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Analysis of Urban Expansion and Land Use/ Land Cover Changes in Abeokuta, Nigeria using Remote Sensing and Geographic Information System Techniques

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Abstract. Since 1976, Abeokuta has functioned as the administrative centre of Ogun State, Nigeria. During this time, significant changes have occurred in its physical landscape, urban growth, and sprawl. These changes, driven by factors affecting Land Use/ Land Cover Changes (LULCC), pose environmental challenges such as transportation issues, land degradation, and pollution. This research investigates the impact of urban expansion in Abeokuta using Remote Sensing (RS) and Geographic Information System (GIS) techniques to monitor changes in land use and land cover from 1972 to 2022, and assess their environmental implications. The study identifies various Land Use and Land Cover (LULC) types, employing maximum likelihood classification to categorise features based on spectral signatures. Using imagery from Landsat satellites (TM4-5 for 1972,1984, 1992, TM7 for 2002, 2013, and OLI/MSS for 2022), the features were grouped into four primary classes: built-up areas, vegetation, drainage, and soil lands. Each year's data was processed using ArcGIS 10.5 to calculate the area covered by each land use class. The results illustrate notable changes in Abeokuta's LULC over the years. Specifically, the proportion of built-up areas increased from 0.66% in 1972 to 10.93% in 2022, while vegetation cover decreased from 93.66% to 58.82% during the same period. Drainage fluctuated, reaching a peak of 4.07% in 1992 but reducing to 2.23% by 2022. The soil land also varied, with significant shifts observed over the studied years (3.54% to 28.02%). The expansion of built-up areas at the expense of vegetation can be attributed to the conversion of natural vegetative surfaces into settlements and impermeable surfaces. The study underscores the importance of effective urban planning and enforcement of planning regulations by local and state governments in Abeokuta. This proactive approach is crucial to curbing the unplanned growth of the city and mitigating its adverse environmental impacts.

Keywords: Urban Expansion, Land Use/Land Cover Changes, Remote Sensing, Geographic Information Systems, Abeokuta

1. Introduction

Urbanisation refers to the growth in both population size and the geographical footprint of cities over time, traditionally seen as a marker of economic strength. As global urbanisation continues, the challenges of sustainable development increasingly centre on cities, especially in lower-middle-income countries where urbanisation is rapid and often uncontrolled (Cobbinah et al., 2015; Nagendra et al., 2018; United Nations, 2018; Guan et al., 2018; Aniekwe & Igu,2019; Shao et al., 2021; Rana & Sarkar, 2021). Cities concentrate production, knowledge, innovation, and economic growth, benefiting from agglomeration economies. They also facilitate the dissemination of knowledge and provision of public goods, enhancing human well-being. However, this ongoing urban development has led to continuous expansion into new territories, putting immense pressure on natural resources and exacerbating environmental issues concentrated within urban areas (Johnson, 2001; Hartig and Kahn, 2016; Cobbinah & Darkwak, 2016; Mosammam et al.,2017; Guite, 2019; Hosseini & Hajilou, 2019; Auwalu et al., 2021).

The expansion of cities contributes to increased emissions from transportation, loss of green spaces, and decline in ecosystem services, particularly biodiversity, all of which have negative environmental impacts (Rodriguez-Alvarez,2016; Cobbinah et al., 2017; Auwalu et al., 2021). Satterthwaite (2005) and Yakubu et al (2020) noted significant changes in urban areas from 1950 to 2000, underscoring the rapid economic growth and competitive dynamics among global cities (Yakubu et al.,2020). According to the UN-HABITAT (2002) and UNECA (2017), approximately half of the world's population resides in urban areas, with an even higher percentage in developed regions, marking the 21st century as an "Urban Millennium."

Scholars have differing views on rapid urbanisation in Africa (Cobbinah et al., 2015; Saghir & Santoro, 2018;), with some optimistic about its potential for industrialisation, infrastructure improvement, and economic growth (Guite et al., 2019), while others view it as problematic, driven by population growth without corresponding development (Guan et al., 2018; Yakubu et al.,2020). Despite these varied perspectives, it is clear that African cities are experiencing significant demographic and spatial expansion, albeit with varying dynamics across different cities (Xu, 2019).

The benefits of urban growth must be balanced against its environmental impacts, which are more pronounced today than ever before. The increase in impervious surfaces due to rapid urban expansion contributes to air and water pollution, habitat fragmentation, resource depletion, and traffic congestion, while also influencing local climate patterns (Yang et al.,2019; Rubiera-Morollón & Garrido-Yserte, 2020). This research contributes to understanding urban environmental changes and their implications.

