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Nigeria

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UTILITY OF UNIVERSAL SOIL LOSS EQUATION MODEL (USLE) AND GEOSPATIAL TECHNOLOGY FOR SOIL EROSION ESTIMATION IN BAYO LGA OF BORNO STATE, NIGERIA

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ABSTRACT: This study, utility of universal soil loss equation model (USLE) and geospatial technology to estimate soil erosion is apt as Bayo LGA of Borno State has been battling with enormous soil erosion problems. The study replicates USLE model with the view to map soil erosion susceptibility in the LGA. The USLE model is an equation that integrates datasets from rainfall, soils, elevation/relief, vegetation and management practices. It utilizes five processed data served as input to the Equation. The study collected climate and soil; radar and optical remotely sensed datasets. While the computation of rainfall erosivity (R-Factor) was made from climate data, soil from FAO soil database was processed to extract soil erodibility (K-Factor) using Williams Equation 1995. The Radar data (digital elevation model – DEM Alos PALSAR with 12.5m spatial resolution) was utilised to compute slope gradient and length (LS-Factor). The optical data (Landsat-8 Operational Land Imager (OLI) with 30m spatial resolution) was sourced from EROS Data Centre and transformed into Normalised Difference Vegetation Index (NDVI) to extract vegetation cover, utilised for Crop/Vegetation Management Factor (C-Factor); and also reclassified the Landsat-8 OLI into land use land cover map for support practice (P-Factor). All the Factors (R, K, LS, C and P) served as input to the USLE model. The result of R-Factor ranges between 250 and 261 (Joule/m²) with south receives higher than the north. The LGA is covered by four different soil types with Lithosols covering about 88% and ranges between 0.034898 and 0.048251 K-Values. The study also found that the LS Factor is high to moderate factors of about 93.62 to 46.81 values respectively, which means the surfaces have steeper and longer slope length. The C-Factor in the LGA ranges from 0.23 to 0.61 and is good enough to stabilise soil loss and in an indication of good vegetation cover. About 41.6% of the LGA landmass is low erosion potential with potential of losing ≤ 5 tonne per hectares, annually. However, about 13% of the landmass has potential to exceptionally loss more than 100 tonne per hectares, annually. Therefore, the study recommends shifting cultivation methods of farming to allow re-vegetation and/or regeneration of nutrient in the LGA.

Key words: Soil Loss Equation, Remote Sensing-GPS-GIS(Geospatial), Vegetation cover

1. INTRODUCTION

Generally, five major factors trigger soil erosion. These are climate, slope, soil properties, vegetation cover and

management practices. Soil erosion is wearing away of topsoil by physical forces of water and wind. According to Abdi *et al.*, (2013), soil erosion by water, wind or tillage, involves three distinct actions: soil detachment, movement and deposition, which lead to threatening of settlements, infrastructure and farmlands. Globally, soil erosion is one of the important land degradation problems that affects soil productivity, loss of nutrient, siltation in water bodies (Lu *et al.*, 2003; Kim *et al.*, 2005) and considers as critical environmental hazard in modern time. The average rates of soil erosion throughout the world are estimated between 12 and 15t ha⁻¹ year⁻¹ (Biggelaar, *et al.*, 2003). This means that annually, land surface lost about 0.90–0.95 mm of soil (FAO, 2015). In the upland area, soil erosion is one of the most dangerous hazards (Ashiagbor, *et al.*, 2013), especially if influenced by water and wind agents. Based on existing literatures, especially Ologe (1972), Ofomata(2007) and Aabeyir (2013), erosion is mainly favourable to areas with high population density (Imo and Anambra States with 1,669 people per km² and 1,160 people per km² respectively), high relief/steep slopes (Gombe and Southern Borno), deforestation and humid tropical climate. Borno state to some extent, exhibits some of these drivers, especially in major settlements of the State (Maiduguri and Bama). The Southern part of the State, Biu, Gwoza, Askira and Brieyel are also witnessing early stages of erosion as well. Lal (2001) documented that 1094 million ha of land affected in 19th century by erosion due to water compared 548 million by winds. Therefore, water is the major agent of erosion on Earth. Rainfall produces four types of soil erosion: sheet, rill, stream channel and gully erosions.

Soil erosion is a widespread phenomenon in Nigeria, as documented by many scholars. Most studies on the erosion, especially gullies come from South-eastern States of Nigeria with high population density, high relief, steep slopes, deforestation, humid tropical climate and friable sandstones (Grove 1951; Ofomata 2007). However, different types of erosion have been sighted in other parts of Nigeria including the states of Oyo, Ogun, Ondo, Ekiti (Ofomata 2007), the Jos Plateau, the Kubani basin in Zaria (Ologe 1972), the Sokoto basin. There are also documented sites in Yola and the Gombe town (Mbaya 2012) in Upper Benue and Gongola Basins respectively. Despite the advancement in research and technology, there are still some challenges in finding a

suitable model that adequately estimates soil loss through erosion sites. There are a number of parametric models developed by researchers for estimating soil loss. These include the Soil and Water Assessment Tool (SWAT); Universal Soil Loss Equation (USLE); Revised Universal Soil Loss Equation (RUSLE); Modified Universal Soil Loss Equation (MUSLE); and the Water Erosion Prediction Project (WEPP). Among them, USLE is popular especially for the study of soil erosion by water due to its flexibility, direct and effectiveness in a data scarce environment. It was formerly accepted as the most suitable equation for estimation of soil loss due to its simplicity and robustness (Desmet and Govers 1996; and Abdi *et al.*, 2013). Being one of the major causes of soil degradation and threats to its ecological functions, study on erosion becomes important in finding a suitable prescriptive measure to address the menace especially at the early stage in agrarian Bayo LGA, Borno State. Therefore, this study selects to apply USLE model to identify and quantify potential sites prone to erosion in the LGA.

