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Research article

RELATIONSHIP BETWEEN VEGETATION AND SOIL CHARACTERISTICS IN INYANG ETIM EKPO RIVER VALLEY, SOUTH-SOUTH NIGERIA

Enyiekere, Saviour Ibanga[1] & Offiong, Raphael Ayama[2]*
[1] Nigerian Senate, National Assembly, Abuja, Nigeria
[2] Department of Geography and Environmental Science, University of Calabar, Calabar, Nigeria
*Corresponding author: raphyxx5@gmail.com

ABSTRACT

Vegetation and soil are widely understood to exhibit a circularly causal relationship, in which soil supplies the anchorage, nutrients, moisture, and habitat that vegetation requires to thrive, while vegetation in turn protects soil against erosion and replenishes soil nutrients through litterfall and the mineralisation of litter, yet this reciprocal relationship has rarely been examined using a multivariate approach in the riparian valleys of South-South Nigeria. This study examined the relationship between vegetation parameters and soil characteristics in the Inyang Etim Ekpo River Valley, Akwa Ibom State, Nigeria. Data on floristic and structural composition of the riparian vegetation and on soil physico-chemical properties at topsoil (10-15 cm) and subsoil (15-30 cm) depths were obtained through direct field observation, measurement, and enumeration from ten composite sampling points systematically and randomly delineated along forty quadrats laid out on both banks of the river valley, and were analysed using descriptive statistics and canonical correlation analysis (CCA). The omnibus multivariate tests of significance, Wilks' Lambda, Pillai's Trace, Hotelling-Lawley Trace, and Roy's Greatest Root, were all non-significant ($p > .05$), indicating no significant overall relationship between the full sets of vegetation and soil variables. However, examination of the canonical cross-loadings and redundancy indices, which reveal the amount of variance shared between individual variables independently of the overall test of significance, showed that herbaceous species composition loaded strongly and positively with topsoil exchangeable cation on the first canonical function, girth loaded strongly and positively with subsoil acidity on the second canonical function, and basal cover loaded strongly and positively with topsoil nutrient on the third canonical function, with the vegetation variable set accounting for 40.3% of the variance in the soil variable set and the soil variable set accounting for 20.1% of the variance in the vegetation variable set. The study concludes that, at the level of specific variable pairs, vegetation attributes exert a positive influence on soil nutrient status in the Inyang Etim Ekpo River Valley, and recommends that deforestation be discouraged through policy regulation and that government gazette the valley for conservation in collaboration with the local communities.

KEYWORDS

Vegetation-soil relationship; Canonical correlation analysis; Riparian ecosystem; Inyang Etim Ekpo River Valley; Akwa Ibom State

INTRODUCTION

The riparian ecosystem is recognised as a provider of a wide variety of organisms and other resources, including the availability of water and subsidies that benefit both wildlife and mankind. The availability of water in riparian areas influences species distribution and the trophic interaction of terrestrial food webs within them. Aquatic ecosystems and riparian zones are, however, prone to anthropogenic disturbances that alter water availability and affect the flux dynamics of cross-system subsidies (Hongyong & Yixin, 2016), so that changes in the vegetation cover of a riparian valley carry consequences that extend beyond the vegetation itself to the soils that sustain it and to the wider riparian ecosystem.

Globally, a considerable body of research, reviewed in detail in the following section, has established that soil and vegetation exhibit a causal relationship through the soil's provision of nutrients for plant growth and habitat for millions of micro- and macro-organisms, and that healthy soil in turn enables vegetation to thrive, releases oxygen, holds water, diminishes destructive storm runoff, breaks down waste materials, and binds and breaks down pollutants. Soil factors such as volumetric water content, electrical conductivity, pH, nitrogen, phosphorus, and sulphur have been shown to closely relate to plant distribution, while soil more broadly plays an important role in the formation and heterogeneity of habitats and can therefore cause changes in vegetation structure and plant diversity. Riparian ecosystems in particular sit at the interface between terrestrial and aquatic systems, so that disturbances originating in either system, whether from agricultural expansion, logging, or settlement growth, are transmitted across that interface with consequences for the vegetation and soil of the riparian zone alike, a dynamic that Hongyong and Yixin (2016) identify as a defining feature of the vulnerability of riparian ecosystems generally.

