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Estimation of Soil Erosion Risk in Mubi South Watershed, Adamawa State, Nigeria

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Abstract

The study aims to estimation soil erosion risk in Mubi South watershed with the aid of RUSLE model and Geospatial techniques. RUSLE model parameters such as rainfall, soil map, topography map, cover management and conservation practice factor map were derived. The method employed includes the use of RUSLE model and Geospatial techniques using ArcGIS 10.3 Software, for analysis and presentation of result. It was found that sandy soil are the dominant soil of the watershed which covered about 65%, 18% silt and 17% clay. The land use landcover has about 29% of area covered by agricultural activities, 19% were covered by forest and 25% were not cultivated and covered by bare land. The study area has about 0.58 to -0.07 normalized difference vegetation index (NDVI) with majority of the area within the lower topography of 570 m above sea level. The Soil cover management factor ranges from the higher value of 0.5 to the lower value of 0.01 in the watershed, 15.8 mm to 15.7 mm occurrences of daily rainfall and 492.34 mm rainfall and runoff covered when rainfall per-day is greater than 15 mm rainfall. The results of the study also show that average rate of soil detachment is 1 t ha^{-1} yr^{-1}. The average transport capacity of overland flow is 1.5 t ha^{-1} yr^{-1}. Average soil per detachability by raindrop is 69.6 t ha^{-1} yr^{-1} total soil particle detachments is 69.66 t ha^{-1} yr^{-1} and average estimated soil erosion of 3.52 t ha^{-1} yr^{-1}. It is recommended that other soil erosion model to be applied in the study area for further comparative analysis of soil erosion risk.

Keywords: Soil erosion; Risk; Watershed area; RUSLE; Geospatial techniques

Introduction

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 [1-4]. However, if soil erosion is occurring faster than necessary due to human disturbance, it will cause negative impacts on the environment and e economy [5].

Soil erosion potential risk is determined by all-natural phenomena, which could cause erosion damages [6]. Soil erosion actual risk is the potential risk plus human induced intensification of the potential risk. The actual erosion and soil erosion risk is determined by all natural and human caused phenomena, which lead to soil erosion [6].

Soil erosion by water is estimated as the most extensive erosion type and results from excess surface runoff. The scope of water erosion is influenced by type of soil, slope and land cover [7]. Through the removal of surface soil (including organic matter and nutrients) from soil mass, effective soil functioning is affected. About one-third of land used for agriculture at global level has been affected by soil degradation. Most of this damage was caused by water and wind erosion [8].

In twenty-first century, soil erosion by water has become a worldwide issue because of progressive decrease in the ratio between natural resources and population and to climate change. Soil erosion negatively impacts on ecology and can lead to reduced crop productivity, worsened water quality, lower effective reservoir of water levels, flooding and habitat destruction [9]. In both the past and present day, soil erosion is one major and most widespread environmental threat. Risk assessment of soil erosion caused by water is indispensable to the creation of effective policies and measures on water and soil resource conservation.

In Nigeria, World Bank [10] estimated that soil erosion affects over 50 million people and account for loss of resources that amount to US 3000 million dollars per year. For decades, soil erosion has been a major environmental problem in Nigeria [11]. Erosion is the most serious natural hazard in Nigeria, affecting several parts of the country. It has killed people, destroyed roads, destroyed homes, schools and farmlands and displaced poor people [12].

To analyse soil erosion and suggest appropriate management plans, Revised Universal Soil Loss Equation (RUSLE) Models was selected for this research. Also, RUSLE was chosen in this research over other model such as; Soil and Water Assessment Tool (SWAT), European Soil Erosion Model (EUROSEM), and Annualized Agricultural Non-Point Source (AnnAGNPS) because these models applied worldwide to soil loss estimation and their convenience in application and compatibility with GIS [13-15]. RUSLE models was selected and applied in this research because of their simplicity and flexibility in use as compared to other models and needs less data than most of the other erosion estimation models. Revised Universal Soil Loss Equation Models is easy in integration with GIS and their performance at a watershed/catchment level in Mubi South is not yet known to the best of the researcher's knowledge; hence, need to apply two models in this study in order to estimate soil erosion in Mubi South Local Government Area of Adamawa State, Nigeria with the aid of geospatial technology.

Statement of Research Problems

Soil erosion and related degradation of land resources are highly significant spatio-temporal phenomena in many countries [14]. Soil problems have become a threat to sustainable agricultural production and water quality. In many regions, unchecked soil erosion and associated land degradation have made vast areas economically unproductive. Often, a quantitative assessment is needed to infer extent and magnitude of soil erosion risk so that effective management strategies can be resorted to. The complexities of variables make precise estimation or prediction of soil erosion difficult.

Soil erosion of various types and extent are also found in various parts of Adamawa state but most especially where man's activities have stripped off vegetation that normally holds and protects the soil. In Adamawa state, researches have shown that the different causes of soil erosion sprang from human activities for various purposes such as; intensive cultivation, over grazing, bush burning and deforestation. These are the principal determinants of variation in types and intensity of soil erosion and Mubi Local Government Area is not exceptional like any other part of Adamawa State [16].

