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Research Article

Impacts of Land Use and Land Cover Changes on Ecosystem Service Values: A Case Study of Lagos Metropolis, Southern Nigeria

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ABSTRACT
Rapid urban expansion and population growth are accelerating the conversion of natural ecosystems into built-up areas, threatening the ecosystem services that support environmental quality and human well-being. Despite these concerns, quantitative assessments linking land use and land cover (LULC) change to ecosystem service values (ESV) remain limited in Lagos, Nigeria's commercial hub and one of Africa's most populous cities. This study evaluated the impacts of LULC change on ESV in Lagos Metropolis between 1984 and 2025 using multi-temporal Landsat and Sentinel-2 imagery. ESV was estimated using the benefit transfer approach with globally established valuation coefficients. The classified LULC maps achieved high overall accuracies of 91% (1984), 92% (2013), and 90% (2025). The results revealed substantial landscape transformation characterized by rapid urban expansion and long-term vegetation loss between 1984 and 2025, despite a modest recovery in forest cover between 2013 and 2025. Built-up areas increased from 16,337 ha in 1984 to 60,018 ha in 2025 (267.3%), while forest and sparse vegetation declined by 60.0% and 63.7%, respectively. Water bodies decreased slightly (6.5%). These changes reduced the total ESV from approximately US$435.57 million in 1984 to US$370.37 million in 2025, representing a net loss of US$65.20 million (14.97%). Water bodies remained the largest contributors to total ecosystem service value, whereas forests experienced the greatest decline in ecosystem service value. These findings demonstrate that accelerated urbanization has altered ecological structure and diminished ecosystem service benefits, highlighting the need for sustainable urban planning and ecosystem conservation in Lagos and other rapidly urbanizing African megacities.

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1 Introduction

An ecosystem is a community of living organisms interacting with each other and with their non-living environment within a specific area (Gómez-Márquez, 2023; Deshmukh, 2024). Ecosystems are essential for human survival and economic development because they support vital life processes through interactions between biotic and abiotic components. These interactions generate a wide range of benefits, known as ecosystem services, which can be considered the direct and indirect benefits that human populations derive from ecosystem functions (Costanza et al., 1997; De Groot et al., 2012). These services include provisioning services such as food and freshwater; regulating services such as climate regulation and flood control; supporting services such as soil formation and nutrient cycling; and cultural services that provide recreational, aesthetic, and spiritual benefits (Costanza et al., 1997; MEA, 2005; Deeksha & Shukla, 2022; Gómez-Márquez, 2023). These services are critical for maintaining environmental sustainability and supporting socio-economic systems (Söderman et al., 2012; Pan et al., 2021; Rahman & Szabó, 2021). Consequently, the degradation of ecosystems represents not only an environmental concern but also a significant threat to long-term sustainable development.

In recent decades, land use and land cover (LULC) transitions have become one of the most significant drivers of ecosystem degradation globally (Foley et al., 2005; Turner et al., 2007; Ellis et al., 2010; Costanza et al., 2014). Rapid urbanization, agricultural expansion, deforestation, and wetland conversion have substantially altered landscape structure and ecological functioning, often resulting in reduced ecosystem service provision (Foley et al., 2005; Costanza et al., 2014; Akber et al., 2018; Hoque et al., 2020; Biedemariam et al., 2022). Urban areas, in particular, experience intense land transformation, where natural and semi-natural land covers are increasingly replaced by impervious surfaces. This transition reduces regulating and supporting services while increasing exposure to environmental risks such as flooding, urban heat stress, and air pollution (Grimm et al., 2008; Seto et al., 2012; Kim et al., 2014; Liu et al., 2018). These changes highlight the need to quantify how LULC transitions influence ecosystem services.

Quantifying the impacts of LULC transitions on ecosystem services is therefore essential for understanding the environmental costs of development. Ecosystem service valuation (ESV) provides a framework for expressing these impacts in economic terms. A key contribution in this area was made by Costanza et al. (1997), who developed a global approach for estimating the monetary value of ecosystem services using biome-based coefficients. Subsequent studies refined these

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methods and demonstrated significant changes in ecosystem service values associated with LULC dynamics (Costanza et al., 2014; Liu et al., 2018).

Two main approaches are commonly used for estimating ESVs: (1) a primary data-based approach, which involves direct estimation using multiple model combinations and environmental valuation techniques; and (2) a LULC proxy-based approach, which is widely applied and quantifies ecosystem service values based on LULC types using the benefit transfer method (Schägner et al., 2013; Jiang et al., 2020; Islam et al., 2025). Due to the high cost, complexity, and data requirements of primary valuation, the LULC-based benefit transfer approach has been widely adopted, particularly in data-scarce regions. This method applies valuation coefficients derived from existing studies to areas with similar ecological characteristics (Plummer, 2009; Tolessa et al., 2017; Msofe et al., 2020; Fakana et al., 2025).

Globally, numerous studies have applied the benefit transfer method to quantify the impacts of LULC change on ESVs (Woldeyohannes et al., 2020; Talukdar et al., 2020; Sannigrahi et al., 2020; Burke et al., 2020). For example, studies in China have reported significant variations in ESVs driven by urban expansion and agricultural activities (Xie et al., 2008; Wu et al., 2024; Liu et al., 2025). Similarly, research in Ethiopia has shown substantial declines in ESVs due to the conversion of forests and wetlands into settlement areas (Gashaw et al., 2021; Admasu et al., 2023). In Nigeria, Arowolo et al. (2018) reported that approximately 70% of ESVs were lost between 2000 and 2010. However, despite these findings, only a few studies have quantitatively assessed the relationship between LULC change and ESVs at the local or metropolitan scale in Nigeria (Ayanlade, 2012; Ayanlade & Proske, 2016; Adedoja et al., 2024). This limitation restricts the ability to fully understand the localized environmental and economic implications of rapid LULC transformation.

Lagos Metropolis represents a critical case for such analysis. As one of the fastest-growing megacities globally, Lagos has experienced rapid population growth, extensive urban expansion, and large-scale conversion of wetlands, forests, and agricultural lands into built-up areas (Koko et al., 2021; Amaechi et al., 2024; Lawanson et al., 2025). These ecosystems historically provided essential services, including flood regulation, coastal protection, carbon sequestration, and climate regulation. However, increasing development pressure has significantly altered the ecological structure of the metropolis. Although previous studies have documented environmental degradation and LULC change in Lagos (Odunuga et al., 2018; Twumasi et al., 2020; Ndimele et al., 2024; Amaechi et al., 2024), the impact of LULC on ESVs remains insufficiently quantified.

This study addresses this gap by integrating remote sensing-based LULC analysis with ESVs using the benefit transfer approach. By combining geospatial analysis with established valuation coefficients, this study provides a comprehensive assessment of ecosystem service dynamics in Lagos Metropolis. The aim of this study is to quantify the impacts of LULC transitions on ESV in Lagos Metropolis, Southern Nigeria. Specifically, the study evaluates spatio-temporal LULC dynamics and estimates corresponding changes in ESVs using the benefit transfer method. The findings provide important insights into the environmental costs of rapid urbanization and offer evidence to support sustainable land-use planning in Lagos and other rapidly developing urban regions.

