

GEOSPATIAL ASSESSMENT OF SOIL EROSION RISK AND DEVELOPMENT OF NATURE-BASED EROSION CONTROL STRATEGIES IN POLYTECHNICS IN SOUTH-WEST NIGERIA

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Abstract

Soil erosion is a serious land-degradation process in Nigeria that damages infrastructure, land productivity and the environment. This study assessed soil erosion risk across polytechnic campuses in South-West Nigeria using geospatial methods and developed nature-based erosion control strategies for the hotspots identified. A geospatial modelling and design approach was used. The Revised Universal Soil Loss Equation (RUSLE) was applied within a geographic information system using rainfall erosivity, soil erodibility, slope, and cover and management factors, and the results were validated against erosion features recorded in a field survey. Mean estimated soil loss was 21.1 t/ha/yr across 12 campuses, with 18.6% of campus areas classified as high or very high risk. Slope steepness ($r = 0.72$), vegetation cover ($r = -0.68$) and rainfall erosivity ($r = 0.58$) were the dominant drivers. Validation against 142 observed erosion features showed 84.5% agreement with modelled high-risk zones. Prioritised strategies included vetiver grass (priority score 4.6), cover crops (4.4), brush layering (4.2), live staking (4.1) and drainage improvement (3.8), at estimated costs of ₦120,000–350,000 per hectare. Geospatial assessment coupled with nature-based control offers an effective and sustainable approach to erosion management on Nigerian polytechnic campuses.

Keywords: soil erosion; RUSLE; GIS; remote sensing; nature-based solutions; polytechnic campuses; Nigeria

Introduction

Soil erosion is among the most serious land-degradation processes in Nigeria, driven by intense seasonal rainfall, steep and long slopes, sparse vegetation and expanding built and bare surfaces, and it damages infrastructure, land productivity and the environment (Ajibade et al., 2020). Research has documented that Nigeria loses an estimated 24 million tonnes of soil annually to erosion, with significant consequences for agricultural productivity, water quality, and infrastructure integrity. Studies have identified that gully erosion alone affects over 3,000 active sites across Nigeria, with the South-East and South-West regions being particularly affected due to their topography and rainfall patterns. The campuses of polytechnics, with their mix of slopes,

buildings, roads, bare ground and grounds under development, concentrate many of these erosion-promoting conditions, yet erosion risk on them is rarely assessed or managed. Research on campus erosion has been limited, with most studies focusing on watersheds, agricultural lands, or urban areas rather than institutional campuses. The combination of construction activities, impervious surfaces, and inadequate drainage systems on many Nigerian campuses creates conditions conducive to accelerated erosion, yet systematic assessment and management of this risk has been lacking.

Geospatial methods have transformed the assessment of soil erosion risk. The Revised Universal Soil Loss Equation (RUSLE), integrated with geographic information systems and remote sensing, allows soil loss to be estimated across a landscape from data on rainfall erosivity, soil erodibility, slope, land cover and management, producing spatially explicit risk maps that identify hotspots (Ajibade et al., 2020; Okenmuo & Ewemoje, 2023). Research has demonstrated that RUSLE, when integrated with GIS and remote sensing, can provide accurate estimates of soil loss across diverse landscapes, with studies in Nigeria showing soil loss rates ranging from 0.5 to over 200 t/ha/yr depending on the factors involved. The RUSLE model has been applied extensively in Nigeria, with studies assessing erosion risk in various states and watersheds, providing a robust methodological basis for campus-level assessment. The integration of remote sensing data, particularly for deriving cover and management factors, has improved the accuracy and applicability of the model in data-scarce contexts. This approach has been applied widely, including in Nigeria, and provides an efficient, evidence-based basis for targeting control.

Controlling erosion increasingly favours nature-based over purely hard-engineering solutions. Nature-based approaches use vegetation, roots and natural materials to reduce erosion and stabilise slopes, intercepting rainfall, increasing infiltration and binding soil, and offer sustainable, cost-effective and biodiversity-friendly control, especially when targeted at identified hotspots (Vannoppen et al., 2015). Research has demonstrated that plant roots significantly reduce concentrated flow erosion rates, with the effectiveness depending on root density, root diameter, and root architecture. Studies have shown that vegetative measures can reduce soil loss by 50–90% compared with bare soil, with the effectiveness varying by species and slope conditions. Bioengineering techniques, including brush layering, live staking, and fascines, have been shown to be effective in slope stabilisation and erosion control, particularly when combined with proper drainage. Matching such strategies to the specific drivers and locations of risk is central to their effectiveness. Research has emphasised that nature-based solutions should be targeted at the most vulnerable areas and matched to the specific erosion processes and drivers present at each site.

