ANALYSIS OF HUMAN-INDUCED LAND COVER DYNAMICS ANALYSIS IN URBAN ABEOKUTA USING REMOTE SENSING AND GIS

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Abstract

Land cover changes (LCCs) detection methods delve into the possibility of using different high and medium-resolution multispectral remote sensing spatial datasets and various land cover software to analyse land cover dynamics as a result of human activities. This study analysed the multiple changes that have occurred in the land cover types of the urban landscape of Abeokuta within the last thirty years using advanced change detection methods. Landsat TM, ETM, and ETM+ Imagery covering Abeokuta, (1988–2022) were obtained from Landsat Global Land-Use and Land Cover Facility and the European Space Agency. Land cover classification was performed using ArcGIS 10.8, six land cover types: Open Space (OS), Built-Up Area (BUA), Light Forest (LF), Dense Forest (DF), Agricultural Land (AL), and Water Bodies (WB) were identified. Land cover modeling tool was employed to calculate changes in land cover metric. Results showed that land cover types change significantly during the study period. F-value of 14.53 indicated significant differences in the mean values of various land cover types; there was a consistent increase in BUA (1988=14.6km^2 <1993=38.8km^2 <1998=42.1km^2 <2003=44.3km^2 <2008=62km^2 <2013=89.8km^2 <2018=109.3km^2 <2022=113.4km^2) and a corresponding decrease in DF 1988=76.6km^2 >1993=66.8km^2 >1998=59.8km^2 >2003=59.0km^2 >2008=52.4km^2 >2013=488km^2 >2018=39.0km^2 > 2022=17.4km^2) over the study period. This is an indication of significant human-induced changes in land cover of Abeokuta as a result of making the environment more conducive for living.

Keywords: Human-induced, Land cover, urban area, Remote Sensing and GIS

Introduction

Land cover is referred to as materials on the Earth's surface that occurs naturally. Forests (thick and light), water bodies, open space, farmland, rangelands and built-up space (urban environment), are examples of land covers. Over time, changes that occur in land cover components are due to both human behaviour and natural proceedings (Fashae, et. al., 2022).

Land cover changes refer to the changes in the features of the Earth's surface, such as alterations in natural landscapes, land cover transformations, and urban areas' expansion. Human activities, natural events, and climate dynamics are the drivers of these identified changes. (Fashae, et. al., 2022; Fasona, et. al., 2014; Dalil, et. al., 2016; Mustapha, et. al., 2019).

Changes in the physical environment that have occurred due to the effects of human activities and human processes could be estimated by evaluating Land cover changes; with intensification in climate change and urbanisation processes, comprehending the influences of land cover dynamics on ecology, hydrology and climate systems is classified among the major challenges of the present time that needs solution (Fashae et. al., 2017; Fasona, et. al., 2014). The health, strength, functionality and biodiversity of an ecosystem can be evaluated by assessing the changes that have occurred in Land cover (Fasona, et. al., 2014; Fashae, et. al., 2020).

Furthermore, change in land cover has far-reaching effects on the ecological balance of an environment both locally and globally; it can induce temperature modifications, water cycles and soil characteristics alteration (Fashae, et. al., 2020; Fasona, et. al., 2014). Urbanisation is a process, it begins when more people move into urban areas (cities) from rural area and then there is population growth and urban expansion; modifications in land covers begin to take place as human make efforts to create a more conducive environment to live in.

Urbanisation is amongst the strongest drivers of land cover change. Urbanisation alters the natural habitats into impervious surfaces like roads, buildings and pavements as cities expand. Land cover changes, which is a prominent feature in urban areas subsequently alter the hydrological processes thereby increasing runoff which can in turn result in recurrent and extreme flood, one of the present day ecological concerns (Arnold & Gibbons, 1996). Additionally, Urbanisation can also lead to distortion in the ecosystem, which causes ecosystems destruction and/or fragmentation, thereby resulting in a reduction in biodiversity.

