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Potential Soil Loss Rates in Urualla, Nigeria using Rusle

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Abstract- Soil erosion represents a natural risk which produces material and human losses annually. The assessment and mapping of erosion prone areas are essential for soil watershed management. The objective was to apply RUSLE model to determine the amount of soil loss in Urualla watershed of Imo, Nigeria. Land use and land cover map was obtained from Google earth satellite image; ground control point data was collected from GeoSmart Survey, Imo State, Nigeria; 25 year sannual rainfall data was obtained from NIMET; soil map was generated from Onyekanne et al. (2012) soil data. The various components of RUSLE were integrated into the ArcGIS 10.2.1 to estimate the annual soil loss in the area. The soil loss in the area ranged from6 to 1200 t/ha/year while the mean annual soil loss is 36 t/ha/yr. The erosion map obtained shows that in the study area, 25.9% has medium erosion rate of 10-15 t/ha/yr; 33.6% has moderately high erosion rate of 15-25 t/ha/yr; 16.4% has high rate of 25-50 t/ha/yr while 14.7% has a rate greater than 50 t/ha/yr. The study shows that GIS presents simple and low cost tools for assessing erosion potential and risk in a watershed.

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I. Introduction

Soil erosion is one of the most serious environmental problems in the world today because it threatens agriculture and also the natural environment [8].The factors which influence the rate of erosion are rainfall, runoff, soil, slope, plant cover and presence or absence of conservation measures, [6]. Erosion control requires a quantitative and qualitative evaluation of potential soil erosion considering these factors [9].

Urualla watershed has massive active erosions currently devastating the land. This has been attributed to several causes [16]. Assessing soil erosion rate is essential for the development of adequate erosion prevention measures for sustainable management of land and water resources [3].

Soil erosion modelling can be undertaken using deterministic, stochastic, or empirical approaches [1]. In an empirical model, theoretically-based procedures are employed using parameters like Universal Soil Loss Equation (USLE), Revised USLE or its modifications and derivatives ([17, [13] and[14]). Geographic Information System (GIS) technologies are valuable tools in developing environmental models through their advance features of data storage, management, analysis and display. There are several GIS-Based models used to estimate soil loss. RUSLE is frequently used due to its simplicity and suitability for integration with GIS. RUSLE has several improvements over USLE in estimation of factors and application to different conditions including forest, rangelands and disturbed areas [5]. Several studies has been carried out in recent years using RUSLE ([2],[10],[3],[4]etc.). With appropriate selection of factors, RUSLE computes average soil loss [13] as follows

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

Where: A = Computed average annual soil loss in (tons/ha/year), R = Rainfall erosivity factor in (MJ.mm/(ha.h.year-1)); K = Soil erodibility factor in (t.ha.h/(ha.MJ.mm); LS = Surface characteristic factor comprising of L = Slope length factor and S = Slope steepness factor; C = Cover management factor; P = Conservation practice factor or support practice factor.LS, C, and Paredimensionless.

The runoff factor [7]is computed as

$$R = 38.5 + 0.35 \times Pr \quad (2)$$

Where, Pr = annual average rainfall (mm/yr)

The LS factor is estimated [17] as

$$LS = \left(\frac{\text{Flow accumulation} \times \text{Cell value}}{22.1}\right)^m (0.065 + 0.045\,S + 0.0065\,S^2) \quad (3)$$

Where cell value = resolution of DEM, S = slope (%) generated from DEM, m is estimated from [17] table.

The support practice factor P classified according to cultivation and slope are obtained from [15]. The objective of the study therefore is to predict soil loss rate in Urualla watershed using RUSLE and compare results with physical site assessment.

a) Study Area

Urualla is located in the north-western region of Idea to North L.G.A of Imo State, Nigeria. It covers a total of approximately 19.570 sq km and is situated between latitude 5° 50´N and 5° 55´N; and longitudes 7° 00´E and 7° 05´E. The area is semi-urban consisting mainly of built up areas which is characterized by humid

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tropical wet and dry climate governed primarily by rainfall. The annual rainfall ranges from 1,990mm to 2,200mm with average annual temperature of 25.8 °C. The study area is shown in Fig. 1.

