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Evaluating Vegetation Change Dynamics in Etung Local Government Area Using Geospatial Tools

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ABSTRACT

Many studies have used GIS and remote sensing to evaluate vegetation changes, but they often overlook the analysis of long-term land-use and land-cover trends using interpolated LULCC and NDVI data. This gap makes it difficult to detect long-term patterns, measure change rates, and forecast future land-use and cover changes. As a result, the usefulness of geospatial analyses for environmental planning and sustainable resource management is limited. The study analysed vegetation changes in Etung LGA, Cross River State, Nigeria, using geospatial techniques to map and quantify shifts in 1980, 1990, 2010, and 2024. It focused on urban growth and forest cover, with vegetation health assessed using NDVI. Landsat images from 1980, 1990, 2010, and 2024 were processed using remote sensing and GIS to identify land-use changes. The data obtained were analysed using tables, simple percentages, maps, charts and trend analysis. Results obtained revealed patterns linking urban expansion to vegetation dynamics.There was a significant change in vegetation, especially in 2024, due to a considerable increase in built-up infrastructure and bare surfaces.The results showed ecological degradation accompanied by some regeneration. Dense forest cover shrank from 773.06 km² in 1980 to 580 km² in 2024, marking a 24.97% decrease. The rate of loss accelerated over the last 20 years, with 84.60 km² lost between 2010 and 2024. The study showed that vegetation in Etung LGA had changed significantly over 40 years due to urban expansion, human-induced land degradation, and environmental shifts.The study suggested expanding green infrastructure, such as urban green spaces and buffer zones, to address environmental problems caused by the growing built-up areas and bare land.

Keywords: Vegetation changes, Geospatial technologies, NDVI, Etung LGA

Introduction

Vegetation is constantly evolving, with its composition and distribution affected by factors such as forest growth, wildfires, storms, pests, and human activities like deforestation, urbanisation, and farming (Kumar *et al.*, 2022; Díaz *et al.*,2019; Njar *et al.*, 2020). Human-induced land-cover changes lead to changes in vegetation, declines in biodiversity, and species endangerment (Mir *et al.*, 2025; Njar *et al.*, 2020). Tracking these changes and disturbances is critical for conservation efforts and for understanding vegetation dynamics and health, both of which are vital for environmental and climate research.

In Etung LGA, vegetation loss results from plantation farming, urbanisation, and agriculture, which replace diverse ecosystems with monocultures such as cocoa and plantain farms, leading to deforestation, habitat destruction, and reduced biodiversity. While these activities promote economic growth and food security, monocultures negatively impact ecological balance, support fewer species, and diminish ecosystem functions (Njar *et al.*, 2020).

Forest fragmentation and degradation disrupt ecological balance, threaten habitats, and affect ecosystem functions. Monitoring land cover changes, disturbance dynamics, and spatial trends is crucial for conserving forests and biodiversity (Mukaku *et al.*, 2024; Ploton *et al.*, 2022). Geospatial tools such as remote sensing and GIS help assess these changes, thereby aiding sustainable land management strategies (Bielecka *et al.*, 2025; Aboelkhair and Atta, 2025). These technologies enable large-scale, cost-effective monitoring of vegetation, allowing researchers and policymakers to track dynamics, predict shifts, and promote conservation and climate resilience (Safavi, 2024). This approach improves decision-making in sustainable ecosystem management by using remote sensing and GIS tools, which detect natural and human-driven ecological changes. Vegetation indicates ecosystem health and biodiversity, with changes caused by wildfires, droughts, deforestation, urbanisation, and agriculture. Understanding these patterns over space and time helps assess environmental trends, climate effects, and land management strategies.

Agriculture accelerates vegetation depletion by converting forests and grasslands into croplands, often without sustainable practices, leading to soil degradation and erosion. Urbanisation replaces natural landscapes with infrastructure, encroaching on fertile lands and wetlands, reducing biodiversity and increasing surface temperatures, which disrupts the local climate. Several studies have employed geospatial technologies, such as GIS and remote sensing, to study vegetation dynamics over time (Enoh *et al.,* 2026; Whig *et al.,* 2024; Li *et al.,* 2023; Zhang *et al.,* 2017). However, these studies often generalise land use stressors without quantifying their direct impacts on vegetation loss. They assessed vegetation changes, but failed toanalyse long-term land-use and land-cover (LULCC) trends using interpolated data. Incorporating interpolated datasets and trend analysis enables researchers to identify long-term patterns, rates of change, and potential future directions in land-use and land-cover dynamics.

Without these datasets, gaining insight into long-term vegetation and land cover changes, especially in fast-changing environments, is limited. Including them in analysis, therefore, improves historical assessments, reveals long-term trends, and supports planning and conservation initiatives. For example, Nie *et al.* (2021) examined vegetation changes on the Loess Plateau in Northern Shaanxi using Normalised Difference Vegetation Index (NDVI) data from 2000 to 2018. They identified key factors influencing NDVI, including GDP, land use, slope, and temperature, but did not present long-term annual trends in vegetation change interpolated from the LULCC and NDVI datasets. This limitation, as stated above, restricts the capacity to recognise patterns of landscape change, their rates, and future land-use shifts.