As cities expand, there is an expectation that economic development will improve living standards and transform both urban and rural areas positively. However, this expectation is not always met in developing countries, where urbanisation is often associated with persistent poverty, food insecurity, inadequate housing, transportation issues, environmental degradation, pollution, energy shortages, and poor planning (Yakubu et al., 2020).

The trend toward urbanisation is accelerating, particularly in developing countries, with millions of people migrating to cities each week (UN-Habitat, 2008; Yakubu et al.,2020). By 2050, it is projected that over 70% of the global population will reside in urban areas, with the majority in the Global South (UN-Habitat, 2009; Rana & Sarkar, 2021). In Nigeria, for example, more than half of the population already lives in urban areas (NPC, 2006; World Bank, 2020; Auwalu et al., 2021), driven by factors such as high birth rates, rural-urban migration, and the establishment of educational, commercial, and industrial centres (Mosammam et al., 2017; Wang et al, 2018; Wang & Maduako, 2018; Auwalu et al., 2021).

Abeokuta, a city in Nigeria, has experienced rapid urban growth, resulting in significant changes to its landscape and environment (UN-Habitat, 2018). This growth, driven by economic expansion, has led to the loss of natural vegetation, farmland, forest reserves, and biodiversity (Adedeji et al.,2020). Understanding the dynamics of urban expansion in cities like Abeokuta is crucial for promoting sustainable development, particularly in the context of global initiatives such as the United Nations Sustainable Development Goals (SDGs) (Anderson et al., 2017).

In summary, urbanisation is a double-edged sword, offering economic opportunities while also posing significant environmental and social challenges. Managing urban growth effectively is essential for achieving sustainable development goals and improving the quality of life in cities worldwide. The primary aims of this research are to investigate the changes in land use and land cover in Abeokuta from 1972 to 2022, and to assess the scale of urban expansion during this time frame.

2. Materials and Methods

2.1 Study Area

Abeokuta, situated in Southwest Nigeria, serves as both the gateway and the capital of Ogun State. It shares distinct borders with Oyo, Ondo, Osun, and Lagos, spanning longitudes 3° 31′ to 3° 41′ East, and latitudes 7° 09′ to 7° 23′ North (Fig. 1). Covering an area of approximately 70 km^2 relative to Lagos, within a broader land expanse of nearly 17,000 km^2, the city has a current population density of around 264 individuals per km^2 (Nkwunonwo et al., 2023). Ogun State, where Abeokuta is located, is home to about 4.5 million people spread across 20 Local Government Areas, experiencing temperatures ranging between 26 ºC and 28 ºC, and an average annual rainfall of 963 mm (Ishola et al., 2016). The region plays a vital role as a significant drainage basin in southwestern Nigeria, with the river Ogun flowing through its territories, eventually emptying into Lagos Lagoon and onward to the Atlantic Ocean in the southernmost part of Nigeria (Tobore et al., 2022). Geologically, the area's parent materials consist of basement rocks and sedimentary deposits. However, the rapid alteration of its natural geomorphology and land-use patterns (Komolafe et al., 2015) underscore its susceptibility to sudden and rain-induced flooding. Consequently, spurred by burgeoning economic growth and socio-cultural activities, the area has witnessed substantial industrial and urban expansion (Kabisch and Haase, 2013; Senan et al., 2022).

Abeokuta, the capital city of Ogun State in Nigeria, has experienced significant urban growth over the decades, evolving from a historic settlement to a bustling urban center. Initially founded by the Egba people in the early 19th century as a refuge from slave trade activities, Abeokuta grew strategically due to its location on the trade routes between Lagos and Ibadan. The city's growth accelerated with the arrival of Christian missionaries and the establishment of various industries, including cocoa processing, which fueled economic development. This period saw Abeokuta transform into a hub of commerce, culture, and education in the region.

In recent decades, urbanisation has intensified, driven by population growth, rural-urban migration, and economic opportunities. The city has expanded outward with new residential and commercial developments, leading to the integration of formerly separate communities into a contiguous urban area. Infrastructure development has been a crucial aspect of Abeokuta's urban growth, with improvements in transportation, healthcare, education, and utilities enhancing the quality of life for residents. The government has also prioritised urban planning and development initiatives to manage the challenges associated with rapid growth, such as housing shortages, traffic congestion, and environmental sustainability. While facing urbanisation challenges typical of developing cities, Abeokuta continues to evolve as a dynamic urban centre, poised for further growth and development in the future.

