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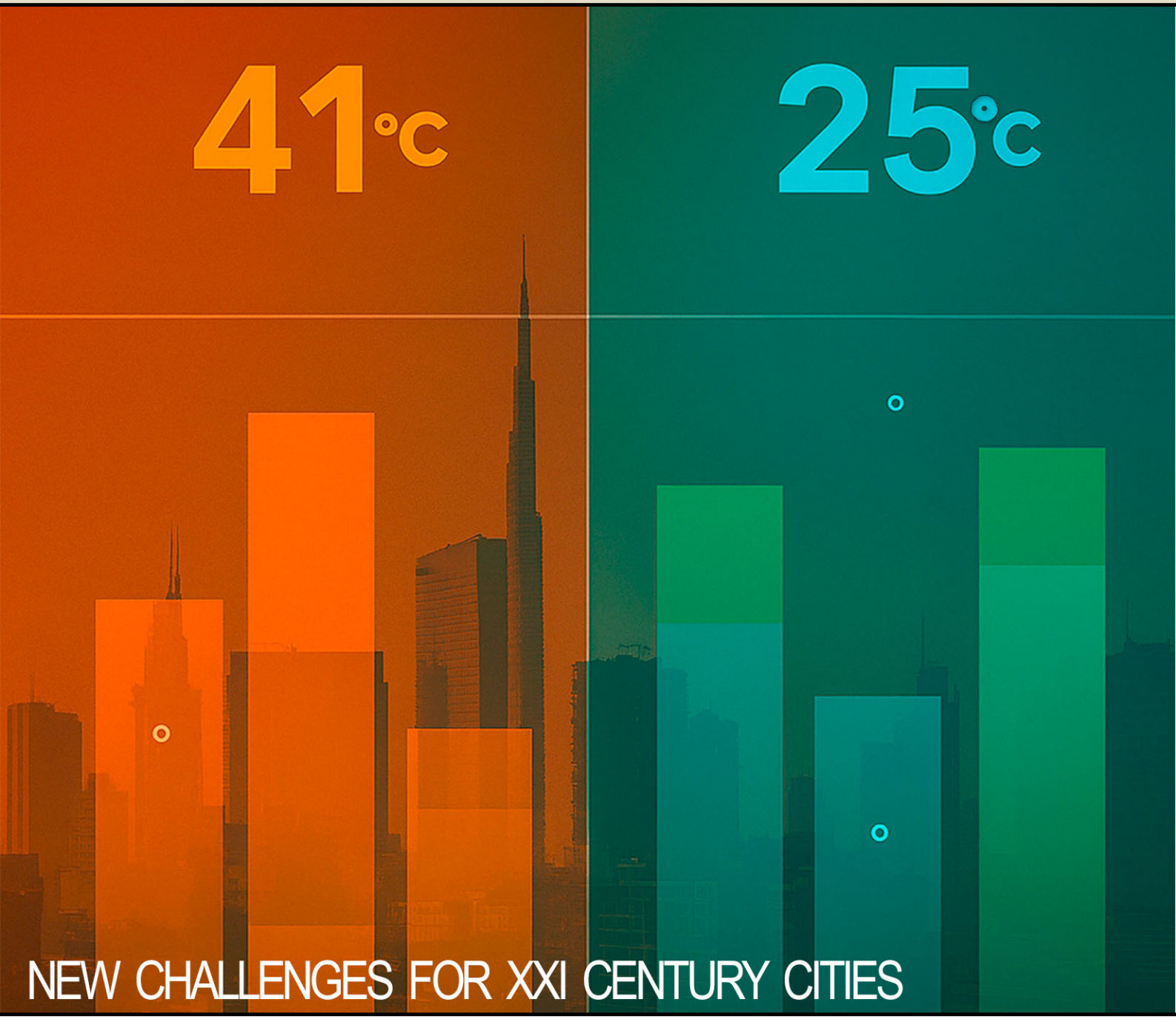

NEW CHALLENGES FOR XXI CENTURY CITIES

Multilevel scientific approach to impacts of global warming on urban areas, energy transition, optimisation of land use and emergency scenario

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Assessing the impacts of climate change on peri-urban land use in Nigeria. A study of Ibeju-Lekki LGA, Lagos State

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Abstract
The study investigated the impact of climate change on land use dynamics in the peri-urban region of Nigeria, focusing on Ibeju-Lekki Local Government Area (L.G.A.) in Lagos State. Integrating both primary and secondary data, the study deployed a structured questionnaire which was administered among 125 respondents across three peri-urban communities in Ibeju-Lekki: Imobido, Idaso, and Ilege. Geographic Information System (GIS) tools, alongside Landsat 7 and 8 imagery, were used for comprehensive land use and land cover (LULC) analysis. The Normalized Difference Vegetation Index (NDVI) was employed to quantify temporal changes in vegetation cover, revealing notable shifts in land use patterns. Findings underscore significant LULC changes within Ibeju-Lekki, reflecting the extensive influence of climate change on land management and urban planning in rapidly urbanizing peri-urban areas. The study highlights the necessity for integrated, adaptive land use policies that address climate-induced challenges and promote sustainable development. These insights offer policy recommendations aimed at enhancing resilience in land use systems, fostering a model for sustainable urban expansion in similar coastal communities.

Keywords
Climate change; Land use and land cover; Peri-urban; Geographic information system; Flooding

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1. Introduction

Climate change, as asserted by Ahove et al. (2021), stands out as a prominent global environmental concern that has garnered widespread attention due to its multifaceted impacts. It represents a singular issue that has spawned a multitude of related challenges, including but not limited to flooding, rising sea levels, warming oceans, heightened temperatures, fluctuations in rainfall patterns, increased evaporation rates, and the intensification of tropical storms. These consequences have manifested in various adverse effects, such as diminished agricultural productivity, drought occurrences, population displacement, public health issues, conflicts between farmers and herders, inundation events, soil erosion, food insecurity, and poverty. Moreover, additional ramifications are anticipated as the full extent of climate change unfolds. Since the early 1990s, climate change has gained prominence as a significant concern for development, primarily owing to its anticipated effects on biodiversity, rural communities, and both national and global economies. The adverse impacts of climate change are expected to disproportionately affect impoverished nations and individuals, who possess limited institutional support, financial resources, and technological capabilities necessary for adaptation (Ogunnaike et al., 2013). Extreme weather events of rare severity that are expected to occur within a 100-year frequency have been noted in almost all regions of the world challenging the traditional forecasting patterns (Pennino, 2024). Climate change is usually caused by the rising average temperature of the earth due mainly to global warming and majorly Human activities, particularly widespread land-use change, large-scale deforestation, and prolonged reliance on fossil fuels, can worsen climate change. Land use is a process of turning the natural ecosystem (land cover) into a socioeconomic ecosystem (Olokeogun et al., 2014). Over time, the rise in population and human activities, such as the conversion of natural land cover such as forests and wetlands to impervious surfaces like roads and buildings, has significantly disrupted natural ecosystem processes (Ogunlade et al., 2021). Peri-urban areas, located at the interface between urban and rural zones, experience dynamic land use changes driven by urban expansion, population growth, and economic development (Tacoli, 2003). These areas often serve as transitional zones where agricultural lands are converted to residential, commercial, and industrial uses, leading to significant alterations in land use patterns (Varkey, 2019). The vulnerability of peri-urban areas to climate change is heightened by their exposure to both urban and rural stressors, making them critical zones for studying the impacts of environmental changes on land use.

As cities expand and develop, they often drive significant changes in land use and land cover, triggering a cascade of ecological consequences. These changes pose substantial challenges to achieving environmental sustainability at both local and global scales. In recent decades, a growing concern has emerged: the ability of ecosystems to provide essential services, such as food production, freshwater resources, healthy forests, and climate and air quality regulation, is increasingly under threat. Addressing this challenge necessitates a delicate balancing act: meeting immediate human needs while safeguarding the biosphere's long-term capacity to provide these vital goods and services (Adewale et al., 2024). Sustainable development has become a cornerstone principle in land-use planning, emphasizing both the preservation of natural resources and the promotion of land-use patterns that are beneficial ecologically, socially, and economically (Leitão & Ahern, 2002).

