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APPLICATION OF GEOSPATIAL TECHNOLOGY IN ASSESSING URBAN EXPANSION IN BENIN AND ITS ENVIRONS – IMPLICATION ON CLIMATE CHANGE

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ABSTRACT
Effective monitoring of urban expansion hits serious difficulties and equally raises great questions for the future. The depletion of the natural vegetation leading to the altering of the ecology of Benin City and its Environs is of serious concern. To ascertain the extent of the aforementioned, this study applied the use of geospatial technology in assessing urban expansion in Benin and its environs. The result revealed that in 1987, forest occupied 56045.37 hectares, disturbed forest 83314.01 hectares, cultivated land 63419.92 hectares and urban land 35446.21 hectares, while in 2024 forest cover declined to 27917.74 hectares, disturbed forest 46956.81 hectares, cultivated land 76852.94 hectares and urban land 86498.02 hectares. On the overall, between 1987 and 2024 forest and disturbed forest were lost by 34.6% and 23.6% respectively, while cultivated land gained 8.7% and urban land 33.1%. This study revealed that urban expansion has severely impacted negatively on natural environment as a result of the spatial spread of urban land use over vegetation contributing to Global Warming and Climate Change. Based on the findings, there is need for conservation and management of existing land fragments in the study area. Alternative source of livelihood for the vulnerable groups should be provided by government as well.

Keywords: ***Geospatial, Urban Expansion, Land Use Land Cover (LULC), Remote Sensing, Geographical Information System (GIS).***

1.0 INTRODUCTION
Global urbanisation is a defining trend of the 21st century, with urban centres serving as key drivers of economic growth worldwide (Wilcox *et al.,* 2017). The proportion of the global population residing in cities has dramatically increased, rising from roughly 34% in the 1950s to about 50% today, and is projected to reach 68% by 2050 (UN DESA, 2018). This demographic shift necessitates a massive physical expansion of human settlements, profoundly altering the Earth's surface (Ifatimehin and Ufuah, 2006). Unfortunately, over 90% of this expansion is occurring in the developing world (World Bank, 2023) and often manifests as uncontrolled, chaotic urban sprawl. This growth pattern results in the irreversible loss of vital natural resources, including forests, biodiversity, and, crucially, productive agricultural lands (Talema and Nigusie, 2023). Their environment is continuously being altered by urbanization as hard, high heat absorbing materials are used to replace the naturally existing vegetal cover (Goselle and Odjugo 2024).

Benin City exemplifies this unsustainable trajectory. The city has undergone an accelerated spatial expansion over recent decades, directly converting its formerly abundant tropical rainforest and peri-urban agricultural lands into low-density built-up areas (Odeleye, 2023). This expansion is characterised by chaotic urban sprawl, where development leaps along major roads and fragments arable land, making effective farming practices impossible. The most severe consequences are two-fold: first, the rampant

removal of vital vegetation and extensive deforestation, leading to environmental degradation; second, the direct loss of prime agricultural land, which threatens the livelihoods of multi-generational farmers and compromises the city's food security (Ayo-Odifiri *et al.*, 2021; de Bruin and Holleman, 2023). The diminishing local food supply inevitably leads to higher food prices and increased reliance on distant, vulnerable sources. The fundamental enabler of this crisis is the pervasive non-compliance with existing land-use master plans, which are routinely overridden for public and private development. Therefore, this study aims to apply remote sensing and geographic information system technologies to quantify the magnitude, rate, and direction of this urban expansion between 1987 and 2024 and assess its physical consequences on the area's vegetation. This will expose the study area to further alterations in its environmental and climate system (Goselle, 2021).

2.0 Theoretical Framework

This paper is anchored in the Theory of Land Use Transition (Lambin et al., 2003), which conceptualises land cover change as a systematic societal process driven by the co-evolution and interaction of biophysical and socio-economic factors (Martens and Rothmans, 2002). The key driver in the Benin Metropolis is population pressure, consistent with Boserup's (1965) model. This model describes a necessary transition from low-intensity land uses (like forest-fallow) to higher-intensity uses (like urban construction) as density increases. The analysis is spatially contextualised by the concept of the peri-urban area (Douglas, 2006). This area, at the city's fringe, is a highly unstable transition zone where the high demand for land for housing and infrastructure directly conflicts with the land's original function (agriculture and ecosystem services). This pressure results in the destruction of plant cover, the core ecological consequence investigated.

Urban sprawl leads to rapid rural-urban migration overwhelms the capacity of municipal authorities, leading to the proliferation of unauthorised squatter settlements in peri-urban zones. The failure is particularly acute in developing nations, where cities are growing "beyond the control of planners" (Agbola and Olurin, 1998). Urban sprawl is fundamentally defined not merely as outward growth but as an inefficient, uncoordinated, and spatially disproportionate pattern of development that fragments the landscape, signalling a deep-seated failure in urban planning and governance (Ewing, 1997). This occurs because the formal housing market prices out low-income earners. This pushes them to the fringes where they self-organise and create a dangerous feedback loop of unserviced and uncoordinated expansion (Olujimi and Gbadamosi, 2007). This uncontrolled Land Use/Land Cover (LULC) change has critical implications for food security, sustainable development, and biodiversity (Akodewou *et al*., 2020).