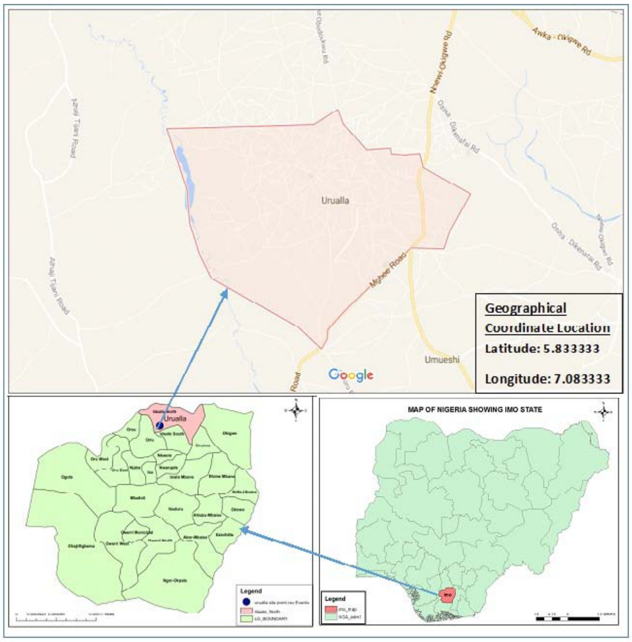

Fig. 1: Location map of the study area

II. Materials and Methods

The primarydata include DEM of Urualla, which was generated from ground control point (GCP) data collected from GeoSmart survey unit in Imo State. A high resolution Google earth satellite image used to obtain the land use and land cover map of the study area. The annual rainfall Owerri, Enugu and Onitsha stations were collected from the Nigerian Meteorological Agency (NIMET) for a period of 25years (1981-2005). The study area soil map was generated from soil data [12]. The various components of RUSLE namely rainfall erosivity(R), soil erodibility(K), topographic factor(LS), crop management factor(c) and conservation practice factor (P) were obtained using equations specified in literature and integrated in ArcGIS 10.2.1to estimate the amount of annual soil loss. A schematic presentation of the procedure as adopted from [11] is shown in Fig.2.

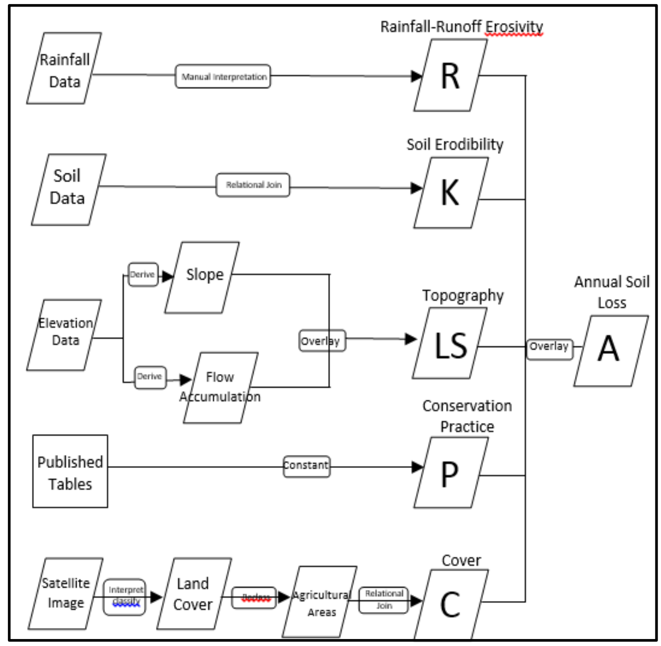

Fig. 2: Procedures of RUSLE integrated in ArcGIS
Source: Omar, (2010)

III. Results and Discussion

The rainfall erosivity factor (R) ranged from98.8939 to100.04 MJ.mm.ha^{-1}.hr^{-1}.year^{-1} (Fig. 3). Based on rainfall erosivity, the higher value which is 100.04 found in the lower part of the study area shows it'smore likely to cause erosion while the lower value in the upper part of the study area indicates less vulnerability to erosion when considering rainfall.

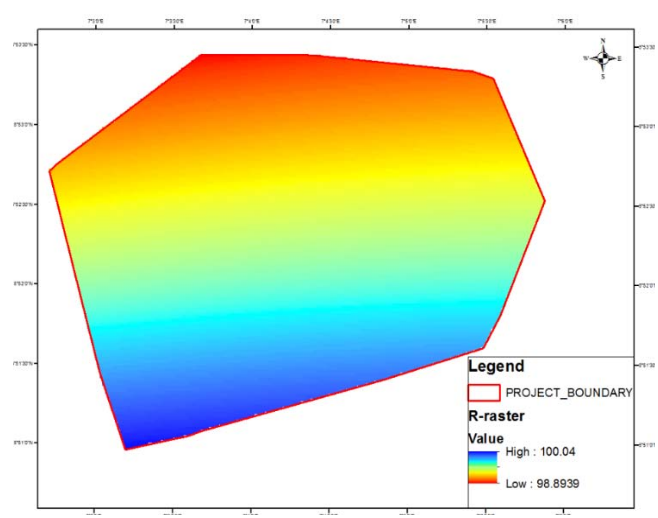

Fig. 3: R factor Map

The value of K-factor in the study area ranged from 0.131454 to 0.140551 ton. ha/MJ.mm (Fig.4). The high K-factor value found in the upper side of the watershed shows that the soil type is more likely to be eroded while the smaller value found in the southeastern part of the watershed shows the soil to be less vulnerable to erosion.