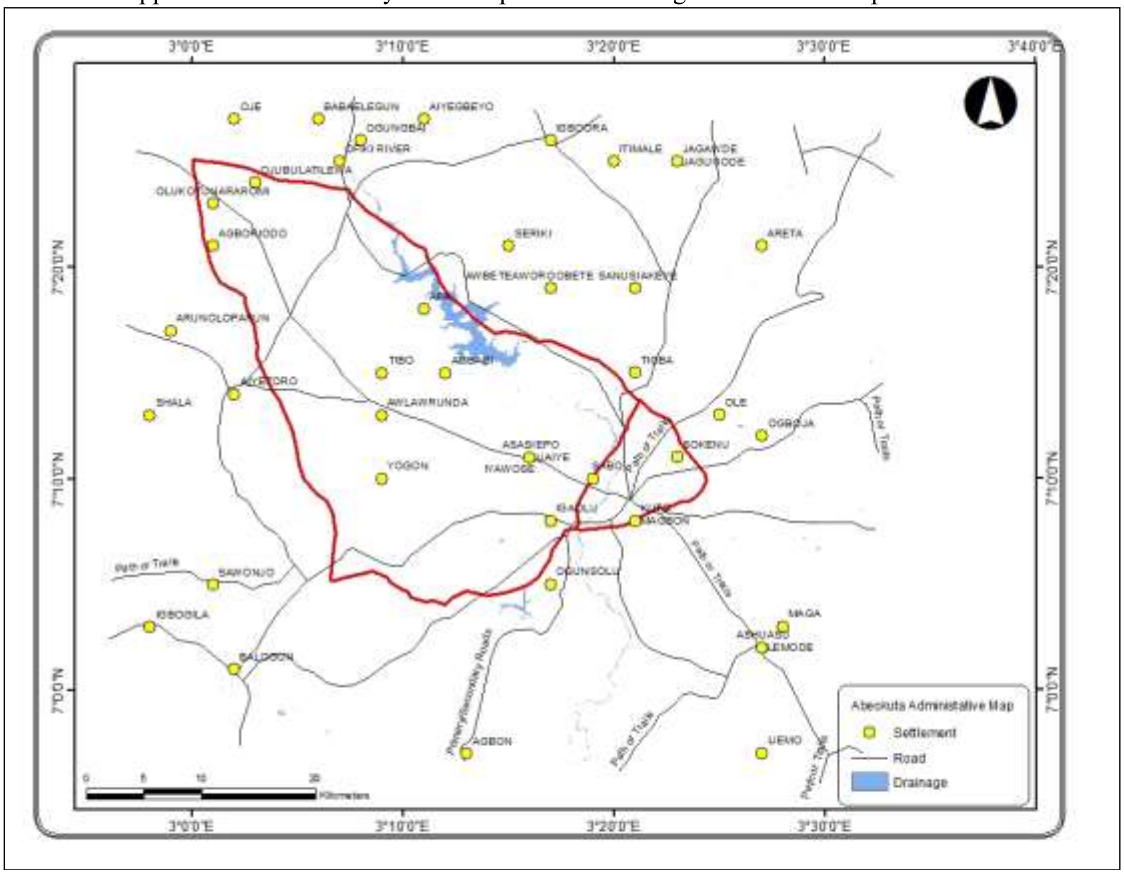


Figure 1: *Administrative Map of Abeokuta*
Source: *Ogun State Ministry of Physical and Urban Planning, Abeokuta, 2018.*

2.2 Data Collection

The study utilised Satellite Imageries of Abeokuta with Geographic Information Systems (GIS), Remote Sensing (RS), and direct observations. Additional data, including Ground Control Points (GCP), topographic maps, Google Earth imagery, and historical land use plans along with digital maps of Abeokuta, were sourced from the Ogun State Ministry of Physical and Urban Planning to aid in analysis and validation. Field surveys were conducted to collect ground reference data using a handheld Global Positioning System (GPS) device. The primary method involved comparing satellite images of Abeokuta downloaded from the United States Geological Survey (USGS) website (https://earthexplorer.usgs.gov) at six (6) intervals over five (5) decades (1972, 1984, 1992, 2002, 2013, and 2022) (Table 1). This approach facilitated analysis of changes in urban growth direction and extent across these periods.

