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Remote Sensing-Guided Land Cover and Land Use Analysis as a Preliminary Step for Assessing Land Degradation and Its Impact

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Abstract This study employed remote sensing to conduct a land cover and land use analysis of Awka Capital Territory in Anambra State, Nigeria, with a primary focus on its role as a precursor to assessing land degradation and its consequences. The findings revealed a noteworthy increase in the urban area, which expanded from 27.92% to 31.19% (an area of 14,437.68 hectares) between 1990 and 1999, further growing to 33.67% (covering 15,586.73 hectares) between 1999 and 2008, and ultimately reaching 37.24% (covering 17,237.45 hectares) between 2008 and 2017. The trend analysis indicated an annual rate of change of 0.62% between 1990 and 1999, 0.43% between 1999 and 2008, and 0.56% between 2008 and 2017 in the urban area. Transition analysis demonstrated that during the first period (1990-1999), urban area gained 1,272.73 hectares from vegetation and 242.5 hectares from open space. Similarly, between 1999 and 2008, urban area gained 1,000 hectares from vegetation and 149.05 hectares from open space. In the final epoch (2008-2017), urban area gained 1,068.27 hectares from vegetation and 582.45 hectares from open space. Predictive analysis for the future urban development dynamics of Awka Capital Territory in 2048 projected an increase in urban areas from 35.45% to 49.41%, equivalent to an expansion from an area coverage of 17,798.44 hectares to 22,871.51 hectares. This study recommends the adoption of this approach as a valuable tool for urban development planning and decision-making, emphasizing its utility in addressing land degradation and its associated impacts.

Keywords Development Dynamics, Growth Pattern, Remote Sensing, Trend Analysis, Urban Growth

1. Introduction

Numerous studies have highlighted the dwindling presence of natural landscapes on Earth due to human activities, signifying the profound impact of land use changes on our environment (Opeyemi *et al*., 2015; Kumar *et al*., 2007). Man-made alterations to the landscape have spurred accelerated expansion, particularly in urban areas, driven by evolving social and economic needs (Zubair, 2008). Unfortunately, many developing countries, including Nigeria, lack regular monitoring of urban expansion (Opeyemi *et al*., 2015), even though urbanization is a global phenomenon of immense significance (United Nations, 2017). It is projected that by 2050, nearly 70 percent of the world's population will reside in cities, owing to the allure of improved quality of life offered by urban amenities (United Nations, 2017; Deng *et al*., 2018).

However, this surge in urban populations has compelled cities to expand both horizontally and vertically, encroaching upon agricultural land and natural boundaries, thereby altering land use and land cover unnoticed (Su *et al*., 2017). Awka Capital Territory is no exception; it is rapidly transforming into an interconnected urban

sprawl, accompanied by significant shifts in land use and land cover. Rural-to-urban migration has urbanized the territory, with 62% of its population now dwelling in urban areas (UN-HABITAT, 2009). This demographic shift has brought challenges such as inadequate infrastructure, erosion, flooding, poor sanitation, noise and air pollution, and overcrowding. Unfortunately, comprehensive data on Awka Capital City's growth dynamics are lacking, complicating decision-making and necessitating a deeper understanding of urban mechanisms to formulate effective growth management policies that mitigate negative impacts and harness positive ones.

Globally, researchers have employed diverse approaches to comprehend urban spatial growth dynamics, including the development of spatial models for studying, predicting, and simulating future urban expansion (Batty, 1994). To gain insight into Awka Capital Territory's growth dynamics, it is imperative to conduct a comprehensive analysis of urban growth trends, which plays a pivotal role in infrastructure planning, especially when resources are scarce. Remote sensing emerges as a powerful tool for analyzing urban development in Awka Capital Territory, offering the capability to synoptically assess changes over time, bridging the gap between localized ecological research and broader conservation and management efforts (Wilkie and Finn, 1996).

By collecting and analyzing spatial and statistical data spanning different time periods, we can monitor and manage urban growth and make informed predictions about future urban expansion. This research leveraged remotely sensed data and the Molusce algorithm to provide a detailed examination of land cover and land use, with a particular focus on urban growth in Awka Capital Territory across the past, present, and future. Consequently, this study sought to investigate and analyze the dynamics of development in Awka Capital Territory from 1990 to 2017, aiming to detect changes, trends, and growth characteristics over the past 27 years and predict potential developments in the coming three decades. These findings serve as a crucial preliminary step in assessing land degradation and its far-reaching impacts.

