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ASSESSMENT OF SOIL EROSION IN BIU LOCAL GOVERNMENT AREA, BORNO STATE, NIGERIA

ABDULLAHI AHMED

Department of Geography

College of Education Waka-Biu, Borno State

Email: abdullahiahmedbiu@gmail.com

Abstract: **Soil erosion is considered as one of the major land degradation process which is also the main source of environmental deterioration, which threatens urban infrastructures, properties, farmlands and physical growth of a town. The study aimed to assess soil erosion in Biu Local Government Area of Borno state and two types of data were used that is both primary and secondary data and were subsequently analyzed using digital spatial data for soil erosion analysis. The field survey and other observations and measurements have revealed that, the study area is majorly affected by rill and gully type of erosion due to high level of rainfall, low infiltration capacity of the soils, sparse vegetation and slope steepness of the area. The study also revealed that the effects of soil erosion in Biu Local Government Area is paramount as roads are being washed away, buildings are gradually degraded, bridges been collapsed and farmlands been leached. The study therefore recommends that the government at all levels should sensitize the masses on the causes and problems associated with soil erosion and the public should be enlightened on the importance of planting desirable trees, shrubs and grasses around possible eroded and erosion-vulnerable areas, individuals should also embark on improved farming techniques, cultural method of gully control, and enactment of laws against any activities that favours erosion growth.**

Keywords: **soil erosion, land degradation, surface run-off.**

I. INTRODUCTION

Soil erosion is also the natural phenomenon (geological process) which is caused by natural force; it can be more accelerated when the process is influenced by human activities (human induced erosion). It is considered that the accelerated soil erosion is a serious global problem and widely recognized (De Graaf, 1996). With the accelerated erosion, it can affect agronomic/biomass productivity (on-site effect) and flooding, sedimentation of reservoirs, siltation of agriculture field and decrease of water quality downstream (off-site effects). The two important agents of erosion are wind and water (Hudson, 1986).

Erosion by water has been identified as the most severe hazard that threatens the protection of soil (Victor 2003). The erosion process starts with sheet erosion (the washing out of surface soil from arable land), followed by rill erosion with the concentration of overland flow into small rivulets in the fields and finally the gully erosion. When the eroded channels are larger than 30cm deep, erosion reduce fertility status of topsoil, soil productivity, soil organic matter content.

Soil erosion is a natural process of soil material removal and transportation through the action of erosive agents such as water, wind, gravity and human disturbance. It is becoming clear that the transport of eroded material from land to water by overland flow via runoff is an important environmental problem promoting the eutrophication of surface waters, damaging freshwater ecosystems and causing microbial contamination of surface water sources (Sender *et al*., 2002). Erosion is generally recognized in several different forms; rill, splash, sheet and gully erosion. Soil loss by runoff is a severe ecological problem occupying 56 % of the worldwide area and is accelerated by human induced soil degradation (Bai *et al*., 2008; Gelagay and Minale, 2016). On a global scale erosion by water affects 1.1 billion hectares of soil worldwide thus representing 56% of the total degraded land area while wind erosion affects 28 % of total degraded land area (Humberto and Lal, 2008). Soil erosion is a single major process responsible for the loss of billions of tones of soil worldwide (Ibitoye and Adegboyega, 2012) and it remains the world's largest environmental problem threatening both plants and animals (Abegbunde *et al*., 2006).

Soil erosion in Africa threatens food and fuel supplies and can contribute to climate change. For over a century, governments and aid organizations have tried to combat soil erosion in Africa, often with limited effect. Currently 40% of soil in Africa is degraded.

Soil erosion and erosion-caused land degradation are serious problems in Nigeria. Low levels of crop yields observed in the some parts of the country are partly due to severe levels of past erosion and resultant decline in soil productivity. Borno as a state in Nigeria suffers a great deal of soil erosion, in several parts of the state under different geological, climatic and soil conditions. But the degree of occurrence varies considerably from one part of the state to the other.

II. STATEMENT OF THE RESEARCH PROBLEM

Soil erosion, is the removal of rock and soil material by natural processes, principally running water, glaciers, waves, and wind. In geomorphology and geology, erosion is the action of exogenic processes (such as water flow or wind) which remove soil and rock from one location on the Earth's crust, then transport it to another location where it is deposited,. Excessive (or accelerated) erosion causes both 'on-site' and 'off-site' problems. Soil degradation by accelerated water and wind-induced erosion is a serious problem and will remain so during the 21st century, especially in developing countries of tropics and subtropics. Erosion is a natural geomorphic process occurring continually over the earth's surface. However, the acceleration of this process through anthropogenic perturbations can have severe impacts on soil and environmental quality (Saha, 1991) Progressive soil erosion increases the magnitude of soil related constraints for crop production. The constraints can be physical, chemical or biological. Among the important soil physical constraints for crop production exasperated by erosion include: reduced rooting depth, loss of soil water storage capacity (Sertsu, 2000).

