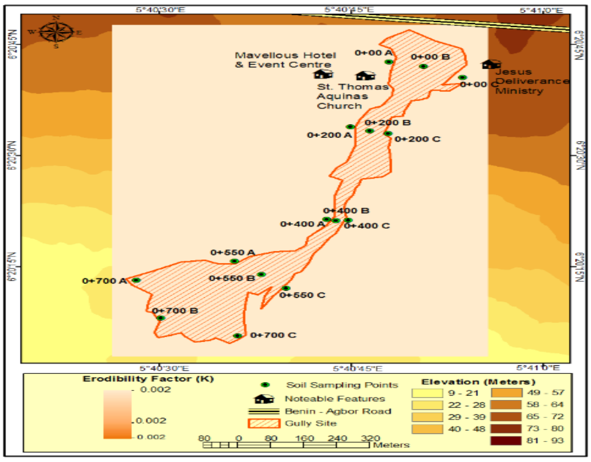


Figure 6. Soil erodibility plot for all sample

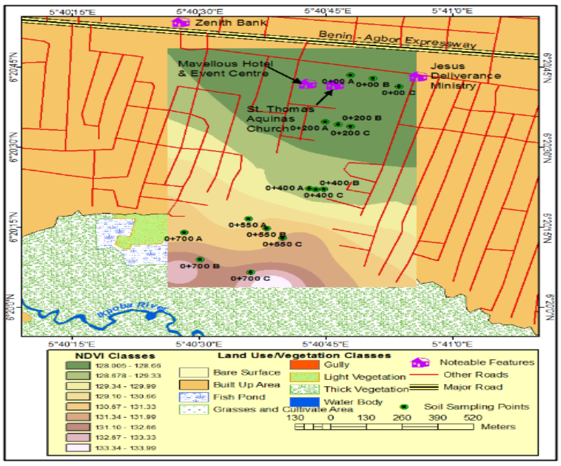


Figure 7. The NDVI classes for the area

However, the erosivity factor is high at about 944.76. The NDVI classes is shown in Figure 7 while the management factor has mean value of 3.25. The support practice factor ranges from 0 to 1. The value of 1 was used in the study to reflect the high level of practices put in place to manage the gullies in the area and is in a highly urbanized area. The result of the soil losses in the area is shown in Table 9. It shows that mean annual soil loss in the area is low (0.71ton/ha/yr). This is due to its low erodibility factor (K), low topographic factor and the ongoing intervention measures in the area under the Nigeria Erosion and Watershed Management Project (NEWMAP). Thus, the area is minimally erodible. The area is dominated by lower slopes (Figure 8). The spatial representation of the annual soil loss in the area is shown in Figure 9.

Table 9: Annual soil loss results over queen Ede gully

SOIL SAMPLES	ERODIBILITY FACTOR (K)	RAINFALL EROSIVITY FACTOR (R), ROOSE (1976)	SLOPE LENGTH & STEEPNESS FACTOR (LS)	COVER MANAGEMENT FACTOR (C)	SUPPORT PRACTICE FACTOR (P)	ANNUAL SOIL LOSS (A)
0+00 A	0.002	944.76	1.15	0.328	1.00	0.71
0+00 B	0.002	944.76	1.15	0.328	1.00	0.71
0+00 C	0.002	944.76	1.15	0.328	1.00	0.71
0+200 A	0.002	944.76	1.15	0.328	1.00	0.71
0+200 B	0.002	944.76	1.15	0.328	1.00	0.71
0+200 C	0.002	944.76	1.15	0.328	1.00	0.71
0+400 A	0.002	944.76	1.15	0.327	1.00	0.71
0+400 B	0.002	944.76	1.15	0.327	1.00	0.71
0+400 C	0.002	944.76	1.15	0.327	1.00	0.71
0+550 A	0.002	944.76	1.15	0.327	1.00	0.71
0+550 B	0.002	944.76	1.15	0.326	1.00	0.71
0+550 C	0.002	944.76	1.15	0.325	1.00	0.71
0+700 A	0.002	944.76	1.15	0.326	1.00	0.71
0+700 B	0.002	944.76	1.15	0.324	1.00	0.70
0+700 C	0.002	944.76	1.15	0.323	1.00	0.71
AVERAGE						**0.71**