Land Use/Land Cover (LULC) within the study area (Abeokuta), using the Anderson 1976 LULC classification scheme (Table 2), was categorised into Built-Up, Vegetation, Drainage, and Soil areas. Maximum likelihood classification was applied to classify features based on their spectral signatures in Landsat 4-5 (TM), Landsat 7 (TM), and Landsat 8 OLI/MSS images for the respective years (Table 1). The total area of each land use category for each year was calculated using the field calculator in ArcGIS 10.5.

Table 1: Satellite Data Sets Used in the Study

S/N	Satellite Number	Year	Date of Acquisition	Path/Row	UTM Zone	Datum	Spatial Resolution(m)	Source
1	Landsat TM 4-5	1972	18/8/1972	205/55	31N	WGS84	30	USGS
2	Landsat TM 4-5	1984	2/4/2014	191/55	31N	WGS84	30	USGS
3	Landsat TM 4-5	1992	30/12/1992	191/55	31N	WGS84	30	USGS
4	Landsat TM 7	2002	28/12/2002	191/55	31N	WGS84	30	USGS
5	Landsat TM 7	2013	18/12/2013	191/55	31N	WGS84	30	USGS
6	Landsat 8 OLI/ MSS	2022	2/2/2023	191/55	31N	WGS84	30	USGS

Source: *Author's Field Work, 2024.*

Table 2: Land Use/Land Cover Classification Scheme Adopted for The Study

S/N	Land Use/Land Cover Classes	Description
1	Built-Up	Area of land used for residential, transportation, and communication.
2	Vegetation	Terrain dominated by trees, grasses, bushes, and plants.
3	Drainage	Area that are submerged under water, such as lakes, rivers, and dams.
4	Soil	Cultivated farmland & irrigation zones

Source: *Author's Field Work, 2024.*

2.3 Data Analysis

The collected data were imported into a GIS environment for further analysis and computation. The effectiveness of using remotely sensed data to detect changes in land cover hinges on careful selection of the data source (Yakubu et al.,2020). In this study, Landsat TM 4-5, 7, and Landsat 8 OLI/ MSS satellite images with a 30-meter resolution covering Abeokuta were utilised (Table 1). Additional bands (4, 3, and 2) were generated and resampled for a new display. A color composite was created using a Region of Interest (ROI) vector frame from the study area map in ArcGIS 10.5, which was then imported into the IDRISI Selva Version 17.0 environment as a shapefile. This facilitated delineation of the study area's Region of Interest (ROI) from the satellite image scene. For the color composite, band 4 of the Landsat image represented red, while bands 3 and 2 represented green and blue, respectively. This color combination is considered effective for studying Land Use/ Land Cover (LULC), particularly in identifying built-up areas, vegetation, soil, and drainage.

Therefore, prior to the change analysis, it's crucial to preprocess satellite images to establish accurate relationships with biophysical conditions (Abd El-Kawy et al., 2011; Coppin et al., 2004), rectify atmospheric conditions, and ensure reliable data. Successful land cover mapping and change detection analysis hinge on appropriately processing satellite images (Hassan et al., 2016).

Change analysis was conducted on Landsat images from different years to examine patterns and trends in land cover changes within the study area. Areas covered by each land use feature were calculated in square kilometres (Km^2) and as a percentage (%) as shown below in equation 1&2;

Area percentage = Count / Sum × 100………… (1)

Area in km^2 = Count (number of pixels) × Resolution of Image/ 1,000,000……….. (2)

3. Results and Discussion

Table 3: Land Use/Land Cover Types Distribution in Abeokuta from 1972 to 2022

Year	1972		1984		1992		2002		2013		2022	
LULC Types	Km^2	%	Km^2	%	Km^2	%	Km^2	%	Km^2	%	Km^2	%
Soil	30.73	3.54	44.49	5.13	66.61	7.68	124.90	14.40	186.67	21.53	242.95	28.02
Vegetation	812.05	93.66	762.64	87.95	728.46	84.01	677.84	78.18	595.01	68.62	510.05	58.82
Drainage	18.53	2.14	29.26	3.37	35.25	4.07	24.70	2.85	27.41	3.16	19.34	2.23
Built-up	5.73	0.66	30.75	3.55	36.77	4.24	39.64	4.57	57.99	6.69	94.74	10.93
Total	867.05	100	867.14	100	867.10	100	867.08	100	867.07	100	867.08	100