As opined by Kebede et al. (2024), the factors influencing land use and cover change are complex, dynamic and vary between locations. The changes also are mostly as a result of both natural and human factors. Scholars have raised concerns regarding the ecological aspects of land-use planning, particularly within the framework of human-environment interactions. This framework emphasizes the interconnectedness of spatial and social dimensions within urban ecosystems (Pickett et al., 2001; Grimm et al., 2008).

Climate change, primarily driven by human activities and the emission of greenhouse gases, has become a significant issue with major political and economic consequences. The scientific agreement on this matter has

grown stronger, as highlighted in the Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report of 2007 (IPCC, 2007).

Nigeria on the other hand was also identified as one of the nation's most susceptible to the impacts of climate change (Okafor et al., 2025). This vulnerability is evidenced by the escalating instances of drought and desertification in the northern regions, as well as coastal flooding and erosion in the southern areas. A notable obstacle confronting Nigeria involves harmonizing its trajectory with the global trend toward low-carbon development, a daunting task given its heavy reliance on the oil and gas sector. This dilemma is particularly evident along the Lagos coastline, where the adverse effects of climate change, including rising sea levels and intensified weather extremes, disrupt both the physical landscape and socioeconomic frameworks (Okeke, 2022).

In Lagos and other subtropical regions, the most concerning impacts of climate change includes; increased flooding, environmental degradation, heightened pest and disease outbreaks on crops, depletion of household resources, rural-urban migration, biodiversity loss, wildlife depletion, shifts in vegetation types, declining forest resources, soil degradation (including moisture and nutrient depletion), increased health risks from infectious diseases, and disruptions to traditional livelihoods. Nigeria, being a developing country, is particularly vulnerable to the negative effects of climate change due to its heavy dependence on agriculture and natural resources for both sustenance and economic stability (Onyeneke et al., 2019). Ibeju-Lekki, a region within Lagos State, exemplifies a rapidly urbanizing area that is also highly susceptible to various climate change impacts, such as sea level rise, extreme weather events, and changes in rainfall patterns (Adelekan, 2010).

One major issue in Ibeju-Lekki is the spread of urban development into areas that were previously rural or semi-rural, resulting in the loss of agricultural land and natural habitats (Ajibade, 2017). This expansion not only changes the landscape but also threatens the livelihoods of local communities that rely on farming and natural resources. Additionally, the absence of effective land use policies and enforcement is exacerbating these problems, leading to unplanned and chaotic development. Moreover, the interaction between climate change and land use in Ibeju-Lekki is worsening environmental degradation. Problems like soil erosion, flooding, and water scarcity are becoming more common, undermining the area's ecological stability and resilience (Ndimele et al., 2024). These environmental changes are not only transforming the physical landscape but also posing serious risks to the socio-economic well-being of the local population.

Therefore, there is an urgent need for thorough research to understand the specific impacts of climate change on peri-urban land use in Ibeju-Lekki. This research investigates the impact of climate change on the interplay between land use and land cover (LULC) alterations in the peri-urban region of Ibeju-Lekki spanning from 1993 to 2023. The assessment of climate change impacts on land use in Ibeju-Lekki is crucial for understanding the interplay between environmental changes and human activities in peri-urban areas. By examining the effects of climate change on land use patterns, this study aims to provide insights into how climate-induced changes influence land allocation, resource management, and sustainable development in Ibeju-Lekki. Understanding these dynamics will aid in the formulation of adaptive strategies and policies to mitigate the adverse effects of climate change and promote resilient land use practices in peri-urban areas.

This research will provide crucial insights into how land use is changing in response to climate variability and help develop sustainable land use strategies that can reduce the negative effects of climate change while encouraging resilient and adaptive urban growth.

This was done by raising the following objectives: ascertain the various land uses in the study area; examine the extent to which climate change has affected land use in Ibeju-Lekki between 2003 and 2023; assess the vulnerability of different land use types to climate change impacts; identify adaptation and mitigation strategies to enhance the resilience of land use systems and finally, analyze the anticipated land use changes over the next decade.

2. Materials and methods

2.1 Research design

Both qualitative and quantitative methodologies was employed in this study, which included case study research design and geospatial analysis. Terrain changes related to land use, vegetation, and ecosystem services were evaluated. Utilizing remote sensing and geographic information systems, the study analyzed the impact of urban land use change effect on ecosystems and their services in Ibeju Lekki, assessing its repercussions on human well-being. The ultimate goal is to propose effective strategies to alleviate the impact of climate change on land use changes and its effects in this specific area.

2.2 Data collection

The primary data collection method involved the distribution of questionnaires to residents and the use of semi-structured interview guides with officials from the various State Government ministries, departments, and agencies in Ibeju Lekki. Additionally, historical satellite datasets were acquired from the United States Geological Survey (USGS). These datasets consisted of unprocessed but high-quality Landsat images captured in, 2003, 2013, and 2023, with specific details needed. These data will be employed to conduct spatio-temporal analyses of land cover changes, thereby examining shifts in land use and land cover within Ibeju Lekki over the specified study period. To supplement this analysis, Google Earth will be utilized to access historical information about Ibeju Lekki, aiding in ground-truthing efforts and the identification of key areas susceptible to significant changes in land cover. The secondary data sources for this research will include government reports and statistics between 1993 and 2023, which will be obtained from the Ministry of Lands in Lagos State. Population data will be obtained from the National Bureau of Statistics to project the population of Ibeju Lekki. Other data regarding historical temperature, human well-being, and ecosystem services will be obtained from academic journals, technical reports, conference proceedings and newspapers.

2.3 Study area

Ibeju-Lekki encompasses an approximate land area of 445 km², representing a significant portion of Lagos State's landmass, situated within the creek zone of tropical South-western Nigeria. Its geographical coordinates are Latitude 6029'36" N, Longitude 3043'14" E, and Latitude 6023'21" N, Longitude 4021'31" E. According to the 2006 Census data, the population of Ibeju Lekki was recorded as 117,793 individuals, with projections indicating an expected population increase to 388,226 by 2023, reflecting a growth rate of 3.2%. The region is characterized by relatively flat terrain, with an elevation of approximately 6.40m, and experiences a tropical climate featuring distinct rainy and dry seasons typical of a tropical monsoon climate. Rainy seasons occur from April to July, with a secondary rainy period, while a brief dry spell occurs in August and September, followed by a more extended dry season from December to March (Folorunso et al., 2024; Olomolatan et al., 2024; Adebisi et al., 2016). Notably, the Lekki Free Trade Zone (LFTZ), Dangote refinery and numerous housing estates are located within the Ibeju-Lekki local government area (LGA) of Lagos state, Nigeria. The area predominantly supports rural communities whose livelihoods depend on natural resource-based activities such as fishing, farming, and oil palm processing. It boasts an environmental landscape characterized by mangrove wetlands along the coasts of the Lekki Lagoon and lush tropical vegetation in central and lower areas, with the Atlantic Ocean and Lekki Lagoon serving as the primary water bodies in the region. These coastal features create a conducive environment for a variety of marine fish, which are crucial for the local economy. Additionally, the predominant soil type in the area is sandy and loosely loamy swamp marsh soil, ideal for palm trees and coconut farms, thereby supporting the promotion of ecotourism in Ibeju-Lekki. Consequently, the abundant marine and terrestrial resources fuel rapid development in the area (Uddin et al.,

2021; Adedire & Adegbile, 2018). Fishing serves as the primary source of income in Ibeju Lekki, supplemented by activities in hospitality, ecotourism, and housing development.

