Effects of Time and Land Use Land Cover Change (LULCC) in the Dimension of the Gully Expansion and Soil Particles Loss at Ibeziako Erosion Site in Nsukka Urban, Enugu State, Nigeria

ABSTACT

Almost all parts of the world are threatened by one type of hazards such as soil erosion, flooding, landslide, earthquake, among others. Various types of soil erosion exist which include splash, sheet, rill and gully erosion. Gully erosion has been recognized as an important environmental threat in many parts of the world and remains the world's biggest problem affecting the lives of man, plants and animals. Gully erosion occurs in various parts of Nigeria under geologic, climatic and soil conditions. The purpose of this study is to look at flood and soil erosion in Nsukka Urban and the erosive activities of the floods along its path ways. The study used both primary and secondary data comprising measurements, oral interviews, photographs, and satellite imageries. This study adopted a mixed method approach in data analysis and representation with ArcGIS version 10.4 software as the major analytical tool used, other calculations were either manually performed or were calculate using Microsoft Excel 2007.The results of the satellite imageries analyzed, were rendered in tables and maps. The soil particles removed from the identified gully site in the study area were calculated and projection of further annual soil loss established, pending when the erosion problem will be addressed. The management, control of flood and soil erosion required to reduce and mitigate against the adverse effect of the gullying were also proffered.

Key words: Time, Land Use Land Cover Change, Dimension, Gully Expansion, Soil Particles Removal, Nsukka Urban

1. INTRODUCTION

Earth's environment is threatened by irreversible damages. Almost all parts of the world is threatened by one type of hazard such as soil erosion, flooding, landslide, earthquake, among others [1](Uchegbu, 2002). Erosion as a term is the reduction in size of a thing, the act of eroding or being eroded. Erosion by its nature is one of the geomorphic processes that affect an area [2](Goudie, 1990). Soil erosion is referred to as the systematic removal of soils, including plant nutrients, from the land surface by various agents of denudation [3](Ofomata, 1987). Erosion is the action of exogenic process such as water flow or wind that removes soil and rock from one location of the earth's crust and then transports it to another location where it is deposited [4](Mozie 2010). Soil erosion is caused by water, wind, glacier, waves and gravity induced events. It is an intrinsic natural process which in some many places is increased by poor land use, poor water management practices, poor irrigation practices, over grazing, bush burning, deforestation and improper construction activity especially, drainage channel construction [5](Ogbue, 2015).

Various types of soil erosion exist which include splash, sheet, rill and gully erosion. Splash erosion results from raindrop energy; that is energy of the raindrop as it strikes the soil surface.

They detached soil particles and destroy soil structure [6](Ofomata, 2001). Sheet erosion occurs where runoff is unconcentrated but rather flows as a thin sheet over the entire surface or a good proportion of that surface [6](Ofomata, 2001). Rill erosion is the removal of soil by concentrated water running through little stream lets or head cuts. Gully erosion occurs where runoff is concentrated along definite channels. The gullies lengthen by head ward erosion, also known as head-scarp retreat, and widen through basal sapping, leading to the collapse of materials on gully walls in the form of sliding and slumping[6] (Ofomata, 2001) (Figures 1, 2 and 3).

Gully erosion has been recognized as an important environmental threat in many parts of the world and remains the world's biggest problem affecting the lives of man, plants and animals. About 65% of the soils on earth have displayed some form of degradation as a result of soil erosion, salinity and desertification [7](Okine, 2002). Gully erosion occurs in various parts of Nigeria under geologic, climatic and soil conditions [8](Ofomata, 1987). For the past three decades, gully erosion has been an issue of concern in the southeastern part of Nigeria in particular. The most devastating gully erosion sites in Nigeria are found in southeastern Nigeria, such as Anambra, Imo, Enugu Ebonyi, and Abia States [9](Igbokwe, et al, 2008; [10]Ayadiuno, et al, 2021a; [11]Ayadiuno, et al, 2022a). Gully erosion in Nigeria occurs both in rural and urban areas, gully erosion could become more severe in areas of high population in urban centers with high rainfall intensity generating high runoffs.

There have been many published and unpublished research on gullies in southern Nigeria [12](Ayadiuno, 2021; [13]Ndulue, et al 2021; [14]Ayadiuno et al 2021b; [15]Adedeji, 2008; [16]Egbueri and Ogbonnaya, 2020; [17]Adedeji, 2010; [18]Okengwo et al 2015; [19]Abolade et al, 2013; [20]Okoyeh et al 2014; [21]Aladelokun and Ajayi 2014; [22]Amangabara et al 2016; [23]Ikechukwu, 2015; [24]Obi and Okekeogbu, 2017; [25]Obiadi et al 2011; [26]Nwilo et al 2011; [27]Amah et al 2020; [28]Amagu et al 2018; [29]Amah et al 2008; [30]Amos-Uhegbu and John, 2017; [31]Egboka et al 2019; [32]Oluwatayo and Olatunji, 2015; [33]Ndukwe et al 2013; [34]Nwunonwo, 2013; [35]Egbueri et al 2021; [36]Nwankwoala and Igbokwe, 2020; [37]Ocheli et al 2021 among others), majority of which dwelt on the dangers of the menace of soil erosion to lives and properties. However, Ihinegbu et al [38](2019) chose to differ by looking at the socio-economic benefit of flooding in Alor Uno community in Nsukka with special focus on the Ibeziako gully site. They maintained that the economic activities being created as a result flood deposits were improving the livelihood of residents of the study area, and at same time warned that such economic activities were not sustainable. They therefore sued for possible mitigation choices such as appropriate policy framework, application of suitable technology in flood control and involvement of institutions with vast knowledge in environmental management and sustainable economic development.