2 Materials and Methods

2.1 Study Area

Lagos State (Figure 1) is the smallest state in Nigeria by land area and covers about 3,577 square kilometers. It lies between latitudes 6°22′ N and 6°52′ N, and longitudes 2°42′ E and 3°42′ E. The state is one of the most densely populated urban centers in the country, with its population estimated to have increased from about 24.5 million to approximately 29 million (Okimiji et al., 2021). It is also among the fastest-growing megacities globally and is projected to have a population of over 58 million by 2100 (Hoornweg & Pope, 2016). The state comprises 20 local government areas, including Agege, Alimosho, Apapa, Ifako-Ijaye, Ikeja, Kosofe, Mushin, Oshodi-Isolo, Somolu, Eti-Osa, Lagos Island, Lagos Mainland, Surulere, Ojo, Ajeromi-Ifelodun, Amuwo-Odofin, Badagry, Ikorodu, Ibeju-Lekki, and Epe, with Ikeja serving as the capital.

The Lagos Metropolis represents the highly urbanized core of the state and includes key local government areas such as Ikeja, Lagos Island, Lagos Mainland, Surulere, Mushin, Oshodi-Isolo, and Kosofe. These areas constitute the economic and administrative hub of Lagos and are characterized by intense commercial activities, rapid urban expansion, and high population density. This rapid urbanization has led to significant LULC changes, including the conversion of natural ecosystems and agricultural land into built-up areas (Amaechi et al., 2024). Such transformations can have profound implications for ecosystem services, including biodiversity conservation, climate regulation, and flood control. Therefore, the Lagos Metropolis provides a critical setting for examining the impacts of LULC transitions on ecosystem services.

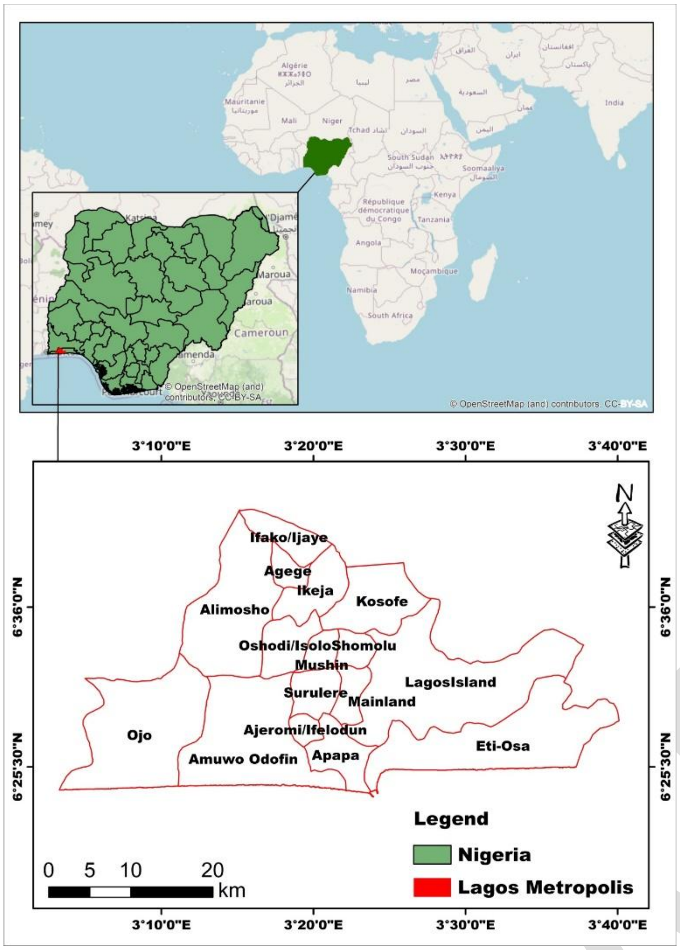

Figure 1: Map of the study area

2.2 Satellite data pre-processing and land use classification

This study utilized Landsat 5 Thematic Mapper (TM) and Landsat 8 Operational Land Imager/Thermal Infrared Sensor (OLI/TIRS) data for the years 1984 and 2013. Sentinel 2 imagery was used for the year 2025. Landsat images were obtained from the United States Geological Survey Earth Explorer platform, while Sentinel 2 imagery was obtained through Google Earth Engine (GEE) (Table 1). To ensure data quality and reliability of the analysis, only images with less than 5% cloud cover were downloaded. The selection of Landsat 5 for 1984, Landsat 8 for 2013, and Sentinel 2 for 2025 was based primarily on the availability of suitable cloud-free imagery. Due to the tropical climatic conditions of Lagos State, persistent cloud contamination frequently limits the usability of satellite data.

Although the study period spans 1984–2025, it was not possible to obtain cloud-free satellite imagery for every year within the study period. Similarly, acquiring images at consistent ten-year intervals was not feasible due to data gaps and cloud interference. Consequently, only years with optimal image clarity and minimal atmospheric distortion were selected for analysis. The three selected observation years are sufficiently spaced to capture major LULC transitions within the study area, including expansion of built-up areas, changes in vegetation cover, bare land, and water bodies. This approach ensures reliable temporal comparison while maintaining methodological consistency and high classification accuracy. Figure 2 shows the research methodology flowchart.

Table 1: Data type and data sources

Data	Source	Resolution (m)	Cloud Cover (%)	Date
Landsat 5 OLI/TIRS	USGS Earth Explorer	30	2	1984/12/18
Landsat 8 OLI/TIRS	USGS Earth Explorer	30	0.1	2013-12-20
Sentinel 2	GEE	10	0	2025/01/17

Figure 2: Research Methodology Flowchart

2.3 Image Pre-processing

To ensure the accuracy and consistency of the LULC classification, standard preprocessing procedures were applied to all satellite images before classification. Landsat 5 TM and Landsat 8 OLI/TIRS images were obtained as Level-2 Surface Reflectance products from the United States Geological Survey Earth Explorer, while the 2025 Sentinel-2 image was acquired as a Level-2A Surface Reflectance product through Google Earth Engine. These products had been radiometrically and atmospherically corrected by the data providers before acquisition. Only near cloud-free images with less than 5% cloud cover were selected to minimize atmospheric interference and improve image quality.

All images were projected to the Universal Transverse Mercator (UTM) coordinate system using the World Geodetic System (WGS) 1984 datum to ensure spatial consistency across the different acquisition years. Each image was subsequently clipped to the Lagos Metropolis boundary using the study area shapefile to remove areas outside the region of interest, thereby reducing processing time and ensuring that subsequent analyses were restricted to the study area. Although the study utilized imagery from different satellite sensors (Landsat 5 TM, Landsat 8 OLI/TIRS, and Sentinel-2), all datasets were processed as surface reflectance imagery and classified independently using the same classification scheme and processing workflow to facilitate consistent temporal comparison. These preprocessing procedures ensured data consistency, minimized geometric and atmospheric distortions, and improved the reliability of the subsequent image classification and change detection analyses.

2.4 Image Classification

ArcGIS 10.7.1 software was utilized for LULC classification of all images. Supervised classification using the Support Vector Machine (SVM) algorithm was employed to classify the satellite imagery into five land use/land cover classes: built-up (impervious surfaces including buildings and asphalt), forest, sparse vegetation, bare land (non-vegetated barren areas), and water bodies. These land-cover classes were identified based on visual interpretation of false-colour and true-colour composites (Figure 3), following standard LULC classification procedures.