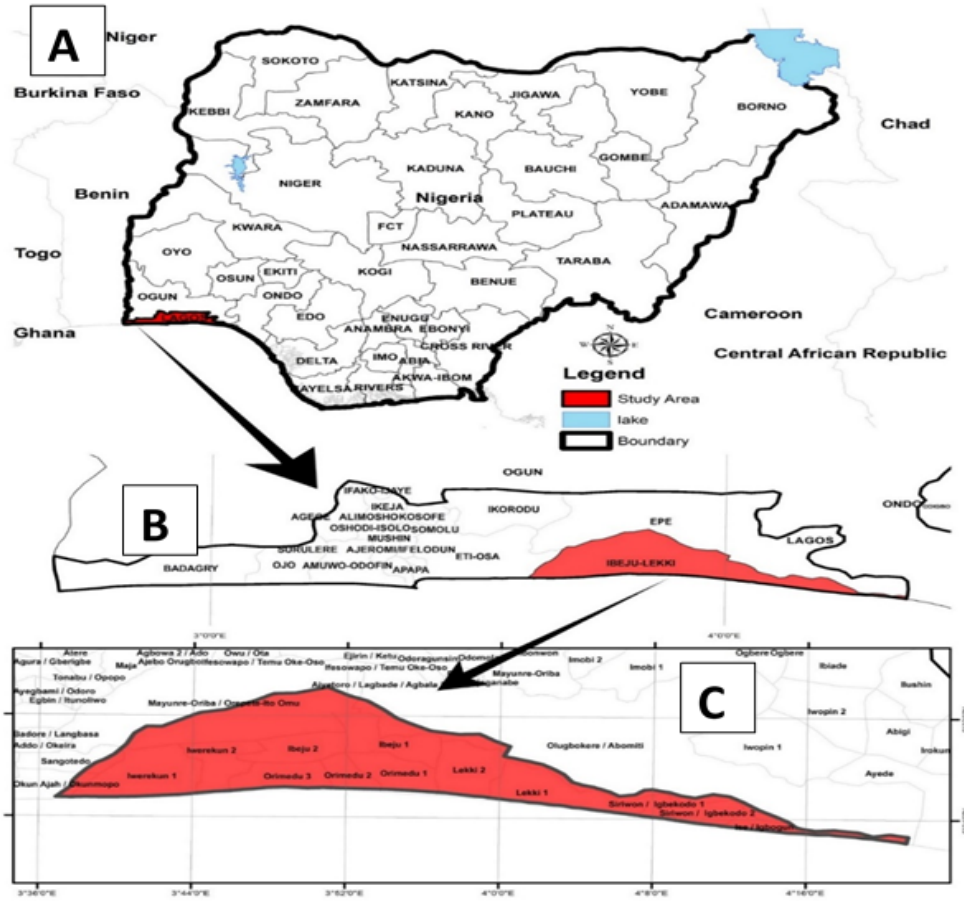


Fig.1 (A) Map of Nigeria showing Lagos State in the National Context, (B) Map of Lagos State showing Ibeju Lekki and (C) Map of Ibeju Lekki showing surrounding communities

2.4 Sample, sampling technique and data collection

The study population includes the companies, stakeholder groups, and communities along the Free Trade Zone and Dangote Refinery in Ibeju Lekki. From a preliminary investigation, 24 companies, 12 other stakeholder groups, and 15 communities are found in the free trade zone at Ibeju Lekki. Interview guide was adopted to elicit information from the companies and other stakeholder groups, while questionnaires were used for the communities. Three communities were randomly selected for questionnaire administration using the Random Number Generator of the SPSS package. The three communities are Ilege, Idasho, and Imobido. The systematic random sampling technique with replacement was adopted to select 20% of the buildings in each community for questionnaire administration. The Random Number Generator in the SPSS Application was used to select the first sample, and then every 5th building was selected for questionnaire administration. Where the selected building on the map is discovered to be commercial, religious or industrial purposes on the ground, it will be replaced with the nearest residential building. The selected sample is as seen in Tab.1.

Settlements	No. of buildings	Sample size (20%)
Ilege	171	34
Idasho	250	50
Imobido	204	41
Total	625	125

Tab.1 Selected settlements and sample size. Source: Authors' Field Work (2024)

Geographic Information Systems and Remote Sensing (GIS & RS) techniques were employed to perform a geospatial analysis regarding the land use land cover change analysis and Normalized Differential Vegetation Index (NDVI) in Ibeju Lekki. NDVI is a common tool used as an indicator to analyze the vegetation and the biomass of an area using multi spectral satellite images (Dahanayake et al., 2024). This involved using historical Landsat data in spatial analysis to ascertain changes over the years in the selected parameters. The Maximum Likelihood (ML) Classification Algorithm technique will be used for the classification. Map algebra script was used to generate spectral indices for the NDVI.

2.5 Data analysis

After obtaining Landsat imageries for 1993, 2003, 2013, and 2023. The images were pre-processed to establish a proper relationship between the acquired satellite data and various biophysical conditions (Abd El-Kawy et al., 2011). This is vital in rectifying and removing various atmospheric conditions from satellite images. A geometrically corrected satellite imagery is vital for successive land cover mapping and change detection analysis (Hassan et al., 2016). The study area was delineated using Google Earth Imagery and digitized into a polygon feature class using ArcGIS 10.8. This was overlaid on the acquired historical Landsat datasets. Appropriate band compositions were made using the Raster Processing algorithm in ArcGIS 10.8 for land use and land cover changes. The clip function was used to delineate the Landsat imageries using the digitized feature class as a mask. This enabled attribute of the study area to be obtained for the various years, displaying the different land uses and land cover.

From the Image Classification algorithm, a supervised classification function was adopted to create training samples, which was subjected to the Maximum Likelihood Classification technique. This produced classification including built-up areas, forest/vegetated areas, bare ground, and water bodies based on the study of (Anderson et al., 1976). These classifications were overlaid on a spatially disaggregated ecosystem dataset, which showed different ecosystem biomes in the study area. Hence, to aid the spatial analysis for detecting the ecosystem biomes that have depleted over the years through changes in spectral indices. The simple benefit transfer, as used by (Costanza et al., 2014) and (Popoola et al., 2018), was used to monetarily quantify the ecosystem services in Ibeju Lekki for the year 1993 as well as the changes in value by the year 2023. Maps will be produced to show areas of change and will be highlighted in percentages for the years considered. Classifications made for the Land Use Land cover map are seen in Tab.2.

Classifications	**Method of data collection**
Built-up areas	Residential, commercial, industrial, government facilities and settlements
Bare Land	Areas cleared for physical development are usually open spaces with little or no vegetation at all.
Dense Vegetation	Areas that are ever green with a high density of trees.
Sparse Vegetation	Open areas with very light vegetation.

Tab.2 Classification made for the Land Use Land cover map. Source: Popoola (2021)

The responses obtained from the companies and stakeholders was analyzed using the Content Analysis method. This method is used mainly in qualitative assessments, especially in interviews and focused group discussions. The responses were transcribed using Microsoft Excel for Content Analysis. The Statistical Package for the Social Sciences (SPSS) was used to enter, code and transpose the responses from the structured questionnaires.

3. Results and discussion

The socio-economic characteristics of the respondents reveal a diverse composition that reflects the dynamics of a peri-urban community undergoing change. The age distribution shows that the majority of the respondents are middle-aged, with 28.8% falling within the 40-50 years age bracket. This indicates that the area is predominantly populated by adults in their prime working years, which could influence local land use dynamics, as these age groups are typically more involved in economic and residential decision-making. However, considering the land use dynamics in the area such as the free trade zone, Dangote refinery and numerous new housing estates with the employment opportunities that come with them, having a working population in such a peri-urban area is not uncommon.

The gender distribution is skewed slightly towards females, who make up 53.6% of the sample. This female predominance is notable in peri-urban areas, where women often play significant roles in household management and informal trading activities, contributing to the local (Lenshie et al., 2021). In terms of educational attainment, most respondents (39.2%) have received secondary education, while a smaller percentage (21.6%) have attained tertiary education. This education profile suggests that the population is relatively well-educated, which could influence their awareness and adaptability to environmental changes, such as those brought about by climate change. Higher levels of education are often associated with greater involvement in decision-making processes and a better understanding of sustainable land use practices. The occupational data reveals that trading and self-employment are the most common occupations, each accounting for 25.6% of the respondents. This highlights the importance of informal economic activities in Ibeju-Lekki, which is consistent with findings in other peri-urban areas where formal employment opportunities are limited, and residents often engage in small-scale trading or entrepreneurship (Adeyinka et al., 2006). The prominence of self-employment and trading in this area underscores the potential vulnerability of these individuals to changes in land use, particularly if commercial spaces are affected by urban expansion or climate impacts such as flooding.