Biu as the study area is affected by immense soil erosion due to natural and artificial factors such as floods, soil creep, gully erosion, farming activities and deforestation

III. OBJECTIVES OF THE STUDY

The specific objectives of the study are to:

i. Examine types of soil erosion in Biu and its environs;

ii. Examine factors of soil erosion in the area and

iii. Assess the effects of soil erosion in the area.

IV. MATERIALS AND METHODS

The researcher visited various sites within Biu and environs for the research purpose and at each location erosion features were observed and the coordinates of these locations were taken to serve as the primary source of data for the study and measurement of features of interest such as settlements and excavation sites, farmlands, grazing land, refuse dump site were considered. Data on slope gradient in some selected locations were obtained through the use of the Abney level, ranging poles and measuring tape were used in measuring the slope. Digital Camera was used in taking photographs of features of interest while the researcher used GPS to take coordinates of features of interest. Various natural and artificial factors were examined on different location in Biu and their GPS coordinates were recorded. Types of soil erosion were observed and recorded along various gradients and locations.

Method of data analysis

This study relies on digital spatial data for soil erosion analysis. Therefore, satellite images, Digital Elevation data, soil data, and rainfall data were used in this study to derive land cover and land use maps, flow accumulation and stream network, predict areas susceptible to soil erosion, and the resultant effect in the environment. This detailed analysis was conducted at the Biu and environs' scale. To analyze soil erosion on the Biu Plateau, the following were acquired:

i. Digital elevation model (Data source: NASA/USGS)

ii. Average daily, monthly and annual precipitation Data (Source: NIMET)

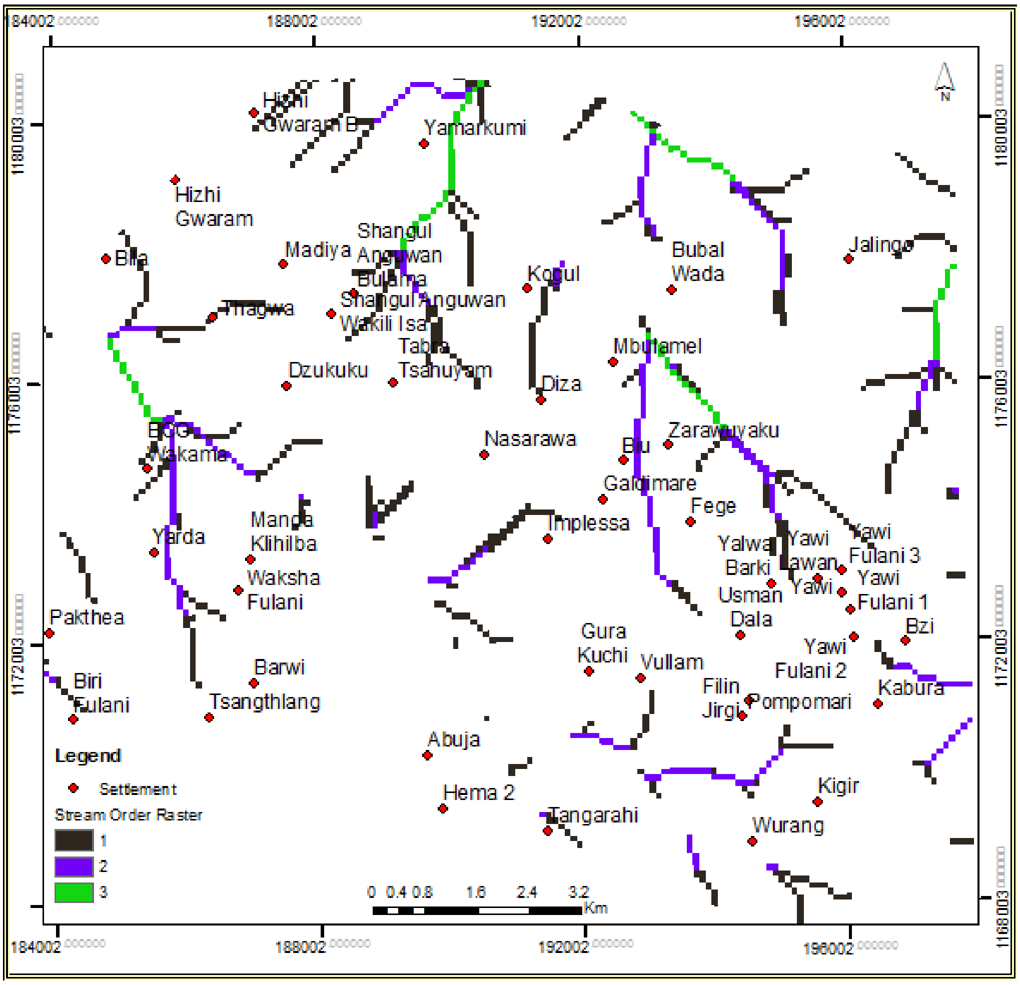
iii. Soil type map (Data source: NGS)

iv. Satellite images (Source: NASA/USGS)

