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Analyzing Land Use Dynamics over Time in Awka Capital Territory: Leveraging Time Series Modeling and Remote Sensing for Sustainable Development

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Abstract
This study harnessed remote sensing technology to analyze land cover and land use in Awka Capital Territory, Anambra State, Nigeria, with a focus on modelling sustainable land use dynamics. The research uncovered a significant urban area expansion, increasing from 27.92% in 1990 to 37.24% in 2017, with an annual urban growth rate fluctuating between 0.43% and 0.62%. Predictive analysis for 2048 projected a further urban expansion to 49.41%, covering 22,871.51 hectares. These findings highlight the pressing need for informed urban development planning and decision-making to ensure sustainable growth. This approach, integrating remote sensing and modelling, emerges as a valuable tool for addressing urban development and promoting sustainable development in Awka Capital Territory. It offers insights into the region's evolving land use dynamics and provides a roadmap for proactive, sustainable land management aligned with global sustainability goals.

Keywords: Development Dynamics, SDGs, Remote Sensing, Trend Analysis, Urban Growth.

1.0 Introduction

Nestled in the heart of Anambra State, Nigeria, Awka Capital Territory has emerged as a dynamic and evolving region, bearing witness to substantial transformations in recent decades. This unique convergence of urbanization, agricultural activities, and environmental shifts has garnered considerable attention from researchers and policymakers alike, recognizing the profound implications of these dynamics on the region's sustainable development (Li et al., 2017; Seto et al., 2011).

Against the backdrop of a global landscape marked by unprecedented urbanization and development, Awka Capital Territory serves as a captivating microcosm for the study of land use evolution (Iloka and Omojola, 2015; Nzeadibe et al., 2012). As the capital of Anambra State, it stands at the nexus of rapid urban expansion and infrastructural development, making it an intriguing and relevant case study (Nwankwo et al., 2019).

In the realm of contemporary environmental research, remote sensing technology has emerged as an indispensable tool for monitoring and analyzing land use changes, owing to its capacity to capture intricate spatial and temporal data (Lu et al., 2004). This study pioneers an innovative approach by synergizing this technology with advanced time series modeling techniques. This holistic methodology empowers us to gain a profound understanding of how land use in Awka Capital Territory has evolved over time, offering insights into trends, patterns, and informed projections concerning future developments in the region (Lu et al.,2004; Pettorelli et al., 2014; Sulla-Menashe and ; Su et al., 2017).

In today's era of heightened environmental awareness and sustainable development imperatives, it is crucial to comprehensively assess the far-reaching consequences of land use dynamics on the local ecosystem.

Pressing issues such as land degradation, habitat loss, and urban sprawl demand meticulous examination within this context [9], [10]. Given Awka Capital Territory's distinctive characteristics and its pivotal role as an administrative and economic center, this study takes on paramount significance. Its findings are poised to make substantial contributions to informed decision-making processes regarding urban planning and environmental management, resonating with the principles of sustainable development [2], [6].

This research stands on the foundation of a robust body of literature in the fields of remote sensing and land use analysis, aiming to offer fresh insights that not only guide land management policies at the local level but also contribute to a broader comprehension of the intricate dynamics of urban development [4], [7], [11]. As we embark on this journey of exploring land use dynamics over time in Awka Capital Territory through time series modeling and remote sensing, our mission is clear. We endeavor to illuminate the past, present, and potential future of this vital region, all while providing valuable insights that resonate with the broader global pursuit of harmonizing development with environmental stewardship [3], [5]. In the subsequent sections, we will delve into the intricacies of our methodology, the depth of our data analysis, and the significance of our findings, ultimately painting a comprehensive picture of Awka Capital Territory's evolving landscape and its implications for sustainable development and the achievement of global SDGs.

2.0 Study Area

Awka Capital Territory is located in Anambra State, South Eastern Nigeria (See figure 2.1). It is located between latitude 6^0 5' N and 6^0 15' N and longitudes 7^0 0' E and 7^o 5' E. Awka capital territory covers a land mass of 400 square kilometres and comprises of six local government areas namely Anaocha. Awka North, Awka South, Dunukofia, Njikoka and Orumba North, in part or full [12].

