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PROJECTED ECOSYSTEM SERVICE DYNAMICS: A PREDICTIVE MODEL FOR ASSESSING CHANGES IN ECOSYSTEM SERVICE VALUES IN LAGOS COASTAL ZONES

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ABSTRACT

Global human activities are placing unprecedented pressures on ecosystems, particularly in vulnerable coastal areas, where the degradation of crucial ecosystem services threatens both environmental sustainability and the socio-economic security of local communities. This study aims to inform sustainable land use planning, coastal management strategies, and conservation policies to safeguard the long-term resilience of Lagos vulnerable coastal ecosystems. To achieve this, the research employs artificial neural networks and Landsat imagery spanning three decades (2003–2023), combined with the value transfer method, to project the future dynamics and economic implications of ecosystem services in Lagos' coastal zones by 2050. Findings reveal a significant overall decline in total ecosystem service value, amounting to $2,971.60 million, with a net loss of $835.34 million (₦65.84 billion). Wetlands experienced the most dramatic decline, losing $1,141.26 million (₦1.87 trillion), underscoring the heavy economic cost of environmental degradation. Conversely, freshwater swamps experienced the most significant gain, increasing by $499.66 million (₦817.29 billion), highlighting their growing role in sustaining ecosystem value. These Findings emphasize the critical economic importance of maintaining ecosystem services, as their degradation carries severe financial implications for livelihoods, biodiversity, and long-term coastal resilience. By providing a predictive framework, this research offers valuable insights for decision-makers and policymakers, enabling proactive strategies to mitigate further ecosystem losses. The approach can be adapted to other rapidly urbanizing coastal regions facing similar environmental and economic challenges.

Keywords: Coastal communities, Coastal management, Ecosystem dynamics, Environmental sustainability.

INTRODUCTION

Ecosystems presents complex dynamic systems where biotic and abiotic components interact in multifaceted ways (Lakshmi, 2021) Ecosystems services (ES) are the conditions and processes through which natural ecosystems and the species that make them up sustain and fulfil human life. They are ecological traits, functions, or processes that directly or indirectly contribute to human well-being. These services are evident as ecological traits, functions, or processes that contribute, either directly or indirectly, to human well-being (Costanza *et al.*, 1997). Africa, home to more than 1.5 billion people with an annual population growth rate of 2.3% (Codur, 2021), houses some of the world's most diverse and valuable ecosystems. Among these, the Congo Basin Forest demonstrates this ecological wealth, storing over 60 billion metric tons of carbon exceeding the combined carbon storage capacity of all Amazon and Asian tropical forests (Wangai *et al.*, 2016). These ecosystems play a crucial role in supporting human life and societal development by providing essential services such as climate regulation, water purification, biodiversity conservation, and livelihood support for millions of people.

However, the continent's ecosystems face severe degradation, leading to biodiversity loss and disruption of crucial ecosystem functions and services. This decline generated from multiple anthropogenic stressors, including rapid population growth, high demands for food, water, and energy, climate change impacts, and overuse of resource (Jamouli and Allali, 2020). While ecosystems provide invaluable services such as food production, hydrological regulation, climate control, biodiversity maintenance, gas regulation, waste treatment, erosion control, seafood provision, timber resources, and recreational opportunities, these services are increasingly compromised by land-use/land-cover (LULC) dynamics.

Through human history, land alteration for obtaining food, fiber, fuel, and other resources remains a constant practice. Yet, current human activities pose unprecedented pressures to the natural environment, resulting in habitat destruction, biodiversity loss, and the proliferation of invasive species (Okorondu *et al.*, 2022). The preservation of healthy ecosystems remains crucial for maintaining essential services, including oxygen production, that are fundamental to human survival (Hernández - Blanco *et al.*, 2022). This delicate balance between human development and ecosystem preservation presents one of the most significant challenges in modern environmental management. The alteration of earth's surface by human activities has deepened dramatically in recent decades, with the pace, extent, and intensity of dynamics far exceeding historical patterns (Ellis and Pontius, 2007). These anthropogenic alterations have profoundly impacted the natural environment, creating distinct and observable patterns in land use over time (Aminigbo, 2021; Fashae *et al.*, 2022). This rapid transformation presents significant challenges for achieving the Sustainable Development Goals (SDGs) established in the UN 2030 Agenda for Sustainable Development (Whittingham *et al.*, 2023).

In Nigeria, a country predominantly vulnerable to climate change and frequently affected by flooding, emphasizes the critical importance of prioritizing ecosystem conservation in future land-use management strategies (Arowolo *et al.*, 2018). The situation is particularly worrisome in coastal areas, where rising human activities exert serious pressure on marine and coastal ecosystems. Following a global trend, land reclamation from the sea has become a common solution to address land shortages (Wang *et al.*, 2014). The Nigerian context reflects these global patterns, with land-use/land-cover undergoing dramatic changes driven largely by rapid population growth. The impact has been severe, with approximately 70% of the country's ecosystem service functions experiencing degradation (Arowolo *et al.*, 2018). The monitoring and assessment of natural resources, land cover dynamics, and Earth's surface changes have been significantly enhanced by satellite imagery applications. Geographic Information Systems (GIS) have emerged as an indispensable tool for rapid and informed decision-making, particularly in addressing challenges that directly impact human livelihoods (Nizamani *et al.*, 2023). Investments in satellite ground stations and GIS technology continue to yield substantial benefits, both in the present and for future resource management. This technological advancement is especially crucial for studying Lagos' coastal zones, which have undergone significant land use and land cover transformations in recent years (Fashae *et al.*, 2022). Among the available satellite datasets, Landsat imagery stands out as the most widely used and accessible option for ecosystem monitoring. Its extensive historical archive, dating back to 1972 (Gopalakrishnan *et al.*, 2021), provides an invaluable resource for tracking long-term environmental changes. Landsat offers free and consistent data, making it a cost-effective solution for researchers, particularly in regions where funding for high-resolution satellite imagery is limited.