2. 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 (UN-HABITAT, 2009).

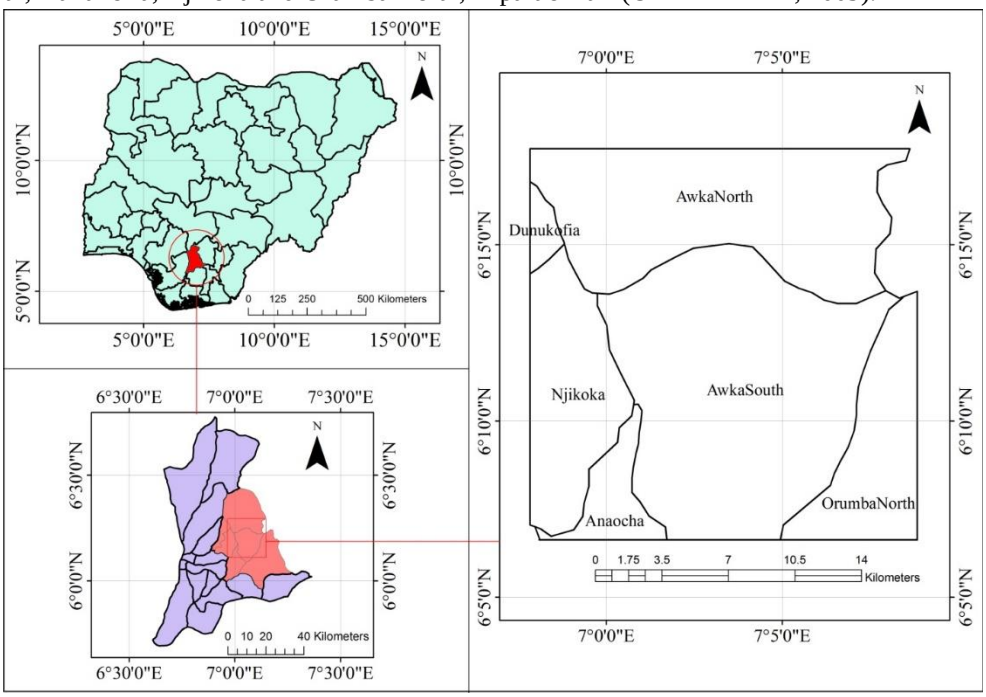

Figure 2.1: Map of Study area

3. Materials and Method

3.1 Materials

The data that was used in this research were Landsat 5 Thematic Mapper for the year 1990, Landsat 7 Enhanced Thematic Mapper for 1999 and 2008, Landsat 8 Operational Land Imager for 2017 and Sentinel-2 for 2018, all obtained from www.earthexplorer.usgs.gov. Other ancillary data used were boundary map of Awka Capital Territory, transportation data of Awka Capital Territory and population data of Awka Capital Territory.

3.2 Method

The thematic mapper for the year 1990, enhanced thematic mapper for 1999 and 2008, operational land imager for 2017 and sentinel-2 for 2018 were radiometrically and geometrically corrected as used in (Orimoloye *et al*, 2018), after which level one classification scheme was developed for the study area after (Anderson *et al*, 1967), this resulted in the following class features: urban area, water body, vegetation and open space. Ground truthing was carried out to collect sample data for accuracy assessment, for this purpose, the coordinates of 256 selected ground control points was collected and used to assess the accuracy of classification of images. Random sampling technique was used to determine the location of the points.

The spectral bands were then stacked to produce a color composite of the study area for each year (1990, 1999, 2008, 2017 and 2018), after which land cover maps of the study area were produced using the supervised maximum likelihood classification algorithm in ERDAS Imagine used by (Onojeghuo and Onojeghuo, 2013). In order to ascertain the trend of change and transition of the landcover/landuse classes in the last 27 years, the results obtained from the landcover/landuse classification statistics table were used to compute trend analysis as adopted from long *et al* (2007).