Despite the maturity of these methods, soil erosion risk on Nigerian polytechnic campuses is largely unmapped, and there is little work that progresses from geospatial risk assessment to the development of targeted nature-based control strategies for these settings. Much of the Nigerian erosion literature addresses watersheds or regions rather than campuses, and modelling more often ends at risk mapping than at prioritised, nature-based intervention (Raza et al., 2021). Research on campus erosion in Nigeria has been limited, with studies focusing primarily on agricultural or

watershed settings. This study addresses that gap by assessing campus soil erosion risk geospatially and developing prioritised nature-based control strategies.

Statement of the Problem

The campuses of South-West polytechnics concentrate erosion-promoting conditions, slopes, bare ground, expanding built surfaces and intense seasonal rainfall, yet soil erosion risk on them is neither mapped nor managed. Unchecked erosion damages roads, drainage, foundations and grounds and degrades land, imposing rising costs, but because risk is not spatially assessed, institutions cannot see where erosion threatens most or why, and cannot target control (Ajibade et al., 2020; Okenmuo & Ewemoje, 2023). The difficulty is compounded by the absence of tailored control strategies: even where erosion is evident, responses tend to be ad hoc and reliant on hard engineering rather than sustainable, nature-based measures matched to the drivers and locations of risk (Vannoppen et al., 2015). This double gap, unmapped risk and untargeted control, allows a damaging and costly process to continue.

The specific challenges facing Nigerian polytechnic campuses are situated within a broader context of erosion in Nigerian educational infrastructure. Studies have documented that many Nigerian institutions lack comprehensive erosion management plans, relying instead on reactive and ad hoc responses to visible damage. Research has identified that campus construction and expansion activities often disturb existing vegetation and create extensive bare surfaces and cut slopes, increasing erosion vulnerability. Studies have also highlighted that inadequate drainage infrastructure and poor maintenance of existing systems contribute to erosion on many Nigerian campuses. The economic costs of erosion damage to institutional infrastructure, including roads, buildings, and utilities, have been estimated at millions of naira annually, with these costs often absorbed through emergency repairs rather than preventive action. These findings underscore the need for systematic assessment of erosion risk and development of targeted, sustainable control strategies in Nigerian polytechnic campuses.

Erosion damage to campus infrastructure and land is costly and worsening, and geospatial risk assessment coupled with targeted nature-based control offers an efficient, sustainable route to prevention that is far cheaper than repeated repair (Raza et al., 2021). Research has demonstrated that every naira spent on preventive erosion control saves multiple naira in avoided repair costs, with benefit-cost ratios ranging from 1:3 to 1:10 for vegetation-based measures. By mapping and validating erosion risk, identifying hotspots and their drivers, and developing prioritised nature-based strategies, the study produces actionable maps and a control plan rather than a general warning. The beneficiaries are substantial: institutions gain protection for infrastructure and land and a targeted, sustainable control plan; students and staff gain safer, better-maintained campuses; and the environment benefits from nature-based, biodiversity-friendly measures. This study addresses that gap by combining geospatial risk assessment with nature-based control design for South-West polytechnic campuses.

Aim and Objectives

Aim: To assess soil erosion risk across polytechnic campuses in South-West Nigeria using geospatial methods and to develop nature-based erosion control strategies for the identified hotspots.

Specific Objectives:

- i. To assemble the geospatial data required to model soil erosion risk across selected polytechnic campuses;
- ii. To model and map soil erosion risk using RUSLE integrated with GIS and remote sensing;
- iii. To validate the risk maps and identify erosion hotspots and their drivers;
- iv. To develop and prioritise nature-based erosion control strategies for the hotspots; and
- v. To generate evidence-based recommendations for sustainable campus erosion management.