2. MATERIALS AND METHODS

2.1 Study Area

Borno State lies between Latitudes 10°00'20" N and 13°43'36" N; and from Longitudes 11°30'30" E to 14°41'13" E. The State covers a total landmass of about 72,655.78 Km² (Sambo, 2021). Bayo LGA lies between Latitudes 10°10'09" N and 10°43'02" N; and from Longitudes 11°31'30" E to 11°49'43" E with a total landmass of about 956.18 Km² (1.32%) of Borno State.

The topography of Bayo LGA, as shown in Figure 2.1, is undulating with elevation range between 216 m and 608 m (a.s.l.) respectively. The topography is found the highest spot height 608 m a.s.l. is found about 4 km North of Pono Town. Being an agrarian LGA, farmers are utilising the terrain for food and cash crop production. About 21.5% of the terrain in the LGA is very low floodplain (between 216m and 271m) is used for rice cultivation, while about 28.3% of the terrain is low floodplain (between 271.5 m and 316 m) is used for cotton cultivation. The remaining part of the surface (50.2%) forms the moderate, high and very high that is used for terrace farming.

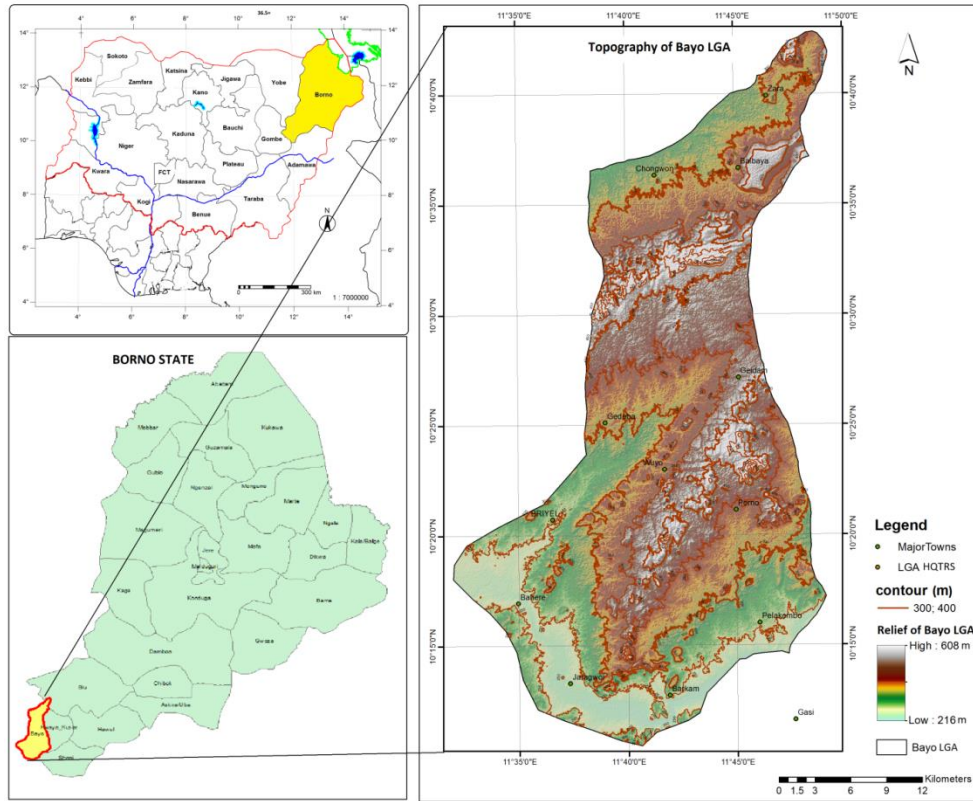


Figure 2.1: Location and Relief of the Study Area (Sambo, 2021)

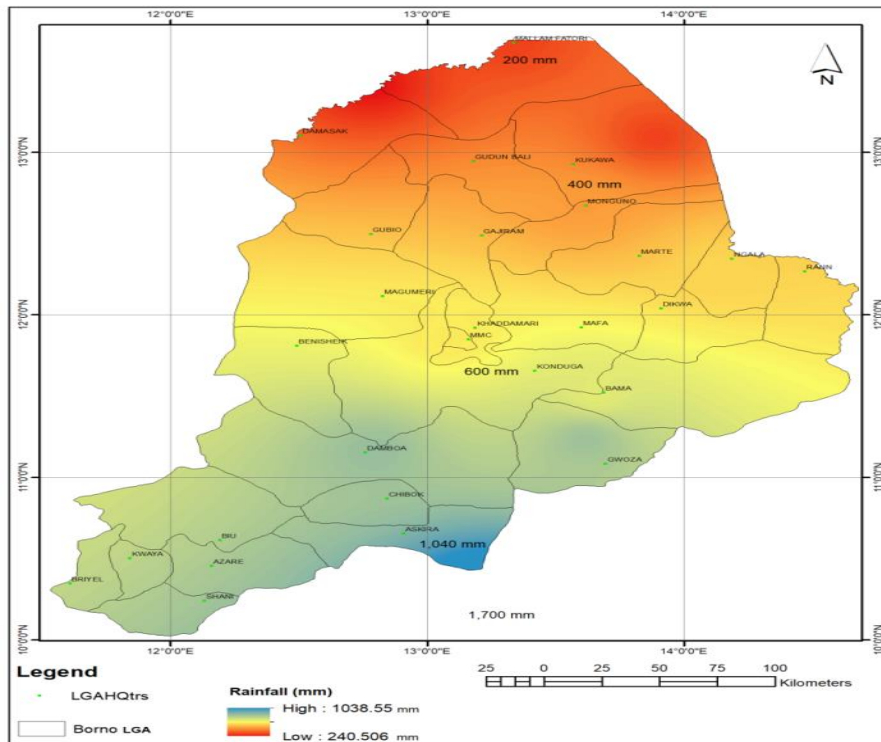


Figure 2.2: 10-Year Long Term Rainfall in Borno State (Extract from Tropical Rainfall Measuring Mission 2010 to 2020)

The climate of Bayo in Southern part of Borno State, is between 600 mm and 1039 mm. Rainfall records from nearby Kiri Dam show between 700mm and 900 mm. Figure 2.1 shows the long term 10-year rainfall records of Borno State (2010 to 2020) using the TRMM (Tropical Rainfall Measuring Mission).