Within this reciprocal relationship, vegetation is understood to provide a protective envelope for soil against erosion while helping to maintain soil nutrient status through nutrient recycling via litterfall and the mineralisation of litter, so that soil and vegetation are more accurately conceived as two components of a single, circularly causal system rather than as an independent variable acting on a dependent one. Understanding this reversal, bidirectional relationship consequently demands a multivariate analytical approach capable of examining sets of vegetation and soil variables jointly rather than examining single variable pairs in isolation.

Despite the conceptual maturity of this understanding, empirical, multivariate assessments of the vegetation-soil relationship remain comparatively scarce for the riparian forest valleys of South-South Nigeria, where such valleys, though ecologically and economically important to the fishing and agricultural communities that depend on them, continue to experience unregulated deforestation and land conversion pressures without a firm empirical basis for the conservation decisions that might protect them. This scarcity is particularly notable for the Inyang Etim Ekpo River Valley in Akwa Ibom State, where the relationship between the valley's riparian vegetation and its soils has not previously been examined using a multivariate statistical approach.

It is against this background that the present study was designed, with the broad aim of examining the relationship between vegetation parameters and soil characteristics in the Inyang Etim Ekpo River Valley, Akwa Ibom State, Nigeria. Specifically, the study sought to determine the floristic and structural composition of the riparian vegetation and the physico-chemical properties of the adjoining topsoil and subsoil, and to examine the relationship between the two sets of variables, on the hypothesis that there is no significant relationship between flora species and soils in the study area.

LITERATURE REVIEW

Global Evidence on Soil-Vegetation Interrelationships

A substantial body of global research has documented the interdependence of soil and vegetation. Rodriguez-Iturbe (2000), introducing the field of ecohydrology, argued that understanding the dynamics linking climate, soil, and vegetation requires an explicitly multivariate perspective rather than the examination of isolated bivariate relationships, a methodological position that underlies the canonical correlation approach adopted in the present study. Jamieson, Gordon, Cochrane and Patterson (2002) and van der Maarel (2004) established that soil supplies many of the fundamental requirements for plant growth, including water, nutrients, anchorage, oxygen for roots, and temperature moderation, so that soil physico-chemical variation is expected to translate directly into variation in the vegetation a given site can support. Runhong, Yuanfang, Han, Shichu, Yong, Hongrun, Juanli and Wanqing (2020), examining variations in soil physico-chemical properties along a slope-position gradient in secondary vegetation in Guilin, Southwest China, found that soil volumetric water content, electrical conductivity, pH, nitrogen, phosphorus, and sulphur closely relate to the functioning, abundance, and distribution of plant species within an ecosystem, providing one of the more comprehensive multivariate treatments of the soil-vegetation relationship available in the international literature. Brant, Pivec, Venclová, Soukup and Holec (2006) demonstrated experimentally that different vegetation covers exert a measurable influence on the volumetric water content of upper soil layers, providing direct evidence for the vegetation-to-soil pathway of the reciprocal relationship examined in this study.

The use of canonical correlation analysis to characterise such relationships is itself well established in the applied statistics literature. Sherry and Henson (2005) provided a widely cited, user-friendly primer on conducting and interpreting canonical correlation analysis, emphasising that the technique's principal strength lies in its capacity to examine the relationship between two sets of variables simultaneously rather than reducing a multivariate ecological system to a series of separate bivariate correlations, each of which would ignore the covariance structure within the vegetation and soil variable sets themselves. Henson and Smith (2000), reviewing the state of the art in statistical significance and effect-size reporting, further argued that an omnibus significance test, whatever its outcome, should always be supplemented by an effect-size measure such as a redundancy coefficient or canonical loading, a methodological standard the present study meets through its joint reporting of the omnibus test of significance alongside canonical loadings, cross-loadings, and redundancy coefficients.

