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InVEST-based assessment of carbon sequestration potentials and environmental dynamics in the coastal area of Lagos

T.B. Adedoja
S.A. Adegboyega
A.M. Fakpor
Federal University of Technology (FUTA), Nigeria

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Abstract

Coastal environments comprise multiple arrays of ecosystems, including forests, mangroves, wetlands, and oceans. These ecosystems possess a unique ability to store Carbon for prolonged periods, acting as natural carbon sinks and contributing to reducing atmospheric greenhouse gas concentrations. However, despite their significance, the potential of coastal land covers and their associated land use in mitigating global warming through carbon absorption is often overlooked. This study employed the InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) model together with Intergovernmental Panel on Climate Change (IPCC) Carbon pool data to assess the carbon stock and dynamics of various land use and land cover types in the coastal environment of Lagos for 20 years. The results revealed a substantial reduction in net stored Carbon from 1.33 x 10^8 metric tons of Carbon in 2003 to 1.21 x 10^8 metric tons of Carbon in 2013, which accounts for a 6.66% decline in stored Carbon during that period. Furthermore, the total carbon stock decreased by approximately 3.5 x10^8 Metric tons, equating to a loss of over 300 million tons between 2013 and 2023. By identifying and measuring the carbon sequestration capacity of these varied coastal land covers, researchers can gain insight into their function in reducing global warming. These natural carbon sinks can be preserved and enhanced by conservation efforts, sustainable management practices, and policy decisions informed by this information, aiding the global fight against climate change.

Keywords: Ecosystems, Coastal region, Carbon sinks, Cabon sequestration, Global warming

Introduction

Carbon sequestration, the process of capturing and storing atmospheric carbon dioxide (CO2), is a crucial ecosystem service in mitigating climate change and global warming. This process is particularly significant as atmospheric concentrations of greenhouse gases, especially CO2, substantially influence Earth's climate (Kweku et al., 2018). Over the past century, burning fossil fuels and other human activities have released Carbon into the atmosphere, significantly increasing atmospheric CO_2 concentrations (Soeder & Soeder, 2021; Yoro & Daramola, 2020). This has raised global temperatures by trapping more heat than required. However, recent studies have shown that coastal ecosystems are responsible for 55% of all Carbon captured worldwide (Yang et al., 2024), thereby acting as significant carbon sinks, absorbing and storing Carbon through photosynthesis and other natural processes (Das et al., 2022; Iqbal and Shang, 2020). The global carbon cycle depends critically on this stored Carbon, sometimes known as the carbon stock. The stored Carbon is released back into the atmosphere when these ecosystems are disrupted or destroyed, which raises atmospheric CO_2 levels (Lorenz & Lal, 2018).

Lagos, Nigeria, emerges as a focal point for this study due to its high population density and intense industrial and commercial activities (Fakinle et al., 2020). The megacity is currently undergoing significant developmental projects, which have been linked to increased carbon emissions (Bola-Popoola et al., 2019).. Recent studies have examined various aspects of Nigeria's environmental management and carbon emissions, particularly in Lagos, aiming to provide scientific evidence for state-specific restoration initiatives. These studies include assessments of energy consumption and carbon emissions across different sectors (Maduekwe et al., 2020) as well as estimations of forest carbon storage for REDD+ strategy development using the InVEST model (Ibeabuchi, 2023).

Lagos's coastal environment stands out for its exceptional carbon sequestration capacity, driven by its natural carbon sinks (Okeke, 2022). The coastline is characterized by extensive mangrove forests, whose intricate root systems efficiently trap and store organic matter, acting as powerful carbon storage systems. These mangroves work in tandem with wetland systems and seagrass beds, forming an interconnected network of blue carbon repositories, that play a vital role in global carbon cycling. The region's unique hydrological dynamics (Ikuemonisan et al., 2021), further amplify its carbon sequestration potential. Tidal influences, seasonal flooding patterns, and

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interactions between groundwater and surface water create specialized conditions for carbon accumulation. These natural processes are closely tied to salinity gradients, which shape vegetation patterns and ultimately determine the efficiency of carbon storage mechanisms across the coastal ecosystem.

However, this coastline is not without its challenges. It faces significant erosion, threats from sea-level rise, and complex sediment transport patterns. These issues, coupled with seasonal climate variations, create a dynamic environment where carbon cycling processes can be observed under constantly shifting conditions. Beyond its local significance, Lagos holds logical importance as the largest coastal city in West Africa (Chang & Ross, 2024). It serves as a model for understanding tropical coastal systems under stress. Its connection to the Gulf of Guinea and its influence on regional climate patterns (Dahunsi et al., 2022), makes it a critical site for studying coastal carbon dynamics across West Africa. This intricate interplay of ecological processes, environmental challenges, and research opportunities makes Lagos's coastal region an invaluable hub for advancing carbon sequestration studies.

Despite growing recognition of coastal ecosystems as crucial carbon sinks (capable of absorbing and storing atmospheric carbon dioxide (CO2), the potential role of land use and land cover (LULC) dynamics in Lagos's coastal areas as a mechanism for carbon sequestration and global warming mitigation remains unexplored (Bola-Popoola et al., 2019). Therefore, this indicates a substantial knowledge gap about the ability of various LULC types in this region to function as efficient carbon sinks. The region's capacity to naturally absorb carbon dioxide and lessen the consequences of climate change is significantly impacted by these dynamic shifts in the carbon cycle. In addition, the quantification, distribution, and assessment of carbon stocks across various LULC classes in Lagos's coastal areas remain largely unexplored. The study estimated the carbon stock for each land use type, carbon sequestration, and storage across the landscape based on land cover, and it provides spatially explicit estimates of carbon sequestration in the eco-region.

Materials and Methods

Data Acquisition

The multispectral datasets needed for this research were obtained from the USGS Landsat Archive (https://earthexplorer.usgs.gov). The study area covers three scenes of the Landsat image catalogue with: Path 191/Row 55, Path 191/Row 56, and Path 190/Row 56. Landsat 7 Images of the selected scenes for 2003 and Landsat 8 Images of the exact location for 2013 and 2023 were downloaded from the online archive. Furthermore, the InVest 3.13.0 workbench version for the Windows operating system was downloaded from

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the official website of the Natural Capital Project Group of Stanford University (https://naturalcapitalproject.stanford.edu/software/invest). The model requires land use/land cover (LULC) maps representing current and future conditions as primary inputs. Additional necessary inputs include carbon pool data associated with each LULC class. Carbon pool estimates for vegetation classes in this study were derived from guidelines provided by the Intergovernmental Panel on Climate Change (IPPC, 2006)for tropical moist deciduous forests aligned with the study area's climatic zone, as shown in **Figure 1.** In this study, InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs), a tool developed by the Natural Capital Project at Stanford University, was utilized to model and map the delivery, distribution, and economic value of ecosystem services including carbon sequestration (Hamel et al., 2020) was used to estimate the carbon stock for each land use type in the study area. The tool estimates carbon sequestration and storage across a landscape based on land cover and can help inform decisions about natural resource management. InVEST provides spatially explicit estimates of carbon sequestration that account for various sequestration approaches across different land cover types (Tallis and Polasky, 2009). **Figure 2** shows the flow chart of the methods explored.