Previous studies have been conducted within and outside the study area. Tekwa et al. [16] conducted a research titled "estimation of monthly soil loss from ephemeral gully erosion features in some parts of Mubi North and Mubi South, LGA of Adamawa State, Northeastern Nigeria". They found that soil aggregate particles in the study area were mainly sandy; with silt content range of 18-25% and clay contents in the range of 19-26% that did not differ significantly among selected sites. Organic matter content was low. The monthly area of soil loss ranges from 1.5 to 143 m^2, and volume of soil loss was 0.4 to 131 m^3, that were significantly higher in the months of August and September than in the months of June, July and October. Ephemeral gully erosion rates for Muvur and Digil sites were greater than at other sites. The monthly rates of ephemeral gully erosion ranged from 35 to 132 m^3, and 15 to 79 m^3 in terms of surface area and volume of soil loss respectively. The soil loss rates thereafter decreased from 18 m^2 to 5 m^2 and 11 m^2 to 2 m^2 in terms of surface area and volume of soil loss respectively. The researcher recommended that future researches should consider developing empirical soil loss predictor model (s) for Mubi and environs. The researches concentrated on only gully erosion for selected sites and concentrated mainly on their chemical properties. Also, the authors took soil samples only in gully areas and did not employ GIS techniques to estimate and predict spatial distribution of soil erosion risk.

Interest in soil erosion risk was triggered by a growing awareness of off-site impacts of soil erosion. These impacts are predominantly associated with movement of eroded soil, sediment particles and changes in water flows (both through and across the soil). The off-site problems are often more evident and include loading and sedimentation of water courses and reservoirs, increases in stream turbidity; all of which can disturb aquatic ecosystems and upset the geomorphological functioning of river systems.

To reduce such limitations; geostatistic techniques that interpolate data for an entire catchment from appropriately sampled point measurements, are readily available [17]. Mapping through conventional methods demand intensive data collection, which is often difficult to practice in complex terrains [17]. The Geographic Information System (GIS) techniques can provide easy and time effective tools to map and analyze erosion input data of hydrophysical parameters [17].

Aim and Objectives

The aim of this study is to estimate soil erosion risk in Mubi South watershed area with the aid of RUSLE models and Geospatial techniques.

The Scope of the Study

On the basis of spatial extent, the research was carried out in Mubi south watershed area, Adamawa State and focused on analysis of soil erosion risk using Revised MMF and RUSLE model with GIS techniques. The watershed area consists of the following fourteen (14) villages and Local Government Headquarters, namely: Sebbore, Gude, Gudere, Wafa, Chaba, Masuwa, Lunguwa, Gyakwar, Wuro Babbowa, Gavayi, Gella 2DH, Gella, Giranburum and Uro Gella which is the Local Government Headquarters of Mubi South. On content, 80 soil samples were collected in July 2016 and coordinates of the sample points were derived using grid system in GIS software environment. The parameters used as input data were collected from different sources such parameters such as rainfall, soil map, topography map, cover management and conservation practice factor map were derived. The research covered soil erosion data as at July 2016.

The Study Area

Location and description of the study area

Mubi south Local Government Area is located in Northeast Nigeria between latitudes 10°4′30"N-10°15′0"N, and Longitudes 13°20′E0"-13°27′0"E of the Greenwich Meridian. The study catchment area covered about 148.43 km^2 (sq km).

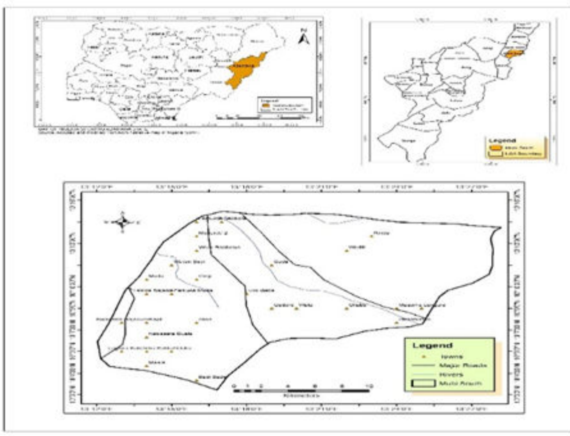

Figure 1: Map of the Study Area. Source: Modified from the Administrative Map of Adamawa State and field Survey (2015).

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The study area is bordered by Lamurde from North-East, Gella Local Government Area to the East, Wuro Bobbowa and Girgi in the South-West. The map and location of study area is show on Figure 1.

The climate of the study area is typical of the West African Savanna climate. Temperature in this climatic region is high because of the radiation income, which is relatively evenly distributed. However, there is usually a seasonal change in the temperature. There is gradual increase in temperature from January to April. There is also a distinct drop in temperature at the onset of rains due to the effect of cloudiness. A slight increase after the cessation of rain (October to November) is common before the onset of harmattan in December the temperature in Yola reach 40°C particularly in April and while minimum temperature can be as low as 18°C in the south to 27.8°C in the northeastern part in December [18]. Rainfall Erosivity ranges between 481 m to 192 m with about 15.5 mm to 15.8 mm rainfall per day and 4.5 m to 4.6 m rate of potential evapotranspiration.

