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Research Paper

Modelling and Mapping Area susceptible to soil erosion: a case study of Federal Polytechnic Ado-Ekiti

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Abstract
Modelling and mapping of soil erosion is an indispensable activity which can assist decision makers and planners to know areas susceptible to erosion and also to help limit the development of further deterioration in the area of study. While Universal Soil Loss Equation (USLE) is that the most commonly employed model because it gives a straight forward approach for qualitative evaluation of soil loss, however its rainfall erosivity component is found inadequate in most parts of the world. To beat this deficiency, the Revised Universal Soil Loss Equation (RUSLE) was implemented using rainfall erosivity (R) values peculiar to the area of study. Rainfall erosivity (R-factor), soil erodibility (K-factor), slope factor (LS-factor), and canopy/cover management (C-factor) were generated in GIS environment and then integrated based on RUSLE equation to estimate the rate of soil erosion. The study reveals that areas vulnerable to very high erosion potential are located towards the eastern part of the area of study.

Keywords: Modelling, Mapping, Soil erosion

I. Introduction

In regard to tropical and semi-arid areas, soil erosion is a hazard customarily connected with agriculture and is crucial for its long-term consequence on soil productivity and sustainable agriculture [[1]]. Since the soil revamps itself, although slowly, some erosion is permissible in as much as no more soil is removed than is formed. However, if the soil is eroded faster, the quality of the soil as a crop-growing medium decreases, costs of production will increaseand at a certain stage economic production of crop will no longer be practicable.One of the major global environmental problems is soil erosion, having extensive and consequential negative effects on quality of water and biodiversity and promoting the emission of climate changing greenhouse gases.

Soil, after water, is the most essential resource for the continued prosperity of human populations. The major threat to the continued productivity of the soil resource is persistent mismanagement [[2, 3, 4]].

To reduce the effects of erosion, there is a need to forestall further degradation through natural recovery and restoration strategies such as exclosures, reforestation, including other soil and water conservation (SWC) interventions[[5, 6, 7]]. Since erosion reveals spatial variability across the landscape, it is not economically practicable or technically possible to conserve all areas experiencing loss of soil. Consequently, it is essential to identify vital areas of erosion that require priority management intervention.

Soil is animportant valuable natural resource that performs significant ecosystem functions, and provides many valuable environmental resources [[8]]. Soil erosion and its effect on ecosystem services receive rising attention from scientists and policy makers [[9]]. To evaluate the socio-economic and environmental effects of soil erosion and to develop management plans to confront them; quantitative data on soil erosion rates at both regional and global scales are required [[10]].

Soil erosion, a major factor for the reductions in soil fertility and land value, is largely recognized as a threat to farm livelihoods and ecosystem integrity all over the world. The operations involved in soil erosion by water change over time and space and depend on various factors such asground cover, soil texture, structure, porosity/permeability, and topography [[11, 12]].

This study aimed at carrying out modeling and mapping of area susceptible to soil erosion with the view of improving management of erosion and rehabilitation of gully with a view to provide for:

- Reduction in the loss of infrastructure such as roads, houses, markets etc.
- Reduction in the loss of agricultural land and productivity from loss of soilas a result of surface erosion.
- Siltation in rivers reduction leading to less flooding particularly in urban areas which will also lead to preservation of some of the water systems for improved access to domestic water supply.
- Flood risks reduction (due to reduced siltation) in rural areas and reduced effects on villages and agricultural areas.
- Reduction in sedimentation in rivers and water infrastructures such as canals and dam reservoirs thereby improving their life and productivity.
- Improvement in the access to economic activities, social services, and communication and road networks.
- Progressive restoration of vegetative cover and improved environmental conditions due to increment in vegetation cover for wildlife, carbon sequestration, and make local microclimates more humid.

II. Study area

The study area is Federal Polytechnic Ado-Ekiti and it's located at Ado-Ekiti local Government area of Ekiti state. The study area lies within latitude 70.41 – 70.45N and longitude 3.830 – 3.880E. The study area was originally acquired by government under the public lands acquisition ordinance of 1941. The institution was established at the expense of the movement of academic activities of the state.

