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RESEARCH ARTICLE

Spatio-Temporal Distribution of Land Use and Land Cover of Imo State from 2005 to 2025

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ABSTRACT

The paper seeks to establish the land use and land cover change of Imo State in two epochs (2005-2025) and the extent of the changes using geospatial techniques, which is very vital in sustainable land use planning and environmental management. Two satellite imagery images were acquired, one for 2005 and another for 2025. The acquired images were analyzed, classified, and subjected to the change detection tool of ArcGIS to assess the change in land use and land cover patterns. To produce a land use land cover map, image processing and classification were used to establish the land use land cover of the state. Result: The result of the image output from the change detection analysis on the two Landsat images showed the extent of change that occurred in the various land use land cover classes in the state. The result revealed that thick forest decreased from 243839.61 in 2005 to 233839.61 hectares in 2025 while light forest degenerated from 88673.11 hectares in 2005 to 87673.13 hectares in 2025 likewise other land use classes except built up areas which rose from 50374.96 in 2005 to 52374.95 hectares in 2025. This shows that urbanization is one of the major drivers of land use and land cover change in the state. The study concluded that the environment is still threatened by land use and land cover change despite government efforts in ensuring a sustainable environment through planning laws and policies. Hence, the study recommends stricter compliance and regulation of economic and physical developments and land use activities in the state.

Keywords: *Spatial-Temporal, Distribution, Land use/cover, Change, Imo State*

1. INTRODUCTION

The changes in land use and land cover are the major driving forces in modifying the environment in any society. These normally result from physical and economic developments. These changes are taking place at a very fast rate, and most of them are irreversible. This has resulted in the redistribution of land use and land cover in space and time. Imo State has experienced sudden and rapid economic and physical development in recent times, especially in the areas of urbanization and provision of infrastructural facilities. These developments have triggered an increasing demand on land for the various developmental projects, thereby altering the natural setting of the environment. Land use and land cover change have incredible consequences on the status of the environment, affecting the ecological landscape function and processes of the natural environment within the state.

Spatio-temporal changes in land use and land cover are the major driving forces in environmental modification and conversion, which have given rise to environmental degradation and the related social disruptions. In many developing nations, population growth has been associated with land use and land cover change (Teeuw, 2012). Alterations in land use and land cover change can equally be attributed to both natural and socio-economic elements and how they interact over time and space. The rapid expansion of cities in Imo State due to urban population growth has exacerbated the problem, creating urban sprawl and consequences on agricultural lands. The utilization of land undergoes historical transformations that influence how individuals interact with the landscape, altering the accessibility of resources such as water, vegetation, and soil (Ahmad, 2014). Sankhala and Singh (2014) highlighted that the shift in land use and land cover, especially observed in developing nations like Nigeria, frequently leads to land degradation, widespread urban sprawl, and the conversion of agricultural land to alternative uses. Land use type needs to be designed in a way that ensures that the natural basis of living is sustained (Smith, 2019). Addressing the challenges related to sustainability requires effective management of land use and cover change.

Land-use refers to the way in which, and the purpose for which, human beings employ the land and its resources (Khwanruthai, 2013). Hence, land use is anthropogenic in nature. Is the land used for residential, commercial, industrial, among others? It is any human activity or economically related function associated with a particular piece of land. Land cover, on the other hand, describes the physical structures that cover the surface of the Earth (Geoffrey, 2013). Here, it refers to the natural features of the Earth's surface, such as rivers, forests, mountains, etc. It is related to the type of feature present on the Earth’s surface. The land use/land cover system requires thorough systematic monitoring and management to create better urban forms, protect the environment, and public health (Musa & Musa, 2016). It is vital in natural resources management, which tends to create a balance amongst ecological systems, economic, and social requirements. Land use/land cover assessment and planning can provide a means of controlling land development through imposing some kind of legal limitation on land owners, securing consistency and continuity in the execution of policies with respect to the use and development of land (Jones et al, 2021). These will limit some of the negative impacts of land use activities and development on the environment and other existing infrastructure. It is therefore very imperative to possess first-hand information on the existing land use/ land cover patterns change in time and space to plan and use land optimally.

