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TEMPORAL CHANGES IN LAND USE LAND COVER OF BAUCHI METROPOLIS, NIGERIA

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Abstract
Like all urban areas, Bauchi metropolis, northeast, Nigeria is experiencing land use and land cover changes due to land consumption for its expansion. Despite the relevance of these changes to urban planning for sustainable development, they are not prioritized in the management of the expansion of the town. This study profiled the decadal history of the changes in built-up, bare surfaces, farmland, and vegetation of the metropolis from 1993 to 2023. Data for the study were derived from Landsat satellite images using ArcGIS 10.7 and IDRISI 17.0 Software packages. While built-up and bare surfaces increased by 643.836 ha and 60.561 ha respectively, farmland and vegetation decreased by 162.437 ha and 541.963 ha respectively. This pattern of change, if sustained, will have negative environmental and socioeconomic consequences, especially on food security and climate change. The government should build capacities of urban planning agencies to effectively manage the expansion of the built-up cover, activate and prioritize control measures for the depletion of vegetation, and encourage the adoption of smart agricultural practices.

Keywords: Temporal, Land use, Land cover, Changes, Metropolis

Introduction
The landscapes of urban areas are covered by mosaics of natural and manmade biophysical features (broadly attributed to built-up, vegetation, farmland, and bare classes) that provide spaces and resource support for urban socioeconomic uses and physical development. Driven by increasing population pressures, expanding economies, and infrastructure development (Liu, He, & Wu 2016, Erasu, 2017, Bagheri, & Soltani, 2023; Miah *et al.*, 2024; Amaechi, Ogbemudia, & Okoduwa, 2024) the area covered by urban areas globally has been increasing. For example, Shlomo, Jason, Daniel, Alexander, & David (2010) estimated that between 1990 and 2000, a 1.66% increase in the global urban population was associated with a 3.66 % increase in urban areas. At these rates, while the global urban land coverage will double in only 19 years, the urban

population will double in 43 years. In a similar trend, the proportion of the global population that will be urban is estimated to increase from 55% in 2018 to 68% in 2050 (UN, 2019). Between 2015 and 2050, urban areas are projected to increase by 0.6-1.3 million km^2 (Huang, Li, Liu, & Seto, 2019). Projections of the world urban population growth suggest that the fastest growth is in Sub-Saharan Africa and Asia, a reason why by, 2050, they will have the largest share of the world urban population (UN, 2018). Accordingly, urban spatial expansion is expected to be more than 12-fold between 2000 and 2050 in Sub-Saharan Africa, the fastest in the world (Shlomo, Jason, Daniel, Alexander, & David, 2010).

Urban areas' expansion implies continuous modification of the biophysical features covering their landscapes. The general trend of these modifications is the consumption of peri-urban farmlands and forests into built-up areas (Bagan & Yamagata, 2014; Hassan, Shabbir, Ahmad, Malik, Aziz, Butt & Erum, 2016; 2016; Liu, He & Wu; 2016; Onwuzuligboa, Okekea, Udochukwub, Effiomc & Kikpoyed, 2023; Yeneneh, Semahagne, Birhanu & Benti, 2024; Amaechi, Ogbemudia, & Okoduwa, 2024). The modifications of the biophysical features (land cover changes) are associated with environmental, and socioeconomic consequences. For instance, environmentally, the changes have resulted in habitat and biodiversity losses (Simkin, Seto, McDonald & Jetz, 2022; Guilherme, Goncalves, Carretero, & Marques, 2024), increasing land surface temperature (Igun & Williams, 2018; Obiefuna, Nwilo, & Okolie, 2018), increasing surface runoff and flooding (Da Lima, Salaza, & Campo, 2023; Valencia, Kampana, Ramos, Pillco, Ollero, & Manrique, 2024), decreasing water quality (Carpio & Fath, 2011; Rivera, Fonseca, Mora, Suastegui, Bravo, Vega, Perales, & Silva, 2022), and loss of terrestrial carbon (Seto, Guneralp, & Hutyra, 2012). The socioeconomic consequences include a decline in agricultural land use intensity (Jiang, Deng, & Seto, 2013; Assefa & Kassa, 2020) and an associated decline in food productivity and security (Brook & Davila, 2000; d`Amour, *et.al,* 2017), increasing peri-urban land values, land speculation and contentious land tenure changes (Delbecq & Florax, 2010; Baba, Kasim, & Muhammad, 2019; Ogunlade & Adewale, 2022; Babalola, Hull, & Whittal, 2024). The environmental and socioeconomic consequences are linked to issues of insufficient or ineffective land administration that should ensure minimal negativities from the land cover changes. The ineffectiveness is the outcome of institutional capacity limitations, poorly coordinated overlapping land governance regimes, and gaps in policy formulation (Nega, Tenaw, Hunie, Agegnehu, & Mansberger, 2021; Koroso & Zevenbergen, 2024. Notably, these consequences are more in cities of the global South where urban expansion and associated land cover changes are not only rapid but also largely fragmented and unplanned (Shlomo, 2023).