Land cover changes and subsequent increase in impervious surfaces in urban areas have profound influence on the relationship between rainfall and runoff, which causes increased surface runoff (Bai et al., 2010). These changes bring about increased peak flows and reduced time to peak, which can submerge functioning drainage systems and intensify flood risk. The transformation of natural land cover to urban settings alters the hydrological cycle by reducing the rate of infiltration and changing evapotranspiration rates (Pielke et al., 2007). Increased surface runoff and reduction in infiltration rate after sometimes can bring about increase in flood incidence and intensity especially in urban watersheds.

The upsurge in impervious surfaces in various urban areas, Abeokuta inclusive, as a result of city growth has altered rainfall-runoff patterns. Various scholars have established that urban centers experience increased peak flows and reduced time to peak in comparison to natural or rural landscapes (Ogundele and Jegede 2011). Overtime, there has been increase in surface runoff, decrease in ground water discharge and higher flood risks in Abeokuta as a result of modification in land cover types. These changes are intensified by the poor drainage system that struggles to cope with increased surface runoff when heavy rainfall episodes are experienced (Adebayo et al., 2022). The natural landscape of Abeokuta has undergone modifications and changes with the forests and farmlands evolving into urban landscapes. This change has substantial consequences on the ecosystem, water balance and weather patterns (Oyinloye and Kufoniyi, 2011).

Land cover dynamics researches in Abeokuta underscore the decrease in vegetal cover, which have an influence on the biodiversity thereby causing soil erosion and reduction in soil fertility. The forces of land cover changes in an urban environment include but are not limited to population increase, agricultural expansion, urbanisation, economic growth, (construction, mining, industrialisation, and commerce), Climate change (Oyinloye and Kufoniyi, 2011; Salami *et al.,* 2016; Adetunji and Oyeleye, 2013; Adeoye *et al.,* 2009). Land cover changes have a deep consequence on the ecosystem, for example, deforestation creates habitat disintegration, jeopardising biodiversity; likewise, urban expansion in form of tarred roads and constructions enhances the impacts of urban heat island thereby raising local temperature and constituting risk to the health of human (Salami *et al.,* 2016).

Studies on Land cover dynamics have impacts on the water cycle as it alters its infiltration rate, surface overflow, and groundwater recharge; playing a fundamental role in water resources management. As Abeokuta continues to experience growth, understanding how land cover changes works is important for sustainable urban planning and management and putting operational policies in place in managing natural resources (Adetunji and Oyeleye, 2013). Researchers and policymakers can employ mechanisms such as Geographic Information Systems (GIS) and remote sensing to track these land cover changes and appraise their effects, allowing them to make informed choices for the city's sustainable future.

Changes in land cover can occur on short-term, medium-tern and long-term basis. Short-term changes are seasonal changes in vegetal cover like greening and browning of plants in reaction to rainfall or temperature changes. Medium-term changes comprise of urban growth, steady deforestation, and agricultural patterns shifting as a result of changes in socio-economic features or policy interventions. Long-term changes are usually multi-decade modifications like desertification, wanton deforestation, or glacier retreat caused by climate change that naturally develop over a few decades due to urban growth in many developing countries (Oyinloye and Kufoniyi, 2011); changes such as these usually have intense, long-term impacts on the ecosystem and climate (Turner *et al.,* 1994).

Aim

The aim of the paper is to analyse human-induced land cover changes in Abeokuta using remote sensing and GIS.

Objective

The objective of the study is to:

Identify and analyse the spatial and temporal changes in the different land cover types within Abeokuta from 1988 to 2022

Hypothesis

H_0: There is no significant variation in land cover types in Abeokuta from 1988 to 2022.