One of the variable tools for evaluation and management of land use and land cover modifications is the Geographic Information System (GIS). It encompasses the examination of environmental data obtained through remote sensing for informed decision-making purposes. According to Ogbuji and Ede (2021), GIS is a computer software that is capable of capturing, storing, retrieving, manipulating, analyzing, and presenting spatially referenced information, which aids in development- oriented management and decision- making processes. The use of GIS has significantly improved the detection of land use changes, thereby providing an effective and comprehensive approach to delineating land into sustainable uses. GIS also helps in the precise assessment of the diverse transitions taking place on land (Notti et al, 2018).

An in-depth analysis of land use/ land cover change is of paramount importance for efficient and effective resource planning and management. This is because access to information on land use and land cover plays a significant role in site allocation, planning, sustainable resource management, and the understanding of changes in hydrological processes (Mahmood & Rahman, 2018). Hence, this understanding can help in meeting escalating demands of human sustenance and well-being (Akpoti, at et al., 2016). It is against this backdrop that this study tries to investigate the shift in land use and land cover of Imo State with a view to analyzing the extent of changes in each of the land use categories so as to offer recommendations to ensure harmonious equilibrium with the ecosystem. The research will constitute a crucial document for urban planners in the state whose effective planning hinges on a comprehensive knowledge of land use change patterns and extant environmental conditions.

The issues of land use and land cover change in Imo State have been very noticeable in time and space. This can be easily observed by the encroachment of built-up areas into previously vegetated and agricultural lands in the state. The incidences of soil erosion and flooding have witnessed an increase in time and space, especially the flooding of major cities in the state. The inadequate comprehensive study concerning the evolving patterns and characteristics of land use and land cover modifications in the state in recent times has escalated these environmental challenges and made their predictions increasingly unreliable. Hence, there is a need to evolve a comprehensive study aimed at understanding the progression and the dynamics of change in land use and land cover of Imo State, evaluating the pace of change in temporal dimensions and providing preventive measures against unsustainable land uses in the state.

2. MATERIALS AND METHODS

The Study Area

The study was conducted in Imo State, Nigeria. Imo State lies within latitudes 50 121 and 50 561N and longitudes 60 501 and 70 251E. It is among the five states that make up the south-east geopolitical zone of Nigeria. Imo State derived its name from the Imo River, which takes its source from the Okigwe/Awka upland. It occupies the area between the lower River Niger and the upper and middle Imo River. It shares common boundaries with Abia State on the east, Anambra State on the north, Rivers State on the south, and, on the west, with Delta State and the River Niger. The state covers a total land area of about 5184.1214 square kilometers.