The Lagos metropolis coastal area serves as a prime example of these challenges, where increasing human-induced evolving activities continue to generate social and environmental challenges that have yet to receive adequate attention (Adegboyega *et al.*, 2019). The coastal regions of Lagos State stand at a critical crossroads where environmental sustainability meets human development needs (Merem *et al.*, 2018). These areas, vital for both their ecological functions and human livelihoods, face mounting pressures from various factors that threaten their long-term sustainability (Ndimele *et al.*, 2024). The current challenges began from a complex interplay of insufficient governance mechanisms and limited environmental awareness among coastal inhabitants, leading to unintended but significant ecosystem degradation (Fakoya *et al.*, 2022). The severity of this matter becomes more apparent when considering the future impacts. As these ecosystems continue to deteriorate, both local dwellers and government organizations face potentially serious consequences (Sogbanmu *et al.*, 2021). The current situation suggests a future where crucial ecosystem services might be compromised, stressing not only environmental stability but also the socio-economic state of coastal communities. Current research on ecosystem services in Nigeria's coastal areas is limited by its broad scope, isolated focus, and potentially biased methodologies. Studies have either provided nationwide overviews (Arowolo *et al.*, 2019) or concentrated on single local governments (Adegboyega *et al.*, 2019) or specific ecosystems (Israel, 2021). This study seeks to address this gap by looking into a thorough baseline assessment of current ecosystem services through its valuation and developing predictive models for future ecosystem states.

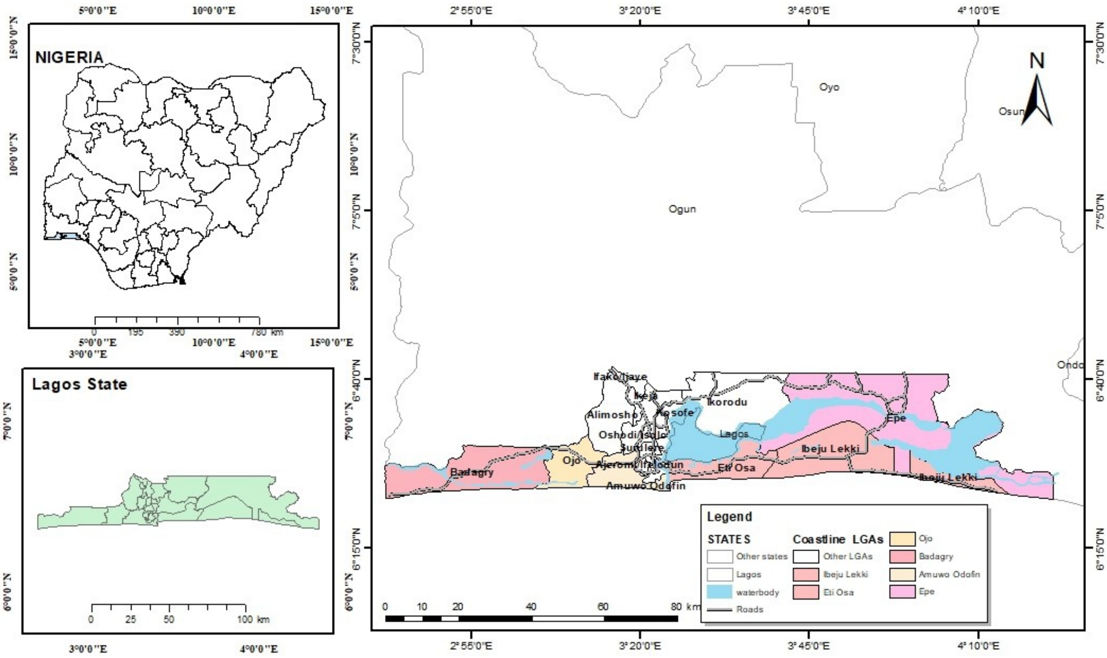

Figure 1: Study Area Map

Description of Study Area

Lagos, the economic hub of Nigeria, is a coastal city characterized by its low-lying topography and abundant ecological assets, including lagoons and wetlands. The Lagos Lagoons, the largest of which spans 646 square kilometres, are entirely surrounded by wetlands (Obiefuna *et al.*, 2017). For the purpose of this study, the six local government areas (LGAs) in Lagos that share boundaries with the coast (Ibeju-Lekki, Eti-Osa, Ojo, Lagos Island, Epe and Badagry LGAs), were considered. This study employed a comprehensive approach to analyze land use dynamics and predict future ecosystem service scenarios in the study area, utilizing multiple temporal datasets and advanced geospatial analysis techniques.

Data Acquisition and Processing

The analysis focused on land use dynamics over three decades using 30m resolution Landsat imagery from 2003, 2013, and 2023. Through supervised classification with post-processing, eight distinct land use classes were identified: Bare surface, Built-up areas, Fresh water swamp, Cultivated land, Mangrove Forest, Shrubland, Water body and Wetland.