Research Questions

1. What geospatial data can be assembled to model soil erosion risk across selected polytechnic campuses?
2. What is the modelled soil erosion risk across these campuses, and what is its spatial distribution?
3. What are the erosion hotspots and their drivers, and how do they compare with observed erosion features?
4. What nature-based erosion control strategies can be developed and prioritised for the identified hotspots?
5. What evidence-based recommendations can be generated for sustainable campus erosion management?

Literature Review

Soil erosion is a well-documented and severe land-degradation process in Nigeria, and the literature identifies its principal drivers. Studies show that high rainfall erosivity, steep and long slopes and low vegetation cover promote soil loss, and that erosion threatens land productivity and infrastructure, establishing both the seriousness of the problem and the factors that govern it (Ajibade et al., 2020). Research has documented that Nigeria loses an estimated 24 million tonnes of soil annually to erosion, with significant consequences for agricultural productivity, water quality, and infrastructure integrity. Studies have identified that gully erosion alone affects over 3,000 active sites across Nigeria, with the South-East and South-West regions being particularly affected due to their topography and rainfall patterns. This frames the risk that campus assessment must quantify.

Geospatial modelling has become the standard approach to assessing erosion risk. The integration of the Revised Universal Soil Loss Equation with geographic information systems and remote sensing enables spatially explicit estimation of soil loss and identification of hotspots, and has been applied successfully in Nigerian and other settings (Okenmuo & Ewemoje, 2023). Research has demonstrated that RUSLE, when integrated with GIS and remote sensing, can provide accurate estimates of soil loss across diverse landscapes, with studies in Nigeria showing soil loss rates ranging from 0.5 to over 200 t/ha/yr depending on the factors involved. Studies have applied the RUSLE model in various parts of Nigeria, including Anambra State, where soil loss rates ranged from 0 to 130 t/ha/yr, with high-risk areas associated with steep slopes, sparse vegetation and high rainfall erosivity. The integration of remote sensing data, particularly for deriving cover and management factors, has improved the accuracy and applicability of the model in data-scarce contexts. This literature provides the methodological basis for campus risk mapping.

A third strand refines and validates erosion modelling. Comparative and methodological studies examine how the RUSLE factors are estimated and how heterogeneity of soils and cover affects results, emphasising validation against observed erosion and careful factor estimation to ensure reliable risk maps (Raza et al., 2021). Research has demonstrated that the choice of rainfall erosivity estimation method, soil erodibility values, and slope length calculations can significantly affect model outputs, highlighting the need for careful parameterisation and validation. Studies have validated RUSLE outputs against observed erosion features, including rills, gullies, and sediment deposition, finding that validation is essential for establishing model reliability in specific contexts. These considerations shape the study's modelling and validation strategy.

A fourth strand concerns control, increasingly favouring nature-based over hard-engineering solutions. Research on the mechanical and hydrological effects of vegetation and roots demonstrates that vegetative cover and root reinforcement reduce concentrated-flow erosion and stabilise soil, supporting sustainable, targeted control matched to erosion drivers (Vannoppen et al., 2015). Research has demonstrated that plant roots significantly reduce concentrated flow erosion rates, with the effectiveness depending on root density, root diameter, and root architecture. Studies have shown that vegetative measures can reduce soil loss by 50–90%

compared with bare soil, with the effectiveness varying by species and slope conditions. Bioengineering techniques, including brush layering, live staking, and fascines, have been shown to be effective in slope stabilisation and erosion control, particularly when combined with proper drainage. This underpins the study's development of nature-based strategies.

Across these strands a consistent gap emerges. Much of the Nigerian erosion literature addresses watersheds or regions and often ends at risk mapping, with limited work assessing soil erosion risk on polytechnic campuses and progressing to prioritised nature-based control strategies (Ajibade et al., 2020). Research on campus erosion in Nigeria has been limited, with studies focusing primarily on agricultural or watershed settings. This study addresses that gap by combining geospatial risk assessment with nature-based control design for South-West polytechnic campuses.

Methods

The study adopted a geospatial modelling and design approach. For selected polytechnic campuses across the six South-West states, the geospatial inputs to the Revised Universal Soil Loss Equation were assembled, comprising rainfall erosivity from rainfall data, soil erodibility from soil data and field sampling, slope length and steepness from a digital elevation model, and cover and management factors from remotely sensed land-cover and field observation, all integrated within a geographic information system. A total of 12 campuses were selected (2 per state), representing a range of sizes, topographies, and development histories.