Source: *Author's Field Work, 2024.*

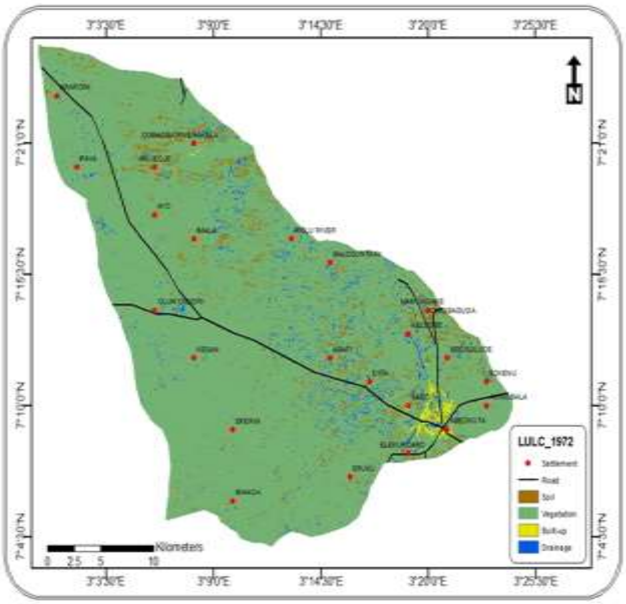


Figure 2a: LULC Classified Map of Abeokuta For Year 1972.

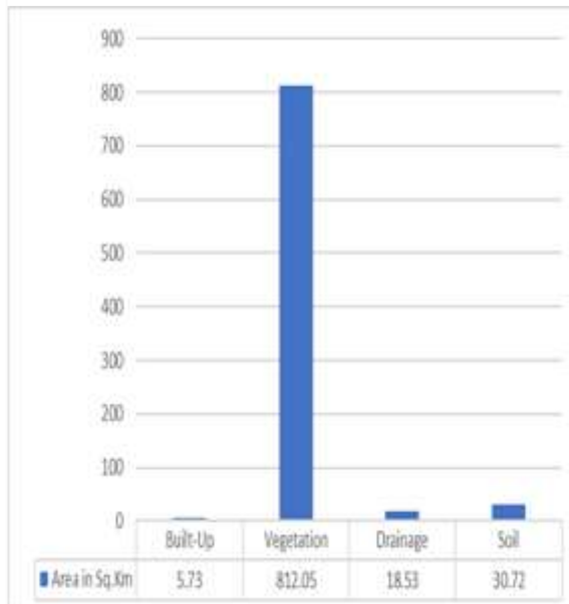


Figure 2b: The Extent of Classified LULC of Abeokuta For the year 1972.

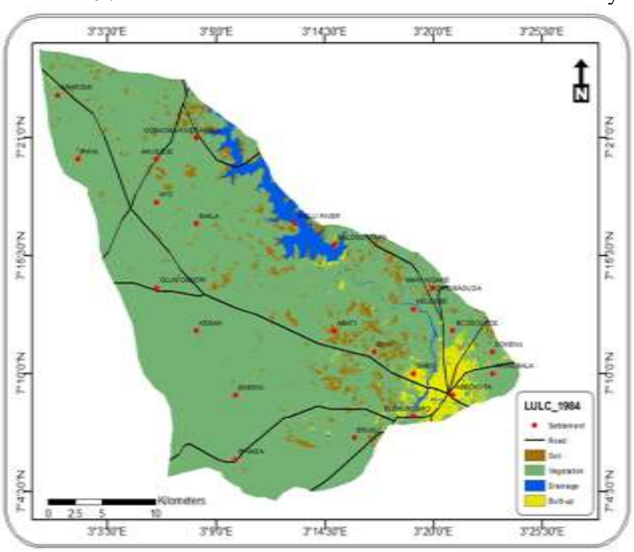


Figure 3a: LULC Classified Map of Abeokuta For Year 1984.