This study filled this gap by using spatiotemporal tools and interpolation to evaluate vegetation change in Etung LGA, Nigeria, analysing trends, stressors, and ecological impacts to support sustainable land use and conservation. Monitoring these human-induced changes is vital for policy, conservation, and climate resilience. Spatiotemporal analysis of vegetation change uses geospatial tech, remote sensing, and analytics to identify when and where changes occur, revealing trends and drivers at multiple scales (Foșalau*et al.,* 2025). It helps address deforestation and biodiversity loss and guides land management. Geospatial tools efficiently monitor and analyse vegetation changes in Etung Local

Government Area, delivering precise data for environmental management and conservation efforts.

Materials and methods

Study area

Etung LGA in central Cross River, Nigeria, covers 815 km² and borders Ikom, Boki, Obubra, and Cameroon, playing a vital role in cross-border trade (Fig. 1). The geographical coordinates of Etung Local Government Area are approximately latitude, 5°51'32″ N and longitude, 8°47'30″ E. It has a humid rainforest climate with 2,500-4,000 mm annual rainfall, peaking in July-September (Ogar *et al.*, 2024). The rainy season is from March to October; the dry season is from November to February. Temperatures range from 24 °C to 32 °C, with the warmest temperatures in January-March. Humidity exceeds 70%, rising to 85% during rain. Soils are ferrallitic from weathered sandstones and rocks, with sandy loam on slopes and sandy clay loam in valleys. Dense forests of mahogany, iroko, oil palm, and gmelina support diverse plant life. Riparian zones have freshwater swamp forests; hilltops show secondary regrowth. Deforestation from logging, cocoa farming, and settlement occurs near Agbokim, BendegheEkiem, and Ajassor.

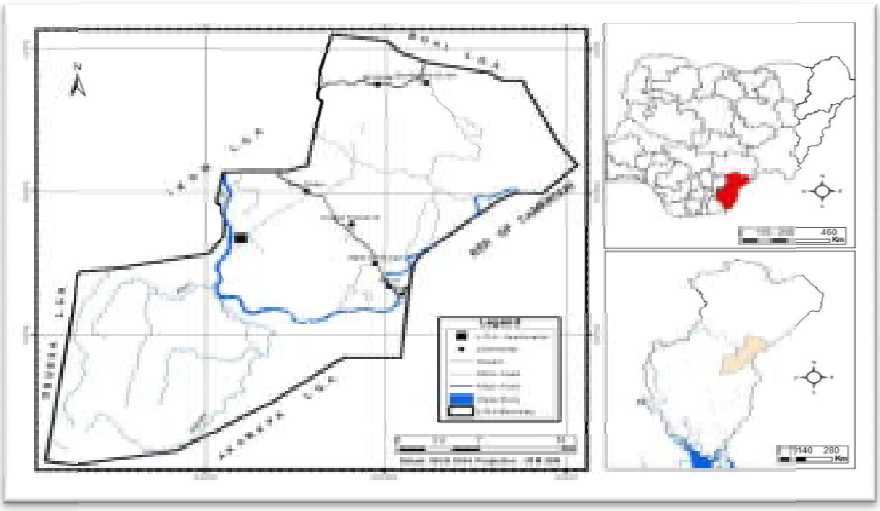


Figure 1: An insert map showing Etung LGA

Research design, types and sources of data

This study used a longitudinal design with geospatial tools to analyse vegetation changes over time, considering urban expansion and land use. It relied on secondary data, including vegetation cover and land-use stressors (built-up areas, bare surfaces, roads), obtained from 1980 to 2024, with key years: 1980, 1990, 2010, and 2024. NDVI analysis was alsoconducted for the same period.Interpolation methods were used to fill in missing annual data, resulting in a continuous temporal dataset that enables a more thorough analysis of vegetation and land-use change trends throughout the study period. Data from Landsat satellite imagery via USGS Earth Explorer and GLCF were used to assess vegetation and land-cover changes using remote sensing and GIS. Supervised classification improved accuracy in land cover differentiation.

Sampling technique

The stratified sampling technique was employed to divide the vegetation change and land-use stressor dataset into annual

groups, creating distinct time frames for easier comparison. This segmentation improved trend identification, enabled calculation of annual averages, and supported detailed analysis of spatial and temporal variations. This sampling technique enhanced comparison accuracy, revealed subtle patterns, and identified long-term environmental shifts, ensuring insights into vegetation dynamics were based on a statistically sound, time-resolved dataset.

Epoch-based analysis and linear interpolation

The years 1980, 1990, 2010, and 2024 were selected to examine Land Use and Land Cover (LULC) changes in Etung LGA, Cross River State, based on satellite image availability and significant events. Despite uneven intervals, each year marks important phases of land transformation driven by population growth, policy, agriculture, infrastructure, and environmental pressures. Data from 1980 and 1990 showed pre-deforestation land, while data from 2010 and 2024 reflected expansion due to cocoa farming, development, conservation, climate-resilient farming, and improved land management. Linear interpolation was used to estimate data for missing years, creating a reliable timeline for vegetation change analysis. These key years supported a long-term analysis of landscape change in Etung LGA.

