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Spatial-temporal Dynamics of Urban Expansion and Land Cover Transformation in Uyo Capital City, Akwa Ibom State, Nigeria

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Abstract

This study examined the spatial-temporal dynamics of urban expansion in Uyo Capital City, Akwa Ibom State, Nigeria. Landsat satellite imageries from 1986, 2005, and 2024 with 30-meter resolution were analyzed using supervised and unsupervised classification techniques in ERDAS Imagine 10.5. The research employed Remote Sensing and GIS-based spatial analysis to assess land use and land cover (LULC) transformations, urban growth patterns, and environmental impacts. The results revealed notable LULC transitions during the study period. Forest cover declined from 31.05% in 1986 to 16.43% in 2024, while built-up areas expanded from 23.44% to 44.80%, signifying rapid urbanization and infrastructure development. Agricultural land increased slightly by 2005 but later decreased to 22.83% in 2024, indicating urban encroachment. Water bodies steadily declined, highlighting potential hydrological stress. Between 1986 and 2024, forest and farmland decreased by 4,923.6 and 1,525.4 hectares respectively, while built-up areas increased by 7,192.74 hectares. Urban growth showed a concentric pattern outward from Ibom Plaza, influenced largely by road infrastructure. NDVI analysis showed vegetation degradation, especially between 2005 and 2024, attributed to economic changes. Population and economic growth were identified as the primary drivers of urban expansion, followed by infrastructure, housing demand, and policy influences. Farmland loss and land use transformation emerged as the most critical consequence, along with livelihood disruption, environmental degradation, and economic impact. Projections using the MOLLUSC model in QGIS indicate a 79% rise in built-up areas by 2050. The study recommends sustainable urban planning, land use regulation, reforestation, and predictive modeling to mitigate ecological damage and enhance urban resilience in Uyo.

Key words: Monitoring; Spatial-temporal dynamics; Change; Urban expansion; Uyo capital city

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INTRODUCTION

Globally, cities have undergone significant growth and transformation in recent decades accompanied by substantial changes in land use (1, 2, 3). Monitoring change of expansion involves studying how cities grow and develop overtime, using tools that provide accurate, up-to-date data remotely sensed data and geospatial techniques. (2, 4, 5). Urban growth monitoring play pivotal roles in understanding the evolving dynamics of urban landscapes, offering essential insights for sustainable urban development (6, 7, 8, 9,10). These measures are aimed at evaluating human activities and socioeconomic advancement, encompassing qualitative and quantitative aspects across different temporal and spatial dimensions (11, 12, 13). For instance, urban centres have always continued to experience unprecedented population growth due to the fact that they have always been seen as the engines of economic growth (14, 15).

Urban growth has four components according to studies done recently, namely, urban natural increase, rural-urban migration, international-urban migration and urban reclassification (16, 17, 18, 19). Urban growth could be characterized by the transition that occurs in natural

environment where it turns into an artificial one which is often brought about by built-up areas created by humans (20, 21, 22, 23). In the global world for instance, there has been a continuous conversion of land cover to other land uses. According to the Food and Agriculture Organization, about 10 million hectares (ha) of the world's forest, which was estimated to be one-third of the total world land cover, was converted mainly to agricultural land and other uses from 2015 to 2020 (11). During this period, Africa had the highest annual rate of forest loss at 3.9 million hectares (23,24,25). With the rapid increase in human population, particularly in many African nations, coupled with continuous land development and high demand for food, the situation is expected to continue.

Another study observed that land is seen as a social security asset to most people because after all else has failed in the city, they can still manage to go back to their villages to demand a piece of their inherited family land and start subsistence farming (12). Land control and land use policy must consider the fact that most people's existence relies on having access to a piece of land, and they would strongly resist and oppose any act to deprive them of this land (8). Therefore, the detection of changes in land use reveals noticeable differences in the developmental process of a particular area, by monitoring urban growth at different time periods (7).

The recent rapid population growth in Uyo, the capital city of Akwa Ibom State, has led to a significant increase in unplanned urban development, drawing more attention from planning authorities than any other urban issue (26,27). This highlights the urgent need for comprehensive and standardized urban planning. To effectively manage this growth, it is essential to systematically select and collect relevant data, analyze development trends, and monitor the city's growth rate.

The following research objectives are considered:

i. To take inventory of land use and land cover classes for three years period (1986, 2005 and 2024).

ii. To examine the trend, rate and direction of urban land use change detection in the study area using remote sensing and GIS.

iii. To examine the likely land use pattern of Uyo capital city in the year 2050.

MATERIALS AND METHODS

This research analyzed the monitoring of the trends in urban expansion in Uyo capital city. The city covered the spatial extent of 25702.65 hectares and has been expanding at a varying pace in different directions. Landsat imageries and ancillary data are utilized to achieve these. The imageries of 1986, 2005 and 2024 was used for the study. This study made use of remote sensing data through ERDAS imagine software 10.5 to monitor urban growth and changes in land use in order to assess the trends, rate, and direction of urban growth in the study area.