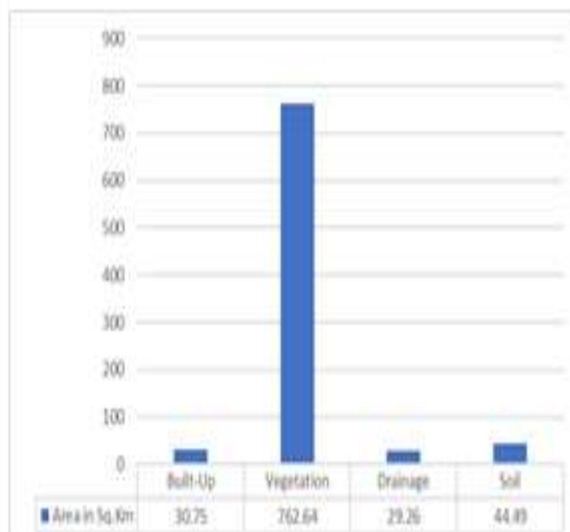
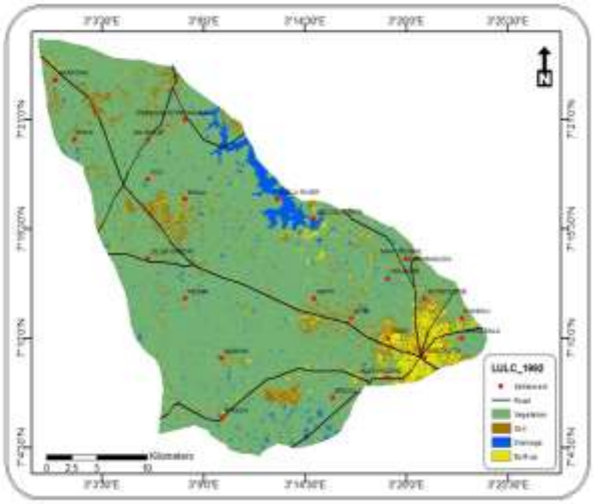


Figure 3b: The Extent of Classified LULC of Abeokuta For the year 1984.



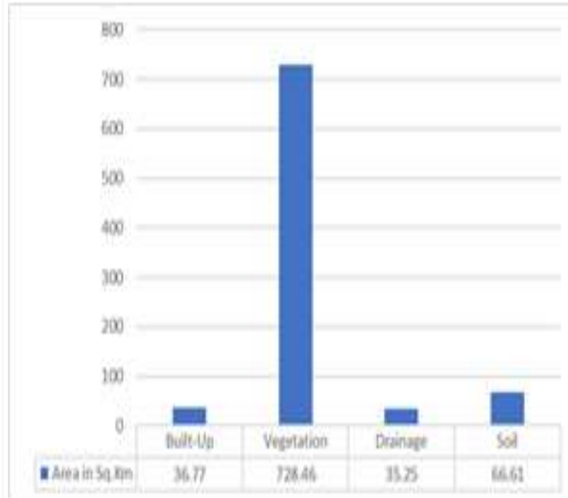
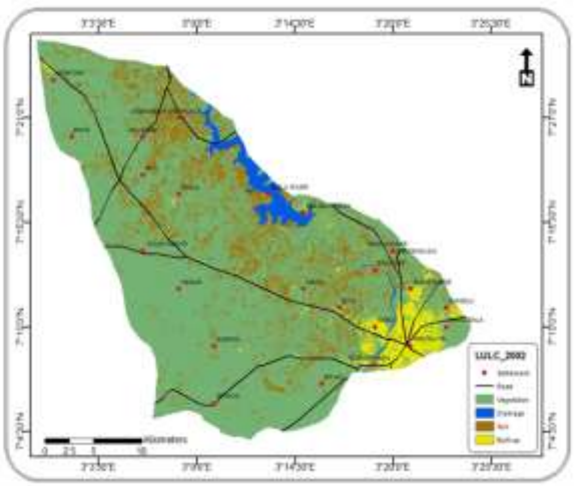


Figure 4a: LULC Classified Map of Abeokuta For Year 1992.

Figure 4b: The Extent of Classified LULC of Abeokuta For the year 1992.