Image classification method

This study used four cloud-free Landsat images of Etung LGA, projected onto UTM Zone 32 N with WGS 84, from 1980, 1990, 2010, and 2024 for long-term vegetation analysis. Data from the USGS were processed in the ArcGIS Geographic Information System (GIS) 10.8, with ward boundaries extracted and projected to the Universal Transverse Mercator (UTM) projection. Preprocessing corrected distortions and enhanced image quality for accurate vegetation change detection. Land use and cover types (bare surface, built-up area, dense forest, sparse forest and water body) were classified using supervised classification, which assigns pixels to categories based on spectral characteristics (Richards and Richards, 2022) through pattern recognition. The maximum likelihood approach ensured high accuracy by statistically evaluating pixel groups (De Jong *et al.,* 2007). Training sites developed statistical reflectance profiles, called signatures, which the algorithm used to assign pixels by comparing reflectance with these profiles. The combination of visual interpretation and digital processing, considering tone, texture, shape, size, and pattern, enabled precise monitoring of environmental and land-management changes.

Techniques of data analysis

This study analysed data using averages, charts, tables, percentages, and the Normalised Difference Vegetation Index (NDVI). NDVI was used to assess vegetation health and distribution by measuring the contrast between near-infrared and red-light reflectance. NDVI values range from - 1 to +1, where negative values indicate water bodies, values near zero represent barren or built-up surfaces, and higher positive values signify dense healthy vegetation. Vegetation change rates were calculated as percentage changes by comparing initial and subsequent land-cover values, following the method of Njar *et al.,* (2020).

Interpolatingvegetation change andland cover change data

The linear interpolation technique was employed to estimate missing values for vegetation and land-use/land-cover change (LULCC) stressors, following the approaches of Njar *et al.,* (2020) and Noor *et al.,* (2014). Using observed data from

1980, 1990, 2010, and 2024, annual estimates for missing years (1981, 1982, 1983,1984, 1985, 1986, 1987, 1988, 1989, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023) were systematically derived. The method applied the interpolation formula proposed by Noor *et al*. (2014) to generate continuous yearly data from the available LULC analysis results. To achieve this, the interpolation formula defined by Noor *et al.,* (2014) was used, which is expressed in equation 1:

$f1(x) = b0 + b1\ (x - x0)$ …… (1).

Where: *x* is the independent variable; x_0 is a known value of the independent variable; $f_1(X)$ is the value of the dependent variable for a value *x* of the independent variable (the year for which the estimation is needed). At the same time, b_0 and b_1 are the unknown coefficients.

Results and discussions

Descriptive statistics of vegetation change and land use cover stressors

The results in Table 1 present land-use and land-cover changes in Etung LGA, Cross River State, Nigeria, from 1980 to 2024. Bare surfaces average 2.16 km² with moderate variability, indicating episodic land degradation from agriculture, logging, and infrastructure. Built-up areas average 20.94 km², reflecting rapid urban growth, threatening habitats near forests. Dense forests average 710.22 km² in area and are stable, likely due to conservation efforts, though illegal logging and encroachment remain threats. Sparse forests, highly variable at 35.85 km² (CV 81.96%), were heavily affected by logging and shifting cultivation, which are predominant human activities in the area. Water bodies stayed stable at 7.84 km².

Table 1: Descriptive statistics of vegetation change and land cover change stressors

Land use types	Mean (km²)	Std Dev (km²)	CV (%)
Bare surface	2.16	1.19	55.09
Built-up area	20.94	19.12	91.31
Dense forest	710.22	56.06	7.89
Sparse forest	43.74	35.85	81.96
Water body	7.84	0.05	0.64

Rate and extent of change in vegetation cover

This analysis maps vegetation change from 1980 to 2024, shown in Table 2 and Figures 2-5. It revealed ecological degradation and some regrowth. Dense forest cover decreased from 773.06 km² in 1980 to 580 km² in 2024, a 24.97% decline. Losses accelerated over the last two decades, with 84.60 km² lost between 2010 and 2024. These trends reflect deforestation driven by logging, agriculture, and infrastructure, aligning with studies by Ozigis *et al.* (2025) and Kalischek *et al.* (2023), which reported that cocoa and oil palm plantations are encroaching on forest reserves, causing habitat loss. Similarly, Taylor*et al*. (2025) also found that logging impedes regrowth where sustainable practices are lacking.

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Table 2: Rate and extent of vegetation change in Etung LGA from 1980 to 2024

Land uses	1980	1990	2010	2024	1990 – 1980		2010 – 1990		2024 – 2010		2024 – 1980	
					km^2	%	km^2	%	km^2	%	km^2	%
Dense forest	773.06	765.3	680.7	580	-7.76	-1.00	-84.60	-11.05	-100.70	-14.79	-193.06	-24.97
Sparse forest	2.21	7.66	65.66	122.66	5.45	246.61	58.00	757.18	57.00	86.81	120.45	5450.23

In addition, sparse forest areas increased from 2.21 km² in 1980 to 122.66 km² in 2024, a 5450.23% increase (Figures 2-5), mainly due to degraded dense forests transforming into fragmented or secondary growth. The fastest growth was between 1990 and 2010, with 58.00 km² (757.18%), and between 2010 and 2024, with 57.00 km² (86.81%). Ologunde *et al.* (2025) warned that sparse forests lack the qualities of primary forests and support fewer species. This expansion may also stem from rural practices such as fallow farming and bush encroachment, which risk undermining ecosystem stability.