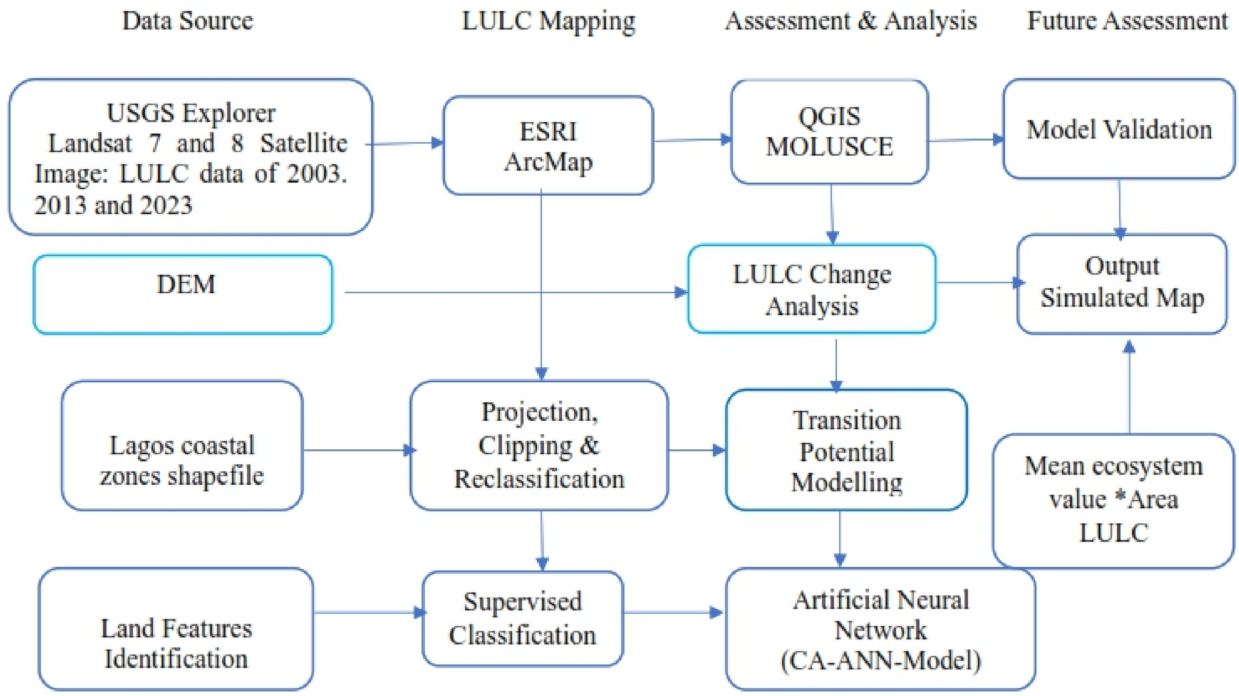

Figure 2: Work flow for prediction of LULC for 2050

Modelling and Prediction of 2050 Ecosystem Services:

The future ecosystem service scenario for 2050 was modelled using the Artificial Neural Network (ANN) approach, implemented through the Modules for Land-Use Change Simulation (MOLUSCE) plugin in QGIS. This plugin, developed by Asia Air Survey, integrates several sophisticated algorithms for land use change analysis, including: Cross-tabulation techniques, Artificial Neural Networks (ANNs), Multi-criteria evaluation (MCE), Weights of evidence (WoE), Logistic regression (LR) and Monte Carlo cellular automata (CA) models for the spatiotemporal transition analysis and future predictions, the CA-ANN technique was employed using : Landsat 7 and Landsat 8 data (2003-2023) at ten-year intervals with Spatial attributes including Digital elevation model (DEM), Slope characteristics and Proximity to roads. Furthermore the method proposed by (De Groot *et al*., 2012), value transfer method See (Table 1) was used to value the projected year.

Model Validation

1[st] Validation process was generated on the Artificial neural network curve generated from QGIS with Kappa coefficient 0.71782 which is considered accurate (Shivakumar and Nagaraja, 2021). Furthermore, model validation through comparison of projected 2023 land use (based on 2003-2013 data) and the Actual 2023 land use classification utilized data from 2013 was used to model land use for the year 2023. Then, the resulting modelled data was compared with the actual land use classification observed in 2023. (Gautama *et* Data source; *Muhammad et al., 2022).*

Ecosystem Service Valuation

The projected land use changes were translated into ecosystem service values by multiplying the simulated land use areas with mean ecosystem values derived from Value transfer method curled from (Costanza, 2000; De Groot *et al*., 2012). This approach enabled the estimation of future ecosystem service scenarios for 2050.

RESULTS AND DISCUSSION

The landuse/landcover analysis report provides valuable insights into the distribution and composition of different land cover types within the study area (Figure 3). Through the image classification process, landuse and landcover datasets were generated, resulting in the creation of a detailed landuse/landcover map for the year 2003. The Landuse/Landcover map visually illustrates the interplay between fresh water swamp, shrubland, built-up areas, coastal and inland water systems within the study area. Moreover, the associated statistics for LULC in 2003 highlighted the abundance and percentage cover of each landcover type. The analysis revealed that the study area is predominantly composed of fresh water swamp and shrubland, accounting for 28.22% and 26.62% of the landcover respectively (Table 2). Additionally, the study area also exhibits an extensive waterbody coverage of approximately 24.62%, while the built-up area covers 11.54% of the total land area (Table 2). Furthermore, the analysis also identified wetland areas along the drainage system, which have a percentage cover of 7.87%. Other landuse/landcover types in the study area include Mangrove Forest, baresurface, and cultivated land. The landuse and landcover datasets produced by the classification method used in this study are precise and comprehensive. The Quantity allocation disagreement (QADI) index provides a better assessment of classification accuracy compared to traditional metrics like Kappa, by accounting for both quantity and allocation disagreements (Feizizadeh *et al.*, 2022).