To analyse and quantify this chaos, the theoretical framework relies on the robust integration of Remote Sensing (RS) and Geographic Information Systems (GIS), with multi-spectral Landsat imagery serving as the key data source. The analysis is made reliable by using high-accuracy classification algorithms, such as the Maximum Likelihood Classification, which consistently achieve accuracy metrics over 90% (Mishra and Jabin, 2020). Quantification precisely measures the speed and intensity of the expansion. This is a move beyond simple area statistics through the use of essential rate metrics, including the Annual Expansion Rate and the Land Consumption Rate (LCR), to Advanced models like Cellular Automata (CA).

Crucially, the theoretical consensus mandates a mixed-method approach, integrating primary household surveys to validate satellite data and link the physical changes to the specific socio-economic drivers, such as land tenure insecurity and population pressure, that underpin the transformation (Ituen *et al*., 2007; Mehari *et al*., 2021). Empirical evidence confirms a state of hyper-urbanisation and aggressive resource consumption, especially across Nigerian metropolitan regions. For instance, the Federal Capital City, Abuja, experienced a massive surge in built-up area, quantified by an astonishing annual expansion rate of 14.39 km² (Ujoh *et al*., 2009). This expansion is consistently disproportionate and inefficient, as demonstrated in Uyo, where infrastructure growth exhibited a massive ratio compared to the population spread (Essien and Akpan, 2013). This relentless growth translates directly into a critical, quantifiable loss of natural capital; studies consistently show that urban and cultivated areas expand at the expense of forests, wetlands, and grazing lands, with figures like 47% of land in Akwa Ibom State being converted over a 17-year period (Ituen *et al*., 2007). The key driving factors identified across these cases are high population growth, rural-urban migration, and a lack of effective planning and control (Idowu *et al*., 2023).

Despite this extensive and robust quantitative documentation of the problem, a significant research gap exists in the domain of implementation and control. Available literatures are predominantly descriptive, detailing the high rates of sprawl but failing to be prescriptive by empirically testing the effectiveness of proposed planning interventions. The core crisis is the ineffectiveness of development control and a pervasive lack of political will to enforce existing planning laws (Olujimi and Gbadamosi, 2007). The imperative for future research is, therefore, to move beyond merely documenting the problem and focus on quantifying the measurable impact of specific regulatory frameworks and mitigation strategies to address the systemic failure of physical development control.

3.0 MATERIALS AND METHODS

3.1 Study Area

The study area is the Benin Metropolis, the capital of Edo State, Nigeria, located in the South-South geopolitical zone. Geographically, it covers approximately 500 square kilometres and is situated between latitudes $6^0 06'$ N and $6^0 30'$ N and longitudes $5^0 30'$ E and $5^0 45'$ E as shown in Figure 1. Benin grew in size and splendour, becoming the major urban settlement of its kingdom, with boundaries stretching to the Niger River and the Atlantic Ocean. Today, Benin metropolis functions as a major industrial, commercial, and administrative centre. It exhibits a dual pattern of urban life in which its traditional role remains strong, sustaining many communities that trace their descent to the ancient kingdom speaking the main language, Edo (Ojo and Raimi, 2025). On the other hand, contemporary modernisation has driven the emergence of new socio-economic groups, resulting in a complex, evolving modern city (Aimurie, 2022).