These changes cause ecological issues, including the loss of vital services, such as carbon storage and habitats for species like the Cross River gorilla. Despite its apparent benefits, sparse forest growth often signals ecological decline, increasing vulnerability to erosion, reducing soil fertility, and disrupting water cycles. This underscores the need for land use planning and conservation in Etung LGA. As Alegbeleye *et al.*, (2024) emphasised, sustainable management must balance development and ecological health. Results in Table 2 and Figures 2-5 reveal a shift from dense to sparse forests, reducing biodiversity, increasing erosion and flooding risks, and impairing the land's capacity for sustainable agriculture and climate resilience.

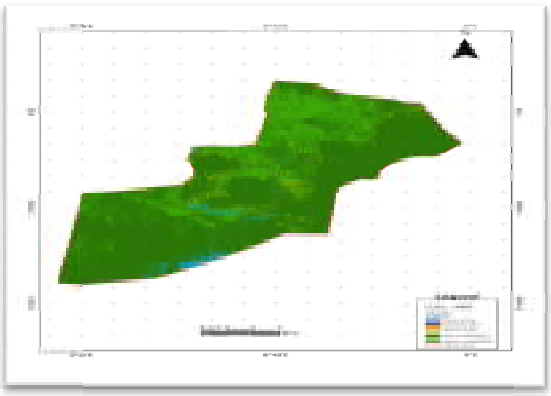


Figure 2: 1980 Land use map of Etung LGA

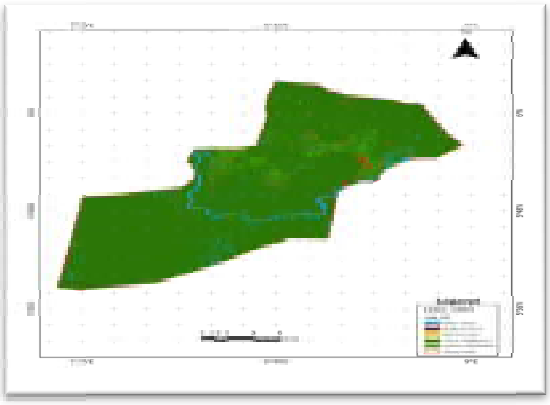


Figure 3: 1990 Land use map of Etung LGA

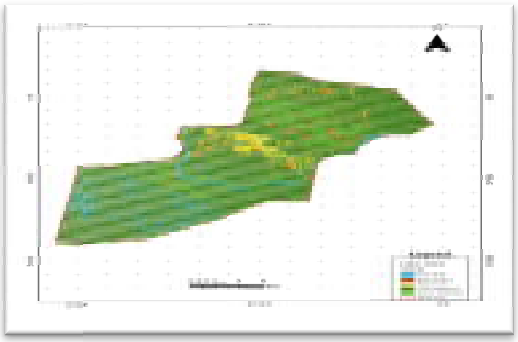


Figure 4: 2010 land use map of Etung LGA

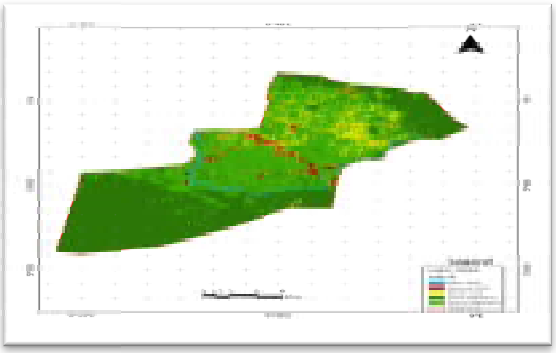


Figure 5: 2024 land use map of Etung LGA

Rate and extent of urban expansion (built-up area and bare surface)

The results in Table 3 and Figures 2-5. Revealed that from 1980 to 2024, built-up areas grew from 1.07 km² to 68.61 km², a 6312.15% increase, fueled by population growth, changing livelihoods, infrastructure, and investments in real estate, transportation, and commerce. Between 1990 and 2010, there was a rapid increase of 26.05 km² (990.49%), indicating significant development linked to decentralization, improved governance, and enhanced accessibility.

Between 2010 and 2024, built-up areas grew by 39.93 km² (139.23%), reflecting ongoing urban expansion at edges, driven by land demand, weak zoning, and planning gaps, especially in southern Nigeria's peri-urban zones. In Etung, built-up land expansion into forests and farms causes ecosystem fragmentation, reduces agricultural productivity, and increases reliance on external food supplies, a pattern common in sub-Saharan Africa. Bare surface area increased from 0.82 km² in 1980 to 5.89 km² in 2024, a 618.29% increase, indicating environmental concerns such as soil erosion and rising temperatures. The largest growth from 2010 to 2024, 3.95 km² (203.61%), likely results from land clearing for development and agriculture, leading to soil degradation.