Wagari and Tamiru [39](2021) in their paper demonstrated the integration of RUSLE model and GIS techniques on annual soil loss quantification as well as soil erosion protection in Ethiopia. They maintained that the techniques are very powerful and are relevant in the quantification of soil loss and assessment of effective management of soil resources in a large spatial dimension rate. This study therefore looks at time dimension in relation to flood and soil erosion in Nsukka Urban, the anthropic ventures (land cover change) responsible for the increased flood generation over time and the erosive activities of the floods along its path ways, the dangers and losses so far created, with suggested measures to trap, harvest and reduce the devastations so caused.

2. **MATERIALS AND METHODS**

2.1 Study Area

Nsukka urban is located at the centre of Nsukka Local Government Area which lies between latitude 6° 44'N and 6^0 55'N; and longitude 7° 12' and 7° 35' E. Relatively it is positioned at the east of Nrobo and Nkpologu in Uzo-Uwani Local Government Area; south east of Ugwuaka and Afulugo in Idah Local Government Area of Kogi State; south of Igbo-Eze South Local Government Area, west of Isi- Uzo, south west of Udenu and north of Igbo-Etiti Local Government Area. Nsukka Local Government is one of the 17 local government Areas that made up of Enugu State in south east Nigeria.

According to Thornthwaite [40](1948) climate classification, Nsukka has a humid (forest) mega thermal climate. But there is a seasonal drought from November to March, when soil moisture storage is nil. Consequently, the climate is of tropical wet and dry (savanna) type, in which 89 % of the annual rainfall (approximately 1715 mm) for Nsukka falls in seven months of April to October. Temperatures are uniformly high (37^0C), as a result, only patches of moist forest remain within an area that is predominantly covered by grasses, giving rise to a vegetation complex described as derived guinea savanna (forest savanna-mosaic) [41](Iyang 1978; [42]Anyadike, 2002). All these conform very well to the explanation and support of the law of terrain which states that differences in the topography is as a result of variation in geology of a place under similar climatic conditions [43](Gilbert, 1877).

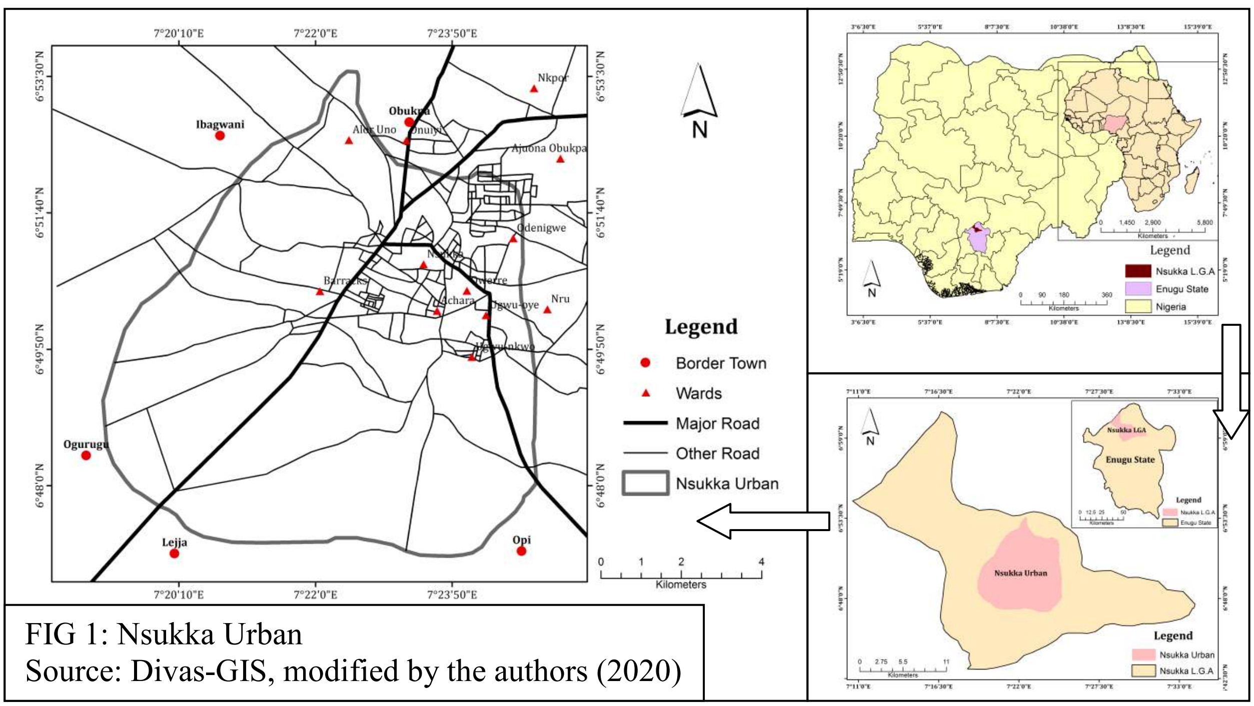


FIG 1: Nsukka Urban
Source: Divas-GIS, modified by the authors (2020)

Nsukka Local Government Area falls into four landform divisions (a) Western lowland, (b) A plateau, (c) An escarpment and (d) An eastern lowland [44](Ofomata, 1973). Akamigbo et al. [45](1994) reported that the plateau landform (Nsukka area) is characterized by residual hills separated by generally wide and flat-bottomed dry valleys. The western lowland forms the Northern section of Anambra plains of the Niger landforms; it is a gentle rolling plain which slopes gradually westwards to the Niger River. Udi-Nsukka plateau falls gently towards the lowlands along the Niger Rivers. In Nsukka Urban, the plateau is about 48 km^2 wide and slopes from a height of 459 m to 249 m Above Sea Level (ASL) along the escarpment to about 214 m ASL to the west and finally merges with the low land areas of the Anambra plains [46](Ofomata, 1975; [47]Amah, 2006; [48]Ekechukwu, 2009). The area is covered by sedimentary formations which fall into three main geological groupings: the shale, coal measures and sandstones [46](Ofomata, 1975). The soil of the study area comprises of the shallow and stony lithosols found at the steep slopes or the cuesta, the ferrallitic soils (red earth or acidic soils) found on the plateau, and the hydromorphic soils found at the depositional plains (Plates A, B, C and G).

