ISSN 2354-9114 (online), ISSN 0024-9521 (print)
Indonesian Journal of Geography Vol 54, No 2 (2022):313 - 320
DOI: 10.22146/ijg.70316 website: https://jurnal.ugm.ac.id/ijg

INDONESIAN JOURNAL OF GEOGRAPHY

RESEARCH ARTICLE

Rapid spatial growth of cities and its planning implications for developing countries: a case study of Abuja, Nigeria

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Received: 2021-12-22
Accepted: 2022-08-11

Keywords:
Environmental sustainability; land cover; planning implications; settlement patterns; urban growth

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Abstract. Accelerated spatial growth of urban areas is a key driver to land use/land cover change with its concomitant effect on environmental sustainability. The dearth of data on the rate of urban expansion, especially in many developing countries, including Nigeria has continued to hinder effective land use planning and sustainable development. The study aims to identify and analyze the settlement patterns and trends in urban growth at ten years intervals and their planning implications in Abuja, Nigeria. It relied on data generated via remote sensing and Geographic Information Systems to create the map and examine the land cover change in the study area. Classification of land cover using LANDSAT data and land cover transitions for 29 years (1990 to 2019) were mapped and the net land cover change was computed. The results showed the settlement pattern and an increase in the urban built-up area ranging from 1.8% in 1990 to 19.3% in 2019. The dispersion pattern revealed a large concentration of the built-up spaces to be in the eastern region and that the expansion continued from east to south and south-west. The bare land cover types were found to have increased while vegetation land cover decreased rapidly by 30.4% from 1990-2019. The study recommends the need for city planners to decentralize urban planning and development control with adequate provision of affordable urban facilities at the peripheries of cities in Nigeria. Furthermore, massive integration of green infrastructure in built-up areas is required to mitigate the effects of vegetation loss in cities.

1. Introduction

Global urban growth continues to be witnessed in most locations, especially in the global south (Okpalike et al., 2021; Okeke et al., 2021), resulting in significant consequences on land with regional and local levels of environmental dynamics. As reported by the studies of Montgomery and Hewett (2005), and also that of Arifeen et al. (2021), developing countries have experienced the highest rates of urbanization and associated land use or cover changes. This suggests, therefore, that cities in developing countries are doubling their built-up or impervious surface areas in order to support the growing population. Literature has established further that the global growth of urban areas is a major front in habitat destruction, which starts with habitat loss and eventually leads to species extinction (Hahs et al., 2009). The foremost human-led land-use activity has been urbanization, which has had massive and irreversible effects on the ecological ecosystem. It is a significant driving force behind changes in landuse, climate, vegetation cover, biogeochemical cycle, hydrological processes, and loss of biodiversity (Cohen, 2006; Okeke et al., 2021). Another key factor that can be linked to the exceptional growth in urban expansion is population rise (Holdgate, 1993; Daramola & Ibem, 2010; Okeke et al., 2020; Echendu et al., 2020). Over the past 100 years, cities have been transformed from small, isolated population centers to large, interconnected urban centers with huge human populations and massive physical infrastructure (Xian, 2007). According to Lilly and Monsingh (2009), the major factors contributing to these differences are land use and land cover transformations. These land use changes often include replacements of natural surfaces with highly reflective parking lots, concrete pavements, asphalt roads, and other surfaces that contribute to urban heat islands among other adverse environmental and social challenges. A typical example is the Lagos state government's planned gentrification of the Makoko waterfront with asphalt plains, concrete boxes, and cubic glass phallic symbols as the solution to the social development of the community in 2012 (Okeke et al 2019). There is a burgeoning concern about the impacts of human activities on the urban environment, especially as it relates to the local climate system (EPA, 2016; Anierobi et al., 2022). Notably, rapid and unplanned spatial growth of urban areas threatens sustainable development when this is not accompanied by physical infrastructure development or policies are not well-implemented to adequately guide and sustain such growth