The geologic setting and slope of Bayo LGA, as well as the climatic conditions depict the type of dendritic drainage pattern, which is a pattern that is created by

stream erosion over time. This pattern reveals the characteristics of the rocks and geologic structures that drained by streams in the LGAs shown in Figure 2.3. The slope of the terrain is complex and steep to the North and middle part of the LGA. While the steeper parts range between 10° and 56°, the flat surfaces in the area range from 0° to 3° and found at the southern part of the LGA see Figure 2.3. The drainage density in Bayo LGA is high, more than 12.9 channel length per km².

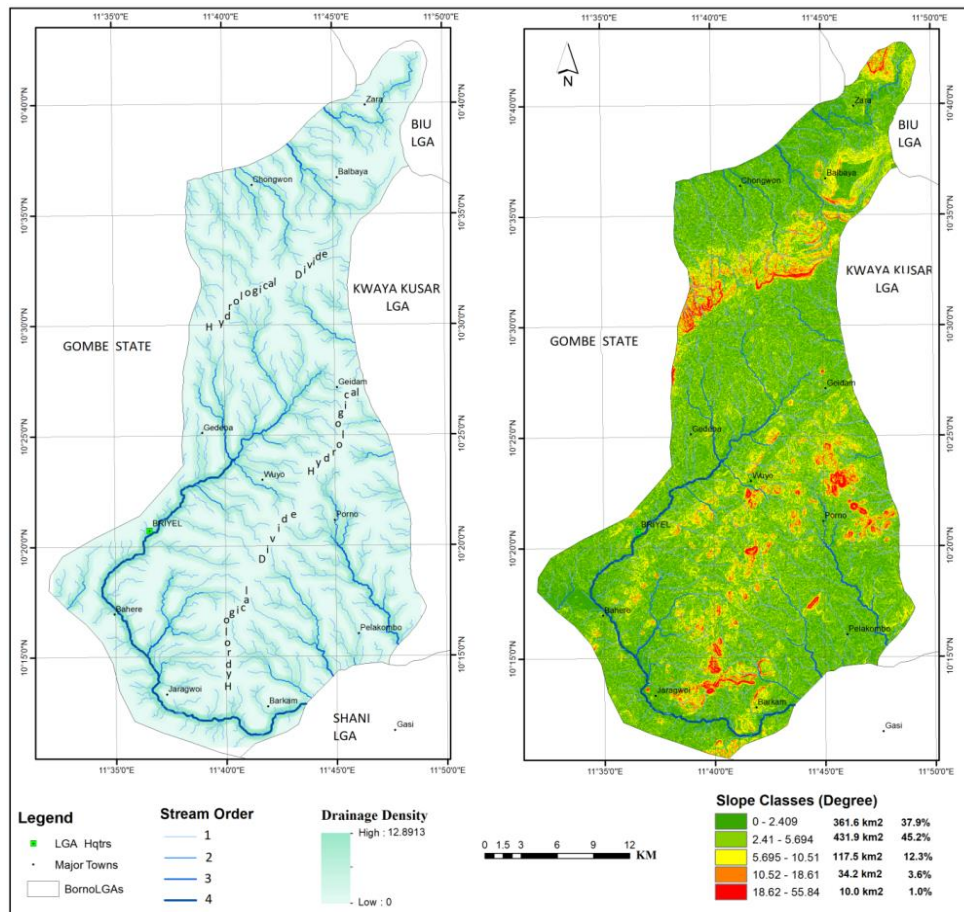


Figure 2.3: Drainage Pattern and Slope of Bayo LGA

2.2 Methodology

This study was based on Geospatial Mapping of erosion sites in Bayo LGA using USLE model. The study utilized Optical and Radar remotely sensed datasets and ancillary datasets (“a” and “b”), as shown in Table 3.1. Optical and Radar remotely sensed datasets; climate data; and locational datasets. The optical data were collected from Landsat 8 OLI (Operational Land Imager), Normalised Difference Vegetation Index (NDVI) image datasets.

Table 3.1, presents the characteristics of the optical remotely sensed data. Landsat-8 and NDVI datasets were collected from the University of Maiduguri Geospatial Data Infrastructure. The NDVI was downloaded from VITO collection catalogue. The Landsat 8 datasets, with 30 m spatial resolution were used for land use land cover mapping (Factors “C”) and Management Practice Factor “P” served as input for Universal Soil Loss Equation (USLE).

Table 3.1: Characteristics of the Datasets used for the work

SN	Type of Data	Temporal Resolution	Spatial Resolution	Date Available	Source(s)
Section “A” Optical Remote Sensing Images					
1.	Landsat-8 OLI	16 Days	30 m	2013 – Date	Unimaid; Earthexplorer USGS
Section “B” Radar Satellite Images					
2.	DEM ALPSRP – ALOS PALSAR	Once	12.5m	2013	Alaska Satellite Facility: asf.alaska.edu
Section “C” Climate and Ancillary Data					
3.	Rainfall Records	Monthly	In-Situ Station	2011 to 2019	Kiri Dam (Gombe) and Biu BOSADP (Borno)
4.	GPS point data	Once	± 3 m	2020	Bayo LGA
5.	Soil	Soil Map of the World	FAO	FAO	Land and Water Development Division, FAO,2003
6.	Admin map	LGA map of Borno State with communities			Bayo LGA