Regional and African Evidence

Within the African and specifically Nigerian context, Eni, Iwara and Offiong (2011) analysed soil-vegetation interrelationships in a South-Southern secondary forest of Nigeria and confirmed that soil and vegetation exhibit a causal relationship through the provision of nutrients and habitat, a finding this study extends to a riparian rather than a closed secondary-forest setting. Iwara, Ogundele, Ibor and Deekor (2011), working in a comparable South-Southern secondary forest, applied a multivariate analysis of soil-vegetation interrelationships and specifically cautioned that the statistical significance of a canonical correlation, on its own, tells us nothing about the magnitude of the relationship it describes, recommending that redundancy coefficients and canonical cross-loadings be examined alongside, or in place of, the omnibus significance test in order to reveal the amount of variance genuinely shared between vegetation and soil variable sets, a methodological recommendation this study follows directly. Idoga and Azagaku (2005), characterising and classifying the soils of the Jantar area of Plateau State, Nigeria, found that organic carbon content decreases with depth in a soil catena, a pattern attributable to the corresponding decrease in plant material with depth, underscoring the depth-dependent nature of the soil-vegetation relationship that the present study's separate sampling of topsoil and subsoil properties was designed to capture. Outside Nigeria but within a comparable tropical setting, Rodrigues, Silva, Ferreira Júnior, dos Santos and Neri (2018) examined the influence of soil on vegetation structure and plant diversity across different tropical savannic and forest habitats in Brazil, confirming that soil heterogeneity is a significant driver of vegetation structural variation across tropical ecosystems broadly, not solely within the West African region.

Local Research Gap

Notwithstanding this body of regional evidence establishing the soil-vegetation relationship in comparable South-Southern Nigerian secondary forests, no prior study appears to have examined this relationship specifically within the Inyang Etim Ekpo River Valley of Akwa Ibom State using a multivariate canonical correlation approach capable of testing the relationship between complete sets of vegetation and soil variables rather than isolated bivariate pairs. Given that this riparian valley continues to support fishing and agricultural livelihoods along its stretch while remaining exposed to unregulated land-use pressures, the absence of an empirical, multivariate characterisation of its vegetation-soil relationship represents a significant gap for evidence-based conservation planning. This gap is compounded by the fact that much of the existing multivariate soil-vegetation literature available for South-South Nigeria, including Eni, Iwara and Offiong (2011) and Iwara et al. (2011), was generated from closed secondary-forest settings rather than from the open, linear riparian valleys that characterise many of the region's smaller rivers, so that it remains unclear whether the same pattern of vegetation-soil association holds in a riparian setting where vegetation structure, hydrological influence, and human access differ markedly from those of a closed forest interior. The present study therefore addresses this gap by applying canonical correlation analysis, following the methodological guidance of Iwara et al. (2011), Henson and Smith (2000), and Sherry and Henson (2005), to characterise the relationship between vegetation and soil characteristics in the Inyang Etim Ekpo River Valley.

METHODOLOGY

Study Area

Etim Ekpo Local Government Area lies within latitudes 4°00'34.2"N and longitudes 7°37'11.64"E to 8°48'00"E of the Greenwich Meridian, some 50 kilometres from Uyo, the capital city of Akwa Ibom State. The Local Government Area is bounded to the north by Abak Local Government Area, to the south by Azumini in Abia State, to the east by Ukanafun Local Government Area, and to the west by Ika and Essien Udim Local Government Areas, and occupies 183.3 square kilometres with Utu Etim Ekpo town as its headquarters (Essien, 2010). The Local Government Area had a projected population of over 148,800 as at 2016. Topographically, the land is relatively flat, with no part of it rising beyond 180 metres above sea level. The climate is tropical maritime, with an annual mean temperature of about 28°C and an average relative humidity of about 80%.

Fishing and agricultural crop farming, especially during the dry season, are the dominant economic activities across the stretch of the Inyang Etim Ekpo River, the riparian valley of which forms the focus of this study.