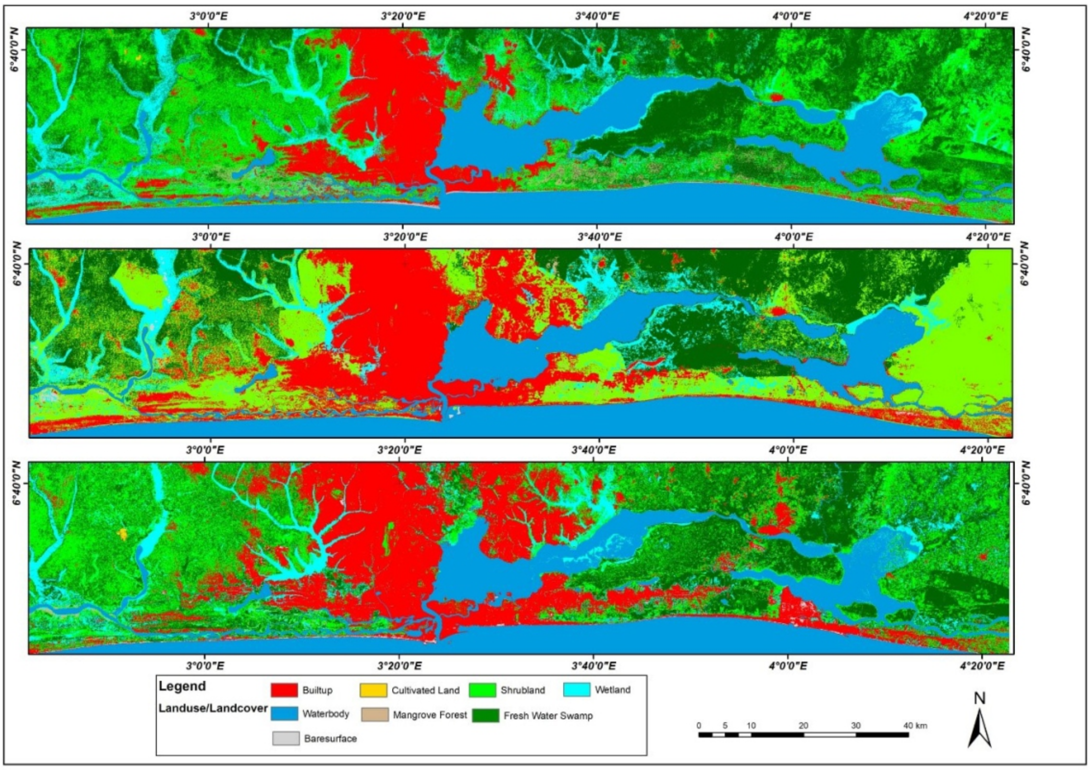

Figure 3: Land use/land cover for 2003, 2013 and 2023.

Based on the strong QADI index value, it is safe to consider this classification to be accurate because of its obtained QADI value of 0.05341, Indicating that the accuracy of the classification is high.

The landuse and Landcover datasets for the year 2013 are shown in (figure 3) while the associated statistics is presented in (Table 3.) The analysis revealed that the study area predominantly summarizes the land cover composition in the study area. revealing dominant classes such as Builtup (18.70%), Shrubland (26.44%), and Fresh Water Swamp (25.58%), while also highlighting minor classes like Wetland, Mangrove Forest, and Baresurface, and cultivated land, with 4.93%, 0.39%, 0.37%, 0.05% representing the total area respectively. The classification process utilized in this study has resulted in the generation of accurate and detailed landuse and landcover datasets with classification accuracy QADI value of 0.14251.

Table 2: Statistics of the Landuse and Landcover Datasets for the study area in year 2003

Class	Pixel count	Area (sqkm)	Percent Cover (%)
Builtup	997059	897.35	11.54
Baresurface	32383	29.14	0.37
Wetland	680454	612.41	7.87
Waterbody	2128182	1915.36	24.62
Mangrove Forest	63752	57.38	0.74
Shrubland	2300971	2070.87	26.62
Fresh Water Swamp	2439343	2195.41	28.22
Cultivated Land	1580	1.42	0.02

Author's Field Survey, 2024.

The landuse and landcover datasets for the year 2023 are shown in figure 3 while the associated statistics is presented in Table 4 The analysis revealed that the study area is predominantly composed of Shrubland, Fresh water swamp, Waterbody and Builtup accounting for 24.71%, 23.72%, 23.47%, 21.12% of the total area respectively. The dataset also identified wetland areas along the drainage system, which have a percentage cover of 6.31%. Other landuse/landcover types in the study area include Mangrove Forest, baresurface, and cultivated Land with 0.24%, 0.34% and 0.1% of the total area. This study's classification procedure produced a precise and comprehensive landuse and landcover accuracy QADI value of 0.10571.

Table 3: Statistics of the Landuse and Landcover Datasets for the study area in year 2013

Class	Pixel count	Area (sqkm)	Percent Cover (%)
Built-up	1616596	1454.94	18.70
Bare surface	31949	28.75	0.37
Wetland	425979	383.38	4.93
Waterbody	2034774	1831.30	23.54
Mangrove Forest	33374	30.04	0.39
Shrubland	2285743	2057.17	26.44
FreshWater Swamp	2211502	1990.35	25.58
Cultivated Land	4035	3.63	0.05

Author's Field Survey, 2024.

Table 4: Statistics of the Landuse and Landcover Datasets for the Study Area in year 2023

Class	Pixel count	Area (sqkm)	Percent Cover (%)
Builtup	1823506	1641.16	21.12
Baresurface	29216	26.29	0.34
Wetland	544482	490.03	6.31
Waterbody	2026989	1824.29	23.47
Mangrove Forest	20399	18.36	0.24
Shrubland	2133878	1920.49	24.71
Fresh Water Swamp	2048590	1843.73	23.72
Cultivated Land	8226	7.4	0.1

Author's Field Survey, 2024.

Future Prospect of Ecosystem Services in the Study Area

The projected Landuse/Landcover (LULC) for year 2050 using the Artificial neural network based cellular automation (CA-ANN) multilayer perception technique which is included in the MOLUSCE plugin is presented in this section.

The projected landuse and landcover map for 2050 is shown in Figure 4 and the associated statistic on table 5. The dataset show that Builtup areas covers about 26.95% of the total area understudy and an area of 2118.1 sq.km by the year 2050. Bare-surface comprises a mere 0.01% of the landscape covering an area of 1.27 sqkm by 2050. Wetlands account for 0.58% of the total area having a size of 45.65 sqkm by 2050, while waterbody represent 23.84% of the landscape (1873.68 sqkm).