STUDY AREA

The study area Abeokuta, is located in southwestern Nigeria, located roughly between latitudes 7°6' and 7°15' North of the equator, and longitudes 3°16' and 3°35' East of the Greenwich Meridian (Figure 1). Abeokuta is bounded in North by Odeda town, Odeda Local Government Area; in the East by Osiele and some other smaller towns also in Odeda Local Government Area;

in the West by Owode and other surrounding towns near the border of Benin Republic in Obafemi Owode Local Government Area and in the South by Ewekoro and Ifo Local Governmnt Areas. The land area covers an urban centre of about 879 km^2, making it a significant sub-section of the Lower Ogun Basin.

It experiences tropical climate characterised by distinct wet and dry seasons. The seasonal average of rainfall is high (1300 mm). Temperature is highest on the average in March at 30ºC and lowest on the average in August at 24ºC in the year. Humidity exceeds 80% usually as a result of consistent rainfall. The Geology of the area is characterised by the Nigeria *Basement complex rocks* characterised by Ancient Crystalline Rocks that are part of the Pre-Cambrian formation with six major lithologic units namely: Quartzite, Banded-gneiss, Biotite-gneiss, Biotite-Schist, Quartz-Biotite Schist and Pegmatite (Akinse & Gbadebo, 2016). The relief is characterised by undulating topography and rocky outcrops with elevations ranging from 50 to 200 metres above sea level (Bello *et al.,* 2009).

Abeokuta is dissected by several river systems, including tributaries of the Ogun River which include Rivers Ewekoro, Opeki, Eredu, Iwofin, Sokori, Owiwi, and Ajire amongst others.

The soils of the study are diverse and support various agricultural activities; soil types in the region range from lateritic soils to clay and alluvial soils near riverbanks. The vegetation of the study area is predominantly characterised by a mix of forested areas, savanna woodlands and open grassland formed by both nature and human activities.

According to the 2006 census, the population of Abeokuta and the surrounding area was 446,088 (National Population Commission, 2006). The current metro area population of Abeokuta in 2023 is estimated to be 571,000, at a rate of 2.51% increase from the 2022 population which was estimated as 557,000.

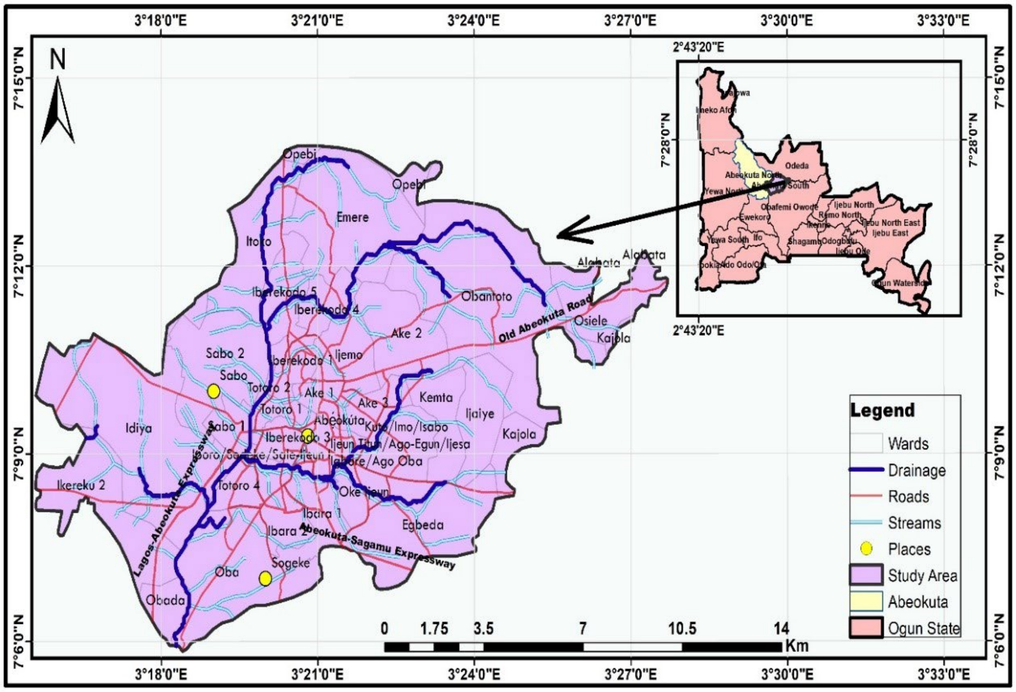

Figure 1. Map of Abeokuta the study area

MATERIALS AND METHOD

Data Used:

Landsat TM, ETM, and ETM+ imageries covering urban city of Abeokuta for 1988, 1993, 1998, 2003, 2008, 2013, 2018 and 2022 were gotten from Landsat Global Land-Use and Land Cover Facility, the United States Geological Survey (USGS), and the European Space Agency (ESA). (https://earthexplorer.usgs.gov). The land cover classification was performed using Arc GIS 10.8. Land cover modeling tool was utilised to compute changes in land cover metric through Abeokuta town. The Landsat images used from 1988 to 2022 are:

Table 1. Landsat images used from 1988 to 2022

Landsat image TM for Abeokuta 1988	30m resolution, pan-sharpened to 15m
Landsat image ETM for Abeokuta 1993	30m resolution, pan-sharpened to 15m
Landsat image ETM for Abeokuta 1998	30m resolution, pan-sharpened to 15m
Landsat image ETM for Abeokuta 2003	30m resolution, pan-sharpened to 15m
Landsat image ETM+ for Abeokuta 2008	30m resolution, pan-sharpened to 15m
Landsat image ETM+ for Abeokuta 2013	30m resolution, pan-sharpened to 15m
Landsat image ETM+ for Abeokuta 2018	30m resolution, pan-sharpened to 15m
Landsat image ETM+ for Abeokuta 2022	30m resolution, pan-sharpened to 15m

The study made use of six land cover types, a land cover classification system was developed to enable consistent and reliable assessment. This classification system was employed in bringing about the classes of the land cover on the maps. Though, generalisation and reclassification was made to a number of land cover classes in the study area so that consistency can be achieved in the land cover classes for the study period. The study adapted these classification to work with: Built-Up Area, Open Space, Light Forest, Dense Forest, Agricultural land and Water bodies.

Source, Collection and Analysis of Data

Satellite imagery for the period of study was downloaded from online repositories, and specific bands or indices; the Normalised Difference Vegetation Index (NDVI) for land cover analysis, were derived from online source, https://earthexplorer.usgs.gov. The land cover classification was performed using remote sensing data and techniques of image processing. Supervised and unsupervised classification was applied to generate land cover maps (e.g. Built-Up Area, Open Space, Forest (light and dense), Farmland and Water bodies).

Spatial and temporal patterns of land cover were identified and the changes that have occurred were assessed using change detection methods, including post-classification comparison and land change modeller. The percentage and change in percentage of impervious surface (built-up area) at 5-year intervals were calculated using the land cover maps. Analysis of variance was employed in testing null hypothesis.

RESULTS AND DISCUSSIONS

Objective: Spatial and temporal pattern and analysis of different land cover types in Abeokuta from 1988 to 2022.