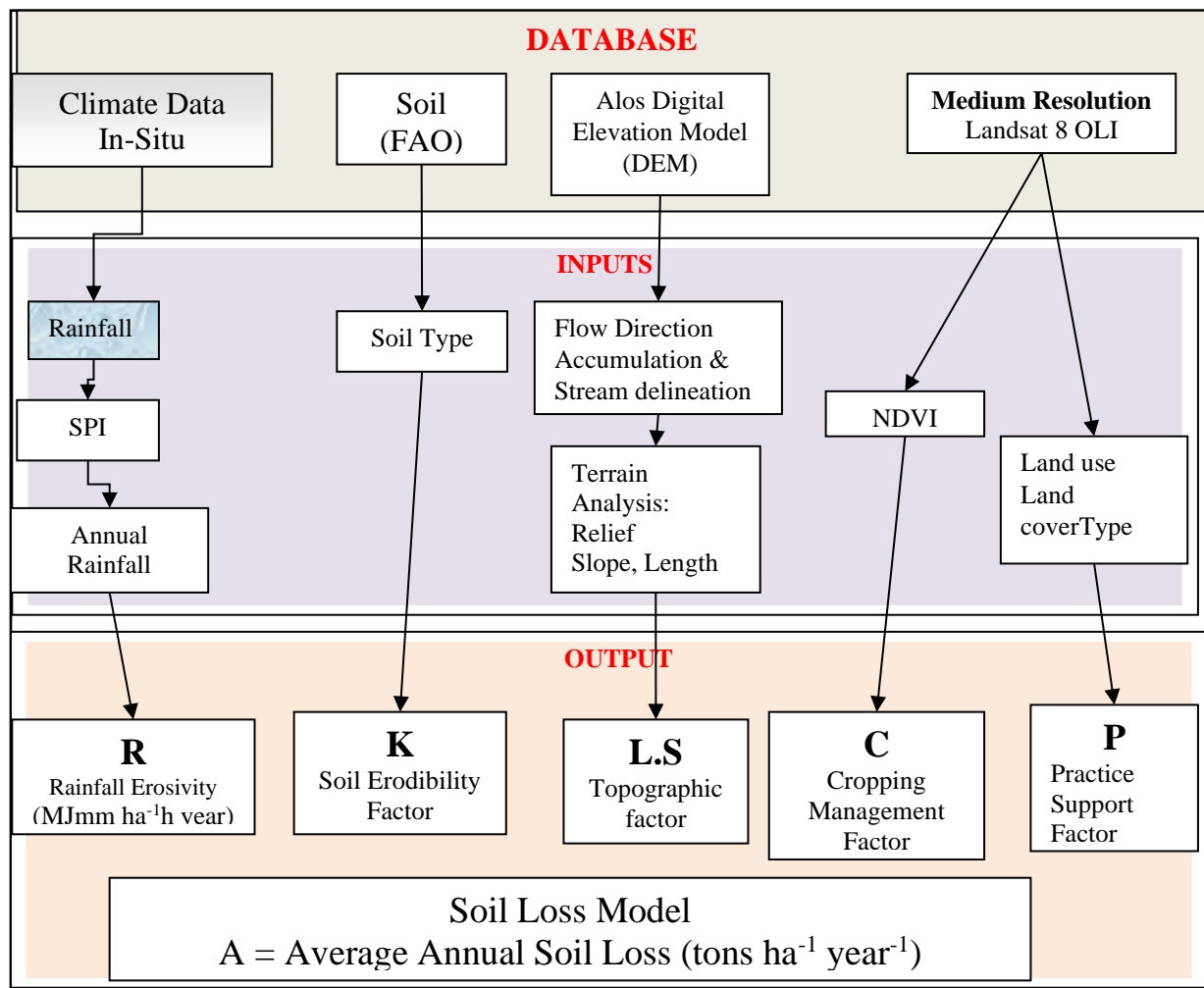


Fig. 3.1: Flowchart of the study frame (Sambo, 2020)

2.3 Calculation of Erosion in Universal Soil Loss Equation (USLE)

As identified, the major factors causing erosion comprise of climate, soil properties, vegetation cover and management practices. These factors are considered for estimating soil loss in Bayo LGA. The methodological steps involved the use of Universal Soil Loss Equation (USLE) in GIS environment framed in Figure 3.1. The calculation was structured into three phases: building of database (Phase I) that involves pre-processing of four parameters: climate, soil, DEM and Landsat 8 OLI. The Phase II accepts all the pre-processed data from Phase I. They are processed to five different results and finally the outputs were integrated to form Soil Loss Model (Map).

2.4 Procedure for Using the USLE Model

i. Rainfall Erosivity (R Factor) is the product of total kinetic energy and maximum 30 mins rainfall intensity (Wischmeier and Smith, 1978; and Pham *et al.* (2018), however, there are many popular equations to calculate annual R-Factor (Gitas *et al.*, 2009; Parveen and Kumar, 2012). The Equations 3.1 was applied in the computation of R-Factor because the rainfall in Southern Borno is more than 200mm.

$$R = 0.548257 * P - 59.9 \quad \text{Eq. 3.1}$$

Where P is rainfall image (map); and the figures are constant.

Using the Moving Average method for interpolation of the rainfall data recorded from in-situ stations (Kiri Dam, Mubi Meteorological Station and Biu BOSADP) and Tropical Rainfall Measuring Mission, the rainfall was integrated and converted into rain image.

ii. Based on the Soil Texture, determination of the **K Value**, FAO of UN’s soil types and textures were used. The results (K-Factor) of the soil types and textures not only for Bayo LGA but also for entire Borno State are computed and presented in Appendix I. The study adopts Williams (1995) Equation and FAO Soil K_{usle} as:

$$K_{usle} = F_{csand} * F_{cl-si} * F_{orgc} * F_{hisand} \quad \text{Eq. 3.2}$$

Where: F_{csand} is a factor with low soil erodibility factors for soils with high coarse-sand contents and high values for soil with little sand;

F_{cl-si} is a factor with low soil erodibility factors for soils with high clay to silt ratio;

F_{orgc} is a factor that reduces soil erodibility for soils with high organic content; and

F_{hisand} is a factor that reduces soil erodibility for soils with extremely high sand content.