Table 3: Rate and extent of urban expansion (built-up area and bare surface) in Etung LGA from 1980 to 2024

Land uses	1980	1990	2010	2024	1990 – 1980		2010 – 1990		2024 – 2010		2024 – 1980	
					km²	%	km²	%	km²	%	km²	%
Bare surface	0.82	1.47	1.94	5.89	0.65	79.27	0.47	31.97	3.95	203.61	5.07	618.29
Built-up area	1.07	2.63	28.68	68.61	1.56	145.79	26.05	990.49	39.93	139.23	67.54	6312.15
Water body	7.74	7.84	7.92	7.74	0.10	1.29	0.08	1.02	-0.18	-2.27	0.00	0.00

The shift from bare surfaces to built land reflects a process in which clearing leads to infrastructure, increasing ecological pressures without strong protections. Water bodies in Etung changed little in size, from 7.74 km² in 1980 to 7.92 km² in 2010, then back to 7.74 km² in 2024, yet face qualitative threats from land use changes like deforestation, bare land, and expanding settlements, risking sedimentation, chemical runoff, and water quality, as noted by Ogundairo *et al.* (2025) and Engdaw *et al.* (2024). Activities such as sand mining, waste dumping, and open defecation can degrade water quality despite no substantial change in water extent. Table 3's land cover data shows the tension between development and sustainability: converting forests and farmland to urban and bare areas increases flood risk, reduces arable land, fragments habitats, and exposes soils, elevating local temperatures and reducing landscape resilience.

Trend in vegetation cover

As shown in Figure 6, dense vegetation in Etung LGA declined significantly from 1980 to 2024, primarily due to human activities such as agriculture, logging, and development. Cover decreased from 773.06 km² to 580 km², a 25% drop, with a slow decline (under 2 km²/year) from 1980 to 2000, then accelerating after 2000, especially between 2010 and 2024, with over 100 km² lost. This aligns with increased commercial farming, notably of cocoa and oil palm, and intensified logging, which hinder forest recovery (Kalischek *et al.,* 2023; Ozigis *et al.,* 2025). The ecological impacts include habitat fragmentation, biodiversity loss, and disrupted ecosystem functions such as

carbon storage and water regulation. Experts warn that this endangers species like the Cross River gorilla (Gorilla gorilla diehli). Lack of land-use regulation exacerbates resource exploitation (Alegbeleye *et al.*, 2024), and global studies confirm the vulnerability of tropical biodiversity to land use and climate change (Newbold *et al.*, 2020). This ongoing forest loss threatens ecological stability, biodiversity, climate regulation, water systems, and rural economies, increasing environmental and socio-economic risks.

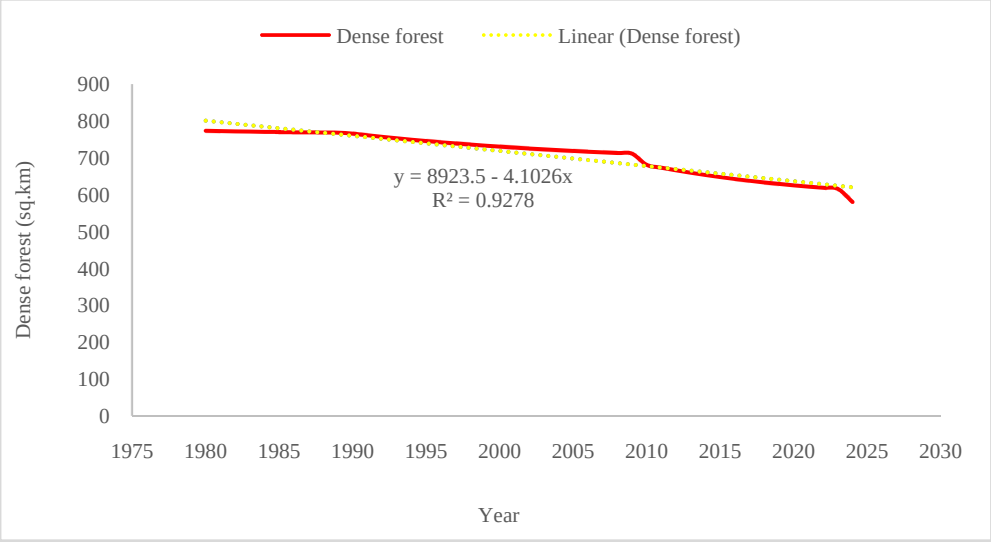


Figure 6: Trend in dense forest from 1980 to 2024

It also shows that over 44 years, a 24.97% decline in dense vegetation affects biodiversity, carbon storage, and climate regulation, endangering species such as primates and rare plants. Forest loss diminishes ecosystem services such as soil stability and water retention, thereby increasing the risks of erosion and flooding (Haseeb *et al.*, 2024). The line graph in Figure 6 shows a steady decline in the extent of dense forest in Etung LGA, Cross River State, from 1980 to 2024.