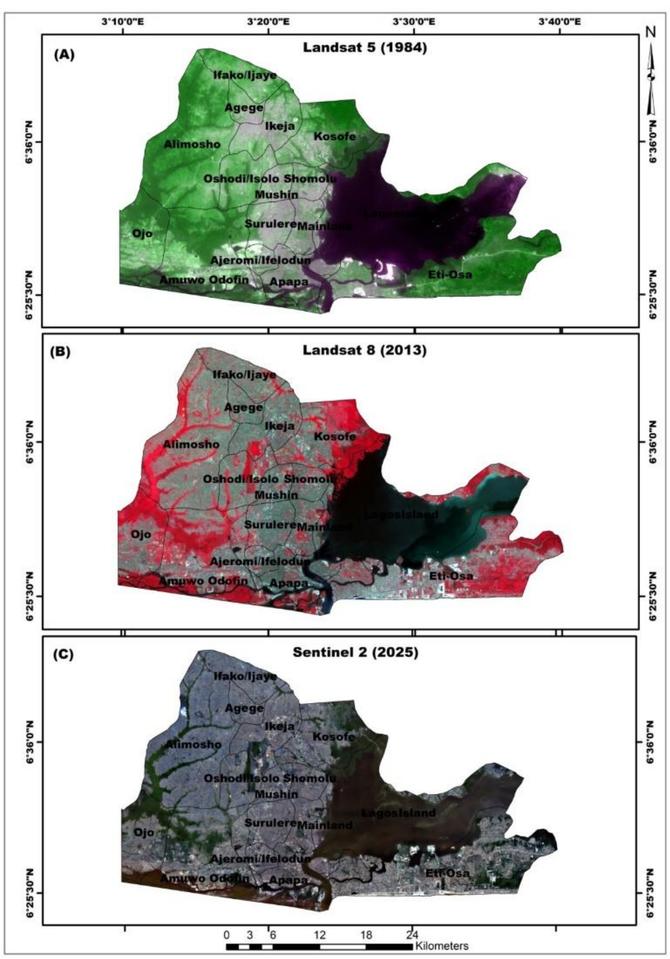

Figure 3: Spatiotemporal satellite images of Lagos Metropolis derived from (A) Landsat 5 (1984), (B) Landsat 8 (2013), and (C) Sentinel-2 (2025). In the true color and false color composites, forest appears in dark green/red, sparse vegetation appears in light green, built-up areas in grey, bare land appears bright white, and water bodies in dark blue to black.

Training samples were manually digitized using the satellite imagery as reference data. A total of 40 training polygons were collected for each image year (1984, 2013, and 2025), with multiple pixels contained within each polygon to adequately capture the spectral variability of the five land-cover classes. The training polygons were selected from homogeneous areas that were representative of each land-cover class and were used to train the SVM classifier. After classification, ArcGIS 10.7.1 was used to mask the study area boundary, perform post-classification processing, generate statistical outputs, develop map layouts, and create visualizations.

2.5 Accuracy Assessment

The accuracy assessment of the classified LULC maps was conducted using ArcGIS and Google Earth Pro. Google Earth Pro provided access to historical high-resolution imagery, which enhanced the validation process. A total of 150 accuracy assessment points were generated in ArcGIS using the Create Accuracy Assessment Points tool, with the equalized stratified random sampling method ensuring balanced distribution across all LULC classes. The generated points were then converted to Keyhole Markup Language (KML) format and opened with Google Earth Pro, where the Show Historical Imagery feature was used to retrieve corresponding satellite imagery. Each assessment point was visually cross-referenced with the historical imagery to verify classification accuracy. After cross-referencing, a confusion matrix was computed in ArcGIS to assess classification performance. The results obtained included the user's accuracy (UA), producer's accuracy (PA), overall accuracy, and Kappa coefficient (KC).

The various accuracy assessments can be calculated using the following formulas:

$$UA = \frac{\text{Number of correctly classified training samples in each class}}{\text{Number of training samples classified to that class}} \quad 1$$

$$PA = \frac{\text{Number of correctly classified training samples in each class}}{\text{Number of training samples in each class}} \quad 2$$

$$OA = \frac{\text{Number of correctly trained samples}}{\text{Number of total samples}} \quad 3$$

$$KC = \frac{\text{Overall Accuracy} - \text{Estimated chance agreement}}{1 - \text{Estimated chance of agreement}} \quad 4$$

Source: Okoduwa and Amaechi (2024)

2.6 Assignment and Estimation of Ecosystem Service Value/Values (ESVs)

The estimation of ESV for the different LULC categories was conducted using the benefit transfer approach. This method involves assigning economic values derived from previously established studies to comparable ecosystems in the study area where primary valuation data are unavailable (Costanza et al., 1997; Fakana et al., 2025). The approach is widely accepted in ecosystem service assessments, particularly in data-scarce regions, due to its practicality and scientific robustness.

In this study, each LULC category was matched with its most representative biome based on global ecosystem classifications. This matching process ensures that the ecological characteristics and service functions of each land cover type are appropriately represented. Specifically, forest land was associated with tropical forest biomes, sparse vegetation was matched with cropland, water bodies were linked with lakes and rivers, while built-up and bare land were assigned urban and ice/rock biomes, respectively (Costanza et al., 1997; Fakana et al., 2025). The valuation coefficients corresponding to these representative biomes were then used as proxies for estimating ecosystem service values in the study area.

Although these biome equivalents are not perfect representations of local land cover types, they provide a scientifically acceptable approximation of ecosystem functions. For instance, sparse vegetation does not possess the same canopy structure as dense forests but still provides ecosystem services, though at lower levels. Built-up and bare land were assigned zero value coefficients due to their minimal contribution to ecosystem service provision, particularly in terms of regulating and supporting services. These assumptions are consistent with established ESV studies (Costanza et al., 1997; Nelson et al., 2010).

The ecosystem service valuation model applied in this study is based on the framework developed by Costanza et al. (1997), which provides standardized coefficients for multiple biomes. Despite criticisms regarding uncertainties associated with global value transfer (Nelson et al., 2010), this method remains widely used and has been refined and validated in subsequent studies (de Groot et al., 2012; Costanza et al., 2014). Furthermore, its application in regional studies has demonstrated its reliability when implemented with methodological transparency.

The total ESV for each study year was calculated using the following expression:

$$\mathrm{ESV} = \sum (\mathrm{A_k} \times \mathrm{VC_k}) \qquad (5)$$

where ESV represents the estimated ESV (US$), A_k is the area (ha) of LULC category k, and VC_k is the value coefficient (US$ ha^{-1} $year^{-1}$) assigned to that category. The change in ESV was obtained by calculating the differences between the estimated values for each year.

To further evaluate temporal dynamics, the percentage change in ESV over time was computed using the following formula:

$$\text{ESV change percentage (\%)} = \frac{\mathrm{ESV_{end\ year}} - \mathrm{ESV_{start\ year}}}{\mathrm{ESV_{start\ year}}} \times 100 \qquad (6)$$

This expression provides a standardized measure for quantifying the rate and direction of ESV changes over time.

The ESV coefficients adopted in this study were derived from the global valuation framework developed by Costanza et al. (1997) and subsequently refined by de Groot et al. (2012) and Costanza et al. (2014). These coefficients have been widely applied in ecosystem service assessments through benefit transfer approaches and have been validated in multiple regional studies (Liu et al., 2025; Gashaw et al., 2021). The selected coefficients represent standardized values expressed in 2007 US$ ha^{-1} $year^{-1}$ and correspond to equivalent biomes.

The assigned coefficients for each LULC category are presented in Table 2. These include forest (2,007 US$ ha^{-1} $year^{-1}$), sparse vegetation (92 US$ ha^{-1} $year^{-1}$), water bodies (14,785 US$ ha^{-1} $year^{-1}$), and zero values for built-up and bare land. The high value assigned to water bodies reflects the significant ecological functions of aquatic and wetland systems, including water regulation, nutrient cycling, and habitat provision, which are consistently recognized as among the most valuable ecosystem services globally (Costanza et al., 1997; de Groot et al., 2012).

Table 2: LULC types, equivalent biomes, and ESV coefficients expressed in 2007 US$ ha^{-1} $year^{-1}$.