The population of Nsukka Urban is currently projected at 111,017 with a population density of 2,313 persons per square kilometer (https://worldpopulationreview.com/countries/cities/nigeria). For the purpose of this study, the population of 2005 (67,503); 2015 (89,011) and 2020 (105,052) with their densities (1,406; 1,854 and 2,189 persons per square kilometer) were calculated respectively using the formulae as:

$P_2 = P_1 \ (1 + r)^n$..(Eqn 1)

$P_1 = \frac{P_2}{(1+r)^n}$..(Eqn 2)

Where; P_2 is the projected population.
P_1 is the unknown population census figure.
r is the rate of natural increase, 2.8%, [49](UNWFP, 2019; [50]Ndulue and Ayadiuno, 2021).
n is the number of years interval between P_1 and P_2.

2.1.2 Flood Path Ways in Nsukka Urban

Horton and others have proposed that there is an orderly development of drainage basins according to a set of principles, which Marisawa [51](1968, P. 113) calls the “laws of drainage composition.” Horton noted that the number of streams of different orders in watershed decreases with increasing order in a regular manner known as the law of stream numbers [52](Ofomata 2009). There is a natural pattern of flow, whether of streams or floods. Flow directions have always been from uplands to lowlands in all directions [53](Ayadiuno et al. 2022b), and in most cases along fault lines. The same is the case of Nsukka Urban (Figure 2).

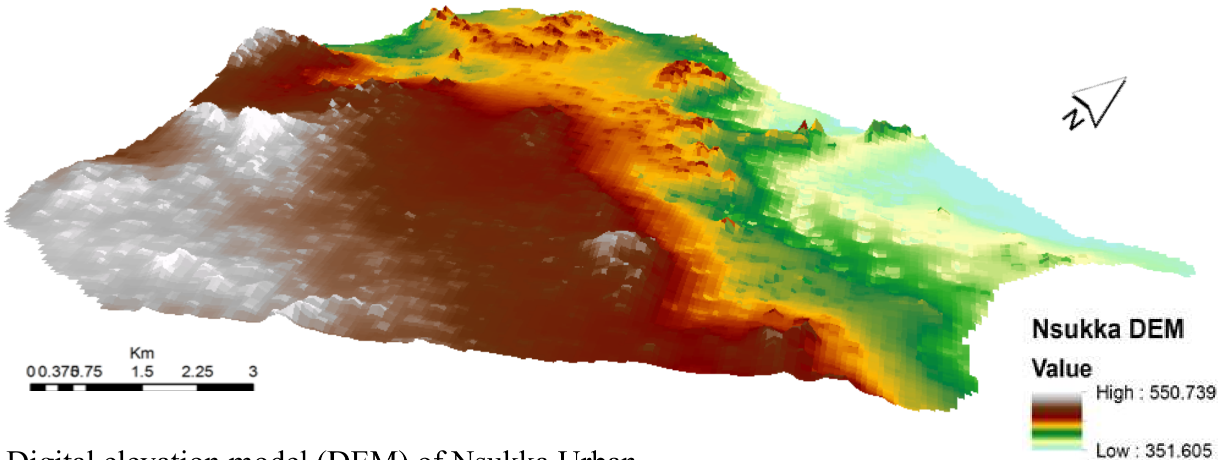


FIG 2: Digital elevation model (DEM) of Nsukka Urban
Source: USGS, modified by the authors (2020)

The flow pattern and flood path ways in Nsukka urban follows after the same natural patterns of flow. The peaks of the hills in the area is where all floods begin and form the first order of flood channel and the type of erosion experiences at these area is basically splash and sheet erosion. These areas are the peaks and the bases of the hills in area like Okpa-Ogwu Hill, Edem-Ani hill, Olivert Hill, *Ugwu* Sister, *Ugwu Ike-agwu*, Agric Hill, Aso Hill, Odenigwe Hill etc. The second order is where the various first orders floods join together; these are found usually at the middle slope of the entire landscape of the area and they are basically drainage channels constructed at these areas especially where there are roads. Places that fall under these areas are Ugwu-oye, Ugwu-nkwo, Aku road, Odenigbo through Total filling station to University road, Obollo road, Obukpa layout etc. At this point, volume of flood water, its velocity and erosive force have increased and the resultant effect in areas that do not have concrete gutters and culverts is rill erosion. When second order joins together, a third order is formed and so on. Here, the volume of flood water is so large, its velocity high and erosive force so strong that the resultant effect is gully erosion. As the topography of Nsukka urban is, whenever it rains, all flows are directed naturally from the south to the north of the area and this concentrates all the flood channels northwards and a greater percentage of the floods (about 90%) meet at University road as was channeled through the University of Nigeria Secondary School premises. At Catering Rest House road, the flood drainage channels from Obukpa layout joined the main channel from University road, thereby increasing the volume, velocity and erosive force. As the gully cuts its way through Onuiyi to Ibeziako Street, Onuiyi road drainage channels joined the main gully channel too. Ogurugu road, Ugwu Awarawa and Ibeagwa road drainage channels were joined at Onuakachi village in Alor Uno where all the debris is deposited (FIG 3) and (Plates A - L).