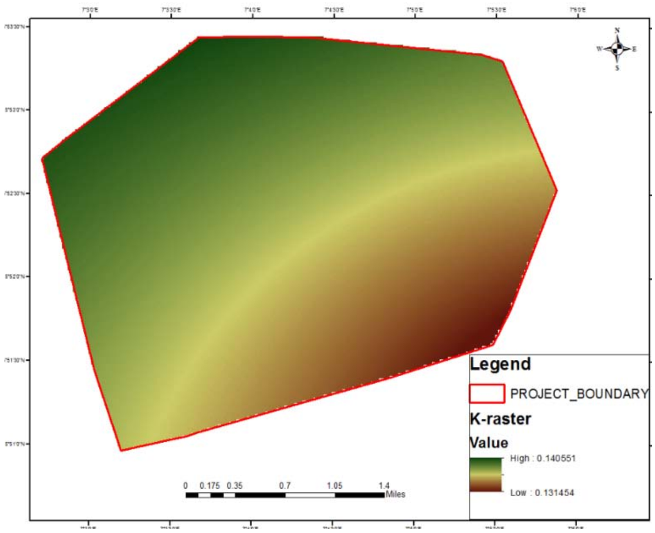

Fig. 4: K Factor Map

The topographic factor, LS increases in the range of 0.0-39.045 (Fig.5) as the slope and flow accumulation increases. The high LS values are associated with steep slopes between 15% - 50% and greater than 50%. Areas of high LS value are more likely to be eroded than other areas.

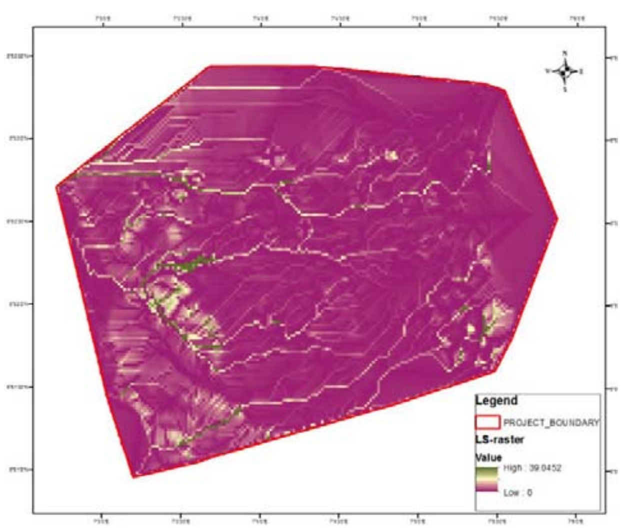

Fig. 5: LS Factor Map

Fig. 6 shows spatial distribution of crop management factor C which ranged from 0 to 0.5. Thus, based on C-factor the large value shows more vulnerable land use/land cover to erosion and on the other hand the lower value shows less vulnerable land use/land cover to erosion. From the result bare lands have a large value of C-factor of 0.5.

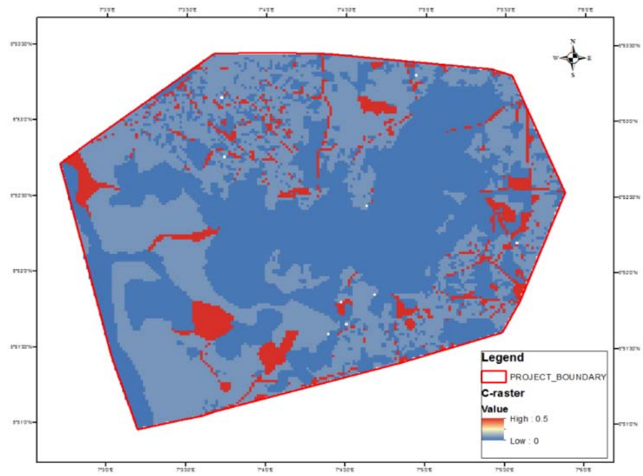

Fig. 6: C Factor Map

The P factor ranged from 0.55 to 1.0 (Fig.7). By contrast, maximum P values correspond exactly with areas of steep slopes while the minimum values corresponds with areas of gentle slope