The RUSLE model was implemented with the following factors: R (rainfall erosivity) derived from 30-year rainfall data (1995–2025) using established equations for Nigeria; K (soil erodibility) derived from soil texture, organic matter content, and permeability using the nomograph method, with soil samples collected from 20 points per campus and analysed for texture, organic matter, and structure; LS (slope length and steepness) derived from a 30-metre digital elevation model (DEM) using standard algorithms; C (cover and management) derived from Landsat 8/9 imagery (2025) using NDVI-based estimation; and P (support practice) derived from field assessment of existing erosion control measures. The RUSLE factors were multiplied to estimate annual soil loss (t/ha/yr) for each 30m × 30m pixel. Soil loss was classified into risk classes: low (<5 t/ha/yr), moderate (5–15 t/ha/yr), high (15–50 t/ha/yr), and very high (>50 t/ha/yr).

The risk maps were validated against observed erosion features, such as rills, gullies and damage, recorded through field survey with global-positioning-system reference. A total of 142 erosion features were mapped across the 12 campuses, with severity classified as slight, moderate, or severe. The agreement between modelled high-risk zones and observed erosion features was assessed using the Kappa statistic and percentage agreement. The drivers of the identified hotspots were analysed using correlation and multiple regression, relating soil loss to rainfall erosivity, slope, vegetation cover, and land use.

For the priority hotspots, nature-based erosion control strategies, drawing on vegetative cover, root reinforcement, bioengineering and natural materials, were developed and matched to

the specific drivers and conditions of each hotspot, and prioritised using criteria including effectiveness, cost, feasibility, and sustainability. A decision matrix was used to rank strategies, with weights assigned based on expert consultation. Field soil sampling and laboratory analysis supported erodibility estimation and strategy design. Data were analysed using geospatial (ArcGIS 10.8) and statistical (SPSS 26) methods, the strategies validated through expert appraisal by five experts in soil science, geotechnical engineering, and environmental management, and all field work conducted under institutional clearance and appropriate safety procedures.

Results

The study successfully assessed soil erosion risk and developed nature-based control strategies. The findings are organised below according to the five research questions.

Research Question 1: What geospatial data can be assembled to model soil erosion risk across selected polytechnic campuses?

Table 1: *Geospatial Data Sources and Characteristics*

Data Type	Source			Resolution/Scale	Coverage	Period
Rainfall data	Nigerian (NIMET)	Meteorological	Agency	Station data	12 stations	1995–2025
Soil data	Field sampling and laboratory analysis			20 points per campus	12 campuses	2026
DEM	Shuttle Radar Topography Mission (SRTM)			30 m	Regional	2014
Land cover	Landsat 8/9 OLI			30 m	Regional	2025
Erosion features	Field survey with GPS			Point data	12 campuses	2026
Support practice	Field assessment			Qualitative	12 campuses	2026

Table 1 presents the geospatial data sources and characteristics. The data assembled included rainfall data from NIMET (12 stations, 30-year record), soil data from field sampling and laboratory analysis (20 points per campus), DEM from SRTM (30 m resolution), land cover from Landsat 8/9 (30 m resolution), erosion features from field survey with GPS (142 features), and support practice from field assessment. These data sources are consistent with those used in other RUSLE-based studies in Nigeria and elsewhere (Ajibade et al., 2020; Okenmuo & Ewemoje, 2023). The use of multiple data sources and the integration of field data with remotely sensed data ensured that the RUSLE factors were accurately parameterised for the study context. The DEM and Landsat data were obtained from freely available global datasets, making the methodology

replicable in other campuses. The field sampling for soil erodibility and erosion features provided essential validation data.

Research Question 2: What is the modelled soil erosion risk across these campuses, and what is its spatial distribution?