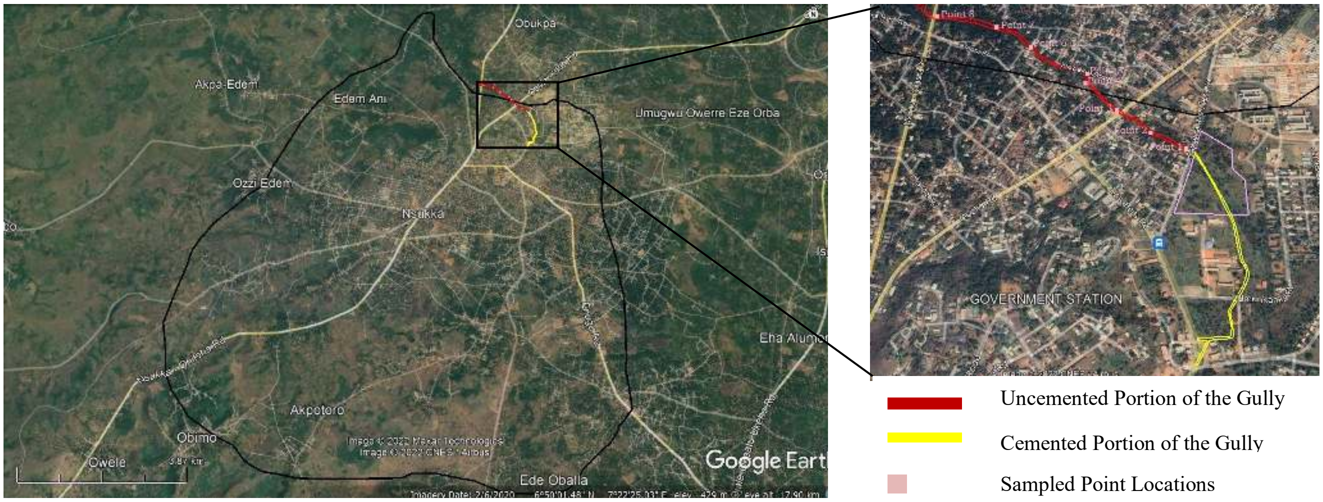


FIG 3: Google Earth Image of Nsukka Urban showing the road networks as the flood path ways channeled and diverted through the University of Nigeria main gate (depicted in yellow) towards Catering Rest House Road to Onuiyi and Alor Uno (depicted in red)

Plate A: Sheet and Splash erosion at the base of northeastern slope of Aso Hill in 2016

Plate B: Rill erosion at the base of northeastern slope of Aso Hill in 2016

Plate C: Gully erosion section at Onuiyi in 2016

PLate D: The same gully erosion section at Onuiyi in 2020

Plate E: Gully erosion at Onuiyi Road Culvert in 2016 (Note the author, whose height is almost half way the gully depth at 1.9 m)

Plate F: The same gully erosion at Onuiyi Road Culvert in 2020 (Note the house around the gully site, with the height of the house about half of the gully depth at 3.84 m)

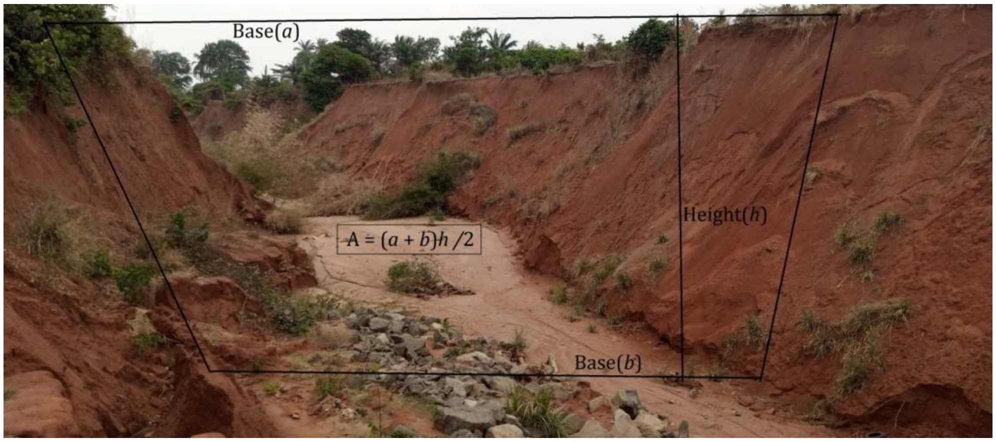
Plate G: Ibeagwa Road Culvert at the Alor Uno end of the gully depositional plane in 2016
Source: Authors Fieldwork, (2016 and 2020)

2.2 Research Design and Methodology

Primary and secondary data were used in this research work. The primary data used were obtained from field visits, which include measurements, photographs and oral interviews while the secondary data were from other existing literature and related organizations such as satellite imageries, (www.earthexplorer.org), Nigerian and African maps shapefiles (www.divas-gis.org; https://open.africa/dataset/africa-shapefiles), topographic sheets, among others. Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) imageries of the selected years which require bands 4, 3 and 2 of the nine (9) spectral bands of thirty (30) m spatial resolution were used for the land use land cover change (LULCC) classification. ERDAS IMAGINE version 9.2 was used for the radiometric, geometric corrections and image sharpening. This study adopted a mixed method approach in data analysis and representation with ArcGIS version 10.4 software as the major analytical tool used, other calculations were either manually performed or were calculate using Microsoft Excel 2007.

