2025 Scienceline Publication

Journal of Civil Engineering and Urbanism

Volume 15, Issue 2: 65-76; June 25, 2025

ISSN-2252-0430

DOI: https://dx.doi.org/10.54203/jceu.2025.5

Erosion Susceptibility Mapping for Owena River Basin, Nigeria

Obinna Anthony Obiora-Okeke

Department of Civil and Environmental Engineering, Federal University of Technology, Akure, Nigeria

Corresponding author's Email: oobiora-okeke@futa.edu.ng

RESEARCH ARTICLE

PII: S225204302500005-15

Received: May 11, 2025

Revised: June 17, 2025

Accepted: June 20, 2025

ABSTRACT

Erosion susceptibility studies on a basin scale is critical to integrated water resources planning of a river basin. Rapid urbanization, uncontrolled deforestation and overgrazing have made these studies even more important for development of strategies for soil conservation and land management in river basins. In this study, maps were developed to describe the spatial susceptibility to soil erosion within the Owena River basin using the RUSLE model. The parameters of the model include rainfall erosivity factor, soil erodibility factor, slope steepness and length factor, cover management factor and support practice factor. Rainfall erosivity was high in the southern and coastal parts of the river basin (RB) but had little erosion severity impact due to low slope steepness and length factor, and low cover management factor that characterized most of the RB. These low values were due to the flat topography of the basin and that 89% of the basin is of dense vegetation landscape. The soil erodibility range for the RB was low to moderate. The predominant soil erosion rate estimated was 0 – 10 ton/ha/yr and it covered 97% of the RB. This range implies that soil loss due to water erosion in the basin was low to moderate. However, low to moderate soil erosion susceptibility degrades agricultural topsoil in long-term, underscoring the need for sustainable land use and agricultural practices. High to severe erosion rates affected 1, 646 hectares of the RB and was mostly in grass lands and urban areas of the RB. This is attributed to rapid urbanization, which increased runoff and its erosive force, and overgrazed grasslands, which are more vulnerable to erosion due to vegetation loss. The annual soil loss for the whole RB is 5.5 tons/ha/yr while the total the annual soil loss from the RB was calculated as 38, 316 tons. This study has provided important information on parts of the RB needing targeted soil conservation and land management applications.

Keywords: Erosion susceptibility, Annual soil loss, RUSLE, Land use and Land cover, Soil conservation

INTRODUCTION

Soil erosion especially water erosion depletes the fertile organic top soil thereby reducing the nutrients available for plant growth. The loss of arable lands is exacerbated by increasing population in Nigeria that relies on the limited fertile land (Nnanguma, 2025).These losses have threatened livelihood and increased migration. Soil erosion in Nigeria particularly in parts with high intensity rainfall and deforestation, have grave implications on food security, water resources and infrastructure (Samuel et al., 2025). Worldwide, between 25 and 40 billion tons of fertile top soil is eroded yearly (Montanarella, 2015; Opeyemi et al., 2019; Hajisheko et al., 2025). Increase in flood vulnerability on degraded lands is another challenge of erosion of top soil due to depletion of available storage capacity of the soil. Risk of flooding is also high because of erosion of top soil that is rich in organic matter. Organic matter has high water retention capacity (Eurostat, 2025). The largest reservoir for carbon are found in tropical soils and disruption of this storage, increases the greenhouse gases and therefore impacts on the climate (Zhou et al., 2019; Lense et al., 2020). 75% - 85% carbon content of the eroded soil is at risk of being lost due to release of carbon to the atmosphere during erosion processes (Eurostat, 2025). Climate change has been known to cause increase rainfall intensity and floods in southern parts of Nigeria. Therefore, there is need to address these problems in order to develop resilience to climate change, improvement of food security and promotion economic growth (Mesele et al., 2025).

Owena river basin has two multipurpose dams for water supply, irrigation and hydropower. The reservoirs of these dams are at risk of excessive sediment deposition. Soil erosion and sediment deposition will cause loss of storage capacity of reservoirs. Globally, reservoirs storage capacity is predicted to be lost at a rate of 0.5% to 1% of its original capacity annually (Wisser et al., 2013, Minchev et al., 2025). Sedimentation in reservoir due to soil erosion has serious environmental and economic consequences.

Deforestation for urbanization, agriculture or mining activities has been the major cause of land degradation and vulnerability of lands to soil erosion. Globally, an annual mean area of 10 million hectares is lost to deforestation in tropical forests (Ritchie, 2021). Tropical parts of Africa have seen a surge in deforestation due to expansion of agricultural activities (Francispillai and Chapman, 2025). Deforestation involves cutting down of plants that anchors the soil with their roots. The plants leaves in dense vegetation, including the fallen decayed ones provides protective cover to impacts of raindrop and surface runoff. According to Chen et al. (2012) and Li et al. (2025), plant root provide tensile strength to compact the soil. Exacerbation of soil erosion should be prevented by soil and water conservation methods, good crop management practices and sensitization techniques to prevent bad cropping techniques (Okorafor et al., 2017).

Igwe et al. (2017) reviewed major soil erosion models and grouped them into observational, theoretical, and scale based models. Empirical models such Universal Soil Loss Equation and Revised Universal Soil Loss Equation (RUSLE) models are based on statistical data, and are simple, but limited to specific conditions (Igwe et al., 2017). The development of remotely sensed data and Geographic Information System (GIS) has seen a surge in creation of erosion based model that relies on physical factors driving erosion in a RB. RUSLE model is one of such erosion models and it depends on factors such rainfall, soil type, land use and land cover (LULC) and soil conservation practices. RUSLE model is a simple model with ubiquitous internal process that relates input and output very well, and has good compatibility with GIS (Olorunfemi et al., 2020; Kebede et al., 2021; Kumar et al., 2022). The model integrates remotely sensed data of topography and LULC, and physical data of rainfall and soil texture in GIS to estimate soil losses. The model have small and large scale applications (Kebede et al., 2021; Kumar et al., 2022) and the parameters of the model include rainfall erosivity, soil erodibility, slope steepness and length, cover management and support practices. In south-eastern Nigeria, Ajibade et al. (2020) studied the soil erosion susceptibility in Anambra state using RUSLE model. Their findings show that most of the state had low susceptibility to erosion while 7% of the state had erosion susceptibility of medium to high. In the north-central part of the country, Ugese et al. (2022) investigated erosion of soil due water by adopting the integration of RUSLE and remotely sensed data. Their findings indicate that rainfall erosivity, and slope steepness and length factor were the most sensitive parameters influencing erosion and that while most of the basin (95.3%) had very low susceptibility to erosion, 0.12 % of the basin had extreme susceptibility. Eremen et al. (2025) using RUSLE studied the soil loss in Ikpoba-Okha local government area; an urban area under Benin - Owena River Basin Authority. Their findings showed very severe annual soil erosion of rates of 74.9 tons/ha.

Given the increasing severity of soil erosion in the Owena River Basin (RB), particularly in areas characterized by elevated erosion risk, there is an urgent need for developing targeted soil conservation strategies. Effective and tailored interventions will not only mitigate erosion impacts but also contribute to the sustainable management of land resources critical for the local ecosystem and agricultural practices. To address this pressing issue, this study aims to create a detailed erosion susceptibility map that elucidates the geo-spatial variability of the basin's vulnerability to water erosion. Utilizing RUSLE in conjunction with GIS, this research processes a combination of remotely sensed data and topographic features of the Owena RB. Specifically, slope steepness and length parameters are derived from precise topographic analyses, while rainfall erosivity and soil erodibility factors are extracted from relevant physical datasets. Furthermore, the cover management factor and support practices factor are informed by meticulously analyzed remotely-sensed LULC data. This comprehensive approach not only enhances the accuracy of the susceptibility map but also establishes a robust framework for informing future soil management strategies in the basin, ensuring that interventions are both evidence-based and context-specific.