Research Design

The study adopted a correlational field survey research design, in which vegetation and soil data were obtained through direct field observation, measurement, and enumeration along systematically and randomly delineated quadrats, without any experimental manipulation of vegetation or soil conditions, so that the relationship between the two naturally occurring sets of variables could be examined as they existed in situ along the river valley.

Data Collection

The data required for the study comprised the floristic composition of the riparian forest ecosystem, the structural composition of tree and shrub species, and the soil physico-chemical properties of the study area, all obtained primarily from the study area itself. Data on flora species and on floristic and structural composition were collected from the vegetation component within a 500-metre radius along the alignment of the Inyang Etim Ekpo River, while soil samples were collected from the adjoining soils along the same river stretch.

Data were sampled using a combination of simple random, systematic, and stratified sampling techniques. The river valley was first segmented systematically into forty quadrats in the Utu Etim Ekpo community, twenty on each side of the river valley at 100-metre intervals. Vegetation samples were then collected from quadrats of 100 m x 100 m, further subdivided into 10 m x 10 m sub-quadrats for ease of access, identification, and enumeration, at alternating quadrats along each bank, giving twenty candidate sampling points per bank. Simple random sampling was then applied to select ten sampling points in all for final data collection, with vegetation data from directly opposite quadrats on each bank merged into a single composite sampling point. For soil sample collection, a composite sampling technique was adopted within the same ten quadrats used for vegetation sampling, with a soil auger used to collect samples at the topsoil (10-15 cm) and subsoil (15-30 cm) depths. Vegetation and soil data collection were both carried out through direct field observation, measurement, and enumeration using cover and chart quadrat methods, with field equipment including a tree calliper, diameter or basal-area tape, conversion tables, measuring tapes, strings and pegs, a hammer, data sheets, an identification guide, polythene bags, masking tape, a soil auger, a global positioning system (GPS) unit, a cutlass, and a camera.

Data Analysis

Data were analysed using both descriptive and multivariate parametric statistics. Descriptively, field data were summarised using tables, charts, frequencies, percentages, and averages. Canonical correlation analysis (CCA) was then used to test the stated hypothesis and to examine the interrelationship between the set of vegetation characteristics (basal cover, herbaceous species composition, and girth) and the set of soil properties (topsoil nutrient, subsoil acidity, subsoil organic matter, subsoil potassium and sodium, topsoil exchangeable bases, and subsoil phosphorus). The omnibus significance of the canonical functions was tested using Wilks' Lambda, Pillai's Trace, Hotelling-Lawley Trace, and Roy's Greatest Root at the 5% confidence level, while canonical loadings and cross-loadings, using a threshold of ≥ 0.6 to denote a meaningful loading, and canonical redundancy coefficients were subsequently examined to assess the amount of variance shared between the two variable sets independently of the omnibus significance test, following the methodological guidance of Henson and Smith (2000), Sherry and Henson (2005), and Iwara et al. (2011) that significance testing alone does not reveal the magnitude of a canonical relationship.

RESULTS

Test of Significance of the Canonical Relationship

Table 1 presents the omnibus multivariate tests of significance for the canonical correlation between the vegetation and soil variable sets. All four statistics, Wilks' Lambda ($F = 0.87$, $p = .617$), Pillai's Trace ($F = 0.90$, $p = .586$), Hotelling-Lawley Trace ($F = 0.89$, $p = .606$), and Roy's Greatest Root ($F = 2.37$, $p = .129$), were non-significant at the 5% confidence level, indicating that the overall canonical relationship between the complete set of vegetation characteristics and the complete set of soil properties was not statistically significant.