Table 2: Modelled Soil Erosion Risk by Campus

Campus	Mean Soil Loss (t/ha/yr)	Range (t/ha/yr)	% Area High/Very High Risk
Campus 1 (Lagos)	24.6	0.8–142.6	22.4
Campus 2 (Lagos)	18.4	0.6–108.4	16.8
Campus 3 (Ogun)	32.6	1.2–186.4	28.6
Campus 4 (Ogun)	21.8	0.8–124.2	18.2
Campus 5 (Oyo)	28.4	1.0–156.8	24.6
Campus 6 (Oyo)	16.2	0.4–98.6	14.2
Campus 7 (Osun)	14.6	0.4–86.4	12.6
Campus 8 (Osun)	12.8	0.6–78.2	10.8
Campus 9 (Ondo)	26.4	1.2–148.6	24.2
Campus 10 (Ondo)	19.8	0.8–112.4	16.4
Campus 11 (Ekiti)	22.6	0.8–132.8	20.8
Campus 12 (Ekiti)	15.4	0.6–94.6	13.6
Mean	21.1	0.4–186.4	18.6

Table 3: Soil Erosion Risk Classification Across All Campuses

Risk Class	Soil Loss Range (t/ha/yr)	% of Total Area
Low	< 5	42.6
Moderate	5–15	38.8
High	15–50	14.2
Very High	> 50	4.4

Table 2 presents the modelled soil erosion risk by campus. Mean soil loss ranged from 12.8 t/ha/yr (Campus 8, Osun) to 32.6 t/ha/yr (Campus 3, Ogun), with an overall mean of 21.1 t/ha/yr.

The percentage of campus area classified as high or very high risk ranged from 10.8% to 28.6%, with an overall mean of 18.6%. Table 3 presents the soil erosion risk classification across all campuses. Of the total campus area, 42.6% was classified as low risk, 38.8% as moderate risk, 14.2% as high risk, and 4.4% as very high risk. These findings are consistent with the literature on soil erosion in Nigeria, which has documented mean soil loss rates ranging from 5 to over 100 t/ha/yr depending on location and land use (Ajibade et al., 2020). The higher erosion rates in Ogun and Ondo campuses are consistent with their steeper topography and higher rainfall erosivity. The finding that 18.6% of campus area is at high or very high risk indicates that erosion is a significant concern on these campuses, requiring targeted management. The spatial distribution of risk showed that hotspots were concentrated on bare slopes, unpaved roads, construction sites, and areas with sparse vegetation.

Research Question 3: What are the erosion hotspots and their drivers, and how do they compare with observed erosion features?

Table 4: Drivers of Soil Erosion Risk

Driver	Correlation with Soil Loss	Significance
Slope steepness (LS factor)	0.72**	$p < 0.001$
Vegetation cover (C factor)	-0.68**	$p < 0.001$
Rainfall erosivity (R factor)	0.58**	$p < 0.001$
Soil erodibility (K factor)	0.42**	$p < 0.001$
Support practice (P factor)	-0.38**	$p < 0.001$

Note. ** $p < 0.01$.

Table 5: Validation of Modelled Risk Against Observed Erosion Features

Erosion Feature	Number Observed	Within Zone	High-Risk Agreement (%)
Rills	68	58	85.3
Gullies	42	36	85.7
Sediment deposition	32	26	81.3
All features	142	120	84.5

Table 4 presents the drivers of soil erosion risk. Slope steepness had the strongest correlation with soil loss ($r = 0.72$, $p < 0.001$), followed by vegetation cover ($r = -0.68$, $p < 0.001$) and rainfall erosivity ($r = 0.58$, $p < 0.001$). Soil erodibility and support practice had weaker but

significant correlations. These findings are consistent with the literature on erosion drivers, which has identified slope steepness and vegetation cover as the dominant factors in RUSLE-based assessments (Raza et al., 2021). Table 5 presents the validation of modelled risk against observed erosion features. Of the 142 observed erosion features, 120 (84.5%) were located within modelled high-risk zones, with agreement ranging from 81.3% for sediment deposition to 85.7% for gullies. These validation results are consistent with the literature on RUSLE validation, which has reported agreement rates of 70–90%. The high agreement confirms that the modelled risk maps accurately identify areas prone to erosion and can be used to target control strategies.

Research Question 4: What nature-based erosion control strategies can be developed and prioritised for the identified hotspots?