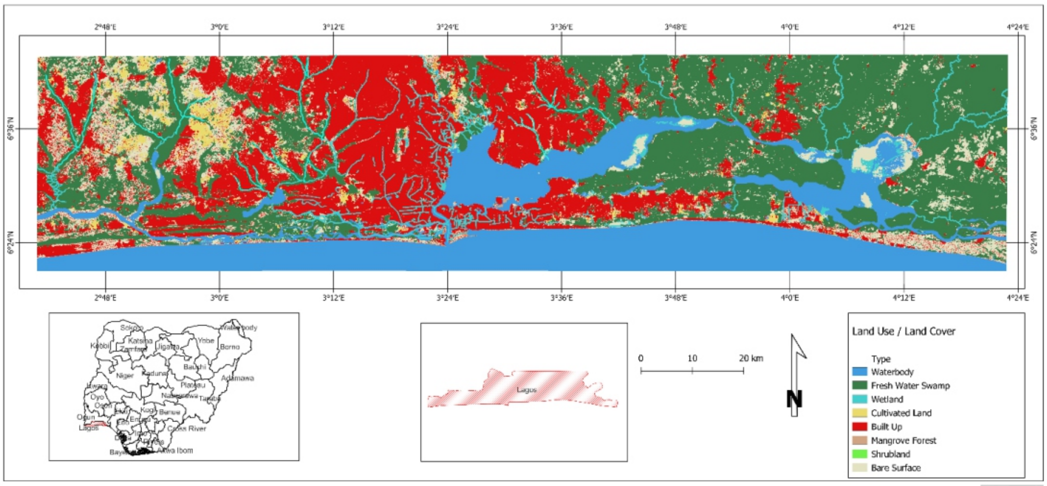

Figure 4: LULC map for the predicted 2050

Mangrove, Shrubland and Forest make up 0.17%, 10.89% and 35.54% respectively. Lastly, cultivation now covers 2.0% of the total area representing an area of 1.42 sqkm. The validation process for the land use change model will enable the generation and authentication of ecosystem future prospect as a measure of the model's accuracy.

Table 5: Statistics of the Projected Landuse and Landcover Datasets for 2050

Class	Pixel count	Area (sqkm)	Percent Cover (%)
Built up	2507846	2118.1	26.95
Bare surface	28758	1.27	0.016
Wetland	481443	45.65	0.58
Waterbody	1925815	1873.68	23.84
Mangrove forest	21649	13.93	0.177
Shrubland	1910990	855.59	10.89
Fresh water swamp	1751462	2793.02	35.54
Cultivated land	7210	157.27	2.0

The projected study for the year 2050 reveals substantial transformations across various land use categories in the zones. The analysis displays notable increment in several land types present in the study area, with freshwater swamp experiencing the most substantial growth of 949.29sqkm, representing a 51.48% gain (Table 5). Built-up areas also expanded significantly, growing by 476.94 sqkm, which amounts to a 29.06% rise. (Table 5) Cultivated land witnessed a remarkable expansion, increasing by 149.87sqkm, equating to an exceptional 2,025.2% growth. Water bodies showed a moderate increase of 49.39sqkm, corresponding to a 2.70% growth (Table 6) and (Figure 5)

In contrast, some land categories witnessed notable reductions. Bare surface area decreased dramatically by 25.02 sqkm, representing a 95.16% loss. Wetlands also experienced a substantial decline, reducing by 444.38 sqkm, which equates to a 90.68% decrease (Table 6). These significant reductions in bare surface and wetland areas suggest a major transformation of these landscapes, likely converting into other land use types.

Table 6: Landuse and Landcover dynamics between year 2023 and 2050

Class	2023 Area (sqkm)	2050 Area (sqkm)	Change	Percent Change (%)
Builtup	1641.16	2118.10	476.94	29.06
Baresurface	26.29	1.27	-25.02	-95.16
Wetland	490.03	45.65	-444.38	-90.68
Waterbody	1824.29	1873.68	49.39	2.70
Mangrove forest	18.36	13.93	-4.43	-24.13
Shrubland	1920.49	855.59	-1064.5	-0.55
Freshwater swamp	1843.73	2793.02	949.29	51.48
Cultivated Land	7.40	157.27	149.87	2025.20