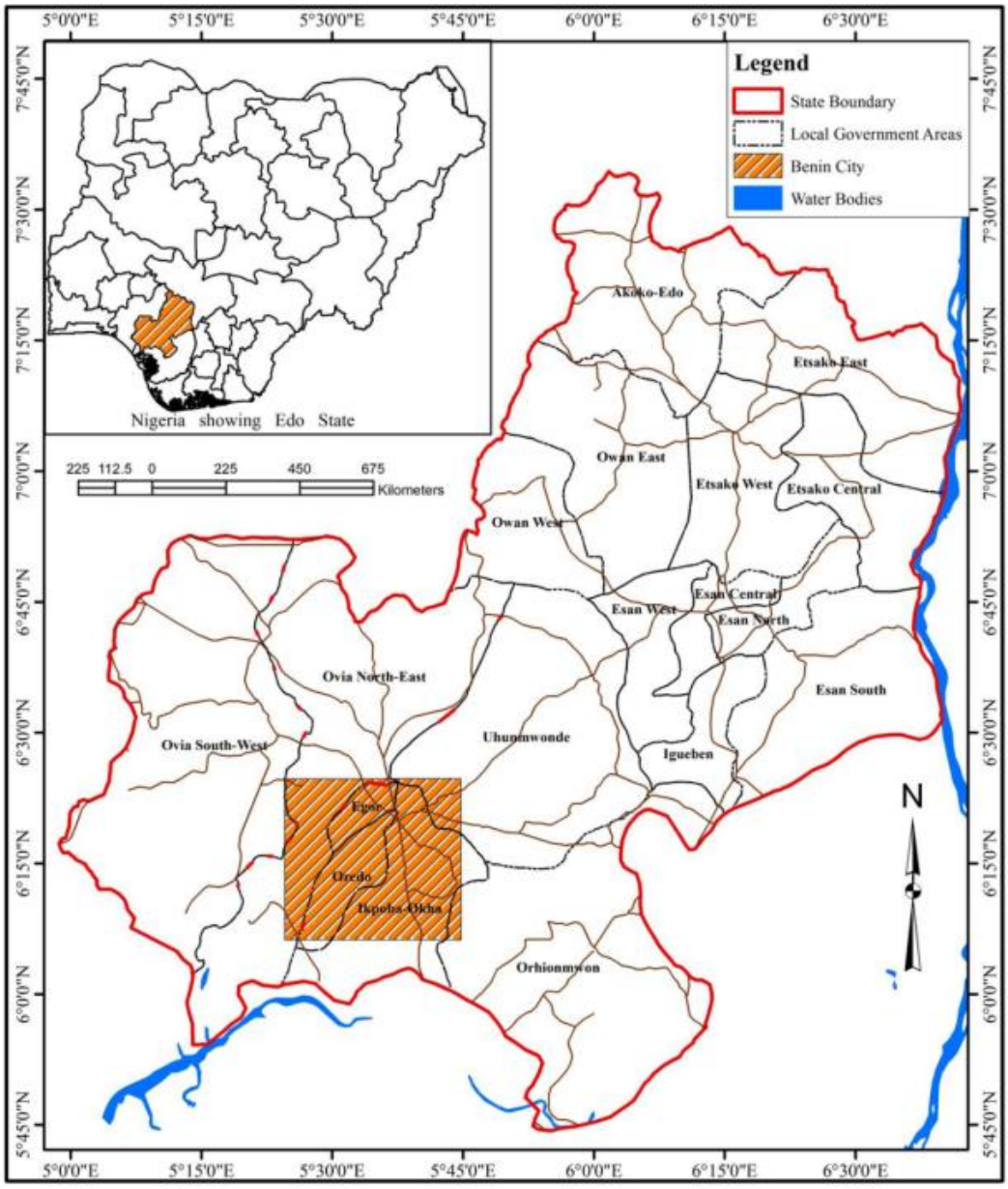

Figure 1: Location of Benin City on the Map of Edo State
Source: GIS laboratory, IUOkada

3.2 Data Types and Sources

This study relied on secondary geospatial data, specifically Landsat satellite imagery which spanned 38 years (1987 and 2024), which was acquired from the United States Geological Survey (USGS). Rigorous geospatial analysis of the satellite imagery was carried out using ERDAS Imagine and ArcGIS software. A supervised classification method, based on Anderson's classification technique, was applied to classify four Land Use/Land Cover (LULC) classes, namely, Forest, Disturbed Forest, Cultivated Land, and Urban Land. This geospatial analysis served three main purposes:

1. To determine the status of land use/land cover for both periods.
2. To quantify and measure the growth and change pattern of the urban land use class.
3. To extract and assess the corresponding changes in vegetation cover (all green areas) within the study area.

These satellite-derived data were contextualised using additional secondary materials, including the 1991 National Population Census report. Various

cartographic materials, such as the Administrative Map of Edo State and the Map of Benin City (obtained from the Ministry of Lands), were used to accurately determine and delineate the study area boundaries from the satellite imagery.

3.3 Data Analysis

A post-classification change analysis was performed. The net change and the rate of urban expansion were determined by calculating the absolute gain in the urban land class (in hectares) and deriving the average yearly change for the 38-year interval. The loss of vegetation was quantified by aggregating the non-urban classes.

4.0 RESULTS AND DISCUSSION

4,1. Status of Land Use/Land Cover (LULC) Change

The result revealed significant temporal changes in land use land cover (LULC) distribution between 1987 and 2024, confirming a rapid and transformative shift in the metropolitan landscape. The findings which indicated that between 1987 and 2024, forest and disturbed forest areas were lost by substantial amounts, with a combined total loss of -53,247.63 hectares (34.6%) and -36,357.2 hectares (23.6%), respectively, expressed that urban land was the sole LULC type to record a massive increase, gaining 51,051.81 hectares (33.1%) and growing its share from 14.9% to 36.3%. In agreement with Musa and Oladipo, (2023), the reported imbalance demonstrated that Benin Metropolis was undergoing changes at a significantly faster rate, predominantly driven by population increase resulting from migration from other parts of the country. The exposed drastic Land Use/Land Cover (LULC) transformation, with Urban Land increasing at the direct expense of natural vegetation is shown in Table 1. Plate 1 and Figures 2 and 3.