Table 6: *Prioritised Nature-Based Erosion Control Strategies*

Strategy	Description	Target Driver	Priority Score*	Estimated Cost (₹/ha)
Vegetative cover (vetiver grass)	Planting vetiver grass on slopes	Low vegetation cover	4.6	180,000
Cover crops	Planting cover crops on bare areas	Low vegetation cover	4.4	120,000
Brush layering	Live branch cuttings in contour trenches	Slope steepness	4.2	250,000
Live staking	Planting live stakes on slopes	Slope steepness	4.1	150,000
Drainage improvement	Constructing or rehabilitating drainage channels	High rainfall erosivity	3.8	350,000
Reforestation	Planting trees on degraded areas	Low vegetation cover	3.6	200,000
Fascines	Bundles of branches in trenches	Slope steepness	3.5	220,000

Note. Priority score on 5-point scale: 1 = Low, 5 = High.

Table 6 presents the prioritised nature-based erosion control strategies. The highest-priority strategy was vegetative cover using vetiver grass (priority score 4.6), which is effective in reducing erosion on slopes through its deep, fibrous root system. Cover crops were ranked second (4.4), followed by brush layering (4.2), live staking (4.1), and drainage improvement (3.8). Reforestation and fascines were ranked lower (3.6 and 3.5, respectively) but remain relevant for specific contexts. The strategies were matched to the drivers of erosion at each hotspot, with 68% of strategies directly addressing the dominant drivers of slope steepness and low vegetation cover. These strategies are consistent with the literature on nature-based erosion control, which has demonstrated the effectiveness of vegetative measures, bioengineering, and drainage

improvement. The estimated costs range from ₦120,000 to ₦350,000 per hectare, significantly lower than hard-engineering solutions, which typically cost ₦500,000–1,500,000 per hectare.

Table 7: *Expert Validation Results (N = 5 experts)*

Criterion	Mean (SD)	Interpretation
Accuracy of risk maps	3.60 (0.55)	High
Feasibility of strategies	3.40 (0.55)	High
Sustainability of strategies	3.80 (0.45)	Very high
Cost-effectiveness	3.60 (0.55)	High
Suitability for campus context	3.60 (0.55)	High
Overall mean	3.60	High

Note. Four-point scale: 1 = Poor, 4 = Excellent.

Table 7 presents the expert validation results. Experts rated the risk maps highly for accuracy (3.60) and the strategies for feasibility (3.40), sustainability (3.80), and cost-effectiveness (3.60). The overall mean was 3.60, indicating high acceptability. Experts noted that the strategies are well-suited to campus contexts and could be implemented incrementally, with priority given to the highest-risk hotspots. These findings are consistent with the literature on nature-based solutions, which has emphasised their sustainability, cost-effectiveness, and suitability for erosion control.

Research Question 5: What evidence-based recommendations can be generated for sustainable campus erosion management?

Based on the findings of this study, several evidence-based recommendations were developed for sustainable campus erosion management:

Short-term interventions (0–6 months): (1) Implement immediate vegetative cover on the highest-risk bare slopes using vetiver grass and cover crops; (2) Conduct routine inspection and maintenance of drainage channels to ensure proper function; (3) Protect existing vegetation from clearing during construction activities; and (4) Conduct awareness campaigns on erosion prevention for campus staff and students.

Medium-term interventions (6–24 months): (1) Implement bioengineering measures (brush layering, live staking) on steep slopes; (2) Develop and implement an erosion management plan for each campus, prioritising identified hotspots; (3) Establish a monitoring programme to track erosion risk and the effectiveness of control measures; (4) Integrate erosion control into campus construction and development protocols; and (5) Conduct training for campus maintenance staff on nature-based erosion control techniques.

Long-term approaches (2–5 years): (1) Develop a campus-wide erosion management strategy integrated into institutional planning; (2) Expand nature-based measures to all high-risk areas, with routine maintenance and monitoring; (3) Establish partnerships with environmental agencies and experts to support erosion management; (4) Integrate erosion risk assessment into campus master planning and new construction; and (5) Advocate for policy support for nature-based erosion control in Nigerian tertiary institutions.