V. RESULTS AND DISCUSSION

Types of Soil Erosion in Biu and environs

A watershed is the upslope area that contributes flow (generally water) to a common outlet as concentrated drainage. It can be part of a larger watershed and can also contain smaller watersheds, called sub basins. The boundaries between watersheds are termed drainage divides. The outlet or pour point, is the point on the surface at which water flows out of an area. It is the lowest point along the boundary of a watershed. The area upon which waterfalls and the network through which it travels to an outlet are referred to as a drainage system. The flow of water through a drainage system is only a subset of what is commonly referred to as the hydrologic cycle, which also includes precipitation, evapotranspiration and groundwater flow. The hydrology tools focus on the movement of water across a surface. This analysis coupled with field exercise reveal that most of the drainage networks receive the highest impact of surface runoffs thus causing washouts of river banks and top soils of certain basins. It was on this combined effects that the location of eroded sites where determined and mapped.



Source: NIMET

Figure 1: Stream Order Raster of Biu and Environs

The idea for calculating stream order was to distinguish between rivers and gullies within the study site. Analysis of the stream order raster reveals that there are basically three orders of stream network. The first order is characterized as locations of rill erosion occurrences normally at the high planes while the second order represents sites of gully usually where buildings are predominated. The third order transforms to relatively large streams where water banks experience washouts because of heavy downpours, this is evident around Biu Township with high percentage of annual rainfall.

The stream network extracted from the hydrologic analysis of Biu and environs came with so many revelations. This was substantiated through rigorous site visit by the researcher. Coordinate of most eroded sites were taken using GPS device and Geotagged Cameras to ascertain the spread and types of soil erosion noticeable in the study area.

The map reveals that Biu and its environs face serious threats of rill and gully type of erosion as a result of combination of different factors ranging from soil characteristics, sloppy and undulating nature of the topography, high intense rainfall, and impact of land cover changes over a period of time. On flat surfaces or early stages of a river, there is mostly sheet erosion of the entire landscape while in due course of time there are small channels that appear as rills. These rills get deeper due to the effect of water to concentrate in cavity and they form gullies. Both such erosion takes place over slopes in general. Hence, Biu and environs suffers the problem of rill erosion due to sloppy nature of the topography and movement of water along small channels on bare land with less vegetation cover and areas that faces gully erosion creates deep channels that the surface runoff is further enhanced.

Factors of Soil Erosion in Biu and Environs

The main factors affecting soil erosion are topography, climate, soil, vegetation, land use, and man-made developments (Shen and Julien 2013). Of these, climate is assumed to be beyond human control, and vegetation – and to a lesser extent soil and topography – may be controlled through management (Borah et al. 2008). A prediction of soil erosion using multiple variables is necessary for guiding the making of rational decisions in conservation planning. This section presents the abilities of GIS firstly by analyzing all the factors that are considered influential in inducing the occurrences of soil erosion in the study area. Analytical features of the GIS were equally utilized especially the spatial analyst tool in fusing together these many factors that are considered as inductors to soil erosion occurrences over the Biu and its environs. Each variable was first reclassified to produce a factor map; that is, each factor as a spatial distribution data spanning throughout the study area was analyzed to reveal areas within its properties that could be liable to soil erosion. Subsequently, soil erosion prediction formula was developed to enable planners to predict areas that could be susceptible to soil erosion.