The comparison of the landcover/landuse statistics assisted in identifying the annual rate of change between 1990 and 2017. In achieving this, table was prepared showing the areas and percentage change for each year measured against each other. To determine the rate of change of landcover/landuse, the year period 1990-2017 was divided into three sub-periods 1990 – 1999, 1999 – 2008 and 2008 - 2017 and compared against each other. A quantitative method by Zeng *et al*, (2010) was also used to distinguish three urban growth types: infilling, edge expansion, and spontaneous growth in the study area. The dominance of each growth types is meaningful to describe the process of landscape pattern changes between two or more time points. The landcover maps of 1990, 1999, 2008 and 2017 were used as inputs in Molusce algorithm alongside explanatory variables such as distance to roads, population density and distance to developable lands. Transition potential was modelled and trained using artificial neural network, the training works by using classic realization of multilayer perceptron. After the ANN training, the model was then used to predict urban development in 2018. The result of the prediction was then validated by comparing it with the reference data i.e. the landcover/landuse map of 2018, using kappa statistics and image correlation. After the validation, and ascertaining that the model results were within acceptable range, future urban development prediction for the next 30years (2018 - 2048).

4. Results

4.1 Landcover/Landuse Classification

The landcover/landuse distribution of Awka Capital Territory in 1990 indicated that vegetation, accounted for the largest land cover with 50% and an area of 23144.9 hectare. Urban area had 27.92 % and a coverage area of 12922.45 hectares. Open space and water body had the lowest turnout with 12.82% and 9.26% with an area of 5936.22 and 4286.22 hectares respectively.

In 1999, vegetation, decreased from 50% to 46.73% to an area of about 21629.79 hectares. Urban area increased from 27.92% to 31.19 %, to area of 14437.68 hectares. Open space decreased from 12.82% to 12.30 to an area of 5693.72 hectares while water body increased from 9.26% to 9.78% to an area of 4528.6 hectares.

In 2008, vegetation decreased further from 46.73% to 44.46%, to an area of 20583.59 hectares. Urban area increased further from 31.19% to 33.67%, to an area of 15586.73 hectares while open space decreased from 12.30% to 12.07%, to an area of 5589.67 hectares. Water body increased slightly from 9.78% to 9.78% to an area of 4529.8 hectares.

In 2017, vegetation continued its gradual decrease from 44.46% to 41.29%, to an area of 19115.32 hectares, while urban area also increased from 33.67% to 37.24%, to an area of 17237.45 hectares. Open space continued decreasing from 12.07% to 11.52%, to an area of 5334.6 hectares while water body increased from 9.78% to 9.94%, to area coverage of 4601.35.

The land cover/land use distribution of Awka Capital Territory in 2018 also indicate gradual decrease of vegetation from 44.46% to 40.08%, to an area of 18555.33 hectares, while Urban area increased from 33.67% to 38.45%, to an area of 17798.44 hectares. Open space also decreased from 11.52% 11.50%, to an area of 5324.67 hectares, while water body increased from 9.94% to 9.96, to an area of 4611.35 hectares. This is shown in table 4.1 and figure 4.1.

Table 4.1: Landcover Distribution for Awka Capital Territory between 1990 and 2018

Class Name	1990		1999		2008		2017		2018	
	Area	%	Area	%	Area	%	Area	%	Area	%
Urban area	12922.45	27.92	14437.68	31.19	15586.73	33.67	17237.45	37.24	17798.44	38.45
Vegetation	23144.9	50.00	21629.79	46.73	20583.59	44.46	19115.32	41.29	18555.33	40.08
Open space	5936.22	12.82	5693.72	12.30	5589.67	12.07	5334.67	11.52	5324.67	11.50
Water body	4286.22	9.26	4528.6	9.78	4529.8	9.78	4602.35	9.94	4611.35	9.96
Total	46289.79	100	46289.79	100	46289.79	100	46289.79	100	46289.79	100