Type of LULC	Equivalent Biome	ESV Coefficient (2007 US$ ha^{-1} $year^{-1}$)
Forest	Tropical forests	2,007
Sparse Vegetation	Crop land	92
Bare land	Ice or rock	0
Built-up area	Urban	0
Water bodies	Lakes and rivers	14,785

Source: Adopted from Costanza et al., 1997; Kaganga and Ngogo, 2024

2.7 Coefficient of sensitivity (CS)

Due to uncertainties associated with the use of global value coefficients and the imperfect matching of biomes to local LULC categories, a sensitivity analysis was conducted to evaluate the robustness of the estimated ESV. This is particularly important when applying benefit transfer methods based on coefficients derived from Costanza et al. (1997). The analysis followed the standard economic concept of elasticity, which examines the relationship between the percentage change in ESV and the percentage change in valuation coefficients (Belay et al., 2022; Sorker et al., 2023; Islam et al., 2025).

To implement this, the value coefficients (VC) assigned to each LULC category were adjusted by ±50% (Li et al., 2007; Tolessa et al., 2017; Belay et al., 2022). The resulting changes in total ESV were then used to compute the CS, expressed as:

$$CS = \frac{(ESV_j - ESV_i)/ESV_i}{(VC_{jk} - VC_{ik})/VC_{ik}} \quad (6)$$

where: ESV_i and ESV_j represent the initial and adjusted ESVs, respectively, VC_{ik} and VC_{jk} denote the initial and adjusted VC for LULC type k.

The CS value indicates the responsiveness of ESV to changes in valuation coefficients. A CS greater than 1 implies that ESV is elastic and highly sensitive to coefficient changes, whereas a CS less than 1 indicates inelasticity and suggests that the estimated ESV is relatively robust (Aschonitis et al., 2016; Rahman & Szabó, 2021). Lower CS values, therefore, imply greater reliability of the valuation results despite inherent uncertainties in coefficient selection. This method has been widely used to validate the stability and reasonableness of ESV estimates in similar studies (Tolessa et al., 2017; Akber et al., 2018; Rahman & Szabó, 2021; Sorker et al., 2023).

3 Results

3.1 Accuracy assessment for the LULC classifications

The accuracy assessment results for the LULC classifications for 1984, 2013, and 2025 are presented in Tables 3–5. The class-level accuracies reveal variations in classification accuracy among the different LULC categories. In 1984 (Table 3), forest and water bodies exhibited perfect PA (100.00%). However, lower producer's accuracy was observed for sparse vegetation (78.95%) and bareland (83.33%), suggesting the presence of omission errors, likely due to spectral similarities between these classes. UA for forest (83.33%) and water bodies (83.33%) further indicates some degree of commission error, reflecting misclassification of pixels into these categories.

For the 2013 classification (Table 4), forest and water bodies achieved perfect UA (100.00%), indicating high reliability of classified pixels in these categories. However, bareland recorded the lowest PA (80.65%), while sparse vegetation showed relatively lower UA (86.67%). These results suggest continued confusion between bareland and sparse vegetation classes, which is a common challenge in transitional landscapes where vegetation cover is heterogeneous.

For 2025 (Table 5), classification accuracy varied among the LULC classes. Water bodies achieved the highest UA (97%), while built-up areas recorded perfect PA (100%). Bareland also exhibited high classification accuracy, with a UA of 90% and a PA of 97%. In contrast, sparse vegetation recorded the lowest PA (82%), while built-up areas had the lowest UA (80%), indicating that some misclassification persisted, particularly among spectrally similar or transitional land cover classes.

The overall classification accuracy was 90.67% in 1984, 92.00% in 2013, and 90.00% in 2025 (Tables 3–5). Similarly, the KC was 0.88 in 1984, 0.90 in 2013, and 0.86 in 2025. These values indicate a strong agreement between the classified LULC maps and the reference data. Overall, the classification accuracies for all years fall within the acceptable range.

Table 3: Confusion Matrix and Accuracy Assessment for 1984 LULC Classification

LULC 1984	Forest	Sparse Vegetation	Built-up	Bareland	Water Bodies	Total	UA (%)
Forest	25	5	0	0	0	30	**83.33**
Sparse Vegetation	0	30	0	0	0	30	**100**
Built-up	0	0	26	4	0	30	**86.67**
Bareland	0	0	0	30	0	30	**100**
Water Bodies	0	3	0	2	25	30	**83.33**
Total	25	38	26	36	25	150	
PA (%)	**100**	**78.95**	**100**	**83.33**	**100**		

OA = 90.67%; KC = 0.88

Table 4: Confusion Matrix and Accuracy Assessment for 2013 LULC Classification

LULC 2013	Forest	Sparse Vegetation	Built-up	Bareland	Water Bodies	Total	UA (%)
Forest	30	0	0	0	0	30	**100**
Sparse Vegetation	0	26	0	4	0	30	**86.67**
Built-up	1	0	27	2	0	30	**90**
Bareland	0	5	0	25	0	30	**83.33**
Water Bodies	0	0	0	0	30	30	**100**
Total	31	31	27	31	30	150	
PA (%)	**96.77**	**83.87**	**100**	**80.65**	**100**		

OA = 92.00%; KC = 0.90

Table 5: Confusion Matrix and Sparse Vegetation Accuracy Assessment for 2025 LULC Classification

LULC 2025	Forest	Sparse Vegetation	Built-up	Bareland	Water Bodies	Total	UA (%)
Forest	15	2	0	1	0	18	**83**
Sparse Vegetation	0	18	1	1	0	20	**95**
Built-up	0	1	8	1	0	10	**80**
Bareland	2	1	0	62	5	70	**90**
Water Bodies	0	0	0	0	32	32	**97**
Total	17	22	9	65	37	150	
PA (%)	**88**	**82**	**100**	**97**	**84**		

OA = 90.00%; KC = 0.86

3.2 Temporal Distribution of LULC Classes

The temporal distribution of LULC classes in Lagos Metropolis for the years 1984, 2013, and 2025 is presented in Table 6, while the magnitude of changes across the study periods is summarized in Table 7. In 1984, sparse vegetation (35,311 ha) and forest (32,600 ha) were the dominant land cover types, followed by water bodies (24,815 ha). Built-up areas accounted for 16,337 ha, while bare land occupied the least area (1,242 ha). By 2013, built-up areas had increased to 46,768 ha, becoming the largest land use category. Forest cover declined to 9,845 ha, while sparse vegetation was reduced to 28,770 ha. Water bodies showed a slight decrease to 23,892 ha, and bare land declined marginally to 1,030 ha. In 2025, built-up areas further increased to 60,018 ha, maintaining their dominance. Forest cover rose to 13,021 ha, while sparse vegetation declined to 12,812 ha. Water bodies decreased slightly to 23,202 ha, and bare land increased to 1,252 ha (Table 6).

Between 1984 and 2013, forest cover decreased by 22,755 ha (−69.8%), while sparse vegetation declined by 6,541 ha (−18.5%). Built-up areas increased by 30,431 ha (186.3%). Water bodies recorded a decrease of 927 ha (−3.7%), and bare land declined by 212 ha (−17.1%). From 2013 to 2025, forest cover increased by 3,176 ha (32.3%). Sparse vegetation decreased by 15,958 ha (−55.5%), while built-up areas increased by 13,251 ha (28.3%). Water bodies decreased by 692 ha (−2.9%), and bare land increased by 222 ha (21.6%). Over the entire study period (1984–2025), forest cover declined by 19,579 ha (−60.0%), and sparse vegetation decreased by 22,499 ha (−63.7%). Built-up areas increased by 43,681 ha (267.3%). Water bodies showed a decrease of 1,619 ha (−6.5%), while bare land increased slightly by 9 ha (0.8%) (Table 7).