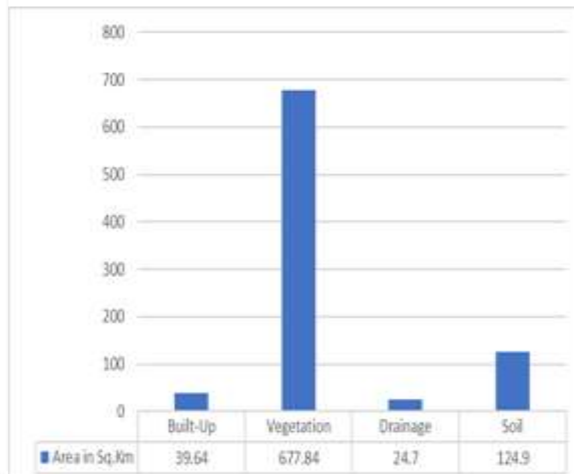
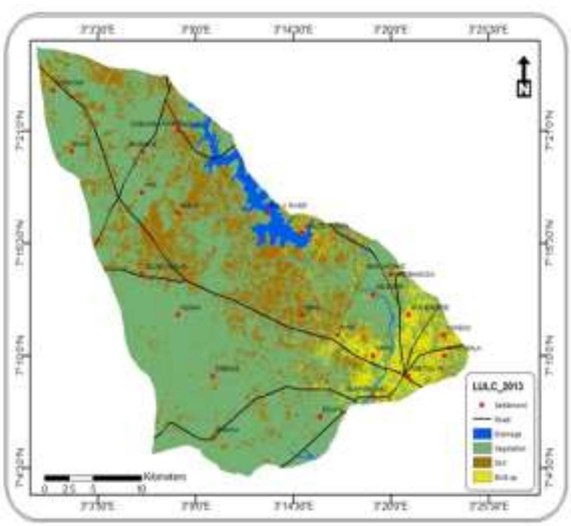
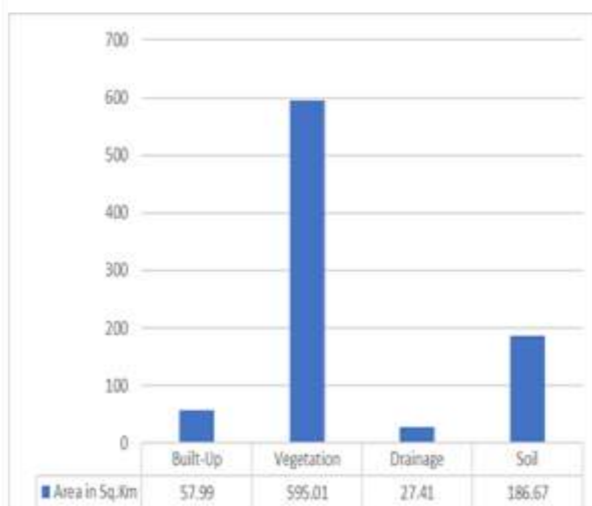


Figure 5a: LULC Classified Map of Abeokuta For Year 2002.

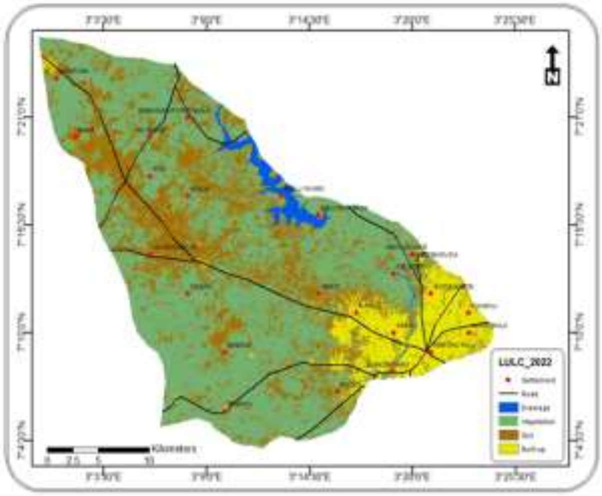
Figure 5b: The Extent of Classified LULC of Abeokuta For the year 2002.





LULC Classified Map of Abeokuta For Year 2013.

Figure 6b: The Extent of Classified LULC of Abeokuta For the year 2013.



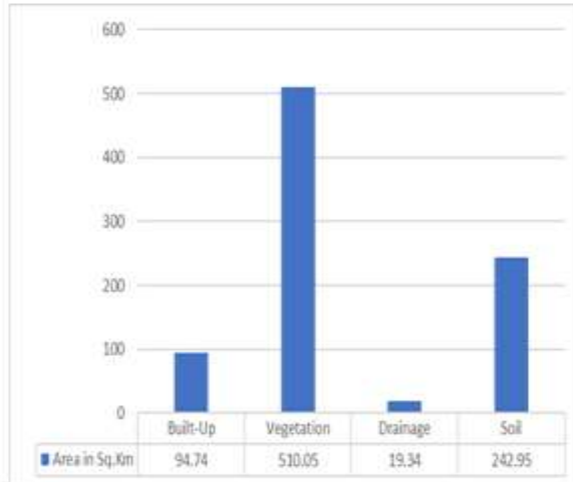


Figure 7a: LULC Classified Map of Abeokuta For Year 2022.

Figure 7b: The Extent of Classified LULC of Abeokuta For the year 2022.