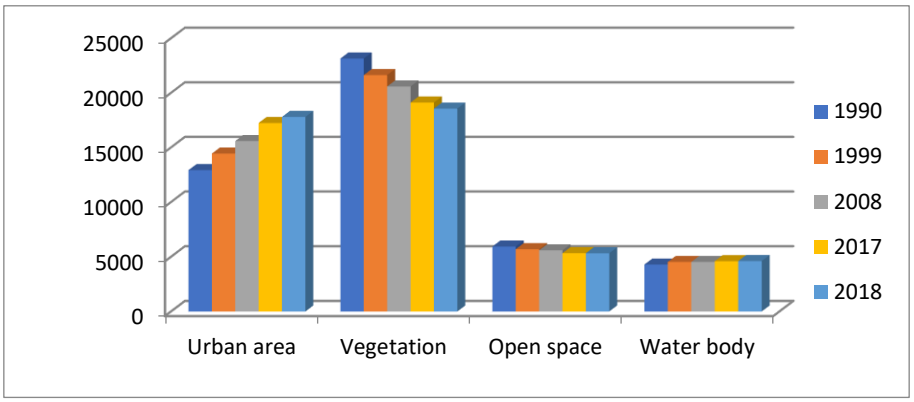

Figure 4.1: Histogram of landcover/landuse distribution of Awka Capital Territory between 1990 and 2018

4.2 Trend Analysis

The annual rate of change between 1990 and 2017, for urban area was given as 0.62% between 1990 and 1999, 0.43% between 1999 and 2008 and 0.56% between 2008 and 2017. For vegetation, the annual growth rate was given as -0.37% between 1990 and 1999, -0.27% between 1999 and 2008, and -0.41% between 2008 and 2017. For open space, the annual rate of change was given as -0.23% between 1990 and 1999, -0.10% between 1990 and 2008 and -0.25% between 2008 and 2017. For water body the annual rate of change was given as 0.30% between 1990 and 1999, 0.001% between 1999 and 2008 and 0.08% between 2008 and 2017, as shown in table 4.2 and figure 4.2.

Table 4.2: Annual rate of change between 1990 and 2017

Class Name	Annual Rate of change 1990 – 1999	Annual Rate of change 1999 – 2008	Annual Rate of change 2008 – 2017
Urban area	0.61	0.42	0.55
Vegetation	-0.37	-0.27	-0.41

Open space	-0.23	-0.10	-0.25
Water body	0.30	0.001	0.08

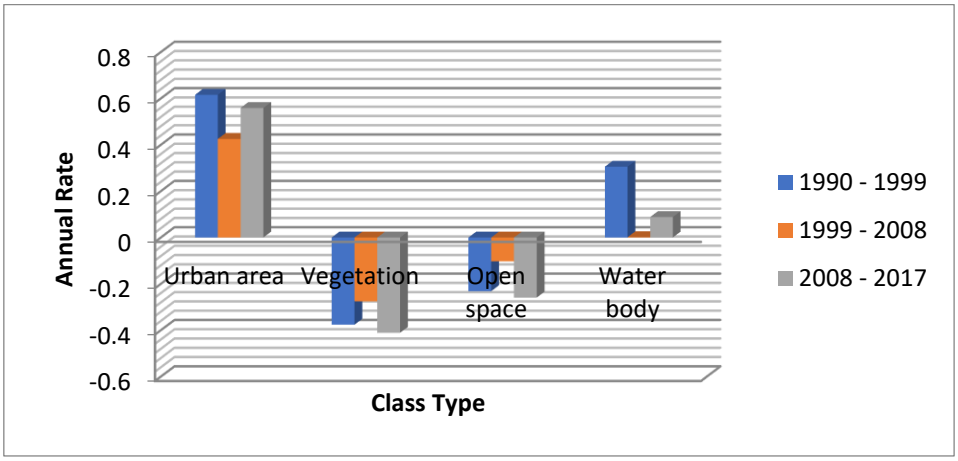

Figure 4.2: Annual rate of change between 1990 and 2017

This indicated that both urban area and water body had a positive growth between 1990 and 2017, while vegetation and open space declined between 1990 and 2017.

4.3 Model Validation

Traditionally, model validation refers to comparing the simulated and reference maps (Vliet *et al*, 2011). Sometimes the simulated maps can give misleading results. In that case, it is necessary to validate the predicted/simulated map with the base/reference map. The main objective of model validation is to find out whether the simulation is giving any abrupt result or not. This justifies the modeling output in terms of reality. In order to validate the model's prediction of landcover/landuse of 2018, the predicted landcover/landuse of 2018 was compared to the actual landcover/landuse of 2018 using kappa statistics, and image correlation.