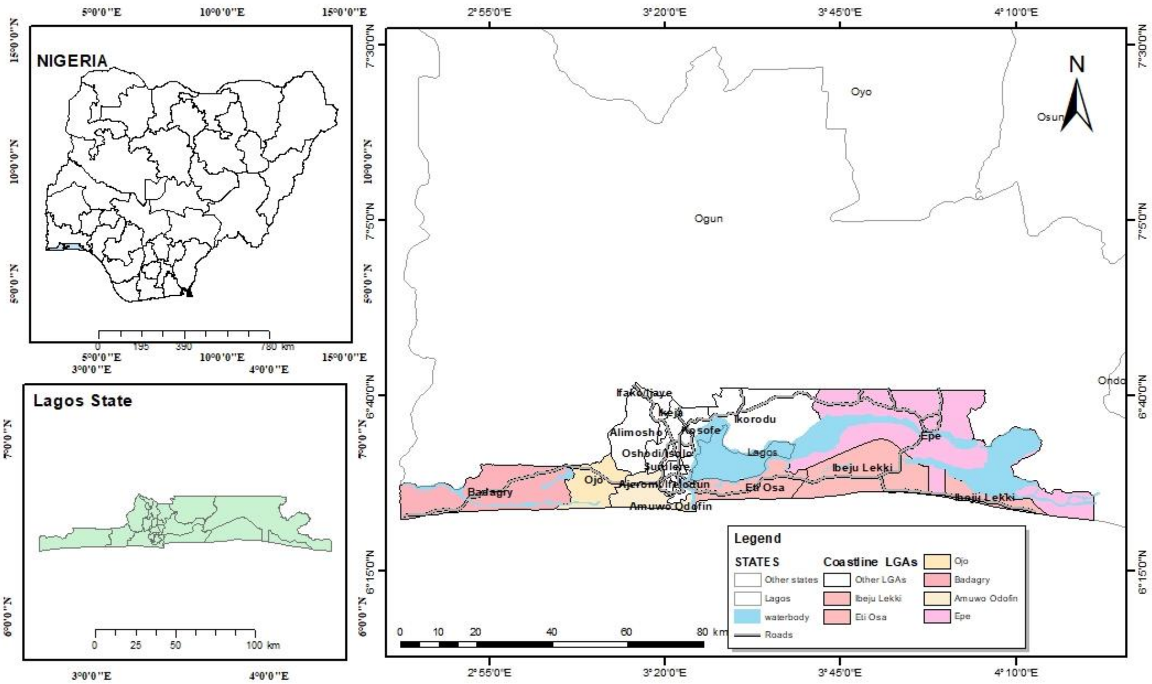

Figure 1: Study area map

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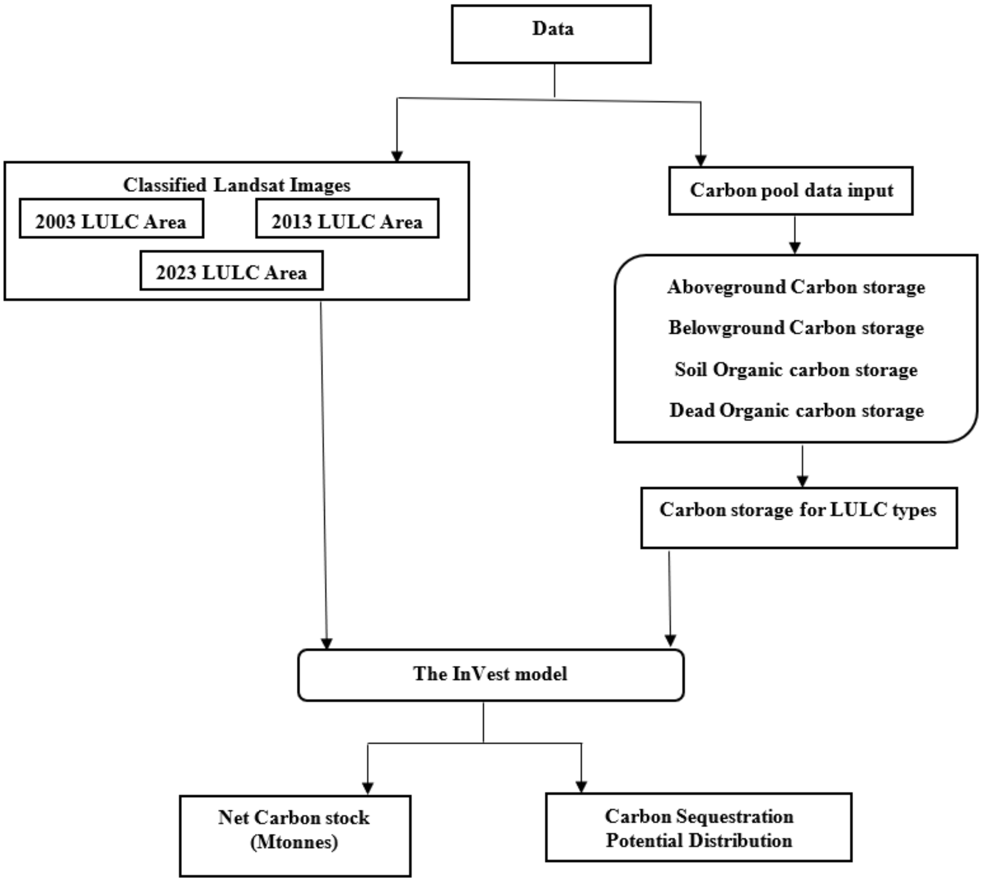

Figure 2: Flow chart of the methodology

Land use Land cover for the years 2003, 2013 and 2023

Image Processing / Classification

The analysis carried out on the data includes band combination, image Mapping, image subsetting, image classification, and accuracy assessment. The combination of bands in Landsat ETM+ and OLI imageries efficiently extracts various LULC features, notably from the coastal area, according to (Kokaly et al., 2017) report on image processing. In this analysis, for the year 2003, the study made use of band 1 (0.45-0.51), band 2 (0.5-0.60), band 3 (0.63-0.69) band 4 (0.76-0.89), and band 5 (1.54-1.75) of the Landsat ETM+ and for the years 2013 and 2023, band 2 (0.45-0.51), band 3 (0.5-0.60), band 4 (0.63-0.67), band 5 (0.85-0.87), and band 6 (1.56-1.65) OLI images are combined into a multispectral image for land feature extraction.