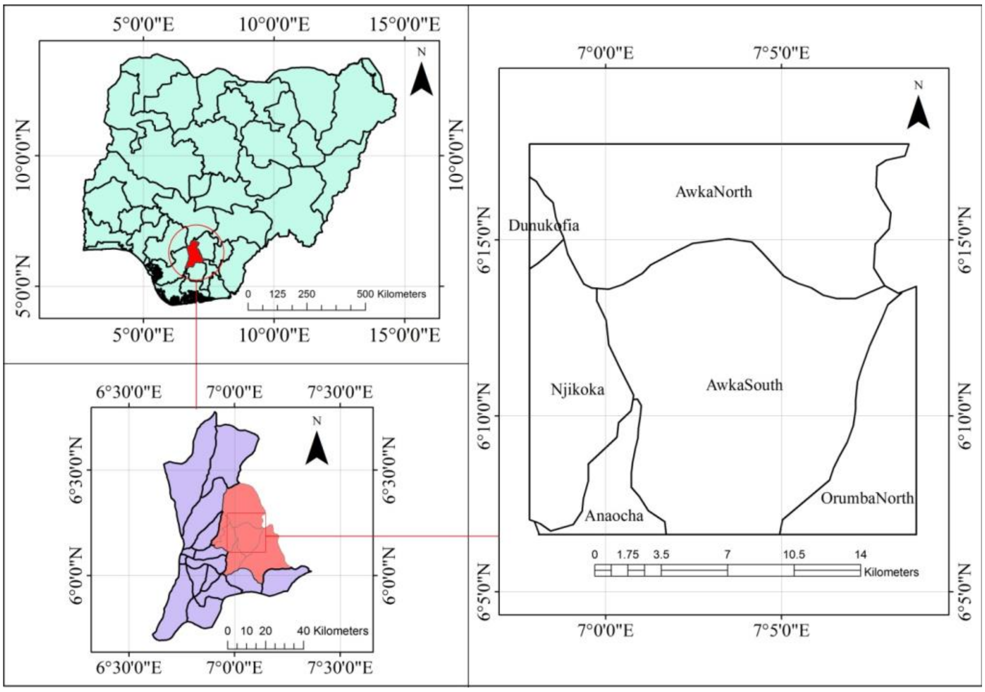

Figure 2.1: Map of Study area

3.0 Materials and Method

3.1 Materials

In this research, a diverse set of data sources was harnessed to facilitate a comprehensive analysis of Awka Capital Territory's land use dynamics. These data encompassed a range of satellite imagery and ancillary datasets, ensuring a thorough examination of the region's transformation over time.

The primary sources of satellite imagery included Landsat 5 Thematic Mapper data for the pivotal year 1990, Landsat 7 Enhanced Thematic Mapper data for the subsequent years of 1999 and 2008, Landsat 8 Operational Land Imager data for 2017, and Sentinel-2 imagery, which played a pivotal role in the analysis, for the year 2018. These datasets were meticulously acquired from the United States Geological Survey (USGS) Earth Explorer platform, accessible at www.earthexplorer.usgs.gov. These satellite datasets provided essential insights into land cover changes over a significant temporal span, enabling a nuanced understanding of the region's evolving landscape.

Complementing the satellite imagery, ancillary datasets were integrated into the analysis to provide contextual information. These ancillary datasets included the boundary map of Awka Capital Territory, which defined the study area and ensured accurate spatial referencing. Additionally, transportation data for Awka Capital Territory was incorporated, shedding light on the region's infrastructure development and its influence on land use patterns. Moreover, population data specific to Awka Capital Territory contributed to a holistic perspective on urbanization trends and their associated impacts.

The amalgamation of these diverse data sources facilitated a robust and multidimensional exploration of Awka Capital Territory's land use dynamics. It enabled the research to assess how factors such as population growth, infrastructure expansion, and changing land cover interacted and evolved over the study period. Through the synergy of satellite imagery and ancillary data, this study aimed to provide valuable insights into the intricate processes shaping the region's land use and development trajectory.

3.2 Method

In this research, a meticulous and systematic approach was undertaken to process and analyze the multi-temporal satellite imagery covering the years 1990, 1999, 2008, 2017, and 2018. The primary satellite sensors employed were the Landsat 5 Thematic Mapper (TM) for 1990, Landsat 7 Enhanced Thematic Mapper (ETM) for 1999 and 2008, Landsat 8 Operational Land Imager (OLI) for 2017, and Sentinel-2 imagery for 2018. The data processing and correction procedures closely followed the methodology described by [13].