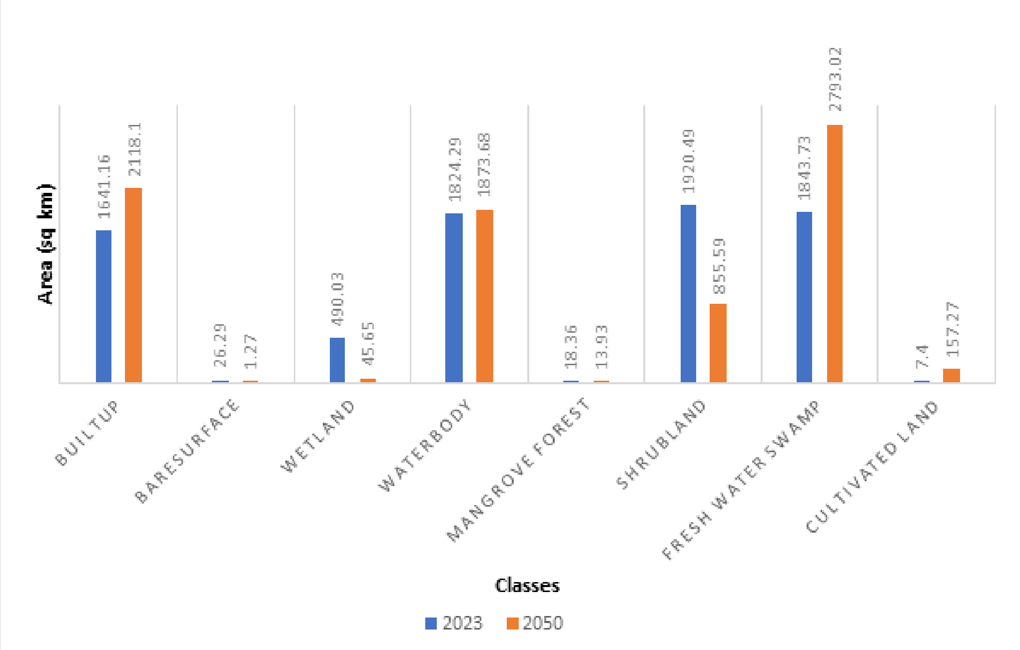

Figure 5: Graphical representation of LULC dynamics between 2023 and 2050

These projected changes indicate a substantial shift in the coastal zone's landscape by 2050. The significant increase in cultivated land (Figure 5) suggests a major expansion of agricultural activities, while the growth in built-up areas points to continued urbanization which support (Nhantumbo *et al.*, 2023) whose studies projected population growth rate of up to 174 million people exposed to sea level rise by 2060 in the study area. Similarly, a little gain in waterbody could be attributed to most likely climate change effects. The loss of wetlands and bare surfaces, coupled with the increase in freshwater swamp areas, indicates a complex transformation of the natural environment. This corroborates with (Croitoru *et al.*, 2020; ObiefuNa *et al.*, 2021). These changes will likely have significant consequences for local ecosystems, urban development, and agricultural practices in the region. The dramatic shifts in these land use patterns may require careful consideration for future environmental management and urban planning strategies to ensure sustainable development while minimizing negative ecological impacts.

Ecosystem service dynamics from 2023 and the projected 2050

A comprehensive analysis of ecosystem service values across different land use and land cover types in the study area revealed significant changes between 2023 and the projected scenario for 2050. The study indicated a substantial overall decline in total ecosystem service value, dropping from \$33,998.97 x 10^6 in 2023 to \$2,971.602 x 10^6 by 2050, representing a net decrease of \$835.338 x 10^6 (₦65.84 x 10^9) as shown on table 7. This transformation reflects complex changes across various ecosystem types, with some ecosystems experiencing gains while others face significant losses. Fresh water swamp ecosystems emerged as the most significant gainer in terms of ecosystem service value. The value increased from \$970.54 x 10^6 in 2023 to \$1,470.2 x 10^6 by 2050, resulting in a substantial gain of \$499.66 x 10^6 (₦817.29 x 10^9). This increase suggests an expansion of fresh water swamp areas, which could enhance various ecosystem services such as water purification, flood regulation, and habitat provision for diverse species.

In contrast, wetland areas experienced the most dramatic decline in ecosystem service value, reducing from \$1,258.50 x 10^6 in 2023 to merely \$117.24 x 10^6 by 2050. See (table 7), representing a staggering loss of \$1,141.26 x 10^6 (₦1866.75 x 10^9). This significant decrease in wetland value indicates a substantial loss of crucial ecosystem services such as water storage, carbon sequestration, and biodiversity support. Similarly, shrubland areas also saw notable decreases, contributing to the overall decline in ecosystem service values.

The implications of these changes are broad and complex. The ecosystem value gains in built-up areas, fresh water swamp, and water body values (Ndimele *et al.*, 2024), suggest a transformation toward more managed landscapes, potentially offering different types of ecosystem services. However, the substantial losses in wetland and shrubland values raise concerns about the overall ecological health and resilience of the region. The decline in wetland services, in particular, could lead to increased flood risks, reduced water quality, and diminished biodiversity support. This corroborates with several projected researches of increased flood in future years (Israel, 2021; Oloyede *et al.*, 2021).

Table 7.: Estimated ecosystem service values and dynamics between 2023 and 2050

Landuse and Landcover Types	Area (Ha)		Ecosystem Service Value US$ X 10^6/Year		2050 - 2023 (US$ X 10^6)	(₦ X 10^9) CBN official rate 27/10/23
	2023	2050	2023	2050		
Builtup	164116	211810	138.51	178.76	40.25	65.84
Baresurface	2629	127	0	0	0	0
Wetland	49003	4565	1258.50	117.24	-1141.26	-1866.75
Waterbody	182429	187368	778.42	799.49	21.07	34.46
Mangrove forest	1836	1393	355.90	270.03	-85.87	-140.46
Shrubland	192049	85559	304.97	135.86	-169.11	-276.61
Freshwaterswamp	184373	279302	970.54	1470.2	499.66	817.29
Cultivated land	740	157.27	0.10	0.022	-0.078	0.13
Total			**33998.97**	**2971.602**	**-835.338**	**1367.19**