(Orum & Chen, 2003; Daramola & Ibem, 2010). Unplanned or inadequately managed urban expansion leads to rapid sprawl, pollution, and environmental degradation, together with unsustainable production and consumption patterns (UN, 2014). According to Potts (2012), rapid urban growth, high population density, and high consumption rate of residents in megacities, especially in the developing countries in the Global South have led to myriads of socioeconomic and environmental consequences that require urgent attention from the global community. This is to ensure that the sustainable development goal can be attained as planned. As urbanization will continue to result in the emergence of new megacities plagued by environmental deterioration, inadequate housing, traffic congestion, slums, crime, and homelessness (Nwalusi et al., 2022). UN-HABITAT (2006; 2010); Makinde, (2012); Nnaemeka-Okeke et al., (2020), and Okeke, (2021) have stressed the need for concerted efforts to address these challenges, especially in sub-Saharan Africa; as this urban growth appears to be on a trajectory to continue (Aljohani et al., 2021).

The trend of urban growth in Federal Capital Territory, Abuja in recent years portrayed a challenging picture for the urban area to cater to the need of the rapidly growing population. Physical development in this city began in 1980 (FCDA, 2001), and since the early 1990s, it has been recognized and described as one of the rapidly budding cities in West Africa. Among other things, this spatial and demographic growth has resulted in a large removal of a portion of the green areas as they are being converted to different land uses (Aliyu & Bashiru, 2015). The city has experienced rapid land use and land cover (lulc) changes, resulting from massive spatial increase and transportation infrastructure provision in the past three decades. Abuja's urban expansion has altered substantially over time, resulting in complicated urban dynamics; and these have been seen in the transformation of arable land into settlements, road networks, and other vital physical infrastructure (FCDA, 2001) required to meet the need of a projected annual growth rate of 9.4% (UNFPA, 2015). According to Adeponle (2013), Abuja city is developing faster (13 percent) than the provisions of its Master Plan, and thus, it is quickly turning into an environmental embarrassment, with development projects sprouting up in flagrant violation of zoning codes and other planning ordinances. Abuja, which was intended to be the epitome of beauty and an enlightened vision of urban planning and city development, has been plagued by unnecessary distortions in the implementation of its Master Plan throughout the years. Unfortunately, due to rapid population growth, some of the initial facilities are now overstretched and dysfunctional. As a result, the city is experiencing a huge shortfall in housing supply, traffic congestion, and marginal supply of social services such as solid waste, educational institutions, health centers, and recreational centers (Lawal & Adekunle, 2018).

In an attempt to understand landuse and land cover change in sub-Saharan cities, Enoguanbhor et al. (2019) using GIS and remote sensing techniques assessed the change in urban land cover in the Abuja (Federal Capital Territory) region of Nigeria in 1987, 2002, and 2017. The study found that urban/built-up and bare land cover categories increased, whereas the green belt dropped. Incongruities between past/present land cover and the existing land use plan were also observed by the authors. Other studies in other cities in Nigeria (Umunnakwe et al, 2018; Umunnakwe & Azubuine, 2019a; 2019b) had reported a mismatch of unregulated city expansion and the land use plan and attributed this to a number of factors such as industrialization and commercialization, development of transport and communication, educational and recreational facilities, the economic pull of the city and technological changes. The consequences of rapid urban growth have been on the increase in many cities in the Global South. On the one hand, urbanization can yield positive effects if it takes place up to a desirable limit. On the other hand, extensive urbanization or indiscriminate growth of cities may result in adverse effects such as over-stretching of existing infrastructure beyond its carry capacity, proliferation and the growth of slums; increased cost of living, crime rates; pollution; traffic congestion, air pollution, sewer system, and water pollution, noise (Mba, et al. 2004; Odjugo, 2011; Daramola & Ibem, 2010; UN-HABITAT, 2010; Okeke et al., 2020; Obi et al., 2021; Chukwurah et al., 2022) as well as massive loss of green areas (Atharinafi and Wijaya, 2021). Some scholars (Sahoo 2016; Merem et al. 2018; Arora et al. 2018) have specifically noted that some of the key challenges associated with rapid urban growth are land degradation, global warming/climate change, lack of potable water supply, and biodiversity loss.