In Erdas Image geoprocessing software, the training sets were derived from polygons drawn on consistent groups of pixels to derive the spectral signature for the different LULC types, as stated above. Spectral signatures for the respective LULC types derived from the satellite imagery were

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recorded using the pixels enclosed by these polygons. A false-color composite image was created from these raw datasets in the same software environment by combining the selected stated bands. The three Landsat scenes were mosaicked together in the same software environment. While subsetting into the study area, the maximum likelihood algorithm was used to classify the image into the following classes: built-up, bare surface, Wetland, waterbody, cultivated land mangrove freshwater swamp, and Shrubland.

Accuracy Assessment

Field observation of the study area was used to support the image classification procedure and enhance the accuracy of the classified image. For each land use and LULC dataset, the accuracy assessment was carried out by randomly locating 10 points per each land use and LULC class. Furthermore, the error matrix was then calculated, and the QADI was run to derive the overall classification accuracy for the years of understudy. To facilitate the process, a plugin for QADI was downloaded and added to the toolbox of ArcMap 10.7 to produce a graph that presented the accuracy and confidence level of the classified imageries for the years under study. The QADI calculator plugin typically saves the error matrix (Feizizadeh et al., 2022).

Data analysis using the InVEST Model

The InVEST model consists of a series of sub-modules and algorithms, which can simulate changes in ecosystem service functions in different land use/cover scenarios (Wei et al., 2021). The amount of Carbon stored in a particular area will be calculated in this study using the Carbon Storage and Sequestration module (He et al., 2016). Specifically, the calculation formulas are as follows:

$$C = C_{above} + C_{below} + C_{soil} + C_{dead} \ldots\ldots\ldots 3.1$$

$$C_{total} = \sum_{k=1}^{n} A_k \, x \, C_k \; (k = 1,2,3, \ldots n) \ldots\ldots\ldots 3.2$$

where C is the total carbon storage per unit area of each land cover type, C_{above} is carbon density in aboveground mass, C_{below} is carbon density in belowground mass, C_{soil} is carbon density in soil, C_{dead} is carbon density in dead mass, A_k is the area of each land cover type, and C_{total} is the total carbon density of a cell. The carbon sequestration potential of the time periods was compared arithmetically to understand the transition concerning carbon storage capabilities of the study area (IPCC, 2006). **Table 1** summarizes the resulting carbon stock estimates derived from IPCC guidelines for each LULC class.

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Table 1: Total Carbon pool for all the Land use and Land cover Classes expressed in Tons/Hectares/Year

Lu code	LULC_name	C_above	C_below	C_soil	C_dead
1	Built-up	2	0.48	30	1
2	Bare surface	0	0	40	0
3	Cultivated Land	50	12	20	0
4	Shrubland	180	43.2	4	2
5	Mangrove forest	150	36	0	0
6	Freshwater swamp	260	62.4	2	10
7	Wetland	100	24	2	0
8	Waterbody	0	0	0	0

IPCC: 2006

The InVEST model integrates this carbon pool input with the current and future LULC maps to estimate changes in carbon storage and sequestration across the study landscape over time. The use of (IPCC, 2006) guidelines provides standardized, globally accepted estimates for carbon modeling

Results

Land use Land cover analysis for the year 2003

The land use land cover classification result for the year 2003 shows that Freshwater swamps, Shrubland, and water bodies were the dominant land use classes, accounting for 28.22%, 26.62%, and 24.62%, respectively. Additionally, mangrove forests, Barren surfaces, and cultivated land had the least area coverage, with less than 1%. The study also shows that Built-up areas and wetlands recorded about 11.54% and 7.87%, respectively. **See Figure 3 and Table 2,** respectively. The result validation using the QADI reveals a high level of classification accuracy.

Land use Land cover analysis for the year 2013

LULC results for the year 2013 show the same trends as the result of the year 2003, with Freshwater swamps, Shrubland, and Water bodies accounting for 26.44%, 25.58%, and 23.54% of the entire study area, respectively. A similar trend was also observed for mangrove forests, bare surfaces, and cultivated land, which account for less than 1% of the entire land use. Validation using QADI reveals a high level of classification accuracy. **Figure 4 and Table 3** show the LULC map and statistics for the year 2003.

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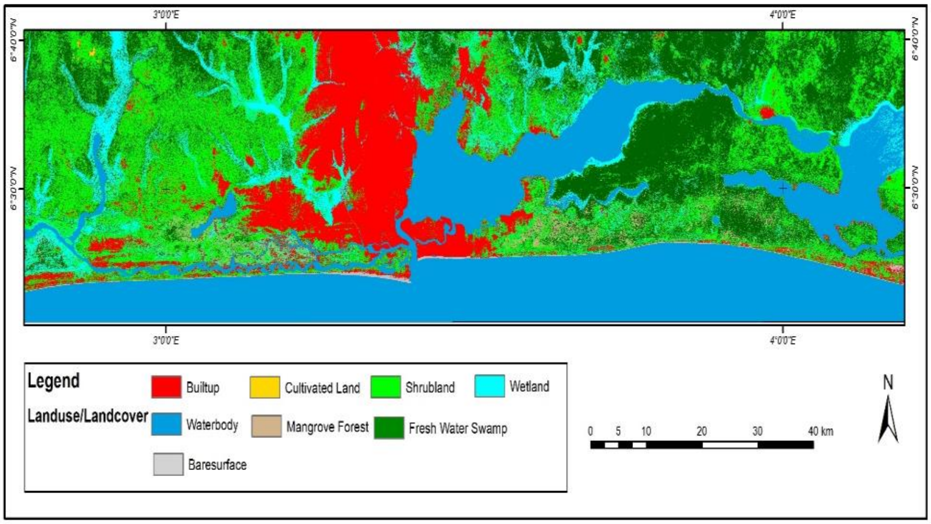

Figure 3: Land use land cover map of the study area in 2003

Table 2: Land use and Land cover Statistics for the year 2003

Class	Pixel count	Area (sq.km)	Percent Cover (%)
Freshwater swamp	2439343	2195.41	28.22
Shrubland	2300971	2070.87	26.62
Waterbody	2128182	1915.36	24.62
Built-up	997059	897.35	11.54
Wetland	680454	612.41	7.87
Mangrove forest	63752	57.38	0.74
Bare surface	32383	29.14	0.37