Table 1 provides an overview of land cover pattern in Abeokuta and Figure 2 depict the summary of coverage of land cover variation during the period of study (1988, 1993, 1998, 2003, 2008, 2013, 2018 and 2022). The study area, totaling 174.5 square kilometres, is characterised by various land cover types, each occupying a distinct percentage of the entire area. In 1988 as shown in Table 1, dense forest emerges as the dominant land cover, encompassing a substantial 43.9% of the entire area. This specifies a noteworthy ecological presence and highlights the area's importance in terms of biodiversity as well as ecosystem services. Agricultural land, with a share of 30.8%, signifies the considerable human influence on the landscape, emphasising the region's agricultural significance. The presence of built-up areas and open spaces, constituting 8.4% and 4.5%, respectively, suggests urbanisation tendencies that may impact the natural environment in the long on. Additionally, 1993 exhibited a land cover pattern close to what we had in1988 but with slight difference here and there, the largest land cover category was still Dense Forest, covering a substantial 38.3% of the total area although there was a decline in size compared to 1988; still reflecting the region's significant forested ecosystem. Agricultural land reduced from 30.8% to 30.0% of the area, highlighting the importance of, and increase in agriculture in the region. The Built-Up Area expanded to 22.2%, indicating gradual urban development in the study area. Light Forest and Open Space collectively represented 8.8%, demonstrating a balance between natural and semi-developed environments. Water bodies and constituted a relatively small portion at 0.7%.

Furthermore, by 1998, dominant land cover was still dense forest accounting for 34.3% of land mass, although it is declining compared to previous years. This is followed by Agricultural land covering 33.0% of the total area. Together, these two categories occupied 67.3% portion of the landscape, reflecting an increase in the area's reliance on agriculture and the presence of gradually declining forested areas. Built-up areas constituted 24.1%, highlighting an upward trend in urban expansion in the study area; while light forests covered 6.9%, indicating a mix of partially wooded areas and grasses. Open space and water bodies collectively covered a minimal 1.8%, underlining the limited extent of both covers types. This composition suggests an equilibrium amid human settlement, agricultural activities, and the effort made in preservation of forested landscapes within the study area since 1998.

Moreover, by 2003, the dominant land cover category remained Dense Forest constituting 33.8%, closely followed by Built-Up Area covering 25.4% of the entire area. The substantial extent of Dense Forest by 2003 reflects probable efforts made in the preservation of the natural environment, indicative of potentially rich biodiversity. The Built-up Area coverage, on the other hand, represents increase in human settlements and infrastructural development. Agricultural land occupied 21.5% of the area, underlining the importance of agriculture in the region. Light Forest and Open Space collectively accounted for 18.5% of the land, suggesting a balance between partially vegetated areas and open, non-built spaces. Water bodies still constituted a relatively small percentage although it decrease from 0.9% in 1998 to 0.8%.

However, the predominant land cover category changed from dense forest to Built-Up Area in 2008, covering 62.0 square kilometres and constituting 35.5% of the total area. This suggests significant urban extension or more developed infrastructures within the region. Dense forests reduced to 30.0% with Agricultural land also decreasing to 15.6% of the total area. This indicates a balance between natural vegetation and agricultural activities, although a gradual decline in farming activities. Open Space, covering 16.6 square kilometres (9.5%), suggests areas with minimal human development, possibly designated for recreational purposes. Light Forest covering 14.8 square kilometres (8.5%), and Water Bodies at 1.4 square kilometres (0.8%), signify areas with varying degrees of vegetation cover and water features, contributing to the overall ecological diversity of Abeokuta. Additionally, the predominant land cover category in 2013 was still the Built-Up Area, covering 89.8 square kilometres, constituting 51.5% of the total area. This suggests a consistent increase in urbanisation and development in the region. Dense Forests dropped to 28.0% of the area, with a coverage of 48.8 square kilometres, indicating a significant portion of the landscape being deforested when compared to 1988 and a smaller portion now left untouched as natural ecosystems. Open Spaces, spanning 18.2 square kilometres, represented 10.4% of the total area, indicating a relative balance between development and preserved spaces. Light Forests, Agricultural lands, and Water Bodies constituted 7.6%, 1.7%, and 0.8%, respectively, reflecting the coexistence of various land covers, including agricultural activities and natural features.