Radiometric and geometric corrections were meticulously applied to ensure the accuracy of the imagery. These corrections are crucial to account for factors such as sensor artifacts and distortions caused by the Earth's surface. The resulting corrected images formed the foundation for subsequent analyses.

A Level One classification scheme, as per the methodology detailed by [14], was meticulously developed for the study area. This classification scheme aimed to categorize the land cover and land use classes into distinct features, including urban areas, water bodies, vegetation, and open spaces.

To validate the accuracy of the classification results, a ground truthing exercise was conducted. A total of 256 ground control points were meticulously selected using a random sampling technique. These ground control points were georeferenced with their coordinates and were used to assess the accuracy of the image classification.

Following the preparatory steps, the spectral bands from the various years were combined to create color composites for each year, effectively visualizing the study area's land cover changes over time.

For land cover classification, the supervised maximum likelihood classification algorithm in ERDAS Imagine, as employed by [15], was utilized. This classification process resulted in the generation of land cover maps for each of the study years.

To analyze the temporal trends and transitions in land cover and land use classes over the past 27 years, the classification statistics table was rigorously examined. The assessment included determining annual rates of change, which involved comparing land cover areas and percentage changes between each consecutive year.

To further investigate urban growth dynamics, a quantitative method proposed by [16] was applied. This method categorized urban growth types, including infilling, edge expansion, and spontaneous growth. Understanding the prevalence of these growth types provided insights into the evolving landscape patterns over time.

In addition to these analyses, the Molusce algorithm was employed to model and predict future urban development. This prediction process was based on the land cover maps of 1990, 1999, 2008, and 2017, in conjunction with various explanatory variables such as distance to roads, population density, and proximity to developable lands. An artificial neural network (ANN) was used for training and prediction. The model's results were rigorously validated against the reference data from the land cover and land use map of 2018, employing statistical measures such as kappa statistics and image correlation.

Upon successful validation, the model was leveraged to project urban development trends for the next 30 years, encompassing the period from 2018 to 2048. This comprehensive approach allowed for a robust examination of land use dynamics and facilitated the forecasting of future urban development patterns within the study area.

4.0 Results

4.1 Landcover/Landuse Classification

The land cover and land use distribution within Awka Capital Territory underwent discernible changes between 1990 and 2018, reflecting dynamic shifts in the region's landscape. These changes were characterized by alterations in the proportions and areas of different land cover categories.

In 1990, the predominant land cover was vegetation, encompassing a substantial 50% of the territory, equivalent to 23,144.9 hectares. The urban area comprised 27.92%, occupying a land area of 12,922.45 hectares. Open space and water bodies represented the minority categories, with 12.82% (5,936.22 hectares) and 9.26% (4,286.22 hectares), respectively.

By 1999, significant transformations had occurred. Vegetation had decreased to 46.73%, covering an area of approximately 21,629.79 hectares. Conversely, the urban area expanded to 31.19%, totaling 14,437.68 hectares. Open space decreased marginally to 12.30%, comprising 5,693.72 hectares, while water bodies increased to 9.78%, occupying 4,528.6 hectares.

In 2008, the trend continued. Vegetation dwindled to 44.46%, spanning 20,583.59 hectares, while the urban area continued its growth, reaching 33.67% and covering 15,586.73 hectares. Open space saw a slight decrease to 12.07%, with an area of 5,589.67 hectares, while water bodies experienced a minor increase, reaching 9.78% and an area of 4,529.8 hectares.

By 2017, the transformation persisted, with vegetation decreasing to 41.29%, covering 19,115.32 hectares, and the urban area expanding to 37.24%, with an area of 17,237.45 hectares. Open space continued its decline to 11.52%, comprising 5,334.6 hectares, while water bodies increased slightly to 9.94%, covering an area of 4,601.35 hectares.

The land cover and land use distribution in 2018 maintained the trend of decreasing vegetation, which reached 40.08% and covered 18,555.33 hectares. Meanwhile, the urban area continued to grow, encompassing 38.45% of the territory with an area of 17,798.44 hectares. Open space decreased marginally to 11.50%, comprising 5,324.67 hectares, and water bodies increased slightly to 9.96%, covering an area of 4,611.35 hectares.