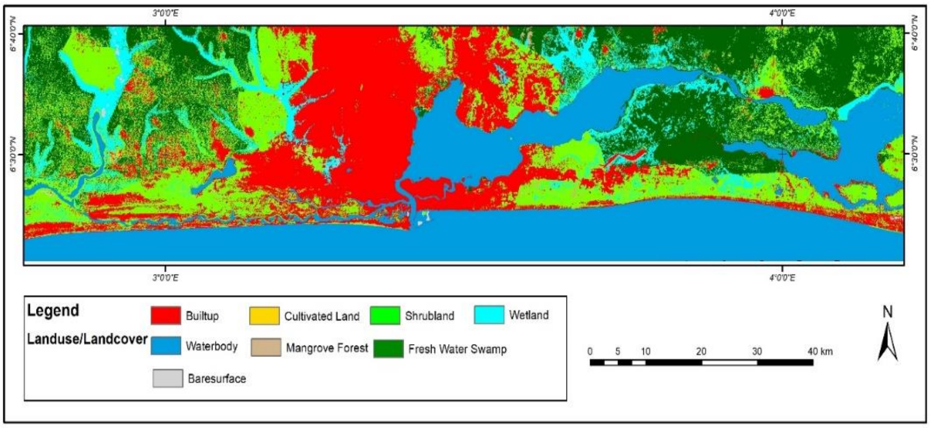

Figure 4: Land use land cover map of the study area in 2013

Table 3: Land use and Land cover Statistics for the year 2013

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Class	Pixel Count	Area (sq.km)	Percent Cover (%)
Shrubland	2285743	2057.17	26.44
Freshwater swamp	2211502	1990.35	25.58
Waterbody	2034774	1831.30	23.54
Built-up	1616596	1454.94	18.70
Wetland	425979	383.38	4.93
Mangrove forest	33374	30.04	0.39
Bare surface	31949	28.75	0.37
Cultivated Land	4035	3.63	0.05

Author's Field Survey, 2024

Land use Land cover analysis for the year 2023

The result of this analysis shows that Shrubland accounted for the largest size, 24.71% of the entire study area. This was followed by Freshwater swamp, Waterbody, and Built-up, recording 23.72%, 23.47%, and 21.12%, respectively. While Wetlands recorded about 6.31% of the entire land use of the study area, Bare surface, Mangrove Forest, and Cultivated land recorded the least with less than 1 % each. See **Figure 5 and Table 4**.

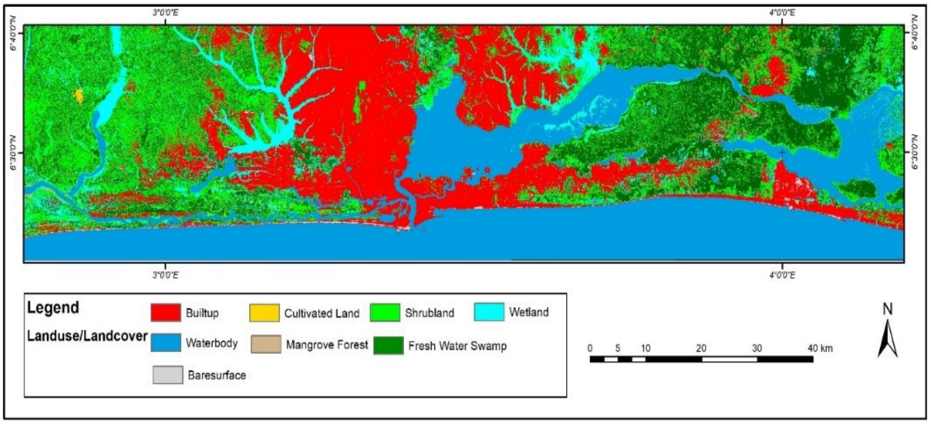

Figure 5: Land use land cover map of the study area in 2023

Table 4: Land use and Land cover Statistics for the year 2023

Class	Pixel count	Area (sq.km)	Percent Cover (%)
Shrubland	2133878	1920.49	24.71
Freshwater swamp	2048590	1843.73	23.72
Waterbody	2026989	1824.29	23.47
Built-up	1823506	1641.16	21.12
Wetland	544482	490.03	6.31
Bare surface	29216	26.29	0.34
Mangrove forest	20399	18.36	0.24
Cultivated Land	8226	7.40	0.10

Author's Field Survey, 2024

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In the study area, an observed transition of land use and land cover classes was attributed to driving some of the environmental degradation mentioned above. The analysis of Land use and Land cover change is expressed in **Table 5.** The built-up and cultivated areas experienced a gain between 2003 and 2013, with a value of 557.59 sq.km (62.14%) and 2.21 sq.km (155.63%), respectively. The remaining land use and land cover classes experienced losses as follows: Wetland: -229.03 (37.4%), bare surface: -0.39 sq.km (1.34%).

Table 5: Land use and Land cover dynamics between 2003 and 2013

Class	2003 Area (sq.km)	2013 Area (sq.km)	Change	Percent Change (%)
Cultivated LandLand	1.42	3.63	2.21	155.74
Built-up	897.35	1454.94	557.59	62.14
Bare surface	29.14	28.75	-0.39	-1.34
Shrubland	2070.87	2033.23	-37.64	-1.82
Waterbody	1915.36	1831.30	-84.06	-4.39
Wetland	612.41	527.45	-84.96	-13.87
Freshwater swamp	2195.41	1873.97	-321.44	-14.64
Mangrove forest	57.38	26.28	-31.10	-54.20

The table of Land use and Land cover change for (2013-2023) is expressed in **Table 6**. The built-up and cultivated Land similarly experienced a gain between 2013 and 2023 with a value of 186.22 sq.km (12.80% gain) and 3.77 sq.km (103.86% gain), respectively. The remaining land use and land cover classes experiences losses as follows: Wetland: -37.42 (7.09%), bare surface: -2.46 sq.km (8.56% loss), Waterbody: -7.01 sq.km (0.38% loss), Mangrove Forest: -7.92sq.km (30.14% loss), Shrubland: -112.74 sq.km (5.54% loss) and Fresh Water Swamp: -30.24sq.km (1.61% loss).