The red line indicates actual loss, the yellow trend, with an equation y=8923.5-4.1026x, estimating an annual loss of about 4.10 km². A high R^2 of 0.9278 confirmed a strong linear trend, with accelerated loss around 2010 and 2020-2024, linked to increased settlement and agriculture and weak conservation, consistent with other Nigerian regions (Uzonu *et al.*, 2025).

Trend in sparse forest

A sharp rise in sparse vegetation from 1980 to 2024 (Figure 7). Sparse forest increased from 2.21 km² in 2024 to 122.66 km² in 2024, a 5,450% rise, with rapid growth after 2010. This shift from dense to degraded forests results from logging, shifting cultivation, deforestation, and disturbances(common human activities in the area), reducing biodiversity and ecological functions. The trend reflects forest degradation primarily driven by human activities, with ecological benefits that are less effective than those of dense forests. This pattern indicates deforestation followed by regrowth of fragmented vegetation, driven by subsistence farming, fuelwood collection, and settlement expansion. The findings, supported by Smith and Boers (2023), who reported concerns, suggest that while sparse vegetation provides some benefits, it is less effective for biodiversity, climate regulation, and water cycles. The increase in

sparse forest cover signals growing vulnerability to degradation in Etung LGA. From 1980 to 2024, the sparse forest in Etung LGA increased from 2.21 km² to 122.66 km². The trend, as shown by data and a linear regression (y = 2.6421x – 5245.6, R^2 = 0.9409), indicates steady growth of about 2.64 km² annually. Notable jumps around 1990 and after 2010 likely reflect land-use changes like agriculture, deforestation, and settlement growth. This growth coincides with a decline in dense forests, pointing to ongoing degradation and fragmentation.

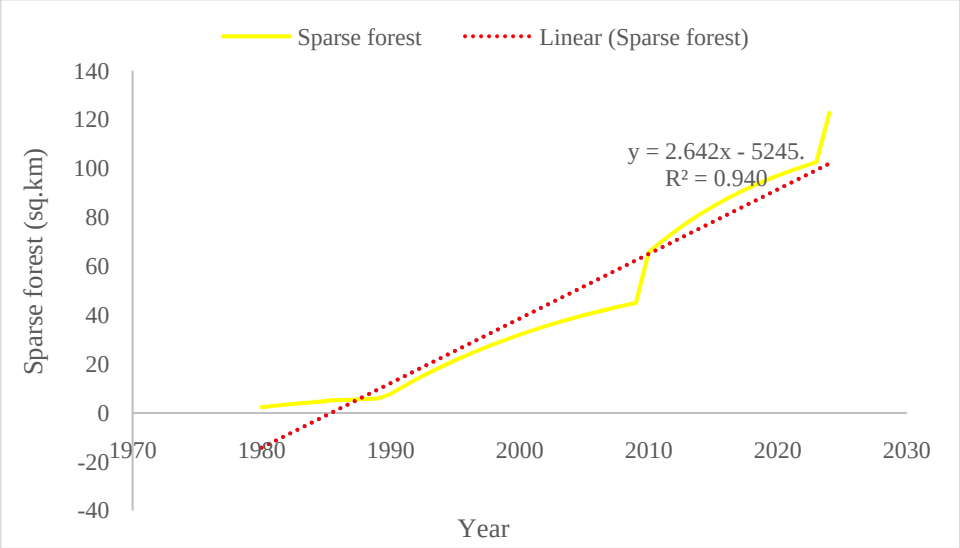


Figure 7: Trend in sparse forest from 1980 to 2024

Total changes in the area of land use and land cover (LULC)

Furthermore, as depicted in Table 3 and Figure 8, land use and cover changes in Etung LGA at 1980, 1990, 2010, and 2024. The area grew from 15.52 km² in 1980 to 386.12 km² in 2024, indicating rapid landscape transformation. The change from 1980 to 1990 was dramatic, increasing by 986.85% to 169.20 km², likely due to agriculture, logging, and settlement expansion. From 1990 to 2010, growth slowed, reaching 201.40 km², a 19.02% rise, possibly reflecting stabilisation. The largest increase occurred between 2010 and 2024, nearly doubling to 386.12 km², a 91.76% increase.

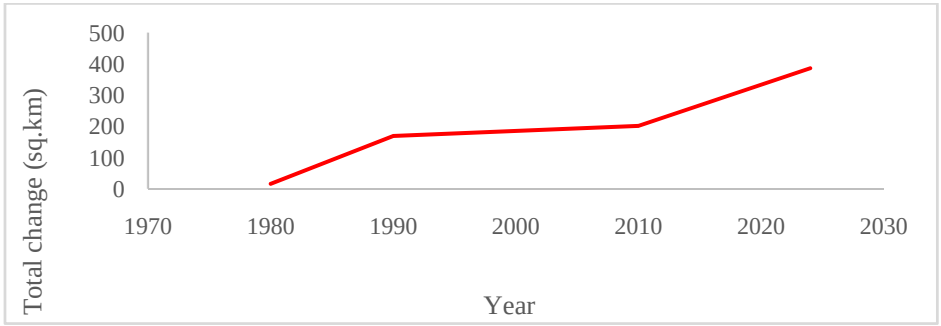


Figure 8: Total area changes in land use and land cover (LULC)

This rapid increase in land-use change in Nigeria is linked to urbanisation, infrastructure, and farming, and is driven by population and economic growth, as well as lax environmental regulations (Ologunde *et al.*, 2025; Alegbeleye *et al.*, 2024). Land shifts pressurise forests and riparian zones, risking biodiversity, soil, and water quality. These changes stem from human activity and natural factors. Built-up areas grew by over 6300%, while bare land grew by 600%, indicating urban sprawl for housing, roads, and agriculture (Ordway *et al.*, 2017). From 1990 to 2010, economic growth increased the area under cultivation for cocoa and oil palm (Potapov *et al.*, 2021).