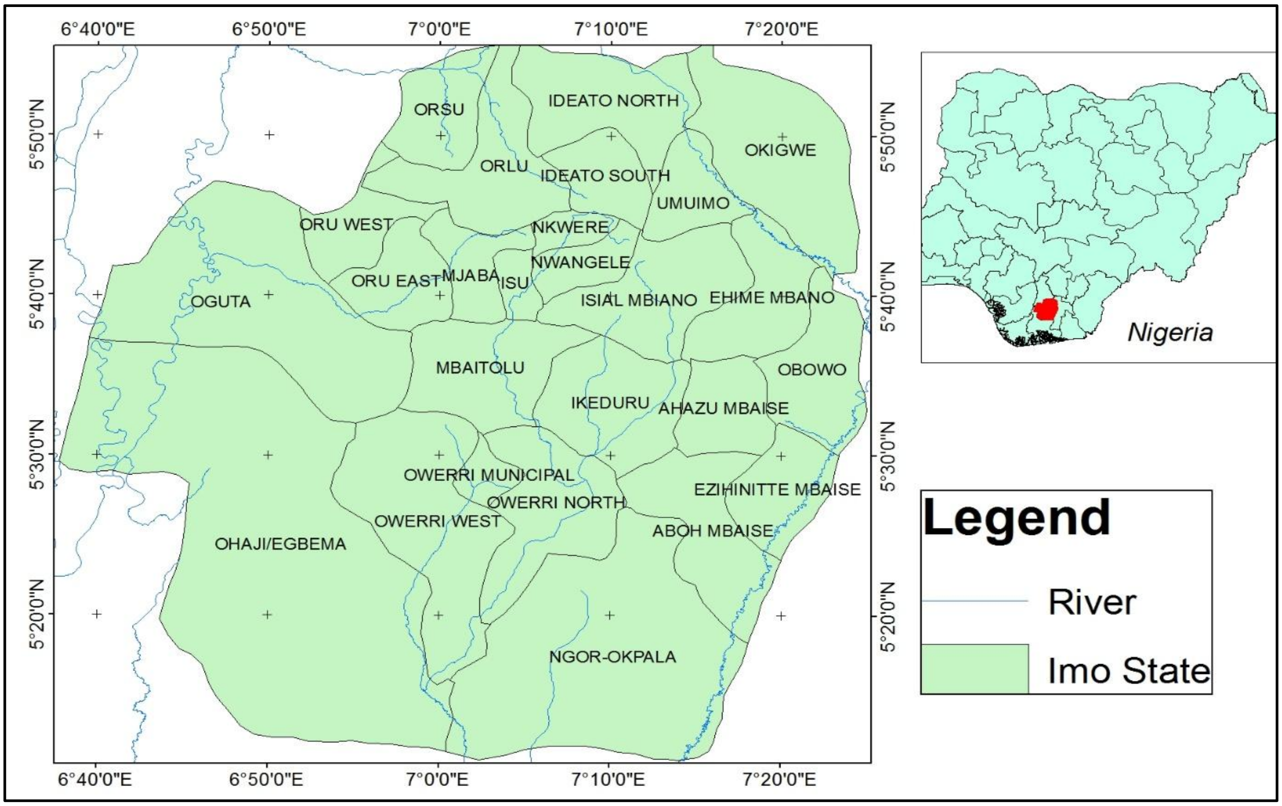

Figure 1: Political Map of the Study Area Showing the Local Government Areas

Source: Imo State Ministry of Lands and Survey, Owerri.

Imo State has a projected population of about 6.01 million people based on the 2006 census and an annual population growth rate of 3.325 percent (National Population Commission, 2025). The state has a high population density, which varies from 230 persons per square kilometer to about 1400 persons per square kilometer (Federal Republic of Nigeria Official Gazette, 2007). The population density of Imo State is by far higher than the national average of 166.0 persons per square kilometer (National Bureau of Statistics, 2009), and this has contributed to the increasing pressure on land, forest, and other natural resources in the state.

Imo State is underlain by the Benin formation of coastal plain sands. The topography of the state is traced to its geology. For instance, in the Okigwe axis, the false bedded sandstone ridge, which is part of the Enugu escarpment, has an elevation of about 315 meters above sea level. Generally, the land surface of most of Imo State is dominantly undulating plains that trend in the north-south direction. Thus, the characteristic trend of the topography is that of gradual slow ascent from the south-west area of Egbema to the false bedded sandstone in the north-east of the state.

There are a few rivers with vast interfluves, which are characterized by dry valleys that carry surface drainage in periods of high rainfall. The main rivers draining the state are Imo, Otamiri, Njaba, and Urasi rivers, all of which have few tributaries, with the exception of the Imo River, which runs through areas underlain by the Imo shale. Other rivers rise within the coastal plain sand. Abadaba Lake at Obowo marks the boundary between Imo clay and coastal plain sand, while Oguta Lake marks the boundary between coastal plain sand and alluvial deposition.

The climate here is humid. Rainfall distribution is bimodal with peaks in July and September and a two-week break in August. The rainy season begins in March and lasts till October or early November. Rainfall is usually at its maximum at night and during the early morning hours, and most times accompanied by violent storms. Variation occurs in rainfall amount from year to year. Annual rainfall varies from 1,900mm to 2,200mm.

Temperatures are similar all over the state, with the hottest months being between January and March. The mean annual temperature is above 200C. The influence of harmattan lasts for about nine weeks (i.e., from late December to late February). Imo State has an average annual relative humidity of about 75%, which is highest during the rainy seasons, when it rises to about 90%. The state lies within the rainforest agro-ecological zone of Nigeria (Nwonu, 2016).

Instruments for Data Collection

These include the major tools used for collecting data in the course of this study, and they are as follows: (i) Primary Data: The main instruments for primary data collection include: (a) Global Positioning System (GPS) Receiver, (b) Field observation; (ii) Secondary Data: Among the instruments for secondary data collection are: (a) Landsat imagery for land use/ cover analysis acquired from the United States Geological Survey (USGS) website, (b) Foundational map of Imo State generated from Google Earth Imagery, (c) Others include published and unpublished dissertations, journals, textbooks, online materials, etc. The raw spatial data used for land-use/cover analysis were also acquired from the United States Geological Survey (USGS) website.