Table 6: Areal extent of LULC classes in Lagos Metropolis from 1984 - 2025

LULC	**1984**	**2013**	**2025**
	Area (ha)	**Area (ha)**	**Area (ha)**
Forest	32600	9845	13021
Sparse vegetation	35311	28770	12812
Built up	16337	46768	60018
Water bodies	24815	23892	23202
Bareland	1242	1030	1252
Total	110305	110305	110305

Table 7: Changes in LULC area and percentage change in Lagos Metropolis between 1984–2013, 2013–2025, and 1984–2025

LULC	1984-2013		2013-2025		1984-2025	
	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)
Forest	-22755	−69.8	3176	32.3	-19579	−60.0
Sparse vegetation	-6541	−18.5	-15958	−55.5	-22499	−63.7
Built up	30431	186.3	13251	28.3	43681	267.3
Water bodies	-927	−3.7	-692	−2.9	-1619	−6.5
Bare land	-212	−17.1	222	21.6	9	0.8

Figure 4 shows the trends of LULC changes for Lagos Metropolis from 1984 to 2025. From this figure, two major patterns of LULC change are clearly identifiable. Firstly, forest and sparse vegetation exhibit an overall declining trend throughout the study period, indicating a progressive reduction in vegetated surfaces. Although forest shows a slight recovery between 2013 and 2025, its overall extent remains largely lower than in 1984. Similarly, sparse vegetation experiences a consistent decrease, with a particularly sharp decline observed between 2013 and 2025. Water bodies, on the other hand, display a relatively stable but slightly decreasing trend, suggesting minor fluctuations with no substantial long-term gain. Secondly, built-up land shows a pronounced and continuous increase across the study period. The most noticeable growth occurs between 1984 and 2013, followed by a further increase up to 2025. Bare land exhibits minor fluctuations, with a slight decrease between 1984 and 2013 and a marginal increase by 2025, indicating relatively limited change compared to other land cover classes.

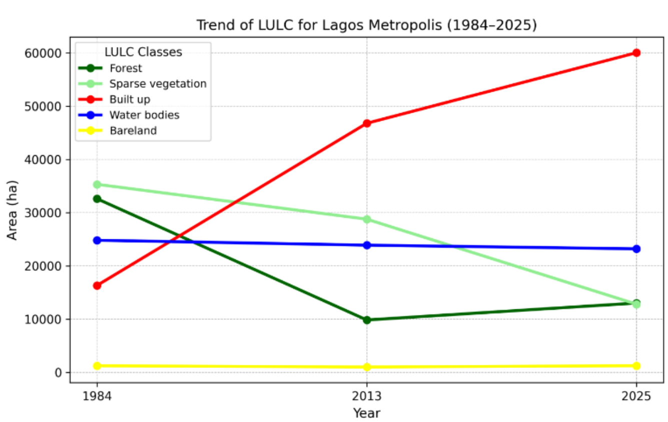

Figure 4: Trend of LULC Change from 1984–2025

3.3 Spatial Patterns of LULC in Lagos Metropolis (1984 - 2025)

In 1984 (Figure 5), built-up areas were largely concentrated in the central and southern parts of the metropolis. High densities of built-up land were observed around areas such as Ikeja, Mushin, Shomolu, Surulere, and Lagos Mainland, forming a relatively compact urban core. Additional built-up clusters were visible around Apapa and parts of Ajeromi/Ifelodun, particularly along the coastal belt. Forest cover was predominantly distributed in the western, northwestern, and eastern parts of the study area. Forest patches were observed in areas such as Alimosho, Ojo, and Eti-Osa, forming continuous green zones around the urban core. Sparse vegetation was widely distributed across the metropolis, especially in transitional zones between forested areas and built-up regions. These areas were prominent in Ifako/Ijaye, Agege, Kosofe, and Oshodi/Isolo, creating a buffer between dense urban and forested landscapes. Water bodies were concentrated mainly in the central and southeastern portions of the study area, dominated by the Lagos Lagoon and associated creeks extending inland. These water features formed a continuous body separating parts of the mainland from Lagos Island and Eti-Osa. Bare land occurred in small, scattered patches with no clear dominant spatial concentration.

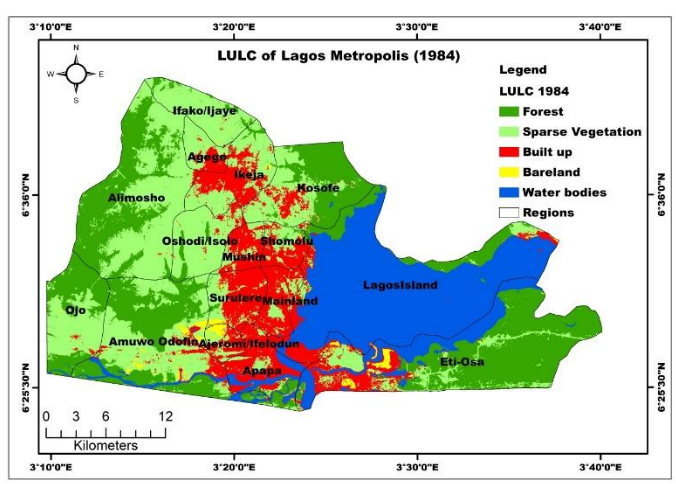

Figure 5: Spatial patterns of LULC in Lagos metropolis (1984)

By 2013 (Figure 6), the spatial pattern of LULC showed a more extensive distribution of built-up areas across the metropolis. Built-up land expanded outward from the previously identified urban core into surrounding regions, covering much of Ikeja, Agege, Ifako/Ijaye, Kosofe, Oshodi/Isolo, Mushin, and Shomolu. The southern coastal corridor, including Apapa and Ajeromi/Ifelodun, also exhibited continuous stretches of built-up areas. In addition, built-up patches became more widespread in Alimosho, Ojo, and parts of Eti-Osa. Forest cover became more fragmented in comparison to 1984, with remaining patches largely confined to the peripheral areas, particularly in Alimosho, Ojo, and the eastern parts of Eti-Osa. Sparse vegetation was still present across the study area but occurred in more scattered and reduced patches. It was mainly observed in the western and northeastern parts, as well as in isolated pockets within the urban region. Water bodies maintained a similar spatial pattern to 1984, remaining concentrated around the Lagos Lagoon and adjoining creeks. The extent and position of these features appeared largely consistent, forming a prominent central water feature. Bare land remained limited in spatial extent and appeared in small, dispersed patches, particularly along the coastal margins and within some inland locations.

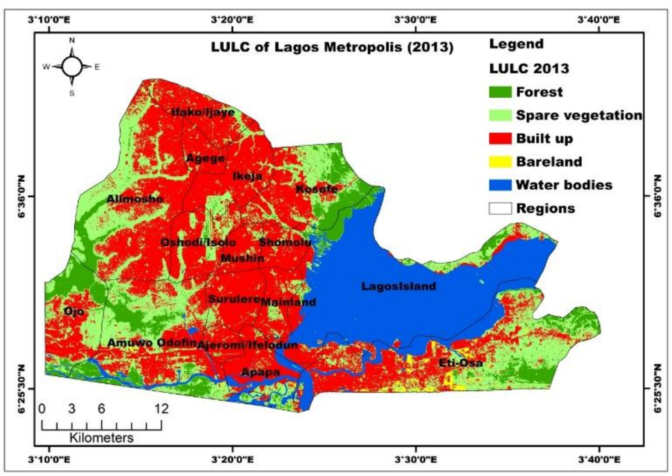

Figure 6: Spatial patterns of LULC in Lagos metropolis (2013)

By 2025 (Figure 7), the spatial patterns of LULC in Lagos Metropolis are characterized by a highly extensive and nearly continuous distribution of built-up areas across the study region. Built-up land dominates the landscape, forming a dense and expansive urban area that extends from the previous urban core into almost all surrounding local government areas. High concentrations of built-up surfaces are evident across Ikeja, Agege, Ifako/Ijaye, Alimosho, Oshodi/Isolo, Mushin, Shomolu, Surulere, and Lagos Mainland, indicating a fully integrated metropolitan structure. The coastal corridor, including Apapa, Ajeromi/Ifelodun, and Eti-Osa, also exhibits intense urbanization, with built-up areas forming continuous stretches along the shoreline and inland corridors.