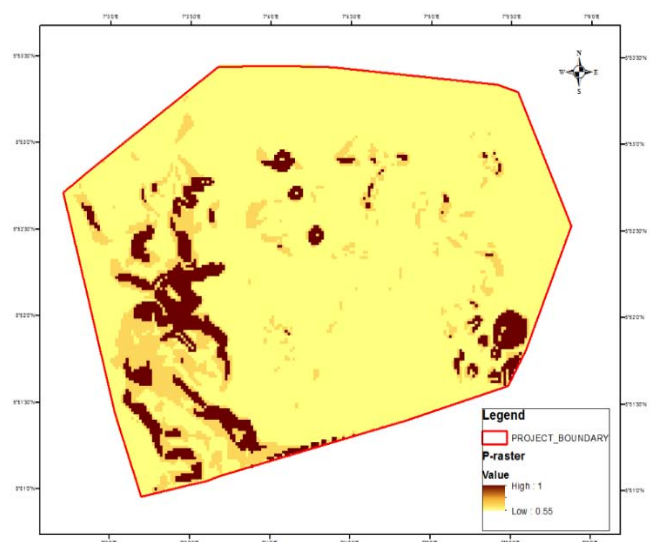

Fig. 7: P Factor Map

This five (R, K, LS, C and P)maps were multiplied interactively using raster calculator tool in ArcGIS 10.2.1. The output gives an erosion map which shows that the potential annual soil loss of Urualla watershed ranges from 6 to 1200 ton/ha/year (Fig. 8).

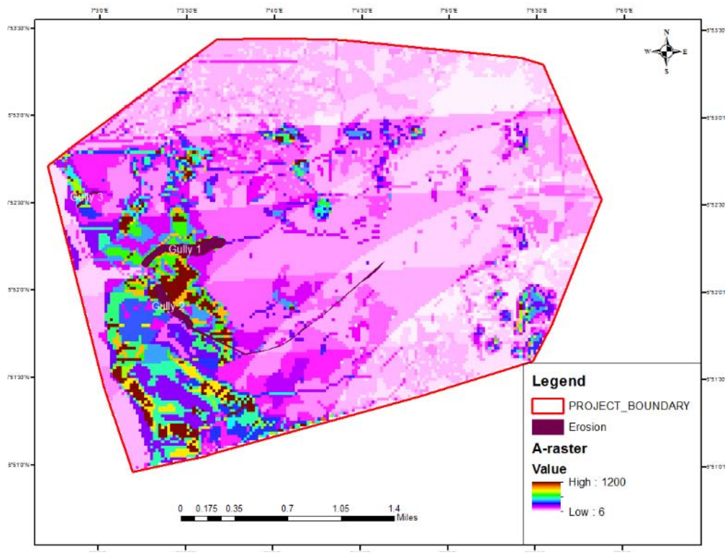

Fig. 8: A Map (Soil loss Map)

The lowest soil loss rate is 6 t/ha/yr while 1200 t/ha/yr shows highest soil loss rate in the study area. The mean annual soil loss rate is 36 ton/ha/year which is much greater than the tolerable level of 10 ton/ha/year (Hurni, 1983).

The result of reclassifying Urualla soil loss rate map into six soil erosion risk categories (Fig. 9) shows that the three identified gullies discovered during site visit falls on the areas having very high and high rate of soil loss. Thus, this accounts for the massive soil loss at the gullies more especially gully 1 to an estimated depth of about 20 m. The result of analyzing the soil loss map to estimate the area of coverage (Fig. 10) shows that 0.2% and 9.2% of the watershed area has very low and low rate of soil loss respectively while 25.9% and 33.6% of the area has medium and moderately high rate of soil loss. 16.4% and 14.7% of the watershed area has high and very high soil loss rate.