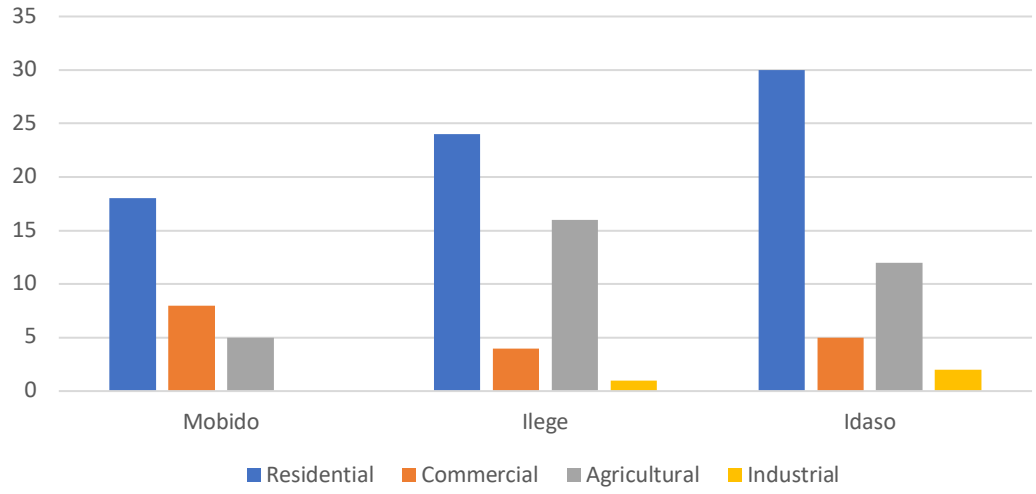
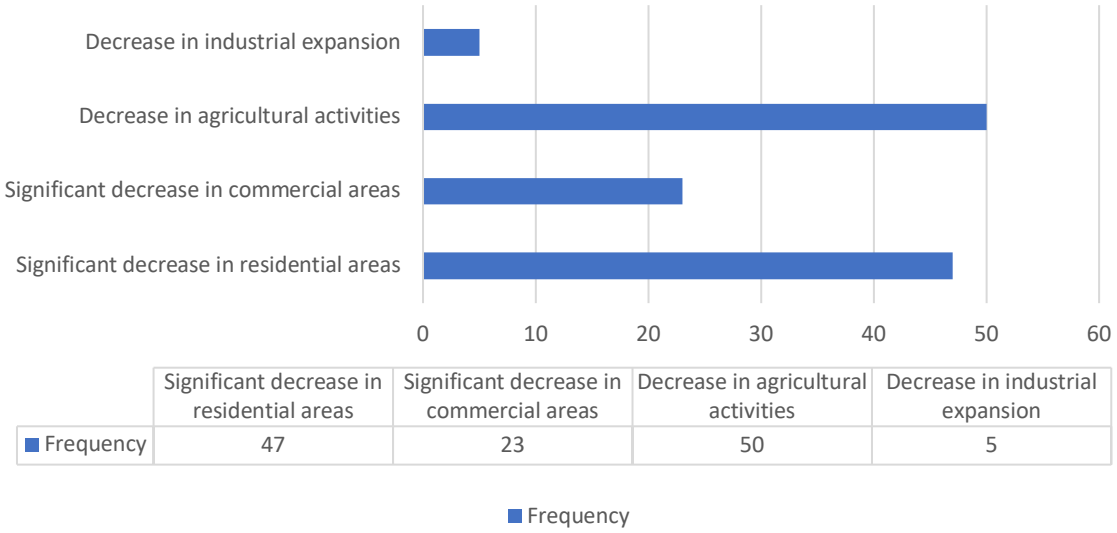


Fig.2 Observed land use types in the study area

The duration of residence data is evenly distributed, with the largest group (26.4%) having lived in the area for 6-10 years. This indicates a stable population that is likely familiar with the local environment and capable of observing long-term changes in land use. A stable, long-term population is crucial in peri-urban areas, as residents' knowledge of land use dynamics can provide valuable insights into how climate change is impacting the landscape.

Overall, the socio-economic characteristics of the respondents suggest a relatively well-educated, and middle-aged population with strong participation in informal economic activities. These factors are likely to influence

both the community's land use patterns and their ability to adapt to climate change. The prominence of trading and self-employment could drive increased demand for commercial and residential land, while their relatively high-income levels suggest that they may have the resources to invest in adaptation strategies for mitigating the effects of climate change.



	Significant decrease in residential areas	Significant decrease in commercial areas	Decrease in agricultural activities	Decrease in industrial expansion
Frequency	47	23	50	5

Fig.3 Perceived primary land use changed over the past 20 years

In response to the first objective which is to ascertain the various land uses in the study area. The results provide insights into the types of land use observed by residents in different areas of Ibeju-Lekki. For each area, Fig.2 shows the distribution of responses across four categories: Residential, Commercial, Agricultural, and Industrial. Overall, the data indicates that Residential land use is the most observed type across all three areas in Ibeju-Lekki. Agricultural use is also notable, particularly in Ilege and Idaso. Commercial and Industrial land uses are less prominent, suggesting that these types of land use are relatively less developed or less frequently encountered in these areas. The results reveal a clear pattern of land use distribution across the Ibeju-Lekki Local Government Area, as seen in the responses from the survey. The most dominant land use observed by residents across all areas is residential, which underscores the ongoing urbanization in the region. This trend is consistent with other peri-urban areas in Nigeria, where rapid population growth and urban sprawl are driving increased residential development (Olokeogun et al., 2014). Specifically, in Ilege and Idaso, residential land use is particularly prominent, indicating that these areas are experiencing significant housing demands, likely fueled by the proximity to Lagos and the expansion of the city into formerly rural areas.

Agricultural land use, though less dominant, remains notable in areas like Ilege and Idaso. The persistence of agriculture in these regions suggests that despite urbanization, some traditional farming practices continue, likely due to the dependence on agriculture for local food production and livelihoods. However, the lower presence of commercial and industrial land use points to the relatively underdeveloped state of these sectors. This may reflect the peri-urban nature of Ibeju-Lekki, where the focus remains on housing and agriculture, with commercial and industrial development lagging behind. Similar patterns have been observed in other coastal regions, where peri-urban areas function primarily as residential and agricultural hubs, with slower economic diversification (Adedire & Adegbile, 2018).

The data presented in Fig.3 illustrates the perceived changes in primary land use in Ibeju-Lekki over the past 20 years. The most notable change reported by respondents is a decrease in agricultural activities, with 40% indicating a significant reduction. This suggests a shift from traditional agricultural practices, possibly due to urbanization, land conversion, or environmental factors that make farming less viable. The data reveals that all 125 respondents (100%) observed a significant change in the primary land use within their communities in Ibeju-Lekki. This unanimous response underscores a widespread recognition of land use transformations,

suggesting that the area has undergone substantial shifts in its landscape. Such changes are likely influenced by both anthropogenic factors, including urban expansion and economic activities, as well as environmental pressures, particularly those related to climate change. The observed land use changes align with global patterns, where peri-urban areas, especially in developing countries, experience rapid land transformations due to urbanization pressures and economic development (Seto et al., 2011). In Ibeju-Lekki, the growing population and urban sprawl have likely contributed to the conversion of agricultural and natural lands into residential, commercial, and industrial uses. This is consistent with the findings from other studies in peri-urban regions of Lagos State, where the demand for housing, infrastructure, and commercial spaces has intensified land conversion (Folorunso et al., 2024).

Moreover, climate change may be accelerating these land use changes by making certain types of land, such as agricultural areas, less viable. For instance, increased flooding, coastal erosion, and other environmental challenges could be pushing communities to abandon traditional land uses in favor of urban development, which is perceived as more resilient or profitable in the long term (Folorunso et al., 2024). This dynamic is evident in other coastal areas of Nigeria, where climate-induced changes in land and water resources have led to shifts in land use patterns (Abija et al., 2020). The unanimous recognition of land use changes by the respondents also highlights the importance of local perceptions in understanding environmental transformations. Communities are often the first to experience the effects of land use changes and can provide valuable insights into the drivers and consequences of these shifts. This participatory approach to assessing land use changes is critical in developing context-specific adaptation and mitigation strategies (Turner et al., 2016). Respondents' perceptions in this study confirm that climate change is playing a crucial role in shaping land use. This is further compounded by the growing demand for housing as Lagos expands, pushing urban boundaries further into peri-urban areas like Ibeju-Lekki.