Previous studies such as Daramola and Ibem (2010) have examined urban environmental challenges associated with urbanization in Nigeria, others have examined urban land use patterns and spatial changes in Nsukka, Enugu State (Umunnakwe et al, 2018), spatial land use changes in Umuahia Abia State (Umunnakwe & Azubuine, 2019), land use spatial changes in Enugu State, South Eastern Nigeria (Umunnakwe & Azubuine, 2019b) and impact of landuse structure on urban transportation in Enugu (Okeke et al., 2021). Another study by Enoguanbhor et al (2019) investigated the urban change of land cover in the Abuja region between 1987 and 2017. Although these studies provide useful insight into the trend loss of green areas in these cities, only one focused on Abuja, and the reference period was between 1987 and 2017. Given the rapid spatial growth, Abuja city is currently witnessing, there is a need for current data on land cover change in the city. Thus, the underpinning necessity of this study is to fill the gap and examine the settlement patterns and trends in urban growth and its imperative to city sustainability. This study, therefore, assessed the spatial growth dynamics and its planning implications for Abuja, Nigeria between 1990 and 2019. The specific objectives were: (1) to examine the change in the built-up area, the vegetation cover, bare land, and the water bodies in Abuja, Nigeria in the referenced period and; (2) to analyze the trend and directions of the spatial growth of the city between 1990 and 2019. The study is relevant in that it provides baseline information on the growth trend of Abuja, Nigeria, which is considered vital for effective urban planning and management and further research on this subject. Its findings are again crucial to contribute to the existing knowledge base that would advance stratic policy formation towards acceleration of the uptake of sustainable urban planning and city development

in the developing world. Lastly, it also analyzed the implications of such spatial dynamics as a way of providing useful insight into the various aspects that require more attention for sustainable urban spatial planning and growth in Abuja, Nigeria, and beyond.

2. The Methods

The study area is Abuja, which is located in Northcentral and the Federal Capital Territory (FCT) of Nigeria. Abuja is a planned city, and was built in the 1980s (Abubakar 2014); the city lies between latitudes 8º 25' N and 9º25' N of the Equator and longitudes 6º 45' E and 7º39' E of the Greenwich Meridian (See figure 1). Based on the 2006 census figure, the city of Abuja had a population of 776,298 (National Population Commission, 2006), making it one of the ten most populous cities in Nigeria. Abuja has over the years witnessed a huge influx of people into the city; and this has led to the emergence of satellite towns such as Karu Urban Area, Suleja, Gwagwalada, Lugbe, Kuje, and several other smaller settlements where the planned city is sprawling. Currently, Abuja has a population of over three million and comprises the fourth largest urban area in Nigeria. According to the Abuja Master plan (1979), at each stage of its development, the city was designed to be an efficient and appealing environment – from Phase I, which was designed to accommodate 230,000 residents, to Phases II and III, which were designed to accommodate 585,000 and 640,000 residents, respectively, to Phase IV, which was designed to accommodate 1. 7 million. Its total population is projected to be 3.1 million people (Olaitan, 2004).

The data for this study were obtained through Geography Information System (GIS) and Remote Sensing. This was used to produce the map of the area, and capture and analyze the geographic distribution and spatial growth pattern of Abuja Metropolis. Previous research on this subject had used this method (see Enoguanbhor et al., 2019). The research was designed in a way that detailed information of the pattern of growth is gotten at an interval of 10 years starting from 1990 to 2000, 2010, and 2019. In this research, four eras of virtualized Landsat series pictures were obtained from the Internet search engine via the Earth Explorer web page (2019) for 1990, 2000, 2010, and 2019. The downloaded satellite images were ortho-rectified/ georeferenced L1T (terrain corrected) and produced from the source. However, the geometric correctness was confirmed by superimposing and comparing it to existing maps.