For this study, Landsat imagery of Akwa Ibom State was obtained for three years period; 1986, 2005 and 2024 from united State Geological Survey (USGS). Population census report was obtained from national population census report of 1990. The administrative map and vegetation land use map of Akwa Ibom State was obtained from Akwa Ibom State Ministry of lands and Town Planning. Information for likely land use and land cover pattern of Uyo Capital City for projected year 2050 was obtained using the Landsat satellite imagery of the years under investigation from United State Geological Survey (USGS) to monitor and depict the changes in urban growth.

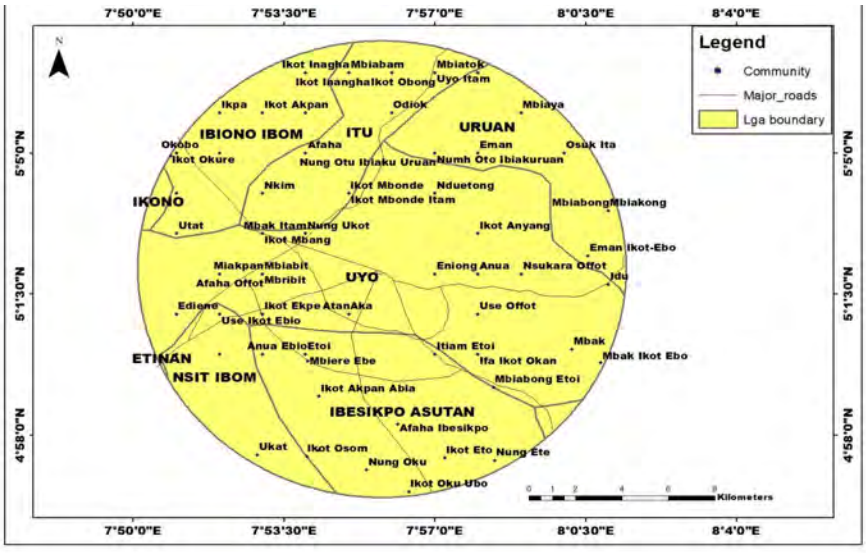

Figure 1
Administrative Map of Uyo Capital City-study Area
Source: GIS Unit (2024)

Data on inventory of land use land cover classes was derived from Landsat satellite imagery for 1986, 2005 and 2024 acquired from United States Geological Survey (USGS), to get the view of Uyo capital city. The image was corrected for atmospheric interference, sensor inaccuracies and geometry correction to make them ready for analysis. The images were layer stacked, mosaic. These processes are crucial in refining the raw data from remote sensing satellites. The study area (Uyo Capital City) was extracted using subset menu after defining the area of interest (AOI). The data was classified into four different land use type using Erdas imagine software 10.5. The both supervised and unsupervised classification method was used in ERDAS Imagine 10.5 software to classify the images into four land use cover classes. The classified classes include; Forest, Agricultural land, Water and Built up following modified Anderson's land use classification and the area of each class was generated in hectares.

This study also employs the used of the overlay analysis to produce the change map. The analysis processes provide good information and changes of both land use and land cover due to urbanisation. The extraction of the green area covers using NDVI was also done using ERDAS imagine software 10.5, for the period under investigation. Monitoring of land use cover pattern prediction (2050) was done using image classification of Landsat satellite imagery of the years under investigation and land cover maps. The model plaque in MOLUSCE technique was used which enable the projection of land use/land cover change for future prediction over time using QGIS software for year 2050.

RESULTS AND DISCUSSIONS

Inventory of Land Use classes

The status of land use classes for the three decades 1986, 2005, and 2024 as derived from the analysis is presented in Table 1.

Table 1
Inventory of Land Use Status

Land use classes	Statuses					
	1986		2005		2024	
	Hectare	%	Hectare	%	Hectare	%
Forest	10455.40	31.05	8300.69	24.66	5531.80	16.43
Agricultural land	9213.3	27.36	10689.60	31.75	7687.90	22.83
Water	6110.00	18.15	5579.59	16.57	5366.26	15.94
Built-up	7891.16	23.44	9099.98	27.02	15083.90	44.80
Total	33669.86	100	33669.86	100	33669.86	100

Note: Values represent land size in hectares.
Source: Digitized data from Satellite Imageries (1986, 2005 and 2024) of Uyo Capital City.

