American Journal of Geographic Information System 2016, 5(2): 55-67
DOI: 10.5923/j.ajgis.20160502.03

Erosion Sensitivity Assessment of Communities in Owerri, Nigeria Using Geographic Information System and Revised Universal Soil Loss Equation- Based Model

Ngozi AC-Chukwuocha*, Ogbenna Uchechukwu, Ogugua Chizoba, Emenike Nnedinma

Department of Environmental Technology, Federal University of Technology, Owerri, Nigeria

Abstract Soil erosion menace is a major environmental concern in South East Nigeria; that calls for quick measures to minimize the rate of devastation. These measures are sustainable if geospatial information on erosion sensitivity and degree of sensitivity is provided. This study identifies and integrates variables such as land use (derived from IKONOS 2012 Satellite Image), soil erodibity, rainfall erosivity, slope steepness (from Digital Terrain Model), level of imperviousness, drainage and population density to assess the degree of sensitivity in Owerri area of Nigeria to water erosion. The datasets were integrated into the GIS environment with the use of ArcGIS 10.3. The functions of weighted overlay were used to analyze the degrees of sensitivity of the entire study area to erosion hazards. The results showed that 57.56% of the study area mapped ranked medium sensitivity to erosion. With the built-up and forest land use accounting for 29.84% and 12.16%. Impervious surface analysis showed that 53.57% of the sub-watersheds had low level of imperviousness. While 46.43% of the study area had medium level of imperviousness (between 10%-25%). The study also revealed that Ohii with highest percentage sand (87.3%) and lowest percentage organic matter (0.635%) had the highest erodibility status. The study concludes that the degree of erosion sensitivity prevalent (medium) was observed in the low population density areas with substantive vegetative covers. While areas close to the city recorded very high sensitivity to erosion because of the high population density.

Keywords Soil Erosion, RUSLE, GIS, Soil Erosion Sensitivity Assessment

1. Introduction

The spate of land degradation through soil erosion is of great concern in South east Nigeria. Soil erosion caused by water is triggered by a complex interaction process of many factors such as natural (climate, topography, soil, vegetation) and anthropogenic (tillage systems, soil conservation measures, overgrazing and deforestation [1]. Soil erosion occurring under natural conditions or geologic time scale is slow and has produced some of the most spectacular landscapes in the world. This continuously slow and constructive process can be significantly altered and aggravated by anthropogenic activities such as encroachment of agricultural activities on forest areas, deforestation for commercial and industrial purposes, urbanization and general misuse of land, as well as the effect of climatic changes such as high rainfall regime, drought, and desertification. This creates an imbalance in the natural equilibrium between soil loss and soil formation. The consequences of this imbalance are in many cases highly unfavorable to the human society.

Erosion can be said to be a catalyst to several environmental problems such as decreased land productivity, challenges to agricultural sustainability, degradation of soil and water quality, and indirect pollution of the environment through the transport of contaminants such as agricultural and industrial waste attached to sediments to other parts of the environment and the hydrographic network [2, 3]. Some of these problems are presently witnessed in the South east region of Nigeria. The region of high population density with high rate of infrastructural development and the consequential flood and erosion hazards [4]. A report shows that about 45% of the region is affected by considerable sheet erosion and about 20% of the land area suffers severe sheet erosion [5].

The Soil Erosion Sensitivity Assessment provides a method of identification and prioritization of the potential risks posed by erosion to both the environment and the populace by identifying the areas or surfaces that are likely to be affected by erosion and the extent to which they are affected. This can be done by identifying various factors that determine the rate and intensity of erosion. These factors include; soil erodibility (dependent on inherent soil

* Corresponding author:
chukwuochang@yahoo.com (Ngozi AC-Chukwuocha)
Published online at http://journal.sapub.org/ajgis

properties such as soil texture, structure and organic matter content), rainfall erosivity (dependent on rainfall amount, frequency and intensity), terrain (dependent on slope length and steepness), land cover (includes canopy cover, biomass and root system), socio-economic factors (include landuse, policies, population density, etc.). Various erosion focused studies have been carried out by researchers in the country [6-8] but most of these studies have largely been made through ground survey of the affected sites. Few studies [9], [8] and [10] have employed the power of the Revised Universal Soil Loss Equation in modeling erosion processes and mapping areas of high erosion risks in the South east of Nigeria. This study however focuses on a particular locality, and therefore integrates some measurable variables such as erodibility index assessed from soil samples, erosivity index determined from rainfall data, slope length and steepness derived from Digital Terrain Model, land cover management factor derived from classified landuse of Landsat 7 ETM satellite image. In addition other variables such as drainage density, impervious surfaces, were analysed. These variables were integrated with the RUSLE (Revised Universal Soil Loss Equation), in GIS (Geographic Information System) environment to determine the degree of sensitivity of the study area and to identify sub-areas of high sensitivity to erosion, so they could urgently be targeted for mitigation and remediation strategies, as well as serve as a tool for the development of best management plan.

2. Materials and Methods

2.1. Study Site

The study area covers five (5) communities in Owerri West Local Government Area in Imo State, Nigeria. The communities are Ohii, Irete, Obinze, Naze and Ihiagwa. Two surface waterbodies flow through the study area, Otamiri and Nworie River. Owerri is a rapid growing urban centre consequent to its designation as the capital of Imo state in 1977, in South-Eastern Nigeria. The study area is located between longitude 6° 56’ 45’’E and 7° 5’ 0’’E, and latitude 5° 18’ 15’’N and 5° 34’ 45’’N shown in figure 1. The general topography of Owerri is fairly flat and its watershed is mostly covered by depleted rainforest vegetation, with mean temperatures of 27°C throughoutthe year and total annual rainfall exceeding 2500mm [11]. The Otamiri River is joined by the Nworie River at Nekede in Owerri, a river about 9.2 km in length. The climate of Imo State is typically humid and its vegetation is tropical rain forest. Owerri has its max temperature as 33.4°C and min temperature as 21.2°C, its highest and lowest rainfall was recorded as 19 and 2mm respectively for 2012.