These dynamic changes in land cover and land use over the years are visually depicted in Figure 4.1. The evolving landscape of Awka Capital Territory underscores the need for informed planning and sustainable land management strategies to address the challenges and opportunities presented by urbanization and environmental transformations in the region.

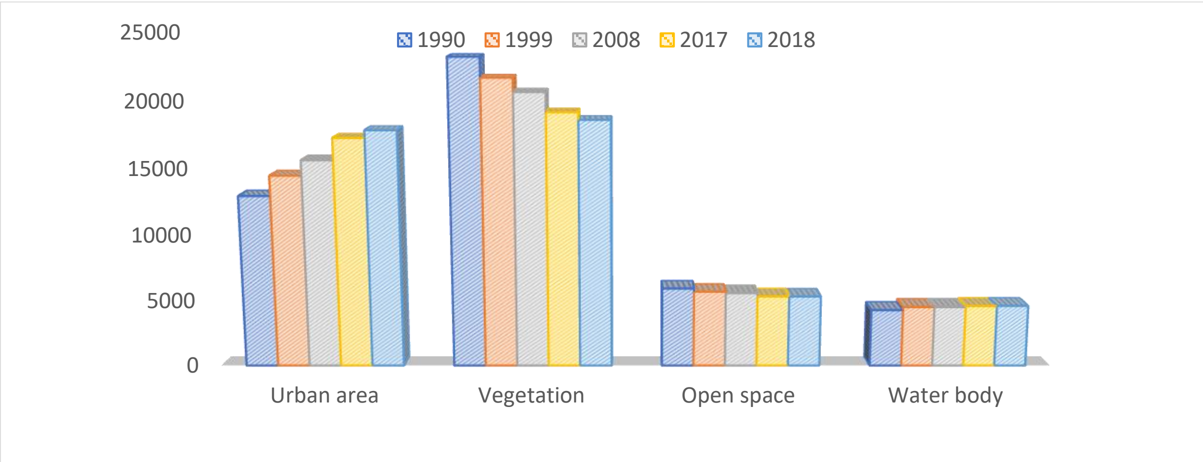

Figure 4.1: Histogram of landcover/landuse distribution of Awka Capital Territory between 1990 and 2018

4.2 Trend Analysis

The analysis of annual rates of change in land cover and land use between 1990 and 2017 provides valuable insights into the dynamic transformations within Awka Capital Territory. These rates reflect the varying pace and direction of change across different land cover categories.

For the urban area, the annual rate of change was observed as 0.62% between 1990 and 1999, signifying a steady increase in urbanization during this period. Between 1999 and 2008, the rate slightly declined to

0.43%, indicating a somewhat slower pace of urban expansion. Subsequently, between 2008 and 2017, the rate experienced a modest increase to 0.56%, suggesting a resurgence in urban growth during this interval.

In contrast, vegetation exhibited an annual decline rate of -0.37% between 1990 and 1999, indicating a reduction in vegetative cover during this period. This negative trend continued, with a rate of -0.27% between 1999 and 2008. Between 2008 and 2017, the decline rate intensified to -0.41%, underscoring the ongoing challenges related to vegetation loss within the territory.

Open space, as a land cover category, showed a consistent negative annual rate of change. It declined at a rate of -0.23% between 1990 and 1999, followed by a slower decline rate of -0.10% between 1999 and 2008. Subsequently, between 2008 and 2017, the decline rate accelerated to -0.25%. This trend highlights the progressive reduction of open spaces within the territory.

Water bodies, on the other hand, exhibited a varying pattern of annual rate of change. Between 1990 and 1999, there was an increase at a rate of 0.30%, indicating a growth in water bodies during this period. However, the rate between 1999 and 2008 was minimal, at 0.001%, suggesting relative stability. From 2008 to 2017, there was a modest increase in the rate to 0.08%, indicating a slight expansion of water bodies within the territory.

These annual rates of change, illustrated in Figure 4.2, underscore the dynamic nature of land cover and land use within Awka Capital Territory over the analyzed period. The contrasting trends among different land cover categories emphasize the complex interplay of factors shaping the region's evolving landscape. Understanding these rates of change is essential for informed planning and decision-making processes, particularly in the context of urban development and environmental conservation.