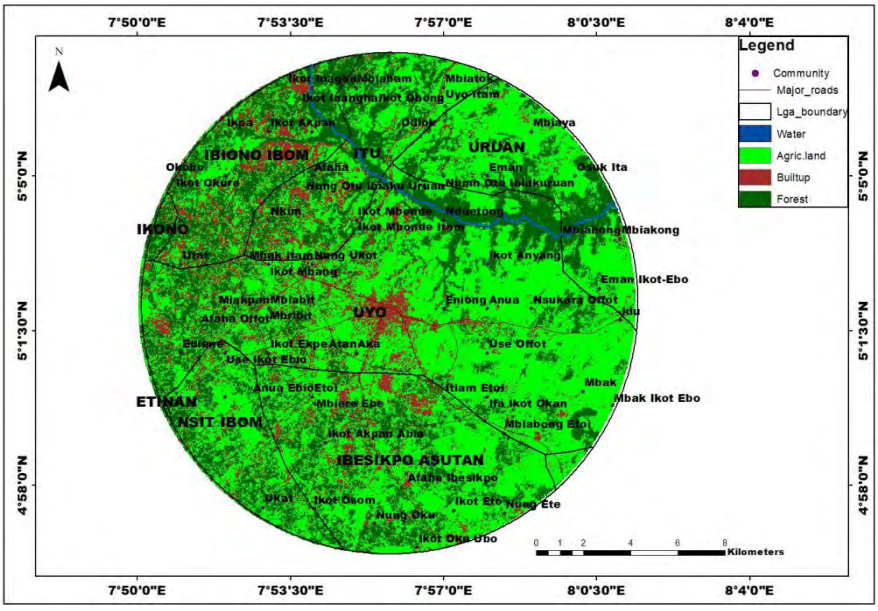

Figure 2
1986 Land use Classes
Source: Classified Satellite Image of Uyo Capital City (1986).

In 1986, forest occupied 10455.40 hectares at (31.05%) agricultural land occupied 9213.3 hectares (27.36%), water occupied 6110 hectares (18.15%) and built-up occupied 7891.16 hectares (23.44%). While

in 2005 forest occupied 8300.69 hectare at (24.66%), agricultural land occupied 10689.60 hectares (31.75%), water occupied 5579.59 hectares (16.57%) and built-up occupied 9099.98 hectares (27.02%). In 2024, forest covered 5531.80 hectares representing (16.43%) agricultural land occupied 7687.90 hectares (22.83%), water occupied 5366.26 hectares (15.94%) and built-up area occupied 15083.90 hectares (44.80%). This implies that, in 1986 there was a relatively balanced landscape significant forest cover and moderate levels of farmland, water and built up. In 2005 there was a clear shift in forest loss which also showed a significant loss of water, while agricultural land and built-up area have increased overtime. In 2024, domination of built-up areas was noticed and critical low forest and water while agricultural land has also decreased significantly, this showed a landscape heavily impacted by urban growth in the study area.

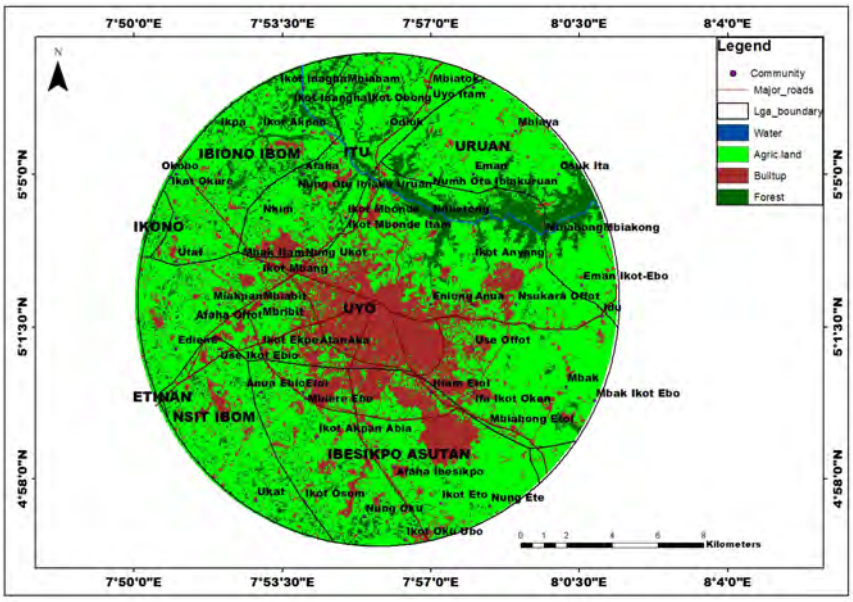

Figure 3
2005 Land use Classes
Source: Classified Satellite Image of Uyo Capital City (2005).