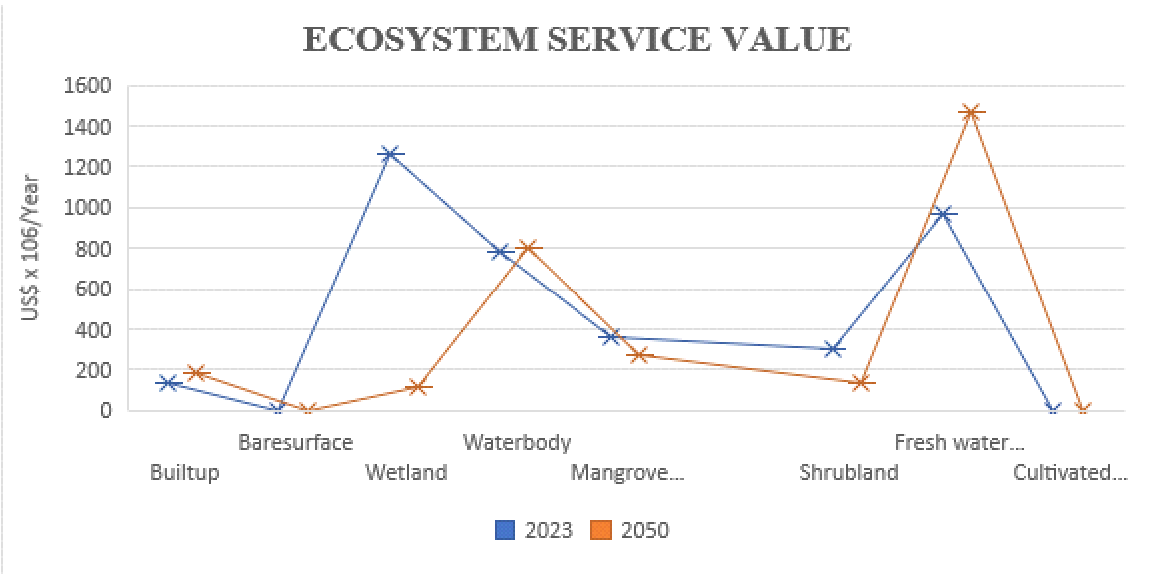

Figure 7: Estimated ecosystem service dynamics between 2023 and 2050

These shifts in ecosystem service values reflect wider changes in landscape composition and function. While some ecosystems are expanding and potentially providing enhanced services, the overall negative balance suggests a net loss of natural capital. This transformation could have significant implications for environmental sustainability, community resilience, and the economic benefits derived from natural ecosystems. The findings emphasize the need for careful land use planning and management strategies that can balance development needs with the preservation of vital ecosystem services, particularly focusing on the protection and restoration of high-value ecosystems like wetlands.

The simultaneous increase in ecosystem values across built-up areas, water bodies, and freshwater swamps by 2050 presents an interesting and complex ecological scenario. This unusual combination of growth patterns indicates a transforming landscape where urban development coincides with the expansion of aquatic ecosystems, creating a unique set of challenges and opportunities for both environmental management and urban planning.

The expansion of built-up areas typically signals urban growth and development which is in line with projected urbanization in Lagos coastal zones (Oloyede *et al*., 2021). This has traditionally been viewed as a loss for natural ecosystems. However, the increase in ecosystem value from these areas suggests a shift toward more sustainable urban planning approaches. Modern cities are gradually incorporating green infrastructure such as urban parks, green roofs, and vertical gardens (Lant *et al.,* 2008) *as* well as sustainable urban drainage systems that mimic natural water flows. These developments provide new types of ecosystem services, including local climate regulation through urban cooling effects, enhanced pollination services from urban green spaces, improved air quality, and cultural and recreational services for urban residents.

Concurrent with urban expansion, the increased ecosystem value from water bodies might indicate the creation or expansion of artificial lakes and reservoirs, restoration of existing water bodies within urban areas, or the integration of water features into urban planning. This growth in aquatic ecosystems can result in improved water regulation and flood control, enhanced recreational opportunities, creation of new aquatic habitats, better microclimate regulation, and increased property values in adjacent areas. The presence of water bodies in urban settings also contributes to the aesthetic value of cities (Hashemi Sigari and Panagopoulos, 2024), and can create corridors for wildlife movement

The growth in freshwater swamp ecosystem values, particularly alongside urban development, presents captivating implications. This could be attributed to climate change impacts leading to the natural expansion of swamp areas, intentional creation or restoration of swamp ecosystems for their services, or the integration of swamp ecosystems into urban water management strategies. These ecosystems offer enhanced natural water filtration, improved flood control capabilities, create biodiversity hotspots, and provide significant carbon sequestration opportunities (Hagger *et al*., 2022).

The harmonious effects of these simultaneous increases create unique opportunities and challenges. Urban areas can benefit from the natural water management services provided by swamps and water bodies, potentially reducing flood risks through integrated water storage and drainage systems. This integration can lead to the creation of unique urban ecosystems (Peng *et al*., 2019), that combine built and natural elements, supporting both aquatic and terrestrial species. However, this also presents challenges in managing human-wildlife interactions in urban areas and ensuring the health and stability of these urban aquatic ecosystems.

From a climate resilience perspective, the combination of water bodies and green infrastructure in urban areas can enhance cooling effects, improve carbon sequestration, and provide greater resilience to extreme weather events. Socioeconomically, these changes can create new recreational opportunities that combine urban and natural experiences, potentially boosting eco-tourism (Shang *et al.,* 2024), within urban areas and improving the overall quality of life for urban residents.

Looking ahead, this unique ecological scenario calls for integrated urban-ecological planning approaches, comprehensive monitoring systems, and educational programs about urban ecology and ecosystem services. Further research will be needed to understand the long-term stability of urban aquatic ecosystems, assess the carrying capacity of urban water bodies, and evaluate the economic benefits of integrated urban-ecological systems. As cities continue to evolve, the successful integration of urban development with thriving aquatic ecosystems could provide a model for sustainable urban growth that enhances rather than diminishes ecological values. The decline in ecosystem values across wetlands, shrublands, mangrove forests, and cultivated lands in coastal environments presents significant concerns for both ecological stability and human communities (Adedoja *et al.*, 2024). This loss of diverse ecosystems creates a cascade of effects that ripple through both natural systems and human societies, particularly in vulnerable coastal regions where these ecosystems play crucial protective and productive roles.

The dramatic decrease in wetland ecosystem values represents a critical loss for coastal environments. Coastal wetlands serve as nature's shock absorbers, buffering inland areas from storm surges and tidal forces. Their decline significantly reduces the natural coastal defence system, potentially exposing coastal communities to increased flooding and erosion risks (Li *et al.*, 2018). Beyond their protective function, wetlands act as vital filters, trapping sediments and pollutants before they reach the ocean. Their loss may lead to decreased water quality in coastal waters, affecting both marine life and human activities such as fishing and recreation. Wetlands also serve as carbon sinks, and their destruction releases stored carbon while reducing the ecosystem's capacity to sequester future carbon emissions.