MATERIALS AND METHODS

Description of study area

Owena RB cover an area of 6910.3 km^2 with average and river bed slope of 5.6% and 2.3% respectively. The basin lies within latitude 4^{o}45’0” and 5^{o}30’0” East, and longitude 5^{o}55’0” and 7^{o}45’0” North. The RB elevation varies from 1065 m at highest level in Ekiti state to 7 m above sea level at the lowest level in Ondo state. Owena RB as shown in Figure 1 drains five states in Nigeria and they include Osun, Ondo, Ekiti, Edo and Delta states. Most of the RB drains Ondo state with part of the state capital of Akure within the basin. The urban and semi-urban centers in of the RB are Akure, Ondo, Ore, Owena, Igbara Oke and Okitipupa. The river is a 4th order stream. The LULC of the basin is predominantly dense forest and grassland. The dense tropical rain forest is mostly located in the south and central regions of the basins. Recent studies has that there has been a significant reduction in forrested area due to logging and expansion of agricultural activities (Adepoju et al., 2018; Akinbobola et al., 2022). Grass lands are more widespread in the Northern parts of the RB and in fallow previously cultivated areas. This LULC classification has seen expansion (Adepoju et al., 2018) due to overgrazing and deforestation, Other LULC types include farmands and built-up areas. Farmlands are predominant in the north and central parts of the RB and includes mixed cropping fields and plantations such as cocoa and oil palm (Popoola et al., 2020). Built-up areas has seen rapid expasion in recent times with encroachment into forrested and grassland LULC. The expansion has been as a result of population growth and infrastructural development (Oyinloye and Oloukoi, 2016; Akinbobola et al., 2018). The basin lies over the basement complex made up of migmatite-gneiss complex, metasediments/mata-igneous rocks and pan African older granitods (Aladejena and Fagbonhun, 2019). The average annual rainfall depth and evapotranspiration of 6640 mm and 4622.8 mm respectively (Okpara et al., 2006). The RB is characterized by two seasons namely the wet and dry season. The wet season has duration of 7 months; beginning in April and ending in October. The dry season begins in November and ends in March lasting for 5 months. The yearly mean range for temperature and humidity are 24^{o}C - 33^{o}C and 60% – 80% respectively (Ikhile et al., 2015). Farming is the main occupation of the population within Owena RB; crops cultivated include cocoa, maize, cassava, banana, plantain, oil palm and yam.

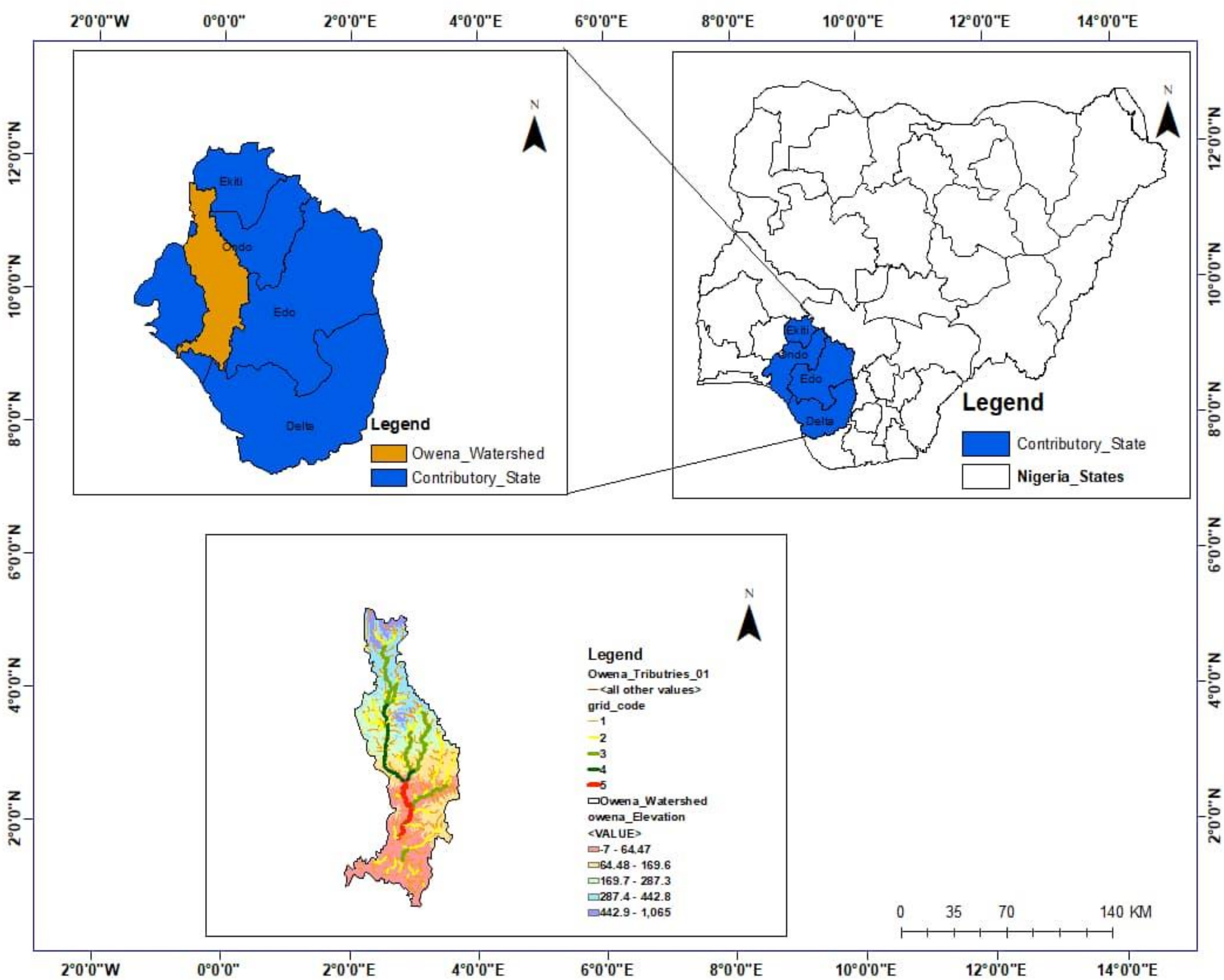

Figure 1. Study area map of Owena river Basin

Data collection

In this study, the Maximum Likelihood Classification type of supervised classification was adopted for LULC mapping. LULC data were extracted from the operational land imager of Landsat 8. The 2021 images were sourced from the website of United States Geological Survey's earth explorer. USGS automatically preprocesses with LaSRC for atmospheric correction to convert top-of-atmosphere to surface reflectance. Image quality assessment was achieved using CFMask to flag and mask cloud and cloud shadows with spectral and thermal data. The least cloud cover filter was used to reduce cloud-prone images upfront. Soil data were sourced from the 2023 global soil map of FAO Harmonized Soil World Map. The soil data are provided at 250 m resolution at a standard depth of 0 – 30 cm). The administrative shape file for Nigeria and its states were extracted from the Global Administrative Area map. Slope steepness and length factor were generated from the 2021 Shuttle Radar Topographic Mission (SRTM) DEM data on 30 m resolution. Rainfall erosivity factor data was downloaded from European Soil Database center.