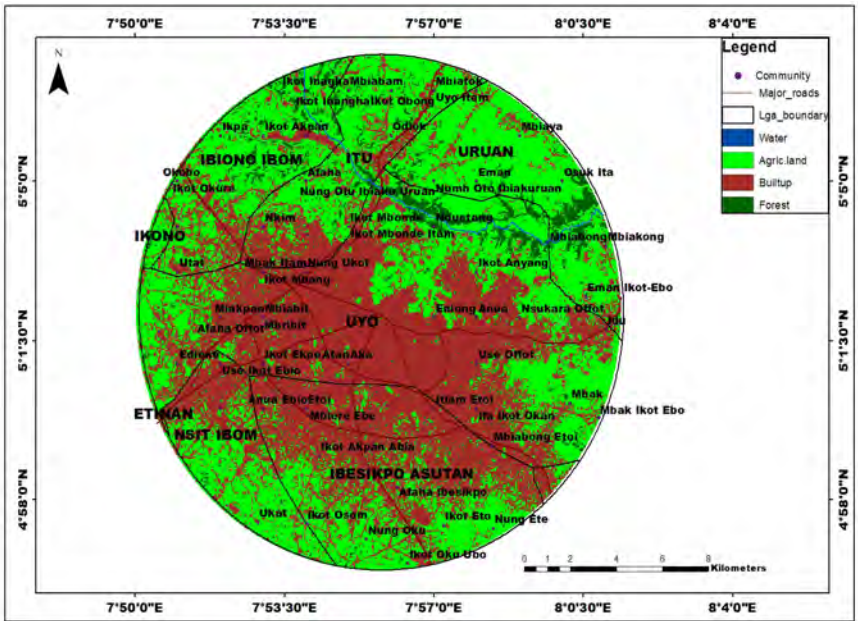

Figure 4
2024 Land use Classes
Source: Classified Satellite Image of Uyo Capital City (2024)

Table 2
Trend and rate of change of urban land use in the study area

Classes	Change between 1986 & 2005	% Change between 1986 & 2005 (Trend)	% Annual Change 1986 & 2005 (Rate)	Change Between 2005 & 2024	% Change Between 2005 & 2024 (Trend)	% Annual Change 2005 & 2024 (Rate)	Change between 1986 & 2024	% Change between 1986 & 2024 (Trend)	% Annual between 1986 & 2024 (Rate)
Forest	-2154.71	40.12	4.01	-2768.89	23.14	2.31	-4923.60	34.23	3.42
Agricultural Land	1476.30	27.49	2.75	-3001.70	25.08	2.51	-1525.40	10.60	1.06
Water	-530.41	9.88	0.99	-213.33	1.78	0.17	-743.74	5.17	0.52
Built up	1208.82	22.51	2.25	5983.92	50	5.0	7192.74	50	5.0
Total	5370.23	100		11967.84	100		14385.48	100	

Note: Values represent land size in hectares.
Source: Digitized data from Satellite Imageries (1986, 2005 and 2024) of Uyo Capital City.

With reference to Table 2, this showed the percentage change and the annual rate of change that occurred between 1986 and 2005 (19 years). Forest area reduced by 40.12%, at annual rate of change: which implies that forest area decreased at a rate of 4.01% per year. An annual decrease of 4.01% indicates a gradual and consistent decline in forest cover, Agricultural land increased by 27.49%, at annual rate of 2.75% per year, which implies that agricultural land has experienced steady growth, but at a lower rate compared to the loss in forest area over 19 years, the increase is moderate at an annual rate of 2.75%. Water decreased by 9.88%, at annual rate of 0.99% per year. This implies that, water bodies experience a relatively slow and annual decrease of 0.99% at gradual depletion over the period. And built-up areas (Urbanization) increased by 22.51% at annual rate of 2.25%. This implies that built-up areas expanded at 2.25% per year. Urban areas grew steadily over the 19 years, with the expansion rate being moderate (2.25% annually). This suggests increasing development and urban expansion.

Between 2005 to 2024 (19 years), forest decreased by 23.14%, at annual rate 2.31%, This implies that, the rate of loss is slower than in the previous period (from 4.01% to 2.31%). This could suggest a reduction in the pace of deforestation or some conservation efforts starting to take effect. Agricultural land reduced by 25.08%, at annual rate of 2.51%. This reduction in agricultural land is more pronounced, with a higher annual rate of loss (2.51%) compared to the forest reduction. This could indicate a broader loss of natural vegetation beyond just forests. Water bodies decreased by 1.78%, at annual rate of 0.17% per year. This implies that water loss slowed down, and this decrease is less significant annually, possibly suggesting a stabilization in water loss or changes in water management. Built-up areas equally increased by 50%, at annual rate of 5% per year. The implications is that built-up areas grew at a dramatic increase in urbanization, with built-up areas growing much faster than in the first period. The annual growth rate of 5% showed a much higher rate of urban sprawl, likely reflecting intensified development pressures and population growth.

Between 1986 to 2024 (38 years), forest reduced by 34.23%, at annual rate of 3.42% per year, reflecting that forest areas have been severely reduced, with a high annual rate of 3.42%. This could be due to conversion of wetland areas for agricultural or urban uses, as well as potential changes in the hydrology of the study area, agricultural land reduced by 10.60% at annual rate of 1.06% per year. Agricultural land decreased by 1.06% over the long 38-year period, agricultural land has experienced a slight decline, at a much slower rate (1.06% annually). Water bodies reduced by 5.17%., at annual rate 0.52% per year. This statistic indicates a steady, though slow, decline in water bodies over 38 years, with an annual decrease of 0.52%. This is slightly more pronounced than the loss between 2005–2024, indicating ongoing environmental pressures. Built-up areas (urbanization) increased by 50%, at annual rate of 5% per year. This implies that built-up areas have been significantly increased, with a faster rate of growth compared to the 1986–2005 period. It suggests accelerated development and expansion of Uyo over the entire 38-year period.