The predicted landcover/landuse of Awka Capital Territory in 2018 as shown in table 4.4 indicate that vegetation had 40.04 %, with area of about 18534.38 hectares. Urban area had 38.67% with an area of 17901.32 hectares while water body and open space had 9.95% and 11.33% with an area of 4609.22 and 5244.87 hectares respectively. In comparison with the actual landcover/landuse of Awka Capital Territory in 2018, it read that vegetation had 40.08 %, with area of about 18555.33 hectares. Urban area had 38.45% with an area of 17798.44 hectares while water body and open space had 9.96% and 11.50% with an area of 4611.35 and 5324.67hectares respectively. This gives a difference of 102.88 hectares between actual and predicted urban area, 20.99 hectares between actual and predicted vegetation, 79.8 hectares between actual and predicted open space and 2.13 hectares between actual and predicted water body.

Table 4.3: Comparison between 2018 predicted landcover/landuse and actual 2018 landcover/landuse

Class Name	2018 Landcover/landuse		2018 Predicted Landcover/landuse		Difference	
Urban area	17798.44	38.45%	17901.32	38.67%	102.88	0.22
Vegetation	18555.33	40.08%	18534.38	40.04%	20.99	0.04
Open space	5324.67	11.50%	5244.87	11.33%	79.8	0.17
Water body	4611.35	9.96%	4609.22	9.95%	2.13	0.01
Totals	46289.79	100%	46289.79	100%		

b

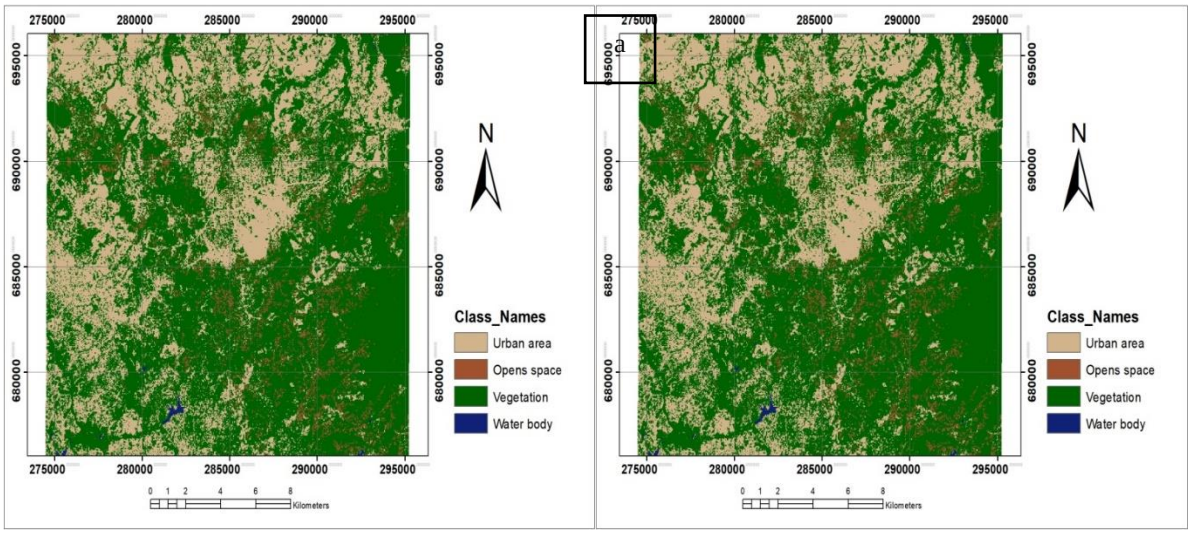

Figure: 4.3: (a) 2018 landcover/landuse map, (b) predicted 2018 landcover/landuse map