The area is characterized by a typical tropical wet (April-October) and dry (November-March) climate with a mean annual rainfall ranging from 700 mm to 1,050 mm [19]. The vegetation is a typical Sudan savanna with short grasses interspersed with shrubs and few trees [19,20].

The study area is usually characterized by orchard-type vegetation due to its limitation in inherent fertility [21]. The major vegetation formations in the State are the Southern Guinea Savannah, Northern Guinea Savannah, and the Sudan Savannah. Within each formation is an interspersion of thickets, tress savannah, Open grass savannah and fringing forest in the river valleys. It is however necessary to note that large scale deforestation resulting from indiscrimination extraction of wood for fuel and expansion of agricultural land areas have left large area within each vegetation type with few indigenous woody plant species. Most areas especially those close to settlements are covered with exotic species such as the neem and eucalyptus trees.

Soils of the study area belong to the order lithosols [19,20]. Lithosols constitute one of the upper categories of FAO/UNESCO soil classification system [22]. They refer to soils with rock-basements within shallow depths from the soil surface and this implies shallowness and stoniness of the surface soil depths. Arenosols and Regosols: There are relatively young soils or soils with very little or no profile developments, or very homogenous sands, are grouped together. These are found on mountain sites within the 213 and 232 units. On these types of soils, weathering is slight and involves no accumulation of the products of weathering. The B horizon may not be very clear and reddish in colour, while the original carbon content is most of the time leached out. The study area has soil moisture 0.072%, bulk density of 1.63 Mgm^{-3}, 2.33 gkg^{-1} soil particle densities, 6.66 gkg^{-1} organic carbon, 0.68 mm of soil porosity and 11.46 gkg^{-1} organic matter.

Geology of the area consists of Precambrian Basement rocks, while parent material of the soil is undifferentiated Basement Complex, represented by migmatite-gneisses, schists, quartzites aplite, medium and coarse-grained granites, pegmatite, diorite, and amphibolites [19].

The dominant land uses in the study area are; agricultural land, forestry/vegetation, water body, built up area and bare land. Moreover, the town has become center of learning with numerous tertiary and secondary institutions established in the metropolis.

The study area has a total projected population of 126,378 people (National Population Census) in 2015. The growth of Mubi town is traced to agricultural, administrative, and commercial functions it performs.

Methodology

Reconnaissance survey

Reconnaissance survey was carried out by the researcher to get acquainted with the study area in terms of selections of coordinate location points, choice for major land use classes, ground thruthing and major crop types selected for the study.

Type and sources of data used

The types and sources of data used for this research are summarized in Table 1.

S.No	Types of Data	Sources of Data	Uses
1	Landsat thematic mapper of 2016 with 30 m resolution	Download from GLCF web	Input Parameter for the Model as land use type
2	ASTER Image (DEM) (Advanced Spaceborne Thermal Emission and Reflection Radiometer)	Download from GLCF web	Input Parameter for RUSLE Model
3	Rainfall data	Geography department ADSU Mubi	Input Parameter for the RUSLE Model
4	Soil texture (Particle size distribution)	Laboratory determination	Input Parameter for the RMMF Model
5	Crop types cover	Field survey	Input Parameter for RUSLE Model
6	Vegetation cover	Landsat imagery of 2015 in ArcGIS 10.3	vegetation cover conditions for RUSLE
7	Slope steepness	From ASTER image	Input Parameter for RUSLE Model

Table 1: Types, Sources and Used of Data. Source: Adopted from Iguisi.

Input parameters for the RUSLE model

The Input Parameters used for the RUSLE Model were presented on Table 2.

Factor	Parameter	Definition and remarks
Rainfall	R	Rainfall-runoff erosivity factor (MJ.mm/ ha.hr.year) [24].
Soil	K	Soil texture/ erodibility in ton.ha.hr/ (MJ.mm.ha) [25].

Topographic	LS	Slope length and slope steepness (m) [26,27].
Cover management	C	Ratio of soil loss from land cropped under specific conditions to the corresponding loss from clean-tilled, continuous fallow conditions [30].
Conservation practice	P	Soil conservation operations or other measures that control the erosion. The values of P-factor ranges from 0 to 1 [33].

Table 2: Inputs Parameters for RUSLE. Source: Compiled by the Author.

Deriving Inputs of RUSLE Model: The RUSLE Model equation is a function of five input factors in raster data format: rainfall erosivity, soil erodability, slope length and steepness, cover management and support practice. These factors vary over space and time and depend on other input variables. Therefore, soil erosion within each pixel was estimated with the RUSLE. The RUSLE method is expressed as:

$$A = R \times K \times LS \times C \times P \quad (1)$$

where A is the computed spatial average of soil loss over a period selected for R, usually on yearly basis (t ha^{-1} y^{-1}); R is the rainfall-runoff erosivity factor (MJ mm t ha^{-1} y^{-1}); K is the soil erodability factor (t ha^{-1} $y^{-1}MJ^{-1}$ mm^{-1}); LS is the slope length steepness factor (dimensionless); C is the cover management factor (dimensionless, ranging between 0 and 1.5); and P is the erosion control (conservation support) practices factor (dimensionless, ranging between 0 and 1).