Table 6: Land use Land cover dynamics between 2013 and 2023

Class	2013 Area (sq.km)	2023 Area (sq.km)	Change	Percent Change (%)
Built-up	1454.94	1641.16	186.22	12.80
Bare surface	28.75	26.29	-2.46	-8.56
Wetland	527.45	490.03	-37.42	-7.09
Waterbody	1831.3	1824.29	-7.01	-0.38
Mangrove forest	26.28	18.36	-7.92	-30.14
Shrubland	2033.23	1920.49	-112.74	-5.54
Freshwater swamp	1873.97	1843.73	-30.24	-1.61
Cultivated Land	3.63	7.40	3.77	103.86

Carbon sequestration dynamics of the ecosystem in the study area

The InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) model was used to assess the carbon sequestration potential of the various land use and land cover types found in the study area. Additionally, the model was used to estimate carbon sequestration rates by considering

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factors such as vegetation type, biomass, land cover change, wave exposure, sea level change, population, and land management practices (Bola-Popoola et al., 2019). To determine the potential for carbon sequestration, the model uses data inputs such as maps of land cover, climate information, and soil details. Using spatially explicit models and algorithms, it estimated carbon stocks and sequestration rates based on ecosystem properties and management scenarios.

Table 7: Net Carbon Stock for the study area between 2003 and 2013

Land use/Land cover	2003 (Mtons of C)	2013 (Mtons of C)	Difference	Percentage Change
Built-up	3004327.80	4871139.12	1866811.32	62.14
Bare surface	116560.00	115000.00	-1560	-1.34
Wetland	7716366.00	6645870.00	-1070496	-13.87
Waterbody	20.63	7.15	-13.48	-65.34
Mangrove forest	1067268.00	488808.00	-578460	-54.20
Shrubland	47464340.40	46601631.60	-862708.80	-1.82
Freshwater swamp	73414510.40	62665556.80	-10748953.6	-14.64
Cultivated Land	11644.00	29766.00	18122	155.63
Total Carbon	132795036.83	121417778.67	-11377258.56	-8.57

Table 8: Net Carbon Stock for the study area between 2013 and 2023

Landuse/Land cover	2013 (Mtons of C)	2023 (Mtons of C)	Difference	Percentage Change
Built-up	4871139.12	5494603.68	623464.56	12.80
Bare surface	115000.00	105160.00	-9840	-8.56
Wetland	6645870.00	6174378.00	-471492	-7.09
Waterbody	7.15	6.03	-1.12	-15.66
Mangrove forest	488808.00	341496.00	-147312	-30.14
Shrubland	46601631.60	44017630.80	-2584000.8	-5.54
Freshwater swamp	62665556.80	61654331.20	-1011225.60	-1.61
Cultivated Land	29766.00	60680.00	30914	103.86
Total Carbon	121417778.67	117848285.71	-3569492.96	-2.94

The spatial distribution of the carbon sequestration potentials in 2003, 2013, and 2023.

The spatial distribution of carbon sequestration potential across the Lagos coastal area for the years 2003, 2013, and 2023 is presented in **Figures 6, 7,** and **8**, respectively. A visual analysis of these maps reveals a decreasing trend of carbon sequestration potential over time within the study area. In the 2003 map, large swaths of the region are depicted in darker shades, representing areas with high carbon sequestration capacity. However, the region's carbon sequestration potential will progressively decrease between 2013 and 2023. Hence, low carbon sequestration potential becomes more prevalent.

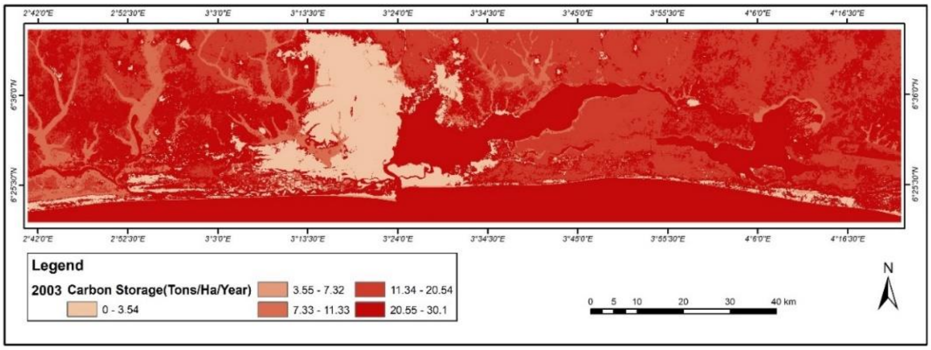

Figure 6: Distribution of Carbon Sequestration Potential in 2003

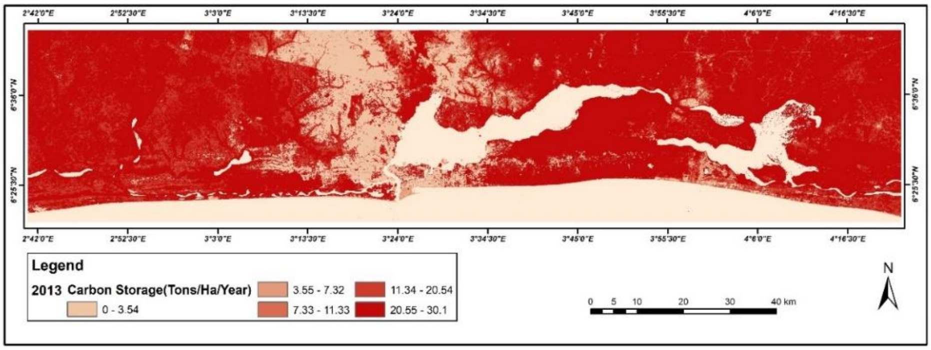

Figure 7: Distribution of Carbon Sequestration Potential in 2013

Figure 8 below shows an alarming trend of reduction of the study area to absorb Carbon. The diminishing carbon sequestration potential over the 20 years can be attributed to various factors, including urbanization, deforestation, unsustainable land-use practices, and the degradation of natural ecosystems. These changes in land cover and land use have likely reduced the overall capacity of the Lagos coastal area to mitigate climate change through carbon sequestration and storage.