Specifically, the coordinate system was verified and projected to UTM Zone 32, WGS1984, Minna Datum. The radiometric correction was carried out by converting the digital numbers (DN) to at-sensor radiance using ENVI-5's radiometric calibration module in conjunction with the information provided in the header file. The Flash Line-of-sight Atmospheric Analysis of Spectral Hypercubes (FLASH) atmospheric correction in ENVI-5 was applied to the at-sensor radiance corrected images of 1990, 2000, 2010, and 2019 with the appropriate atmospheric and aerosol models to produce atmospherically corrected sensor reflectance images.

Additionally, satellite imagery acquired through Google Earth software in 2019, the FCT Abuja regional land use plan (AGIS, 2015), and the 2011 updated FCC Abuja urban land use plans of Phases 1, 2, and 3 carried out by Fola Consult (2011) were used in this study. The regional land use plan was obtained from the Abuja Geographic Information System (AGIS), while the source of the urban land use plan is the Department of Urban Development planning office in the Federal Capital Territory. Other ancillary datasets used include the Abuja master plan retrieved from the Federal Capital Development Authority's Survey and Mapping Department (FCDA, 1979), socio-economic statistics including population figures obtained from National

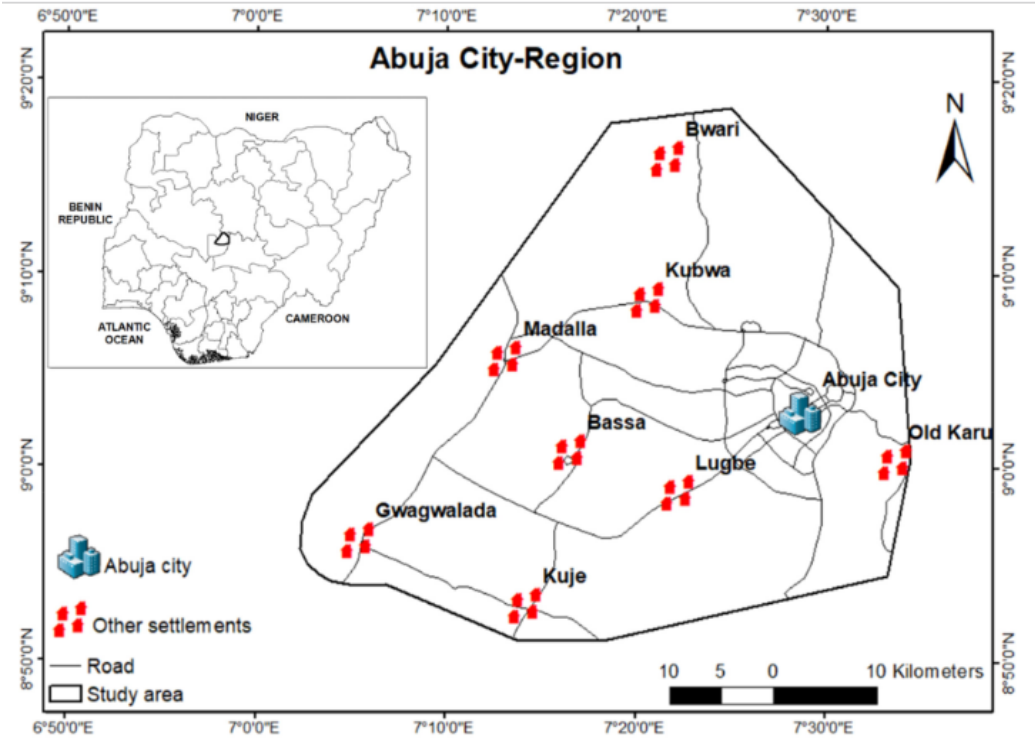

Figure 1. Map showing the locations of the city of Abuja and the neighbourhood settlements. Source: Enoguanbhor et al., (2019)

Population Commission. Due to the nature of the data collected, analysis was based on thematic content. Further analysis was made by inferential means drawing out conclusions and deductions for the study based on the change in the spatial growth and settlement pattern of the population, and descriptive statistics to calculate the rate at which the growth occurs. The results for the land cover of Abuja city are presented graphically. The data are broadly classified into four categories, based on the reference years: 1990, 2000, 2010, and 2019.