The area of study is situated within the lower boundary of Guinea Savanna vegetation belt having the combination of equatorial and tropical hinterland climate.

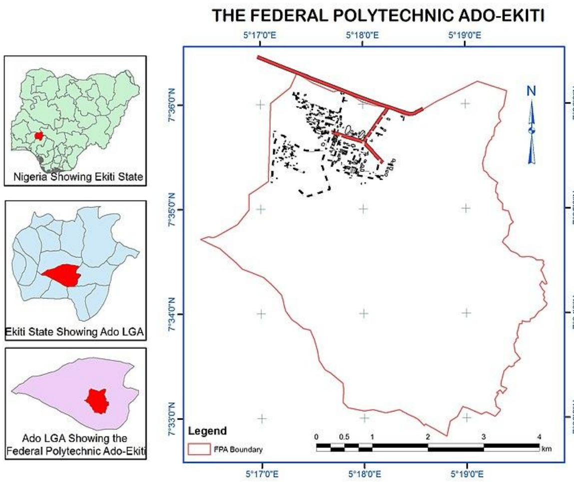

Fig. 1: Map showing the study area

III. Materials And Methods

The data used in this study were generated from both primary and secondary source.

Primary data

The primary data utilized in this study were GPS coordinates obtained on the field using Global Positioning System (GPS).

Secondary data

The secondary data used in this research were; satellite imagery, rainfall data, soil map and topographic map covering the area of study. Table 1 shows the summary of the data used and their sources.

Table 1: Data used and their sources

S/N	Data	Source
1	Rainfall data	Nigeria Meteorological Agency
2	Soil map	Federal Ministry of Agriculture & Rural Development
3	Satellite imagery	Scihub.copernicus.eu
4	Topographic map	Office of the Surveyor General of the federation

5	GPS coordinates	Field survey

Source: Author

Various parameters used in RUSLE Rainfall
$Y = A * B * C * D * F * F$
Where, Y = Annual soil loss (tons/hectare) resulting from sheet and rill erosion.
A= Rainfall - runoff erosivity factor
B= Soil erodibility factor.
C= Slope length factor.
D = Slope steepness factor
E = Cover management factor.
F = Erosion control factor

The methodology adopted for this research work is in the figure 2 below

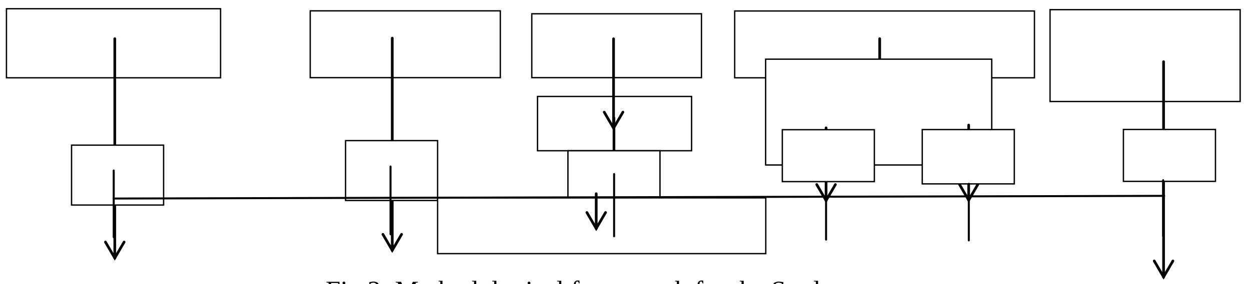

Fig 2: Methodological framework for the Study

i. Erosivity Factor (A)
The rainfall erosivity factor (A) is the ability of rain to affect or detach the particles of soil based on the extent of rainfall. Erosivity used in the RUSLE must recognize the aftermath of raindrops that cause impact on soil and clarify the amount of runoff associated with rainfall.

ii. Soil Erodibility Factor (B)
Measure ofvulnerability of soil particles being detached and transported by rainfall is termed as soil erodibility factor. B factor is highly affected by soil texture, organic matter contained, soil structure and permeability of the soil.