Type of Change Observed	Strongly agree [%]	Agree [%]	Disagree [%]	Strongly disagree [%]
Increased flooding in agricultural land use	6.4	32.0	44.0	17.6
Increased flooding in residential land use	9.6	44.8	27.2	18.4
Coastal erosion in residential areas	7.2	16.0	60.0	16.8
Coastal erosion in agricultural areas	5.6	5.6	69.6	19.2
Destruction of road infrastructure by erosion	7.2	16.0	62.4	14.4
Sea level rise	32.0	24.0	44.0	0.0

Tab.3 Perceived environmental changes and their impact on land use and infrastructure

To examine the extent to which climate change has affected land use in Ibeju-Lekki between 2003 and 2023 was the second objective of this study, Tab.3 presents the respondents' perceptions of various environmental changes, focusing on the impact of flooding, coastal erosion, destruction of infrastructure by erosion, and sea level rise. Increased flooding emerged as a critical issue, with 48 respondents agreeing or strongly agreeing that agricultural land has been affected by flooding, while 77 respondents reported flooding in residential areas. This indicates that flooding is a dominant environmental challenge, particularly in built-up areas where urban expansion may have exacerbated the problem due to inadequate drainage systems (Folorunso et al., 2024). Coastal erosion was perceived as less impactful, with only 29 respondents expressing concerns about its effects on residential areas, and even fewer (14 respondents) indicating it as a concern for agricultural land. This suggests that while erosion is a present risk, it may not yet be as widespread as other challenges, though it could increase in severity as sea levels continue to rise (Choukri et al. 2024). The destruction of infrastructure by erosion was acknowledged by 29 respondents, further highlighting the vulnerability of the region's transportation and public infrastructure to climate change. Erosion's impact on roads and bridges

could exacerbate economic challenges, hinder trade and mobility. Meanwhile, 70 respondents agreed or strongly agreed that sea level rise is a significant concern. This aligns with broader predictions of rising sea levels in coastal Nigeria, where low-lying areas are at heightened risk of inundation (Akiyode, 2024). These findings collectively demonstrate that flooding and sea level rise are the most critical environmental challenges affecting land use in Ibeju-Lekki, with potential long-term consequences for residential and agricultural land, as well as infrastructure. Land use allocations for development are severely affected by the possibilities of what a particular piece of land can achieve based on its topography. Whilst a particular portion of land may be needed for residential dwellings due to the high cost of accommodation in the urbanized areas of the city, it is practically impossible to address this need in a peri-urban location like ibeju-lekki due to the flooding issues faced by the community. It is important to note here that on-going developmental activities on the lekki free trade zone and Dangote estate are very high capital-intensive projects that can only be undertaken by the financially capable establishments and not individuals. The ibeju-lekki axis provides them with the needed space (land) at a cheaper ownership rate irrespective of the topography.

Impact on Livelihoods or Daily Activities	Percent
Reduced agricultural productivity	17.6%
Relocation due to flooding or erosion	44.8%
Increased cost of living	37.6%
Total	100.0%

Tab.4 Impact of environmental changes on livelihoods or daily activities

Tab.4 details the perceived impact of environmental changes on the livelihoods of the respondents. A significant proportion (44.8%) of respondents reported relocation due to flooding or erosion, indicating the displacement of communities as a major outcome of climate change in the region. Displacement is a common response to environmental hazards in coastal areas, where increased flooding and erosion make certain locations uninhabitable (Luederitz et al., 2015).

Land Use Types	2003 Land Use		2013 Land Use		Difference (2003-2013)		2023 Land Use		Difference (2013-2023)	
	sq. km	%	sq. km	%	sq. km	%	sq. km	%	sq. km	%
Water Body	13.235	3%	12.378	3%	-0.857	0%	16.107	4%	3.729	1%
Dense Vegetation	172.679	38%	162.86	36%	-9.819	-2%	124.69	27%	-38.17	-8%
Sparse Vegetation	100.889	22%	145.838	32%	44.95	10%	150.623	33%	4.785	1%
Bare Land	138.63	30%	61.216	13%	-77.414	-17%	60.868	13%	-0.348	0%
Built-Up Area	32.242	7%	75.38	16%	43.138	9%	105.381	23%	30.001	7%
Total	457.675	100%	457.672	100%	-0.003	0%	457.669	100%	-0.003	0%

Tab.5 Land use/land cover analysis of Ibeju-Lekki 2003, 2013 and 2023

Additionally, 37.6% of respondents reported increased living costs, which can be attributed to the economic strain imposed by environmental changes. As infrastructure deteriorates and agricultural productivity declines, the cost of goods and services in the region increases, placing additional pressure on local populations. This economic burden is particularly evident in the reduction in agricultural productivity, as reported by 17.6% of respondents. The loss of arable land due to flooding and erosion reduces the viability of farming, further

threatening food security in the region. These findings align with broader research on the socio-economic impacts of climate change, where vulnerable populations often bear the brunt of environmental challenges, experiencing both displacement and economic hardship (Akiyode, 2024). The results underscore the need for adaptation strategies that address both environmental and socio-economic vulnerabilities in Ibeju-Lekki.