The validation tab in Molusce was used to validate the predicted map against the reference map and the overall accuracy gotten was as 93.36%; overall kappa was given as 0.9083 and the model error was given as 6.64%. Hence the model result is adjudged to be acceptable. Image correlation coefficient (*r*) between two images was also calculated to determine the similarities between the two images. The *r*-value is a measure of the linear association in the variation of the input variables (images, in this case). The coefficient ranges from -1, indicated a perfect negative linear association, to 1, indicated a perfect positive linear association. An *r*-value of 0 indicates no correlation between the test variables. The results of the correlation coeffcient gave a value of 0.9585, which indicates a good positive relationship between the two images as shown in table 4.4 and figure 4.4

Table 4.4: Image correlation matrix

	2018 Reference LULC	**2018 Predicted LULC**
2018 Reference LULC	1.000	0.9585
2018 Predicted LULC	0.9585	1.000

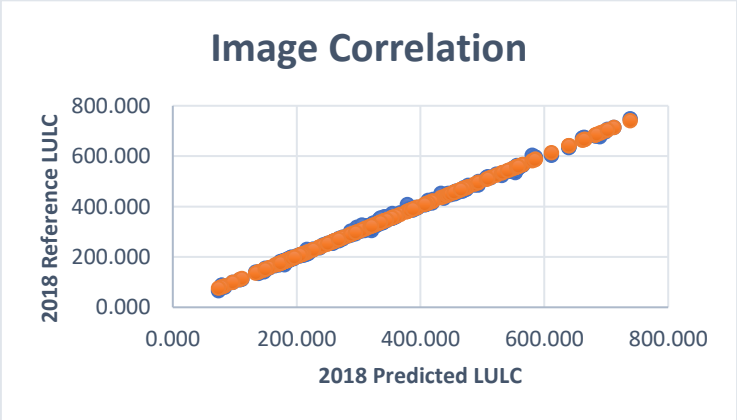

Figure 4.4: Correlation graph between 2018 reference LULC and 2018 predicted LULC

4.4 Future Urban Development Prediction

Urban growth prediction in Molusce is an empirically given process that moves in a step wise fashion from change analysis; to transition Potential Modeling; to change prediction. It is based on the historical change from

1990 to 2018. The change assessed between 1990 and 2017 are identified and modeled as transitions from one landcover/landuse state to another. Molusce was used to predict the change for (30 years) from the 2018 to 2048 and the result is shown in figure 4.5 and table 4.5.

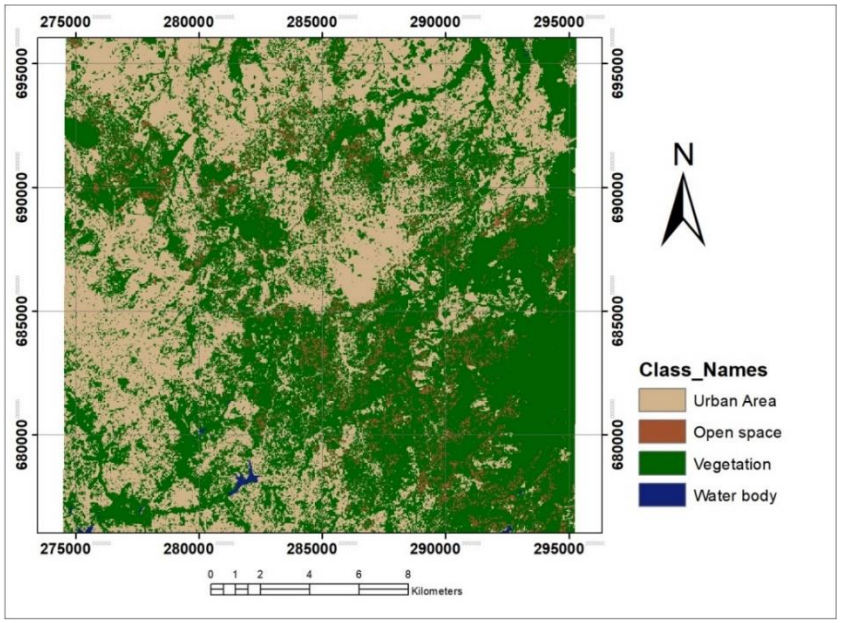

Figure 4.5: 2048 predicted future urban development

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 prediction results tabulated in table 4.5, indicated that by 2048 urban area is expected to grow to 49.41% covering an area of 22871.51 hectares (figure 4.5), vegetation is expected to decrease to 29.93% covering an area of 13853.39 hectares, open space is expected to decrease to 10.48% covering an area of 4852.99 hectares while water body is expected to increase to 10.18% covering an area of 4711.9 hectares.