With reference to Table 3, the change detection showed that, between 1986 to 2005, there was a substantial loss of forest cover at a decrease of -2154.71 hectares, showing a significant deforestation trend over the 19years period. Meanwhile agricultural land exhibit a net gain of 1476.3, suggesting an expansion in farming activities. This expansion could be attributed to various factors including increase agricultural demand or land conservation. Water reduction of -530.41 hectares in water body area detected, indicating a reduction in surface water resources. This factor may be attributed to factors such as climate variability, water extraction or land reclamation. Built-up areas experienced a net gain of 1208.82 hectares, signifying urban expansion. The observable increase reflects the development of infrastructure and settlement within the study area between 2005 to 2024, there was a substantial reduction of -2768.89 hectares in forest cover observed. Reduction in agricultural land by 4027.4 hectares showed a significant drop suggesting a shift away from agricultural practices, possibly due to urbanization and land degradation or change in economic activities. Water bodies experienced a decrease of -213.33 hectares. This indicates a decline in a surface water resource, which could attribute to factors like drought, increase water consumption or land reclamation. A

substantial increase in built-up areas expanding by 5983.92 hectares, indicates urbanization trend, reflecting the growth of settlement and infrastructure.

The overall change detected between 1986 to 2024 indicate a substantial reduction of -4923.6 hectares in forest cover recorded, this signifies the major deforestation event over the 38-years period and it further show a reduction in agricultural land decrease at -1525.4 hectares. By implication, it shows a contraction of agricultural land, suggesting a shift away from farming practices or conversion to other land uses. Water showed a reduction of -743.74 hectares, with a decline in surface water within the study area. There was a significant increase in built-up by 7192.74 hectares, representing a high percentage of increase within the study area, this demonstrates a clear and substantial urbanization trend.

Table 3
Land use Change Detection

Classes	Change between 1986 and 2005			Change between 2005 and 2024			Change between 1986 and 2024		
	1986	2005	change	2005	2024	change	1986	2024	Change
Forest	10455.40	8300.69	-2154.71	8300.69	5531.80	-2768.89	10455.40	5531.80	-4923.6
Agricultural land	9213.3	10689.60	1476.3	10689.60	7687.90	-3001.7	9213.3	7687.90	-1525.4
Water	6110.00	5579.59	-530.41	5579.59	5366.26	-213.33	6110.00	5366.26	-743.74
Built-up	7891.16	9099.98	1208.82	9099.98	15083.90	5983.92	7891.16	15083.90	7192.74
Total	33669.86	33669.86	5370.24	33669.86	33669.86	11967.84	33669.86	33669.86	14385.48

Note: Values represent land size in hectares.
Source: Digitized data from Satellite Imageries (1986, 2005 and 2024) of Uyo Capital City.

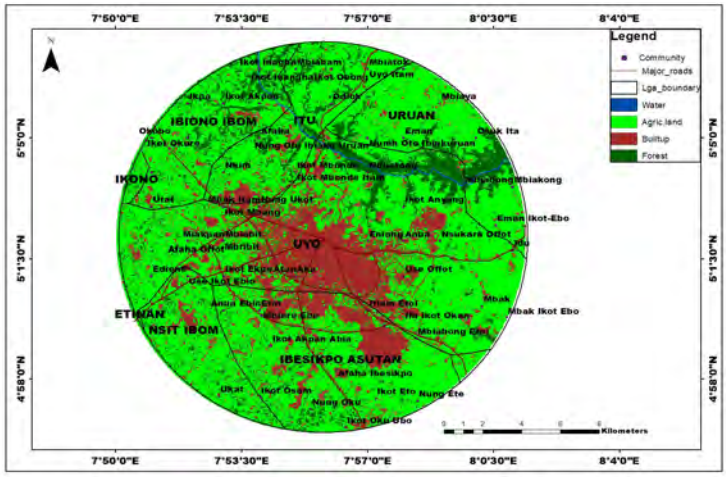

Figure 5
Urban land use change detection between 1986 and 2005
Source: Classified Satellite Image of Uyo Capital City (1986 and 2005)

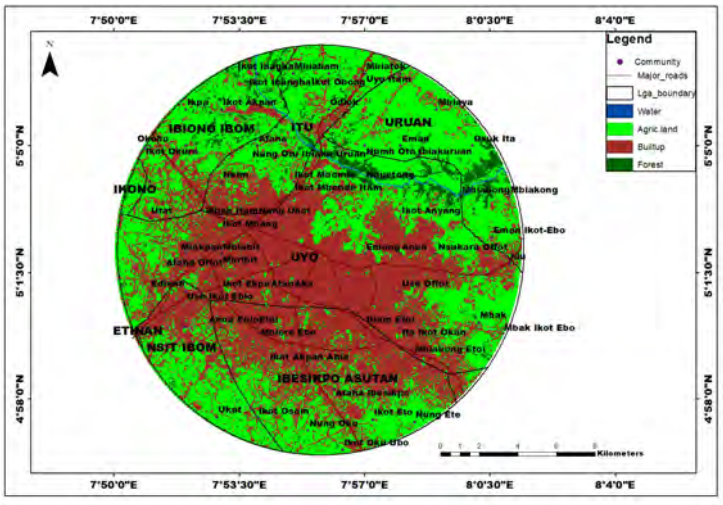

Figure 6
Urban land use change detection Between 2005 and 2024
Source: Classified Satellite Image of Uyo Capital City (2005 and 2024).