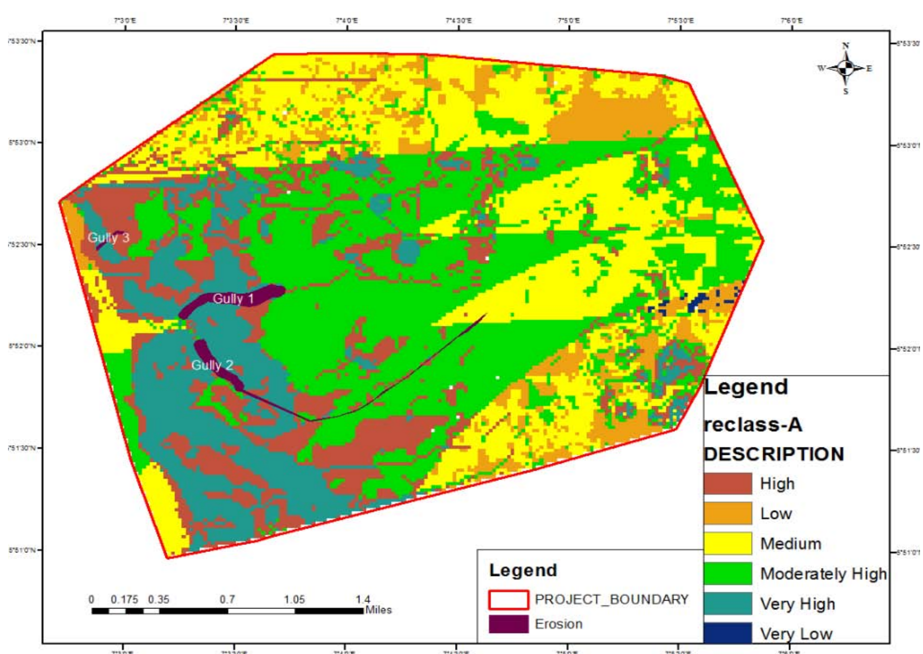

Fig. 9: Reclassified soil loss rate (A) Map

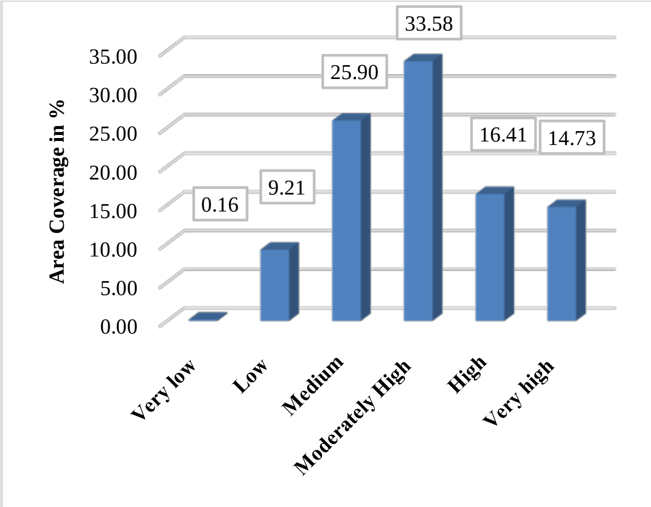

Fig.10: Classes of average annual soil loss and corresponding area

From the results shown in Figs.8,9 and 10, this study has however, clearly highlighted the spatial distribution of erosion hotspots in the region, thus providing a great insight of erosion impact trends in the study area. These results are expected to serve as a relevant guide to environmental and water resources managers involved in the mitigation of the impact of erosion in the study area. It is obvious that surface erosion can vary spatially due to rainfall variability, topographic changes, different soil types and characteristics, and human-induced disturbances. The C and P factors can be improved to reduce the soil erosion loss through afforestation and shifting community environmental practice. The LS factor also can be modified by shortening the length and steepness of slopes by the construction of contour walls and terraces. Construction of soil conservation measures like cistern to harness precipitation is vital to control runoff and soil erosion across different agro-ecological zones and under various land uses/land cover. Expected benefits of enhancing soil and water conservation in the studied area could be summarized in the following: reduction in sediment load of Urualla; and reducing the peak flows of the Urualla watershed. Also, the construction of check dams along gullies is an essential measure to minimize gully erosion.

IV. Conclusion

The extent of soil erosion occurring in the study area is still increasing and is now a major cause for concern. The present determination of RUSLE parameters for mapping potential soil loss rates in Urualla, Imo State has revealed the severity of soil erosion in the area and identified critical areas for soil conservation measures and sustainable environment. The approximate mean annual rate of soil loss in the watershed is 36 ton/ha/year, which is very large enough to degrade the area, with the six erosion risk classes, ranging from 6-1200 t/ha/year. 14.7%, 16.4% and 33.6% of the area experience very high, high and moderately high erosion rate which shows that greater part of the study area are highly at risk. This has also been proven to be correct from site visitation results. They study also revealed that high rainfall erosivity and soil erodibility combined with moderate to high slope and decreasing vegetal cover are the major factors driving soil loss in the area.

Finally, the present investigation has demonstrated that GIS techniques are simple and low-cost tools for modeling soil erosion, with the purpose of assessing erosion potential and risk for Urualla watershed.

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