Parameters of RUSLE model

RUSLE model categorizes the RB into different erosion susceptibility classes. This is achieved by utilizing GIS to process and analyzes spatial data of rainfall erosivity maps, DEM, soil and LULC maps (Ashiagbor et al., 2013). The yearly mean soil loss for each erosion susceptibility class is estimated by uploading the parameters' maps into Arc Map in ArcGIS as layers. The soil loss is estimated with Raster Calculator in ArcGIS using the RUSLE in equation 1 below:

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

A is the potential annual average soil loss, R is the Rainfall erosivity factor, K is the soil erodibility factor, LS is the slope length and steepness factor, C is the cover management factor and P is the support practice factor.

Rainfall erosivity factor (R-factor)

The *R*-factor is the capacity of rainfall to initiate water erosion of the soil (Samuel et al., 2025), *R*-factor is the product of 30-minute rainfall intensity and the rainfall's kinetic energy (Kumar et al., 2022). The velocity of raindrops impact on soils and the distribution of its size influence the value of *R*-factor. The higher the *R*-factor values, the more the effect of rainfall on erosion of soil. Gelagay and Minale (2016) developed the *R*-factor equation described in equation 2:

$$R = -8.12 + (0.562 \ x \ I) \quad (2)$$

where *R* describes the erosivity (MJ/ha/mm/hr.yr) and *I* is the mean yearly rainfall (mm).

Soil erodibility factor (K-factor)

K-factor describes the soil quality to resist detachment and transportation by water (Tian, et al., 2024). The qualities include soil texture, structure and permeability (Ganasri and Ramesh, 2016; Marcinkowski et al., 2022; Salvacion, 2023). They also include organic matter and stone content of soil. The combination of these soil qualities determines the *K*-factor value. Higher *K*-factor values imply higher soil susceptibility to erosion while low *K*-factor depict low vulnerability to erosion. Well graded soils and soils rich in organic matter have low *K*-factor due to increased permeability and infiltration of soil. Clay soil or stony soils have low soil erodibillity values due to their capacity to resist detachment from raindrops or surface runoff. Texture is therefore the quality in soil that reduces susceptibility to erosion (MSM, 2025). Typical *K*-factor range 0.02 for low erodibility and 0.69 for extremely high soil erodibility (Mitchell, and Bubenzer, 1981; Goldman et al., 1986; Yarbroug, 2014). Ganasri and Ramesh (2016) described soil erodibility factor as expressed in equation 3

$$K = 27.66 \ x \ m^{1.14} \ x \ 10^{-8} \ x \ (12 - a) + (0.0043 \ x \ (b - 2)) + (0.003 \ x \ (c - 3)) \quad (3)$$

where *K* is the erodibility factor (in tons.hr/MJ. mm); m is the product of the summation of silt content in % and very fine sand in %, and the complement of the clay content (%); a is the amount of organic matter in %; b shows the extent of soil structure and c is the permeability of the soil profile. The soil texture, organic matter content, permeability and structure were derived from the soil data of Harmonized Soil World Database (HWSD).

Slope steepness and length factor (LS-factor)

Topography of a landscape defines the *LS*-factor of a RB and critically impacts on the pattern and variability of soil erosion (Akhila and Pramada, 2025). The *LS*-factor estimates the joint effect of slope steepness and slope length on the susceptibility of a landscape to erosion. It is the product of slope gradient and slope length. The *LS*-factor is estimated relative to a standard landscape of 9% and 22.13 m length (Mckague, 2023). This factor development is however limited to slopes of less than 50% gradient (Schmidt et al., 2019). Landscapes with steeper slopes are more susceptible to erosion due increases flow velocity and consequent increase kinetic energy of surface runoff to detach and transport soil particles. The erosion severities of steep slopes are exacerbated by lengthy slopes (Das et al, 2021). *LS*-factor has dimensionless unit and are calculated using the DEM and GIS software.

Cover management factor (C-factor)

C-factor quantifies the impact of LULC on erosion. The factor shows the influence of crop and land management practices on severity of erosion by runoff (Renard, 1997; Schmitt et al., 2018). *C*-factor describes the loss of soil from a standard vegetative landscape to loss of soil from a bare landscape and has a values ranging between 0 and 1 (Wischimeier and Smith, 1978; Olivera et al., 2015; Almagro et al., 2019). 0 – 0.025 are *C*-factor values range for low erosion risk LULC of forested lands, wetlands and water bodies while *C*-factor value range of between 0.025 and 1 describe parts of the RB that have LULC of farmlands, open grasslands and built-up areas. It is a dimensionless unit and calculated using the DEM and GIS software.

***Support practice factor (P-*factor)**

The *P*-factor is the RUSLE parameter that assesses the impact of soil conservative practices on soil erosion. These practices which include strip cropping, terracing and contour farming impedes flow thereby reducing runoff velocity and causing sediment deposit (JRC, 2025). *P*-factor relates the erosion of soil for a specific conservative practice to the conventional tilling method. It has value range of 0 -1 with lower values indicating effective conservative practices. The factor has a dimensionless unit.

RESULTS AND DISCUSSION

Rainfall erosivity

Figure 2 show that rainfall erosivity increases southward due to rainfall intensity increase towards the coast of Atlantic ocean. In the northern part of the RB, low *R*-factor values range of 5,376 – 6,731 MJ/ha/mm/hr.yr were estimated. These areas experience less frequent rainfall events with less rainfall intensity. Compared with northern parts the rainfall intensity and frequency are higher central parts In the these parts of RB, there were two *R*-factor ranges of 7,860 – 9,667 MJ/ha/mm/hr.yr and 8629 – 9701 MJ/ha/mm/hr.yr. These ranges represent moderate to slightly high rainfall erosivity.. The southern parts (especially areas bordering the Atlantic Ocean) experience high intensity and long duration rainfall compared to the northern and central parts hence the very high *R*-factor values of 9701 – 11.296 MJ/ha/mm/hr.yr and 11,296 – 14,975 MJ/ha/mm/hr.yr. Rainfall erosivity factor is the most active driver of erosion (Zhu et al., 2024) therefore susceptibility to soil erosion is highest in the southern parts because of very high *R*-factor calculated for these parts. Since rainfall erosivity is the key driver of soil erosion (Abd-Elbasit et al., 2011, Pardini et al., 2017; Dong et al., 2025), understanding the geographic distribution of rainfall erosivity can guide watershed management initiatives, prioritize regions for intervention, and inform local agricultural practices to mitigate soil loss,