The equation uses only Topsoil cover because it is affected directly by raindrop energy.

iii. The Slope Gradient and Length, LS Factor for the LGA, the following equation was originated from Van Remortel and others in 2004 supported by Suhua and others in 2013 was adopted to compute the slope gradient and length for Bayo LGA:

$$LS = [0.065 + 0.0456 * (\text{Slope}) + 0.0065 * (\text{Slope})^2] * (\text{Slope Length}/22.1)^{0.5} \quad \text{Eq. 3.3}$$

Where: Slope = Slope Steepness in %; Slope Length = (Flow Accumulation * 12.5 m – pixel size). Van Remortel *et al.*, (2001); and Suhua *et al.*, (2013).

iv. The Crop/Vegetation Management Factor and tillage method proposed by Durigona *et al.*, (2014) and adapted by Almagro *et al.*, (2019) to estimate C-Factor was considered. The C_{rA} is based on NDVI for tropical climate conditions. Product of the two factors (Crop/Vegetation) together leads to C factor. The selection of Equation 3.4 was made due to its suitability in Bayo LGA, according to its tropical conditions.

$$C_{rA} = 0.1 \left(\frac{-NDVI+1}{2} \right) \quad \text{Eq. 3.4}$$

Where, NDVI = Normalised Difference Vegetation Index, and Equation 3.5 computes the NDVI.

$$NDVI (Landsat8) = \frac{Band\ 5 - Band\ 4}{Band\ 5 + Band\ 4} \quad \text{Eq. 3.5}$$

Where: Band 5 is Near-infrared; and Band 4 is Visible red of the Landsat 8 OLI.

v. Support Practice P factor was based on the contouring and terracing practice (Table 3.2) – (adapted from Shin, 1999). The corresponding values against Strip cropping and Terracing fields were based on the slope % ranges in Bayo LGA.

Table 3.2: P-Factors for Support Practice

S/N	Slope %	Contouring	Strip Cropping	Terracing
1.	0.0 – 7.0	0.55	0.27	0.10
2.	7.1 – 11.3	0.60	0.30	0.12
3.	11.31 – 17.6	0.80	0.40	0.16
4.	17.61 – 26.8	0.90	0.45	0.18
5.	> 26.81	1.00	0.50	0.20

vi. The Products of the 5 factors was used to compute the Soil Loss “A” in tonne per annum, regarded as

the Soil Loss per Hectare (Ha) per annum – see Equation 3.6 (USLE Model).

$$A = R * K * LS * C * P \quad \text{Eq. 3.6.}$$

3. RESULTS

3.1. Extent of Soil Loss in Bayo LGA

3.1.1. Calculation of rainfall erodibility factor (R-Factor) in Bayo LGA

In the USLE equation, R-Factor is represented as rainfall and runoff factor in the LGA. Being a key input to USLE model, the results of the R-Factor model in the LGAs is shown in Figure 4.1. The Figure shows that the Southern part receives higher erosivity than the North, which means the R-Factor model of Bayo LGA ranges between 250 and 261(Joule/m²) as R-Values. The R-Factor shows that of the southern part of the LGA has the highest R-Factor with about 261 Jm⁻² and north western part the least with 261 261Jm⁻²as shown in Figure 4.1.

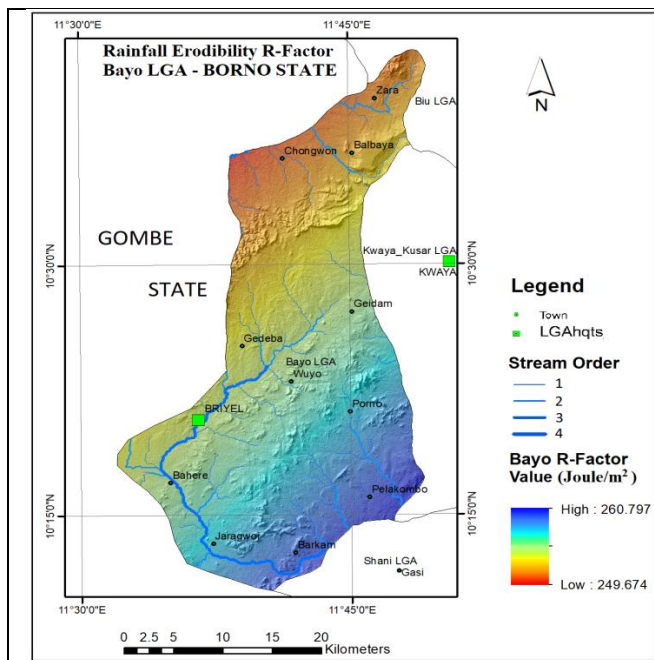


Figure 4.1: Rainfall Erosivity (R-Factor) for Bayo LGA

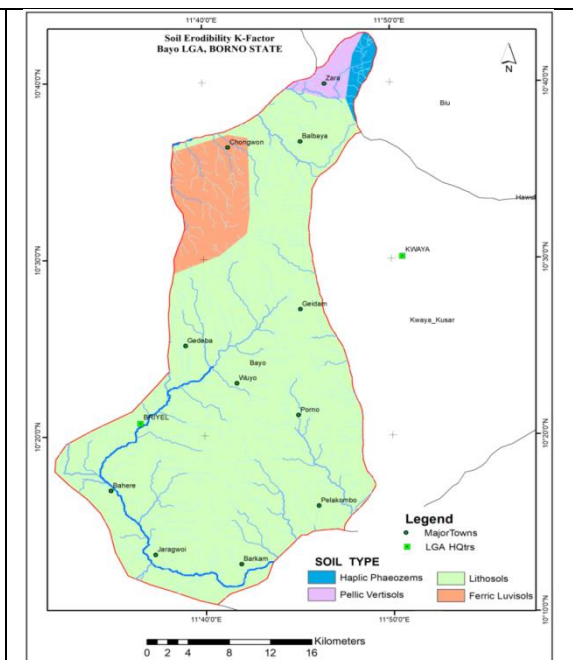


Figure 4.2: Soil Erodibility K-Factor of Bayo LGA, Borno State

3.1.2. Soil erodibility (K-Factor) calculation

K-Factor, being the soil erodibility factor in the Equation 3.6, and as a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff, Bayo LGA shows four different soil textures, which affects K-