Likewise, the predominant land cover in 2018 remained built-up areas, encompassing 62.7% of the total area, underscoring the significant impact of human activities and infrastructure development. Meanwhile, open spaces constituted a minimal coverage reducing drastically from 10.4% in 2013 to 0.1%, emphasising further urbanisation processes. Light and dense forests covered 6.3% and 22.4%, respectively, this suggests efforts undertaken in maintaining green spaces and biodiversity. Agricultural land expanded again from 1.7% to 7.2% of the entire area, signifying probable improved interest in agricultural activities within the region. Water bodies covered 1.4%, reflecting the integration of aquatic ecosystems. Finally in 2022, the study area spanning 174.5 km^2 exhibited a predominantly urbanised landscape, with built-up areas covering majority at 65.0%.

This underscores the high level of development and human activities in the region. Conversely, natural environments decreased in size, with dense forests accounting for a meager 10.0% and light forests covering 7.6% of the entire area, indicating a minor section from the region remains forested. Agricultural activities were assumed to have increased again with agricultural land covering about 15.2% of the area, emphasising the continued importance and increased interest in farming within the region. Meanwhile, open spaces represented a minimal fraction at 0.8%, suggesting limited undeveloped areas. Water bodies remained consistent to area covered in 2018, constituting 1.4% of the total land area. Overall, while urbanisation which is human induced has left a dominant imprint in the study area, retains diverse land cover types, reflecting an imbalance between human development and natural ecosystems (Figure 2).

Land cover modifications in Abeokuta during the duration of study shows a drastic decrease in natural landscape and an incredible increase in built-up spaces, this coincides with the verdicts of Oyedele, *et al.,* 2023; Adebayo, *et al.,* 2019; Adebayo, *et al.,* 2024 also there was an upsurge in agricultural activities in urban areas as Awoniran, *et al.,* 2014); this dynamism indicated significant influence of anthropogenic factors on natural environment, this is in accordance with Oyedele, *et al.,* 2023; Adebayo, *et al.,* 2019; Adebayo, *et al.,* 2024. Humans, in a bid to make their environment more conducive to live in, have encroached on the natural landscape so much to his own detriment leading to soil degradation and loss of biodiversity. These may eventually lead to flood vulnerability in Abeokuta (Awoniran, *et al.,* 2014)

Table 2. Spatial and temporal Pattern of Land cover types, 1988 to 2022

Category / Year	Open Space		Built-up Area		Light Forest		Dense Forest		Agricultural land		Water Bodies	
	km²	%	km²	%	km²	%	km²	%	km²	%	km²	%
1988	7.8	4.4	14.6	8.4	20.3	11.6	76.6	43.9	53.8	30.8	1.4	0.8
1993	9.2	5.3	38.8	22.2	6.1	3.5	66.8	38.3	52.3	30.0	1.3	0.7
1988	1.6	0.9	42.0	24.1	12.0	6.8	59.8	34.3	57.6	33.0	1.5	0.9
2003	21.7	12.4	44.3	25.4	10.6	6.1	59.0	33.8	37.5	21.5	1.4	0.8
2008	16.7	9.6	62.0	35.5	14.8	8.5	52.4	30.0	27.3	15.6	1.4	0.8
2013	18.2	10.4	89.8	51.5	13.3	7.6	48.8	27.9	3.0	1.7	1.4	0.8
2018	0.1	0.1	109.3	62.7	11.0	6.3	39.0	22.4	12.5	7.2	2.5	1.4
2022	1.4	0.8	113.4	65.0	13.3	7.6	17.4	10.0	26.5	15.2	2.5	1.4
Total	**174.5**	**100**	**174.5**	**100**	**174.5**	**100**	**174.5**	**100**	**174.5**	**100**	**174.5**	**100**