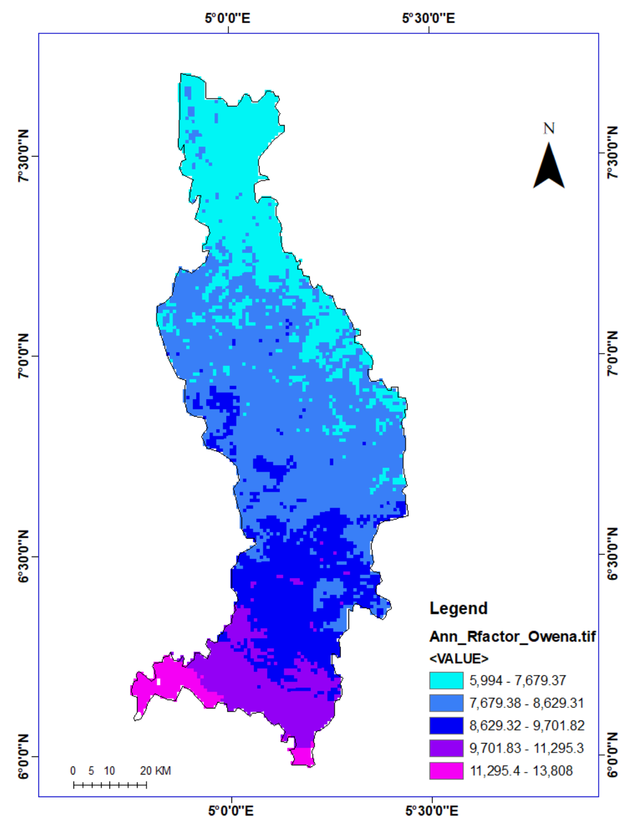

Figure 2. Rainfall erosivity factor map of Owena River Basin

Soil erodibility

K-factor values reflect inherent soil qualities such as texture, structure, permeability, and content of organic matter. Soils with high *K*-factor are highly susceptible to erosion (Dumedah et al, 2019; Sodeke et al., 2025). Figure 3a show the soil types variability across the RB while Figure 3b shows that the *K*-factor spatial distribution in the RB. Table 1 summarizes the soil types correlation with the *K*-factor values.The soil types include loamy sand in the northern tip and south-central parts of the RB. Sandy clay loam soils are found in the north-central area of the basin while loam soils are found in the southern parts of the RB. The *K*-factor values ranges from 0.04 tons.hr/MJ.mm in the north to 0.34 tons.hr/MJ.mm in the southern part of Owena RB. The loamy soils have *K*-factor values varying from 0.04 in the north to 0.21 in the south-central parts (low to moderate soil erodobility). The wide range is due to variation in the organic matter, silt and sand content of the loamy sand. Sandy clay loam soil in the RB has a low to moderate soil erodibility (0.049 – 0.2 tons.hr/MJ. mm). The variability relies on the content of silt in the soil. High silt content within the soil increases *K*-factor value (Keya et al., 2025) thereby increasing susceptibility of a RB to soil erosion. The loam soils in southern have moderate erodibility rates of 0.21 - 0.34 tons.hr/MJ.mm. The combination of very high *R*-factor and moderate *K*-factor values can dispose this area to high susceptibility to erosion. Loam soil types especially in areas with high silt content in the southparts of the RB are highly predisposed to soil erosion due to very high rainfall amounts in these parts. Deforesation and overgrazing in these areas should be discourage to prevent land dergration,

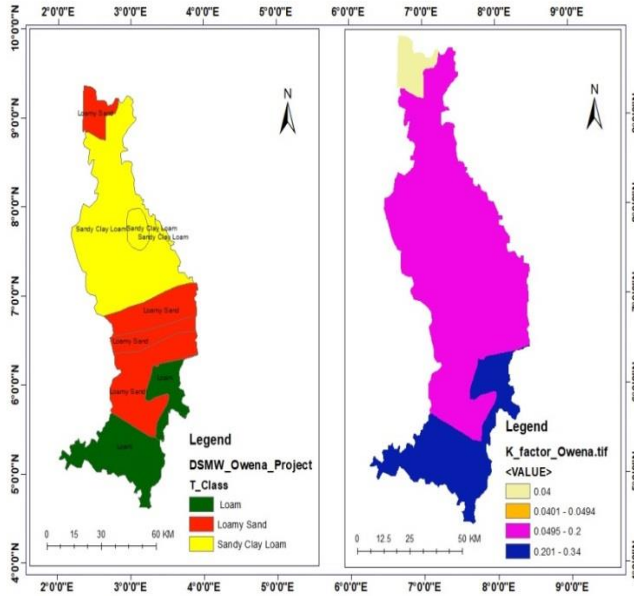

Figure 3. a) Soil classification map for Owena river Basin; b) Soil erodibility factor map for Owena river Basin.

Table 1. Summary of Soil types Correlation with *K*-factor values

Soil type	K-factor (tons.hr/MJmm)	Basin location	Remark
Loamy-sand	0.04 - 0.21	South-central and Northern tip	Low to moderate soil erodibility. Wide range due to variation in organic matter, silt and sand content.
Sandy-clay-loam	0.049 - 0.2	North and North-central	Low to moderate soil erodibility. Variability depends on silt content.
Loam	0.21 - 0.34	South	Moderate erodibility rates

Slope length and steepness

The *LS*-factor reflects steepness of a slope and how water accumulates and flows over the slope. Both features strongly influence the velocity and erosive force of runoff (Nur et al, 2025). The value range of 0 – 0.06178 is the predominant *LS*-factor over the entire Owena RB. The areas with this *LS*-factor have a topography of gentle slopes and short slope lengths, suggesting low runoff velocity and minimal contribution to soil erosion. Erosion susceptibility in these parts has very low contribution of the *LS*-factor. The *LS*-factor values of 0.06178 – 0.4324 are scattered in the RB but clustered in parts of the north and central regions of the RB. This range indicates moderate gradients and slope lengths, leading to a moderate contribution to erosion susceptibility. *LS*-factor values of 0.4325 – 1.236 are also scattered across the watershed but in localized pockets and often corresponding to slightly steeper or longer slope areas. While most of the terrain contributes little soil erosion in the RB, there are notable pockets with moderate to high LS-factor values, especially in the north and central parts. Erosion will be accerelated with the combined impact of high *R*-factor and *C*-factor on *LS*-factor values especially in urban areas in the central parts of the RB– Ondo and Ore towns – with high rainfall intensity.

These areas are therefore required for targeted soil conservation and land management interventions.,

Cover management

The *C*-factor quantifies the effect of vegetative cover, crop types, and land management practices on rates of soil erosion (Nur et al, 2025). It essentially quantifies how well the land surface is protected from the erosive power of rainfall and runoff. *C*-factor have a range of 0 - 1 (Sasi et al, 2025). The LULC map in Figure 5a shows the seven LULC classifications for the RB. Figure 5b shows *C*-

factor values for the Owena RB have two major two categories. The first category are areas with *C*-factor values of 0.0236 – 0.4. This represents parts of the RB with dense vegetation cover such as forests. Such land surfaces absorb rainfall impact and reduce surface runoff, thus minimizing soil erosion. These areas predominant in the RB and are considered to have very low erosion susceptibility and serves as natural protective barriers against erosion. The second are areas with *C*-factor values of 0.023529412 – 1. These areas are scattered mostly in the north and north-central parts of the RB. The LULC consist of farmlands, low vegetation areas, bare lands and urban areas. Higher *C*-factor values within these areas make them highly prone to erosion. Good land management practices are essential for improving the *C*-factor values**.** Afforestation and reforestation, controlled and rotational grazing, conversion from annual crops to perennial crops and mixed cropping are some of the targeted land management strategies that reduce *C*-factor values. Forested land maintains continuous ground cover, litter layer, and root systems that stabilize soil (Wischmeier & Smith, 1978; FAO, 2020). Controlled or rotational grazing maintains lower *C*-factor in grasslands. Perennial crops (like oil palm, cocoa, or agroforestry systems) provide more consistent soil cover than the annual crops thereby reducing the seasonal variability of the *C*-factor. Integrating trees, shrubs, and crops provides multi-layered canopy cover, mimicking natural forest cover that reduces raindrop impact and improves infiltration.