Rainfall erosivity (R): The rainfall factor, an index unit, is a measure of the erosive force of a specific rainfall. This was determined as a function of the volume, intensity and duration of rainfall and can be computed from a single storm, or a series of storms to include cumulative erosivity from any time period. Raindrop/splash erosion is the dominant type of erosion in barren soil surfaces. Rainfall data of 11 years (2004 to 2015) collected from Department of Geography Meteorological unit Adamawa State University Mubi was used for calculating R-factor using the following relationship developed by Wischmeier and Smith [23] and modified by Arnoldus [24]:

$$R = \sum_{i=1}^{12} 1.735 \times 10^{\left(1.5\log_{10}\left(\frac{P_i^2}{P}\right) - 0.08188\right)} \quad (2)$$

Soil Erodability Factor (K): Different soil types are naturally resistant and susceptible to more erosion than other soils and is a function of grain size, drainage potential, structural integrity, organic matter content and cohesiveness. Erodability of soil is its resistance to both detachment and transport. Soil texture map of the study area was used for the preparation of K factor map and soil types were grouped into major textural classes. The corresponding K values for soil types were identified from soil erodability nomograph [25] by considering particle size, organic matter and permeability class.

Slope length and steepness factor (LS): Length and steepness of a slope affects total sediment yield from the site and is accounted by the LS-factor in RUSLE model. In addition to steepness and length, other factors; such as compaction, consolidation and disturbance of the soil were also being considered while generating LS-factor. Erosion increases with slope steepness but, in contrast to L-factor representing effects of slope length. The combined LS-factor was computed for the watershed by means of ArcGIS Spatial analyst extension using DEM, as proposed by Moore and Burch [26,27]. The flow accumulation and slope steepness was computed from the DEM using ArcGIS Spatial analyst.

$$LS = \left(Flow\ accumulation \times \frac{Cell\ size}{22.13}\right)^{0.4} \times \left(\frac{sin\ slope}{0.0896}\right)^{1.3} \quad (3)$$

Where flow accumulation denotes the accumulated upslope contributing area for a given cell, LS=combined slope length and slope steepness factor, cell size=size of grid cell (for this study 30 m) and sin slope=slope degree value in sin.

Cover management factor (C): The C-factor represents effect of soil-Cover management factor (C). The C-factor represents effect of soil-disturbing activities, plants, crop sequence and productivity level, soil cover and subsurface bio-mass on soil erosion. Due to the variety of land cover patterns with spatial and temporal variations, satellite remote sensing data sets were used for the assessment of C-factor [28,29]. The Normalized Difference Vegetation Index (NDVI), an indicator of the vegetation vigor and health was used along with the following formula (eq. 4) to generate C-factor value image for the study area [13,30].

$$C = \exp\left[-\alpha \frac{NDVI}{(\beta - NDVI)}\right] \quad (4)$$

Where a and b are unitless parameters that determine shape of the curve relating to NDVI and the C-factor. VanderKnijff et al. found that this scaling approach gave better results than assuming a linear relationship and values of 2 and 1 were selected for parameters a and b, respectively. This equation was applied for assessing C-factor of areas with similar terrain and climatic conditions [31,32].

Conservation practice factor (P): The support practice factor (P-factor) is the soil-loss ratio with a specific support practice to the corresponding soil loss with up and down slope tillage [33]. In this study, the P-factor map was derived from the land use/land cover and support factors. The values of P-factor ranges from 0 to 1, in which the highest value is assigned to areas with no conservation practices (deciduous forest); the minimum values correspond to built-up-land and plantation area with strip and contour cropping. The lower the P value, the more effective the conservation practices.

Image processing

The Satellite image of the study area was corrected geometrically to remove distortions and subsequently enhanced to improve visual interpretation. This followed by classification into different land use types. Supervised classification was employed because of its high accuracy and the researcher's knowledge of the training areas. Ten coordinates location for each land use class were collected with the aid of GPS during ground thruthing. This was done to aid supervised classification. This is to identify sets of pixels that accurately represent spectral variation present within each information region. The datasets was classified into classes of water body, vegetation, dare land, built-up

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area and Agriculture. These are adopted from Anderson, Hardy, Roach, and Witner [34], to suit the study area.

Techniques of data analysis

The stated objectives were achieved through the following:

Estimate soil loss in the catchment area: This was done using spatial distribution of the rate of soil detachment by rain drop (F) and spatial data layers such as unchanneled and channeled flows (erosion) were input to RUSLE model in ArcGIS 10.3 software environment and predicted annual pixel level soil loss using Equation 1.

$$A = R \times K \times LS \times C \times P \quad (1)$$

Average annual soil loss of various land use/land cover types was estimated and analyzed to understand causes of erosion in the watershed in context to spatial distribution of erosion factors together with RUSLE Model.