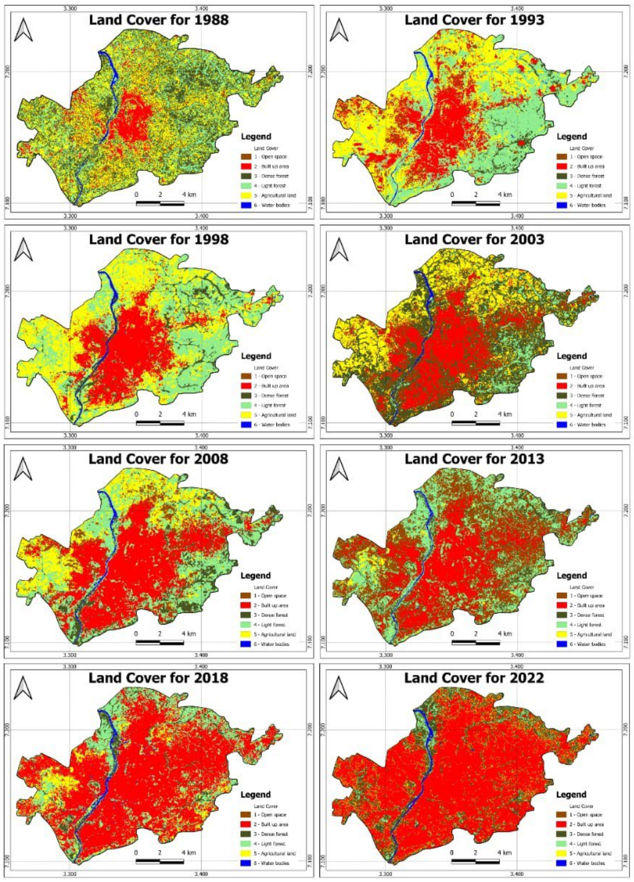

Figure 2. Land Cover Patterns from 1988 – 2022

Significant variation in Land cover patterns from 1988-2022.

The descriptive analysis of land cover patterns Abeokuta from 1988-2022 provides an all-inclusive summary of the six identified categories: Built-up Area, Open Space, Agricultural land, Water Bodies, Light Forest, and Dense Forest (Table 3). The mean values for these categories indicate the size of land cover over the specified time frame. For example, Built-Up Area has the highest mean value of 64.3 in the category, next to that is Dense Forest with a value of 52.5 and coming in the third position is Agricultural land with 33.8 as mean value. These results indicate that a notable portion of the area of study is attributed to having more of built-up areas, dense forests, and Agricultural lands. Conversely, Water Bodies has the lowest mean value of 1.7, signifying a comparatively minor extent of this land cover type.

Moreover, the range values give perceptions into the variability within each land cover category. For instance, the Built-Up Area category exhibits a wide range of 98.8, indicating substantial variability in urban development across the sub-section; following closely is the Dense Forest category that shows a range of 59.2, this also signifies an enormous change in the size of dense forest within the region. Standard deviation and variance additionally enumerate the spread of data points round the average, with higher values indicating larger inconsistency. The skewness and kurtosis values gave information as far as the shape and tail features of the distribution for each land cover category is concerned. In all, these descriptive figures provide valuable understanding into the variation, spatial arrangement, and features of different land cover patterns in Abeokuta, which can be a foundation for further planning, future study, and administration initiatives.

Table 3. Statistical parametres of Land cover patterns from 1988-2022

Open Space	Open Space	Built-up Area	Light Forest	Dense Forest	Agricultural land	Water Bodies
Mean	9.6	64.3	12.7	52.5	33.8	1.7
Standard Error	3.0	12.8	1.4	6.4	7.1	0.2
Standard Deviation	8.4	36.1	4.0	18.2	20.1	0.5
Sample Variance	70.8	1300.6	16.3	329.8	402.9	0.3
Kurtosis	-1.7	-1.4	1.9	1.2	-1.3	-0.1
Skewness	0.3	0.3	0.4	-0.9	-0.3	1.4
Range	21.6	98.8	14.2	59.2	54.6	1.2
Minimum	0.1	14.6	6.1	17.4	3.0	1.3
Maximum	21.7	113.4	20.3	76.6	57.6	2.5
Sum	76.7	514.3	101.4	419.8	270.5	13.4
Count	8	8	8	8	8	8