Table 3 summarizes the findings for 1972, 1984, 1992, 2002, 2013, and 2022 regarding the four-land use and land cover categories studied in Abeokuta. Meanwhile, Figures 2a, 2b, 3a, 3b, 4a, 4b, 5a, 5b, 6a, 6b, 7a, and 7b illustrate the land use and land cover patterns for the years 1972, 1984, 1992, 2002, 20123, and 2022 respectively.

Built-up/Urban Area: The built-up area, which includes residential and commercial zones, expanded significantly over the years. In 1972, it covered 5.73 km^2 (0.66% of the total area), expanding to 30.75 km^2 (3.55%) in 1984, 36.77km2 (4.24%) in 1992, 39.64km^2 (4.57%) in 2002, 57.99km^2 (6.69%) and further to 94.74 km^2 (10.93%) by 2022. This growth is attributed to population increase, influx of migrants, and economic activities driving urban expansion beyond municipal boundaries into peri-urban areas (Boitie, 2018; Hosseini & Hajilou,2019; Omurakunova et al.,2020).

Vegetation: The area covered by forests, shrubs, and agriculture was substantial in 1972, totaling 812.05 km^2 (93.66%). By 1984, this area reduced to 762.64 km2 (87.95%), 728.46km^2 (84.01%) in 1992, 677.84km^2 (78.18%) in 2002, 595.01km^2 (68.62%) in 2013, and by 2022, it further decreased to 510.05 km^2 (58.82%). This decline indicates conversion of vegetated areas for urban development, roads, and public amenities (Cobbinah et al.,2017).

Soil Land: Open spaces and road networks, categorized as bare surfaces, occupied 30.73 km^2 (3.54%) in 1972, increasing to 44.49 km^2 (5.13%) by 1984, 66.61km^2 (7.68%) in 1992, 124.90km^2 (14.40%) in 2002, 186.67km^2 (21.53%) in 2013. However, by 2022, this area expanded significantly to 242.95 km^2 (28.02%), reflecting new land opened for roads and other urban infrastructure (Kuusaana & Eledi, 2015; Cobbinah et al.,2017).

Drainage Area: Areas classified as wetlands and water bodies covered 18.53 km^2 (2.147%) in 1972, expanding to 29.26km^2 (3.37%) by 1984, and 35.25km^2 (4.07%) in 1992. By 2002, this area reduced to 24.70 km^2 (2.85%), 27.41km^2 (3.16%) in 2013, and 19.34km^2 (2.23%) due to urban encroachment and human activities such as water extraction. This poses risks like increased impervious surfaces and vulnerability to flooding from stormwater (Gerald et al., 2020).

In summary, the study highlights significant transformations in land use and cover in Abeokuta over five (5) decades, driven by urbanisation and associated socio-economic factors.

The majority of new land development primarily stems from the conversion of agricultural and forested areas, a trend consistent with findings by Balogun et al. (2011). Urban expansion inevitably impacts the urban environment, introducing uncertainties regarding urban sustainability (Nagendra et al., 2018; Kaur & Garg, 2019; Xu, 2019). Rapid and extensive changes in land use and land cover significantly affect ecosystem services (Wang et al., 2018).

In Nigeria, urban development poses considerable risks due to inadequate planning frameworks and limited resources, resulting in new urban residents often settling in high-risk zones (Balogun et al., 2011; Kaur et al., 2019; Wang et al., 2018; Garg, 2019).

Falade (1985) and Ehrlich et al (2018) advocates for policy makers to adopt strategies that promote effective planning and management of cities as critical drivers of national economic growth and sustainable development.

This study offers valuable insights for researchers, policymakers, and decision-makers into the dynamics of urban expansion in Abeokuta and its implications for future urban planning. Understanding these patterns is crucial for developing effective policies and management strategies to manage urban growth, especially as Abeokuta's urbanisation rate continues to rise.

4. Conclusion and Recommendations

Over a fifty-year (5 decades) span in Abeokuta, the analysis of land use and land cover revealed a rise in built-up/urban and soil areas, coupled with a decline in vegetation and wetlands/water bodies. The expansion of built-up areas and consequent increase in soil areas resulted from the transformation of natural vegetation into urban settlements and impermeable surfaces. Implementing monitoring systems for the built environment is essential to enable planners and decision-makers to anticipate and address potential issues proactively amidst a changing environment.

This study underscores the need for urban planners, local authorities, and state governments to establish robust frameworks for enhanced planning and enforcement of regulations in Abeokuta. Such measures are crucial to curbing unplanned expansion and promoting sustainable development in the city.

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