Table 1: Status of Land Use Land Cover and their Changes

LULC Classes	Areal Coverage in 1987	%	Areal Coverage in 2024	%	Changes in Area b/w 1987-2024	%
Forest	56045.37	23.5	27917.74	11.7	-53247.63	34.6
Disturbed Forest	83314.01	35	46956.81	19.7	-36357.2	23.6
Cultivated Land	63419.92	26.6	76852.94	32.3	13433.02	8.7
Urban Land	35446.21	14.9	86498.02	36.3	51051.81	33.1
Total	**238225.51**	**100**	**238225.51**	**100**	**154089.66**	**100**

Source: Extracted from Landsat 5 8/9 Satellite Imagery 1987 and 2024

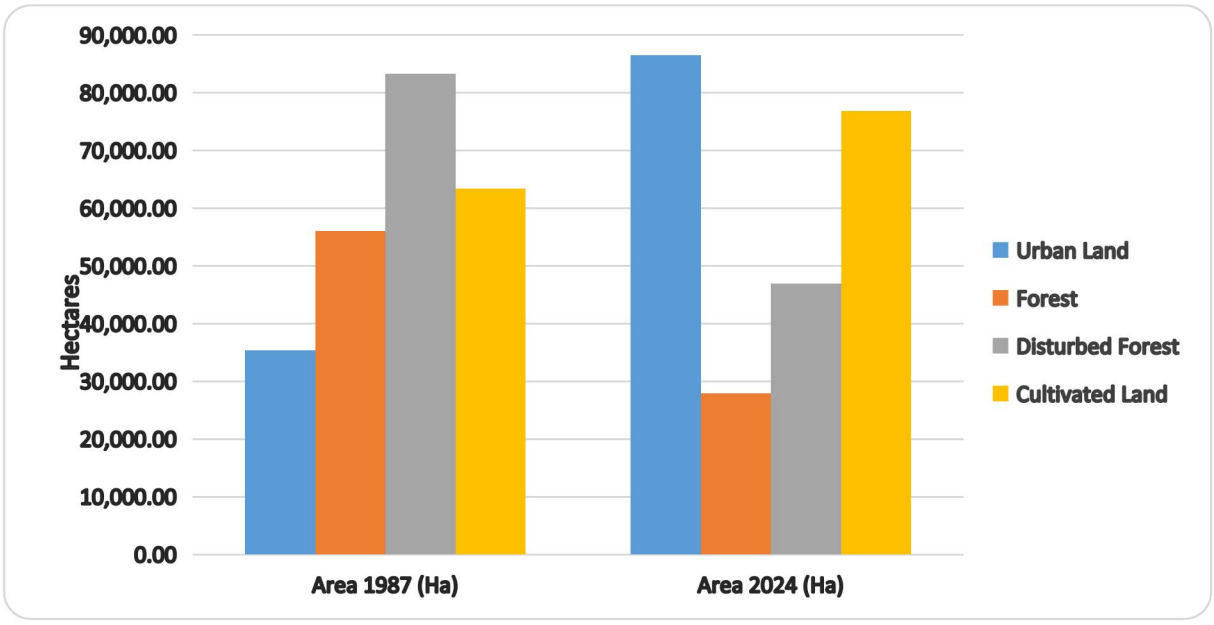

Plate 1: Graph showing status of Land Use Land Cover for 1987 and 2024

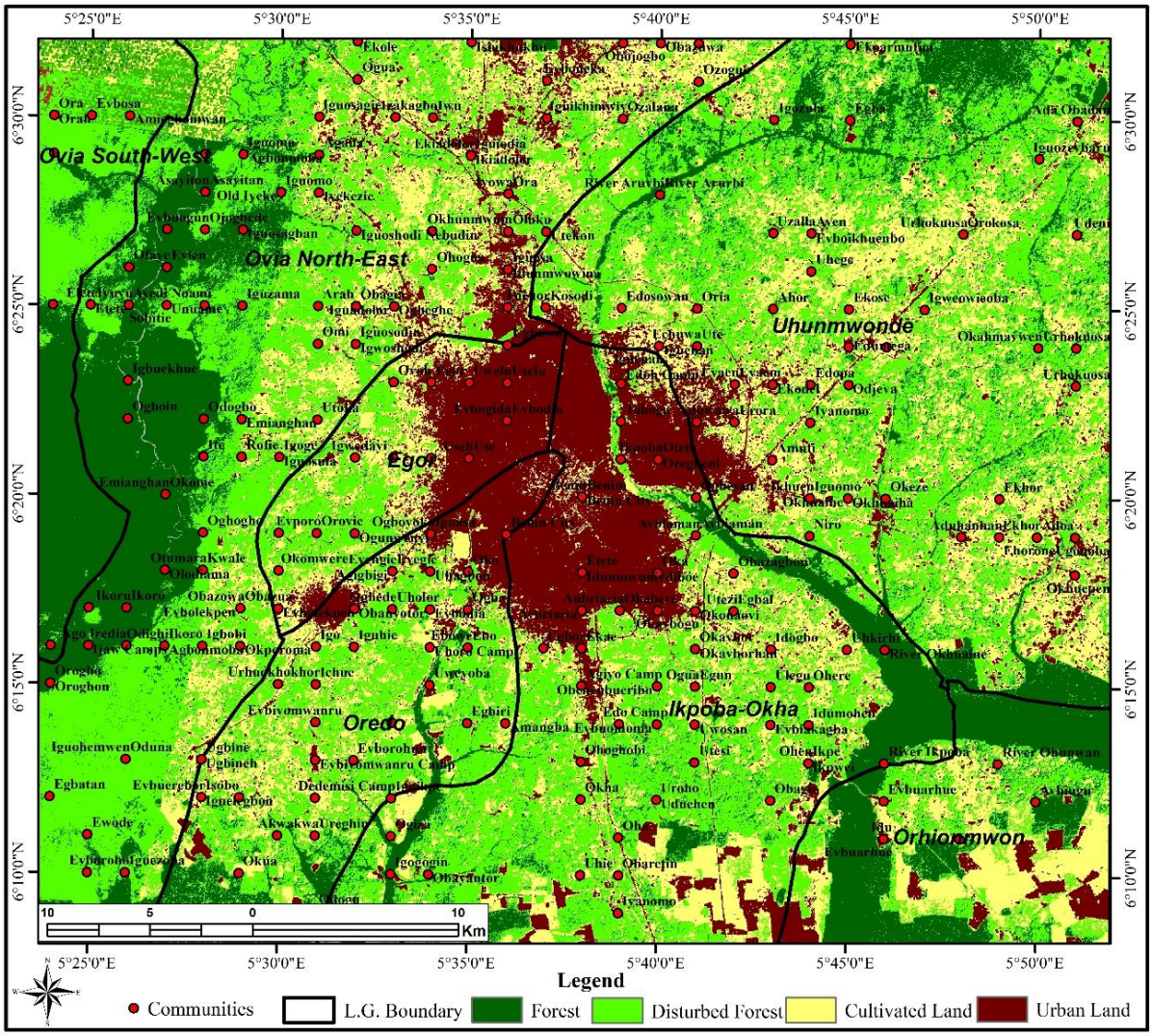

Figure 2: Land Use Land Cover Image of 1987
Source: Classified Landsat 5 Satellite Image of Benin and Environs (1987)