Factor. The Haplic Phaeozems and Pellic Vertisols are found in the extreme north with about 3.4% of Bayo Landmass. Substantial part of the LGA (88%) is covered by Lithosols, as shown in Table 4.1. The spatial extent of the soil types in Bayo LGA are represented in Figure 4.2.

Table 4.1: Soil Type in Bayo LGA

Rowid	VALUE	COUNT	SOIL_TYPE	K- Factor	AREA Km ²	%
0	1	78489	Haplic Phaeozems	0.048251	12.26	1.28
1	2	131070	Pellic Vertisols	0.034898	20.48	2.14
2	3	5359170	Lithosols	0.045041	837.38	87.67
3	4	544255	Ferric Luvisols	0.044725	85.03	8.90
Total					955.15	100.00

Source: FAO, 2003

The Soil, K-Factor of Bayo LGA from Figure 4.2 shows that there are four distinct K-Factors. Hence, soil erodibility in the LGA shown in the Figure ranges between 0.034898 and 0.048251 values. See Appendix I for the steps in computing the K-Factors using the equations provided in Appendix II.

3.1.3. The slope length-gradient (LS-Factor) for Bayo LGA

The result of the slope length-gradient factor (LS) is also one of the third critical factors in Soil Loss Equation, which is shown in Figures 4.3. It represents a ratio of soil

loss under given conditions per location/area with the standard slope steepness of 9% and slope length of 22.13 m as described in Equation 3.3. A standing rule is that the steeper and longer the slope, the higher the risk for erosion. In Bayo LGA, the results of LS Factor are longer with high and moderate factors of about 93.62 and 46.81 values respectively. The SL Factors are scattered along the hilly parts of the LGA. Around Balbaya axis North of the LGA as well as between Wuyo and Porno, Jaragwoi to Barkam all have steeper and longer slope length (Figure 4.3). These parts of the LGA are expected to have high erosion sites. The unit of the Slope Length is in meter (m) and Slope Steepness factor is radians (rads.).

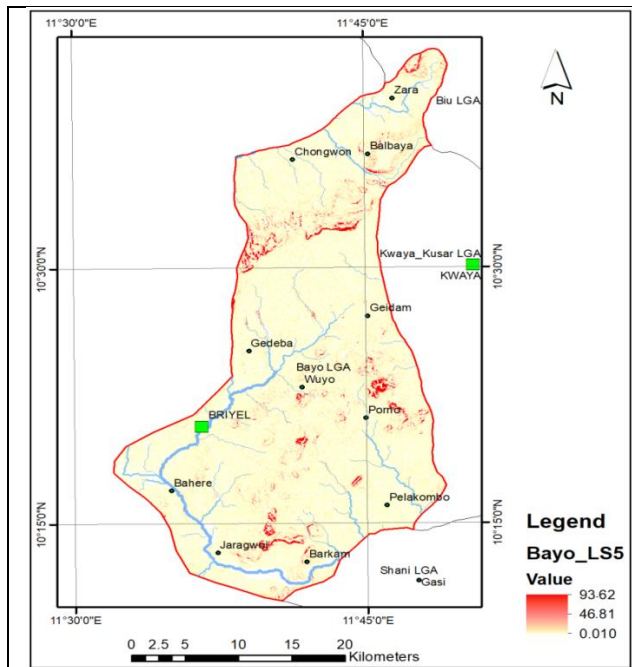


Fig. 4.3: LS Factor Slope Length in Bayo LGA

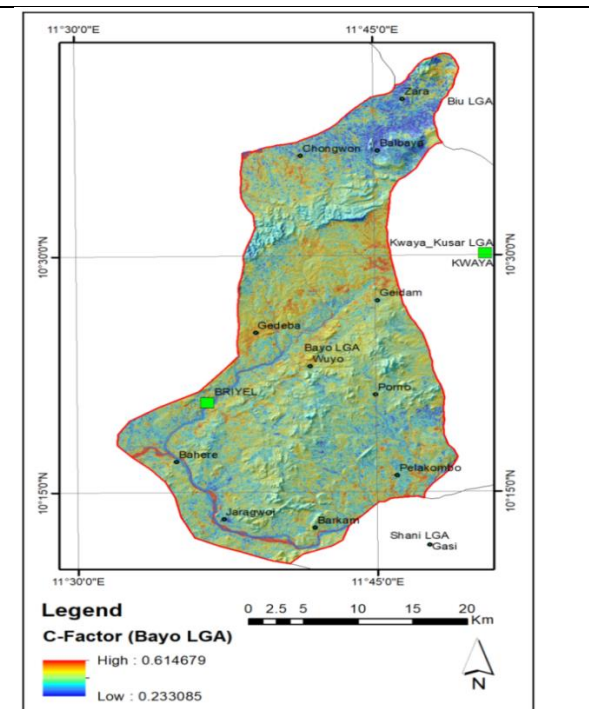


Fig. 4.4: Cover and Management Factor, C-Factor for Bayo LGA

3.1.4. Crop/vegetation and management factor (C-Factor)

The results of C-Factor are also critical factors that serve as input in USLE. Vegetation cover helps to prevent soil loss, hence NDVI (Equation 3.6) was used as relative effectiveness of soil and crop management systems in Bayo LGA. Statistically, the extent of vegetation cover shows that more than 60% of the LGA was covered by good vegetation cover (between 0.4 to 0.61 NDVI values). This fraction is good enough to regulate soil loss. The principal equation for the Universal Soil Loss Equation model (USLE) required the input of Vegetation Cover and urban land use management factor (C-Factor). The vegetation cover and management factor (C-Factor)

for Bayo LGA is shown in Figure 4.4, model of C-Factor, which was integrated into the final equation. The C-Factor of Bayo LGA ranges from 0.23 to 0.61 and is good enough to stabilise some soil loss, an indication of good vegetation cover in the LGA.