iii. Topographic Factor (CD)
This a combination of slope gradient factor (D) and a slope-length factor (C), which is determined from the DEM. Slope length factor is an important parameter in modeling and computing transport capacity of surface runoff by soil erosion. An increment in the slope length of area reveals the steepness in which loss of soil per unit area increases. The association of loss of soil to terrain gradient is influenced by the vegetation coverage and size of soil particle. It depicts the impact of topography, specifically hill slope length on erosion.

iv. Support Practice Factor (F)
The support practice factor (F) helps to lessen the erosion potential of runoff that is influenced by the drainage pattern, runoff velocity and force expended by flow on the surface of soil. It represents the overall impact of supporting conservation practices like contour farming, strip cropping, terracing on loss of soil at a specific site, as these practices affect water erosion by changing the pattern or direction of flow of surface runoff by minimizing the volume and runoff rate.

v. Land Surface Cover Management Factor (E)
The Land Surface Cover Management Factor (E) expresses the ratio of soil erosion from land crop under particular conditions. It estimates how natural vegetation or crop cover minimizes rainfall energy and overflows or intercepts rainfall energy and increases infiltration. It is the second most vital factor aftertopography and rainfall erosivity that regulates soil erosion risk[[13]].E equals 1 under standard fallow conditions where the vegetation cover has been totally stripped off. As vegetative cover nears 100%, the E factor value nears 0.

IV. Results and Discussions

The technique employed in this study is the RUSLE. The RUSLE is an empirical equation which calculates area susceptible to erosion as influenced by four major factors influencing erosion.
The RUSLE is given as:
$Y = A*B*C*D*E*F$ (Eq. 1)

Where Y is the calculated soil loss, A is the rainfall-runoff erosivity factor, B is the soil erodibility factor, C is the slope length factor, Dis the slope steepness factor, E is the cover management factor, while F is the support practice factor.

Rainfall Erosivity Factor (A-factor)

Rainfall erosivity of the area of study was derived by interpolation of erodent lines. The maximum value is 4510 MJ mm ha^{-1} h^{-1} while the minimum is 3894 MJ mm ha^{-1} h^{-1}. The mean and standard deviations are 4209.75 and 147.18 MJ mm ha^{-1} h^{-1} respectively. The highest values occur in the southern part of the study area and decreases gradually toward the northern part. The rainfall erosivity map (Fig. 3) indicates that distribution of rainfalldiffers within the study area and the use of a single A value cannot adequately capture the rainfall variability in the area of study.

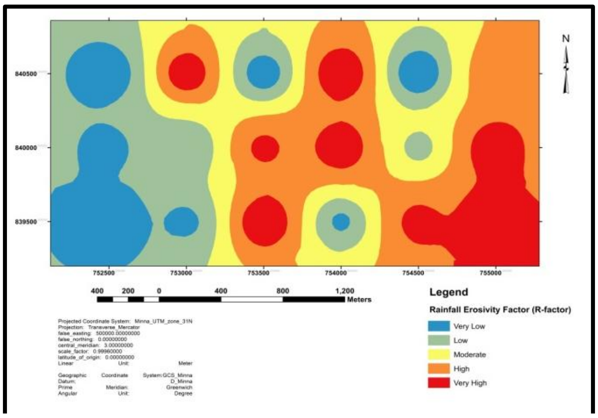

Fig 3: Rainfall Erosivity Factor (A-factor)

Slope Length and Steepness Factors (CD-factor)

The calculated slope length and steepness factorvaries from 0 to 193.5 (Fig.4) and (Fig 5). The average is 1.64 while the standard deviation is 5.60. Examination of the histogram of CD-factor reveals that 98% of the study area has values less than 15. The higher values occur mainly along the slopes of highlands in the south while low plains lying to the east, west and north generally have low values. Although past researches suggest that slope lengths are usually less than 120m and generally do not exceed 300m,though the validity of this is yet to be confirmed in mountainous and complex landscapes.