Results and Discussion

Spatial distribution of land morphological factors

S.No	Land use type	Area Sqkm	Percentage%
1	Agriculture	42.32	28.60%
2	Forestry/Vegetation	28.05	19.00%
3	Water body	14.72	10.00%
4	Built up Area	25.3	17.10%
5	Bareland	37.33	25.30%
Total		147.72	100

Table 3: Landuse Landcover of the study area. Source: Author's Analysis.

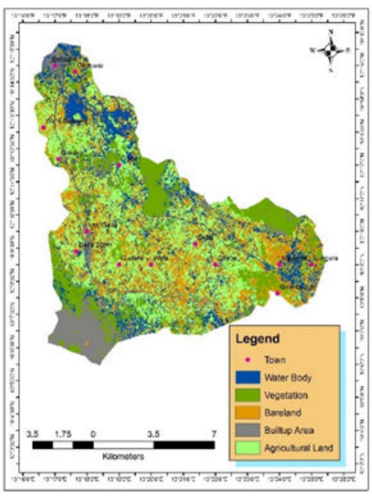

Figure 2: Land Used with the Watershed. Source: Author's Analysis.

Land morphological factors are those features which are considered to be important determinant factors in soil development and also affect soil erosion of an area. The spatial distribution of land use of Mubi South watershed is show in Figure 2 and Table 3 shows the land covered.

Land uses land cover within the watershed: Figure 2 shown that Mubi South watershed is dominantly covered by Agricultural activities with agricultural land constituting about 28% of the area, followed by bare land with about 25% of the land covered. Figure 2 show that built up area covered about 10% of land use whereas water bodies covered 17% of the land in the study area. Also, forest covered about 19% of the study area. On the basis of the analysis, it can be inferred that Mubi South is a dominant agricultural area with most of the forest cleared and cultivated as on agrarian land (Figure 2). Also, it was observed that there was a higher rainfall in the study area.

Landuse, landcover in the watershed

Table 3 presents result of land use land cover of the study area. The land uses were categorized based on five Major land uses in the study area, which were: Agricultural land, forestry, water body, built up and bare land.

As shown in Table 3, about 29% of the watershed was covered by agricultural activities, 19% was covered by forest, and 25% was not cultivated and covered by bare land while 17% was covered by built up areas and 10% by water bodies. From the result it was inferred that major land use of the watershed was agricultural activities. However, most to be area was also covered by bare land where no agricultural activities are taking place neither covered by forest.

The Normalised Difference Vegetation Index (NDVI): The Normalized Difference Vegetation Index (NDVI) is an indicator of vegetation vigor and health used in determining cover management factor (c), which represents effect of soil disturbing activities, plants, crop sequence and productivity level, soil cover and subsurface biomass on soil erosion risk. Figure 3 shows spatial distribution of NDVI in the study area.

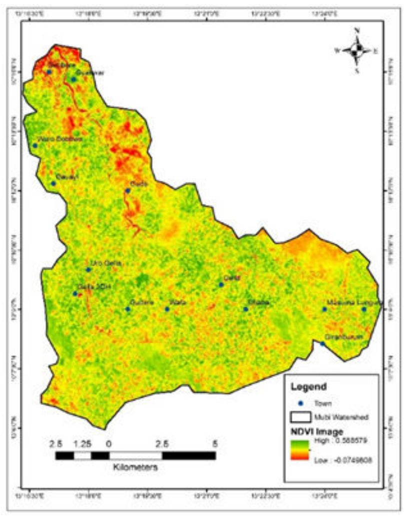

Figure 3: NDVI within the Watershed. Source: Author's Analysis.

It reveals that majority of the watershed area was covered by higher NDVI, which was about 0.58 with a lower value of -0.07. These show that the target area being observed contains live green vegetation at the

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ground cover. Yellow colour on Figure 4 represents bare soil which reflects moderately in both the red and infrared portion of the electromagnetic spectrum as supported by Holme et al. [35].

This study noted that the study area has dense vegetation because the Normalized Difference Vegetation Index (NDVI) takes value between -1 and 1, with values 0.5 indicating dense vegetation and value less than 0 indicating no vegetation as shown in Figure 3. Symeonakis and Drake [36], and Tateishi et al. [37] studies were compared using satellite imagery to produce maps of vegetation-related variables for soil erosion and found out that the normalized difference vegetation index (NDVI) was the most useful in estimating soil erosion.

Digital elevation model: The digital elevation model contains information derived from long-track, 15 m ASTER optical data acquired in near infrared bands 3N and 3B. The topographic data used to derive slope and slope aspect are basic to all aspect of land surface. The DEM of Mubi South watershed is shown on Figure 4.

From Figure 4, it was inferred that spatial distribution of DEM in the study area ranges from higher value of about 1261 m lower value of about 570 m respectively. Figure 4 shows that majority of the study area has was within the lower topography of 570 m above sea level and also all settlements of the study area were located within the lower topography with the exception of Giranburum town which is located in higher elevation area. The evidence of higher elevation of about 1261 m is the Mandara Mountain which serves as a border between Nigeria and Cameroon.