Tables 4a and 4b are presentation of the analysis of variance for the evaluation of significant variation in land cover types in Abeokuta from 1988-2022. The single factor analysis of variance (ANOVA) results presented in Table 4.18b examining land cover patterns in Abeokuta from 1988-2022 shows a statistically significant variation among the six different land cover categories: Built-Up Area, Agricultural land, Open Space, Water Bodies, Light Forest, and Dense Forest. The F-value of 14.53, is greater in value than the critical F-value of 2.44 at a significance level of 0.05. Moreover, the p-value is 0.000 in relation to this F-test and that is less than the standard alpha level of 0.05. The presentation of these results infers that 'there is no significant variation in land cover types within Abeokuta over the study period cannot be acceded; the null hypothesis is therefore rejected.

ANOVA: Single Factor
Table 4a. Statistical summary of land cover patterns

Groups	Count	Sum	Average	Variance
Open Space	8	76.7	9.59	70.81
Built-up Area	8	514.3	64.29	1300.65
Light Forest	8	101.4	12.68	16.32
Dense Forest	8	419.8	52.48	329.83
Agricultural land	8	270.5	33.81	402.89
Water Bodies	8	13.4	1.68	0.26

Table 4b. ANOVA Test

Source of Variation	Sum of Squares (SS)	*df*	Mean Square (MS)	*F*	*P-value*	*F crit*
Between Groups	25675.25	5	5135.05	14.53	0.000	2.44
Within Groups	14845.31	42	353.46			
Total	40520.56	47				

Furthermore, when examining the variability within each group and between the groups, the between-group variation (SS = 25675.25) is substantially larger than the within-group variation (SS = 14845.31). This large discrepancy suggests that there are indeed notable differences in land cover patterns between the various categories, thereby rejecting the hypothesis of uniformity in land cover across the area of study. The differences observed among the land cover categories may have important consequences on ecological conservation, urban planning, and resource management in the region, warranting further investigation and targeted interventions to talk about the distinct problems and opportunities associated with each land cover type.

Modification in land cover categories in Abeokuta showed a drastic reduction in vegetation cover (dense and light forest) and an upsurge in built-up area and agricultural land overall for the period of study. There are indications of indiscriminate land utilisation (Adebayo, *et al.,* 2019) and there is need to control land cover changes in form of urban growth and preserve natural landscape for sustainable development (Adeleke and Orimoogunje, 2016). A vigorous increase in farming activities was recorded around this time which has both progressive and destructive implications on the environment. The destructive impacts being soil erosion, loss of biodiversity, emission of greenhouse gases, and in effect climate alteration, and sometimes increased surface runoff depending on the types of crops. The positive aspects of agriculture are support of local economy, plants serve as carbon sink, biodiversity preservation, watershed protection and food security.

Conclusion and Recommendations

Rapid urbanisation and agricultural expansion have predominantly transformed natural landscapes into impermeable surfaces as a result of human-induced factors. This study evaluated changes in land cover pattern as driven majorly by human activities. The study reveals a pronounced trend of urbanisation, with the built-up area increasing significantly from 42.0 km² in 1998 to 115.5 km² by 2018, ultimately constituting 65.0% of the total area by 2022. This rapid urban growth happened at the expense of dense forests, which declined from 59.8 km² in 1998 to just 10.0 km² in 2022, reflecting a negative rate of change of -6.1% annually during the latter years.

The study shows land cover changes, from 1988 to 2022, where urbanisation and deforestation have increased impermeable surfaces, the findings indicate a significant enlargement in built-up areas, rising from 42.0 km² in 1998 to 115.5 km² in 2018, largely at the expense of dense forests.

As a result of the above findings, the study recommends implementation of urban planning strategies to control and manage rapid expansion in built-up areas to minimise environmental degradation; and also adopt sustainable land use practices that reduce impervious surfaces to maintain natural landscape as much as possible.

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