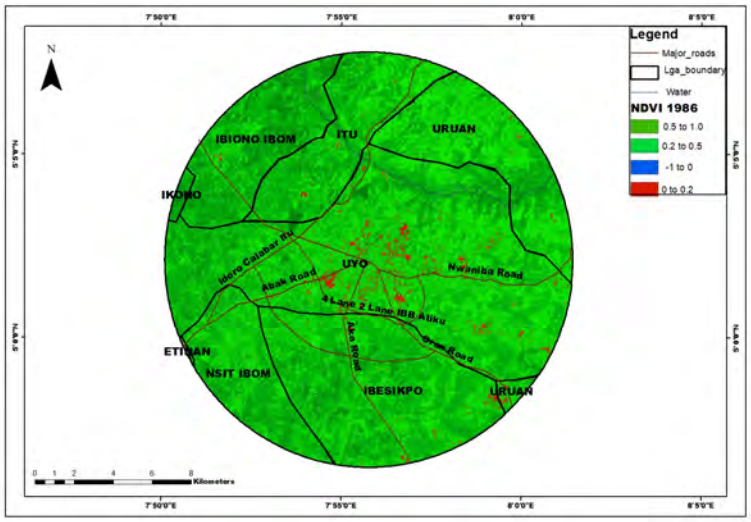

Figure 7
Normalized difference vegetative index for 1986
Source: Landsat Imagery of Uyo capital city 1986

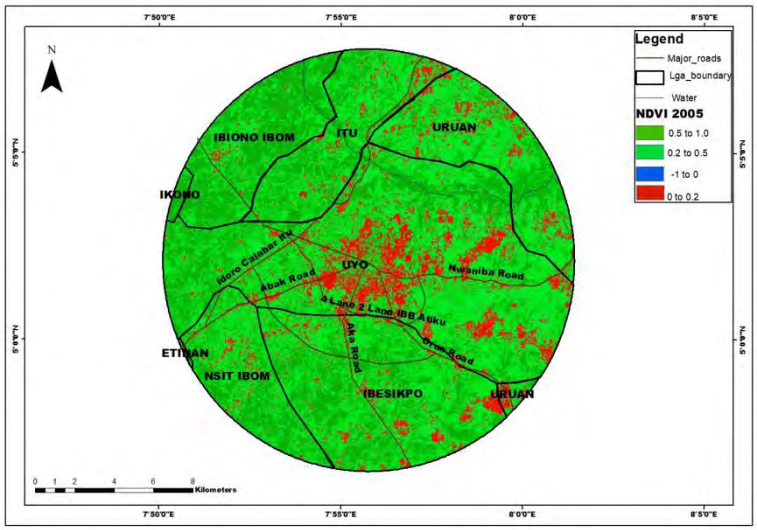

Figure 8
Normalized difference vegetative index for 2005
Source: Landsat imagery of Uyo Capital City 2005

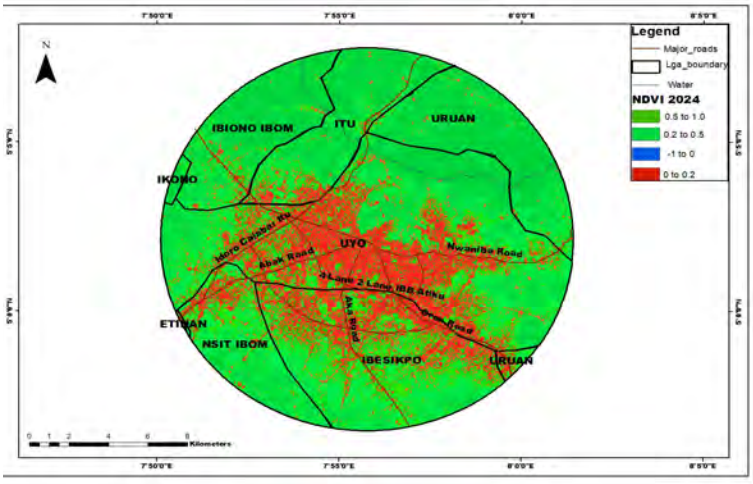

Figure 9
Normalized Difference Vegetative Index of 2024
Source: Landsat imagery of Uyo Capital City 2024