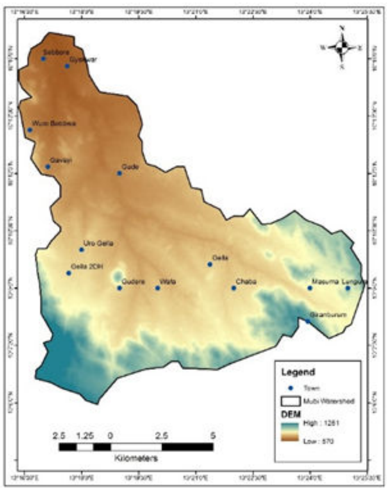

Figure 4: DEM within the Watershed. Source: Author's Analysis.

The area covered by high elevation or mountainous area has mixed up vegetation as shown in Figure 2 and this attributted agricultural activities taking place in the area and people from the communities engaged on deforestation in the area for domestic fuel and selling them to solve their financial problems as it were.

Soil of mubi south: Soil of the Mubi South watershed is shown in Figure 5. The soil map was produced for the soil sample collected from the study area during field work. Laboratory analysis was conducted, and the result obtained from the laboratory was used as basis for producing soil map of the study area and compared with FAO [38] global soil data result. From Figure 5, it was observed that there are three dominant soil classes in the study area which comprised of Luvisols, Regosols and Arenosols. Luvisols constitute about 30% Regosols 35% and Aresonols 35% respectively.

The Luvisol was in pediplain of the watershed, which has about 570 m above sea level as shown in Figure 5, along sabbore, Gyakwa, Wuro Babbwa, Gavayi and some part of Gude town of the study area. Lowland and low vegetation in the study area resulted to the presence of Luvisols in the watershed. Also, Regosol and Arenosol were located between mixed vegetation in the study area and also agricultural areas.

The movement of soil detachability from highland area contributed to the presence of Regosol and Arenoso, because nature of topography, time climate and vegetation types plays a major role on soil formation and Mubi south watershed area is not exception from the factors. Dominant soil groups of the study area are shown in Appendix III as well as their sequence, dominant soil, association and inclusion supported by FAO [39]. The soil group of study area is further divided into soil types.

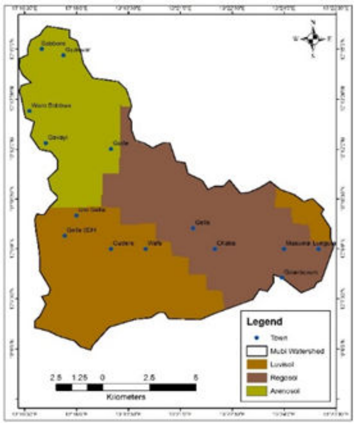

Figure 5: Soil within the Watershed. Source: Author's Analysis.

Spatial distribution of factors used in assessing Revise Universal Soil Lost Model (RUSLE)

In order to assess spatial distribution of RUSLE, five factors were chosen based on the model which served as input in the equation for assessment of soil loss in the watershed area.

Amongst factors used are: cover management factor (factor), soil erodibility factor (k-factor), slope length and steepness factor (Ls-factor), conservation practice factor (p-factor) and Rainfall erosivity (R-factor). All the factors were derived from land morphological factors; except rainfall factor. That asserts the need for assessment of morphological factors for watershed of the study area for proper analysis and assessment of soil erosion risk in the study area. The factor maps result obtained from analysis is presented in Figures 6-10.

Cover management factor: The result of cover management factor (c-factor) is presented in Figure 6 to show spatial distribution of cover management factor that range from higher value of 0.5 to lower value of 0.01 in the watershed.

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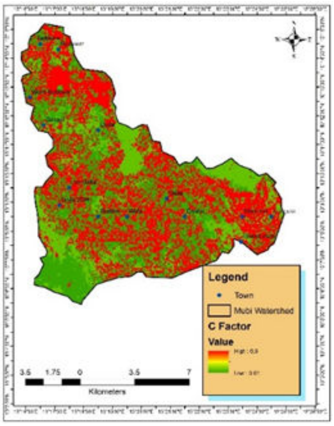

Figure 6: Cover Management Factor (C-Factor). Source: Author's Analysis.

Result of Figure 6 was due to land use covered within watershed which shows that most of the vegetation and agricultural activities were around the river. There is an intersection of low and high cover management practices in the study area. High cover management factor was observed around mountainous area of the watershed. This finding shows that land use slope and hill shade plays vital role in determining cover management practices in an area.

Soil erodibility factor: Result of soil erodibility of the watershed is shown in Figure 7. The soil erodibility factor (k-factor) measures susceptibility of soil particle to detachment and transport by rain or runoff [40].