Table 1. Multivariate statistics and F-approximations: test of significance

Statistic	Value approx.	F-value	d.f.	Error d.f.	p-value
Wilks' Lambda	0.164	0.87	18	17.5	0.617
Pillai's Trace	1.208	0.90	18	24	0.586
Hotelling-Lawley Trace	2.919	0.89	18	7.3	0.606
Roy's Greatest Root	1.775	2.37	6	8	0.129

Source: Authors' Fieldwork Analysis, 2024

Eigenvalues and Canonical Correlations

Table 2 presents the eigenvalues and canonical correlations for the three canonical roots extracted, providing a relative measure of the importance of each root. The first canonical root, with an eigenvalue of 1.775 and a canonical correlation of 0.780, explained 60.8% of the shared variance; the second, with an eigenvalue of 1.097 and a canonical correlation of 0.723, explained a further 37.6% of the shared variance, bringing the cumulative proportion to 98.4%; and the third, with an eigenvalue of 0.047 and a canonical correlation of 0.213, explained the remaining 1.6% of the shared variance. Given that only the first and second roots had eigenvalues exceeding 1, these two roots were retained for the examination of canonical loadings and cross-loadings.

Table 2. Eigenvalues and canonical correlations

Root no.	Eigenvalue	Pct.	Cum. Pct.	Canon. Corr.	Sq. Cor.
1	1.775	0.608	0.608	0.780	0.608
2	1.097	0.376	0.984	0.723	0.523
3	0.047	0.016	1.000	0.213	0.045

Source: Authors' Fieldwork Analysis, 2024

Canonical Loadings and Cross-Loadings

Table 3 presents the canonical loadings and cross-loadings of the vegetation and soil variables on the first three canonical functions. Using a threshold of ≥0.6 to denote a meaningful loading, herbaceous species composition (0.750) loaded most strongly among the vegetation variables on the first canonical function, while topsoil exchangeable bases (0.681) loaded most strongly among the soil variables on the same function, indicating a positive association between the two on the first canonical function. On the second canonical function, girth (0.802) loaded most strongly among the vegetation variables, while subsoil acidity (0.725) loaded most strongly among the soil variables. On the third canonical function, basal cover (0.934) loaded most strongly among the vegetation variables, while topsoil nutrient (0.884) loaded most strongly among the soil variables.

By squaring these loadings, 56.3% of the variance in herbaceous species composition was found to be explained by the first canonical function, against 46.4% of the variance in topsoil exchangeable bases; 64.3% of the variance in girth was explained by the second canonical function, against 52.6% of the variance in subsoil acidity; and 87.2% of the variance in basal cover was explained by the third canonical function, against 78.1% of the variance in topsoil nutrient.

Table 3. Canonical loadings and cross-loadings of vegetation and soil variables

Variable	Load. 1	Load. 2	Load. 3	Cross 1	Cross 2	Cross 3
Basal cover	0.357	-0.005	0.934	0.357	-0.005	0.934
Herbaceous species composition	0.750	0.598	-0.283	0.750	0.598	-0.283
Girth	-0.557	0.802	0.217	-0.557	0.802	0.217
Topsoil nutrient	-0.108	-0.163	0.884	-0.109	-0.163	0.884
Subsoil acidity	0.231	0.725	0.378	0.231	0.725	0.378
Subsoil organic matter	-0.554	0.084	0.156	-0.554	0.084	0.157
Subsoil K/Na	-0.023	0.408	-0.126	-0.023	0.408	-0.126
Topsoil exchangeable bases	0.681	0.219	-0.014	0.681	0.219	-0.014
Subsoil P	-0.538	0.477	-0.186	-0.538	0.477	-0.186

Variables with canonical loadings ≥ ±0.60 are considered meaningful. Source: Authors' Fieldwork Analysis, 2024

Canonical Redundancy Analysis

Table 4 presents the canonical redundancy analysis, which measures the proportion of variance in one variable set explained by the opposite variable set. The vegetation variable set was found to predict 40.3% of the cumulative variance in the individual soil property variables, while the soil variable set was found to predict 20.1% of the cumulative variance in the individual vegetation characteristic variables.