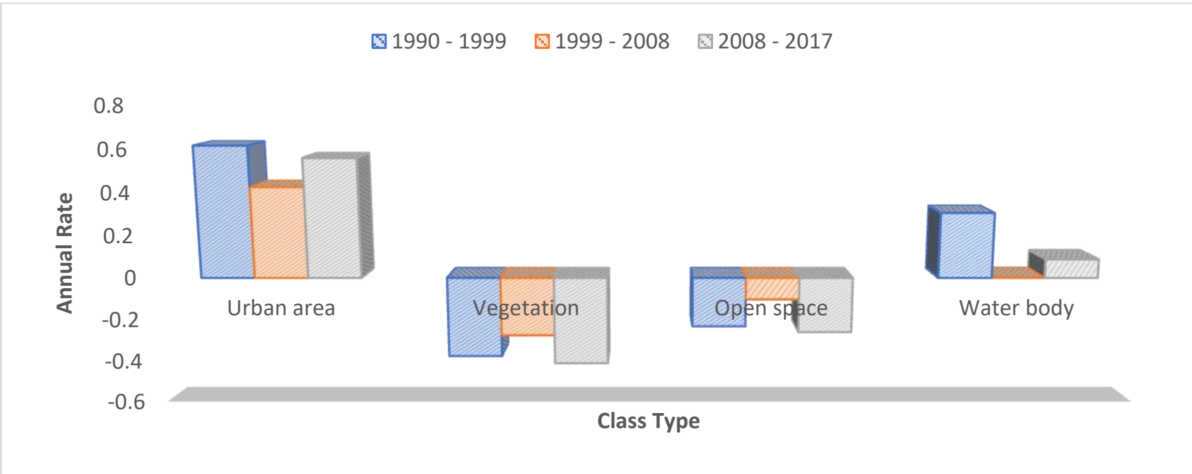

Figure 4.2: Annual rate of change between 1990 and 2017

4.3 Future Urban Development Prediction

The process of urban growth prediction within the Molusce framework is a meticulously structured and empirically-driven procedure. It unfolds in a systematic sequence, progressing from change analysis to transition potential modeling and ultimately culminating in change prediction. This predictive modeling is rooted in the historical land cover and land use changes observed between the years 1990 and 2018.

The initial step involves a thorough analysis of the historical change dynamics within the study area, specifically spanning the period from 1990 to 2017. During this phase, changes that occurred within this timeframe are identified and meticulously modeled as transitions from one land cover or land use state to another. This granular analysis provides a comprehensive understanding of how different areas within Awka Capital Territory evolved and transformed over nearly three decades.

Subsequently, the Molusce algorithm is harnessed to forecast land cover and land use changes over a future timeline extending 30 years from 2018 to 2048. This forward-looking prediction process leverages the insights gained from historical change analysis and transition potential modeling. The result of this predictive modeling effort is presented in detail in Table 4.5, providing valuable projections of anticipated changes in land cover and land use within the study area for the forthcoming decades.

The Molusce-based urban growth prediction method stands as a robust tool that incorporates both historical trends and spatial dynamics to inform decision-making processes related to urban planning, resource allocation, and environmental management. By forecasting land cover changes over a significant time horizon, it offers essential insights for policymakers and stakeholders tasked with addressing the complex challenges and opportunities associated with urban development in Awka Capital Territory.

Table: 4.5: Landcover/landuse distribution of Awka capital territory 2048

Class Name	2048 Landcover/landuse Prediction	
	Hectares	Percentage (%)
Urban area	22871.51	49.41%
Vegetation	13853.39	29.93%
Open space	4852.99	10.48%
Water body	4711.9	10.18%
Totals	46289.79	100%

The urban growth predictions, meticulously presented in Table 4.5, offer a compelling glimpse into the anticipated changes that are expected to shape the landscape of Awka Capital Territory by the year 2048. These projections are rooted in comprehensive modeling and analysis, taking into account various factors influencing land cover and land use dynamics.

According to the prediction results, it is envisaged that by 2048, the urban area within Awka Capital Territory will undergo significant expansion, encompassing approximately 49.41% of the total land area. This substantial growth is expected to translate into an urban land coverage of approximately 22,871.51 hectares, as illustrated in Figure 4.5. This marked increase underscores the persistent trend of urbanization within the region.