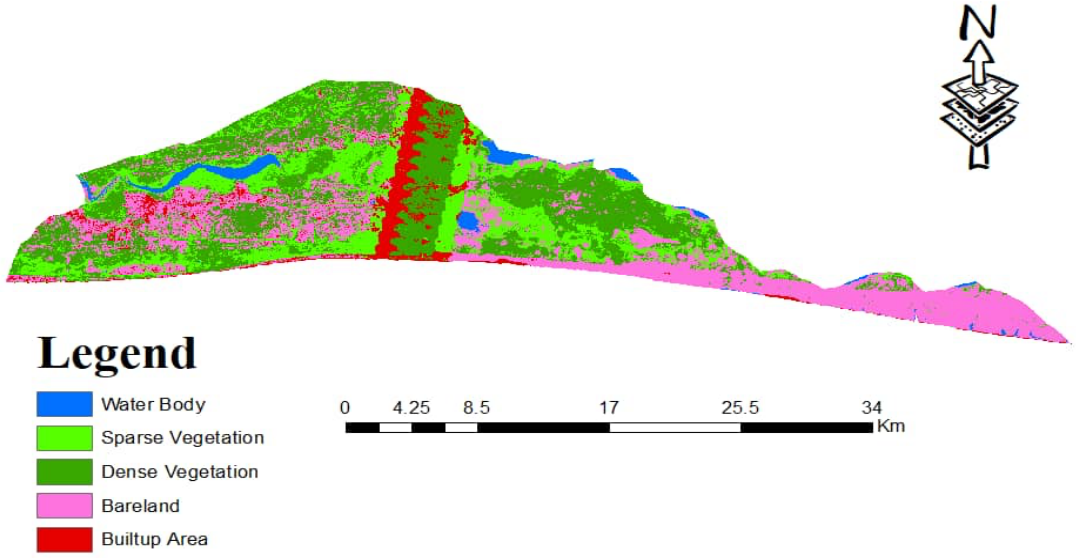


Fig.4 Land use/Landcover of Ibeju-Lekki for 2003

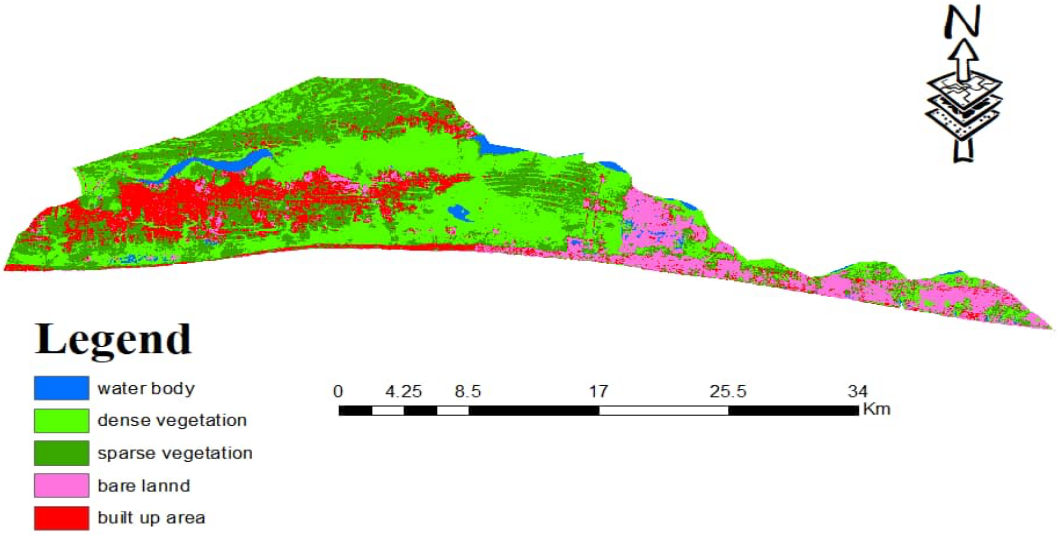


Fig.5 Land use /Landcover of Ibeju-Lekki for 2013

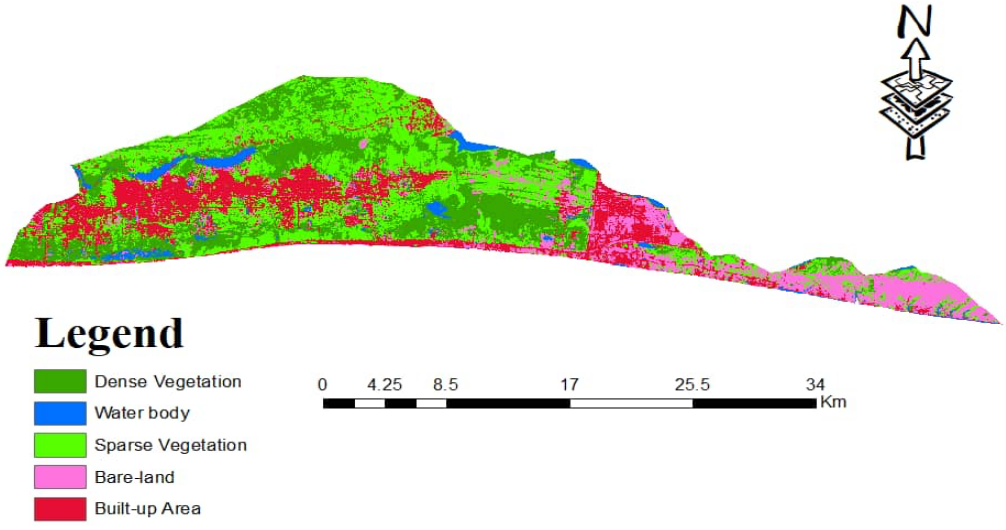


Fig.6 Land use /Landcover of Ibeju-Lekki for 2023

Tab.5 and Fig.4, 5 and 6 went on to show the comparative land use analysis between 2003 and 2023 revealing significant shifts in the landscape of Ibeju-Lekki. The data shows a sharp decline in bare land (-77.41 sq. km), accompanied by a substantial increase in built-up areas (+43.14 sq. km) between 2003 and 2023, reflecting rapid expansion/urbanization over the decade. These changes suggest a shift from rural to urban land use, driven by population growth and economic development in line with the study of Dahanayake et al., (2024) where environmental stressors like land reclamation, and excessive use of natural resources have been noted as a major contributor to the decline of bare lands. Furthermore, Ibeju-lekki currently embodies ongoing infrastructural projects such as the Free Trade Zone, numerous new housing estates and Dangote Refinery as mentioned earlier so it is not uncommon to see a sharp decline in bare land and increase in built up areas.
Sparse vegetation saw a significant increase of 44.95 sq. km in 2013 and a further 4.79 sq.km increase in 2023, indicating land clearance for development or agricultural purposes. This jump also suggests degradation of dense vegetation or abandoned agricultural lands. Meanwhile, dense vegetation declined by 9.82 sq. km in 2013, and even further in 2023 by 38.17 sq. km, representing the loss of forested areas, likely due to both human activity (conversion to industrial zones) and environmental factors such as deforestation and climate change. The reduction of natural vegetation is concerning, as it diminishes the region's ability to mitigate the effects of flooding and erosion (Ogundele et al., 2018; Nifosì et al., 2024). The reduction of natural vegetation has also been noted to reduce carbon sequestration thereby accelerating climate change, increasing local vulnerability to heatwaves, flooding, and ecosystem imbalance. Water bodies remained relatively stable, with a minor reduction of 0.86 sq. km in 2013 but however increased by 1% in 2023, suggesting that changes in water coverage were less significant during this period. However, the expansion of built-up areas highlights the need for careful urban planning to ensure that future development does not exacerbate the vulnerability of the region to climate-related hazards.

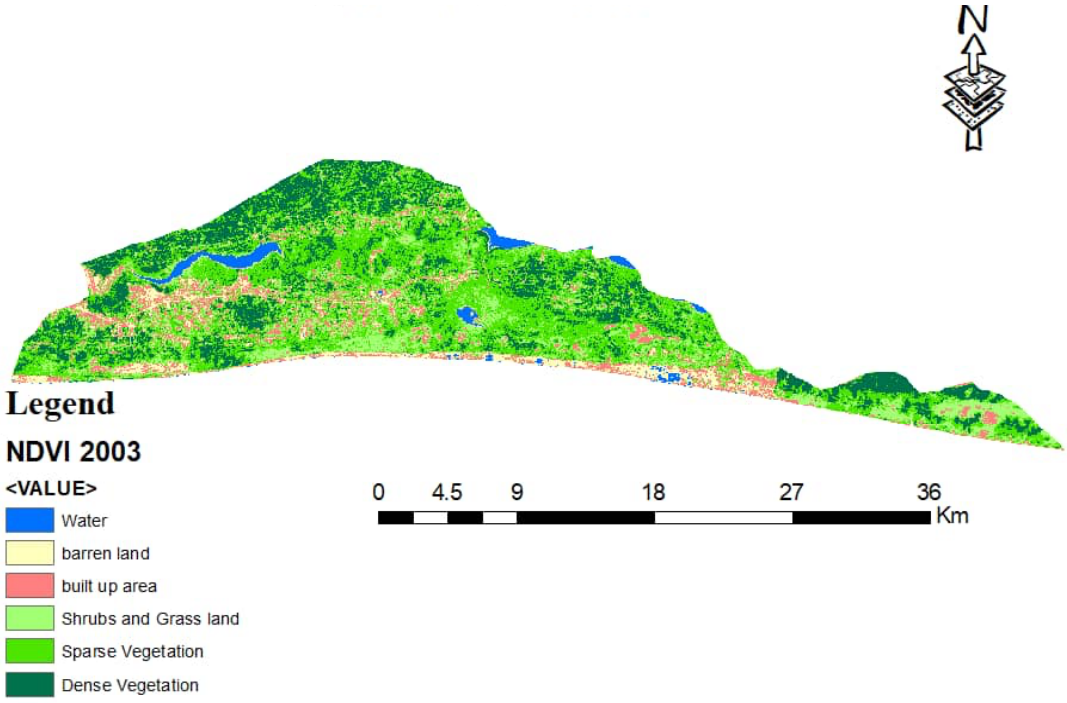


Fig.7 NDVI Analysis of Vegetation Change in Ibeju-Lekki: 2003

Fig.ss 7, 8 and 9 showed the Normalized Difference Vegetation Index (NDVI) values for the years 2003, 2013, and 2023 highlight significant changes in vegetation cover within the Ibeju-Lekki region. In 2003, areas with NDVI values between 0 and 0.3115, represented by green patches in Fig.7, indicate the presence of vegetated areas, predominantly shrublands and grasslands. Coastal regions during this period were still largely covered by marine shrub and grassland, with some areas showing NDVI values ranging between 0 and -0.1052,

reflecting bare surfaces and sandy regions. This observation aligns with the findings of Crippen (1990) and Bid (2016), which state that NDVI values near zero correspond to barren areas such as sand, rock, or snow, while positive values indicate varying levels of vegetation.