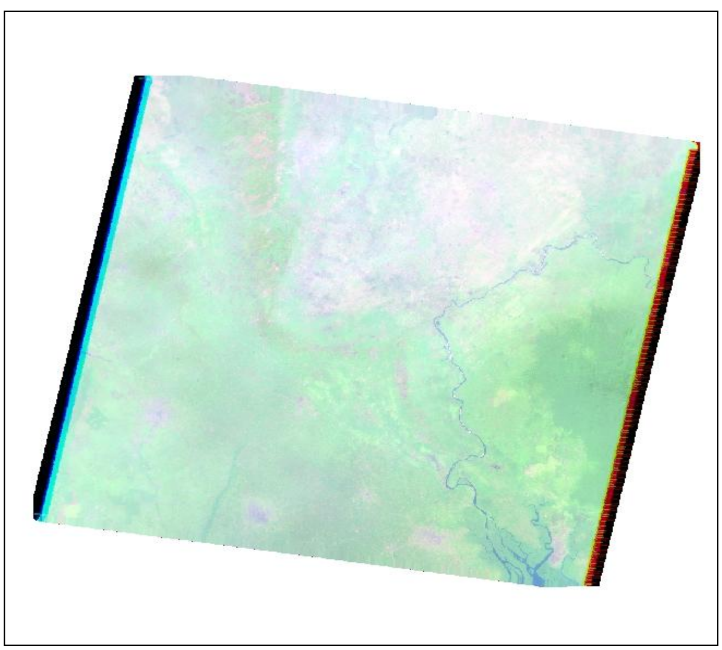

Figure 2. Landsat Imagery of the Study Area

Method of Data Collection

In order to make sample collection and classification process easy, land use/land cover nomenclature was created to define the major land use/cover classes first (Alebachew, 2011). In this study, the five major land use/land cover classes were used to produce the final land use/ cover map of the study area. These include: agricultural land, thick forest, light forest, built-up, and water body.

Method of Data Analysis

Landsat Thematic Mapper at 30m resolution was used for land use/land cover classification. The satellite data covering the study area were obtained from the Earth Explorer site. These data sets were imported into ERDAS Imagine version 9.2 satellite image processing software to create a False Color Composite (FCC). The layer stack option in the image interpreter toolbox was used to generate FCCs for the study areas. The subsetting of satellite images was performed to extract the study area from both images by taking the geo-referenced out polygon boundary of Imo State AoI (Area of Interest). All satellite data were studied by assigning per-pixel signatures and differentiating the area into five classes on the basis of the specific Digital Number (DN) value of different landscape elements. The delineated classes are; built up: built-up area, light forest, agricultural land, water body, and heavy forest. For each of the predetermined land use/land cover types, training samples were selected by delimiting polygons around representative sites. Spectral signatures for the respective land cover types derived from the satellite imagery were recorded by using the pixels enclosed by these polygons, after which accuracy assessment was conducted to ascertain if the output map meets predetermined classification accuracy criteria. In most cases, the obvious types of error that occur in image classifications are errors of omission (producer accuracy) or errors of commission (user accuracy) (Alebachew, 2011). Therefore, in this study, the overall, user's, and producer's accuracies, and the Kappa coefficient were calculated. The error matrix was obtained from reference data [ground control points (GCPs)] using ArcGIS 10.5 software and the Accuracy Assessment and Data Management extensions. The researcher conducted field observations and collected random ground-truth data using GPS at well-known sample sites to obtain reasonable validation statistics.

4. RESULTS AND DISCUSSION

A detailed analysis of the land use and land cover change of the study area was carried out in Figures 3 and 4. The figures show the five different classes adopted in the analysis from the satellite imagery of the area of interest. These five major land use/land cover classes used to produce the final land use/ cover map of the study area include: agricultural land, thick forest, light forest, built-up area, and water body. Figure 3 shows the land area coverage by the various classes in 2005, while Figure 4 shows the area coverage for different classes in 2025.