The reduction in shrubland ecosystem values, though perhaps less immediately apparent, carries its own set of implications for coastal environments. Shrublands often serve as transition zones between different ecosystems, providing crucial habitats for diverse species and helping to prevent soil erosion on coastal slopes. Their decline can lead to increased soil erosion, potentially affecting water quality and sedimentation patterns in coastal areas (Onilude and Vaz, 2020) These areas often act as natural firebreaks and their loss may alter fire regimes in coastal regions, potentially increasing the vulnerability of remaining ecosystems and human settlements to wildfires.

The loss of mangrove forest ecosystem value is particularly concerning for tropical and subtropical coastal regions. Mangroves are powerhouses of coastal ecosystems, serving multiple critical functions. Their complex root systems provide nursery habitats for numerous marine species, supporting fisheries that local communities often depend upon. The decline of mangroves significantly reduces natural coastal protection against storms and tsunamis(Asari *et al.*, 2021), leaving coastal areas more vulnerable to natural disasters. These forests also play a crucial role in preventing coastal erosion and saltwater intrusion into freshwater systems. Their loss can accelerate coastal erosion and potentially lead to the salinization of coastal aquifers, affecting freshwater availability for both ecosystems and human use.

The decrease in cultivated land ecosystem value in coastal areas presents a different but equally significant set of challenges. Coastal agricultural lands often serve as important buffers between natural ecosystems and urban areas (Hasan *et al.*, 2020), providing food security for local populations while maintaining some ecosystem services. Their decline may indicate either abandonment due to saltwater intrusion and soil salinization, or conversion to other land uses such as urban development. This loss can affect local food production capabilities and potentially increase food insecurity in coastal communities (Campi *et al.*, 2021). Additionally, well-managed agricultural lands can help with flood control and provide habitat for various species; their loss further compounds the effects of declining natural ecosystems.

The compounded effects of these ecosystem declines create a troubling scenario for coastal regions. The loss of these diverse ecosystems reduces the overall resilience of coastal areas to environmental changes and natural disasters. Wildlife that depends on these interconnected ecosystems faces habitat loss and fragmentation, potentially leading to local extinctions and decreased biodiversity. The reduced capacity for natural water filtration and flood control may necessitate costly engineered solutions to maintain water quality and protect coastal communities.

Economic implications of these ecosystem declines are far-reaching. Coastal fisheries, which often depend on the nursery habitats provided by wetlands and mangroves, may likely see reduced productivity (Frank, 2024). Tourism could be affected as the aesthetic and recreational value of coastal areas diminishes. The cost of protecting coastal communities from storms and flooding will likely increase as natural buffers disappear. Insurance costs for coastal properties may rise as natural protection decreases, potentially affecting property values and community development patterns. There are also significant implications for local climate regulation. The combined loss of these ecosystems reduces their collective capacity to moderate local temperatures and humidity levels. This could lead to more extreme temperature fluctuations in coastal areas and potentially contribute to the urban heat island effect in nearby developed areas. The reduced capacity for carbon sequestration could contribute to accelerated climate change impacts in these regions. (Adedoja *et al*., 2024).

Looking toward the future, the sequence of these ecosystem deteriorations demands immediate attention and action. Restoration efforts, while challenging and time-consuming, become crucial for maintaining the viability of coastal regions. State-of-the-art approaches to coastal management that prioritize the defence and restoration of these vital ecosystems will be crucial (Jiang *et al*., 2020). This may include developing green infrastructure that mimics natural ecosystem functions, implementing policies that incentivize ecosystem preservation, and promoting sustainable land use practices that balance human needs with ecological integrity.

CONCLUSIONS AND RECOMMENDATIONS

The analysis of ecosystem changes in Lagos coastal areas reveals a concerning path towards 2050. The natural landscape is undergoing significant transformation, where built-up areas, water bodies, and freshwater swamps show increases, but this comes at the expense of critical natural ecosystems. The decline in mangroves, shrubland, cultivated land, and wetlands paints a picture of ecological degradation. This shift not only threatens biodiversity but also compromises the area's natural resilience against coastal hazards. The loss of mangroves is particularly worrying as these ecosystems serve as natural barriers against coastal erosion and storm surges, while also providing essential breeding grounds for marine life. The reduction in cultivated land suggests a decline in local food production capacity, potentially affecting food security. Overall, these changes indicate a pressing need for intervention to prevent further ecosystem degradation and ensure sustainable development of the Lagos coastal region.

The recommendations for addressing ecosystem changes in Lagos coastal areas include a comprehensive method that aligns with multiple Sustainable Development Goals. To protect and restore the declining ecosystems, instantaneous action must emphasize on safeguarding the remaining mangroves and wetlands while establishing clear restrictions between urban development and natural areas. This protective stance supports both marine and terrestrial ecosystem conservation while contributing to climate resilience.

The restoration agenda calls for an ambitious program of mangrove rehabilitation and wetland recovery, complemented by urban greening initiatives. These efforts would not only enhance biodiversity but also strengthen the area's natural defenses against climate change impacts. The urban planning recommendations emphasize the need for compact city development and green infrastructure integration, promoting sustainable urbanization while minimizing ecological disruption. This approach would help Lagos develop resilient communities while preserving critical natural resources.

Agricultural considerations are crucial, given the observed loss of cultivated land. The recommendations advocate for protecting remaining agricultural areas while promoting sustainable farming practices and urban agriculture programs. This would help ensure food security while supporting sustainable livelihoods in the region. These measures directly contribute to zero hunger goals while promoting responsible consumption and production patterns. The governance framework needs strengthening through enhanced environmental protection laws and improved enforcement mechanisms. This should be coupled with incentives for conservation efforts, creating a balanced approach that encourages compliance while rewarding positive environmental stewardship. This institutional strengthening aligns with goals for peace, justice, and strong institutions while fostering partnerships for sustainable development. Community engagement forms a critical component of the recommendations, emphasizing the need for local participation in conservation efforts and environmental education programs.

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AUTHORS' CONTRIBUTIONS

Prof. S.A. Adegboyega supervised the research and verified the results and methodology. Dr. A.M. Fakpor contributed to the editing and review of the manuscript

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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