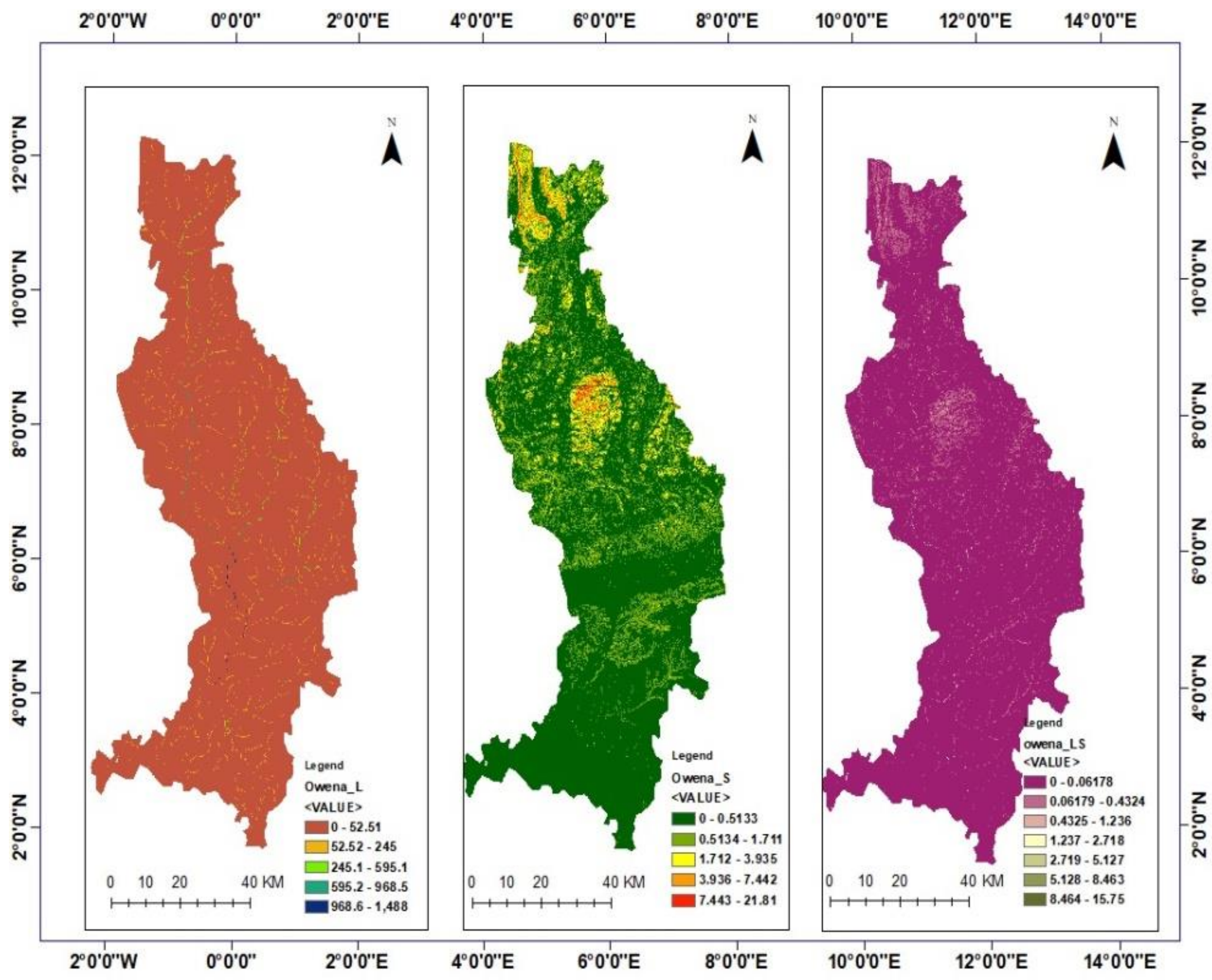

Figure 4. a) Slope length map of Owena river Basin; b) Slope steepness map of Owena river Basin; c) Slope steepness and length factor map of Owena river Basin.

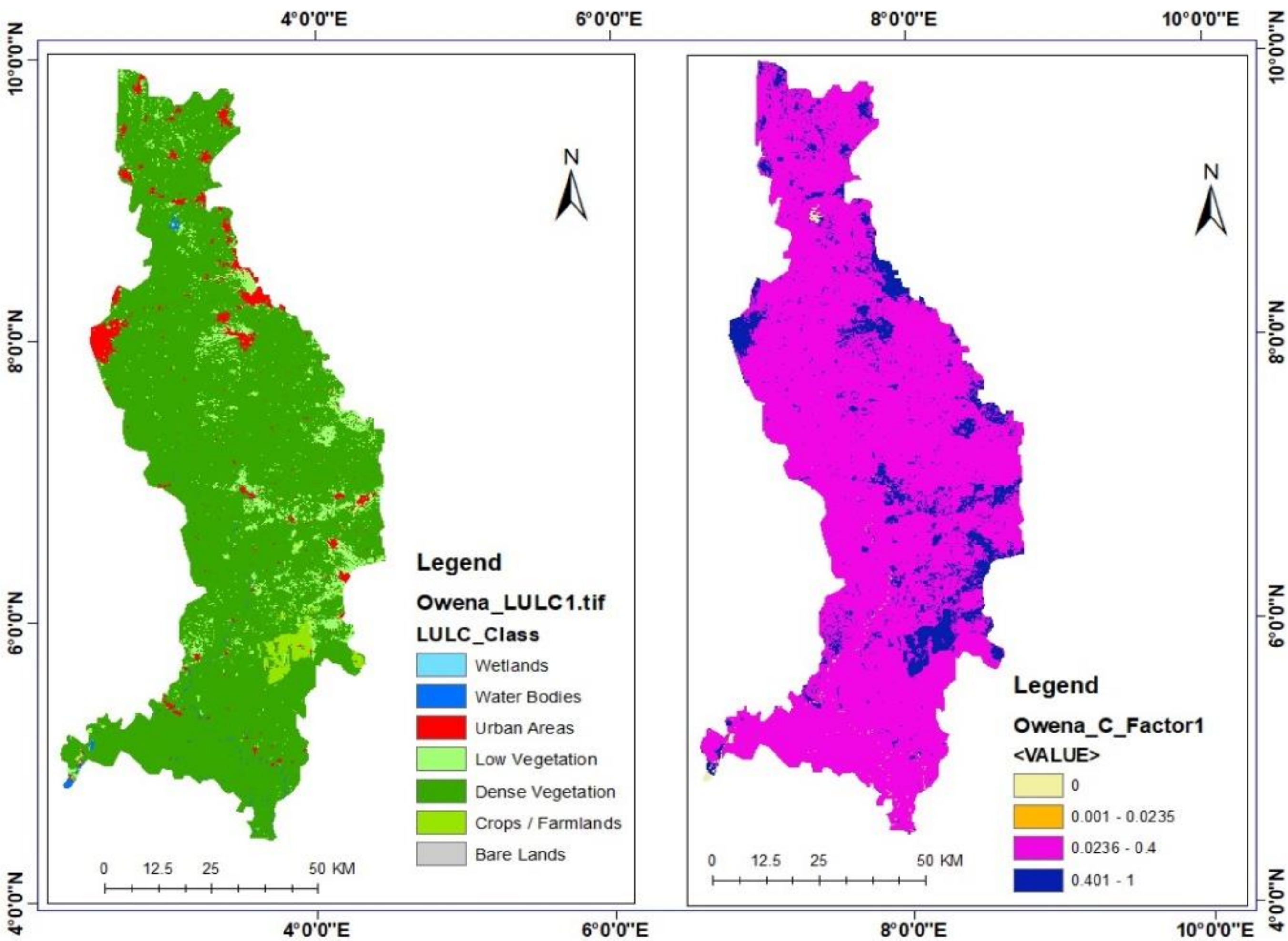

Figure 5. a) Land use and land cover map of Owena river Basin; b) Cover management factor map of Owena river Basin.

Support practice

The *P*-factor measures the impact conservative practices on soil erosion (Nanda et al., 2025). The range for *P*-factor are 0 - 1.0 is assigned for very good conservation and land management practices while 1 is assigned for absence of these practices. The dense vegetation LULC was assigned 0. Based on literature (Rao, 1981; Pandey et al., 2015), 0.27 was assigned for low vegetation since strip cropping is common practice in the basin. Conservative practices are important for improving the P-factor values. Strategies such as conservative tillage (reduced or no-tillage), cover cropping, contour farming, and crop residue management are effective interventions for mitigating erosion risks in agricultural lands LULC. The combined or individual application of these measures will significantly reduce soil erosion by lessening the impact of raindrops and attenuating runoff peaks through increased water storage. Legumes is an example of a cover crop that offers the dual benefit of ground protection and organic matter enrichment. Its usage enhances soil structure, improve infiltration and increases moisture retention (Blanco-Canqui et al., 2015).