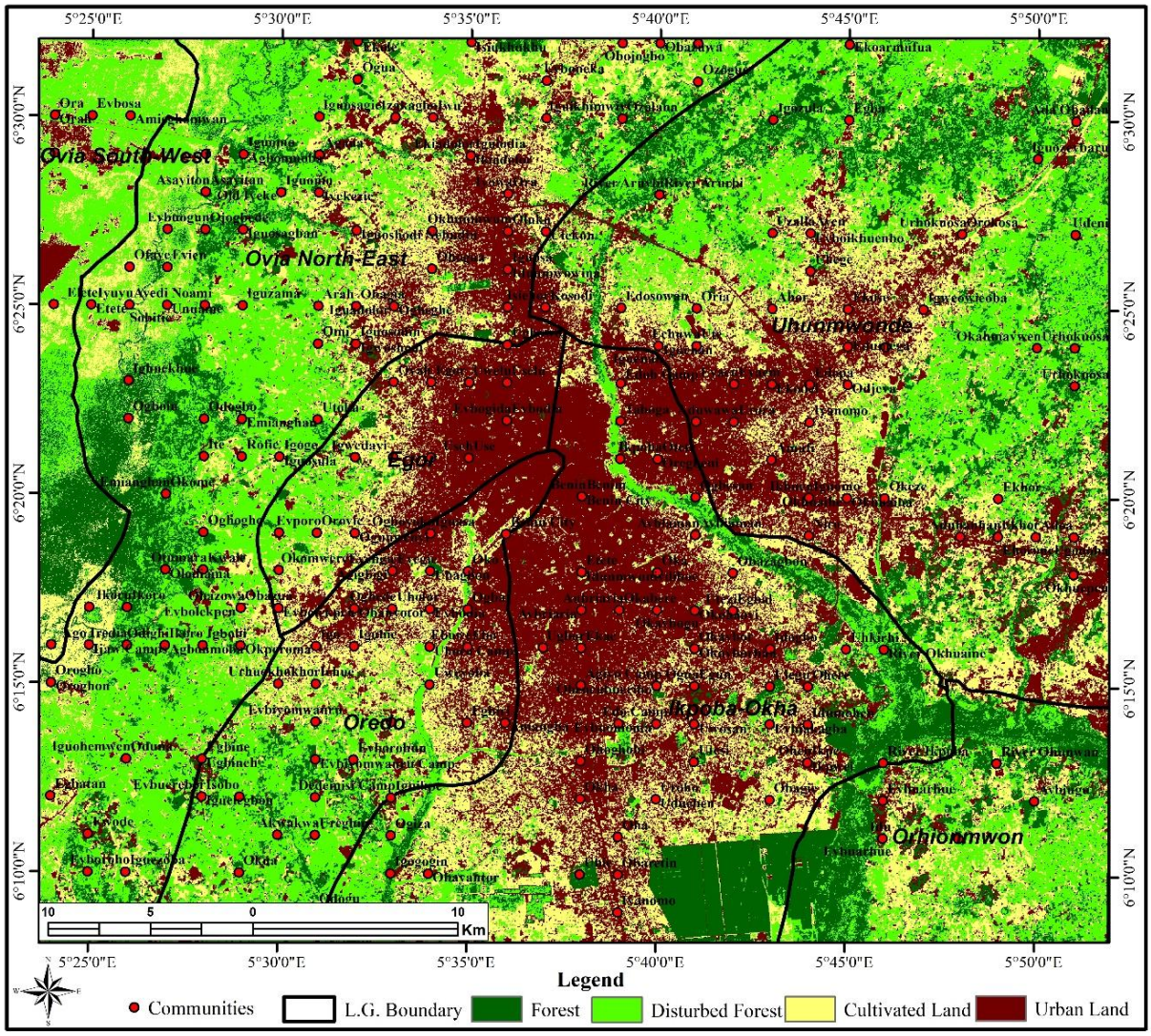

Figure 4: Land Use Land Cover Image of 2024
Source: Classified Landsat 8/9 Satellite Image of Benin and Environs (2024)

The result reported significant temporal changes in land use land cover (LULC) distribution between 1987 and 2024, confirming a rapid and transformative shift in the metropolitan landscape. The assessment, which indicated that between 1987 and 2024, forest and disturbed forest areas were lost by substantial amounts, with a combined total loss of -53,247.63 hectares (34.6%) and -36,357.2 hectares (23.6%), respectively, expressed that urban land was the sole LULC type to record a massive increase, gaining 51,051.81 hectares (33.1%) and growing its share from 14.9% to 36.3%. The analysis reported that this imbalance demonstrated that Benin and its environs were undergoing changes at a significantly faster rate, which was primarily driven by population increase resulting from migration from other parts of the country (Musa and Oladipo, 2023).

The Urban Land class recorded a massive absolute gain of 51,051.81 hectares, more than doubling its area share from 14.9% to 36.3%, as shown in Table 1, Plate 1 and Figures 1 and 2. Concurrently, forest and disturbed forest covers experienced severe losses (−28,127.63 ha and −36,357.20 ha, respectively), providing concrete evidence of extensive deforestation and the direct

consumption of natural capital by the built environment.

4.2. Trend and Rate of Urban Expansion

The overall expansion trend confirms an uncontrolled, aggressive urban uxpansion:

Rate of Expansion: The total gain in urban land translated to an average yearly urban land expansion rate of 1,379.77 hectares between 1987 and 2024. This aggressive rate is driven by increasing population, migration, and the resulting demand for housing and infrastructure. Just like Okunola and Olapade (2022), this was as a result of an increase in demand for housing, industries, infrastructural buildings and vital infrastructure projects such as power, water supply, sewage and drainage infrastructure by the increasing population, as shown in Table 2.

Table 2: Rate and Trend of Urban Land (Urban Expansion) and Vegetation

Year	1987	2024	Changes	Average Yearly Changes
Vegetation	202,779.3	151,727.49	-51,051.81	1,379.77
Urban Land	35,446.21	86,498.02	51,051.81	1,379.77
Total	**238225.51**	**238225.51**		

Source: Digitized data from Satellite Imageries (1987 and 2024) of Benin Metropolis.