i. Rainfall-Runoff Erosivity Factor

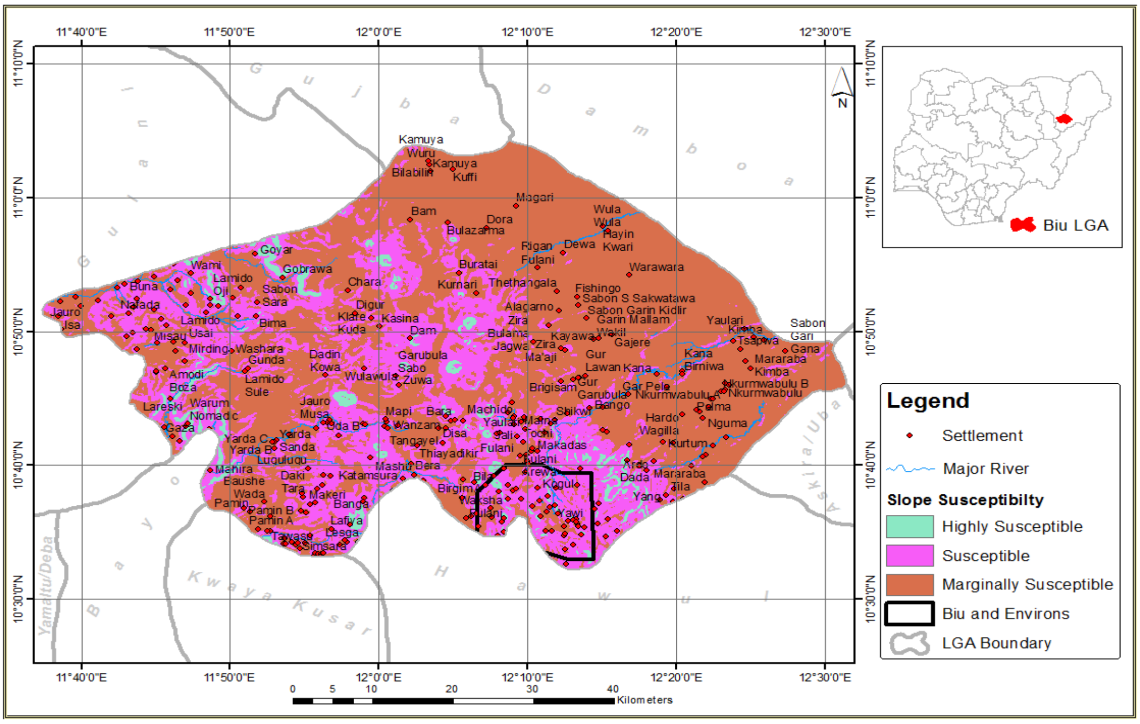
The rainfall-runoff erodibility factor R quantifies the effects of raindrop impact and reflects the amount and rate of runoff likely to be associated with rain (Renard et al. 1997). So a spatial precipitation distribution raster was used in the absence of local gauge data. The data was extracted from the global precipitation data of the West Africa using ArcGIS clip tool. This general approach is based on the extrapolated relationship between R-values estimated from global climatic stations having the required data and the associated annual precipitation data. The study reveals that rainfall-runoff is the most active factor that promotes soil erosion in Biu and its environs due to its plateaux characteristics which indicates high level of rainfall per annum.

ii. Slope Length and Slope Steepness Factor (LS)

The digital elevation data of the study area was in this case used for modeling the slope of the area. It was equally used to compute flow accumulation map of the Biu plateau. The slope length factor (L) and the steepness factor (S) account for the effects of topography on soil erosion modeling in a multivariate analysis. Mahamane (2015) points out that, as slope length (L) increases, erosion increases due to a progressive accumulation of runoff in the down slope direction. As slope steepness (S) increases, soil erosion also increases as a result of the increase in velocity.

Slope length (L) is defined as the horizontal distance from the origin of overland flow to the point where either the slope gradient (steepness) decreases enough so that deposition begins or runoff becomes concentrated in a defined channel (Wischmeier and Smith 1978). Slope length (L) is also defined as the ratio of soil loss from the field slope length to that from a 72.6 ft length under otherwise identical conditions.

The "flow accumulation" function in ArcGIS is a tool which computes accumulated flow as the accumulated weight of all cells flowing into each down slope cell in the output raster. With this function, the value of cells in the output raster is the number of cells that flow into each cell (O'Callaghan and Mark 1984). In Figure 2, the top left image shows the direction of travel from each cell while the top right shows the number of cells that flow into a cell. The bottom left indicates the possible direction of flow which can be in either one of the cardinal direction (i.e. N, S, E, W) or the diagonal directions (i.e. NE, SE, SW, NW) using a colored direction coding. The finding therefore is that most parts of Biu and its environs lies in the susceptible areas of soil erosion due to its slope steepness characteristics.