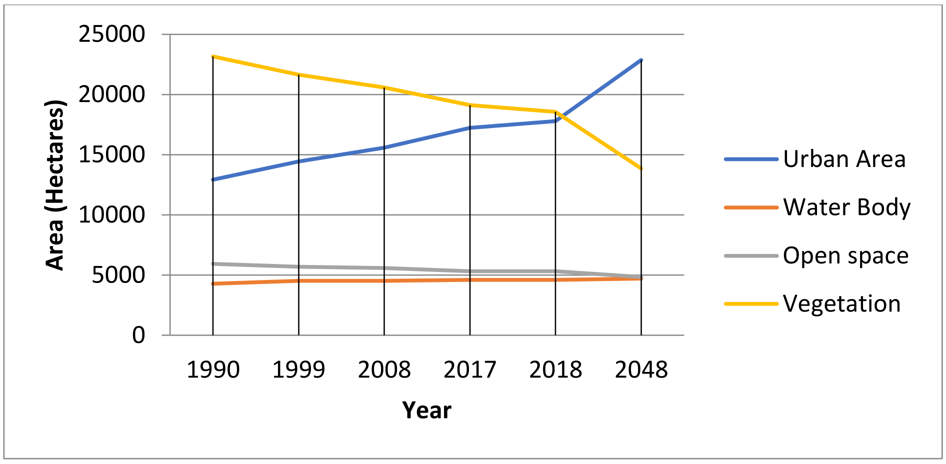

Figure 4.6: Graph of urban development from 1990 to 2048

Conversely, vegetation is poised to experience a reduction in its land cover share, dwindling to an estimated 29.93% by 2048. This transformation is expected to result in a vegetative coverage area of approximately 13,853.39 hectares. Similarly, open spaces are anticipated to decrease, comprising 10.48% of the territory, or approximately 4,852.99 hectares.

One notable shift in the landscape is the projected increase in water bodies, which are expected to expand to 10.18% of the total area, covering approximately 4,711.9 hectares. This increment in water bodies signifies a potential improvement in aquatic features within the region.

The driving forces behind these projections lie in several key factors, notably the geographical proximity to roads, the availability of developable land, and the increasing population density. Over the span of three decades from 2018, both vegetation and open space categories are anticipated to cede portions of their territory to the expanding urban area. This is a direct consequence of urbanization dynamics, as development spreads into previously vegetated and open areas.

Conversely, the projection anticipates an increase in water bodies due to various factors, including potential conservation efforts and environmental considerations. Urbanization, as indicated, is expected to intensify,

with the urban area growing from 35.45% in 2018 to 49.41% in 2048, translating into an area coverage increase from 17,798.44 hectares to 22,871.51 hectares.
In contrast, both open space and vegetation are expected to diminish, with open space decreasing from 11.50% to 10.48% (5324.67 hectares to 4,852.99 hectares) and vegetation decreasing from 40.08% to 29.93% (18,555.33 hectares to 13,853.39 hectares). These trends, as elucidated by the predictions, emphasize the evolving dynamics of land cover and land use within Awka Capital Territory and the critical role of informed planning and sustainable development strategies in shaping its future.

Thirty years from 2018, the vegetation and open space classes are expected to loss part of its area to urban area based on their distance to roads, distance to developable land and as population density increases. Water body is expected to increase from 9.96% to 10.18% with area coverage of 4711.9 hectares. Urban area is expected to increase from 35.45% to 49.41% i.e. from area coverage of 17798.44 hectares to 22871.51 hectares while open space and vegetation is expected to decrease from 11.50% to 10.48% i.e. from 5324.67 hectares to 4852.99 hectares and 40.08% to 29.93% i.e. from 18555.33 hectares to 13853.39 hectares respectively.

4.5 Results Discussion and Conclusion

The analysis of land cover and land use changes in Awka Capital Territory from 1990 to 2018, coupled with the predictions for 2048, holds significant implications for the Sustainable Development Goals (SDGs) and the broader development of the region. These findings are in line with various scholarly works in the field of land cover and land use dynamics, and they underscore the importance of informed planning and sustainable land management.