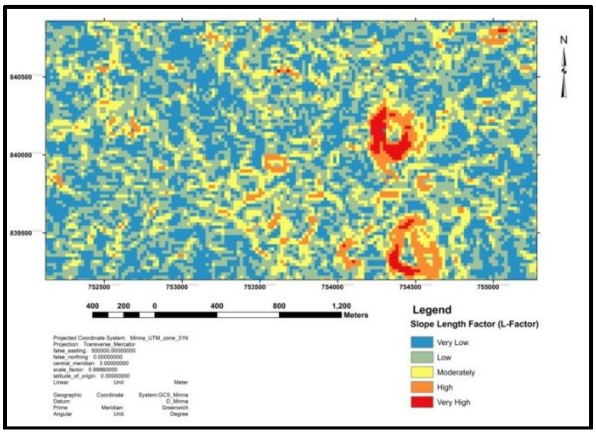

Fig. 4 Slope Length Factor (C-factor)

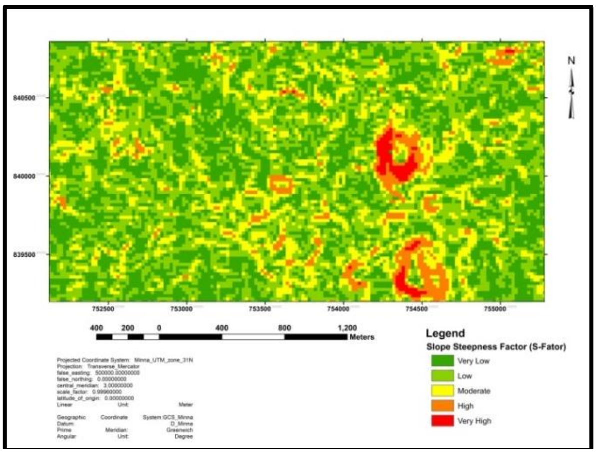

Fig. 5: Slope Steepness Factor (D-factor)

Soil Erodibility Factor (B-factor)

Erodibility values were allocated to each soil type depending on soil description and information available in literature. The spatial distribution of the B-factor in the area of study is shown in Fig. 6. Considering that shale and sandstone are the dominant lithologies in the area of study, the soils derived from these rock types are generally rich in sand and clay having very little silt. The B-factor ranges from 0.08 to 0.19. The soil type with the highest B value (0.19) is a loamy sand/sandy loam soil which has been described as having the highest silt/clay ratio [[14]], and covers 114.75km^2 (2.51%) of the area of study. Soil with erodibility value of 0.15 covers 2387.21km^2 (52.17%) representing the soil with the highest percentage of area covered. Poorly drained loamy sand with B-value of 0.12 covers an area of 92.28km^2 (2.02%), while deep imperfectly drained loamy sand to sandy loam with B-value of 0.10 covers an area of 1348.5km^2 (29.47%). Well drained loamy sand to sandy loam having erodibility value of 0.09 covers 621.55km^2 (13.58%). The soil having the lowest B-value (0.08) which is a well-drained sandy loam to loamy sand and sometimes gravelly soils covers the smallest part of the study area 11.25km^2 (0.25%).

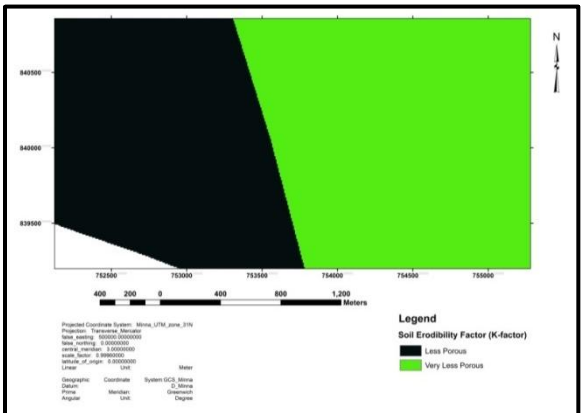

Fig 6: Soil Erodibility factor (B-factor)

Cover Management Factor (E-factor)

Vegetation and landuse/landcover are vital factors in erosion process. The cover management factor expresses the impact of landuse/landcover on erosion. The extent of vegetation cover has great influence on the rate of erosion. By evaluating the extent of vegetation cover through NDVI and subsequently transforming the values, E values between 0 and 0.5 were obtained (Fig. 7). The highest E values correspond to sand deposits occurring along the banks of River Niger on the west while value of 0 is allocated to the river body.