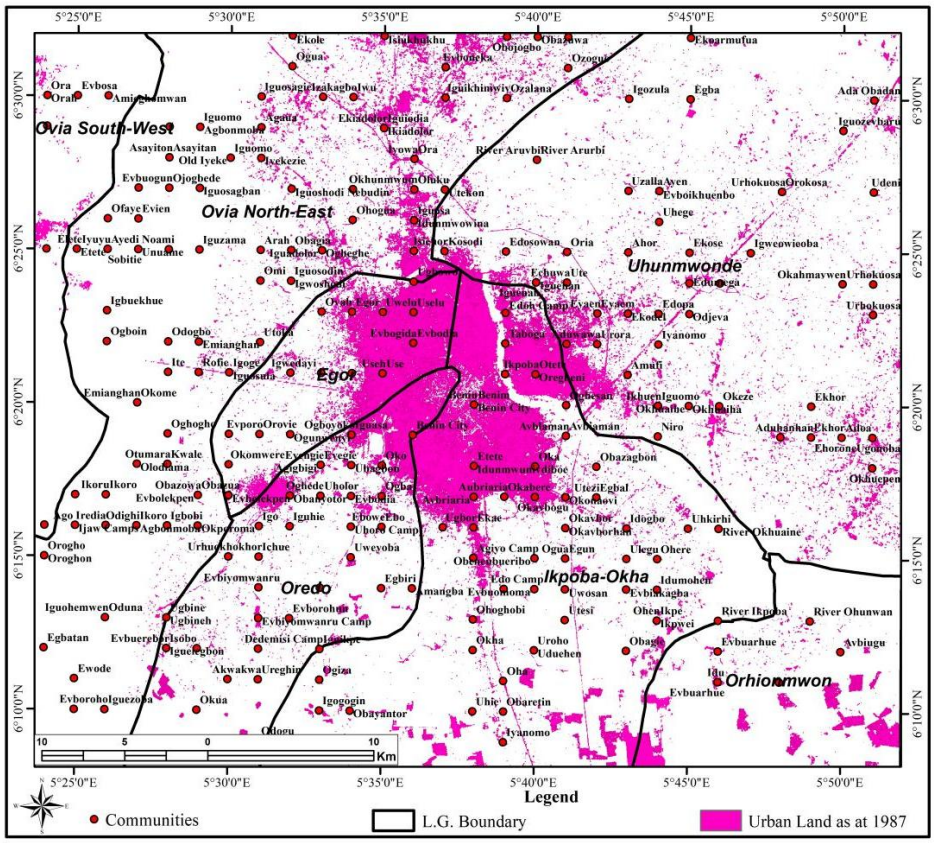

Figure 5: Urban Areas in Benin Metropolis as at 1987
Source: Classified Satellite Image 5 (1987)

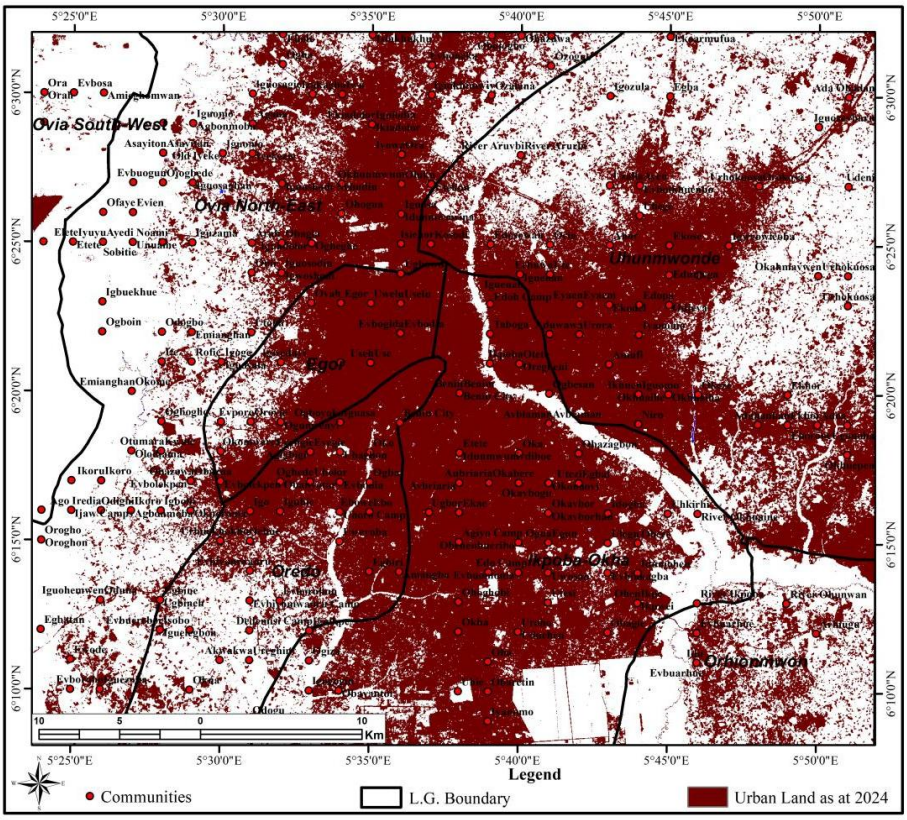

Figure 6: Urban Areas in Benin Metropolis as at 2024
Source: Classified Satellite Image 8/9 (2024)