Annual soil loss estimates

The soil map in Figure 6 describes the spatial variability of soil erosion severity across Owena RB. The predominant soil erosion rate in the RB is 0 – 10 tons/ha/yr and it is described as low to moderate annual soil (Eurostat, 2025). As described in Table 2 the erosion rates of 0 – 10 ton/ha/yr covers 97% of the RB area. The low to moderate soil loss rate is due to the gentle topography (low *LS*-factor) characterizing the RB and that 89% of the RB is dense vegetation landscape (high *C*-factor). The annual soil loss in the southern parts of the RB is predominantly low despite the very high rainfall erosivity factor and moderate soil erodibility factor. This is also because low *LS*-factor and *C*-factor values. Table 2 also show that annual soil erosion rates 10 – 40 tons/ha/yr covers about 2% of the RB while annual soil loss rate of more than 40 tons/ha/yr due to erosion affect area of 51.8 km^2 (1% of the RB). More than 40 tons/ha/yr soil erosion rate is described as very severe (Eurostat, 2025) and 59% of this erosion severity are within in the urban area and low vegetation LULC especially in north-central parts of the basin. 10 – 20 tons/ha/yr describes high erosion rates and 87% of this severity impacts the low vegetation areas. Areas around the water bodies had moderate to high erosion rates due to steep slopes close to the rivers. This is because slopes around water bodies usually induce high flow accumulation and consequent high susceptibility to erosion (Das et al., 2022). In the urban areas, erosion severity increases from 32% for 20 – 30 ton/ha/yr annual soil loss range to 44% in 30 – 40 ton/ha/yr annual soil loss range. Targeted soil conservation and good land management should be implanted in these areas to prevent gully erosion development. The average annual soil losses due to water erosion in Owena RB is 5.5 ton/ha while the total annual loss from the RB is calculated as 38, 316 tons. While the RB generally has a low susceptibility to erosion due to its mostly forested landscape; urban areas, grass lands with low vegetation and river banks used for farming and grazing are exposed high erosion susceptibility.

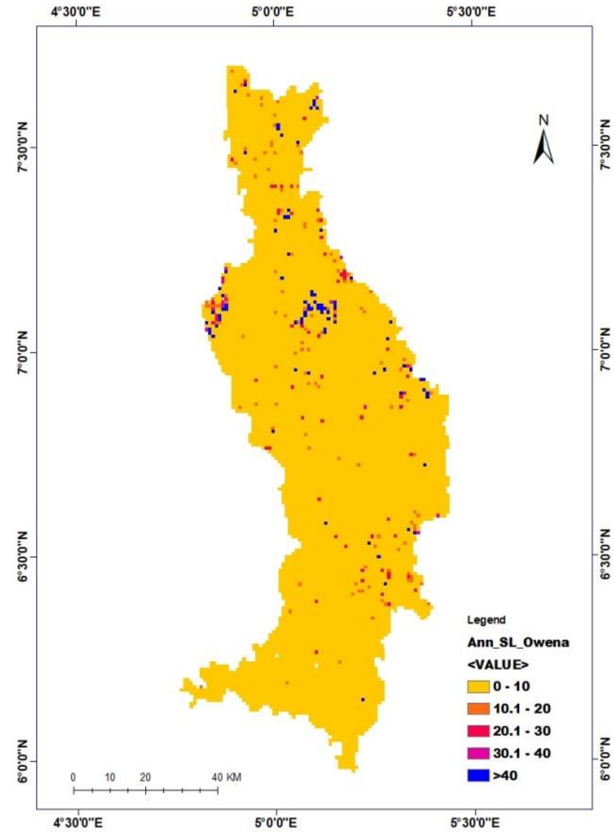

Figure 6. Annual soil erosion rates in Owena river Basin.

Table 2. Annual soil erosion rates in different LULC classifications

LULC classification	Area of LULC exposed to 0 - 10 erosion severity (km^2)	% of LULC exposed to 0 - 10 erosion severity	Area of LULC exposed to 10 - 20 erosion severity (km^2)	% of LULC exposed to 10 - 20 erosion severity	Area of LULC exposed to 20 - 30 erosion severity (km^2)	% of LULC exposed to 20 - 30 erosion severity	Area of LULC exposed to 30 - 40 erosion severity (km^2)	% of LULC exposed to 30 - 40 erosion severity	Area of LULC exposed to >40 erosion severity (km^2)	% of LULC exposed to >40 erosion severity
Bare lands	1.48	0%								
Crops / farmlands	104.96	2%	2.96	4%	0.60	2%			0.60	1%
Dense vegetation	6138.60	91%	4.20	6%	14.34	46%	3.60	28%	20.80	40%
Low vegetation	348.78	5%	59.88	87%	5.32	17%	3.60	28%	14.68	28%
Urban areas	138.55	2%	1.16	2%	9.97	32%	5.38	44%	15.74	31%
Water body	13.10	0%	0.60	1%	1.16	4%				
Wetlands	2.31	0%								
Total area	6745.47		68.80		31.38		12.58		51.82	

CONCLUSION

Rainfall erosivity factor, the major driver for soil degradation was very high in the southern coastal parts of the RB. Soil erodibility factor was moderate for most of the RB. The slope steepness and slope factor was predominantly low in the RB given the flat topography of the basin. 89% of the RB was covered with dense vegetation hence the low cover management factor values range of 0.0236 - 0.4. The combined effect of low *LS*-factor and *C*-factor gave rise to the low annual mean soil erosion loss of 5.5 ton/ha/yr. The annual soil loss was estimated as 38, 316 tons. High to severe yearly soil erosion rates was estimated in 164.6 km^2 of the RB. Targeted soil conservation measures and good land management practices need to be implemented in these areas with high to severe erosion susceptibility.

DECLARATIONS

Corresponding author

Correspondence and requests for materials should be addressed to Obinna Anthony Obiora-Okeke; E-mail: oobiora-okeke@futa.edu.ng; ORCID: https://orcid.org/0009-0004-1530-6261

Data availability

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Acknowledgements

The author thanks Prof. Celso Bandeira de Melo Ribeiro and Federal University of Juiz de Fora for providing computer work station lab for this research.

Funding

This research was self-funded by the author.

Competing interests

The author declares that there is no competing interests whatsoever with any third party.

REFERENCES

Abd-Elbasit MAM, Yasuda H, Salmi A and Ahmad Z (2011). Impact of rainfall microstructure on erosivity and splash soil erosion under simulated rainfall. Soil Erosion Studies, InTech. Pp 167 – 178, DOI: https://doi.org/10.5772/24086

Adepoju KA, Olusola AO, and Adegboyega SA (2018). Assessment of land use/land cover change and its impact on surface runoff in Owena Watershed, Nigeria. *Journal of Geography and Natural Disasters*, 8(2), 230. https://doi.org/10.4172/2167-0587.1000230

Ajibade FO, Nwogwu NA, Adelodun B, Abdulkadir TS, Ajibade T, Lasisi K, George F, Owolabi T and Olajire O (2020). Application of RUSLE integrated with GIS and remote sensing techniques to assess soil erosion in Anambra State, South-Eastern Nigeria. Journal of Water and Climate Change, 11: 1-16, DOI: https://doi.org/10.2166/wcc.2020.222

Akinbobola A, Ajao A and Akinluyi F (2022). Remote sensing and GIS-based analysis of erosion susceptibility and land cover dynamics in Owena Basin, Nigeria. *Environmental Monitoring and Assessment*, 194(3), 177.