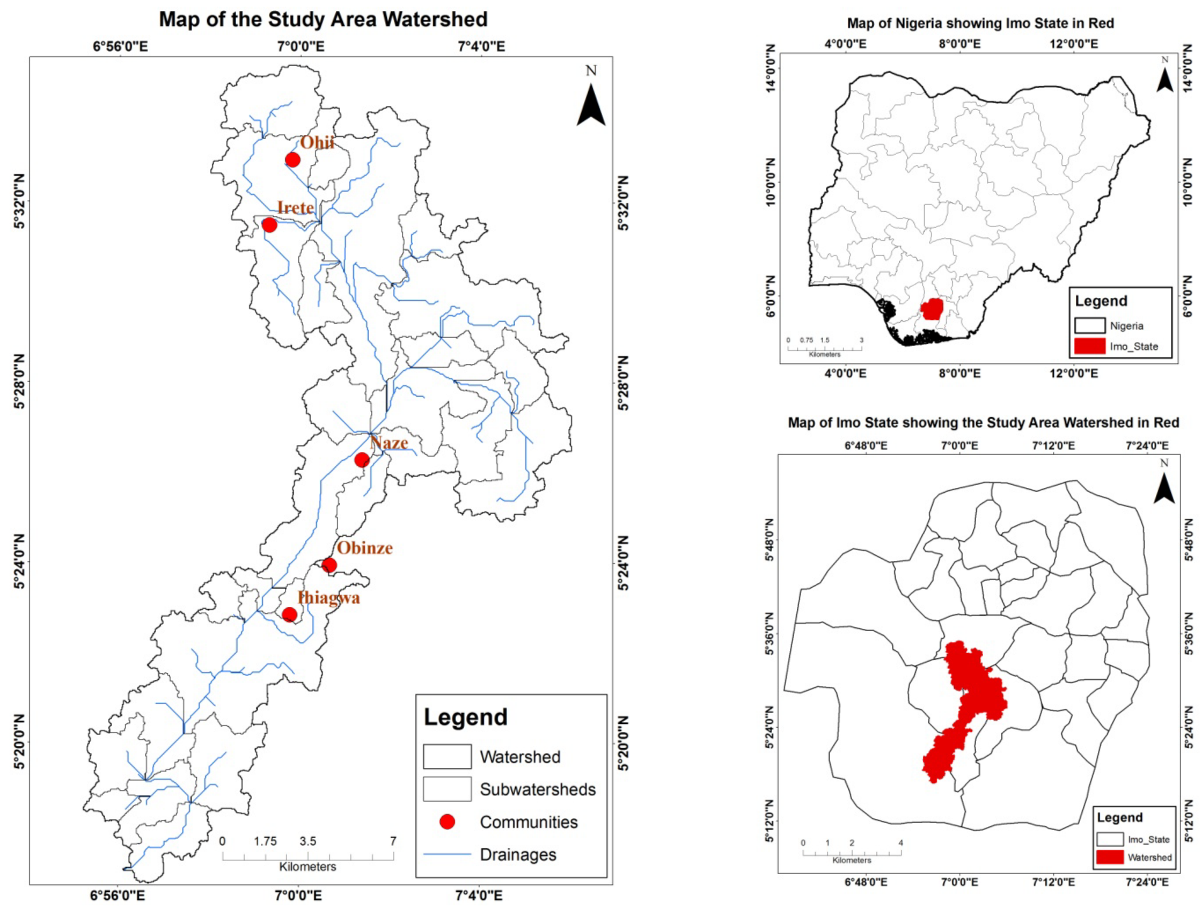

Figure 1. Location Map of Study Site

The population of Imo State is predominantly rural. Some of the most densely settled areas of Nigeria are found in Imo State, where a direct relationship exists between population density and the degree of dispersal of rural settlement, virtually every parcel of the land is settled, and one village merges imperceptibly into another. The climate of Imo State is typically humid and it lies within the tropical rainforest/ equatorial monsoon region of Nigeria, which has its peak rainfall within June, July, September and October and low rainfall in December, January and February [12] and is presently dominated by grasses such as *chromoliar, odoratum*, *euphoribia*, etc. and economic trees such as Iroko mahogany, obeche, bamboo, rubber and oil palm. Civil services and trading seems to be the predominant occupation of the people within the study area, although learned professionals, entrepreneurs and seasoned artists also abound in the state.

2.2. Materials

Table 1. Materials list, Data required and Purpose

MATERIALS	DATA REQUIRED	PURPOSE
GPS Garmin ETREX Vista	Co-ordinate values	Watershed survey and Ground truthing for accuracy assessment.
GEOGRAPHIC INFORMATION SYSTEM Software (ArcGIS 10.2)	Database design, creation, integration of data, processing and spatial analysis, map representation	Watershed characterisation, reclassification mapping,
STRUCTURED QUESTIONS	History of the study area, definition of magnitude of potential release.	Background and Visual Survey
SRTM satellite imagery (Digital Elevation Model-30m)	Watershed delineation, drainage network and slope.	Watershed Mapping, LS factor estimation and classification.
Administrative Map of Imo State	Digital map of study area	Mapping
2012 IKONOS Satellite imagery	Land use/land cover distribution/pattern	Land use and land cover classification, C-factor classification.
Field log book	Characteristics of the watershed	Field survey
Soil Survey Data	%clay, %silt, %sand, % very fine sand, %organic matter, Permeability and structural class.	Estimation and classification of K-factor
10-year Rainfall Data	Rainfall amount	Estimation and classification of R-Factor.
Population Data	Population density	Computation of population density layer

2.3. Methods

The integration of RUSLE equation into the GIS environment led to the following standardised methods which were used to produce each of the factors as grid layers.

- **Geo-Database Design -** A Personal Geo-Database was created in the ArcCatalog environment to store and manage the two different geographic data models (Vector and Raster) as well as their attributes, coordinate systems and projection properties.
- **Coordinate System - A**ll coordinates were in Mercator projection; the Geographic Coordinate System (GCS_WGS_1984) and Datum (D_WGS_1984) were applied in the project.
- **Watershed Delineation Process -** HEC-GeoHMS extension in the ArcMap 10.2 platform was utilized in this process. In this step, a terrain model is used as an input to derive seven additional datasets that collectively describe the drainage pattern of the watershed and allows for stream and sub-basin delineation. The first five datasets were grid layers that represent the flow direction, flow accumulation, stream network, stream segmentation, and watershed delineation. The next two datasets are vector layers of the watersheds and streams.

The values for the RUSLE factors to be inputted into the GIS software include the following:

Rainfall-Erosivity: R-Factor

The rainfall erosivity factor is used to quantify the ability of rainfall to cause soil loss under different conditions. It represents the erosion potential caused by rainfall [13]. The R-factor for a particular locality is the average annual total of the storm EI_{30} values for that locality [13]. EI_{30} is the individual stormindex values which equals to E which is the total kinetic energy of a storm multiplied by I_{30} which is the maximum rainfall intensity in 30 minutes [14].

Due to lack of data on rainfall intensity, the R-factor was computed using an equation developed by [15] as seen below:

$$\mathbf{R = 38.5 + 0.35P_r}$$

Where $\mathbf{P_r}$ is the mean annual rainfall in mm

The mean annual rainfall was estimated from monthly mean precipitation datasets compiled from precipitation records from the year 2004-2013 (10 years) obtained from NIMETS, Owerri Airport Station (Latitude 5° 29'N Longitude 7° 13'E).

Soil Erodibility: K-Factor

The soil erodibility factor is an empirically derived index that indicates susceptibility of soil to rainfall and runoff detachment and transport (rates of runoff) based on soil texture, grain size, permeability and organic matter content. It thus reflects the ease with which the soil is detached by splash during rainfall and/or by surface flow [10]. It denotes the average soil loss per ton per acre per unit area for a particular type of soil under standard unit plot condition (cultivated, continuous fallow with slope length of 22.13m and percentage slope steepness of 9%) [16].

The K-factor was computed using the soil-erodibility nomograph using measurable properties developed by [17]. The soil erodibility nomograph comprises five soil profile parameters which include; percent of silt + very fine sand (0.002-0.1mm), percent of sand (0.1-2mm), percent of organic matter (OM), class for soil structure (s) and permeability (p).

A detailed explanation of the parameters used for K value calculations is as follows:

Percentage Silt (0.002-0.05mm), Very Fine Sand (0.05-0.1mm) and Sand (0.1-2mm)

A mechanical analysis of the particle size distribution using the hydrometer sedimentation test method was carried out to determine the percentage silt, very fine sand, sand and clay (>0.002mm).

Percentage Organic Matter

Percentage Organic Matter was derived using the equation below;

Percentage Organic matter = 1.724 * Percentage Organic Carbon

Organic Carbon was obtained using the Dichromate Oxidation Method [18].

Soil Structure Class

The classificationof structure involves consideration of the shape and arrangement, the size and the distinctness of the visible aggregates or pebbles. The grade of soil structure is dependent upon soil moisture content and varies seasonally.

Permeability Class

Permeability is a measure of the soils ability to transmit a fluid, usually water. Permeability value in cm/sec was determined using Allan Hazens equation.

$$\text{Permeability}=D_{10}*100\text{cm/sec.}$$

Where D_{10} is the diameter corresponding to 10% of percentage passing. It is called the effective size.

The above parameters were inputted into the erodibility nomograph (Figure 2) to obtain the K-factor for the soil in the various communities. The values of the K-factors obtained were inputted into the attribute tables of the communities associated with the study area. An inverse distance weighting interpolation was carried out in the ArcGIS environment to obtain the K-Factor surface for the study area. The result after the interpolation process was reclassified on a scale of 1-5 to reflect its sensitivity to erosion.