3. Results and Discussion

The result (Figure 2) shows the land cover of the Abuja region as of 1990. The built-up area in the city region covers a relatively small portion mostly concentrated at the east end of the city. Figure 3 also shows the proportion of land cover and other features in Abuja in 2000. It can be seen from Figure 2 that the size of the built-up area in the city had increased, with the bare land area, while the vegetation covered massively. It can be seen from these results that in the space of 10 years, the built-up area in Abuja has increased by 8.2%, the vegetation cover has shrunk by 9.7%, while the bare land has increased by 1.5%.

Similarly, Figures (4 and 5) depict the built-up area, vegetation cover, bare land, and water body in Abuja city in 2010 and 2019, respectively. Comparative analysis of the built-up area, the greenbelt vegetation cover, bare land, and the water bodies in Abuja, Nigeria between 1990 and 2019 as captured in this study using GIS and remote sensing tool is shown in Table 1. Examination of the results reveals that between 1990 and 2019, which is a period of 29 years, the built-up area has increased by 348.6sqkm which is about 947.28%, while the vegetation cover has shrunk by 443.7sqkm representing around 30.48%. Similarly, the area of bare land has increased by 96.7sqkm, representing about a 19.66% increment, while only 0.1% was observed in the change of water body in the study area.

The human population dynamics in the FCT Abuja for those reference years are also presented in Table 2. It is evident that the population of the city region grew by 151.92% from 1990 to 2000 with the population rising to 832,556 from 330,473. The growth between 2000 and 2010 was 117.85% which resulted to an increase of 1,813,734 in 2010 compared to 832,556 in 2000. The present population for the year 2019 is 3,095,116 and the growth is calculated to be 70.64% (Table 2). it is evident from the data in Table 2 that there is high population growth in Abuja and this