3.1.5. Support practice factor (P-Factor)

The P (Practice) is the support and/or conservation practice factor. It reflects the effects of practices on Bayo LGA topography in different areas. This is therefore expected to reduce and/or increase the amount and rate of water runoff and thus reduces/increases the amount of erosion. The P factor represents the ratio of soil loss farming system upstream and downstream of a slope.

Therefore, slope (%) in Bayo LGA was used. The results of P-Factors are shown in Figure 4.5. The P-Factors for the LGA are slightly encouraging because of the

differences in vegetation cover. The ranges of the P-Factor were from 0.55 to 1.00 values. This also serves as input into the Soil Loss Equation.

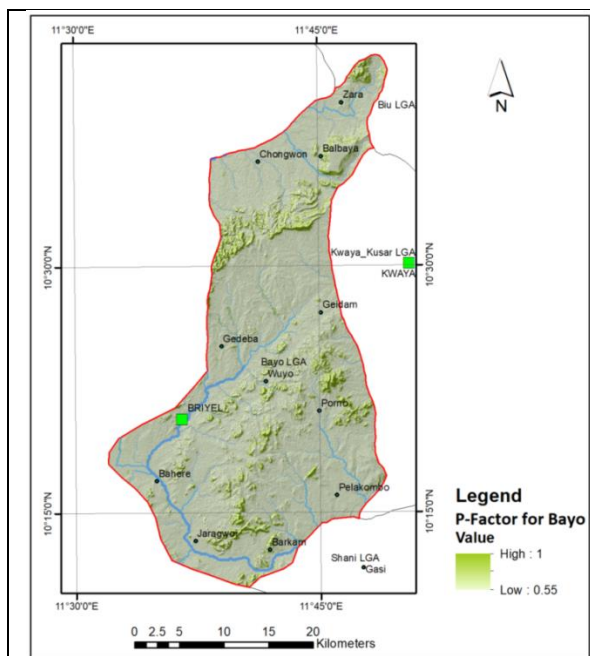


Fig. 4.5: The P-Factor for Bayo LGA

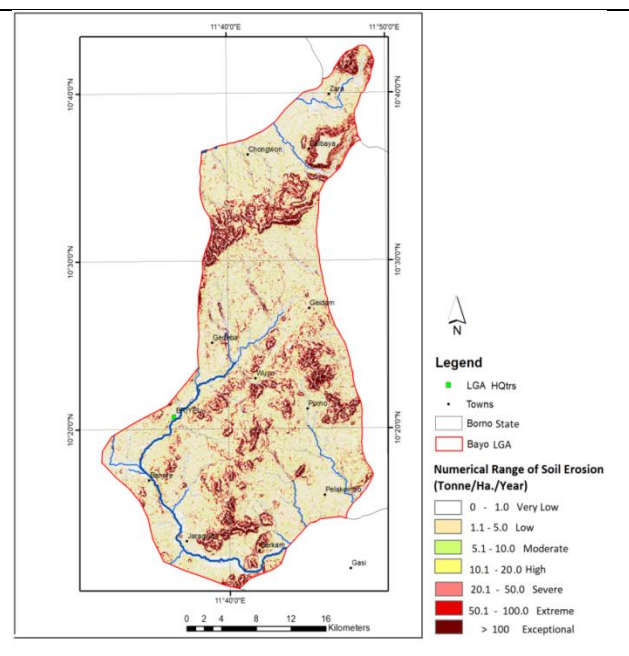


Fig. 4.6: Soil Loss in Tonne per Hectare per annum in Bayo LGA

3.2. Utility of USLE in Geospatial Technology

3.2.1. Potential erosion hazard in Bayo LGA

The study considered five factors for the Universal Soil Loss Equation (USLE). These are: Rainfall erosivity and runoff factor for the LGA (R-Factor); the Soil Erodibility Factor (K-Factor), as measure of the susceptibility of soil particles; LS-Factor as the slope length-gradient factor as ratio of soil loss under given conditions to that at LGA level with the standard slope steepness of 9% and slope length of 22.13m; The C-Factor as the Crop/Vegetation and Management factor in prevention of soil loss; The P-Factor (Practice) as the Support and/or Conservation Practice factor reflects the effects of practices on topography in the area, which reduces and/or increases the amount and rate of the water runoff. As a result, the final results of the erosion loss areas were based on seven (7) severities/categories of erosion loss hazard are presented numerically and spatially as: Very Low; Low; Moderate; High; Severe; Extreme and Exceptional.

Therefore, the results of the potential of erosion hazard in the LGA show high in terms of distribution of potential sites to erosion. This is possible because Bayo with higher rainfall (R-Factor – rainfall/runoff erosivity) with

longer and steeper slope (LS-Factor). However, the good vegetation cover has helped to reduce the chances of increase in the erosion. Figure 4.6 shows the final erosion sites of in Bayo LGA (integration of R-Factor, K-Factor, LS-Factor, C-Factor and P-Factor in GIS environment). It has shown that about 56.3% (53,815.8 Ha) of the LGA exhibits the potentials from low to moderate categories for losing 1 to 10 Tonne/Ha/Yr. However, 43.7% (41,699.1 Ha) of the LGA is also having the potentials from high, severe to extreme categories of losing 10.1 to 100 Tonne/Ha/Yr, as shown in Figure 5.55 and Table 5.5. The Figure shows clearly where areas of erosion are dominant.