Source: USGS/METTI

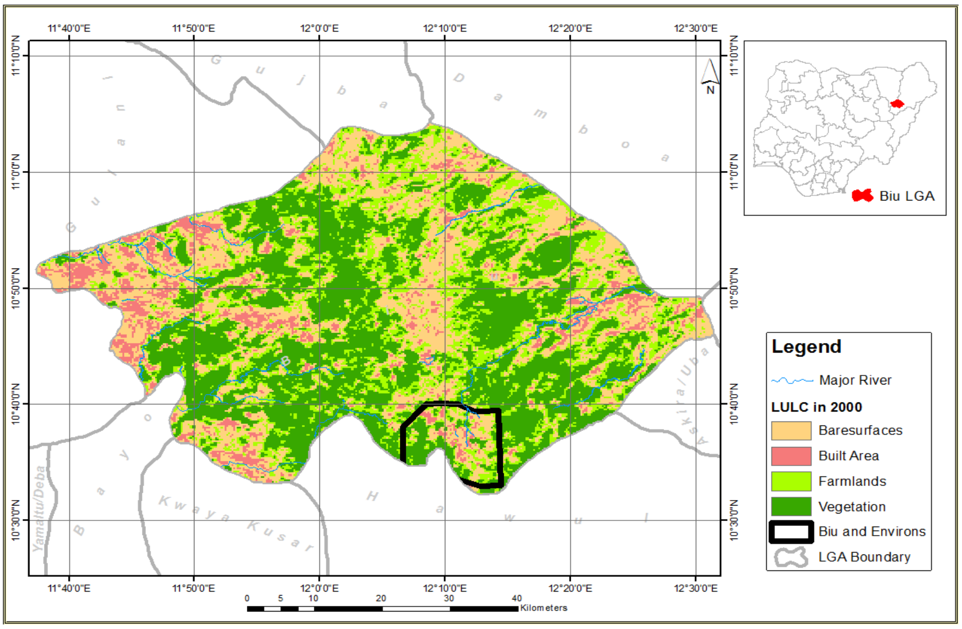
Figure 2: Slope Erodibility Factor Map of Biu LGA (Researcher's GIS Lab Work, 2019)

iii. Cover Management Factor (C)

The Cover Management Factor (C) represents the effect of vegetation, soil cover, below-ground biomass, cropping, soil-disturbing activities and management practices on soil erosion. The C factor is essentially a soil loss ratio (SLR) which is defined as the ratio of soil losses under actual conditions to losses experienced under the clean-tilled continuous fallow reference conditions.

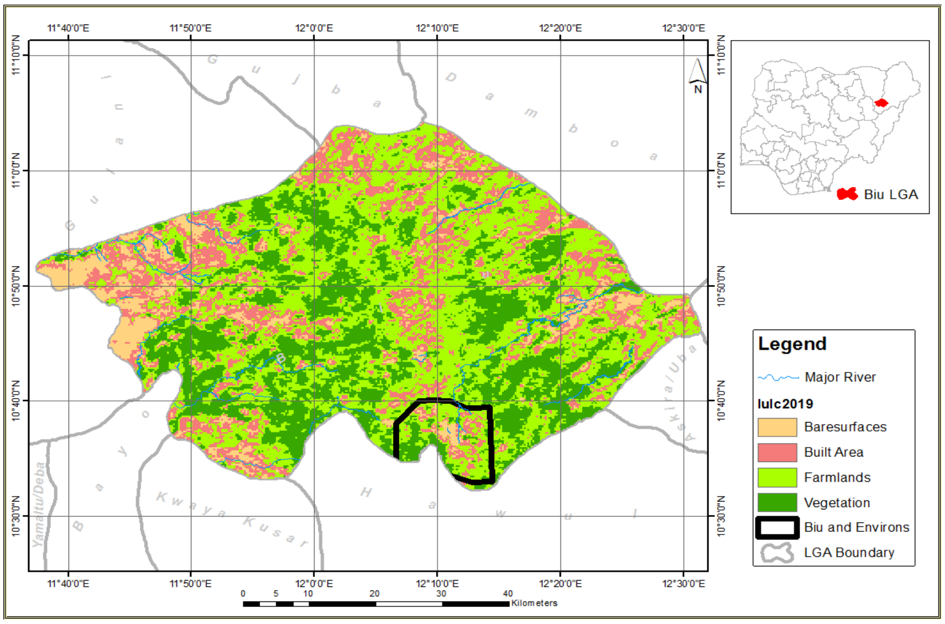
The density of protective cover of vegetation on the land surface affects directly the soil erosion rates. In this research, the entire Biu LGA was firstly used in producing vegetative factor map of soil erosion for multivariate modeling. MODIS data at 30 second representing normalized difference vegetative index of the study area having reclassified into three gave rise to different classes of land cover scales namely: thick vegetation, scanty vegetation, bare surfaces, and water bodies. Analysis of vegetative cover over the Biu Plateau was undertaken temporally from year 2000 to year 2019 so as to understand impact of anthropogenic activities and climate change on the environment and how it induces soil erosion over the Biu Plateau.