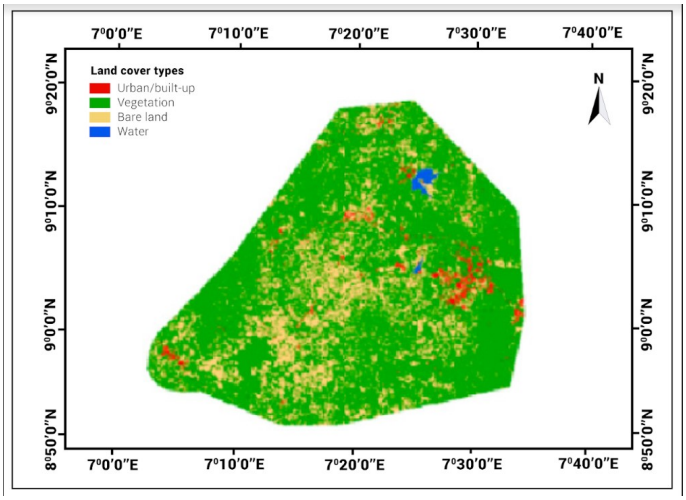

Figure 2. Spatial Map of Abuja showing the Land Cover as of 1990

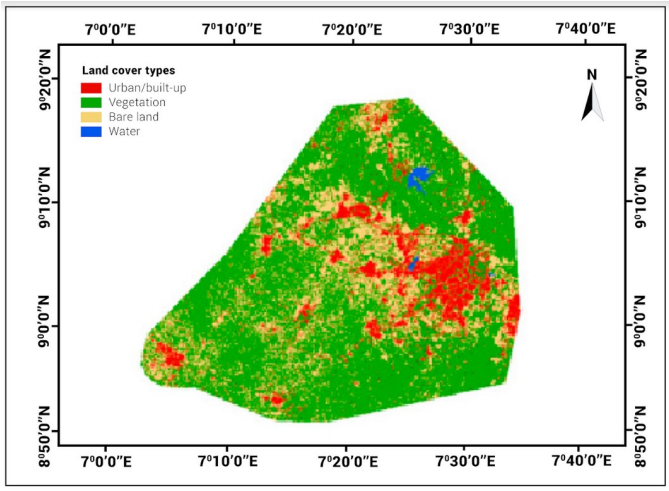

Figure 3. the Abuja City Region Land Use Cover in 2000

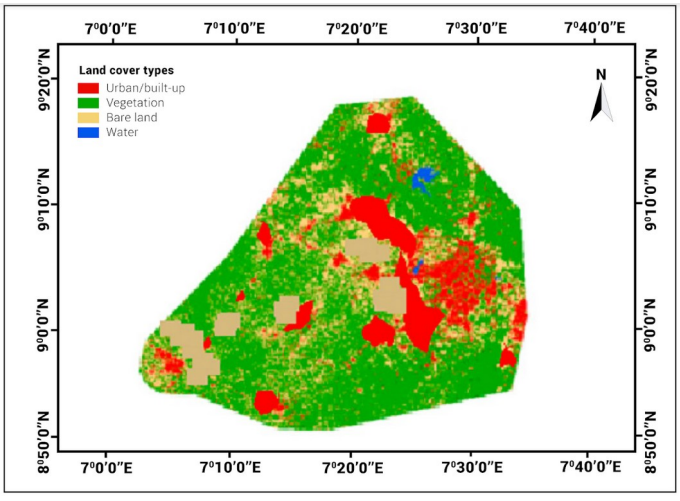

Figure 4. Land Use Cover of the Abuja City Region in 2010

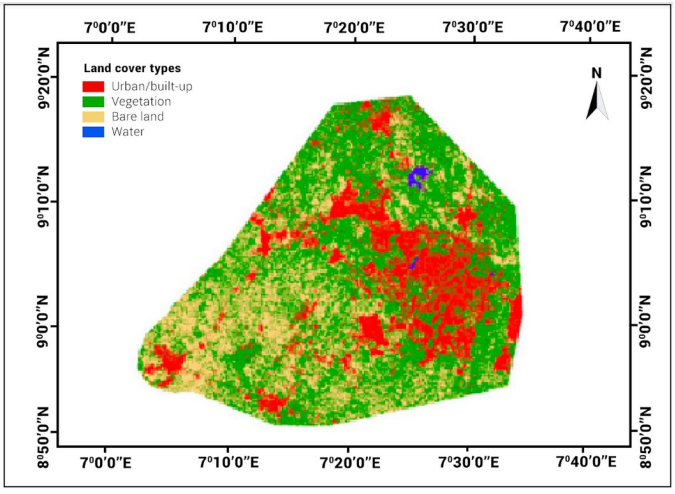

Figure 5. the Abuja City Region Land Use Cover of 2019

according to previous authors has a massive impact on the spatial growth of cities, especially in the conversion of green areas to built forms such as social and economic infrastructural facilities (see Orum & Chen, 2003; UN-HABITAT, 2010).

The spatial pattern of land cover as visualized and quantified for 1990 (Figure 2) reveals that in 1990, the urbanized and built-up regions (shown with red patches) were primarily concentrated in the east. The urbanized and built-up class accounted for approximately 1.8 percent of the total area, while greenbelt vegetation accounted for 73.0 percent, bare ground accounted for 24.7 percent, and waterbodies accounted for 0.5 percent. For the year 2000, the distribution pattern suggests that urbanized and built-up areas were largely intense in the eastern region of the territory, accounting for 10.01 percent of the total area in the Abuja city region. 63.3 percent of the area was covered by vegetation, 26.2 percent by bare terrain, and 0.5 percent with water (Figure 3).