Forest cover in 2025 is significantly reduced and highly fragmented, occurring mainly in isolated patches rather than continuous zones. The remaining forested areas are largely confined to parts of Alimosho, Ojo, Kosofe, and the eastern fringes of Eti-Osa. These patches appear discontinuous and are interspersed within built-up and sparsely vegetated areas, reflecting substantial land conversion over time. Sparse vegetation persists but is limited to scattered pockets distributed across the metropolis. These areas are mainly observed in transitional zones within Alimosho, Kosofe, and parts of Eti-Osa, suggesting ongoing pressure from urban expansion. Water bodies maintain a stable and prominent spatial presence, continuing to be concentrated around the Lagos Lagoon and its network of creeks. The spatial pattern of these water bodies appears largely unchanged, although increased urban encroachment is evident along their margins. Bare land remains minimal in coverage and is distributed in small, scattered patches, primarily along coastal fringes and in isolated inland locations.

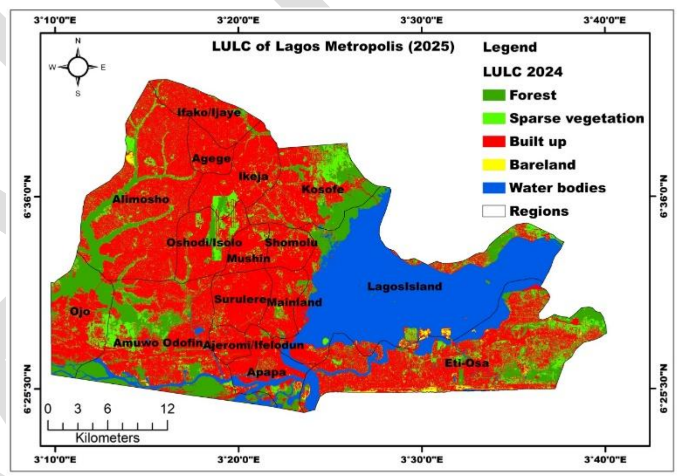

Figure 7: Spatial patterns of LULC in Lagos metropolis (2025)

3.4 Ecosystem Service Value (ESV)

The estimated ESV for the different LULC classes in Lagos Metropolis for 1984, 2013, and 2025 are presented in Tables 8, 9, and 10, while the corresponding absolute and percentage changes are shown in Table 11.

In 1984 (Table 8), the total ESV of the study area was estimated at 435.57 million US$. Water bodies contributed the largest share with an estimated value of 366.89 million US$, accounting for the dominant proportion of the total ESV. Forest areas recorded the second highest contribution with 65.43 million US$, while sparse vegetation contributed a relatively small value of 3.25 million US$. Built-up and bare land classes had no assigned ecosystem service value, and thus contributed zero to the total ESV.

Table 8: Estimated ESV of LULC classes in Lagos Metropolis for 1984

LULC	1984 Area (ha)	ES Coefficient (US$ ha-1/y)	Estimated ESV (Million US$)	
Forest	32600	2007	65,428,200	≈ 65.43
Sparse vegetation	35311	92	3,248,612	≈ 3.25
Built up	16337	0	0	0
Water bodies	24815	14,785	366,889,775	≈ 366.89
Bare land	1242	0	0	0
Total				≈ 435.57

By 2013 (Table 9), the total ESV declined to 375.65 million US$. Water bodies remained the largest contributor, with an estimated value of 353.24 million US$, although this represents a slight decrease compared with 1984. In contrast, forest ESV decreased substantially to 19.76 million US$, reflecting a marked reduction relative to its 1984 value. Sparse vegetation also declined slightly to 2.65 million US$. As in 1984, built-up and bare land classes contributed no measurable ecosystem service value.

Table 9: Estimated ESV of LULC classes in Lagos Metropolis for 2013

LULC	2013 Area (ha)	ES Coefficient (US$ ha-1/y)	Estimated ESV (Million US $)	
Forest	9845	2007	19,758,915	≈ 19.76
Sparse vegetation	28770	92	2,646,840	≈ 2.65
Built up	46768	0	0	0
Water bodies	23892	14,785	353,243,220	≈ 353.24
Bareland	1030	0	0	0
Total				≈ 375.65

In 2025 (Table 10), the total ESV further decreased to 370.37 million US$. Water bodies continued to dominate the total ESV, contributing approximately 343.04 million US$, although this represents a slight decrease compared to 2013. Forest ESV showed a modest increase to 26.13 million US$ relative to 2013, but remained considerably lower than its 1984 value. Sparse vegetation declined further to 1.2 million US$, representing the lowest contribution among the vegetated classes. Built-up and bare land classes were assigned zero ecosystem service values throughout the study period.

Table 10: Estimated ESV of LULC classes in Lagos Metropolis for 2025

LULC	2025 Area (ha)	ES Coefficient (US$ ha-1/y)	Estimated ESV (Million US $)	
Forest	13021	2007	26,133,147	≈ 26.13
Sparse vegetation	12812	92	1,178,704	≈ 1.2
Built up	60018	0	0	0
Water bodies	23202	14,785	343,041,570	≈ 343.04
Bareland	1252	0	0	0
Total				≈ 370.37

The change analysis presented in Table 11 indicates that between 1984 and 2013, the total ESV decreased by 59.92 million US$, representing a 13.76% decline. This reduction was largely driven by a substantial decrease in forest ESV, which declined by 45.67 million US$ (−69.80%). Sparse vegetation also recorded a decline of 0.60 million US$ (−18.46%), while the ESV of water bodies decreased by 13.65 million US$ (−3.72%). Built-up and bare land recorded no changes in ESV because no ecosystem service coefficients were assigned to these land-use classes.

Between 2013 and 2025, the total ESV declined further by 5.28 million US$ (−1.41%). During this period, forest ESV increased by 6.37 million US$ (32.24%), indicating a partial recovery in forest cover. However, this gain was offset by continued declines in sparse vegetation, which decreased by 1.45 million US$ (−54.72%), and water bodies, which declined by 10.20 million US$ (−2.89%).

Over the entire study period (1984–2025), the total ESV decreased by 65.20 million US$, equivalent to a 14.97% reduction. Forest recorded a net decline of 39.30 million US$ (−60.06%), while sparse vegetation decreased by 2.05 million US$ (−63.08%). Water bodies also experienced a net loss of 23.85 million US$ (−6.50%). Overall, the results indicate that the expansion of built-up areas occurred largely at the expense of ecologically valuable land-cover types, resulting in a considerable reduction in the ecosystem services provided by Lagos Metropolis.