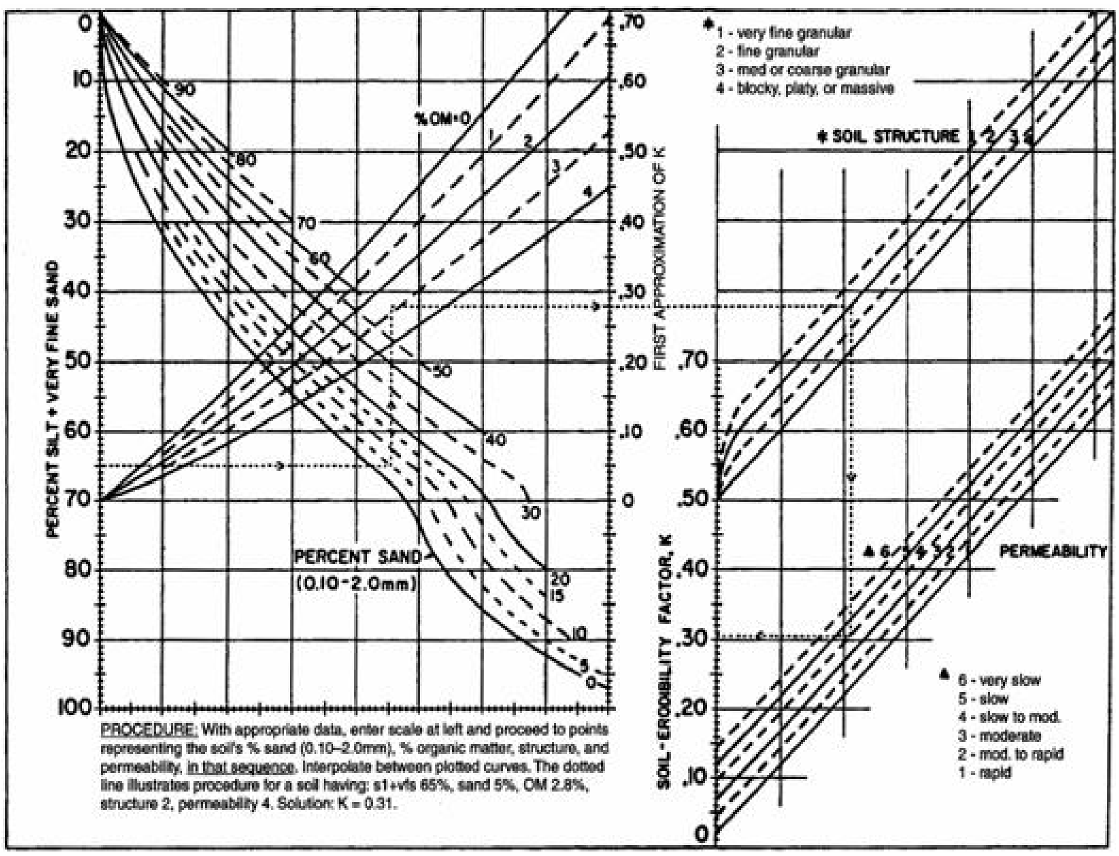

Figure 2. Soil erodibility nomograph by Wishmeier*et al.*, 1971

Slope Length and Steepness: LS-Factor

In the RUSLE model, the effect of topography on erosion is accounted for by the slope length (L) and the slope steepness (S). The L factor is defined as the distance from the source of runoff to the point where either deposition begins or runoff enters a well-defined channel that may be part of a drainage network. S factor reflects the influence of slope steepness on erosion [19].

For computing the LS factor, a Digital Elevation Model (DEM) at 30 meters resolution, was computed directly using the spatial analyst tool in the GIS software. The slope length and slope gradient factors were calculated using the computed DEM and entered into the equation below:

$$LS = (L / 22)^{0.5} (0.065 + 0.045S + 0.0065S^2)$$

Where:

$L = (x/22.13)^m$, in which x is length of slope (in m), m is 0.5 if the slope is >5%, 0.4 if between 3 and 5%, 0.3 if between 1 and 3 percent and 0.2 if below 1and L is the slope length factor;

$S = (0.43 + 0.30\ s + 0.043\ s^2)/6.613$, where s is the gradient (%), and S is the slope gradient factor.

After which the result was reclassified still in the GIS environment to reflect their sensitivity to erosion i.e. very low, low, medium, high and very high.

Cover Management: C-Factor

The cover and management factor is an index that indicates how crop management and land cover affect soil erodibility. It measures the effects of all interrelated cover and management variables [13]. It is used to express the combined effects (reduction of runoff velocity and protection of surface pores) of plants and soil cover as well as those of all other interrelated cover and management variables [20]. The C factor was derived using remote sensing techniques. Thus, the land cover layer was implemented from the results of the supervised classification method based on a Landsat 7 ETM satellite image with a 30 meters resolution. The land use was classified adhering strictly to the Anderson Land Use Classification system (1977). A reclassification analysis was carried out on the C-Factor layer to portray its sensitivity to erosion.

P-Factor

By definition, factor P in the USLE is the ratio of soil loss with a specific support practice to the corresponding loss with up and down slope tillage. The P values are between 0 and 1. P value is equal to 1 when the land is plowed on the slope directly and lower or less than 1 when the adopted conservation practice reduces soil erosion. Due to lack of information on practices conservation tillage, we adopt P = 1 over the study area.

Impervious Surface Analysis

The level of imperviousness of the study area was analysed using the Impervious Surface Analysis Tool, which is a tool developed by National Oceanic and Atmospheric Administration (NOAA) to help managers and planners use remotely sensed data to determine total impervious area and percentage impervious area within specified polygons (sub watersheds). The tool utilized the land use land cover grid and sub watershed polygon to produce an output of impervious surface. The result was converted to raster and then reclassified to represent their sensitivity to erosion.

Drainage Density Layer

Drainage density is calculated using the formula:

$$\text{Drainage Density} = \frac{\text{total length of channels } (m)}{\text{basin area } \left(m^2\right)} = m^{-1}$$

The drainage density of each subwatershed was analysed in the GIS environment and converted to a raster format and then reclassified based on the existing reclassification categories to establish a thematic layer which was to be integrated later to obtain a final sensitivity map.

Population Density Layer

The population data was obtained from the Ministry of Planning and Economic Development, Imo State Secretariat Complex, Owerri; then an inverse distance weighting interpolation was carried out on the data to obtain a surface. The layer was then reclassified to reflect their influence based on erosion.

Table 2. Population of the communities in the study area

COMMUNITIES	POPULATION
Ohii	5,093
Irete	18,271
Ihiagwa	22,220
Naze	20,631
Obinze	20,993
Owerri	40,670

Source: National Population Commission

Integration of the Thematic Layers with GIS

The thematic layers obtained as described above where integrated in the GIS with the aid of the weighted overlay function of the spatial analysis tool to derive the final erosion sensitivity layer for the study area. Figure 3 below explains the indexing of the thematic layers prior to the overlay; these served as basis or input layers for the overlay.

3. Analysis and Results

Watershed Delineation and Characteristics

The watershed land area covers a total of about 229.692km^2 of Owerri West LGA with twenty eight (28) sub watersheds and their drainage networks. The total drainage networks in the watershed ranged from 0.102km to 23.585km length. Figure 3 shows the sub watershed and its drainage networks in the watershed as already described.

Particle Size Distribution

The particle sizes range from clay (>0.002mm) to silt (0.002-0.05mm) to very fine sand (0.05-0.1mm) to sand (0.1-2mm). Results from the particle size analysis indicate that soil samples generally had a high percent of sand (72% - 94.5%) and fell under the USDA textural classification of sand and loamy sand. This signifies the lack of the ability to aggregate together therefore little force is required to detach and transport the soil particles, but because most sandy soils are highly permeable thereby generating low surface runoff, erosion is often light. This suggests that although the soil particles in these areas are easily detached, they are not easily transported due to low runoff and large particle size therefore the overall erodibility is low.

Percentage Organic Matter

Soils with higher organic content form more soil aggregates and hence is less erodible than soils with lower organic matter content. [22] suggested that soil erodibility decreases linearly with increasing organic content over the range of 0 to 10%, therefore Ohii with the least percentage organic matter (0.72 and 0.56) are more susceptible to erosion and Ihiagwa with 2.18 percent had the highest organic matter content therefore is most resistant to aggregate breakdown.

Soil Structure Classification

Well-developed soil structure promotes a network of cracks and large pores that accommodate infiltrating water, resulting in reduced erosion due to decreased runoff. Good aggregation also holds particles together, enabling the soil to resist the detachment forces of water and raindrop impact [21]. The soils were majorly sub-angular soils and from their texture, fell under fine granular soils which form relatively unstable cods. This makes them easily erodible.

Permeability Classification

Permeability is a measure of the rate at which water percolates through a soil. Highly permeable soil encourages infiltration and generates low runoff. In the study area, Ohii had the least permeable soil making them more susceptible to erosion as they produce more runoff.

Generation and Reclassification of Thematic Layers as Regards to Erosion Sensitivity.