From 2010 to 2024, logging, settlement, and land degradation caused dense forests to decline by ~25% and sparse forests to rise by over 5400% (Song *et al.*, 2018). Climate issues such as irregular rainfall and fires worsen these trends (Winkler *et al.*, 2021), showing an inverse relationship between dense and sparse forests (Haseeb *et al.*, 2024). Land use in Etung LGA expanded from 15.52 km² in 1980 to 386.12 km² in 2024, a 2387.63% increase, driven mainly by urban growth, agriculture, logging, and land degradation, threatening biodiversity and ecosystems.

Table 3: Sum of area changes in land use and land cover (LULC)

Years	Total area change (km^2)
1980	15.52
1990	169.20
2010	201.40
2024	386.12

NDVI of 1980

The 1980 NDVI map of Etung Local Government Area shows vegetation health and land cover that year (Figure 9). NDVI values ranged from -0.24 to 0.464, with orange and yellow indicating low to moderate vegetation, and green showing denser, healthier greenery. Moderate cover was common, with dark-green patches in central, southeastern, and riparian zones indicating dense forests and high biomass, typical of Etung's rainforest. The map suggests the area was mainly rainforest, including dense forests, secondary growth, fallows, and farmland. NDVI variations reflect natural and human influences.

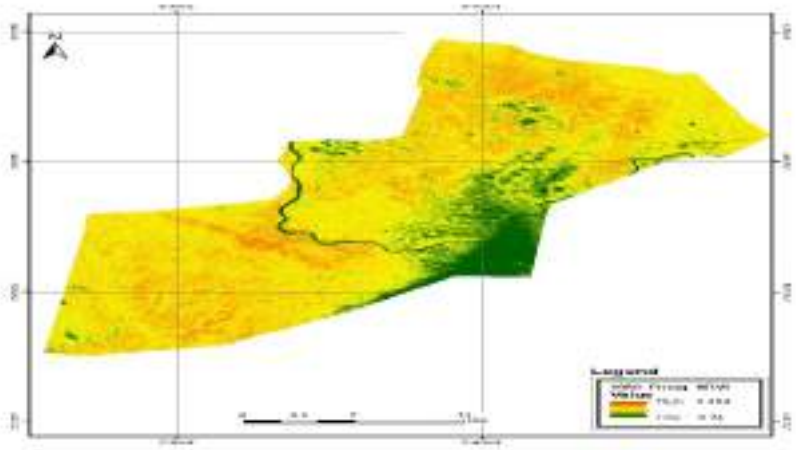


Figure 9: NDVI classes of 1980

NDVI of 1990

The 1990 NDVI map of Etung Local Government Area shows a decline in vegetation compared to 1980, with NDVI values dropping from 0.464 to 0.334, indicating reduced vegetation vigour and density (Figure 10). The map features mostly orange and yellow in the north, west, and southwest, representing low to moderate density, while greener areas in the east and southeast indicate intact forests. In all, the landscape is shifting from dense rainforest to fragmented land cover, reflecting increased human impact.

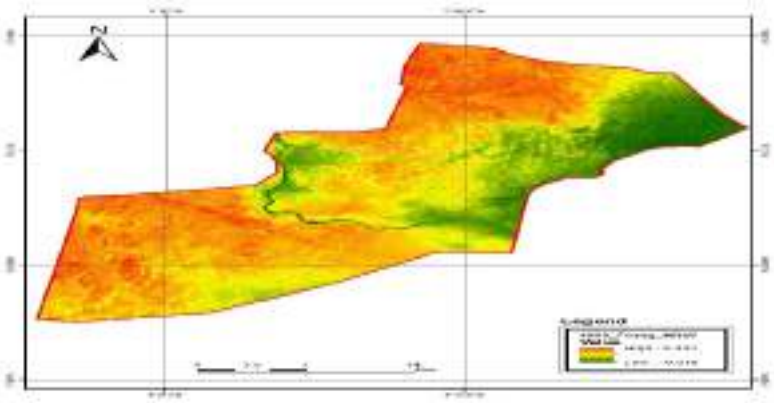


Figure 10: NDVI classes of 1990

NDVI of 2010

The 2010 NDVI map for Etung shows mainly low to moderate vegetation, with NDVI values from 0.045 to 0.366 (Figure 11). Compared to the 1980s (0.464) and 1990s (0.334), this indicates some regeneration, but mostly moderate vegetation rather than dense rainforest. Yellow and light orange areas reflect moderate vigour, while green patches along rivers and in central and eastern regions indicate less disturbed or regenerating vegetation. In all, the map depicts a landscape with fragmented forests, secondary growth, and agriculture. The highest NDVI, 0.366, indicates limited but ongoing healthy vegetation, shaped by land-use activities such as farming, logging, and settlements, as well as natural recovery. This pattern reflects an intermediate stage of land use, with increasing fragmentation and localised ecological recovery.