Akhila R and Pramada SK (2025). Suitability of different Digital Elevation Models in the estimation of LS factor and soil loss. Environmental Monitoring and Assessment, 197(5): 511. DOI: https://doi.org/10.1007/s10661-025-13967-x

Aladejana OO and Fagbohun BJ (2019). Geomorphic, morphometric and structural analysis of North West Benin-Owena River basin, Nigeria: implications for groundwater development. Sustainable Water Resources Management, 5: 715–735, DOI: https://doi.org/10.1007/s40899-018-0252-6

Almagro A, Thomé TC, Colman CB, Pereira RB, Junior JM, Rodrigues DBB and Oliveira PTS (2019). Improving cover and management factor (C-factor) estimation using remote sensing approaches for tropical regions. International Soil and Water Conservation Research, 7(4): 325-334, DOI: https://doi.org/10.1016/j.iswcr.2019.08.005

Ashiagbor G (2013). Modeling soil erosion using RUSLE and GIS tools, In International Journal of Remote Sensing & Geoscience, E. K. Forkuo and P. Laari, Eds., http://www.ijrsg.com/

Blanco-Canqui H, Claassen, MM, and Presley, DR. (2015). Summer cover crops fix nitrogen, increase crop yield, and improve soil–crop relationships. *Agronomy Journal*, *107*(4), 1235–1245. https://doi.org/10.2134/agronj14.0431

Chen S, Chan H and Li Y (2012). Observations on flow and local scour around submerged flexible vegetation. Advances in Water Resources, 43: 28-37, DOI: https://doi.org/10.1016/j.advwatres.2012.03.017

Das S, Bora PK and Das R (2022). Estimation of slope length gradient (LS) factor for the sub-watershed areas of Juri River in Tripura. Modeling Earth Systems and Environment, 8, 1171-1177, DOI: https://doi.org/10.1007/s40808-021-01153-0

Dong M, Wang Y, Guo J, Meng L, Xu Z, Liu Z, Liu B, Zhang L and Yin B (2025). Effects of extreme precipitation on soil erosion affected by typhoons in central Shandong Province, China. Journal of Soils and Sediments, 25: 1022-1039. https://doi.org/10.1007/s11368-025-03967-2

Dumedah G and Evans-Kyeremanteng DE (2019). Spatial targeting of soil loss using RUSL E in GIS: the case of Asokore Mampong municipality, Ghana. Geospatial Information, 3(1): 166-172. https://doi.org/10.30871/jagi.v3i1.1029

Eremen PE, Badru GS, Akoso TM and Odunuga S (2025). Estimation of the volume of soil loss due to gully erosion in Iwogban urban catchment area in Ikpoba-Okha Local Government in Benin city, Edo State, Nigeria Journal of Applied Sciences and Environmental Management, 29(4): 1333-1342.

Eurostat (2025). European Union agri-environmental indicator-soil erosion. Eurostat European Union: Brussel Belguim.

Francispillai KE and Chapman JL (2025). Effects of Deforestation-Induced Warming on the Thermal Tolerance of an African Clariid Catfish. Freshwater Biology, 70(1): e14375. https://doi.org/10.1111/fwb.14375

Ganasri P and Ramesh H (2016). Assessment of soil erosion by RUSLE model using remote sensing and GIS-A case study of Nethravathi Basin. Geoscience Frontiers, 7(6): 953-961. https://doi.org/10.1016/j.gsf.2015.10.007

Gelagay HS and Minale AS (2016). Soil Loss Estimation Using GIS and Remote Sensing Techniques: A Case of Koga Watershed, Northwestern Ethiopia. International Soil and Water Conservation Research, 4: 126-136. https://doi.org/10.1016/j.iswcr.2016.01.002

Goldman SJ, Jackson K and Bursztynsky TA (1986). Erosion and Sediment Control Handbook. New York, NY: McGraw-Hill.

Hajisheko KK, Suryabhagavan KV and Soumya K. WebGIS-based decision support system for soil erosion risk assessment for Guder River catchment, Ethiopia. Geosystems and Geoenvironment, 4(2): 100387. https://doi.org/10.1016/j.geogeo.2025.100387

Igwe PU, Onuigbo AA, Chinedu OC, Ezeaku II, and Muoneke MM (2017). Soil Erosion: A Review of Models and Applications. International Journal of Advanced Engineering Research and Science, *4(*12):138–150. https://doi.org/10.22161/ijaers.4.12.22

Ikhile I (2015). Climate change and erosion activities in Benin-Owena River basin, S. W, Nigeria. Journal of Geography and Regional Planning, 8(4): 99 – 110. https://doi.org/10.5897/JGRP2015.0478

Joint Research Centre (2025). Support Practice factor. European Soil Data Center. Eurostat European Union: Brussel Belguim.

Kebede YS, Endalamaw NT, Sinshaw BG, and Atinkut HB (2021). Modeling soil erosion using RUSLE and GIS at watershed level in the upper beles, Ethiopia. Environmental Challenges, 4(2): 100009. https://doi.org/10.1016/j.envc.2020.100009

Keya DR, Salih HO, Hayder AEP and Mawlood AO (2025). Spatial mapping and assessment of soil erodibility using GIS in the Middle of Erbil province. Iraqi Journal of Agricultural Sciences, 56(2): 827-837. https://doi.org/10.36103/ahbk0k27

Kumar M, Sahu AP, Sahoo N, Dash SS, Raul SK, and Panigrahi B (2022). Global-Scale Application of the RUSLE Model: A Comprehensive Review. Hydrological Sciences Journal, 67(5): 806 –30. https://doi.org/10.1080/02626667.2021.2020277

Lense GHE, Moreira RS, Parreiras TC, Avanzi JC and Mincato RL (2021). Modeling of soil organic carbon loss by water erosion on a tropical watershed. Revista Ciência Agronômica, 52(1): e2020725. https://doi.org/10.5935/1806-6690.20210011

Li J, Chiu Y and Chen S (2025). Impact of vegetation roots on erosion protection of sandbars in laboratory experiments. CATENA, 249: 108631. https://doi.org/10.1016/j.catena.2024.108631

Marcinkowski P, Szporak-Wasilewska S and Kardel I (2022). Assessment of soil erosion under long-term projections of climate change in Poland. Journal of Hydrology, 607:127468. https://doi.org/10.1016/j.jhydrol.2022.127468

McKague K (2023). Universal Soil Loss Equation (USLE), Ontario Ministry of Agriculture and Food (OMAFRA): Ontario, Canada; Available online: https://files.ontario.ca/omafra-universal-soil-loss-equation-23-005-en-2023-03-02.pdf

Mesele SA, Mechri M, Okon MA, Isimikalu TO, Wassif OM, Asamoah E, Ahmad HA, Moepi PI, Gabasawa AI and Bello SK et al. (2025). Current Problems Leading to Soil Degradation in Africa: Raising Awareness and Finding Potential Solutions. European Journal of Soil Science, 76: e70069. https://doi.org/10.1111/ejss.70069

Minchev I, Trendafilov B, Blinkov I, Trendafilov A and Ivanovski D (2025). Measuring and modeling erosion in two successive reservoir catchments on the Drim river in North Macedonia. Geography, Environment, Sustainability, 17 (4): 50-57. https://doi.org/10.24057/2071-9388-2024-0581

Minnesota Pollution Control Agency (2023). Soil Erodibility, In Minnesota Stormwater Manual, Retrieved from: https://stormwater.pca.state.mn.us/index.php?title=Soil_erodibility

Mitchell JK, and Bubenzer GD (1981). Soil loss estimation, In Soil Erosion, M. J. Kirkby and R. P. C. Morgan, Eds., London, UK: Wiley, pp.17–62.