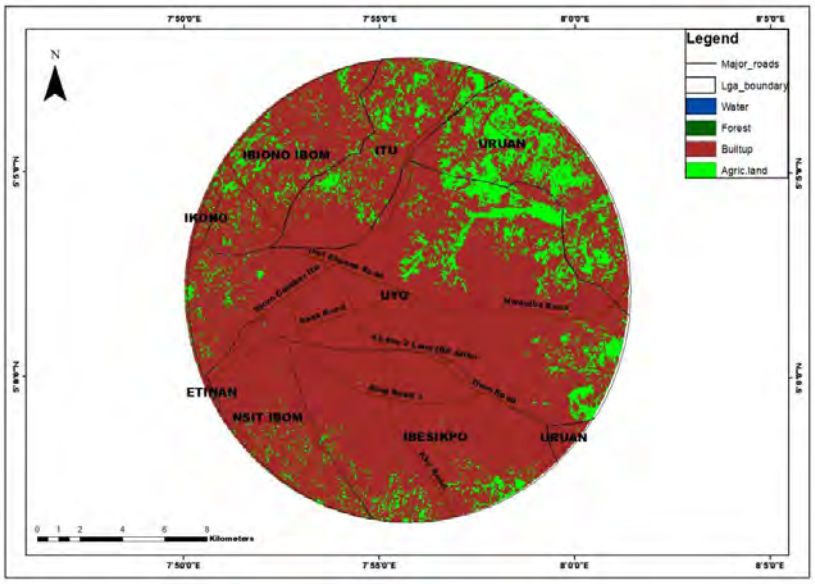

Figure 10
Predicted land use/ land cover of Uyo Capital City for the year 2050
Source: Classified Satellite Image of Uyo Capital City

DISCUSSION OF FINDINGS

The findings of this study on the inventory of land use within the study area reveals over the observed periods. In 1986, forest cover spanned 10,455.40 hectares (31.05%), but by 2005, it had decreased to 8300.69 hectares (24.66%). By 2024, forest cover had further dwindled to 5531.80 hectares (16.43%). This steady decline indicates a substantial loss of forested areas, primarily driven by urban expansion, agricultural conversion, and industrial activities. The reduction in forest cover is associated with habitat loss, diminished biodiversity, and the disruption of critical ecosystem services, such as carbon sequestration and soil stabilization. These findings are consistent with the work of Obot et al. (2019), which highlights urban expansion in Uyo as a significant driver of deforestation, a trend commonly observed in Nigerian urban centers where forests are cleared to accommodate housing and industrial development.

In 1986, agricultural land occupied 9213.3 hectares (27.36%), while in 2005, agricultural land expand to 10689.60 hectares (31.75%). Meanwhile in 2024, agricultural land decreased gradually to 7687.9 hectares (22.83%). Agricultural land in Uyo capital city showed a growth spurt between 1986 and 2005, increasing. This likely reflects a period of agricultural intensification or the conversion of forested areas into agricultural land. However, by 2024, agricultural land had experienced a decline, which could be attributed to the rapid urbanization seen in the city. As the city centre population grew and industrial development accelerated, agricultural land was increasingly converted into residential, commercial, and industrial land. This resonates with findings by **Adebayo & Omojola (2010)**, who documented the widespread loss of agricultural land to urban expansion in Nigerian cities. Their study found that as cities like Uyo grow, agricultural lands are increasingly converted into built-up areas, which directly impacts food security and the livelihoods of farmers.

In terms of water bodies, it covered 6110 hectares (18.15%), reduced to 5579.59 hectares (16.57%) in 2005 and further declined to 5366.26 hectares (15.94%) in 2024. The decrease in water bodies over the decades suggests both direct and indirect impacts of urbanization. As the city expanded, water bodies likely faced encroachment from infrastructure projects, while pollution and climate change might also have contributed to their reduction. The steady reduction in water bodies in Uyo capital city is also in line with broader studies on wetland loss and degradation in urbanizing Nigerian cities. According to Thompson and Olajoke, (2007). water bodies in urban areas are often encroached upon as cities expand.

In addition, built-up areas occupied 7891.16 hectares (23.44%) in 1986, grew to 9099.98 hectares (27.02%) in 2005 and later surged to 15083.90 hectares (44.80%) in 2024. The most dramatic change is seen in the expansion of built-up areas, which increased rapidly within the periods. This expansion reflects rapid urbanization, driven by population growth, rural-to-urban migration, infrastructural development, and economic activities in Uyo. The rise in built-up areas places enormous pressure on remaining natural resources, such as forests, water and agricultural land.

The forecasted land uses for the validation model indicated a very good agreement between the stimulated land use land cover of the study area in 1986 and the actual land use land cover classes in 2024. Hence the

predicted land use of 2050 simulated using MOLLUSC plugin model in QGIS has showed a continues trend of Uyo capital city's built-up area increasing and other land uses (water, agricultural land and forest) etc decreasing for the next 25years in the study area. The prediction pattern indicates that, in year 2050 Uyo capital city built-up area will increase by 26609.85 hectares (79.0%), agricultural land will decline to 5023.76 hectares (14.92%%), water will decline to 1034.98 hectares (3.1%) and forest will decline to 1001.27 hectares (3.0%). The result indicates that, there will be a significant trend toward increasing urbanization. These findings resonate with the findings of Khanal et.al; (2019) opine that urbanization contributes to decline in forest and agricultural lands. The anticipated trends of rapidly expanding built-up areas transforming other important land cover type in Uyo capital city align with the recent study reported the similar scenario in the urbanization of other major cities in developing countries (Wang et. al., 2021).