2.2.1 The Gully Site at the Study Area

There is one major gully site at the northern part of Nsukka urban. During one of the field visits, this gully site was identified and later revisited for data collection. Measurements of the width (bases), depth (height) and the coordinates of three different points along the gully channel; the lower (end), middle and upper (head) parts of the gully, were taken, using a 50 m, 7.5 m steel tapes and a global positioning system (GPS). The length of the gully was also traced using GPS logger. The cross sectional areas of the eight (8) different sampled point locations in the gully were determined as in the example below using the formula given as:



$$A = \frac{\frac{1}{2}(a+b)h_1 + \frac{1}{2}(a+b)h_2 + \frac{1}{2}(a+b)h_3 + \frac{1}{2}(a+b)h_n}{NP} * L \quad \text{(Eqn 3)}$$

where A = Cross Sectional Area of the Gully Sampled Location (m^2),
$\frac{1}{2}(a+b)h$ = Area of a Trapezium of Sample Points
a, b = Bases of a Trapezium of Sampled Points (Widths of Gully (m)),
h = Height of the Trapezium (Depth of Gully (m)),
n = Number of Sampled Points Intended.
NP = Number of Points Sampled
The volume of soil particles removed in the gully was also determined using the formula as:

$$(\widetilde{A})L \quad \text{(Eqn 4)}$$

Where SPL = Soil Particle Loss
$\tilde{A}$ = Mean Area of Gully (m^2)
L = Length of Gully (m).

3 RESULT ANALYSIS AND DISCUSSION

3.1 Season and Causes of Flood and Soil Erosion in Nsukka Urban

Flood in Nsukka urban always occurs during rainy season (April to September). Flood occurs in areas like, Ugwu-nkwo, Ugwu-oye, Aku road, Odenigbo through University road, Obollo road, Obukpa layout etc, during the period of rainy season. When rain falls in these areas, flood accumulates very quickly and also disperses very quickly. In places like Ugbene-Agu, Iheuno, Amaebo, Aguneze villages in Alor Uno which is at the receiving end of all floods in Nsukka urban because of its location at a valley floor and as the lowest point (340-345 m Above Sea Level) in Nsukka urban, experiences flooding beyond September.

3.2 **Causes of Soil Erosion in Nsukka Urban**

Although soil erosion is a natural occurrence on all lands, however, certain human factors exists that can accelerate erosion, making it more noticeable and problematic. They are deforestation, bush burning, over grazing etc. Other physical factors of soil erosion in Nsukka Urban are flood water (rainfall) and wind action.

3.2.1 Rainfall: This has been recognized as the most important causes of soil erosion, it is also very vital in determining the magnitude of erosion [54](Abua et al, 2017). The amount, intensity and duration of rainfall together with the type of soil and nature of the surface are the main reasons for the type of soil erosion in an area [55](Fayas et al., 2019; [39]Wagari and Tamiru, 2021; [10]Ayadiuno et al, 2021a). The speed and velocity of the surface runoffs or flow is determined by the degree of slope of the area. The level of disintegration of soil particles is a function of rainfall erosivity.

3.2.1.1 Rainfall analysis of the study area:

The rainfall analysis was done in order to determine the amount of water infiltrated, amount of runoff generated and the amount of water evaporated in the study area. It was calculated using the formula;

P = I + R + E……………………………………………………………………(Eqn 5)

Where P = Total Annual Precipitation, I = Infiltration, R = Runoff, E = water evaporated with reference to the hydrograph or water budget analysis of the study done by Egboka et al [56](2006) in Agulu in Anambra State. Anambra State shares boundary with Enugu State in the east and northeast, fall into the same climatic zone, shares the same rainfall amount and most importantly, Nsukka in Enugu State, shares the same geologic formation (Bende-Ameke formations) with Nsugbe in Anambra State. Hence the adoption of Nsugbe general ground water budget for the hydrologic system as modified in table 1.

Table 1: Values for Nsukka General Ground Water Budget for the Hydrologic System

Formation	P (m/yr)	%	E (m/yr)	%	I (m/yr)	%	R (m/yr)	%
Nsukka	1.715 $*5.312 \times 10^{8}$	100	1.096 $*3.396 \times 10^{8}$	63.91	0.360 $*1.115 \times 10^{8}$	20.99	0.259 $*8.023 \times 10^{7}$	15.10

Source: Egboka et al, [55](2006) modified by the authors, (2020)

The values of the annual precipitation, evapotranspiration, infiltration and runoffs were adopted from that of Nsugbe [56](Egboka et al, 2006), and was used for the rainfall analysis of the study area because both areas are under the same climatic zone and share the same climatic condition as well as geologic formations. The values of the total annual precipitation, evapotranspiration, infiltration, and runoffs for the catchment or study area are 1.715 m, 1.096 m, 0.360 m and 0.259 m respectively. To determine the initial amount of evapotranspiration, infiltration, and runoffs in percentages that occur within the catchment area, each of the variable values were divided by the value for the total annual precipitation and multiplied by 100 in other to render the outcome in percentages. It was calculated as thus:

P = 1.715 m; E = 1.096 m; I = 0.360 m and R = 0.259 m.

Evapotranspiration (E) = (1.096 m / 1.715 m) 100 = 63.91%

Infiltration (I) = (0.360 m / 1.715 m) 100 = 20.99%

Runoff (R) = (0.259 m / 1.715 m) 100 = 15.10%.

These percentage values are the assumed precipitation, evapotranspiration, infiltration, and runoffs level in the study area as at 2006. Due to the increase in roof tops, cemented and bare land cover, which reduced infiltration and increased the actual value of runoffs as at 2020, the value of runoffs were recalculated using the formula:

$I_{lcc} = \% \, Y_{icc} \, / \, \% \, Y_{lcc} * I_{icc}$……………………………………………………..(Eqn 6)

Where I_{lcc} is the infiltration level of the latest calculated cover, Y_{icc} is the year of initial calculated cover, Y_{lcc} is the year of last calculated cover, and I_{icc} is the infiltration level of the initial calculated cover.