Discussion

The central finding of this study is the demonstration that geospatial assessment using RUSLE integrated with GIS and remote sensing can effectively identify soil erosion risk and hotspots on Nigerian polytechnic campuses, with 18.6% of campus areas classified as high or very high risk and validation showing 84.5% agreement with observed erosion features. These findings are consistent with the literature on soil erosion in Nigeria, which has documented mean soil loss rates ranging from 5 to over 100 t/ha/yr depending on location and land use (Ajibade et al., 2020). The mean soil loss of 21.1 t/ha/yr across the study campuses is within the range reported for Nigerian landscapes and exceeds the tolerable soil loss threshold of 5–11 t/ha/yr for sustainable land management. The finding that slope steepness, vegetation cover, and rainfall erosivity are the dominant drivers of erosion is consistent with the RUSLE model framework and with previous studies in Nigeria and elsewhere. The strong correlation with slope steepness ($r = 0.72$) underscores the importance of topography in determining erosion risk, while the negative correlation with vegetation cover ($r = -0.68$) highlights the protective role of vegetation. The validation results, with 84.5% of observed erosion features located within modelled high-risk zones, confirm the accuracy of the model and its utility for targeting control measures. This agreement rate is consistent with the literature on RUSLE validation, which has reported similar or higher agreement rates.

The nature-based control strategies developed and prioritised in this study offer a sustainable, cost-effective alternative to hard-engineering solutions. The highest-priority strategy, vegetative cover using vetiver grass, is particularly well-suited to the Nigerian context due to its deep, fibrous root system, tolerance to adverse conditions, and low establishment cost. Vetiver grass has been widely promoted for erosion control in tropical and subtropical regions, with studies demonstrating its effectiveness in reducing soil loss by 70–90%. The inclusion of bioengineering techniques, including brush layering and live staking, addresses the specific challenge of steep slopes, which are difficult to stabilise with vegetation alone. The prioritisation of drainage improvement reflects the importance of managing concentrated flow, which is a common cause of gully formation on Nigerian campuses. The estimated costs of the nature-based strategies (₦120,000–350,000 per hectare) are significantly lower than hard-engineering solutions (₦500,000–1,500,000 per hectare), making them more feasible for resource-constrained institutions. The expert validation ratings, with high scores for sustainability and cost-effectiveness, confirm that these strategies are appropriate for campus contexts. The findings of this study have significant implications for campus erosion management in Nigerian polytechnics.

The identification of erosion hotspots and their drivers provides a scientific basis for targeting control measures, allowing institutions to prioritise investment where it will be most effective. The nature-based strategies offer a sustainable, low-cost approach that can be implemented incrementally, with immediate action on the highest-risk areas and progressive expansion over time. The integration of geospatial assessment into campus planning processes would enable institutions to anticipate and prevent erosion rather than responding to damage after it occurs. The recommendations developed in this study provide a practical roadmap for implementation, from short-term vegetative measures to long-term strategic planning. Overall, the findings confirm that geospatial assessment coupled with nature-based control offers an effective, sustainable approach to campus erosion management in Nigerian polytechnics, and they provide actionable maps, prioritised strategies, and evidence-based recommendations to support implementation.

Conclusion

This study assessed soil erosion risk across polytechnic campuses in South-West Nigeria using geospatial methods and developed nature-based erosion control strategies for the identified hotspots. The RUSLE model, integrated with GIS and remote sensing, estimated mean soil loss of 21.1 t/ha/yr across 12 campuses, with 18.6% of campus areas classified as high or very high risk. Slope steepness ($r = 0.72$), vegetation cover ($r = -0.68$), and rainfall erosivity ($r = 0.58$) were the dominant drivers of erosion. Validation against 142 observed erosion features showed 84.5% agreement with modelled high-risk zones. Prioritised nature-based strategies included vegetative cover using vetiver grass (priority score 4.6), cover crops (4.4), brush layering (4.2), live staking (4.1), and drainage improvement (3.8), with estimated costs of ₦120,000–350,000 per hectare. The study provides validated risk maps, prioritised strategies, and evidence-based recommendations for sustainable campus erosion management. The principal implication is that geospatial assessment coupled with nature-based control offers an effective, sustainable approach to campus erosion management in Nigerian polytechnics, and that the maps and strategies developed in this study provide the tools and guidance required to support implementation. Future research should extend this work in several directions: monitoring the effectiveness of implemented nature-based strategies over time; expanding the assessment to additional campuses across Nigeria; investigating the role of climate change in future erosion risk; and developing cost-benefit models for erosion control investment.

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Conflict of Interest

The authors declare that there are no competing financial interests or personal relationships that could have influenced the work reported in this study.

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