Rainfall-Runoff Erosivity (R-Factor) Layer

Due to the nature of data collected from NIMET, there was no spatial variability in the R-Factor layer as shown in Figure 4 below.

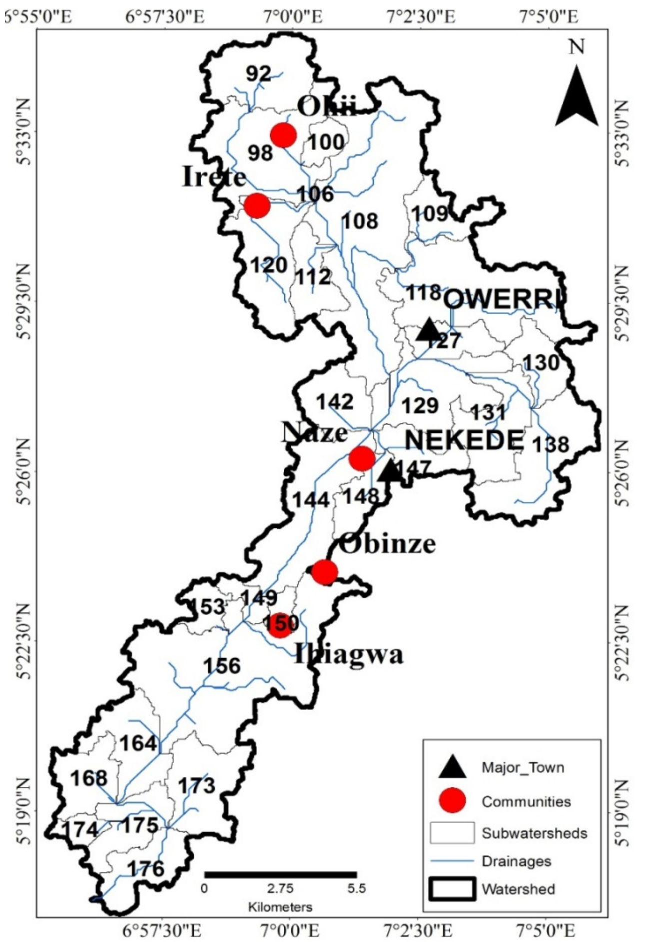

Figure 3. Map of study area sub watershed showing stream networks

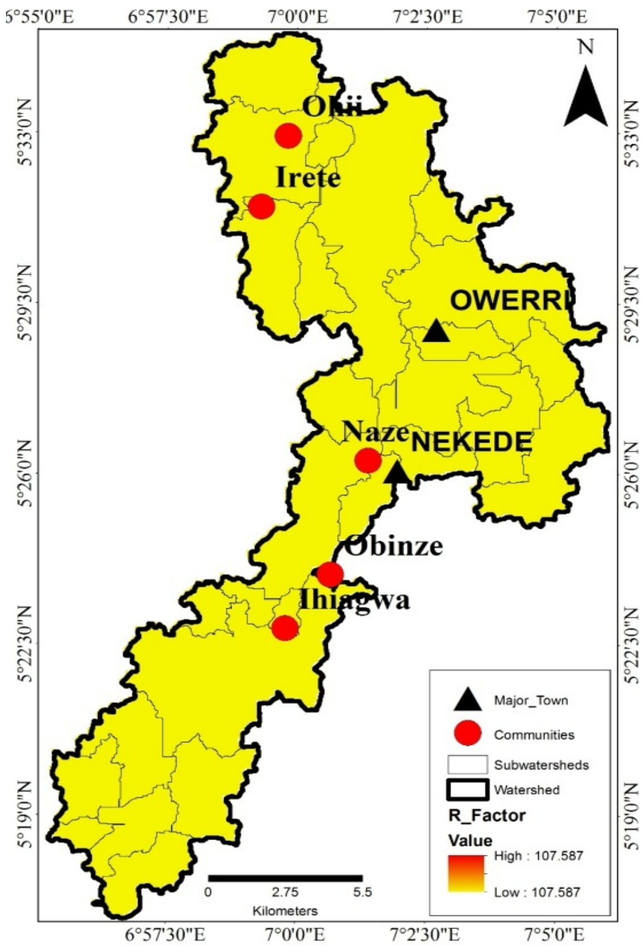

Figure 4. Map Showing Study Area Rainfall Erosivity

Soil Erodibility (K-Factor) Layer

With these results obtained from the erodibility nomograph as shown in table 3 below, the spatial distribution of the K factor was computed in the ArcGIS environment as shown in figure 5 and 6 below using an inverse distance weighting interpolation. Comparing the erodibility indices of the soil samples from the communities in the study area with the standard erodibility indices in table 4, shows that soils from Ohii and Irete with higher erodibility status fall into Group II which indicates well drain soils in sandy graded free materials. While Naze, Ihiagwa and Obinze with lower erodibility status fall under Group I which indicates Permeable outwash well drain soils having stony substrata.

Table 3. Erodibility Factor Values of the Communities in the Study Area

COMMUNITY	K-Factor
Ohii	0.145
Naze	0.1043
Irete	0.125
Obinze	0.0525
Ihiagwa	0.05

Table 4. Standard Erodibility Indices

Group	*K*-Factor	Nature of Soil
I	0.0 – 0.1	Permeable gracia outwash well drain soils having stony substrata
II	0.11– 0.17	Well drain soils in sandy graded free material
III	0.18– 0.28	Graded loams and silt, loam
IV	0.29– 0.48	Poorly graded moderately fine and textured soil
V	0.49– 0.64	Poorly graded silt or very fine sandy soil, well and moderately drain soils

Source: Peter *et al.* (2008)

Slope Length and Steepness: LS-Factor Layer

The percentage slope of the watershed described the relatively flat surface nature of the area as seen in figure 7 and figure 8 below. The average sub watershed slope is 5.89%.