Table 11: Absolute and percentage changes in ESV of LULC classes in Lagos Metropolis between 1984–2013, 2013–2025, and 1984–2025

LULC	1984–2013 (Million US$)	Change (%)	2013–2025 (Million US$)	Change (%)	1984–2025 (Million US$)	Change (%)
Forest	-45.67	-69.8	6.37	32.24	-39.3	-60.06
Sparse vegetation	-0.6	-18.46	-1.45	-54.72	-2.05	-63.08
Built-up	0	0.00	0	0.00	0	0.00
Water bodies	-13.65	-3.72	-10.2	-2.89	-23.85	-6.5
Bare land	0	0.00	0	0.00	0	0.00
Total	-59.92	-13.76	-5.28	-1.41	-65.2	-14.97

Figure 8 illustrates the variation in ESV across the major LULC classes in 1984, 2013, and 2025. The figure shows that water bodies consistently contributed the highest ESV throughout the study period, despite a gradual decline from 366.89 million US$ in 1984 to 343.04 million US$ in 2025. In contrast, forest ESV declined sharply between 1984 and 2013 before showing a modest recovery in 2025, while sparse vegetation exhibited a continuous decline throughout the study period.

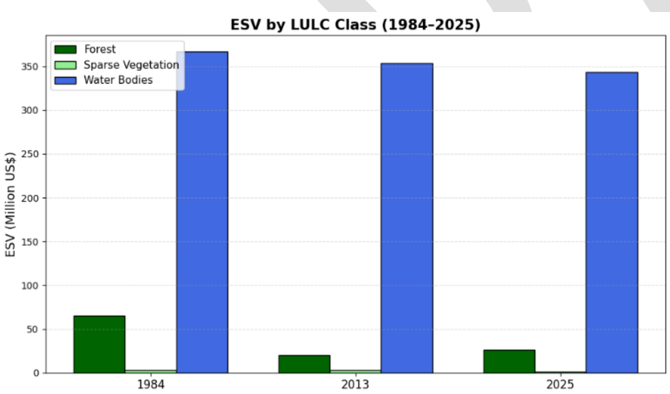

Figure 8: Trend in ESV across the major LULC classes for 1984, 2013, and 2025

3.5 Sensitivity Analysis Results

The results of the sensitivity analysis show that all CS values across the different LULC categories and study years (1984, 2013, and 2025) are less than 1 (Table 12). This indicates that the estimated ESV is inelastic with respect to changes in the valuation coefficients, confirming the robustness and reliability of the results. Among the LULC categories, water bodies exhibited the highest CS values, ranging from 0.90 to 0.94 across the study years. This suggests that ESV is more responsive to changes in the valuation coefficient for water bodies compared to other land cover types. This is expected given that water bodies contribute the largest share to the total ESV in the study area. Forest land showed moderate sensitivity, with CS values ranging from 0.11 to 0.16. This indicates a relatively low but noticeable influence of forest valuation coefficients on total ESV. In contrast, sparse vegetation exhibited very low sensitivity, with CS values close to zero (0.00–0.01), implying minimal impact on overall ESV despite coefficient adjustments. Overall, the low CS values (<1) across all LULC categories confirm that the estimated ESV is not overly dependent on the assigned value coefficients. This suggests that the benefit transfer approach adopted in this study provides reliable and consistent estimates, despite uncertainties associated with coefficient selection and biome matching (Li et al., 2007; Tolessa et al., 2017; Akber et al., 2018; Sorker et al., 2023).

Table 12: Change in total estimated ecosystem services and coefficient of sensitivity (CS) after adjusting ecosystem services valuation coefficients (VC) in Lagos Metropolis

LULC	1984		2013		2025	
	percent	CS	percent	CS	percent	CS
Forest VC ±50%	8.06	0.16	5.26	0.11	7.06	0.14
Sparse vegetation VC ±50%	0.41	0.01	0.35	0.01	0.16	0
Water bodies VC ±50%	45.22	0.9	47.02	0.94	46.32	0.93

4 Discussion

4.1 Land Use Land Cover Change Dynamics

The LULC dynamics observed in Lagos Metropolis between 1984 and 2025 reveal a rapid and large-scale transformation characterized by intense urban expansion and considerable vegetation loss. The increase in built-up area by 267.3%, alongside declines in forest (−60%) and sparse vegetation (−63.7%), indicates an aggressive conversion of natural ecosystems into urban infrastructure. Previous studies in Lagos have reported substantial urban expansion over recent decades (Twumasi et al., 2020; Amaechi et al., 2024). For instance, Koko et al. (2021) documented a significant increase in built-up areas driven by population growth and economic activities, with urban land progressively replacing vegetated surfaces. Similarly, Amaechi et al. (2024) projected continued expansion of built-up areas in Lagos, accompanied by persistent declines in forest and vegetation cover. In a related study, Twumasi et al. (2020) reported extensive degradation of urban green spaces in Lagos, emphasizing that urban growth has significantly reduced vegetative cover and altered landscape structure. Compared to these studies, the 267.3% increase in built-up land observed in this study suggests that urban expansion in Lagos Metropolis is occurring at an accelerated rate, particularly in recent years.

Across Nigeria, similar trends of vegetation loss and urban expansion have been widely reported, although generally at lower magnitudes. For example, Arowolo et al. (2018) found that land-use change in Nigeria resulted in substantial losses of natural ecosystems, with built-up expansion largely occurring at the expense of forests and wetlands. In southwestern Nigeria, Ayanlade (2012) reported significant reductions in vegetation cover due to urbanization and agricultural expansion, highlighting the role of anthropogenic activities in driving landscape transformation. These findings support the results of this study, where vegetation loss is strongly linked to urban growth processes.

The decline in forest cover observed in this study (−60%) is particularly significant and aligns with broader regional trends of deforestation associated with urban expansion. Studies across Nigeria have consistently shown that forested areas are highly vulnerable to conversion into residential and infrastructural land uses (Arowolo et al., 2018; Ayanlade, 2012). However, the magnitude of forest loss in Lagos exceeds many reported cases, suggesting a more intense pressure on ecological systems within rapidly growing metropolitan areas.

The continuous decline in sparse vegetation (−63.7%) further highlights the vulnerability of transitional ecosystems under urban pressure. These land cover types often serve as buffers between dense forest and built-up areas but are typically the first to be converted due to their accessibility. Twumasi et al. (2020) observed similar patterns in Lagos, where green spaces and transitional vegetation were rapidly reduced as urban development expanded into peri-urban zones. This indicates that urban growth in Lagos is not only reducing dense vegetation but also eliminating intermediate ecological zones that support ecosystem stability.

Spatially, the transformation from a relatively compact urban core in 1984 to a highly continuous and expansive built-up landscape by 2025 reflects a classic pattern of urban sprawl. This pattern has been widely documented in Lagos, where urban growth extends outward into surrounding areas, gradually merging peri-urban settlements into a continuous metropolitan region (Koko et al., 2021; Amaechi et al., 2024). Such expansion leads to increased landscape fragmentation, reduced ecological connectivity, and declining environmental resilience.

The slight recovery in forest cover between 2013 and 2025 (+32.3%) is noteworthy. Similar observations have been reported in other studies, where localized increases in vegetation are often associated with secondary regrowth, land abandonment, or small-scale conservation efforts (Amaechi et al., 2024; Okoduwa et al., 2026). However, such recovery is typically fragmented and does not fully restore the ecological functions of original forest systems.

Water bodies in Lagos exhibited relatively minor changes (−6.5%) compared to other land cover classes. This is consistent with findings that aquatic systems are less frequently converted than terrestrial ecosystems (Costanza et al., 1997; Hassan et al., 2016; Idowu & Zhou, 2021). However, studies in Lagos indicate that urban encroachment along water bodies is increasing, leading to concerns about declining water quality, wetland degradation, and increased flood risk (Ayanlade & Proske, 2016; Ndimele et al., 2024). This suggests that even small changes in water extent may have significant implications for ecosystem functioning and urban sustainability.