Considering the continuous character of urbanization, urban expansion, and land cover changes, they are recognized among the transformative trends in the global development agenda. Fundamentally, these phenomena are irreversible, and hence, their socioeconomic and environmental effects across scales will be lasting (Gao & O`Neill, 2020). They are relevant to the realization or otherwise of Millennium

Development Goal (MDG) 7 (ensuring environmental sustainability) and, by extension, the other development goals. For this reason, studies about them cannot be exhaustive. For instance, urban land cover changes require regular monitoring and appraisal to avert undesirable consequences by formulating and implementing appropriate policy and urban planning responses. The combination satellite remote sensing that provides synoptic views of the land surface at different epochs and Geographic Information System (GIS) has provided versatile tools for detecting, visualizing, and analyzing urban spatial changes, their impacts, and predictive scenarios (Ahmad, Goparaju, & Qayum, 2017; Fenta, Yasuda, Haregeweyn, Belay, Hadush, Gebremedhin, & Mekonnen, 2017). According to Lu & Weng (2007) supervised classification method using a maximum likelihood algorithm is commonly used in studying urban land use land cover dynamics. Like all urban areas, Bauchi, the primate city in Bauchi State, northeastern Nigeria, is experiencing changes in its land cover. Personal observations reveal the consumption of peri-urban farmlands, vegetation, and hill surfaces by buildings. This observation motivated this paper which aims to profile the temporal changes in land use and land cover in the Bauchi metropolis. Profiling the temporal changes revealed their patterns, which should be factored into future land use and development planning. The aim was achieved by classifying the land use and land cover and assessing their decadal changes from 1993 to 2023. Essentially, the land use and land cover were attributed into four classes: Built-up, vegetation, farmland, and bare surfaces.

The Study Area

The study was conducted in the Bauchi metropolis, located between Latitudes 10° 12′ and 10° 27′ North and Longitudes 9° 40′ and 9° 57′ East in northeastern, Nigeria (Figure 1). It is a State, Local Government, and Emirate headquarters. This administrative status made it the location of the offices and branches of all Ministries, Departments, and Agencies of the State and Federal governments. In addition, some industries and four tertiary institutions (two Universities, and two Polytechnics) are situated on the outskirts of the town. For these reasons, the metropolis has attracted priority in physical and infrastructural development, making it a destination for formal and informal sector workers, and other migrants. As of 2017, the spatial extent of the town was 632km^2 (Musa, Hashim, & Reba, 2017) while its population in 2023 is estimated at 670,000. The elevation of the metropolis ranges from 640 meters to 880 meters (Danladi & Pindiga, 2020) with 9 isolated hills (Orude, 2018). The vegetation is Sudan Savanna. Statutorily, the land in the metropolis is administered according to the provisions of the Land Use Act of 1979 through the Ministry of Lands and Survey and the State Development Board. The Bauchi State Environmental Protection Agency (BASEPA) is responsible for environmental management.