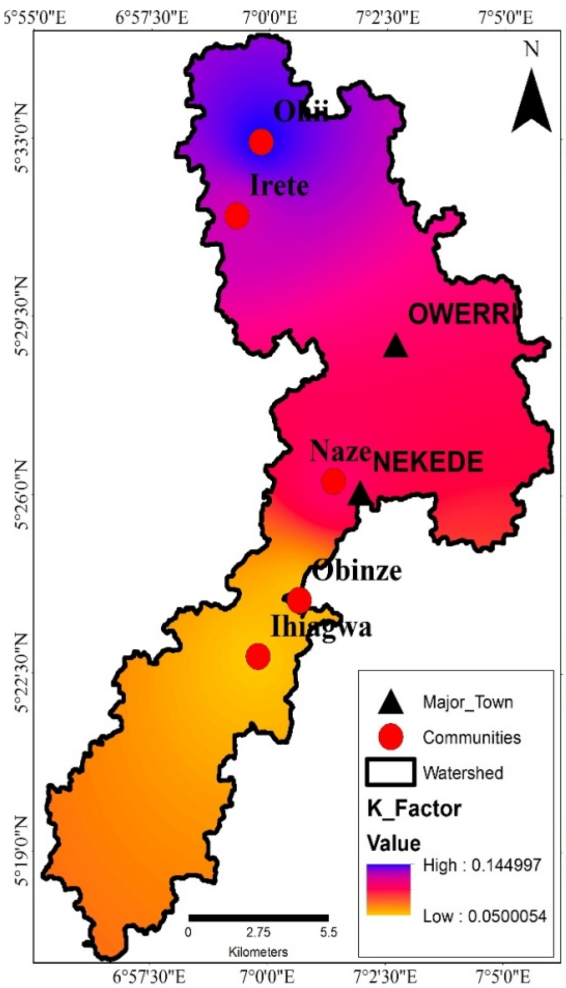

Figure 5. Map showing the Spatial Distribution

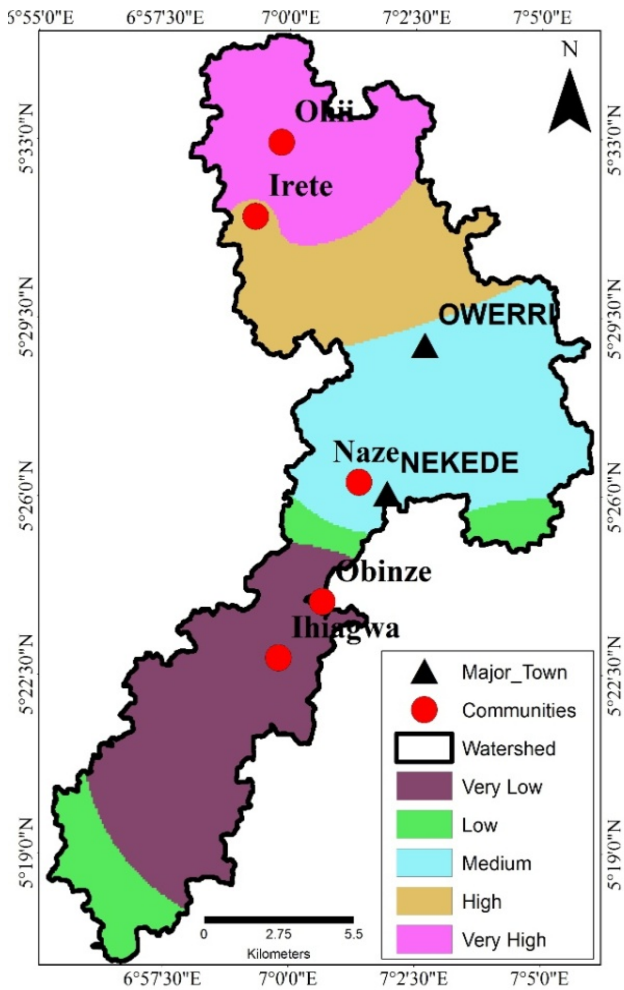

Figure 6. Map showing the reclassified Spatial Distribution

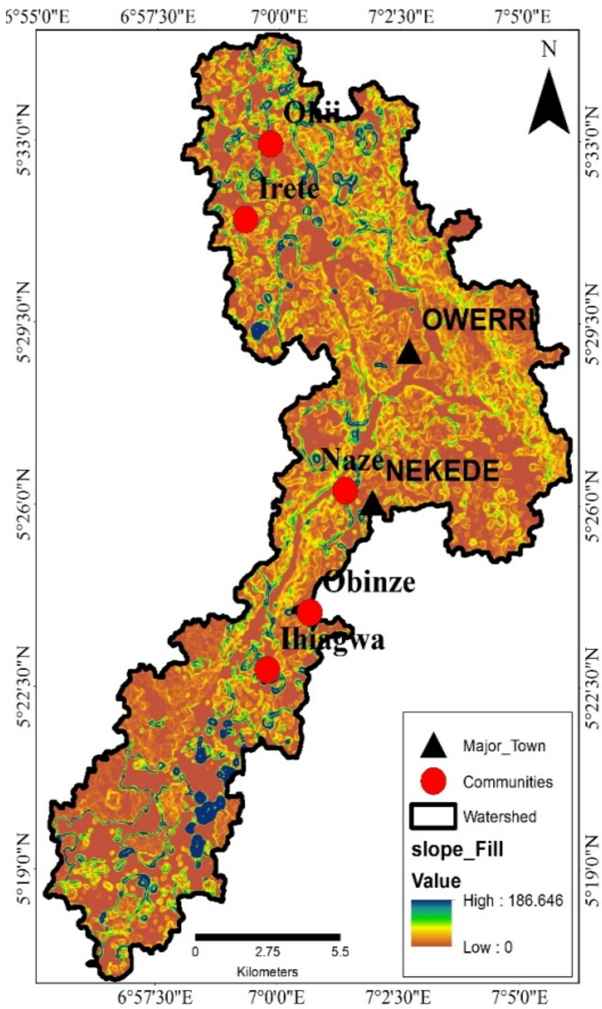

Figure 7. Map showing the LS-Factor of the Study Area Watershed

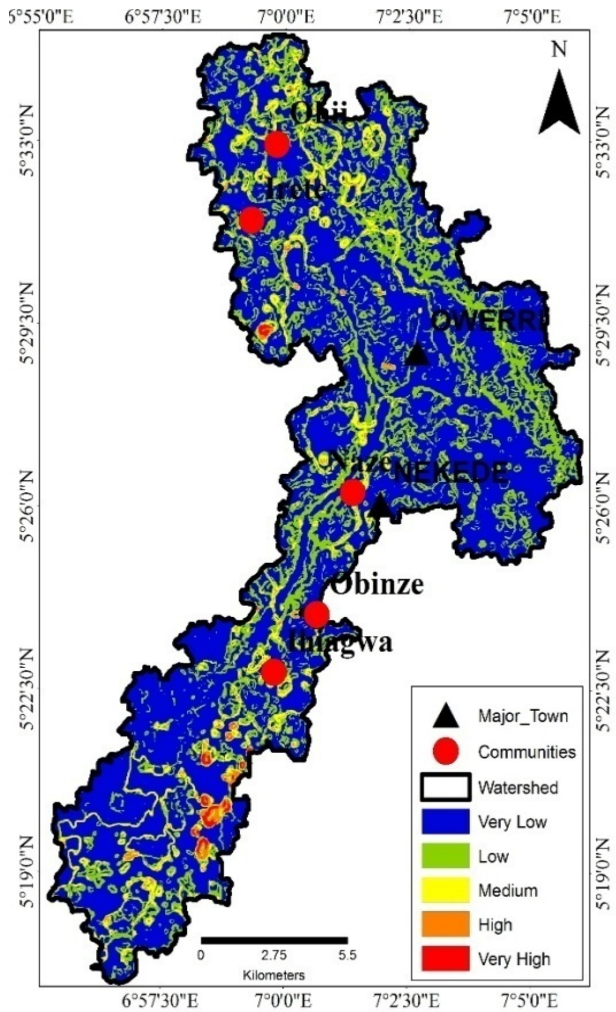

Figure 8. Map showing the Reclassified LS-Factor of the Study Area Watershed

LULC Distribution and Cover Management (C-Factor) Layer

The cover and management factor is an index that indicates how crop management and land cover affect soil erodibility. The distribution of factor C in the study area is quite heterogeneous. Bare soils which have the highest C-factor, are unevenly distributed within the study area accounting for 16.9% of the total area while the forested areas with low C-factor and the least susceptible to erosion accounts for 23.36% of the total area. The area was dominated by built up areas which accounted for 29. 84% of the total area, Agricultural land cover which is the least practiced land use in the study area accounted for 12.16% and so on as seen in table 5 below. The large extent of the built up areas can be said to be the evidence of urbanisation trend in Ihiagwa, Obinze, Owerri municipal and its environs, from the visual assessment the built areas were mainly a function of residential buildings, although banks, school, hotels, shops/offices and eateries can also be attributed to this land use activity.

Table 5. Land Use Percentage Distribution

Land Use	Percentage Coverage	Sensitivity index
Forest	23.36	Very Low Sensitivity
Shrub/ Scrub	16.85	Low Sensitivity
Agric. Land	12.16	Medium Sensitivity
Built-Up	29.84	High Sensitivity
Bare Surface	16.9	Very High sensitivity
Water	0.9	N/A
Total	100	

The figure 9 below is a map showing the land use activities and its distribution on the watershed.

Level of Imperviousness Layer

The result of the impervious surface analysis as shown in figure 11 shows that about 53.57% of the sub watersheds were less than 10% imperviousness while 46.43% were between 10% to 25% imperviousness.

Drainage Density Layer

The result of the drainage density as seen in figure 12 below shows that 22.59% had very low drainage density, 23.50% had low drainage density, 30.04% are of moderate drainage density, 8.69% made up the high drainage density while 15.19% covered very high drainage density areas. High drainage density indicates limited infiltration, promote considerable runoff, and have at least moderately erodible surface materials (www.cengage.com) while low density areas indicates high infiltration, reduced runoff and less erodible soils.

Population Layer

The spatial distribution of the study area as displayed in figure 14 shows that the population ranged between 5,093.078 to 40,668.97 with Owerri municipal surrounding environs owning the highest population therefore likely to account for the area with the highest human impact on the environment that are likely to lead to erosion in the study area.

Erosion Sensitivity Map of the Study Area

All factors referred to as thematic layers analysed were computed and overlaid by the use of GIS functions. The result is a classified erosion sensitivity layer as shown in figure 16 below. The classification was into 4 levels of sensitivity ranging from low to very high. The area expressed majorly a medium sensitivity to erosion constituting 57.56% of the entire area although other sensitivity levels were expressed in the area.