Similarly, in 2010, the research result revealed that urbanized and built-up area coverage expanded from east to south and south-west, covering 14.8 percent of the total land space, while greenbelt vegetation blanketed 57.0 percent, bare ground occupied 27.8 percent, and water encased 0.4 percent (Figure 4). Furthermore, in 2019 the results (see figure 5) indicated that urbanized and built-up area cover continued to extend from east to south and south-west, accounting for 19.3 percent of total land area; greenbelt vegetation accounted for 50.8 percent, while bare land and water accounted for 29.5 percent and 0.4 percent, respectively. These findings seem to agree with the multiple nuclei theory, which suggests that the cities have multiple growth points from which growth emanates. It can be argued that among other factors, the observed expansion of built area from the east to other parts of the region might have been triggered by rapid human population growth as shown in Table 2, which is consistent with the Raynolds and Holwell (2010) on the direct impact of demographic factors on urban growth.

The net land cover changes as shown in Table 1, from 1990 to 2019 were computed. The research result indicated that between 1990 and 2000, urbanized and built-up areas increased by 162 km2 (8.1 percent), whereas bare land grew by 30.2 km2 (1.5 percent). The area covered by water bodies did neither expand nor decrease. Vegetation was the only land cover that declined, with the greatest measured reduction at 193.1 km2 (9.7 percent). From 2000 - 2010, urbanized and built-up land cover increased by 95.7 km2 (4.8%), and bare land changed by 31.2 km2 (1.6%). Water bodies were reduced by 1km2 (0.05%) while vegetation was reduced by 125.3 km2 (6.3%). Between 2010 and 2019, the area of urbanized and built-up land cover increased by 90.9 km2 (4.6 percent), whereas bare land expanded by 35.3 km2 (1.8 percent). Water declined by 0.9 km2 (0.05 percent) and vegetation decreased by 125.3 km2 (6.3 percent). The land cover category undergoing the highest change for the period studied is vegetation followed by urbanized and built -up areas. This is also reflected in the city population dynamics as the population grew from 151.92% in 1990 to 3,095,116 in the year 2019 which is a 70.64% increase. These results were to be expected because the massive loss of land cover and increase in built-up areas have been identified as one of the consequences of rapid urbanization in cities across the globe (Sahoo, 2016; Merem et al. 2018; Arora et al., 2018) and particularly in developing countries (see UN-HABITAT, 2010; Potts, 2012).

The results further highlight a large disparity between the observable urban land cover and the designed regional land use plan, showing unregulated and rapid urban development contradicting proposed and current land use plans. The results of the transition mapping demonstrate rapid urban explosion at the detriment of greenbelt cover, and the spatial distribution pattern clearly shows that the urbanized and built-up areas were primarily centered in the area's east, and have continued to expand from east to south and south-western part of Abuja city. The Abuja City district's regional land use plan identified the proposed land use plan for Lugbe as one of the sites for plantation reserve

Table 1. Summary of Analysis of land use cover of the FCT Abuja city region

Land Cover Classes	1990	2000	2010	2019
	Area km^2 (% of Area)	Area km^2 (% of Area)	Area km^2 (% of Area)	Area km^2 (% of Area)
Urbanized/built-up	36.80 (1.79%)	198.8 (10.01%)	294.5 (14.8%)	385.4 (19.3%)
Vegetation/greenbelt	1455.6 (73.0%)	1262.5 (63.29%)	1137.2 (57.0%)	1011.9 (50.8%)
Bare land	491.9 (24.71%)	522.7 (26.2%)	553.3 (27.8%)	588.6 (29.5%)
Water	9.3 (0.5%)	9.6 (0.5%)	8.6 (0.4%)	7.7 (0.4%)
Total	1993.6 (100.0%)	1993.6 (100.0%)	1993.6 (100.0%)	1993.6 (100.0%)

Source: Researcher's Findings in Estimation

Table 2. Analysis of population data of FCT Abuja

YEAR	POPULATION	POPULATION GROWTH
1990	330,473	-
2000	832,556	151.92%
2010	1,813,734	117.85%
2019	3,095,116	70.64%

Source: National population commission.