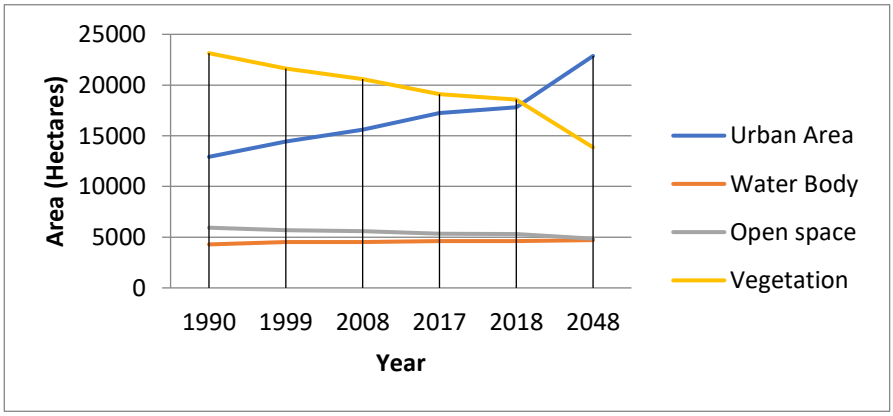

Figure 4.6: Graph of urban development from 1990 to 2048

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 results of the land cover and land use analysis for Awka Capital Territory over the years provide valuable insights into the changing landscape dynamics and their potential implications for land degradation and overall environmental impact.

In 1990, the dominant land cover was vegetation, covering 50% of the territory with an area of 23,144.9 hectares. Urban areas accounted for 27.92%, totalling 12,922.45 hectares. Open spaces and water bodies made up 12.82% and 9.26% of the land, covering 5,936.22 and 4,286.22 hectares, respectively.

Over the following years, several notable changes occurred:

1. **1999:** Vegetation decreased to 46.73% (21,629.79 hectares), while urban areas expanded to 31.19% (14,437.68 hectares). Open spaces decreased to 12.30% (5,693.72 hectares), and water bodies increased to 9.78% (4,528.6 hectares).
2. **2008:** Vegetation further declined to 44.46% (20,583.59 hectares), while urban areas continued to grow, reaching 33.67% (15,586.73 hectares). Open spaces decreased to 12.07% (5,589.67 hectares), and water bodies showed a slight increase to 9.78% (4,529.8 hectares).
3. **2017:** Vegetation decreased to 41.29% (19,115.32 hectares), while urban areas expanded to 37.24% (17,237.45 hectares). Open spaces continued to decrease to 11.52% (5,334.6 hectares), and water bodies increased to 9.94% (4,601.35 hectares).
4. **2018:** Vegetation continued to decline to 40.08% (18,555.33 hectares), with urban areas growing to 38.45% (17,798.44 hectares). Open spaces decreased slightly to 11.50% (5,324.67 hectares), and water bodies increased to 9.96% (4,611.35 hectares).

The annual rate of change analysis indicated that both urban areas and water bodies experienced positive growth rates, while vegetation and open spaces exhibited declining trends between 1990 and 2017. Urbanization was evident in the increasing urban area percentages over the years, signifying ongoing development within Awka Capital Territory.

To validate the model's prediction of land cover and land use for 2018, kappa statistics and image correlation were employed. The results indicated an overall accuracy of 93.36%, a kappa value of 0.9083, and a model error of 6.64%, affirming the reliability of the model's predictions.

The urban growth prediction for the next 30 years (2018-2048) revealed that urban areas are expected to continue expanding, reaching 49.41% of the territory by 2048, covering an area of 22,871.51 hectares. Meanwhile, vegetation is projected to decrease to 29.93%, open spaces to 10.48%, and water bodies to 10.18%. These changes reflect the ongoing trend of urbanization and its potential consequences for land degradation and environmental impact.