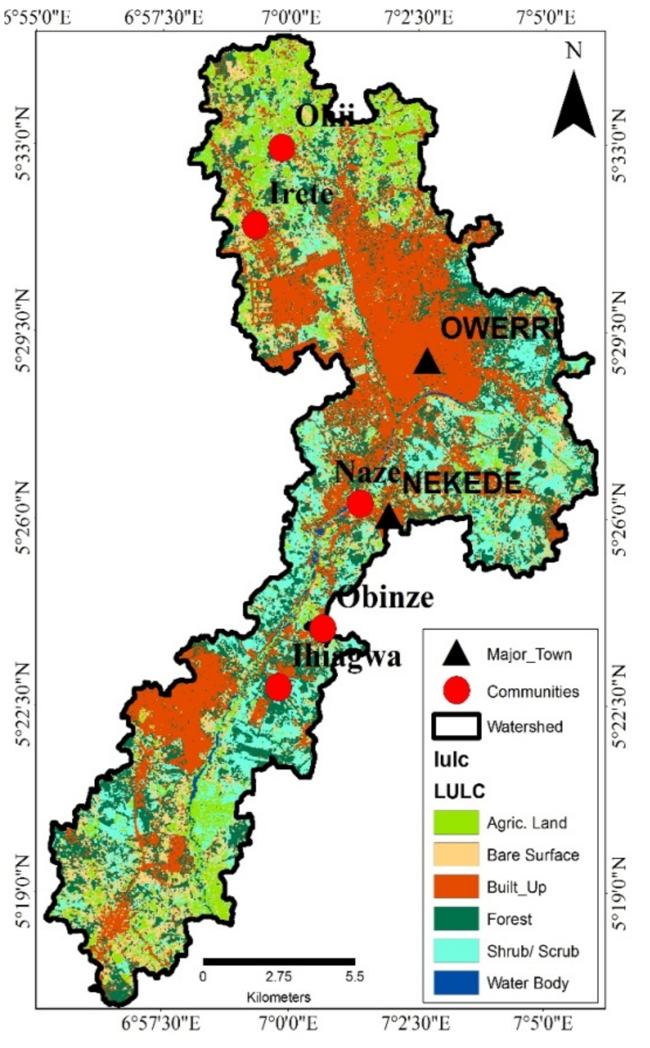

Figure 9. Map of study area sub watershed showing land use distribution

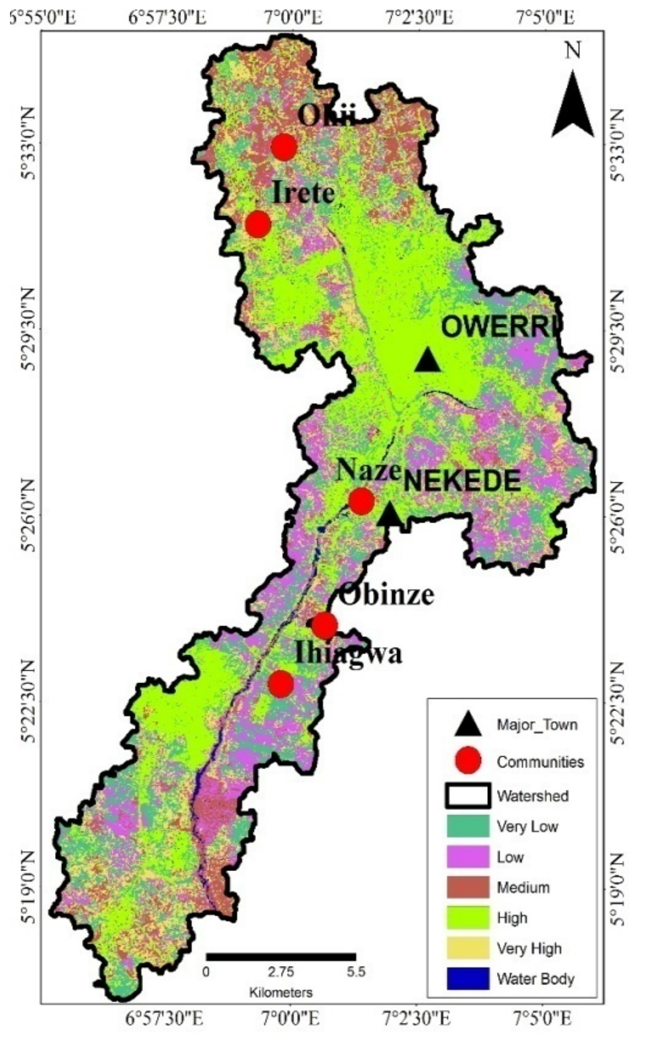

Figure 10. Map of study area showing C_Factor (Reclassified Land use/ Land cover)