Figures 3 and 4 show vegetative cover conditions of the Biu Plateau in 2000, and 2019 respectively; the figures reveal a gradual and subsequently rapid change in the vegetative cover. The thick vegetation had steadily lost to crop fields and scanty woodlands. Bare surfaces and built environment have astronomically increased over the period of 40 years as can be seen from the trend maps; these are major forces within the vegetation parameter that exposed the Biu soil to constant hit by rainfall. To produce a vegetative factor map for multivariate modeling of soil erosion in the area, the recent cover map was used as a benchmark to reclassify the mapped land covers into highly susceptible, marginally susceptible, susceptible, and not susceptible using codes 1 and 2 respectively. The forest area decreased by about by 50% from 2001 to 2019; in 2013, the area covered by the forest represented only 5 % of the Biu Plateau area. According to Ahmed (2002), this forest mainly degraded into grass and shrubs cover during these periods.



Source: USGS

Figure 3: Landuse/Landcover Map of Biu LGA in 2000 (Researcher's GIS Lab Work)



Source: USGS

Figure 4: Landuse/Landcover Map of Biu LGA in 2019 (Researcher's GIS Lab Work)

The area covered by grass and shrubs decreased by about 14% between 2001 and 2019. The bare land/burned grass/plowed land/rain-fed crop area increased dramatically between 2000 and 2019 by about 273%, gaining areas from grass, and shrub-covered areas; the settlement area increased by about 54% between 2000 and 2019.

Weighting and scoring operation was performed to give priority to a factor that is more influential to the erosion processes. In this research, soil characteristics and rainfall intensity were seen as the leading factors; hence 30% impact factors were allotted to each. Practically, in soil erosion modeling, soil erodibility is an integration of the impacts of rainfall and runoff on soil loss for a given soil (Haan et al. 1994). As explained by Mahamane (2015), soil erodibility factor is the rate of soil loss per rainfall erosion index unit for a specific soil as measured on a unit plot. This however, makes soils an integral constituent that remains inseparable with rainfall factor as key ingredient holding the highest percentage weight in modeling soil erosion occurrences of an area.

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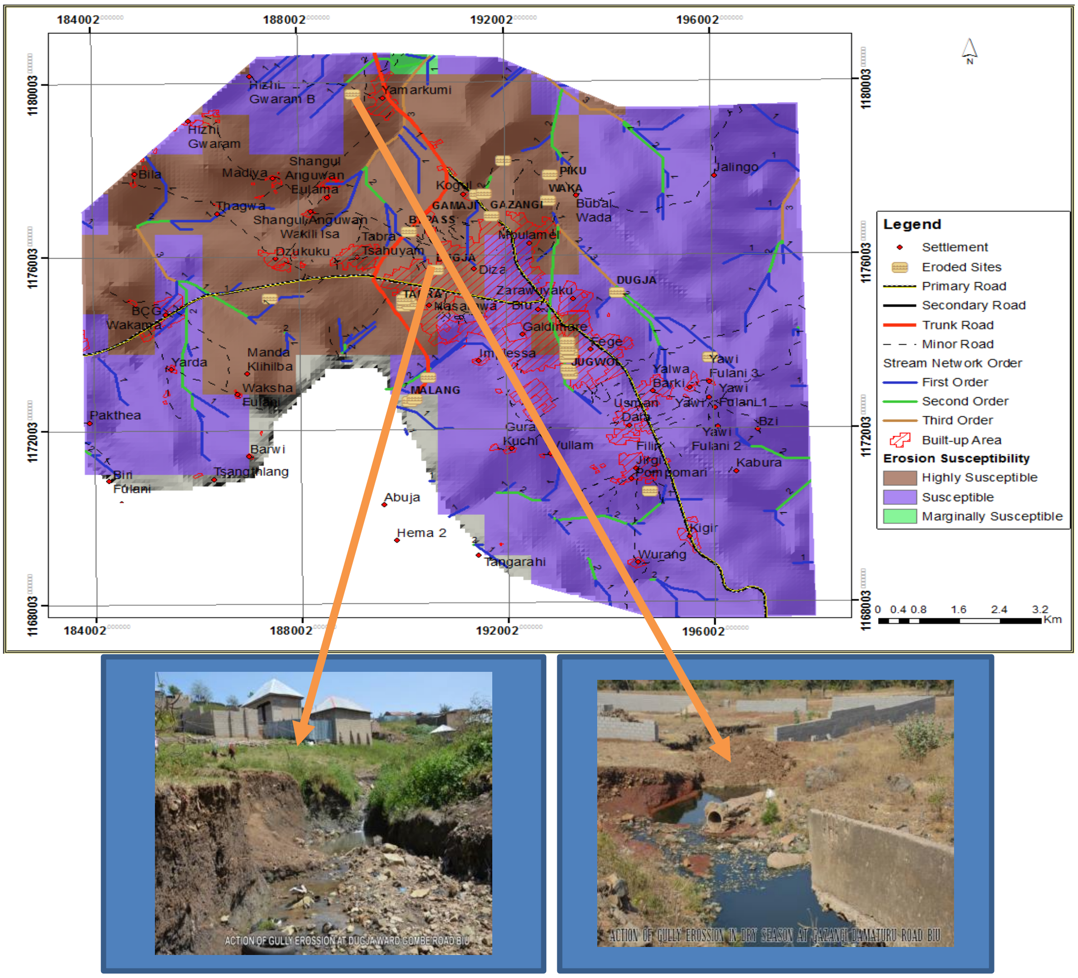
The immediate factor with a reasonable impact factor is 'slope'; this factor was allotted 25% while landuse was finally given 15%, all out of 100%. The raster math tool in ArcGIS spatial analyst extension was used, where the above expression was typed on the syntax space. All the four factor maps indicating the spatial distribution of susceptibility levels were fused to produce a one final map that portrays explicit sites with varying levels of susceptibility to soil erosion.