Montanarella L (2015). Agricultural policy: Govern our soils. Nature, 528(7580): 32-33. https://doi.org/10.1038/528032a

Nanda M, Alwan M, Ghufran M, Fahlefy MII, Husein I, Haridhi HA, Munir B, Sari IM, Asyqari A and Yunus S (2025). Spatial assessment of soil erosion using the revised universal soil loss equation (RUSLE) model for sustainable marine ecosystems in the coastal of northern part, Aceh Province, In BIO Web of Conferences, EDP Sciences 156, p. 02010. https://doi.org/10.1051/bioconf/202515602010

Nnanguma KA (2025). Aspect factor and soil erosion vulnerability on rural livelihoods in Mubi North and Mubi South Local Government Areas of Adamawa State, Nigeria. Journal of Applied Sciences and Environmental Management, 29(4): 1093-1100, DOI: https://doi.org/10.4314/jasem.v29i4.10

Nur AH, Hasan M, Sarmin S, Shahin A, Mohamed A and Ahmed A (2025). Geospatial assessment of soil erosion using Revised Universal Soil Loss Equation in Hirshabelle state of Somalia. Nature Environment & Pollution Technology, 24: 187-199. https://doi.org/10.46488/NEPT.2024.v24iS1.013

Okorafor OO, Akinbile C and Adeyemo AJ (2017). Soil Erosion in South Eastern Nigeria: A Review. Scientific Research Journal, 5: 30-37.

Okpara JN, Akeh LE and Anuforom AC (2006). Possible impacts of climate variability/ change and urbanization on water resources availability and quality in the Benin-Owena River basin. IAHS-AISH Publications, 5(308): 394–400. https://doi.org/10.5194/piahs-308-394-2006

Oliveira PTS, Nearing MA and Wendland E (2015). Orders of magnitude increase in soil erosion associated with land use change from native to cultivated vegetation in a Brazilian savannah environment. Earth Surface Processes and Landforms, 40(11): 1524-1532. https://doi.org/10.1002/esp.3738

Olorunfemi E, Komolafe AA, Fasinmirin JT, Olufayo AA and Akande SO (2020). A GIS-based assessment of the potential soil erosion and flood hazard zones in Ekiti State, Southwestern Nigeria using integrated RUSLE and HAND models. CATENA, 194: 104725. https://doi.org/10.1016/j.catena.2020.104725

Opeyemi OA, Abidemi FH and Victor OK (2019). Assessing the impact of soil erosion on residential areas of Efon-Alaaye Ekiti, Ekiti-State, Nigeria. International Journal Environmental Planning Management, 5(9): 23-31.

Oyinloye MA and Oloukoi G (2016). Land use change, urban expansion and flood risk in Akure, Nigeria. *African Journal of Environmental Science and Technology*, 10(2), 47–55. https://doi.org/10.5897/AJEST2015.2020

Pardini G, Gispert M, Emran M and Doni S (2017). Rainfall/runoff/erosion relationships and soil properties survey in abandoned shallow soils of NE Spain. Journal of Soils and Sediments, 17: 499-514. https://doi.org/10.1007/s11368-016-1532-0

Popoola AT, Ayanlade A, and Ogundele A (2020). Land use and land cover change analysis of the Owena River Basin using Sentinel-2 and Landsat data. *Journal of Environmental Geography*, 13(3–4), 11–21.

Rao YP (1981). Evaluation of cropping management factor in universal soil loss equation under natural rainfall condition of Kharagpur, India, In Proceeding of Southeast Asian Regional. Symposium, pp 241–254.

Renard KG (1997). Predicting soil erosion by water: a guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE). US Department of Agriculture, Agricultural Research Service.

Ritchie H (2021). Deforestation and Forest Loss. Published online at OurWorldinData.org. Retrieved from: https://ourworldindata.org/deforestation.

Salvacion AR (2023). Soil erosion modeling under future climate change: a case study on Marinduque Island, Philippines, In Water, Land, and Forest Susceptibility and Sustainability, Elsevier, pp. 381-398. https://doi.org/10.1016/B978-0-323-91880-0.00012-X

Samuel KJ, Durowoju OS, Ayeni B, Adelabu SA and Chigbundu OS (2025). Geospatial analysis of soil erosion and implications for sustainable development goals in tropical ecological zones. Discover Environment, 3(1): 14. https://doi.org/10.1007/s44274-025-00198-7

Sasi M, Anil SS and Deka D (2025). Soil loss estimation using the Revised Universal Soil Loss Equation and geospatial techniques in the Upper Suvarnavathy River Basin, Karnataka, India. Journal of Degraded and Mining Lands Management, 12(3): 7457-7467. https://doi.org/10.15243/jdmlm.2025.123.7457

Schmidt S, Alewell C and Meusburger K (2018). Mapping spatio-temporal dynamics of the cover and management factor (C-factor) for grasslands in Switzerland. Remote Sensing of Environment, 211: 89-104, DOI: https://doi.org/10.1016/j.rse.2018.04.008

Schmidt S, Tresch S and Meusburger K (2019). Modification of the RUSLE slope length and steepness factor (LS-factor) based on rainfall experiments at steep alpine grasslands. MethodsX, 6*:* 219-229. https://doi.org/10.1016/j.mex.2019.01.004

Sodoke S, Andam-Akorful SA, Amuah EEY, Amoah EG, Anokye K, Nang DB and Kazapoe RW (2025). GIS-based assessment of soil erosion impact and mitigation strategies for sustainable agriculture in Ghana's most vulnerable region. Environmental and Sustainability Indicators, 25: 100551. https://doi.org/10.1016/j.indic.2024.100551

Tian Z, Zhao Y, Cao L, Zhao Y and Liang Y (2024). Assessing the declining trend in soil erodibility across China: A comparison of conventional and digital K-factor maps. International Soil and Water Conservation Research, 13 (1): 15-26. https://doi.org/10.1016/j.iswcr.2024.05.005

Ugese AA, Ajiboye JO, Ibrahim ES, Gajere EN, Itse A and Shaba HA (2022). Soil loss estimation using remote sensing and RUSLE model in Koromi-Federe catchment area of Jos-East LGA, Plateau State, Nigeria. Geomatics, 2(4): 499-517. https://doi.org/10.3390/geomatics2040027

Wischmeier WH and Smith DD (1978). Predicting rainfall erosion losses: a guide to conservation planning (No. 537). Department of Agriculture, Science and Education Administration.

Wisser D, Frolking S, Hagen S and Bierkens MF (2013). Beyond peak reservoir storage? A global estimate of declining water storage capacity in large reservoirs. Water Resources Research, *49*(9): 5732-5739. https://doi.org/10.1002/wrcr.20452

Yarbrough LD (2014). Use of revised universal soil loss equation (RUSLE) and historical imagery for claims of sedimentation of lakes and streams. Environmental Forensics 15 (3): 244–55, https://doi.org/10.1080/15275922.2014.930936

Zhou Y, Hartemink AE, Shi Z, Liang Z and Lu Y (2018). Land use and climate change effects on soil organic carbon in North and Northeast China. Science of the Total Environment, 647: 1230-1238, https://doi.org/10.1016/j.scitotenv.2018.08.016

Zhu Q, Yang X, Ji F and Du Z (2025). Rainfall Erosivity Projection in South-East Australia Using the Improved Regional Climate Simulations. International Journal on Climatology, 45: e8702. https://doi.org/10.1002/joc.8702