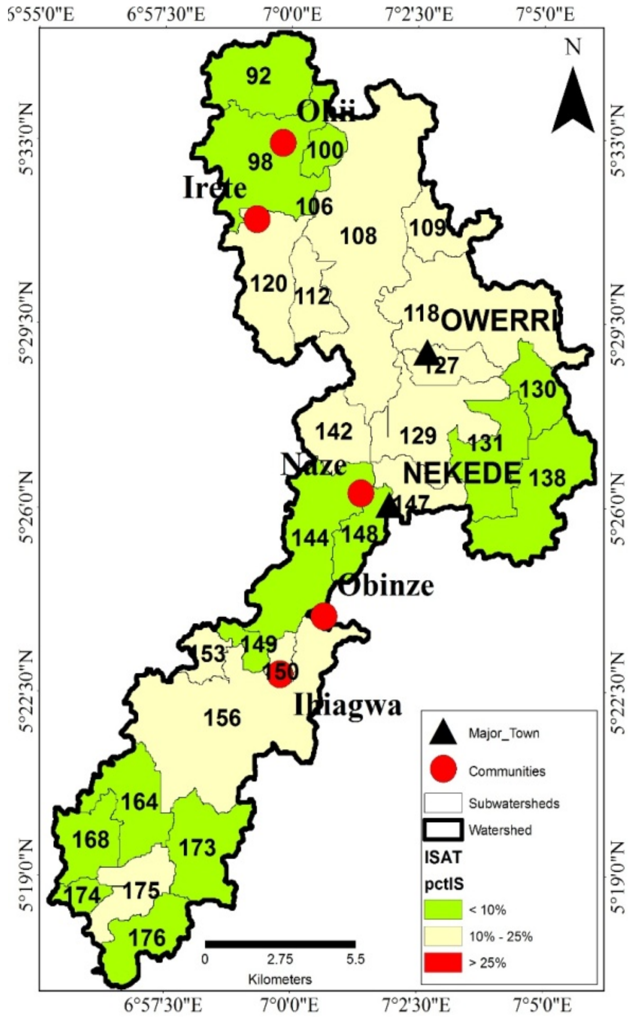

Figure 11. Map Showing Study Area Imperviousness

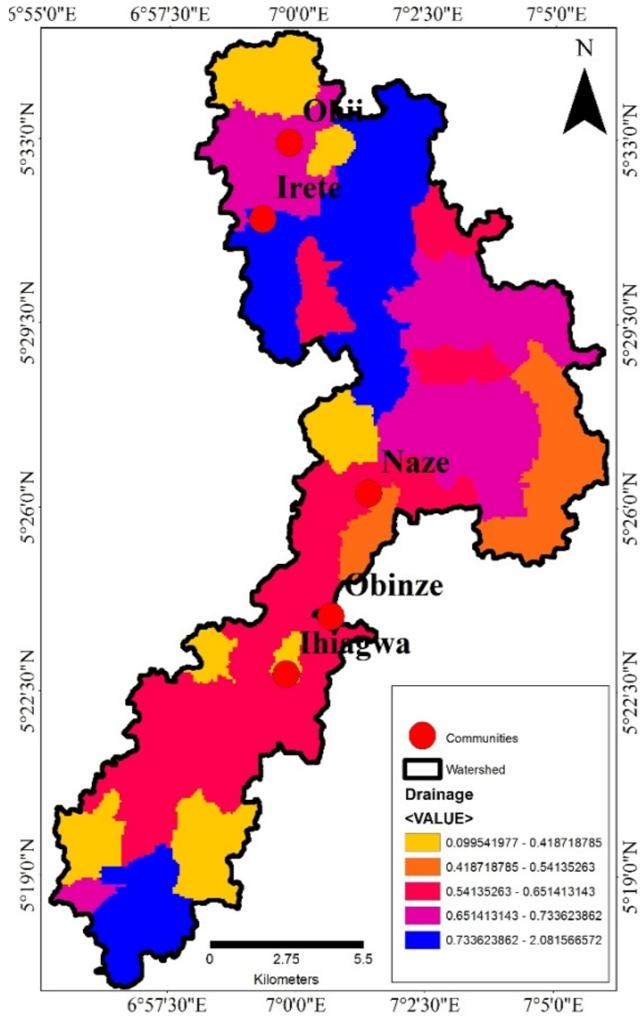

Figure 12. Result of the Study Area Drainage Density

Very High and High Sensitivity classes were experienced majorly at Owerri municipal and its environs, this from the above assessments can be attributed to high population which leads to more human impact that are likely to lead to erosion. Also, the high erodibility of the soils in these areas is a major contributing factor since highly erodible soils are more sensitive to erosion menace. The level of imperviousness in these areas which is relatively high denotes reduced infiltration rate and generation of high amount and rate of runoff which accelerates erosion. Finally, the land use in these areas which is majorly Built-up implies a high cover management factor which in turn indicates poor soil cover and high exposure of soil to the direct impact of raindrops and erosive potential of surface runoff. Although the drainage density in these areas ranges from very low to moderate, its effect in reducing the sensitivity of these areas are nullified by the effect of the above mentioned factors.

Medium sensitive areas were majorly distributed in the study area. This sensitivity class constitutes areas of low population density that reduces human effect on erosion due to population explosion; very low to low erodible soils which reduces its tendency of being detached and transported by raindrops and runoff; relatively flat terrain which produces low runoff rates and hence low runoff erosive potential; low to moderate imperviousness generates low to moderate runoff and low to moderate erosion potential and the LULC is basically shrubs and Agricultural Land which gives a reasonable resistance to erosion.

Low Sensitive areas are the least distributed in the study area. Their low sensitivity can be attributed to low population density, very low to low soil erodibility class, relatively very flat terrain, low level of imperviousness, low to very low drainage density and very low crop management factor.

4. Conclusions

This study has shown that integrating RUSLE prediction model and other environmental components such as drainage density, level of imperviousness and population data were integrated into the GIS platform, thereby making it possible and easier to study each environmental component independent of others. The watershed approach was applied in the study to enable the study area to be broken up into different environmental components and therefore studied independently. This model can be extrapolated to a larger watershed land area if the functional capacities of GIS are used, because they allow model integration of additional basic and factorial data. At the same time, the thematic and derived maps for each factor layer can be updated and evaluated to assure precision before executing the model and obtaining the final map of sensitivity to erosion.