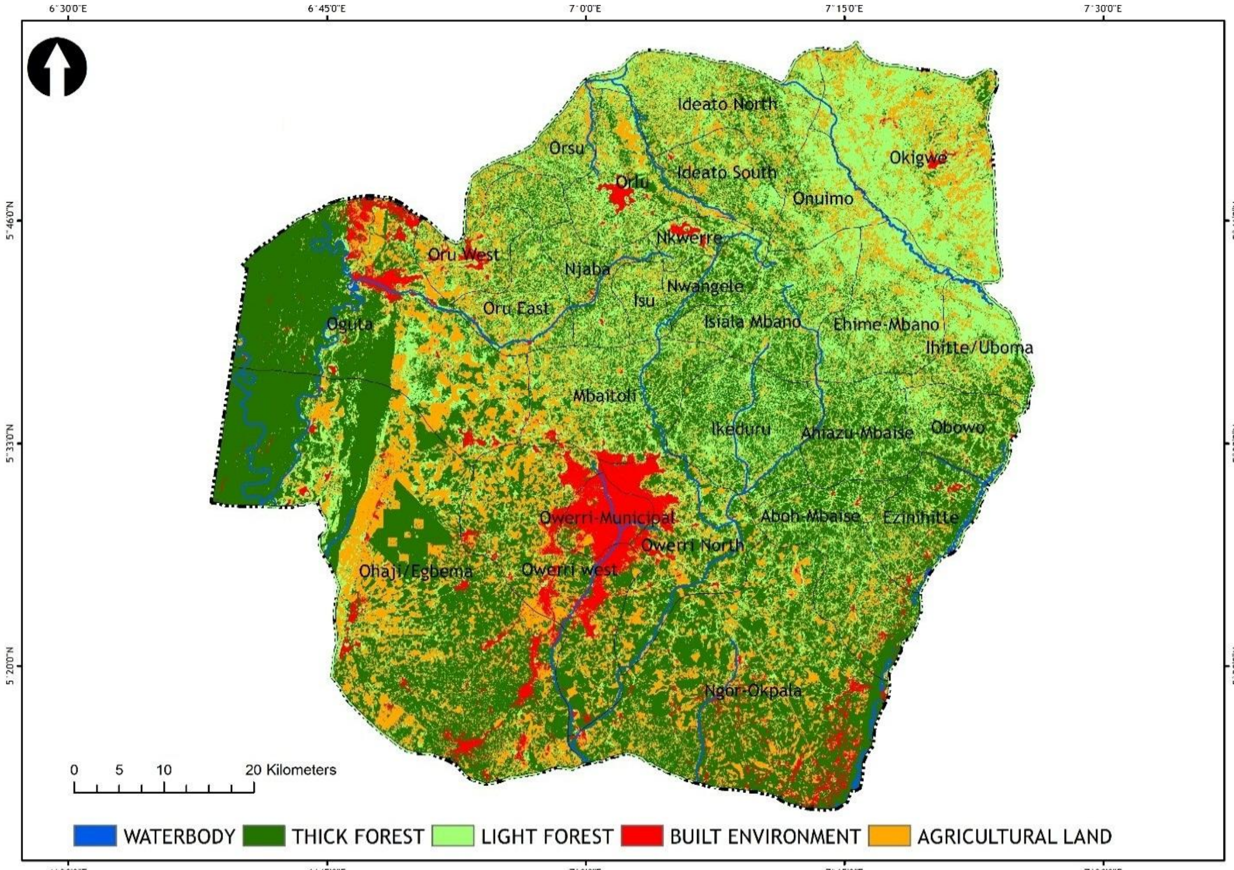

Figure 3. Land Use Land Cover Map of the Study Area 2005

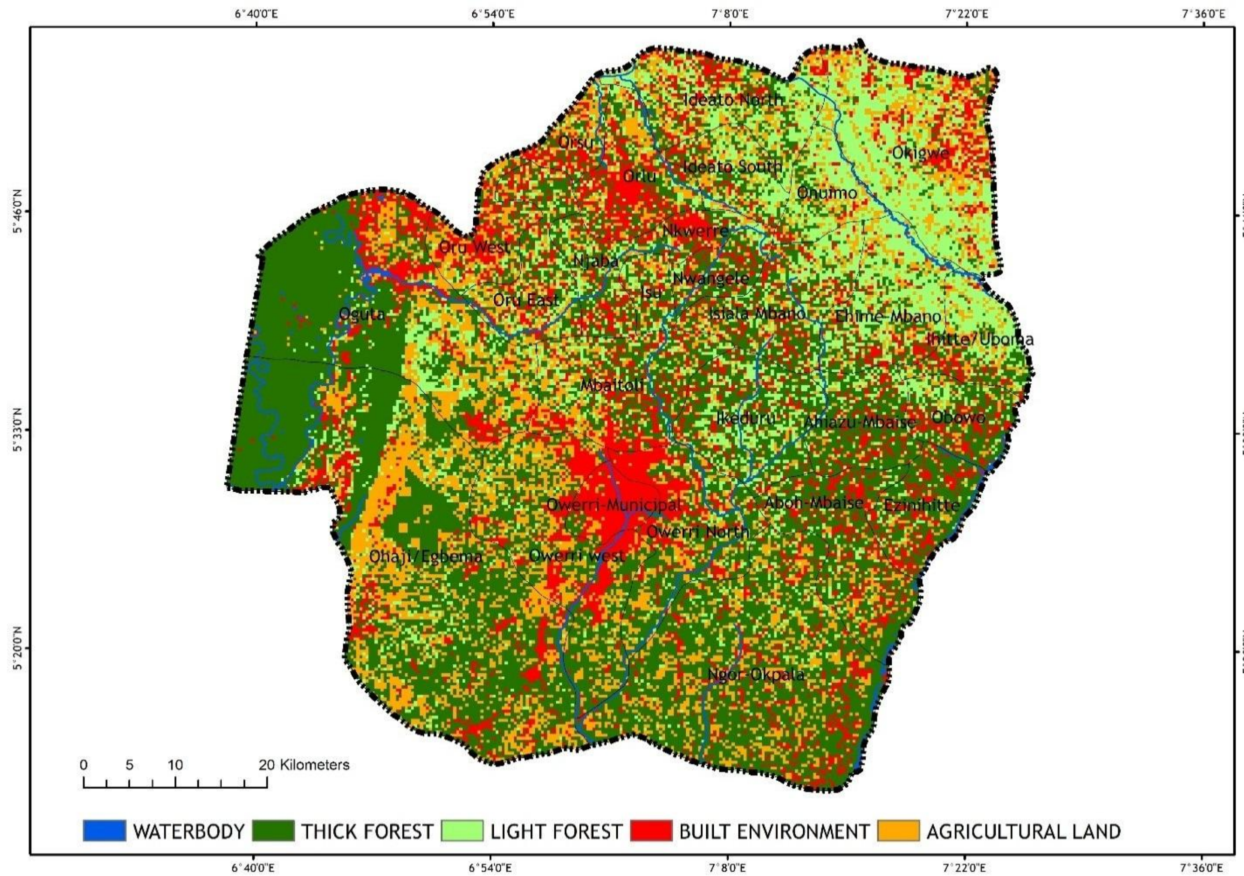

Figure 4. Land Use Land Cover Map of the Study Area 2025

From the land use/ cover area coverage in Table 1 for the year 2025, the majority (45.1%) of the land space was covered with thick forest, agricultural land (22.1%), and light forest (16.9%). Built-up area covered (10.1%) and water body (4.1%) of the study area, while others, such as bare land amounts the least with only 0.8% of the total land area coverage of the state.

Table 1. Land Use/ Land Cover Classes Change Area Coverage (Ha) 2005 and 2025.

LULC	2025 Area Coverage	% Area Coverage	2005 Area Coverage	% Area Coverage
Light Forest	87673.13	16.90	88673.11	17.10
Thick Forest	233839.61	45.10	243839.61	47.03
Agric. Land	114824.47	22.10	106026.48	20.50
Bare Land	3906.80	0.80	3706.80	0.70
Water Body	25793.19	4.10	25791.18	4.8
Built up Area	52374.95	10.10	50374.96	9.8
Total	518412.14	100	518412.14	100

From Table 1, thick forest decreased from 243839.61 hectares in 2004 to 233839.61 hectares in 2024, while light forest degenerated from 88673.11 hectares in 2004 to 87673.13 hectares in 2024. Thick forest is the most affected class by the change. Built-up areas rose from 50374.96 hectares in 2004 to 52374.95 hectares in 2024. This implies that urbanization is one of the major factors driving land use/land cover change in the state. This corroborates a similar study conducted by Ukonu, 2011 who stated that there is a continuous change in the land use/ land cover of the state. Therefore, the government needs to take appropriate measures in planning to ameliorate the wanton urbanization in the state to safeguard the environment.