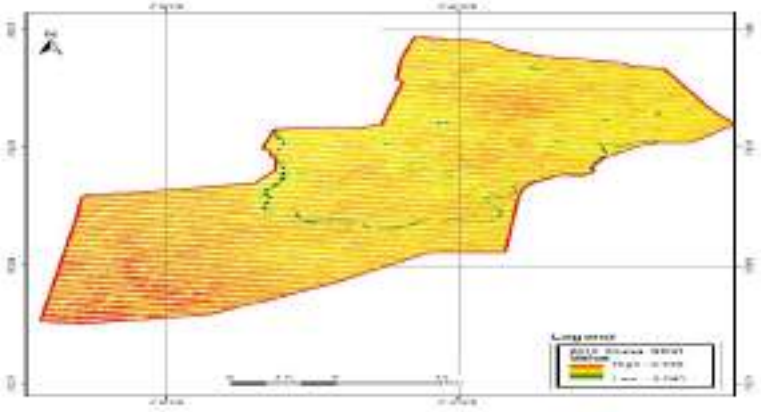


Figure 11: NDVI classes of 2010

NDVI of 2024

The 2024 LULCC map, based on NDVI, displays vegetation density and changes across the area. NDVI values range from -0.001 (indicating sparse cover) to 0.451 (denoting dense vegetation). Orange and reddish shades highlight areas with low to moderate vegetation, whereas green patches indicate healthier, denser growth. The overall pattern reflects notable land-use changes and human activity affecting natural vegetation, with most regions showing low to moderate cover and some localised dense vegetation.

This pattern reveals ongoing ecosystem pressures alongside areas of healthier vegetation. In summary, the NDVI maps for the Etung Local Government Area between 1980 and 2024 reveal a decline from dense rainforest (max NDVI = 0.464) to a more fragmented landscape with low-to-moderate vegetation. This shift is mainly due to human activities such as agriculture, logging, settlement, and other land uses common in the region. Data from 2010 and 2024 show signs of vegetation recovery and patches of healthy growth, attributed to widespread plantations (cocoa, palm, rubber) and plantains intercropped with economic trees. Nevertheless, the overall trend indicates increasing ecosystem stress, decreasing vegetation density, and notable changes in land use.

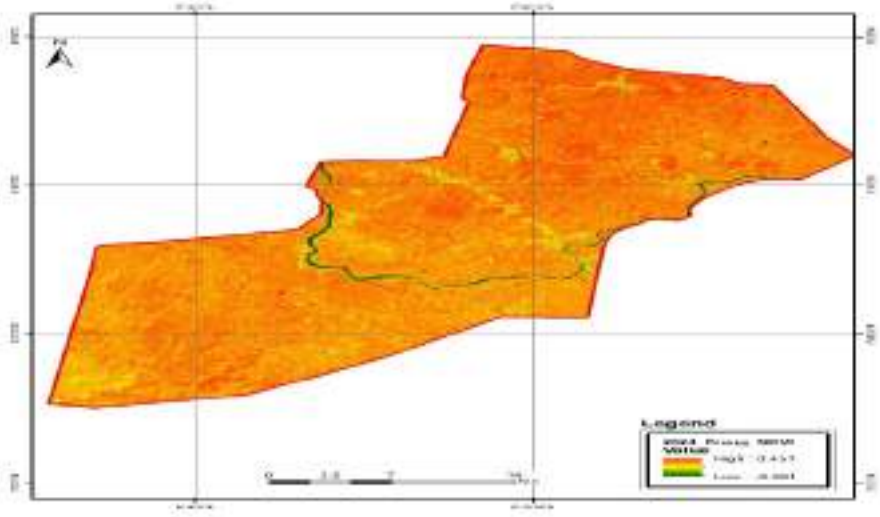


Figure 12: NDVI classes of 2024

Conclusion

The study shows vegetation in Etung LGA has significantly changed over 40 years, with natural flora replaced by urban development and degraded land due to human activities and environmental shifts. Rapid urbanisation, driven by population growth and economic progress, has reduced dense forests to sparser woods, indicating environmental degradation. Farming, logging, and infrastructure activities,which are predominant in the area, have further transformed forests into less vigorous vegetation or urban areas, harming ecological functions such as wildlife habitat and carbon storage.

Water bodies remain stable and support water flow, but nearby degraded land raises concerns about the future. The NDVI mapsreveal a decline from dense rainforest. This shift is mainly due to human activities such as agriculture, logging, settlement, and other land uses common in the region.The study shows a rise in built-up areas and bare

land, causing environmental issues. Urban growth results in habitat loss, increased runoff, and ecosystem fragmentation, harming biodiversity. To address this, green infrastructure standards are essential, like permeable pavements, urban green spaces, and buffer zones to filter pollutants and support wildlife.

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