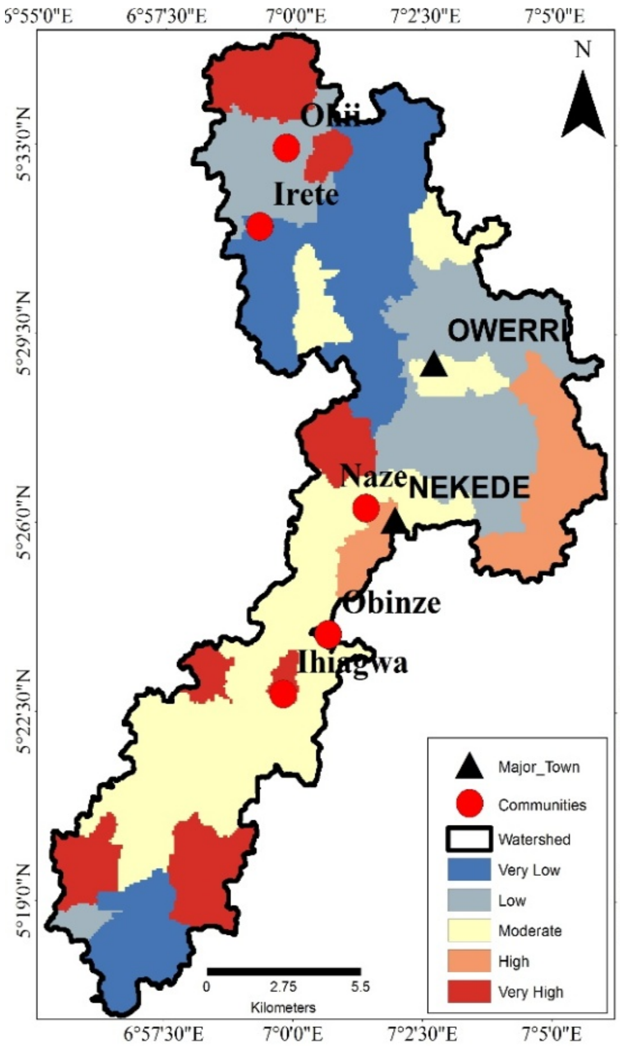

Figure 13. Result of Reclassified Drainage Density

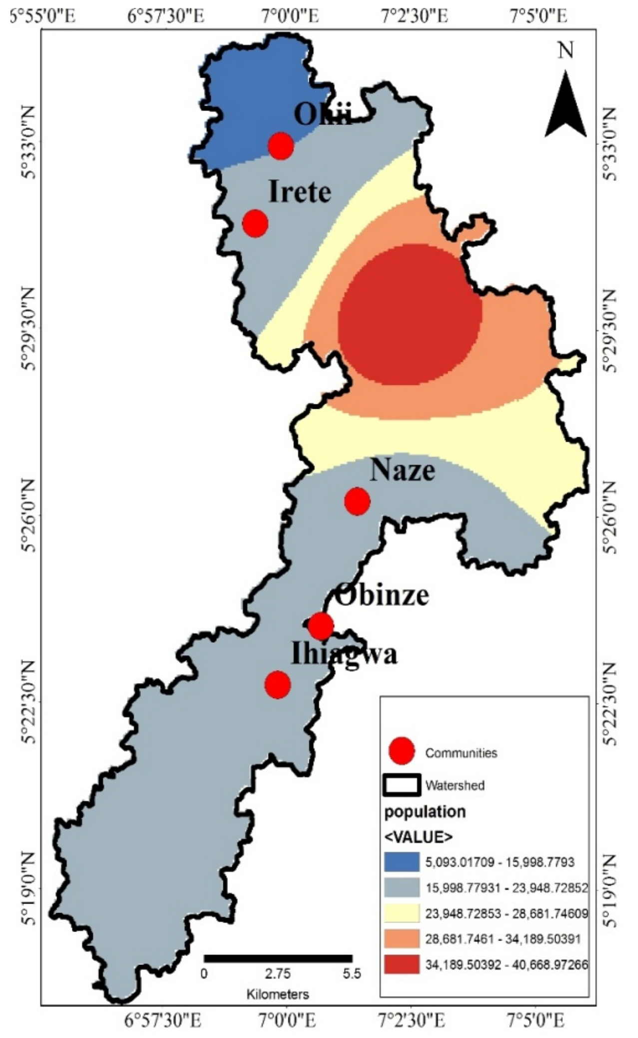

Figure 14. Map Showing the Spatial distribution of population

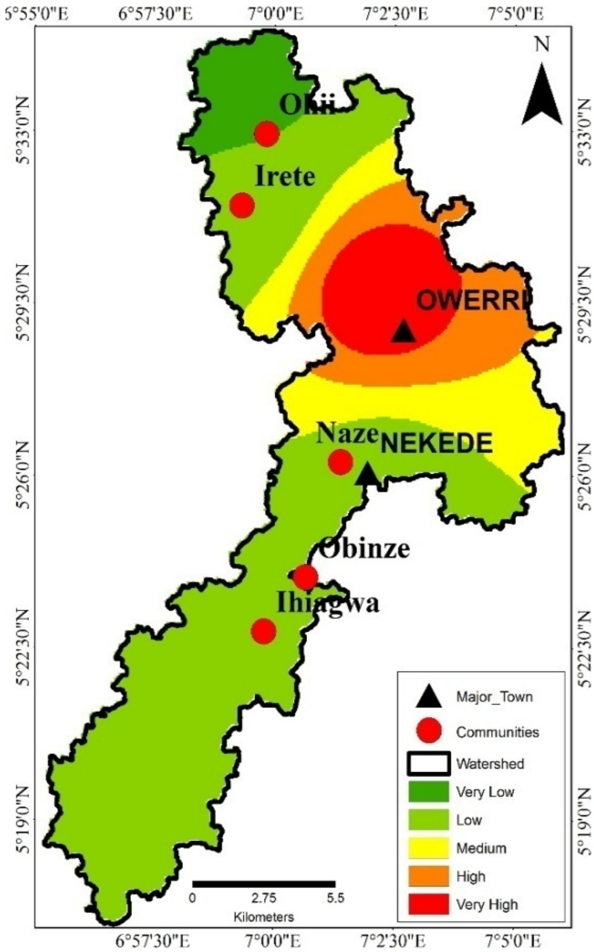

Figure 15. Map Showing the Reclassified Spatial distribution of population

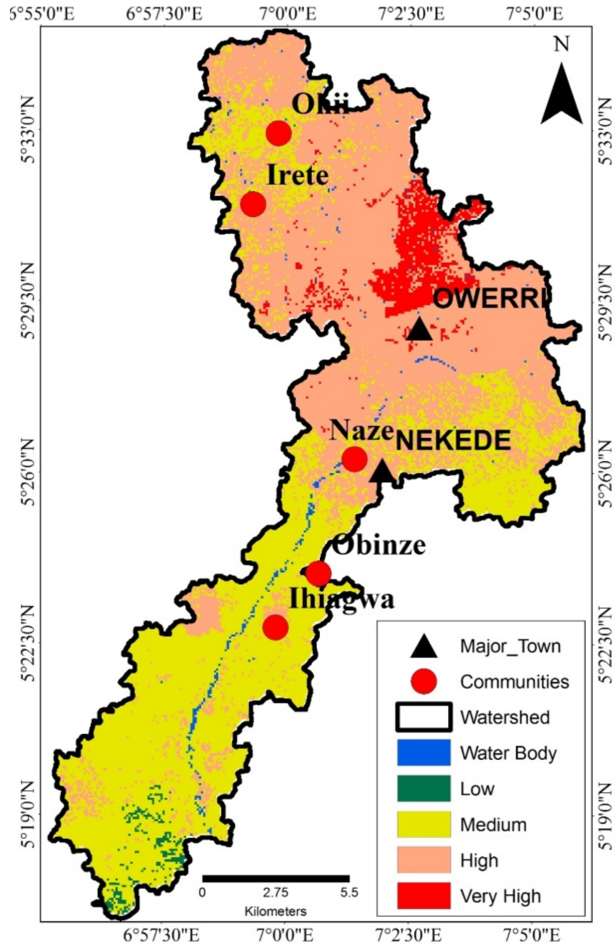

Figure 16. Map Showing the Sensitivity of the Study Area to Erosion

---

REFERENCES

[1] Raissouni, A., L.K. Issa, A. El. Arrim, M. Maatouk and R Passalacqua, 2012. GIS Based Model to Assess Erosion Sensitivity in Northern Morocco, Laou Watershed Case Study. *International Journal of Geosciences*, 2012, 3, 610-626.

[2] Kostadinov, S., 2002. Erosion and Torrent Control in Mountainous Regions of Serbia. *Preceeding Keynote Paper, International Year of Mountainous Conference*. Natural and Socio-economic Effects of Erosion Control in Mountainous Regions.

[3] American Society of Agricultural and Biological Engineers, 2002. In Defence of Soil and Water Resources in the United States: *Soil Erosion Research Priorities.* http://topsoil.nserl.purdue.edu/~flanagan/erosymp/ASAE-position-paper.pdf.

[4] AC-Chukwuocha, N. B. 2015. Analysis of Structural Changes in Landuse and Landcover of Otamiri Watershed in Owerri, South east Nigeria. *Journal of Environmental and Earth science*, 5(6):51-59.

[5] Nwilo, P. C., Olayinka, D. N., Uwadiegwu, I., & Adzandehi, A. E. 2011. An Assessment and Mapping of Gully Erosion Hazards in Abia State. A GIS Approach Journal of Sustainable Development, 4(5).

[6] Ezezika, O. C and Adetona, O. 2011. Resolving the gully erosion problem in Southeastern Nigeria: Innovation through public awareness and community-based approaches. *Journal of Soil Science and Environmental Management,* 2(10), 286-291.

[7] Obiadi, I. I., Nwosu, C. M., Ajaegwu, N.E., Anakwuba, E. K., Onuigbo, N. E., Akpunonu, E. O., and Ezim, O. E., 2011. Gully Erosion in Anambra State, South East Nigeria: Issues and Solution. *International Journal of Environmental Sciences,* 2, (2), 795-804.

[8] Okereke, C. N., Onu, N. N., Akaolisa, C. Z., Ikoro, D. O., Ibeneme, S. I., Ubechu, B., Chinemelu, E.S., and Amadikwa, L.O. 2012. Mapping Gully Erosion Using Remote Sensing Technique: A Case Study of Okigwe Area, Southeastern Nigeria. International Journal of Engineering Research and Applications (IJERA), 2, (3), 19551967.

[9] Igbokwe, J. I. Akinyede, J. O., Dang, B., Alagac, T., Onoa, M. N., Nnodu, V. C., Anike, L. O. 2008. Mapping and monitoring of the impact of gully erosion in Southeastern

Nigeria with satellite remote sensing and Geographic Information System. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 37, B8. Beijing.

[10] Anejionu, O.C.D., P.C. Nwilo and E.S. Ebinne, 2013. Long Term Assessment and Mapping of Erosion Hotspots in South East Nigeria. *Remote Sensing for Land use and Planning* – 6448.

[11] Ezemonye, M.N. and C.N. Emeribe, 2012. Rainfal Erosivity in South Eastern Nigeria. *Ethiopian Journal of Environmental Studies and Management 5,* 2. http://dx.dio.org/10.4314/ejesm.v5i2.1.

[12] Peter, A.I., H.I. Mustapha, J.J. Musa and J. Dike, 2008. Determination of Erodibility Indices of Soils in Owerri West Local Government Area of Imo State, Nigeria. Department of Agricultural engineering, Federal University of Technology, Minna, Niger State, Nigeria.

[13] Renard, K., G. Foster, G. Weesies, D. McDool, and D. Yoder, 1997. Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss. Equation (RUSLE).*Agricultural Handbook 703, USDA-ARS.*

[14] Soo Huey, T., 2011. *Soil Erosion Modelling Using RUSLE and GIS on Cameroun Highlands, Malaysia for Hydropower Development*. The School for Renewable Energy Science, Akareyri, Iceland.

[15] Lee, G.S., and Lee, K.H. 2006. Scaling effect for estimating soil loss in the RUSLE model using remotely sensed geospatial data in Korea. Hydrology and Earth System Sciences Discussuions 3, 135-157. Korea Water Resource Corporation, 462-1 Jeonmin-dong, Yusung-gu, Daejeon, Korea.

[16] Stone, R. P. and D. Hilborn, 2002. Universal Soil Loss Equation (USLE). Factsheet Ministry of Agriculture, Food and Water Resources, Ontario.

[17] Wischmeier, W.H., C.B. Johnson and B.V. Cross, 1971. A Soil Nomograph for Farmland and Construction Sites. *Journal for Soil and Water Conservation 26*: 417-424.

[18] Walkey, A., 1935 An examination of methods for determining organic carbon and nitrogen in soils. Journal of Agricultural Science, v.25, p.598-609.

[19] Wischmeier, W., and D. Smith, 1978. Predicting Rainfall Erosion Losses- A Guide to Conservation Planning. *U.S. Department of Agriculture Handbook*, No.537.

[20] Karaburun, A., 2010. Estimation of C Factor for Soil Erosion Modelling using NDVI in Buyukcekmece watershed. *Ozean Journal of Applied Sciences 3(1*), Turkey.

[21] Anthony, T.O, E. Rachael and L. Davis, 2006. *Erodibility of Agricultural Soils with Example in Lake and Mendicino Countries.* University of California Division.

[22] Morgan, R.P.C., 2001. A simple approach to soil loss prediction: a revised Morgan-Morgan- Finney model. *Catena 44(4)*, 305-22.