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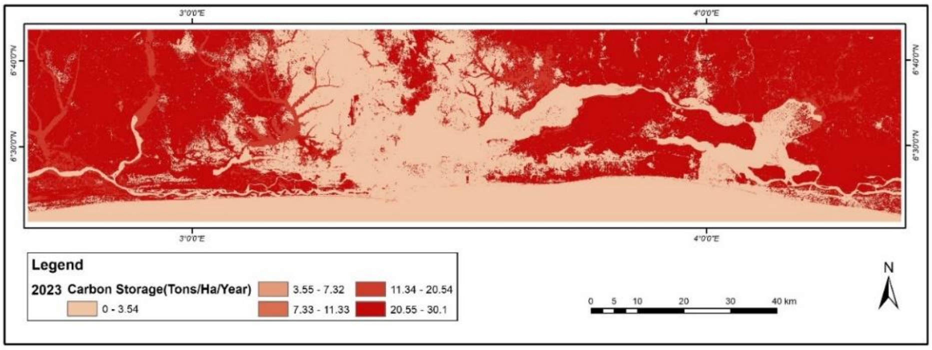

Figure 8: Distribution of Carbon Sequestration Potential in 2023

Discussion

Land use land cover dynamics from 2003-2023

Land use and land cover change are major drivers of environmental degradation globally, significantly impacting biodiversity, climate, biogeochemical cycles, and ecosystem services (Foley et al., 2012; Vitousek et al., 1997) It is estimated that over 75% of the Earth's land surface has been altered by human activities like agriculture, deforestation and urbanization leading to habitat loss, soil degradation, disrupted hydrology, and increased carbon emissions (Ramankutty et al., 2008; Sanderson et al., 2002) Given these substantial impacts, understanding the rates, causes, and consequences of land use and land cover change through methods like remote sensing and modeling is critical for developing strategies towards more sustainable land management (Liping et al., 2018)

Carbon stock dynamics of the Land cover between 2003-2013

The result of the InVEST model executed on the land use and land cover dataset over the study area is presented in **Table 7**. The table presents dynamics and the associated changes in carbon stocks between 2003 and 2013 for different land cover types. The net stored Carbon was substantially reduced from 1.33 x 10^8 Mtons of Carbon to 1.21 x 10^8 Mtons of Carbon between 2003 and 2013, respectively. This indicates a net release of Carbon into the atmosphere, potentially contributing to climate change. The 8.57% decline in stored Carbon between the years under study highlights trends of deforestation and loss of natural carbon sinks across the landscape (Le Quéré et al., 2018). It is essentially due to converting one type of LULC to another. The most significant contribution to the decrease in carbon stock was from the freshwater swamp land cover type, which lost 10.7 x 10^8 Mtons of Carbon (14.64% reduction). This suggests substantial deforestation and forest

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degradation occurred during this period, likely due to activities like logging, agricultural expansion, or urbanization. The built-up area experienced a significant increase of 62.14%, indicating rapid urbanization. This land use change typically involves the conversion of vegetated areas (e.g., forests, wetlands) to impervious surfaces, contributing to the loss of carbon sinks. Both Wetland and mangrove forest experienced significant decreases in carbon stocks, with losses of 13.87% and 54.20%, respectively. This observed pattern suggests a gradual degradation or conversion of land cover types that historically served as significant carbon sinks, such as Freshwater swamps, wetlands, and mangrove forests. The expansion of lighter shades of colors across the maps implies that an increasing proportion of the study area has lost its ability to effectively sequester and store atmospheric Carbon, potentially exacerbating the impacts of global warming. Oguntade et al.(2023) highlighted the impact of land-use changes, particularly the conversion of natural ecosystems to urban and agricultural areas, on reducing carbon sequestration potential in Lagos State.

These ecosystems are known for their high carbon sequestration potential, and their degradation or conversion can release substantial amounts of stored Carbon. The conversion of natural ecosystems to cultivated land can lead to soil carbon losses and reduced carbon sequestration potential. The bare surface and water body land cover types experienced relatively minor changes in carbon stocks, likely due to their limited carbon storage and sequestration capacity. This agrees with (Aitali et al., 2022), who claim that bare surfaces and water bodies have limited carbon storage and sequestration capacity due to their low productivity and minimal carbon accumulation. Overall, the results indicate that LULC changes, mainly deforestation, urbanization, and the degradation of wetlands and mangroves, played a significant role in the net release of Carbon into the atmosphere during the study period.

Carbon stock dynamics of the Land cover between 2013-2023

The total carbon stock decreased by 3.5×10^8 Mtons, approximately 2.94%, equating to over 300 million tons loss between 2013 and 2023. This indicates a continued net release of Carbon into the atmosphere, although at a slower rate compared to the previous period (2003-2013). The forest land cover type experienced a decrease of 1.61%, suggesting that deforestation and forest degradation activities persisted during this period, albeit at a slower pace compared to the previous decade. The built-up area continued to increase, with a 12.8% rise in carbon stocks. This trend likely reflects ongoing urbanization and the conversion of vegetated areas to impervious surfaces, contributing to the loss of carbon sinks. (Ding et al., 2022) Both Wetland and mangrove forest cover types experienced further decreases in carbon stocks, with losses of 7.09% and 30.14%, respectively. This ongoing degradation and conversion of

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these high-carbon ecosystems remains a significant concern for carbon emissions. The cultivation land cover type increased by 103.86%, indicating a substantial expansion of agricultural activities during this period in which their potential is also limited relative to natural vegetation (Lorenz & Lal, 2018). While the overall contribution to carbon stock change may be relatively small, the conversion of natural ecosystems to croplands can lead to soil carbon losses and reduced carbon sequestration potential.

Furthermore, agroecosystems lack the biodiversity and structural complexity of freshwater swamps, wetlands, and mangroves, enabling high carbon accumulation and retention rates. However, crops are important for food production; they are poor substitutes for producers of ecosystem services and climate regulation. As discussed in the previous period, the bare surface and water body land cover types experienced relatively small changes in carbon stocks, consistent with their limited capacity for carbon storage and sequestration. The Shrubland land cover type experienced a notable decrease of 5.54% in carbon stocks, suggesting potential degradation or conversion of these ecosystems, which can contribute to carbon emissions. The results indicate that land use/land cover changes, mainly deforestation, urbanization, and the degradation of wetlands, mangrove forests, and shrublands, continued to drive carbon emissions, albeit slower than in the previous decade. The expansion of agricultural activities also contributed to the loss of carbon sinks.

Distribution of carbon sequestration potentials from 2003 - 2023

This observed pattern in **Figures 6, 7,** and **8** suggests a gradual degradation or conversion of land cover types that historically served as significant carbon sinks, such as Freshwater swamps, wetlands, and mangrove forests. The expansion of lighter shades of colors across the maps implies that an increasing proportion of the study area has lost its ability to effectively sequester and store atmospheric Carbon, potentially exacerbating the impacts of global warming. Oguntade et al.(2023) highlighted the impact of land-use changes, particularly the conversion of natural ecosystems to urban and agricultural areas, on reducing carbon sequestration potential in Lagos State.
The reduction in carbon sequestration capacity across Lagos' coastal zone will trigger a complex set of consequences if action is not taken to reverse this trend. This decline will not only impact global carbon markets but also carry significant economic implications, as the diminishing ability of Lagos' coastal ecosystems to store carbon undermines their contribution to climate finance. Locally, the reduced capacity to generate carbon credits will hinder climate mitigation efforts and limit participation in global carbon trading systems as highlighted by (Tanveer et al., 2024). This economic constraint is particularly concerning, as it restricts access to funding coastal restoration projects and curtails the potential for community-based carbon initiatives.