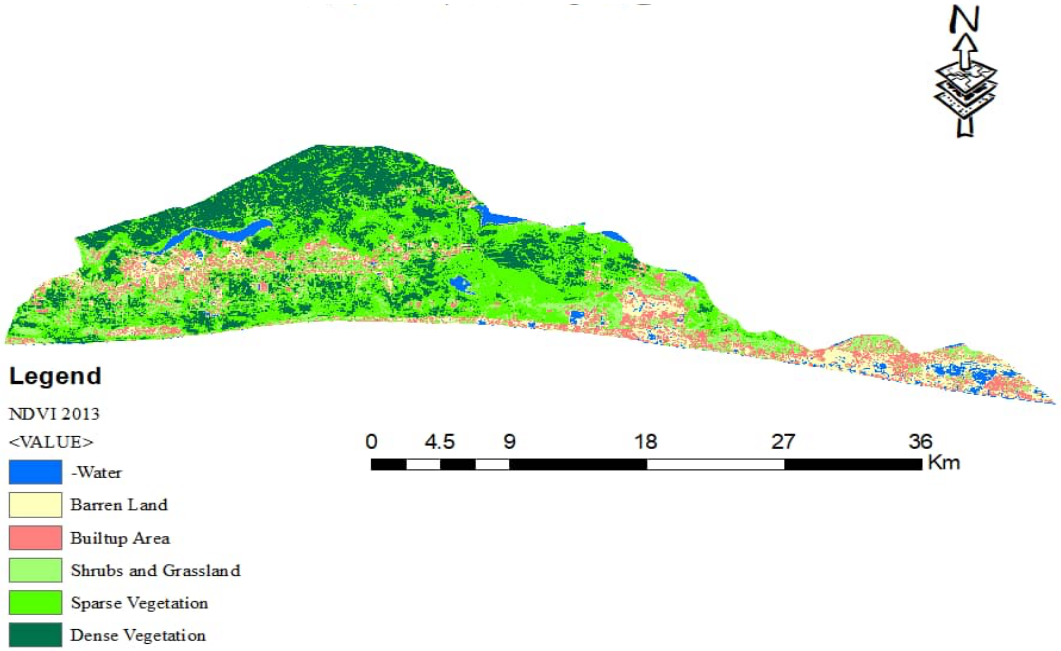


Fig.8 NDVI Analysis of Vegetation Change in Ibeju-Lekki: 2013

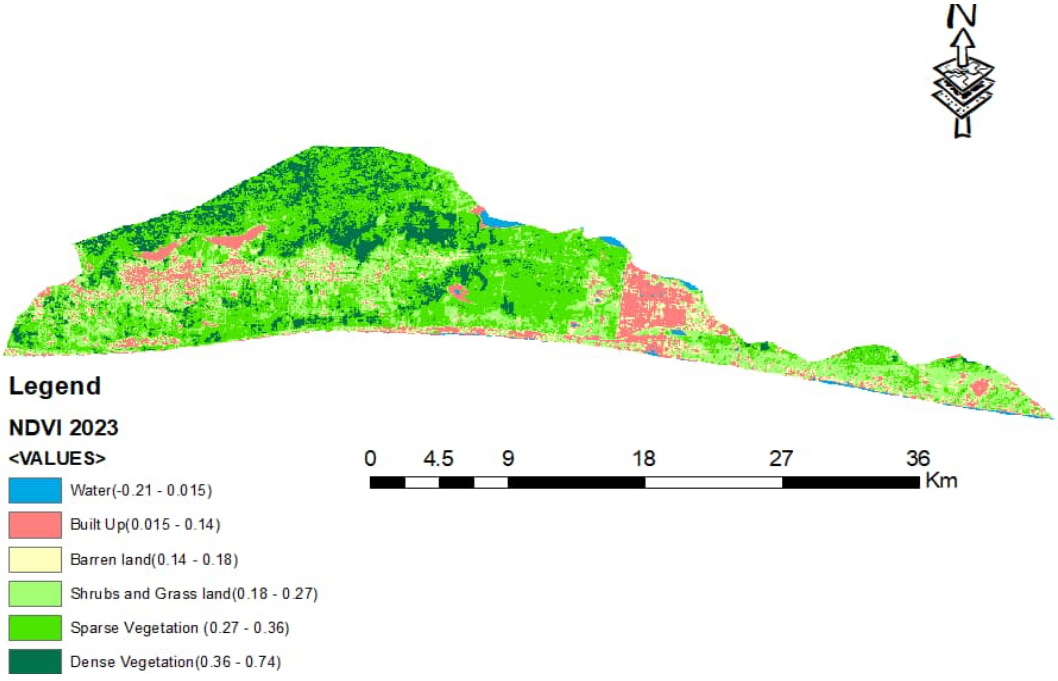


Fig.9 NDVI Analysis of Vegetation Change in Ibeju-Lekki: 2023

By 2013, as shown in Fig.8, the NDVI range expanded slightly, with values between 0 and 0.4270 indicating further degradation of vegetation, as urban expansion and infrastructure development became more prominent in the area. The reduction of shrubs and grassland is evident over the 10-year period, reflecting an ongoing shift towards more built-up areas. In 2023 (Fig.9), the NDVI values range from 0 to -0.0725, further emphasizing the significant loss of vegetation. This is attributed to increased urbanization, with built-up areas and bare surfaces occupying 52.67% and 12.9%, respectively, of land that was once covered by vegetation. Additionally, 0.36% of water bodies have been encroached upon by both urban and bare land as a result of population growth and migration. Over the span of two decades, the substantial reduction of vegetation, 95%

of which was replaced by urban development, indicating a rapid rate of deforestation and environmental degradation. The loss of vegetation has serious environmental implications for Ibeju-Lekki, a low-altitude region where vegetation serves a crucial role in mitigating surface runoff, erosion, and large-scale flooding. The continued depletion of vegetation in favor of urban infrastructure increases the area's vulnerability to these climate-related risks, undermining the ecological balance and contributing to worsening environmental conditions in the region.

Land Use Type	Vulnerable	Not Vulnerable	Total
Flooding			
Residential	50.40%	49.60%	100%
Commercial	40.00%	60.00%	100%
Agricultural	48.80%	51.20%	100%
Industrial	37.60%	62.40%	100%
Coastal Erosion			
Residential	50.40%	49.60%	100%
Commercial	40.00%	60.00%	100%
Agricultural	48.80%	51.20%	100%
Industrial	37.60%	62.40%	100%
Sea Level Rise			
Residential	26.00%	74.00%	100%
Commercial	25.60%	74.40%	100%
Agricultural	31.20%	68.80%	100%
Industrial	20.80%	79.20%	100%
Loss of Vegetative Cover			
Residential	8.00%	92.00%	100%
Commercial	5.60%	94.40%	100%
Agricultural	12.80%	87.20%	100%
Industrial	4.80%	95.20%	100%

Tab.6 Vulnerability to climate change impacts

The third objective, which is to assess the vulnerability of different land use types to climate change impacts illustrated (as seen in Tab.6) that residential areas were of the most concern regarding the perceived vulnerability to flooding. This highlights a significant variation in perceived risk across land use types, with industrial areas as the least. This finding aligns with existing literature that suggests residential areas are often more exposed to flooding due to their higher density and infrastructure vulnerability (Smith & Ward, 1998)
With regards to coastal erosion and sea level rise, the data reveals a consensus that coastal erosion is not a major concern for most land use types. Agricultural land, however, is slightly more perceived as vulnerable compared to other types. This observation underscores the need for enhanced awareness and preparedness regarding sea level rise, particularly for sectors heavily reliant on land and water resources (Nicholls et al., 2011; Boglietti et al., 2024). Tab.6 finally demonstrates that the loss of vegetation cover is perceived as a relatively minor concern across all land use types, though agricultural areas are seen as the most vulnerable. This perception may be linked to the significant role vegetation plays in agriculture, where deforestation and climate change could have pronounced effects. The lower concern for other land uses might indicate either a lower immediate impact or a prioritization of other pressing environmental issues (Lambin & Meyfroidt, 2010).

S/N	Strategies	Percentage
1	Relocation of Residential Communities	32.0%
2	Improved Agricultural Practices	24.8%
3	No Action	20.0%
4	Building Flood Defenses	15.2%
5	Reforestation/Afforestation	6.4%
6	Avoiding the Sea	1.6%

Tab.7 Current Adaptation Strategies for coping with flooding

S/N	Current adaptation strategies for coping with erosion, SLR and LVC	Erosion	SLR	LVC
1	Do Nothing/None	76.8%	70.4%	70.4%
2	Mitigation	2.4%	0.8%	0.8%
3	Planting Trees/Crops	0.8%	0.0%	0.8%
4	Avoiding Certain Areas (Sea Front/Building Near Sea)	0.0%	3.2%	0.0%
5	Clear Path/Return to Sea/Captured by Lake	1.6%	0.8%	0.0%
6	Encouraging Afforestation /Restriction from Cutting Trees	0.0%	0.0%	7.2%
7	Public Awareness/Prevent Indiscriminate Dumping	3.2%	3.2%	2.4%
8	Drainage and Flood Embankments /Creating Defences	0.0%	6.4%	1.6%
9	Other (Self-clearing, Road Construction, etc.)	15.2%	15.2%	16.8%

Tab.8 Current adaptation strategies for coping with erosion, sea level rise (SLR) and loss of vegetative cover (LVC)

In identifying the current adaptation and mitigation strategies to enhance the resilience of land use systems, Tab.7 and 8 reveal a broad spectrum of responses to climate change impacts among the surveyed population. As shown in, Tab.7, the predominant adaptation measures include the relocation of residential communities and improved agricultural practices. These strategies reflect a substantial effort to address climate challenges through significant infrastructural and operational adjustments. However, a noteworthy portion of the respondents indicated the absence of any adaptation strategies, suggesting a substantial gap in active climate response efforts. Other strategies, such as building flood defenses and reforestation/afforestation are less frequently implemented, indicating that while some areas are adopting targeted measures, others are lagging in proactive climate adaptation.