As a result of increase in land cover (Bare land and Built Up) to 59.16%, the value of infiltration was expected to reduced from 0.360 m to 0.184 m, which was added to the value of runoffs, that is 0.259 m + 0.176 m = 0.435 m, while evapotranspiration remained constant at 1.096 m. Therefore runoffs became 0.435 m (25.36%). As it is at this level, runoffs at 25.36% of annual precipitation of 1.715 m is very high, hence the high velocities and competences that are capable of washing off the surfaces, removing soil particles, carving deep gullies along its paths and depositing a large amount of debris in the wide plane north of Nsukka Urban towards Obukpa, Itchi, Nkelagu, Ebulu Mmiri, and Alor Uno (Plates A - L).

3.2.2 Land Use Land Cover Change of Nsukka Urban

The land use land cover distributions for each study year as derived from the map are presented in table 2. The study years were randomly selected and mapped, to depict the various change levels of the land uses. The study years mapped are 2005, this was the year that preceded the 2006 population census in Nigeria, followed by 2015 which was also the year preceded the first reconnaissance visit of the gully site in the study area, and then 2020, the year that the field work of the entire study area was carried out.

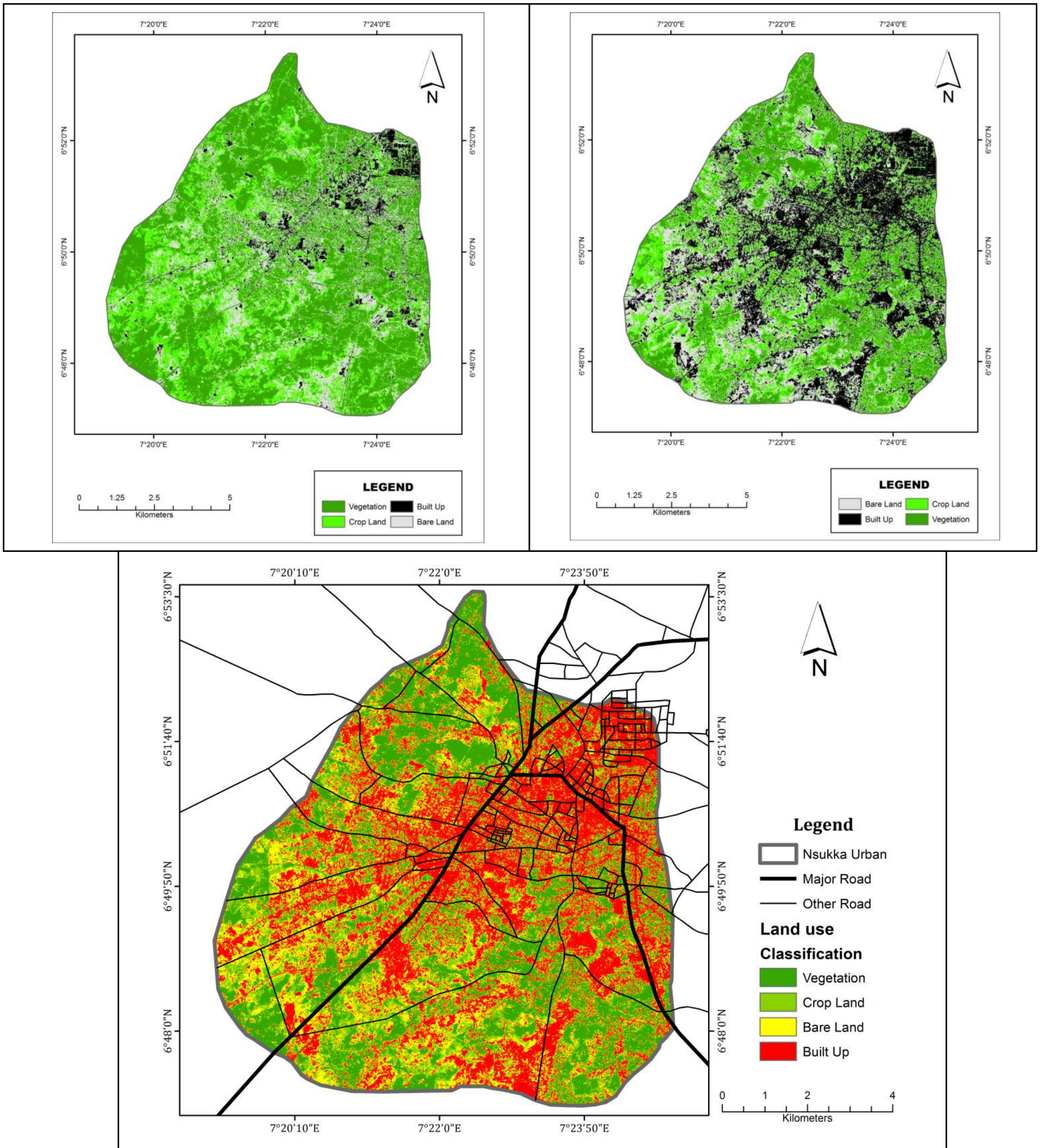


FIG 3: Land use Land Cover Change of Nsukka Urban in 2005, 2015 and 2020. Colour differences used in 2020 version is to differentiate roads from Built Up areas

Source: USGS, modified by the authors, (2020)

Table 2: Land use land cover change distribution (2005, 2015 and 2020)