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Moreover, the complex relationship between biodiversity and carbon storage highlights serious ecological repercussions. As the carbon sequestration capacity of these coastal ecosystems diminishes, their ability to support diverse marine and coastal species reduces (Rogers et al., 2019). Mangrove-dependent fish species will face heightened risks, while vital breeding habitats for commercially important fish will be jeopardized. This loss of biodiversity will ripple through food webs, altering species distributions and eroding the genetic diversity essential for ecosystem stability.

The effect on ecosystem resilience is arguably the most worrisome. The inherent ability of the shoreline to act as a buffer against environmental difficulties is diminished when carbon sequestration capability weakens, which frequently signals a larger decline in ecosystem health (Liu et al., 2023). Historically, these ecosystems have acted as organic barriers to prevent storm surges and coastal erosion, become less effective in their protective role. Local climatic implications are aggravated by the release of stored carbon (Qu et al., 2023), which increases coastal erosion, and makes extreme weather events become more prevalent. Local communities are subsequently impacted by this environmental deterioration through decreased fishery output, limited tourism potential, and increased costs for coastal protection. The situation can create a particularly challenging scenario for coastal communities whose livelihoods depend directly on these ecosystem services.

Conclusion and Recommendation

The findings of this study reveal significant implications for coastal environment management and climate change mitigation. The observed decrease in coastal carbon stocks presents a critical challenge, as it weakens the ecosystem's natural ability to combat climate change. This diminished capacity affects the environment's resilience to climate impacts such as sea-level rise and extreme weather events. It poses risks to communities that depend on coastal resources for their livelihoods.

Findings also emphasize the urgent need for comprehensive management strategies. Environmental managers and policymakers should prioritize the protection of remaining coastal vegetation while implementing restoration programs for degraded areas. This could be achieved through strict zoning regulations and the establishment of buffer zones between urban developments and sensitive coastal ecosystems. Significant is the restoration of mangrove forests and wetlands, which serve as crucial carbon sinks and provide multiple ecosystem services.

This research suggests the need for innovative approaches that combine environmental protection with urban development. Local governments should consider implementing incentive programs for

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developers who incorporate green spaces in coastal developments and establish carbon offset programs that directly fund ecosystem restoration efforts. These initiatives should be supported by robust environmental impact assessment protocols that specifically address carbon stock evaluations. The success of these interventions largely depends on effective stakeholder engagement. Establishing strong partnerships between local communities, government agencies, and environmental organizations is highly recommended. These partnerships should focus on implementing community-based monitoring systems and capacity-building programs that enhance local understanding of coastal resource management. Such collaborative approaches can ensure more sustainable and effective long-term ecosystem management. Long-term monitoring programs should be established to track changes in carbon stocks over time, supported by standardized assessment methods. Future research should also focus on the economic valuation of coastal carbon services and the potential for blue carbon markets. Investigating the relationship between carbon stocks and coastal resilience will also be crucial for developing effective climate change adaptation strategies.

The assesment of carbon sequestration potential in Lagos's coastal area faces several significant limitations. The primary challenge stems from the city's unprecedented rate of urbanization, which outpaces traditional monitoring capabilities. This rapid transformation makes it exceptionally difficult to establish reliable baseline data, as land use patterns change substantially even during ongoing research periods. The challenge is further compounded by the scarcity of historical carbon stock data, creating a significant gap in understanding long-term carbon sequestration trends in the region.

Moreover, the intensive coastal development and ongoing land reclamation projects present additional complexities. These activities progress more rapidly than typical research timelines, making it challenging for researchers to comprehensively document and analyze their impacts on carbon sequestration patterns. The situation is further complicated by the presence of informal settlements along the coastline, which introduces additional variables in assessing human impacts on carbon stocks. These unplanned developments often lack documentation and standardized land-use patterns, making incorporating their effects into carbon sequestration models difficult.

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References:

1. Aitali, R., Snoussi, M., Kolker, A. S., Oujidi, B., & Mhammdi, N. (2022). Effects of land use/land cover changes on carbon storage in North African Coastal Wetlands. *Journal of Marine Science and Engineering*, *10*(3), 364.
2. Bola-Popoola, A. G., Fakinle, B. S., Abosede Odunlami, O., Sonibare, J. A., & Odekanle, E. L. (2019). Investigation and quantification of carbon footprint in Lagos megacity. *Cogent Engineering*, *6*(1), 1703470.
3. Chang, H., & Ross, A. R. (2024). Lagos, Nigeria. In *Climate Change, Urbanization, and Water Resources: Towards Resilient Urban Water Resource Management* (pp. 83–95). Springer.
4. Dahunsi, A. M., Bonou, F., Dada, O. A., & Baloïtcha, E. (2022). Spatio-temporal trend of past and future extreme wave climates in the Gulf of Guinea driven by climate change. *Journal of Marine Science and Engineering*, *10*(11), 1581.
5. Das, S. C., Das, S., & Tah, J. (2022). Mangrove ecosystems and their services. In *Mangroves: Biodiversity, Livelihoods and Conservation* (pp. 139–152). Springer.
6. Ding, Q., Shao, H., Chen, X., & Zhang, C. (2022). Urban land conversion reduces soil organic carbon density under impervious surfaces. *Global Biogeochemical Cycles*, *36*(10), e2021GB007293.
7. Fakinle, B. S., Odekanle, E. L., Olalekan, A. P., Ije, H. E., Oke, D. O., & Sonibare, J. A. (2020). Air pollutant emissions by anthropogenic combustion processes in Lagos, Nigeria. *Cogent Engineering*, *7*(1), 1808285.
8. Feizizadeh, B., Darabi, S., Blaschke, T., & Lakes, T. (2022). *QADI as a new method and alternative to kappa for accuracy assessment of remote sensing-based image classification.le*. *22*, 4506.
9. Foley, R. J., Simon, J. D., Burns, C. R., Gal-Yam, A., Hamuy, M., Kirshner, R. P., Morrell, N. I., Phillips, M. M., Shields, G. A., & Sternberg, A. (2012). Linking Type Ia supernova progenitors and their resulting explosions. *The Astrophysical Journal*, *752*(2), 101.
10. Hamel, P., Valencia, J., Schmitt, R., Shrestha, M., Piman, T., Sharp, R. P., Francesconi, W., & Guswa, A. J. (2020). Modeling seasonal water yield for landscape management: Applications in Peru and Myanmar. *Journal of Environmental Management*, *270*, 110792.
11. He, J., Chu, J., Liu, H., Gao, Y., & Li, B. (2016). Research advances in biogeotechnologies. *Chinese Journal of Geotechnical Engineering*, *38*(4), 643–653.
12. Ibeabuchi, U. (2023). Mapping Carbon Storage and Sequestration in Nigeria: A REDD Policy Initiatives. *Water and Environmental*

Sustainability, *3*(3), 11–29.