Tab.8 indicates a concerning trend regarding the adaptation strategies for erosion, sea level rise, and loss of vegetation cover. As illustrated, most respondents reported not employing any adaptive strategies, revealing a significant gap in proactive responses to these environmental challenges. Only a small fraction of respondents engaged in "Other" adaptive strategies, which include self-clearing of refuse or participating in local infrastructure improvements such as road construction and drainage activities. Minimal engagement was observed in more targeted strategies, such as afforestation or public awareness campaigns, with very few respondents adopting these measures. The predominance of inaction suggests a critical need for increased awareness and support to foster effective adaptation practices. The data highlights a clear opportunity for intervention to enhance adaptive capacity and resilience among the affected populations.

Anticipated land use changes over the next decade indicate that the next decade will bring significant land use changes in Ibeju-Lekki. Residential development emerged as the most significant anticipated change. This is likely a reflection of the region's expanding population and urbanization (Tab.9). Additionally, some of the respondents expect the development of green spaces and recreational areas, signaling an interest in improving the area’s environmental quality and livability. This finding aligns with broader trends seen in urban planning, where cities prioritize recreational areas to enhance the quality of life for residents, as highlighted in similar

studies by Ubani et al. (2024). Some respondents also foresee a decline in agricultural land, which may be attributed to the encroachment of urban development in rural areas, a trend corroborated by similar findings in (Molla et al., 2024). The anticipated expansion of commercial areas, as noted by a small portion of respondents, supports the region's growing economic significance, especially as Ibeju-Lekki is becoming a commercial hub with projects like the Lekki Free Trade Zone.

Anticipated Land Use Changes in Ibeju-Lekki Over the Next Decade	Frequency	Percentage
Decline in Agricultural Land	17	13.6%
Development of Green Spaces and Recreational Areas	34	27.2%
Expansion of Commercial Areas	16	12.8%
Growth in Sectors	20	16.0%
Increase in Residential Development	38	30.4%

Tab.9 Anticipated Land Use Changes in Ibeju-Lekki Over the Next Decade

Factors	Frequency	Percentage
Climate change impacts	45	36.0%
Economic development	19	15.2%
Government policies	30	24.0%
Population growth	18	14.4%
Technological advancements	13	10.4%

Tab.10 Factors Driving These Changes

Tab.10 suggests that climate change impacts are considered the most influential driver of land use changes. This finding is consistent with studies by Effiong et al. (2024) which emphasize the impact of changing weather patterns on land use decisions, especially in coastal regions and Ibeju-Lekki is not an exception. Government policies were also identified as another major factor. This reflects the importance of policy interventions in shaping land use outcomes, particularly with initiatives to boost housing and infrastructure development. In line with similar research by Assede et al., (2023), economic development, population growth, and technological advancements also play roles in driving land use changes, though to a lesser extent.

4. Conclusion and recommendations

This research underscores the profound impact of climate change and urbanization on land use patterns in Ibeju-Lekki. The rapid conversion of vegetation and agricultural land into built-up areas is driven by both population growth, economic development and environmental pressures such as ongoing infrastructural projects like the Free Trade Zone, numerous new housing estates and Dangote Refinery.

These land use changes have heightened the community's vulnerability to flooding, sea level rise, and other climate change impacts, making it crucial for stakeholders to prioritize sustainable land management practices. The decline in agricultural land poses long-term risks to food security and local livelihoods, while the continued expansion of urban areas without adequate climate adaptation measures increases the risk of environmental degradation. Furthermore, the community's lack of preparedness for climate change exacerbates these challenges, leaving them more susceptible to future environmental threats. It is imperative to note that while natural climate change impacts such as extreme weather events, decline in soil fertility/agricultural land drives the populace to seek adaptation, survival and adaptive strategies in turn become a human-induced (such as deforestation) driver of climate change and the cycle continues.

In summary, Sea level rise and flooding can displace coastal populations putting pressure on upland built-up areas. Varying rainfall patterns degrade dense vegetation thereby leading to an increase in sparse vegetation. Drought and extreme weather can turn a fertile land to bare or land leading to abandonment. Increase in temperature also changes crop viability which affects agricultural land use decisions. As climate change impacts worsens, feedback loops are created, causing further land degradation, deforestation as well as urban sprawl. The relationship can be termed as cyclical and mutually reinforcing, Land use in Ibeju-Lekki has evolved in ways that contribute to climate change, and climate change in turn is reshaping how land is used.

Based on the findings of the study, the following recommendations are made to enhance the resilience of land use systems in Ibeju-Lekki and mitigate the impacts of climate change:

1. Strengthening Infrastructure: The government through the Lagos State Physical Planning Permit Authority (LASPPPA) should prioritize the development of climate-resilient infrastructure to protect communities from the impacts of flooding and sea level rise. This includes enforcing improved drainage systems, flood defenses, rain gardens or buffer zones, permeable pavements and the construction of climate-proof buildings, particularly in vulnerable residential areas. This will help to manage stormwater, reduce urban heat thereby improving resilience.
2. Promotion of Sustainable Land Use Practices: It is essential to integrate sustainable land use practices into urban planning processes. This includes preserving green spaces, promoting afforestation, and preventing the overdevelopment of areas prone to climate risks. Authorities should implement stricter regulations on land use to protect agricultural lands from urban encroachment. Train farmers on Agricultural lands protection through practices like mixed faming systems, cover cropping and organic soil management.
3. Community Engagement and Awareness: There is a need for greater community awareness and involvement in climate change adaptation strategies. Local governments should engage residents in participatory land use planning and offer training programs on climate-resilient agricultural practices, environmental literacy programs on land stewardship, climate change impacts and flood mitigation techniques. Well-informed communities are more likely to participate in conservation and sustainable practices. This will also increase awareness of environmental costs of land misuse. Target groups such as religious institutions, schools and community development associations can be leveraged on.
4. Control Unregulated Land Conversions through Land Use Planning: The study highlights the need for comprehensive and forward-thinking land use planning that balances urban development with environmental sustainability. Land use policies should focus on long-term resilience, ensuring that future developments do not exacerbate environmental vulnerabilities. There is a need to enforce zoning laws to limit the illegal conversion of forested areas and agricultural lands to residential or industrial lands. This will protect green spaces and biodiversity.
5. Adoption of Climate Adaptation Strategies: Local authorities should encourage the adoption of climate adaptation measures, such as reforestation, coastal protection initiatives, and improved agricultural practices. Financial and technical support should be made available to farmers and landowners to implement these strategies effectively. For instance, local trees species can be planted along roads, in schools and other public places to restore and protect degraded areas. This will also reverse loss of vegetation, sink carbon, reduce heat and generally improve the quality of air.
6. Collaborative Efforts for Climate Resilience: Finally, the study recommends collaborative efforts between government agencies, private sector stakeholders, and local communities to build a more resilient Ibeju-Lekki. Public-private partnerships can be leveraged to fund climate adaptation projects and develop infrastructure that supports both economic growth and environmental sustainability. This can be done by promoting flood resistant designs and raised buildings in flood prone areas to reduce vulnerability to

coastal flooding intensified by climate change. A resilient infrastructure guideline can be developed through partnership with private developers in the Lekki-free trade zone.

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Image Sources

Fig.1: Authors' elaboration;

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Fig.3: Authors' elaboration;

Fig.4: USGS, 2024;

Fig.5: USGS, 2024;

Fig.6: USGS, 2024;

Fig.7: USGS, 2024;

Fig.8: USGS, 2024;

Fig.9: USGS, 2024.

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