	2005		2015		2020	
Name	**Area (%)**	**Area (Km^2)**	**Area (%)**	**Area (Km^2)**	**Area (%)**	**Area (Km^2)**
Vegetation	41.24	19.80	27.97	13.43	16.82	8.07
Crop Land	29.83	14.32	32.42	15.56	24.02	11.53
Bare Land	20.88	10.02	28.09	13.48	27.64	13.26
Built Up	8.05	3.86	11.52	5.53	31.52	15.13
Total	**100**	**48**	**100**	**48**	**100**	**48**

Source: Authors Analysis and Computation, (2020)

In the analysis above (table 2), the percentage of vegetation cover was 41.24% in 2005; it came down to 27.97% in 2015 and to 16.82% in 2020 respectively showing a general decrease of 24.42% from between 2005 and 2020. Crop land increased from 29.83% in 2005 to 32.42% in 2015 as a result of increase in agriculture, and later decreased to 24.02% in 2020 respectively showing a general decrease of 5.78% from between 2005 and 2020. Bare land was on the increase from 20.88% in 2005 to 28.09% in 2015 and degreased to 27.64% in 2020 respectively showing a general increase of 6.76% from between 2005 and 2020. Built-up area increased to 23.47% from between 2005 and 2020 in the tune of 8.05% in 2005 to 11.52% in 2015 and to 31.52% in 2020 respectively.

Land cover classification (built-up area and bare lands) which are responsible for high runoffs generation recorded an unprecedented increase of 6.76% and 23.47% respectively with the period under review. This result shows that the amount of runoff generated in the study area is to be so high since there was an increase in both built-up area and bare lands from 28.93% as of 2005 to 39.61% in 2015 and to 59.16% in 2020. The implication here is that as at 2020, 59.61% of the entire landmass of the area is either bare, cemented or roof topped, hence preventing infiltration. Low percentage of vegetation cover (8.07%) as well as intermittent baring of the ground (crop lands) during agricultural activities which results in high generation of runoffs because of the absence of materials to slow down flows and encourage much water to infiltrate into the ground. This calculations and analyses show the rationale behind high runoffs generation as seen as one and the main causes of gully erosion in the study area.

3.2.3 Soil Erodibility: The characteristic of each unique soil is more or less susceptible to erosion. Reoccurring erosion is more for soil in the areas that have experienced erosion in the past. Soil erodibility is usually seen as the ability of the soil to be removed. In a sense fundamentally, it should be described as the propensity of the soil to loose and be carried away under the exogenic or erosivity force of rainfall, surface and underground flow. Understanding the concept of soil erodibility is useful in calculating and predicting soil loss [57](Wischmeier, 1959; [10]Ayadiuno et al 2021a; [12]Ayadiuno, 2021).

3.2.4 Slope Gradient: Slope gradient plays a major role in soil erosion, especially if the slope is steep. The steeper the slope, the greater the erosive force and subsequently, the amount of soil that can be erode. As the soil erodes downwards in most cases, it increases the degree of the slope steepness, which in turn creates sliding that is inimical for further erosion.

3.2.5 Deforestation: Vegetative cover of plants or crop residues protects the soil from rain drop and splash more than the areas with less vegetative cover. Here, human beings play a major role in soil erosion through their abuse of vegetated areas like deforestation, over grazing, building constructions etc.

3.3 Negative and Positive Impact of Soil Erosion

3.3.1 Degradation of the Environment: Erosion causes the soil to lose its nutrients in the environment thereby causing the vegetation around to look sickly and become unproductive. This can also affect the amount of carbon dioxide this vegetation removes from the atmosphere and the oxygen they release thereby causing deficiency in the balancing of the atmosphere.

3.3.2 Reduce farmers' income and farmlands: Erosion mostly occurs in agrarian areas like we have in southeastern Nigeria, removing top soils of farmlands and destroying the structure of the land, leaving the farmers in fear of going near the affected areas (gully site) and this has affected farmers in these areas.

3.3.3 Destroys social infrastructure: Erosion affect human life negatively, destroy properties, cut off roads, brought down electricity poles, collapsed pipe lines, culverts and bridges, etc (Plates H - L)

3.3.4 Endangers human health and live stock: Sediments that are deposited in water ways can contaminate the water which will become unhealthy for human and live stock to drink.

3.3.5 Improved Soil Quality: Eroded materials which are deposited when the flood recede recharge the land and improve its quality making it fertile for food production.

3.4 Estimating Soil Particles Loss

Eight (8) point locations of the gully were sample. Point 1 was at the beginning of the gully, points 2 - 7 were at the middle, while point 8 was at the end of the gully. It is worthy to note that the more the sampled area the more accurate the result would have been, however for accessibility and ease of measurements at these sampled points, the authors chose to reduce the number to eight (8).The following measurements as were presented in the table below were collected (Table 3).

Table 3: Measurements of sampled points in the gully channel

Points	Latitude	Longitude	Depth (m)	Base$_a$ (m)	Base$_b$ (m)	$\frac{1}{2}(a+b)h$ (m^2)
Point 1	6^0 52" 28'N	7^0 23" 13'E	1.79	2.17	1.91	3.65
Point 2	6^0 52" 25'N	7^0 23" 26'E	2.39	3.48	2.93	7.66
Point 3	6^0 52" 18'N	7^0 23" 33'E	4.55	6.57	4.88	26.05
Point 4	6^0 52" 17'N	7^0 23" 38'E	3.20	4.67	4.11	14.05
Point 5	6^0 52" 15'N	7^0 23" 37'E	3.84	5.32	4.27	18.41
Point 6	6^0 52" 29'N	7^0 23" 42'E	1.87	4.71	3.96	8.11
Point 7	6^0 52" 06'N	7^0 23" 46'E	1.52	3.66	3.52	5.46
Point 8	6^0 52" 08'N	7^0 23" 53'E	1.22	4.31	4.29	5.25
Average			2.55	4.36	3.73	11.08

Source: Authors Fieldwork, (2020)

The gully length is 1674 m, stretching from Catherine Rest House Road to Alor Uno as depicted in red (Figure 3). Therefore as at 2020, the total soil particles loss (SPL) from the gully site due to erosion is estimated to be 18,547.92 m^3 (1674 m * 11.08 m^2) or 18.548 tons.