Effects of Soil Erosion in Biu and environs

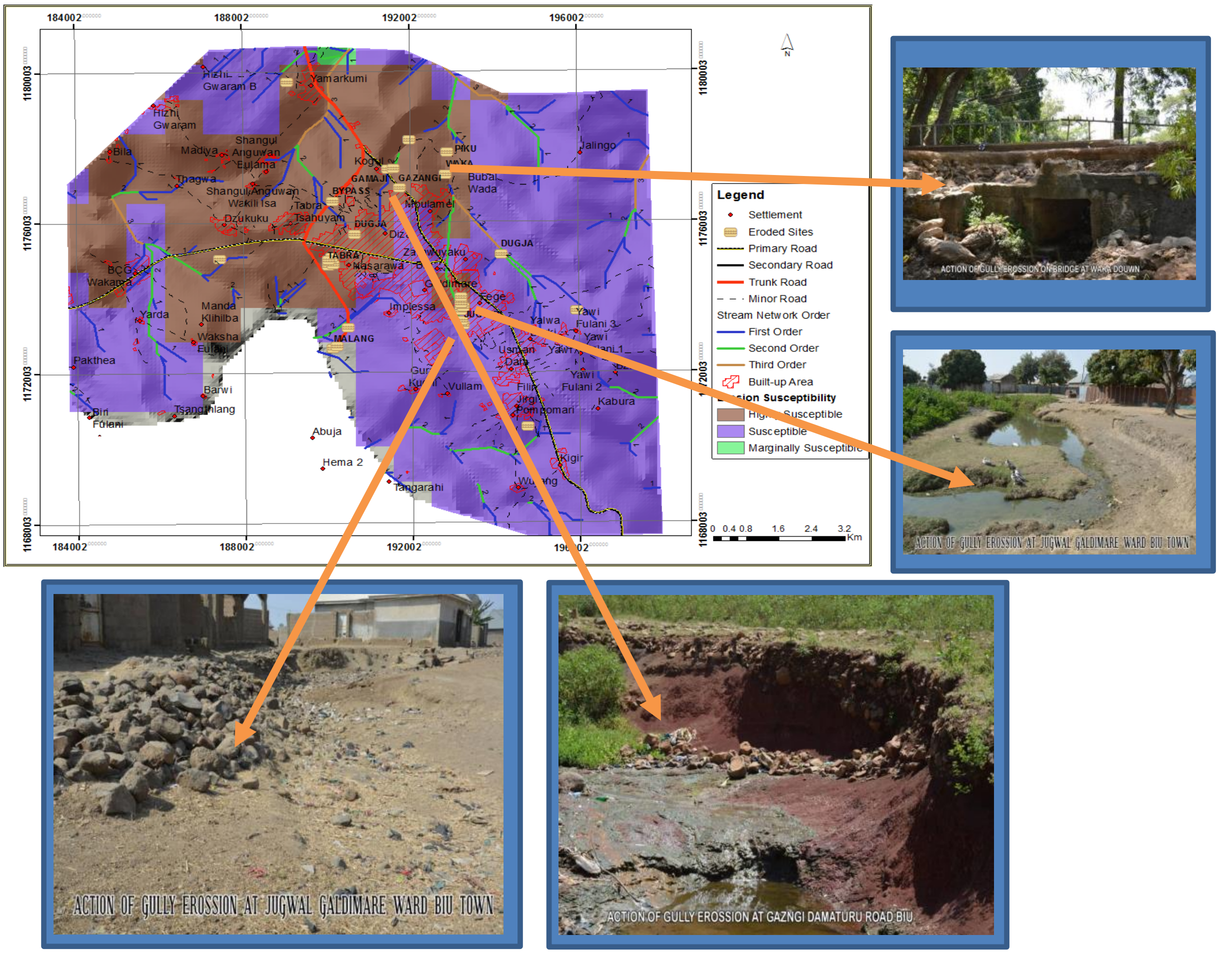
The initial and first impact of land degradation is the abandonment by members of the communities forcing automatic or emergency migration on the dwellers or their means of livelihood. The consequences of land degradation can scarcely be fully quantified considering the deposits of debris in rivers, water paths, and fertile lands over taken by sand deposits or sand dunes or eroded soil, and pollution of water from used agrochemical materials, it has been estimated that over 38 percent of 1.5 billion hectares of arable land worldwide is totally or partially degraded, with Africa and Asia having the largest percentage of agriculture and forest land (Scherr and Satya, 1997).