The comprehensive analysis of land cover and land use changes in Awka Capital Territory provides valuable information for understanding urbanization dynamics, which are critical for sustainable land management and mitigating the potential impacts of land degradation in the region. The findings highlight the importance of ongoing monitoring and planning to address the challenges associated with urban expansion.

References

[1]. Anderson, E. (1976). A Landuse and Landcover Classification System for Use with Remote Sensor Data. Geological Survey Professional Paper No. 964, U.S. Government Printing Office, Washington, D.C. p. 28.

[2]. Batty, M. (1994). A chronicle of scientific planning: The Anglo-American modeling experience, in Journal of the American Planning Association, 60, 1, pp. 7-12.

[3]. Deng, J.S., Wang, K., Hong, Y. and Qi, J.G. (2018). Spatio-temporal dynamics and evolution of land use change and landscape pattern in response to rapid urbanization. Landscape and Urban Planning, 92, 187-198.

[4]. Kumar, J. A. V., Pathan, S. K. and Bhanderi, R. J. (2007). Spatio-temporal Analysis for monitoring urban growth: A case study of Indore city. Journal of the Indian Society of Remote Sensing, 35, 11-20.

[5]. Long, H.G., Tang, G., Li, X. and Heilig, G.K. (2007). Socio-economics driving forces of landuse change in Kunshan, the Yangtze river delta economic area of the China. Journal of Environmental Management, 83 (3): 351-364

[6]. Onojeghuo A. and A. Onojeghuo (2013). Mapping and Predicting Urban Sprawl Using Remote Sensing and Geographic Information System Techniques: A Case Study of Eti-Osa Local Government Area, Lagos, Nigeria. FIG Working Week 2013 Environment for Sustainability, Abuja, Nigeria, 6 – 10 May 2013

[7]. Opeyemi, A. Z., Lazarus, M. O., Richard A. M., (2015), Urbanization: A Catalyst For The Emergence Of Squatter Settlements And Squalor In The Vicinities Of The Federal Capital City Of Nigeria, Journal of Sustainable Development; Vol. 8, No. 2; ISSN 1913-9063 E-ISSN 1913-9071

[8]. Orimoloye, I.R., Mazinyo, S.P., Nel, W., and Kalumba, A.M. (2018) Spatiotemporal monitoring of land surface temperature and estimation radiation using remote sensing: human health implications for East London, South Africa Environ. Earth Sci. 77, 77 (10.1007/s12665-018-7252-6)

[9]. Su, S., Jiang, Z., Zhang, Q. and Zhang, Y. (2017). Transformation of agricultural landscapes under rapid urbanization: a threat to sustainability in Hang-Jia-Hu region, China. Applied Geography, 31, 439-449

[10]. UN-HABITAT, (2009), Executive summary plans for Awka, Onitsha and Nnewi Accessed at Https://unhabitat.org/books/executive-summary-of-structure-plans-for-awka-onitsha-and-nnewi-and-environs-2009-2027/executive-summary-of-structure-plans-for-awka-onitsha-and-nnewi-and-environs-2009-2027/

[11]. United Nations (2017). World Urbanization Prospects (CD-ROM Edition). Population Division of the Department of Economic and Social Affairs, United Nations.

[12]. Vliet, J, Bregt, A, and Hagen Z. (2011). Revisiting Kappa to Account for Change in the Accuracy Assessment of Land-Use Change Models. Ecological Modeling. 222. 1367-1375. 10.1016/j.ecolmodel.2011.01.017.

[13]. Wilkie, D.S. and Finn, J.T. (1996). Remote Sensing Imagery for Natural Resources Monitoring. Columbia University Press, New York. p. 295.

[14]. Zeng, Yongnian & Xu, Y & Li, Songnian & He, L & Yu, F & Zhen, Z & Cai, Chenglian. (2012). Quantitative analysis of urban expansion in central China. ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. XXXIX-B7. 363-366. 10.5194/isprsarchives-XXXIX-B7-363-2012.

[15]. Zubair, A. O. (2008), Monitoring the Growth of Settlements in Ilorin, Nigeria (A GIS and Remote Sensing Approach), The International Archives of The Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. Xxxvii. Part B6b. Beijing 2008, Pp 225-232