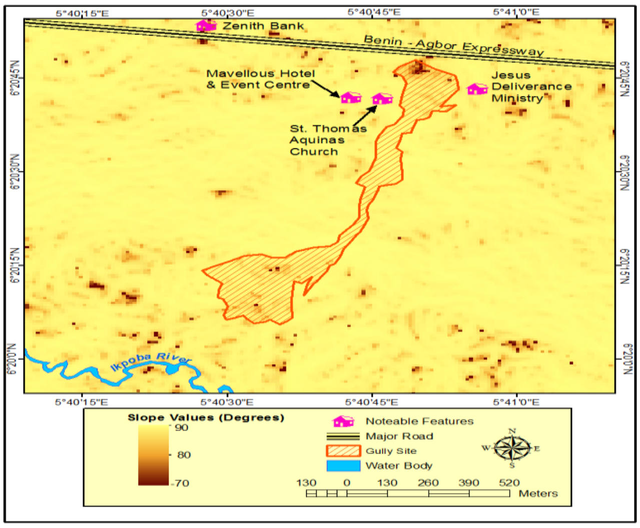


Figure 8. The slope map of the area

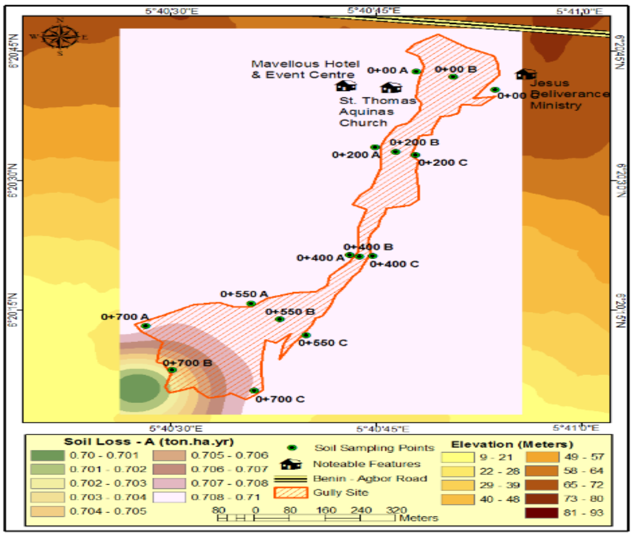


Figure 9. The soil-loss estimation over the area.θ

Discussion

The predominant soil in the area is sandy soil characterized by low silt, low clay and low organic matter. A few locations differ from the rest as they have high clay (QE0+200 A) and high silt content (QE 0+550B). Therefore, the area is characterized by sandy-loam and loamy-sand. The area is very permeable implying that infiltration rate is high. The erodibility factor of 0.002 (Mg h Mj-1 mm-1) indicates the area is minimally erodible. The low erodibility is a reflection of the high porosity of the sandy soils that permits infiltration and high conservation measure put in place to check the gully expansion. The northern part of the study area, however, has higher erodibility factor. Due to its low organic matter, it would have been highly susceptible to erosion but for the intervention measures. Since they lack the compounds that bind soils together, they are susceptible to soil dislodgement by raindrops impact and surface runoff. As Mazllom et al (2016) state that erodibility factor reveals the integrated effect of rainfall and the resistance of soil to particle detachment and transport. However, it has been shown that changes due to human interference accelerates erosion (Bai et al., 2008). Land use change adversely affects soil characteristics such as permeability, soil texture and aggregate stability (Szilassi *et al.*, 2006; Emadi *et al.*, 2009). Changes to these characteristics are critical as they lead to change in the rate of soil erodibility (Lambin and Geist, 2008). The study area is an urbanizing area with intensive farming activities that might explain the very low clay and silt contents in the study area. Such changes by human activities and urbanization compounds the problem of soil erosion as NDVI values and organic matter are low and slopes are favourable (Figure 6). This is the converse of Khademalrasoul and Amerikhah (2020) that high NDVI implies low erosion rates. Additionally, the intervention measures on gully erosion by the Federal government also significantly impacts the erodibility factor of the Queen Ede gully area.

The rainfall-runoff erosivity is high in the area due to the convective nature of tropical rainfall. Its erosivity is 944.76 which indicates sufficient energy to erode materials as it is associated with rainfall intensity (Wischmeier and Smith, 1978; Van Dijk et al., 2002; Hammad *et al.*, 2004). The area has high annual rainfall of about 2200mm. The slope angle of the area is low but with a lengthy slope. The nature of the slope counteracts the erosivity effect as the rate of change in slope or descent is low. Thus, the mean annual soil loss rate is estimated to be 0.71 tonha^{-1}yr^{-1} which is a little higher than the amount of 0.541 tonha^{-1}yr^{-1} obtained by Ehiorobo and Izinyon (2013). The low value might be due to the intervention measures put in place by the NEWMAP programme of the Nigerian government. Nevertheless, the high sand content and the high dispersion ratios inferred that most of the soils are highly detachable. However, with remarkably good properties exhibited by a majority of these soils, particularly the high infiltration rate, it can be concluded that adequate vegetative cover and higher organic matter are the main characteristics the soil should possess in order to completely resist erosion.

Conclusion and Recommendations

The soils taken at a depth of 0.3m from the queen Ede gully are predominantly sandy. They are characterized by low silt, low clay, low organic matter and very high permeability. The value of soil erodibility factor (K) estimated by the RUSLE equation was found to be 0.002 (ton • ha • h• ha $^{-1}$ • MJ^{-1} • mm^{-1}), at all points, which was generally low. The low erodibility shows that the soil in the gully has low susceptibility to erosion by rainfall. Also, the rainfall erosivity factor (R), which was estimated by the Roose (1976) equation was found to be 944.7597 [MJ·mm/(ha·hr)], which is high, and was due to the fact that total annual seasonal rainfall reaches about 1940.60 mm/year in Benin city, with very high intensities. The combination of these factors above, as well as the other factors in the RUSLE, gave a soil loss of 0.71 ton/ha/year, which is generally low. As major structural works have already taken place at the queen Ede gully, other measures that are recommended include improved farming practices such as mulching, cover cropping, contour farming and tie ridging, sand bagging and land refilling, terracing and deep ploughing that reduce the gully erosion processes to the barest minimum. It is also recommended that more trees should be planted at the site to prevent the soil loss and nutrient loss as this will reduce the effect of the rain on the soil. Finally, refuse dump along the river courses which impede the flow of water leading to flooding especially during heavy rainfall must be discouraged.

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