The off-site impacts of soil erosion by water are not always as apparent as the on-site effects. Eroded soil, deposited down slope, inhibits or delays the emergence of seeds, buries small seedlings and necessitates replanting in the affected areas. Also, sediment can accumulate on down-slope properties and contribute to road damage. Sediment that reaches streams or watercourses can accelerate bank erosion, obstruct stream and drainage channels, fill in reservoirs and degrade downstream water quality. Some of the challenges of this menace are noticeable in figures 5 and 6. Having land uses overlaid on the mapped eroded sites and the susceptibility map, it is evident that many roads are currently being washed away, buildings are gradually degraded, bridges been collapsed, and the agricultural lands been leached as a result of soil erosion in Biu and Environs.



Source: Researcher's Field Survey 2019

Figure 5: Soil Erosion Map and Impacts on Biu and Environs



Source: Researcher's Field Survey 2019

Figure 6: Erosion Map and Impacts on Biu and Environs

VI. DISCUSSION OF FINDINGS

Biu and its environs face serious threats of rill and gully erosion as a result of combination of different factors ranging from soil characteristics, sloppy and undulating nature of the topography, high intense rainfall and impact of land cover changes over a period of time. The immediate factor with a reasonable impact factor is 'slope' the slope steepness and slope length are the key characteristics of topography on erosion. More runoff with higher velocity will occur with an increase in the slope steepness; therefore, the steeper the slope of a field the greater the amount of soil loss from erosion by water (Wall, 2003). This factor was allotted 25% while land use was finally given 15%, all out of 100% The vegetation cover can break the impact of raindrop before directly hitting the soil, thus reducing its ability to erode. Soil erosion potential increases if the soil has no or very little vegetative cover of plants and/or crop residues (Wall, 2003) plant and residue cover protect the soil from raindrop impact and splash, tends to slow down the movement of surface of surface runoff and allows excess surface water to infiltrate. The raster math tool in ArcGIS spatial analyst extension was used, where the above expression was typed on the syntax space. The figure shows that 90% of the Biu town and environs is susceptible to water soil erosion with 25% of the delineated empirical study site lying on a highly susceptible zone to soil erosion. Geostatistically, 55% of the entire LGA is marginally susceptible, 40% is susceptible, and 5% highly susceptible to soil erosion.

Some of the challenges of this menace noticeable in the area, having land uses overlaid on the mapped eroded sites and the susceptibility map, it is evident that many roads are currently being washed away, buildings are gradually degraded, bridges been collapsed and the agricultural lands been leached as a result of water soil erosion in Biu and Environs. Soil loss is closely related to rainfall partly through the detaching power of raindrops striking the soil surface and partly through the contribution of rain to runoff (Morgan, 1995).

VII. CONCLUSION

Soil erosion is very common in northeastern Nigeria. This study has shown the influence of geology, climate, geomorphology (slope), vegetation, man and soil itself on soil erosion development. Therefore the following conclusions can be drawn from the study; the type of erosion more prevalent in Biu and its environs is rill and gully type of erosion and a gradual and subsequently rapid change in the vegetative cover resulted to the thick vegetation being steadily lost to crop fields and scanty woodlands. Bare surfaces and built environment have astronomically increased over the period of 19 years as can be seen from the trend maps; these are major forces within the vegetation parameter, slope steepness of the environment have opined for the major factors have increase the vulnerability level of Biu and its environs to soil erosion thereby leading to destruction of farmlands, plots and roads. Therefore, the inherent characteristics of the local soils to a large extent promote the spread of soil erosion especially the rill and gully type in the area.

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