13. Ikuemonisan, F. E., Ozebo, V. C., & Olatinsu, O. B. (2021). Investigating and modelling ground settlement response to groundwater dynamic variation in parts of Lagos using space-based retrievals. *Solid Earth Sciences*, *6*(2), 95–110.
14. IPPC. (2006). 2006 IPCC guidelines for national greenhouse gas inventories. *Institute for Global Environmental Strategies, Hayama, Kanagawa, Japan*.
15. Iqbal, A., & Shang, Z. (2020). Wetlands as a carbon sink: Insight into the Himalayan Region. In *Carbon management for promoting local livelihood in the Hindu Kush Himalayan (HKH) Region* (pp. 125–144). Springer.
16. Kokaly, R. F., Clark, R. N., Swayze, G. A., Livo, K. E., Hoefen, T. M., Pearson, N. C., Wise, R. A., Benzel, W. M., Lowers, H. A., & Driscoll, R. L. (2017). Usgs spectral library version 7 data: Us geological survey data release. *United States Geological Survey (USGS): Reston, VA, USA*, *61*.
17. Kweku, D. W., Bismark, O., Maxwell, A., Desmond, K. A., Danso, K. B., Oti-Mensah, E. A., Quachie, A. T., & Adormaa, B. B. (2018). Greenhouse effect: greenhouse gases and their impact on global warming. *Journal of Scientific Research and Reports*, *17*(6), 1–9.
18. Le Quéré, C., Andrew, R. M., Friedlingstein, P., Sitch, S., Hauck, J., Pongratz, J., Pickers, P. A., Korsbakken, J. I., Peters, G. P., & Canadell, J. G. (2018). Global carbon budget 2018. *Earth System Science Data*, *10*(4), 2141–2194.
19. Liping, C., Yujun, S., & Saeed, S. (2018). Monitoring and predicting land use and land cover changes using remote sensing and GIS techniques—A case study of a hilly area, Jiangle, China. *PloS One*, *13*(7), e0200493.
20. Liu, W., Cui, L., Guo, Z., Wang, D., & Zhang, M. (2023). Wetland ecosystem health improvement from ecological conservation and restoration offset the decline from socio-economic development. *Land Degradation & Development*, *34*(1), 283–295.
21. Lorenz, K., & Lal, R. (2018). *Carbon sequestration in agricultural ecosystems*.
22. Maduekwe, M., Akpan, U., & Isihak, S. (2020). Road transport energy consumption and vehicular emissions in Lagos, Nigeria: An application of the LEAP model. *Transportation Research Interdisciplinary Perspectives*, *6*, 100172.
23. Oguntade, S. S., Aborode, A. T., Afinjuomo, O. H., Kayode, V. A., Atanda, T. A., Amupitan, O. D., Ojajune, O. B., Ajagbe, A. B., & Omonitan, M. O. (2023). The Impact of Climate Change on the State

of Carbon Footprint in Nigeria. In *Climate Change Impacts on Nigeria: Environment and Sustainable Development* (pp. 155–177). Springer.
24. Okeke, G. N. (2022). THE NIGERIAN PERSPECTIVE OF GLOBAL CLIMATE CHANGE: A CASE STUDY OF COASTAL AREAS OF LAGOS. *Open Journal of Environmental Research (ISSN: 2734-2085)*, *3*(2), 38–53.
25. Qu, Q., Xu, H., Ai, Z., Wang, M., Wang, G., Liu, G., Geissen, V., Ritsema, C. J., & Xue, S. (2023). Impacts of extreme weather events on terrestrial carbon and nitrogen cycling: A global meta-analysis. *Environmental Pollution*, *319*, 120996.
26. Ramankutty, N., Evan, A. T., Monfreda, C., & Foley, J. A. (2008). Farming the planet: 1. Geographic distribution of global agricultural lands in the year 2000. *Global Biogeochemical Cycles*, *22*(1).
27. Rogers, K., Macreadie, P. I., Kelleway, J. J., & Saintilan, N. (2019). Blue carbon in coastal landscapes: a spatial framework for assessment of stocks and additionality. *Sustainability Science*, *14*, 453–467.
28. Sanderson, E. W., Jaiteh, M., Levy, M. A., Redford, K. H., Wannebo, A. V, & Woolmer, G. (2002). The human footprint and the last of the wild: the human footprint is a global map of human influence on the land surface, which suggests that human beings are stewards of nature, whether we like it or not. *BioScience*, *52*(10), 891–904.
29. Soeder, D. J., & Soeder, D. J. (2021). Fossil fuels and climate change. *Fracking and the Environment: A Scientific Assessment of the Environmental Risks from Hydraulic Fracturing and Fossil Fuels*, 155–185.
30. Tallis, H., & Polasky, S. (2009). Mapping and valuing ecosystem services as an approach for conservation and natural-resource management. *Annals of the New York Academy of Sciences*, *1162*(1), 265–283.
31. Tanveer, U., Ishaq, S., & Hoang, T. G. (2024). Enhancing carbon trading mechanisms through innovative collaboration: Case studies from developing nations. *Journal of Cleaner Production*, *482*, 144122.
32. Vitousek, P. M., Mooney, H. A., Lubchenco, J., & Melillo, J. M. (1997). Human domination of Earth's ecosystems. *Science*, *277*(5325), 494–499.
33. Wei, P., Chen, S., Wu, M., Deng, Y., Xu, H., Jia, Y., & Liu, F. (2021). Using the InVEST model to assess the impacts of climate and land use changes on water yield in the upstream regions of the Shule River Basin. *Water*, *13*(9), 1250.
34. Yang, D., Qin, Y., Xu, Y., Xing, K., Chen, Y., Jia, X., Aviso, K. B., Tan, R. R., & Wang, B. (2024). Sequestration of carbon dioxide from

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

the atmosphere in coastal ecosystems: Quantification, analysis, and planning. *Sustainable Production and Consumption*, *47*, 413–424.
35. Yoro, K. O., & Daramola, M. O. (2020). CO2 emission sources, greenhouse gases, and the global warming effect. In *Advances in carbon capture* (pp. 3–28). Elsevier.