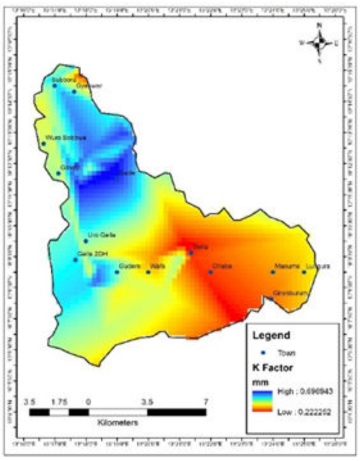

Figure 7: Soil Erodibility Factor (K-Factor). Source: Author's Analysis.

From Figure 7, it was inferred that soil erodibility factor reveals that different soils erode at different rates. For example, comparing this result with soil map on Figure 5, it was observed rate of soil erodability in heigher (0.69) around areas having Arenosol. Also, Arenosol had highest clay content and lower silt content in the study area. Luvisol had moderate (0.4) erodibility factor and characterized with moderately clay and silt content and sandy soil deposit.

The findings of soil erodibility factor range in value from 0.02 to 0.69 and support Goldman et al. [40] and Mitchell and Bubenzer. This result shows that there was lower permeability in Southeast; moderately in Southwest and higher at the Northern part of the watershed. This was as result of soil type, land use and hill shed of the area which show vidence of resistance of soil to detachment by rainfall impact and surface flow. Research Toy et al. [41] shows that soil with larger sand and silt properties are more vulnerable to water erosion due to lack of stability of the soil particle. Soil texture with large particles are resistant to transport because of the greater force required to entrain them and fine particles are resistant to detachment because of their cohesiveness. The least resistant particles are silts and fine sands. Thus, soils with silt content above 40 percent are highly erodible [42].

Slope length and steepness (Ls-factor): Slope length and steepness factor represent effect of slope length on soil erosion. The slope length is the ratio of soil loss from field slope length and soil loss increase more rapidly with slope steepness than it does with slope length. The Ls-factor result of the area is presented on Figure 8.

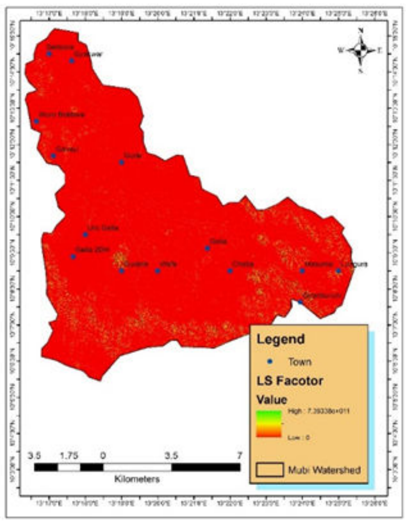

Figure 8: Slope Length and Steepness (LS-Factor). Source: Author's Analysis.

From Figure 8, the result of Ls-factor shows even distribution of slope steepness along each watershed. Research by Tay et al. [43] shows susceptibility of soil to water erosion depends on soil length and is more prevalent in sloping area [44]. Also, the result of these studies suggests a curvilinear relationship between soil loss and slope steepness, with erosion initially increasing rapidly as slope increases from gentle to moderate, reaching a maximum on slopes of about 7° and then decreasing with further increases in slope. Such a relationship would apply only to erosion by rainsplash/sheet and surface runoff. It would not apply to landslides, piping or gully erosion by pipe collapse.

Again, studies of Toy et al. [41] show that slope length has effect on soil loss for steep slope. Also reported that greater sensitive of slope had effects on soil loss due to differences in rainfall. Areas having about 7.39 m length of cell slope length and steepness in the watershed as show on Figure 8, will have greater soil loss as supported by Toy et al. [41], than those areas having 3 m and 0 m length of cell slope length respectively.

Citation: Thlakma SR, Iguisi EO, Odunze AC, Jeb DN (2018) Estimation of Soil Erosion Risk in Mubi South Watershed, Adamawa State, Nigeria. J Remote Sensing & GIS 7: 226. doi:10.4172/2469-4134.1000226

Conservation practice factor (P-factor) within the watershed: Conservation practice (p-factor) is the support practice factor. Reflect effect of practices that will reduced amount and rate of water runoff; hence reduce the amount of erosion [33].

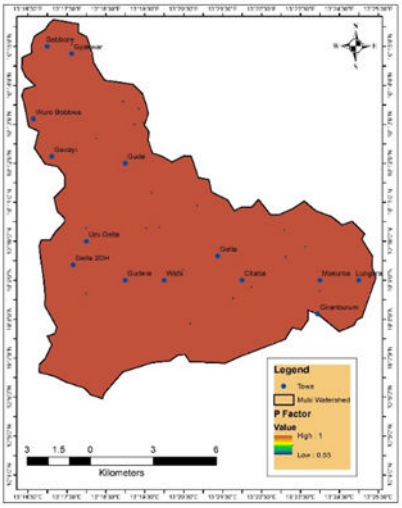

Figure 9: Conservation Practice Factor (P-factor). Source: Author's Analysis.

The p-factor represents ratio of soil loss by a support practice to that of straight-row farming up to down the slope. The result of the p-factor for the watershed is presented in Figure 9.