The study assessed the image classification accuracy by using 71 random GCPs for all land use classes (16, 12, 15, 11, and 17) for agricultural land, built-up area, water body, thick forest, and light forest, respectively.

Table 2. Error Matrix Table

Class category	**Reference (GCP) data**						**Producer accuracy %**	**User accuracy %**
	1	**2**	**3**	**4**	**5**	**Total**		
Agricultural land (1)	16	0	1	0	1	18	86.36	90.47
Built-up area (2)	0	12	1	0	1	14	88.25	88.23
Thick forest (3)	1	0	15	0	1	17	86.36	90.47
Water body (4)	1	1	1	11	2	16	85.71	70.58
Light forest (5)	1	1	0	2	17	21	77.27	80.95
Total	19	14	18	13	22	86		

Overall accuracy

This was computed by dividing the total correct number of pixels, i.e., the summation of the diagonal (16+12+15+11+17= 71), by the total number of pixels in the matrix [total (86)]. It can be expressed as Xn divided by N; hence;

Overall Accuracy = Σ Xn/N

Where, Xn = number of correctly classified pixels, or the diagonal value, and

N= entire number of pixels in the matrix.

Therefore, the overall accuracy under this classification = (71/86) *100 = 82.6 %. Hence, the classification is relatively accurate (see Appendix G).

Producer's accuracy

This refers to the probability of a reference pixel being classified correctly. It is also known as an omission error because it only gives the proportion of the correctly classified pixels. It is obtained by dividing the number of correctly classified pixels in the class category by the total number of pixels of the category in the data. As clearly indicated in Table 2, lower producer's accuracy exists for light forest (77.27 %). The remaining 22.73 % percent is omission error. This is probably due to the similar spectral properties of pixels in these land use/land cover classes with some of the other features. For instance, bare land may be similar to grassland and pasture land in the dry season and farm land under crop harvesting season, and fallowing time may have relatively similar spectral properties and might make it difficult for the researcher to identify at the pixel level.

User accuracy

This presents the probability that the pixels in the classified image of the study area represent that class on the ground. It is obtained by dividing the total number of correctly classified pixels in the category by the total number of pixels in the classified data. As in the case of this study, from the user's accuracy point of view, the water body presented low accuracy (70.58 %). This implies that, to some extent, it is misclassified. This is probably caused by the presence of the built environment in other land use classes in the study area.

Kappa coefficient

The Kappa coefficient, which measures classification agreement, can also be used to assess the classification accuracy. It expresses the proportionate reduction in error generated by a classification process compared with the error of a completely random classification (Congalton, 1999). The Kappa coefficient (K) is calculated using the information in the error matrix table (Table 2) and using the equation given by Congalton (1999).

Where: r = the number of rows in the matrix; Xii = the number of observations in row i and column i (along the major diagonal); Xi+ = the marginal total of row i (right of the matrix); Xi+1 = the marginal total of column i (bottom of the matrix); N is the total number of observations.

Therefore, to get the kappa coefficient of the classification process, the Congalton formula was applied.

$$K = \frac{(total*sumofcorrect)-sumofallthe(rowtotal*columntotal)}{totalsquared-sumofthe\ (rowtotal*columntotal)} \quad \text{Equation (3)}$$

Therefore, K= 0.84 implies that the classification was relatively good. It is reasonable to employ the generated map for further analysis and studies of potential ecotourism site selections.

5. CONCLUSION

Despite the efforts of the state government to ensure a sustainable environment through various planning laws and policies so as to achieve a balanced ecosystem, the environment is still threatened by land use and land cover changes occasioned mainly by urbanization. It should be noted that economic and physical developments are the major driving forces in the distortion of the natural setting of the environment. This is in a bid to meet the needs of development; hence, it is inevitable to stop. Rather, it can be minimized through proper land use and environmental planning with the incorporation of environmental components into planning processes. The study therefore recommends strict regulation and implementation of development and land use activities in the state. The study furthermore advocates land use zoning, planning permission, and environmental impact assessment for land use. Others include the use of density control and carrying capacity, which are equally highly recommended.

6. COMPETING INTEREST

None to declare

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