and productive forestry. However, urban growth did not halt at the designated urban development borders. Between the years 2000 and 2019, urban areas continued to spread towards Lugbe and into its area space. Various land uses earmarked for environmental conservation, intensive farming, and livestock production have been lost to urbanized and built-up areas in the city region, and this has intensified in recent times. When the region was mostly comprised of a few, isolated dwellings, urbanized and built-up land coverage was quite low in 1990, at 1.8 percent. In the year 2000, there was a significant rise in the urbanized and built-up areas by 10%. 14.8% in 2010 and later increased to 19.3% in 2019. Previous studies in Nsukka, Enugu State (Umunnakwe et al, 2018), Umuahia Abia State (Umunnakwe & Azubuine, 2019), and Enugu State, South Eastern Nigeria (Umunnakwe & Azubuine, 2019b) had reported similar findings, particularly, as it relates to massive loss of green areas due to intensive and uncontrolled physical development.

The transition mapping findings showed accelerated urban development, and the distribution pattern revealed that urbanized and built-up areas have been largely focused in the eastern part of the region, and continued to stretch from east to south and south-west, covering 19.3%, 50.8% respectively, of vegetation covered, bare land covered 29.5% and 0.4% of water. The reduction of vegetation coverage in the study area as indicated by these results also emphasized that the fast urban expansion has resulted in a significant loss of greenbelt. Parallel to the rise of metropolitan areas, there has been an increase in barren lands, contributing to an even faster decline of vegetation within the region. Despite the significant proportion of bare land transformed into urbanized and built-up areas between 2000 and 2019, the result still revealed an increase in bare land. The reported rise in bare land could be attributed to a sharp decline in agricultural activities and deforestation as previously indicated in the literature (Daramola & Ibem, 2010; UN, 2014; UNFPA, 2015; Obi et al., 2021; Okeke et al., 2021).

4. Conclusion

In this study, the spatial growth dynamics and their planning implications for Abuja, Nigeria were investigated. The data showed an upsurge in urbanized and built-up and bare land cover, leading to a shrinkage in greenbelt vegetation cover. Vegetation had the greatest observed net change in land cover types, followed by urbanized and built-up and bare land. A comparison of actual land cover changes to city master plans revealed a significant discrepancy. Perhaps the most concerning is the sudden disappearance of land allocated for nature reserves, intensive farming, and livestock production, which is now being supplanted by the haphazard urbanization process and unplanned city development. In view of the massive loss of vegetation cover, urgent steps are needed to ensure that developers make a conscious effort at improving the green content of the city through the integration of green infrastructure in residential, commercial, and industrial developments. In achieving this, the current percentage of developable areas within plots should be increased with a higher proportion dedicated to the provision of vegetation such as grasses, shrubs, and trees. In addition, urban greenbelts should form part of the city landscape, especially in the axes the city is currently expanding.

The built-up area of Abuja has been spreading from east to south and the south-west. This implies that managers in this city need to pay more attention in the monitoring of physical developments in these axes of the city to ensure that there is strict compliance with the master plan of the city. Furthermore, the study implies that physical planning and monitoring activities in the city and surrounding areas should not be restricted to the central business district (CBD), but should be extended to encompass peri-urban and other city-regional towns and neighborhoods. The administrative problems impeding the full integration of land use plans should be closely monitored and resolved. The study surmises that by providing such geospatial information, crucial steps toward a strategic and holistic action (ie. land use policies and compliance) can indeed be implemented. Such statistics is critical for effective land use planning to improve ecological sustainability and urban development.

Even though this current study is perceived to have achieved its stated objectives, further research on land use and land cover change is suggested using heat island analysis and vegetation impervious surface-soil model (V-I-S models) incorporating recent years to derive more robust results for land use dynamics in sub-Saharan Nigeria.

Acknowledgments

The authors wish to appreciate Mr. Collins Nnamani for his support during the course of this study.

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