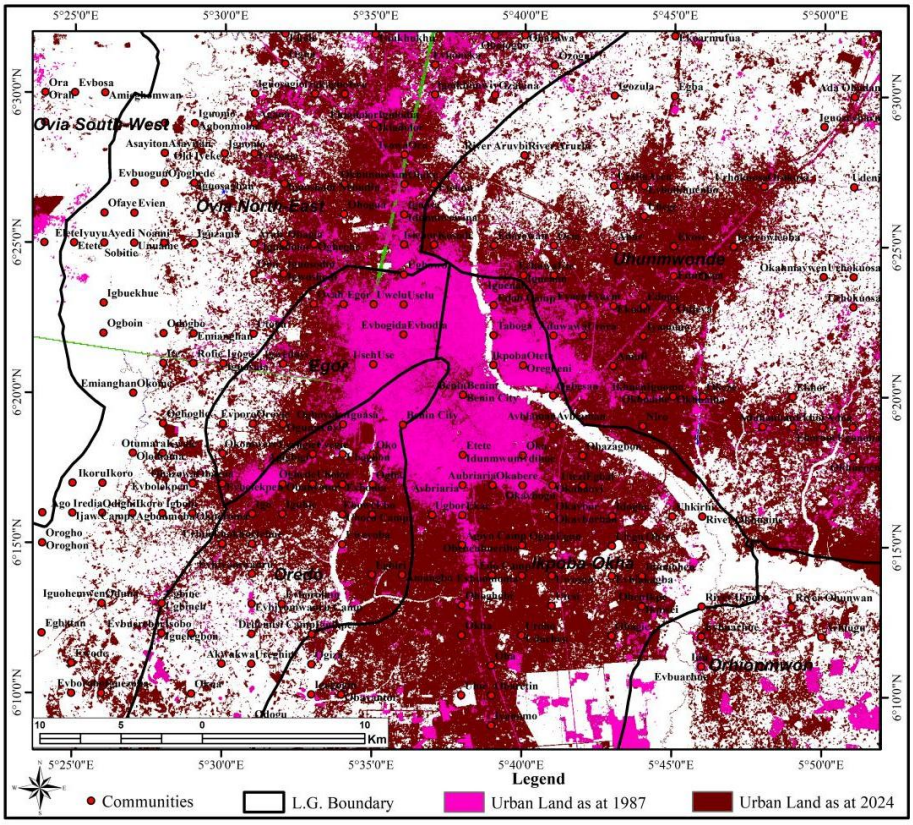

Figure 7: Trend of Urban Expansion between 1997 and 2024
Source: Classified Satellite Images 5and8/9 (1987 and 2024)

The result revealed that Urban Expansion was concentrated principally along major roads, extending towards the North, North East, South, and South East regions. This pattern confirmed the characteristic ribbon and leapfrog development of chaotic urban expansion. Based on this information it was clear that the increasing rate of urbanisation into the suburbs has made farming a less direct source of livelihood due to conversion of farmlands to urban land (built-up). Hence, there was constant competition for space for development by individuals, developers, and government especially the politicians who influenced the use of land for their personal gains, this brought about devastated reduction in vegetation the major roads in the study area. Moreover, the findings that the total vegetation cover (forest, disturbed forest, and cultivated land) was reduced by 51,051.81 hectares, an amount exactly equal to the urban gain. This deduced that fierce competition for space, often influenced by political and commercial interests, has led to a devastating reduction in vegetation along major corridors, severely displacing farmers and making agriculture a precarious source of livelihood. In agreement with Ede and Ojo (2019), the result confirmed a massive gain in urban land at the direct expense of forest and disturbed forest areas and provided concrete evidence of uncontrolled urban expansion extending into ecologically sensitive zones. This displacement of natural vegetation by the built environment, which was shown to be consistent and alarming, conformed with the pattern reported across rapidly urbanising West African cities (Dekolo *et al*., 2025). The findings overall underscore that the rate and magnitude of LULC transformation are far outpacing institutional management, leading to irreversible ecological fragmentation and loss of natural capital necessary for urban sustainability, also aligned with Osayande *et al.* (2023).

5.0 CONCLUSION

This study which applied remote sensing and geographic information technology in assessing the rate and trend of urban expansion in Benin and its environs, established that urban expansion is a serious problem and life-threatening especially to agricultural lands in the study area and must be reduced. It was concluded that the study area is experiencing rapid, uncontrolled urban sprawl that is aggressively converting natural vegetation and land at an unsustainable rate, primarily driven by population growth and institutional failures. The quantification of this transformation, revealed that between 1987 and 2024, Urban Land increased by a massive 51,051.81 hectares, growing its total portion to 36.3% of the study area. This growth came directly at the expense of natural capital, with the Forest and Disturbed Forest covers suffering a combined severe net loss exactly matching the urban gain, providing concrete evidence of extensive deforestation. The pattern of expansion is chaotic, following major road networks (ribbon and leapfrog development), which confirms the characteristic nature of the expansion.

Ultimately, the study concludes that this aggressive, disproportionate growth, fueled by population increase and demand for infrastructure has led to a fierce competition for space and the displacement of farmers, making agriculture a precarious livelihood. The central enabler of this unsustainable pattern is the non-compliance with land-use plans and the failure of development control, often influenced by commercial and political interests. The rate of land use land cover change is thus far outpacing institutional management, leading to irreversible ecological loss and threatening the city's long-term sustainability. The continuous depleting

of vegetal cover and replacing with built-up areas contributes to Global Warming and Climate Change.

6.0 RECOMMENDATION

Based on the evidence of accelerated, uncontrolled expansion and the devastating loss of natural cover, the following are recommended:

1. Government should immediately strengthen development control agencies to establish and rigorously protect designated agricultural greenbelts and conservation zones from both private and public encroachment.
2. There should be an aggressive, state-mandated afforestation and ecological restoration programmes on designated urban green spaces to mitigate the severe environmental degradation caused by the massive loss of forest cover.
3. The conservation and management of existing land fragments in the face of rapid urbanization, as well as ensure proper enforcement of legislation governing land uses. This will facilitate a green environment and mitigation of global warming and climate change.
4. Shift planning policies focus from horizontal expansion to vertical growth, within the existing urban core. This will reduce pressure on peripheral lands.
5. Finally, address the socio-economic impact by providing livelihood diversification programmes and vocational training for farmers displaced by urban conversion to ensure social equity and stability.

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