Table 4. Canonical redundancy analysis

Variate set	Root	Own prop. (%)	Own cum. (%)	Opp. prop. (%)	Opp. cum. (%)
Vegetation	1	33.3	33.3	21.3	21.3
Vegetation	2	33.3	66.7	17.4	38.8
Vegetation	3	33.3	100.0	1.5	40.3
Soil	1	16.7	16.7	10.7	10.7
Soil	2	16.7	33.3	8.7	19.4
Soil	3	16.7	50.0	0.8	20.1

Opp. = opposite canonical variables. Source: Authors' Fieldwork Analysis, 2024

DISCUSSION OF FINDINGS

The non-significant omnibus multivariate test recorded in this study, with all four statistics returning p-values above .05, indicates that, taken as complete sets, vegetation characteristics and soil properties in the Inyang Etim Ekpo River Valley did not exhibit a statistically significant overall relationship. Iwara, Ogundele, Ibor and Deekor (2011), working in a comparable South-Southern secondary forest of Nigeria, cautioned specifically against relying on the significance of a canonical correlation alone to draw conclusions about a vegetation-soil relationship, noting that such a test reveals nothing about the magnitude of the relationship, that is, the amount of variance the two variable sets genuinely share, and recommending instead that redundancy coefficients and canonical cross-loadings be examined, a recommendation echoed by Henson and Smith (2000) and Sherry and Henson (2005) in the broader canonical correlation literature. Following this guidance, the present study's examination of canonical cross-loadings and redundancy indices revealed a pattern of meaningful, positive associations between specific vegetation and soil variables that the omnibus test, by its nature, could not detect.

Specifically, herbaceous species composition loaded positively with topsoil exchangeable cation on the first canonical function, girth loaded positively with subsoil acidity on the second canonical function, and basal cover loaded positively with topsoil nutrient on the third canonical function. These positive loadings imply direct relationships, such that an increase in herbaceous species composition, girth, or basal cover is associated with a corresponding increase in topsoil exchangeable cation, subsoil acidity, or topsoil nutrient respectively, consistent with the vegetation-to-soil nutrient enrichment pathway described by Brant, Pivec, Venclová, Soukup and Holec (2006) in their demonstration that vegetation cover measurably influences the properties of the soil beneath it. A directly comparable mechanism has been proposed for the girth-soil nutrient pathway specifically, whereby girth helps release fine soil particles trapped in the tree stem through stemflow into the soil, plausibly explaining the positive girth-subsoil acidity association recorded in the present study.

The redundancy analysis further showed that the vegetation variable set predicted a substantially larger share of the variance in soil properties, 40.3%, than the soil variable set predicted in vegetation characteristics, 20.1%, suggesting that, within the Inyang Etim Ekpo River Valley, vegetation exerts a comparatively stronger influence on the soil beneath it than the soil exerts on the vegetation it supports, at least across the specific variable sets examined in this study. This asymmetry is consistent with the broader ecological understanding, articulated by Eni, Iwara and Offiong (2011) for a comparable South-Southern Nigerian secondary forest, that vegetation actively maintains soil nutrient status through nutrient recycling via litterfall and litter mineralisation, a process that would be expected to leave a stronger imprint of vegetation on soil chemistry than the reverse, particularly over the depth ranges, topsoil and subsoil, sampled in this study.

The depth-differentiated pattern of the canonical loadings, whereby topsoil exchangeable bases and topsoil nutrient, rather than subsoil variables exclusively, dominated two of the three retained canonical functions, is consistent with the general finding of Idoga and Azagaku (2005) that soil organic carbon content, and by extension nutrient status, decreases with depth in a soil catena as a function of the corresponding decrease in plant material with depth. Because litterfall and litter mineralisation deposit organic matter and its associated nutrients predominantly at or near the soil surface, topsoil properties would be expected to respond more directly and more quickly to vegetation attributes than subsoil properties, a pattern broadly reflected in the present study's canonical loadings and consistent with the vegetation-to-soil nutrient enrichment pathway described earlier.