1. **Urbanization Trends and Sustainable Cities (SDG 11)**: The substantial increase in urban area from 1990 to 2018 and the projected expansion by 2048 align with the goals of SDG 11, which aims to make cities and human settlements inclusive, safe, resilient, and sustainable. The study's findings echo the concerns and discussions raised in research by [17], on Africa´s urbanization trends their implications for sustainable development.
2. **Vegetation Loss and Environmental Conservation (SDG 15)**: The consistent decline in vegetation cover over the years reflects the challenges posed by urbanization and land use changes. This reduction is a matter of concern as it impacts biodiversity and ecosystems, aligning with SDG 15's focus on protecting, restoring, and promoting sustainable use of terrestrial ecosystems. The work of [18] underscores the global implications of land use changes on ecosystems and biodiversity.
3. **Open Space Preservation (SDG 11 and SDG 15)**: The reduction in open space area emphasizes the need for balanced urban development that preserves green spaces and recreational areas, which is crucial for achieving SDG 11's goal of creating inclusive, safe, and sustainable urban environments and SDG 15's emphasis on safeguarding ecosystems and landscapes. Research by [19] highlights the importance of green spaces in urban planning and development.
4. **Water Body Expansion and Environmental Quality (SDG 6 and SDG 15)**: The slight increase in water bodies reflects a potential improvement in aquatic features, aligning with SDG 6's focus on clean water and sanitation and SDG 15's emphasis on healthy ecosystems. The work of [20] discusses the importance of water bodies in maintaining environmental quality.
5. **Population Dynamics (SDG 3 and SDG 11)**: The projections for urban growth and population density indicate demographic shifts within the territory. This underscores the importance of health and well-being (SDG 3) and sustainable urbanization (SDG 11), as ensuring access to healthcare and infrastructure for the growing population is essential. Research by [21] discusses the interplay between urbanization, population dynamics, and sustainable development.
6. **Planning and Sustainable Development (Cross-cutting)**: The findings emphasize the significance of informed planning and sustainable land management. Policymakers and stakeholders must consider the implications of land use changes on infrastructure, environment, and the well-being of the population. Integrated planning that addresses multiple SDGs is crucial for balanced development. Research by [2] highlights the importance of urban planning in achieving sustainability goals.
7. **Environmental Conservation and Monitoring (Cross-cutting)**: The analysis and predictions highlight the importance of ongoing monitoring and conservation efforts. This includes tracking

changes in land cover, assessing their impacts on ecosystems, and implementing measures to mitigate negative effects. The work of [7] discusses the role of remote sensing and monitoring in conservation and environmental management.

In conclusion, the comprehensive analysis of land cover and land use dynamics within Awka Capital Territory spanning from 1990 to 2018, along with the insightful predictions for 2048, yields valuable insights that resonate with the Sustainable Development Goals (SDGs) and relevant scholarly research. These findings underscore the critical importance of informed planning and sustainable land management in shaping the region's development trajectory.

The observed trends in urbanization, with a notable increase in urban areas and a concurrent decline in vegetation and open spaces, align closely with the objectives of SDG 11, which seeks to foster inclusive, safe, resilient, and sustainable cities and human settlements. This emphasizes the need for urban planning strategies that accommodate the rapid growth in urban areas while preserving green spaces and recreational zones to enhance the quality of urban life.

The persistent loss of vegetation highlights the challenges posed by urbanization and its impacts on biodiversity and ecosystems, emphasizing the relevance of SDG 15, which focuses on protecting, restoring, and sustaining terrestrial ecosystems. Strategies for vegetation preservation and restoration should be integral to regional development plans to mitigate the environmental consequences of land use changes.

The expansion of water bodies indicates potential improvements in aquatic features and underscores the importance of clean water and healthy ecosystems, aligning with the principles of SDG 6 and SDG 15. These findings emphasize the interdependence of environmental health and human well-being, highlighting the need for sustainable land management practices that consider water resources.

Population dynamics, as evidenced by projections of urban growth and population density, emphasize the importance of healthcare and infrastructure development (SDG 3) and sustainable urbanization (SDG 11). Meeting the needs of a growing population within urban areas necessitates a multifaceted approach to ensure access to essential services and improve overall living conditions.

The overarching theme of informed planning and sustainable development resonates throughout the analysis, aligning with research in the field of urban planning and land use dynamics. Holistic planning strategies that account for the multifaceted impacts of land use changes on infrastructure, environment, and human well-being are vital for balanced regional development.

Moreover, ongoing monitoring and conservation efforts, as emphasized in academic literature, will play a pivotal role in addressing the challenges posed by changing land use patterns. Remote sensing and monitoring technologies provide valuable tools for assessing environmental changes and implementing effective conservation measures.

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