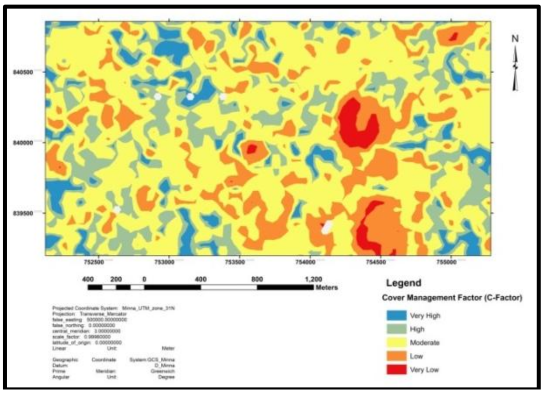

Fig. 7: Cover Management Factor (E-factor)

Soil loss in area of study

The mean annual soil erosion (Y) is evaluated by using Eq. 1 which involves multiplying the factors developed as raster data. The map of mean annual soil loss is shown in Fig. 8. The mean value of the evaluated soil loss is 214.82 t ha^{-1} $year^{-1}$. The evaluated soil erosion is further categorized into six (Table 1) in order to discover the severity of soil loss. The classification reveals that about 1804.39km^2 (39.49%) has erosion rate of 0-10 t ha^{-1} $year^{-1}$ which can be considered as slight rate of erosion, while about 746.6km^2 (16.34 %) experience moderate soil loss between 10.6-85.3 t ha^{-1} $year^{-1}$. The areas under classes of high, very high, severe and very severe are: 1025.38, 659.55, 287.08, and 46.59km^2 amounting to 22.44, 14.43, 6.28, 1.02% respectively. The highest erosion rates were found to occur in areas where slope is greater than 15^0. The study reveals that rainfall and slope factors are the critical factors driving soil erosion in the study area. High rainfall erosivity combined with moderate to high LS factor and low cover result in high rate of soil loss. Southern Nigeria is a high rainfall region, good vegetation cover and heavy plant residues would be expected to protect the soil surface throughout most part of the year. However with rapid rise in population, the demand for more agricultural lands has significantly increased, and marginal lands have been cleared up for farming. The soil is no longer sufficiently protected by vegetation cover, thereby exposing the soil to heavy tropical storms. The greatest erosion will henceoccur when rain storms fall on bare or poorly covered soils.

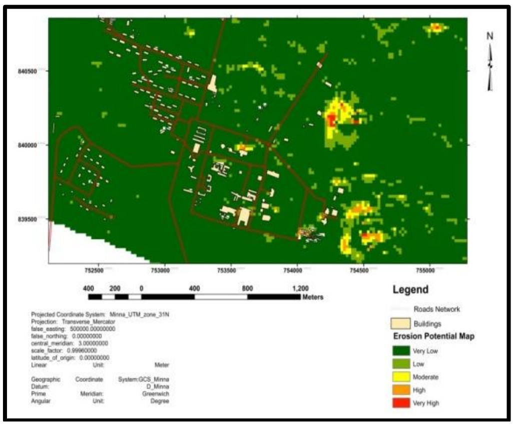

Figure 8: Areas Susceptible to Erosion in the Study Area (The Federal Polytechnic, Ado-Ekiti)

V. Conclusion

This study focused on area vulnerable to erosion and identifying crucial areas for soil conservation measures. The RUSLE has been the most widely used method to evaluate soil loss due to water erosion at any point in a landscape where erosion is active because it is conceptually simple to understand and easy to implement. Implementation of RUSLE shows that the western part of the study area is mostly affected with splash, sheet and rill erosion. It is therefore necessary for the management of Federal Polytechnic, Ado Ekiti through the maintenance unit to actively look into the study area so as to provide the necessary conservation measures in other to curb the continuity of erosion within the school premises.

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