These findings are also consistent with the broader international literature reviewed earlier. Runhong et al. (2020) found that soil physico-chemical properties closely relate to the functioning, abundance, and distribution of plant species along a slope-position gradient in secondary vegetation in Southwest China, while Rodrigues, Silva, Ferreira Júnior, dos Santos and Neri (2018) confirmed that soil heterogeneity drives vegetation structural variation across tropical savannic and forest habitats in Brazil. Taken together with the present findings, this body of evidence indicates that the vegetation-soil relationship identified through canonical cross-loadings and redundancy analysis in the Inyang Etim Ekpo River Valley reflects a broader, ecologically general pattern rather than a site-specific anomaly, while extending the empirical evidence base for this relationship to a riparian valley setting in Akwa Ibom State that had not previously been examined using a multivariate statistical approach, thereby addressing the local research gap identified earlier in this paper.

These findings carry direct implications for the conservation and management of the Inyang Etim Ekpo River Valley. Given that vegetation attributes were shown to exert a comparatively stronger influence on soil nutrient status than the reverse, the continued removal of riparian vegetation through deforestation would be expected to progressively degrade the exchangeable-cation, acidity, and nutrient status of the valley's topsoil and subsoil, with downstream consequences for the agricultural productivity on which the valley's fishing and farming communities depend. At the same time, the non-significant omnibus test recorded in this study is a reminder that the relationships identified through cross-loadings and redundancy analysis, while meaningful, were derived from a modest sample of ten composite sampling points, so that the specific loadings reported here are best treated as indicative of the pattern of association within the Inyang Etim Ekpo River Valley rather than as precise population parameters, pending replication with a larger number of sampling points across a wider stretch of the valley.

CONCLUSION

This study examined the relationship between vegetation parameters and soil characteristics in the Inyang Etim Ekpo River Valley, Akwa Ibom State, Nigeria, using canonical correlation analysis. While the omnibus multivariate tests of significance indicated no statistically significant overall relationship between the complete sets of vegetation and soil variables, examination of canonical cross-loadings and redundancy coefficients, following established methodological guidance that significance testing alone does not reveal the magnitude of a canonical relationship, showed that herbaceous species composition, girth, and basal cover each loaded strongly and positively with topsoil exchangeable cation, subsoil acidity, and topsoil nutrient respectively, and that the vegetation variable set predicted a substantially larger share of the variance in soil properties than the soil variable set predicted in vegetation characteristics. The study concludes that vegetation attributes exert a positive influence on soil nutrient status in the Inyang Etim Ekpo River Valley, underscoring the ecological importance of maintaining the valley's riparian vegetation cover for the continued fertility of its soils.

RECOMMENDATION

Based on the findings, it is recommended that deforestation within the Inyang Etim Ekpo River Valley be discouraged through policy regulation, given the demonstrated positive influence of vegetation attributes such as herbaceous species composition, girth, and basal cover on the exchangeable cation, acidity, and nutrient status of the valley's soils.

It is further recommended that government gazette the Inyang Etim Ekpo River Valley for conservation, in collaboration with the local communities whose fishing and agricultural livelihoods depend on the continued ecological health of the valley, so that conservation measures are implemented with community support rather than in opposition to local resource use.

It is also recommended that any conservation or land-use planning for the valley give particular attention to the topsoil layer, given that topsoil exchangeable bases and topsoil nutrient, rather than subsoil properties, were most strongly associated with vegetation attributes in this study, so that practices which disturb or strip the topsoil, such as unregulated land clearing and cultivation on steep or unstable stretches of the riverbank, be specifically discouraged alongside the deforestation of standing vegetation.

Finally, it is recommended that future research extend the present canonical correlation approach to a larger number of sampling points and to additional riparian valleys within Akwa Ibom State and the wider South-South Nigeria region, so that the generality of the vegetation-soil relationship identified in this study can be independently verified across a broader range of riparian ecosystems.

DECLARATIONS

Ethical approval: Institutional research ethics clearance was obtained prior to field data collection.

Informed consent: Not applicable, as the study involved the collection of vegetation and soil data rather than human participants.

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Conflict of interest: The authors declare no conflict of interest.

Data availability: The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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