4.2 Assessment of Ecosystem Service Values (ESV)

The assessment of ESV in Lagos Metropolis reveals a substantial decline of 65.20 million US$ (14.97%) between 1984 and 2025, reflecting the ecological cost of LULC transformation. This decline is primarily driven by the conversion of forest and vegetated land into built-up areas, a pattern that is widely reported across both regional and global studies (Rahman & Szabó, 2021; Xiong et al., 2022; Kaganga & Ngogo, 2024; Alegbeleye et al., 2025).

Comparable studies confirm that urban expansion is a major driver of ESV decline. For instance, Xiong et al. (2022) reported a reduction of 7.41 million US$ in total

ESV between 2009 and 2018, mainly due to the conversion of cropland into construction land. Similarly, Li et al. (2007) observed that total ESV declined by 10.6 million US$, 6.7 million US$, 6.8 million US$, and 19.4 million US$ across successive periods, largely attributed to the conversion of forest land to other uses. These findings reinforce the belief that forest loss remains a dominant driver of ecosystem service decline, consistent with the Lagos results.

At the national scale, Alegbeleye et al. (2025) provide strong supporting evidence for widespread ecosystem degradation across Nigeria. Their study reported a decline in major ecological land cover types, including grassland/shrubland/rangeland (−12.8%), forest (−5.7%), and wetlands (−4.1%), alongside a total ESV loss of approximately 20 billion US$ over two decades. Regionally, ESV declined across most geopolitical zones, including the South-West (−2.91%), where Lagos is located. These findings are highly significant, as they demonstrate that the ESV decline observed in Lagos is not an isolated phenomenon but part of a broader national trend driven by land-use change and urban expansion. However, the magnitude of decline in Lagos suggests a more localized and intensified form of ecosystem degradation, particularly within rapidly urbanizing metropolitan areas.

The observed decline in ecosystem service values is consistent with findings from northern Nigeria. For instance, Ayeni et al. (2019) reported that the Hadejia-Nguru Wetlands in northern Nigeria provide important provisioning ecosystem services, including fisheries, farming, fuelwood, and non-timber forest products that directly support local livelihoods. They further demonstrated that degradation of wetland ecosystems through human activities reduced ecosystem benefits and increased pressure on natural resources. Although the Hadejia-Nguru Wetlands represent a rural wetland ecosystem while Lagos Metropolis is a rapidly urbanizing coastal environment, both studies demonstrate that land-use change and ecosystem degradation diminish the capacity of ecosystems to provide valuable services. These findings suggest that conserving natural ecosystems is essential for sustaining ecosystem services across different ecological regions of Nigeria.

The dominant contribution of forest ecosystems to total ESV, and their subsequent decline, is also consistent with global findings. In Ethiopia, Tolessa et al. (2017) reported a reduction in total ESV from 9.06 million US$ in 1973 to 5.37 million US$ in 2015, representing a 40.7% decline. Importantly, forest ecosystems maintained the highest contribution to total ESV despite their reduction in extent. A similar trend is observed in Lagos, where forest loss (−39.30 million US$) represents the largest component of total ESV decline, highlighting the critical role of forest ecosystems in sustaining ecological and economic functions.

Urban-based studies further illustrate the impact of LULC change on ecosystem services. In Dhaka, Bangladesh, Rahman and Szabó (2021) reported a decline in total ESV from 142.72 million US$ in 1990 to 57.72 million US$ in 2020, representing a loss of over 85 million US$. The study emphasized that water bodies contributed the largest share of ESV, followed by forest and vegetation, while built-up areas contributed nothing. This pattern closely mirrors the Lagos case, where water bodies account for over 85% of total ESV, and built-up areas contribute no ecosystem service value. Further supporting evidence is provided by Islam et al. (2025), who reported that built-up areas experienced the most significant increase in land-use change.

At a more localized Nigerian scale, Temitope et al. (2025) provide a detailed case study from Kuje, Abuja, which further reinforces these dynamics. Their study shows cultivated land ESV increased from 49,830.24 to 107,926.05 (US$ ha^{-1} yr^{-1}) due to intensified agricultural activities. However, these gains were accompanied by a dramatic decline in forest and vegetation ESV, with forest values dropping from 333,079.84 to 2,787.89 (US$ ha^{-1} yr^{-1}) and vegetation from 1,722,931.73 to 898,293.49 (US$ ha^{-1} yr^{-1}). This represents a severe loss of high-value ecosystem services, particularly those related to carbon sequestration, climate regulation, and biodiversity conservation. These findings strongly support the Lagos results, demonstrating that urban and agricultural expansion often occur at the expense of ecologically valuable land covers, leading to long-term sustainability challenges. Similarly, Kaganga and Ngogo (2024) reported a total ESV decline of 14.61 million US$ (24%) between 1999 and 2019, driven primarily by reductions in vegetated and agricultural land. Their findings showed that vegetated land alone lost 10.47 million US$ (49%), while water bodies increased their contribution by 47%, reflecting a compensatory dynamic. This pattern is consistent with Lagos, where water bodies remain the dominant contributor to ESV despite overall ecosystem degradation.

From a comparative perspective, the magnitude of ESV decline in Lagos (65.20 million US$) is higher than that reported in several regional case studies, such as Xiong et al. (2022) (7.41 million US$) and Tolessa et al. (2017) (3.69 million US$), but lower than large metropolitan cases such as Dhaka (>85 million US$ loss) (Rahman & Szabó, 2021). However, when considered alongside national-scale losses such as the 20 billion US$ decline reported by Alegbeleye et al. (2025), it becomes evident that Lagos represents a high-intensity local manifestation of a broader national and global trend of ecosystem service degradation.

5 Conclusion

This study assesses the impact of land use and land cover (LULC) change on ecosystem service values (ESV) in Lagos Metropolis between 1984 and 2025, providing empirical evidence in monetary terms of the ecological consequences of rapid urban expansion. The results reveal a persistent transition from vegetation-dominated landscapes to built-up environments, with urban growth occurring primarily at the expense of forest and sparse vegetation, thereby driving landscape fragmentation and a decline in ESV. Total ESV decreased from approximately US$435.57 million in 1984 to US$370.37 million in 2025, representing a net loss of US$65.20 million (14.97%) over four decades. Water bodies remained the dominant contributors to ecosystem services throughout the study period. In contrast, forest ecosystems exhibited the most significant proportional decline in ESV, highlighting their critical role in maintaining ecological stability.

This reduction reflects a loss of natural capital that underpins key functions such as climate regulation, flood mitigation, environmental quality, and human well-being. By integrating LULC change with ESV, the study provides quantitative evidence linking land transformation to environmental economic loss in rapidly urbanizing regions where such assessments remain limited. However, the application of the benefit transfer method introduces uncertainties, as it assumes spatial uniformity of ecosystem service values within LULC classes and relies on globally derived valuation coefficients that may not fully capture local ecological variability. In addition, the use of land cover as a proxy for ecosystem services may overlook differences in ecosystem condition and service intensity. Future research should therefore prioritize the development of locally calibrated ecosystem service valuation coefficients for Nigeria and comparable African environments through primary valuation studies and regional meta-analyses. Overall, the findings demonstrate that accelerated urbanization in the Lagos Metropolis has led to sustained declines in ecosystem service values over the past four decades, underscoring the urgent need to integrate ecosystem service valuation into land-use planning and urban management frameworks as a decision-support tool to balance development with long-term ecological sustainability.

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