3.2.2. Extent of Potential Erosion Sites in Bayo LGA

Extract from Figure 4.6 shows that about 41.6% of Bayo LGA landmass is low erosion potential with potential of losing ≤ 5 tonne per hectares, annually. This is also being controlled by the level of vegetation cover in the LGA. About 12.94% of the landmass in Bayo LGA is exceptionally potential to loss more than 100 tonne per hectares, annually. There is also various degree of severity ranging from moderate to extreme in the LGA. Table 5.5 presents the results of the soil loss in the LGA.

Table 5.5: Derivation of the Ordinal Categories of Soil Erosion Potential in Bayo LGA

Rowid	Numerical Range (ton/ha/year)	Count	Erosion Potential	AREA_Ha	Proportion (%)
0	0 – 1.0	89,621	Very Low	13,339.83	13.97
1	1.1– 5.0	177,340	Low	26,396.55	27.64
2	5.1 – 10.0	94,590	Moderate	14,079.45	14.74
3	10.1 – 20.1	81,695	High	12,160.07	12.73
4	20.1 – 50.1	75,428	Severity	11,227.24	11.75
5	50.1 – 100.0	39,996	Extreme	5,953.29	06.23
6	>100	83,028	Exceptional	12,358.48	12.94
Total				95,514.91	100.0

4. DISCUSSION

Desmet and Govers (1996) and Abdi *et al.* (2013), agreed that USLE is the most suitable equation for estimation of soil loss, simple and robust. This study confirms that the Equation is very suitable, flexibility, direct and effective in a data scarce environment, like Borno State. According to Ofomata (2007) and Aabeyir (2013), erosion is mainly favourable to areas with high population density. This is contrary to the findings of this study, because the projected 2022 population with 3.5% growth rate of Bayo LGA is 121,542 (NPC, 2016) with density of 127 people Km⁻². This means that erosion is mainly favoured by climatic and morphology in Bayo LGA. Based on this study crop growing on the sloping land causes erosion, therefore, sloping areas in the LGA can be monitored, regularised and protected. The USLE is one of the most suitable models for determining soil loss due to erosion. The erosivity R-Factor of the USLE obtained from south is higher than the North with ranges between 250 and 261 (Joule/m²).

The soil K-Factor (between 0.034898 and 0.048251 values), erodibility detects four different soil textures, with 88% Landmass covered by Lithosols. The slope length-gradient factor (LS) are scattered along the hilly parts of the LGA longer with high and moderate factors of about 93.62 and 46.81 values respectively. Additional on one hand, the C-Factor input to USLE (vegetation cover) shows good vegetation cover (between 0.4 to 0.61 NDVI values). The P (Practice) in the LGA is slightly from 0.55 to 1.00 values for its farming system, reduces the chances of increase in the erosion. It has shown that about 56.3% (53,815.8 Ha) of the LGA exhibits the potentials from low to moderate categories for losing 1 to 10 Tonne/Ha/Yr. However, 43.7% (41,699.1 Ha) of the LGA is also having the potentials from high, severe to extreme categories of losing 10.1 to 100 Tonne/Ha/Yr.

5. CONCLUSION

The following can be conclusions are drawn from this study

1. The USLE model is replicable, especially in GIS environment because it is capable to integrate all the input parameters to the model.
2. Where erosion sites are dominant and extent soil loss are easily determined and calculated as seen in Bayo LGA case study.
3. This model, can be employed in researches on water and environment.
4. The soil loss equation as a model offered in this study fills in the gaps in water and environmental studies.

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Appendix I: Soil Units and Types in Bayo LGA, Borno State Using Williams Equation to determine the f factors

S/No.	Soil unit Symbol	sand % Topsoil	Silt % Topsoil	Clay % Topsoil	OC % Topsoil	f_csand	fcl_si	f_orgc	f_hisand	K-Factor
1.	HH	37.2	31.2	31.6	1.09	0.200428	0.810697	0.989839	0.300000	0.048251
2.	I	58.9	16.2	24.9	0.97	0.200001	0.756314	0.992542	0.300000	0.045041
3.	LF	74.6	9.6	15.9	0.39	0.200000	0.745966	0.999258	0.300000	0.044725
4.	VP	25.1	12.2	62.7	0.68	0.201064	0.580181	0.997206	0.300000	0.034898

Source: FAO, 2003

Bayo LGA Soils (HH; I; LF; and VP)

Appendix II: K-Factor Using Williams (1995) Equations and FAO Soil to Derive K-Factor

The values for f_csand; fcl_si; f_orgc; f_hisand; and K-Factor were derived from the following Equations:

$$KUSLE = f_{csand} \cdot f_{cl-si} \cdot f_{orgc} \cdot f_{hisand}$$

$$f_{csand} = \left(0.2 + 0.3 \cdot \exp \left[-0.256 \cdot m_s \cdot \left(1 - \frac{m_{silt}}{100} \right) \right] \right)$$

$$f_{cl-si} = \left(\frac{m_{silt}}{m_c + m_{silt}} \right)^{0.3}$$

$$f_{orgc} = \left(1 - \frac{0.0256 \cdot orgC}{orgC + \exp[3.72 - 2.95 \cdot orgC]} \right)$$

$$f_{hisand} = \left(1 - \frac{0.7 \cdot \left(1 - \frac{m_s}{100} \right)}{\left(1 - \frac{m_s}{100} \right) + \exp \left[-5.51 + 22.9 \cdot \left(1 - \frac{m_s}{100} \right) \right]} \right)$$

Williams Equation (1995)