The mean volume of soil particles lost per annum since the inception of the gully from 1984 according to the respondents to 2020 is calculated using the formula as:

V_SPL/ n_yrs…………………………………………………………………….(Eqn 7)

Where V_SPL is the volume of soil particles lost, and n_yrs is the number of years.

Since there are variations in the conversion from cubic meter to tonnes (metric), this study used the conversion calculator and table of 1 m^3 to 0.001 ton (http://convertwizard.com/convert-cubic_meters-to-tons). The volume of soil lost divided by the number of years which is (18,547.92 m^3 / 36 years) = 515.22 m^3 (.515 ton per annum).

Plate H: Gully cut at Ibeziako Street with the street reduced to a footpath and house endangered by the gully in 2016

Plate I: The same gully cut at Ibeziako Street with the reduced street totally cut off and the endangered houses abandoned in 2020

Plate J: Property partially destroyed by the gully in 2016

Plate K: A full size street reduced to foot path

Plate L: The same property completely destroyed by the gully in 2020

3.4 Management and Control of Soil Erosion in Nsukka Urban

3.4.1 Control measures

Measures to control erosion can be in two ways which are preventive and curative measures.

3.4.1.1 Preventive Measures

In preventive measures, there is a saying that *"prevention is better than cure*". Where the incidence of erosion has not occurred, but is likely to occur, some measures are needed to be taken in order to prevent the inception of the soil erosion. Some of these measures are reducing the level and extent of degrading the forests, adopting a system of farming or crop cultivation that will always ensure that there is vegetation cover on the ground surface to prevent the ground being bare of vegetation cover; eliminate and control the extent to which bushes are set on fire for any slightest excuse like hunting; reducing overgrazing by herders; due to the topography, adapting contour ploughing will go a long way in checking surface flow; introduction of multiple or mixed cropping and the use of cover crops effectively; checking and controlling sand mining that can expose the ground surface and trigger flow; proper channelization for easy evacuation of floods whenever it rains; constructing cemented drainages that will prevent erodibility and introducing rain water harvesting system to trap these water at homes so that little will be released to the environment which will pose no threat [58](Ofomata, 2007).

3.4.1.2 Curative Measures

In curative measures, actions to be taken will depend on the type of erosion involved, whether it is gully, sheet, splash, etc. If it is gully erosion, preventing the concentration of flows will be necessary so as to prevent so much runoff from getting at the gully at once; stabilization of the slopes using concrete or retaining walls among others will be useful. Combining afforestation, ridging across slopes, contour ploughing, among others in farming areas, while in urbanized areas, construction of well articulated side road drainages that will direct floods to soak-away pits designed to accommodate such floods for the time being, and the construction of concrete structures and drainage channels large enough to evacuate large volumes of flood out of the urbanized areas, areas devastated by gully erosion can be reclaimed and sand filled to the level it was before the erosion occurred with proper channelization to avoid reoccurence. If it is on sheet erosion, reducing the extent of the ground that is bare in the area by planting trees and grasses such as Bahamas grass, and shrubs like Acioa bacteri will go a long way in protection the soil from splash erosion [58](Ofomata, 2007).

4. CONCLUSION AND RECOMMENDATIONS

Several research and researchers’ result and experience have shown that rainfall is the principal cause of flooding, gully erosion and siltation of streams and agricultural lands, destruction of properties, and sometimes loss of lives in southeastern Nigeria. Flooding often results from poor or absence of well articulated drainage systems. Water budget analysis and interviews extracted from residents in the study area has identified April, September and October as the months during which flood and soil erosion are at their peak, the anthropic and natural causes of gully erosion are rainfall, gradient and land cover as a result of urbanization, which has provided for tiled roads, cemented compound, roof tops that has prevented infiltrations and encouraged increased generation of runoffs. The computed data, information and results obtained from this research are very vital in the design of suitable and sizeable drainages for flood and soil erosion control.

The authors are of the opinion that alignment of sewers and storm water drainages should follow the natural drainage patterns considering topography, land use, land cover and right of way for both the drainages and other environmental activities for cultural, social, and economic sustainability. The study therefore recommends collaboration with all the three tiers of government and their environmental management agencies in Nigeria and Nsukka Urban Municipal Development in designing and constructing an earth dam and water recycling facility in the area that the concentrated drainage passed through in the University of Nigeria, Nsukka premises, to trap, harvest and recycle this flood water. The recycled water can be treated and made available and accessible to the university community or better still to the Nigerian Fire Service in Nsukka, whose facility is incidentally located just opposite the university. In the absence of funds to put up a mechanically manned recycling facility, the flood water trapped by the earth dam may be allowed to infiltrate naturally and transmit to nearby aquifers as a source of groundwater recharge, while the silts generated can be evacuated intermittently and used as a source of nutrients to the surrounding farm lands in the suggested proposed locations.

This suggested proposed location for the earth dam and the flood water (mechanical or natural) recycling facility was selected based on the antropic and the natural providence. Anthropic in the sense that the concentrated drainage channels from the study area passed through the area (marked area in pink and yellow colours in figure 3) before getting to Ibeziako Street where the damages are being occurred, and natural in the sense that the area is used for agriculture by the university community. Siting the project in this location will serve multiple purpose of providing recycled and treated water for the university community, making same water available for the Nigerian Fire Service located opposite the university, providing nutrients for the university farmers, and also serve as a way of recharging the groundwater in the area.

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