Assessing the spatial dynamics of urban expansion in Uyo Capital City, an analysis of satellite imagery between 1986 and 2005 reveals that the urban expansion predominantly extended toward the southeastern zone of the city. Uyo Capital City is characterized by four major arterial roads, Ikot Ekpene Road, Aka- Obot Idim Road, Abak Road, and Oron Road which play a pivotal role in shaping the spatial growth and directional pattern of urban growth within the study area. These road networks enhance accessibility and facilitate connectivity with surrounding Local Government Areas, thereby influencing the spatial organization of the city. Notably, the area between Oron Road and Ikot Ekpene Road exhibited a particularly high rate of expansion, suggesting a zone of intensified urban development during this period. The direction of distribution of residential structures further indicates a concentric pattern of settlement, with a high density of housing within the city center that progressively decreases with increasing distance from the urban core. This pattern is consistent with classical urban models and reflects a typical trend of population concentration and development intensity within central urban areas, tapering off toward the periphery. Between 1986 and 2005 Urban expansion predominantly occurred along major transportation corridors, notably Oron Road, Nwaniba Road, Ikot Ekpene Road, Aka–Obot Idim Road, and parts of the Uruan axis. The directional pattern of this expansion suggests a pronounced growth trend toward the southeastern, northeastern, and northwestern zones of Uyo Capital City. This spatial expansion reflects a typical peri-urbanization process, wherein urban development increasingly encroaches upon rural and agricultural landscapes. The consequence of this rapid and often unregulated urban growth has been a marked reduction in vegetative cover, particularly along the aforementioned corridors. Villages such as Eniong, Afaha Etok, Ifa Ikot Ubo, and Mbierebe Obio, which fall within the expanding urban fringe, have experienced substantial landscape transformation. These areas serve as critical zones of urban change, highlighting the spatial extent and socio-environmental impact of expansion in the study area during the observed period.

A comparative analysis of land use patterns between 2005 and 2024 reveals that urban expansion became increasingly dispersed, occurring in virtually all directions across the study area. This diffuse pattern of expansion underscores a shift from linear or corridor-based growth to a more radial and fragmented urban spread. Despite the widespread nature of urbanization, significant vegetation cover persists in the northern part of Uyo Capital City, largely due to the presence of ravine landscapes, present challenging topographic and geotechnical conditions that constrain infrastructural development. Additionally, remnant vegetation zones are observed along the peripheries of neighboring Local Government Areas, including Nsit Ibom, Ibesikpo Asutan, Uruan, Itu, Ibiono Ibom, and Ikono, all within the metropolitan influence of Uyo Capital City. These fringe areas, though still semi-rural, are increasingly under pressure from expanding urban development. The ongoing conversion of vegetated and agricultural land to built-up uses signals a trend of unsustainable land use practices, with adverse implications for agricultural productivity and food security.

NDVI time series (Figure 6, 4.6, 4.9) showed that from 1986, 2005 and 2024, the change in the vegetation in Uyo Capital City occurred at a slower rate from 1986 to 2005 and beyond, as the vegetation (forest) decreasing rapidly without increasing at any time of the year, in 2005 to 2024 vegetation went up and down because of its seasonal variation, and the vegetation keep decreasing because of built-up increased between 1986 and 2024. This decline in vegetation could be attributed to rapid urbanization, infrastructure development and population growth in Uyo Capital City.

CONCLUSION AND RECOMMENDATIONS

This study provides a comprehensive assessment of urban expansion in Uyo Capital City from 1986 to 2024, utilizing remote sensing, GIS, and socio-economic analysis. The findings reveal substantial land use/land cover transformations, particularly the decline in forest cover and agricultural land, and a significant increase in built-up areas. NDVI analysis confirmed a notable reduction in vegetation due to infrastructural development. Population and economic growth emerged as the dominant drivers of urban expansion, corroborated by weighted average analysis, while secondary factors such as infrastructure and policy also contributed. Farmland loss was and land use transformations was identified as the most critical impact, underscoring threats to food

security and ecosystem services. The spatial pattern of urbanization followed a concentric model driven by road infrastructure and socio-economic dynamics, with pronounced growth in southeastern Uyo and surrounding LGAs. Future projections using the MOLLUSC model suggest that by 2050, built-up areas will increase by 79%, with corresponding declines in agricultural land, forests, and water bodies. These findings call for proactive, sustainable land-use strategies and integrated urban planning to address the challenges posed by rapid urbanization, ensuring ecological sustainability, socio-economic equity, and spatial resilience in Uyo Capital City and similar urbanizing regions.

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