As shown in Figure 9, areas which shows the spatial distribution value of 1 from the legend show no conservation practice (deciduous forest) while the minimum value of 0.55 corresponds to built-up with strip and contour cropping as supported by Renard et al. [33]. The lower the p-value (0.55) as in the watershed, the more effective is conservation practice in the study area.

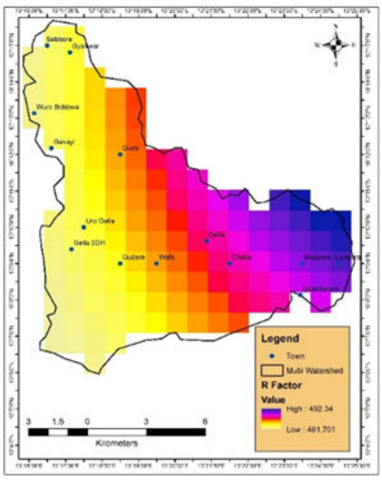

Figure 10: R-Factor. Source: Author's Analysis.

Also, result of the practice correspond to nature and land use landcover map of the watershed. The result also proves that practice factors supported in the watershed was contouring and contourstrip cropping with the value ranges between (0.350-0.600).

Rainfall erosivity (R-factor): Rainfall erosivity is a measure of the erosive force of a specific rainfall. Rainfall is the main climatic characteristics that influence soil erosion; given the extraordinary importance of soil detachment process due to drop impact and runoff shear [23]. Rainfall erosivity map of the watershed is shown on Figure 10.

As shown in Figure 10, spatial distribution of rainfall map of the watershed indicates that it ranges between 481 m to 192 m. It also shows that the rainfall is higher towards northwest of the watershed and the area of higher rainfall were in the mountainous area of the watershed along Masuma and Lumgura which shares boundary with the Republic of Cameroon.

The spatial distribution of five factors map produced were used as input for derivating GIS-based RUSLE and also served as input for some of the RMMF model. These analyses explored the importance of GIS and remote sensing in integrating both spatial and non-spatial data/information; hence the needs for the technique in assessing and analyzing spatial distribution of soil erosion data. Results obtained were used as input in estimating rate of soil erosion in objective four of this study.

Estimated spatial distribution of soil loss risk in the watershed area

The result of the estimated spatial distribution of soil loss in the study area is presented in Figure 11.

Figure 11 indicates that soil erosion loss in the watershed area was 3.5 t h^{-1} yr^{-1} as at the time of this research. It was observed that higher soil loss was obtained were crop cover management is high; with about 4.5 rate of potential evapotranspiration and between 0.08 to 0.24 high soil moisture. It was also observed that soil loss was high between 15.8 mm to 15.7 mm high to medium occurrences of daily rainfall.

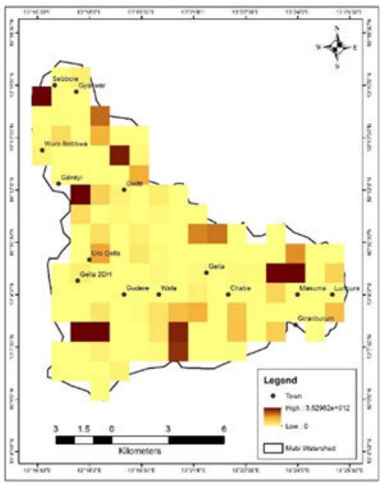

Figure 11: Estimated Soil Erosion Using RUSLE. Source: Author's Analysis.

Also, it was noticed that area with high soil loss was observed within low soil porosity area, except around Sebbore which was located in an area of high porosity with lower slope steepness length mostly having low to moderate silt content (52.8 to 223.9) with 1.4 Mgm^{-3} to 1.6 Mgm^{-3} bulk density.

Contributions to Knowledge

The outcome of this research provides blueprint showing that estimated spatial distribution of soil loss in Mubi South indicated high soil erosion loss of 3.5 $t\ h^{-1}\ yr^{-1}$ in the watershed.

Results of this study serve as a document that can help town planners, road construction planners, engineers and site constructors to design urban land use plan that are less vulnerable to erosion.

Conclusion

Studies had shown that recent global land degradation caused by increase in soil erosion risk lead to land degradation and in Mubi South Watershed and Nigeria are not exceptions of degradation. Remote sensing data and GIS successfully enabled rapid, as well as detailed assessment of estimating soil erosion and show spatial distributions of soil erosion related factors and features.

Recommendations

Reduced on-site impacts of soil erosion: Vegetative buffers (trees, understory, and ground cover) combat soil erosion as they protect the soil from erosion processes, allow greater infiltration of water and trap sediment entering from cultivated areas. Appropriately designed windbreaks can also significantly reduce soil loss from fields by reducing wind velocity as recommended by Salah et al. [45].

Recommendation for Further Research

- This present research did not measure the area coverage of individual soil erosion types; hence, the need for further research to measure the magnitude of all forms of soil erosion.
- It is also recommended for research like this to be conducted in Mubi North Local Government because it was confirmed during field work that the area is also experiencing soil erosion and there are the needs to know the areas vulnerable to soil erosion risk for proper conservation practices, planning and management.

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