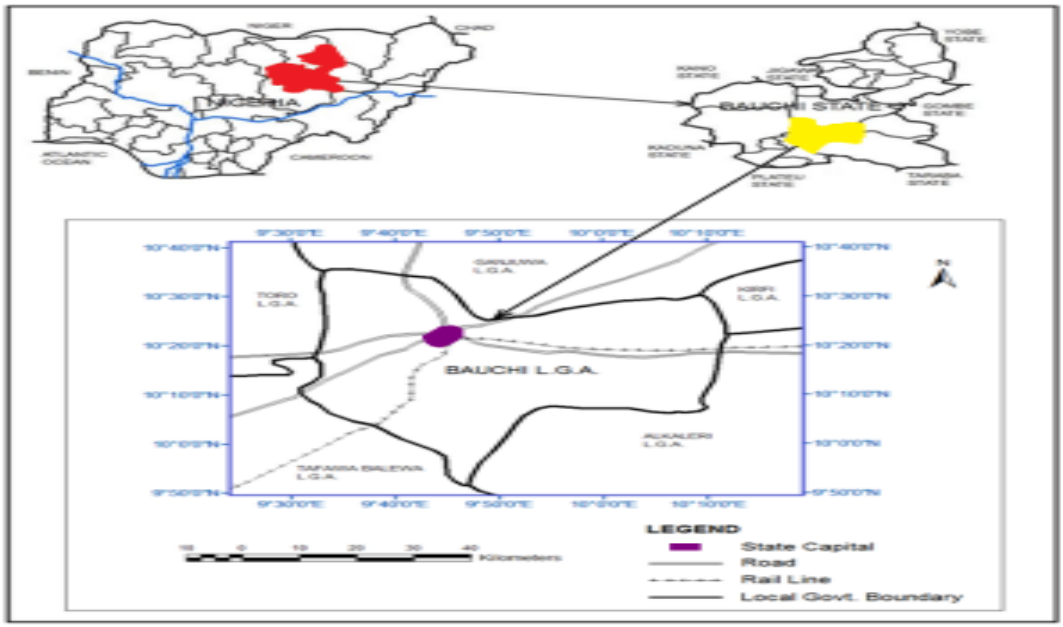

Figure 1: Location of the Study Area Source: Musa, Hashim, & Reba (2017)

Materials and Methods

The 1993, 2003, 2013, and 2023 Landsat images of the study area, as indicated in Table 1, were obtained from the USGS website.

Table 1: Metadata of Satellite Images

Sensor	Bands	Resolution	Path	Row	Date of Acquisition
Lansat-7 ETM	2, 3, 4	30m	187	053	1993-8-8
Lansat-7 ETM	2, 3, 4	30m	187	053	2003-8-2
Lansat-7 ETM	2, 3, 4	30m	187	053	2013-8-15
Lansat-8 OLI	3, 4,5	30m	187	053	2023-8-12

Coordinate data for training samples were obtained by field measurement with a handheld GPS. ArcGIS 10.7 and IDRISI 17.0. Software packages were used to process the data used for the study. The images were then enhanced by applying geometric and radiometric corrections after which training samples were generated. The maximum likelihood classification algorithm was used to classify the images using the supervised classification method. The LULC was classified into four categories (built-up, bare surface, farmland, and vegetation) by grouping homogeneous cells with similar reflectance values. The accuracy of the classification was assessed with cross-validation statistics using the confusion matrix. The accuracy was field-validated using hand-held GPS measurements. Overall, an accuracy assessment result of 90% was obtained. To detect the changes in the LULC, the images were compared and analyzed.

To determine the changes in the LULC classes, the classified LULC maps were converted to an image raster data format (.img), which enabled overlay analysis in IDRISI 17.0. The Crosstab tool of the Change/Time series analysis tools was used to simultaneously overlay LULC data from 1993, 2003, 2013 and 2023. As a result, the changing nature of each pixel associated with urban land use were determined.

Results and Discussion

Figures 2 (A, B, C, and D) are the images of the four LULC classes considered in this study.

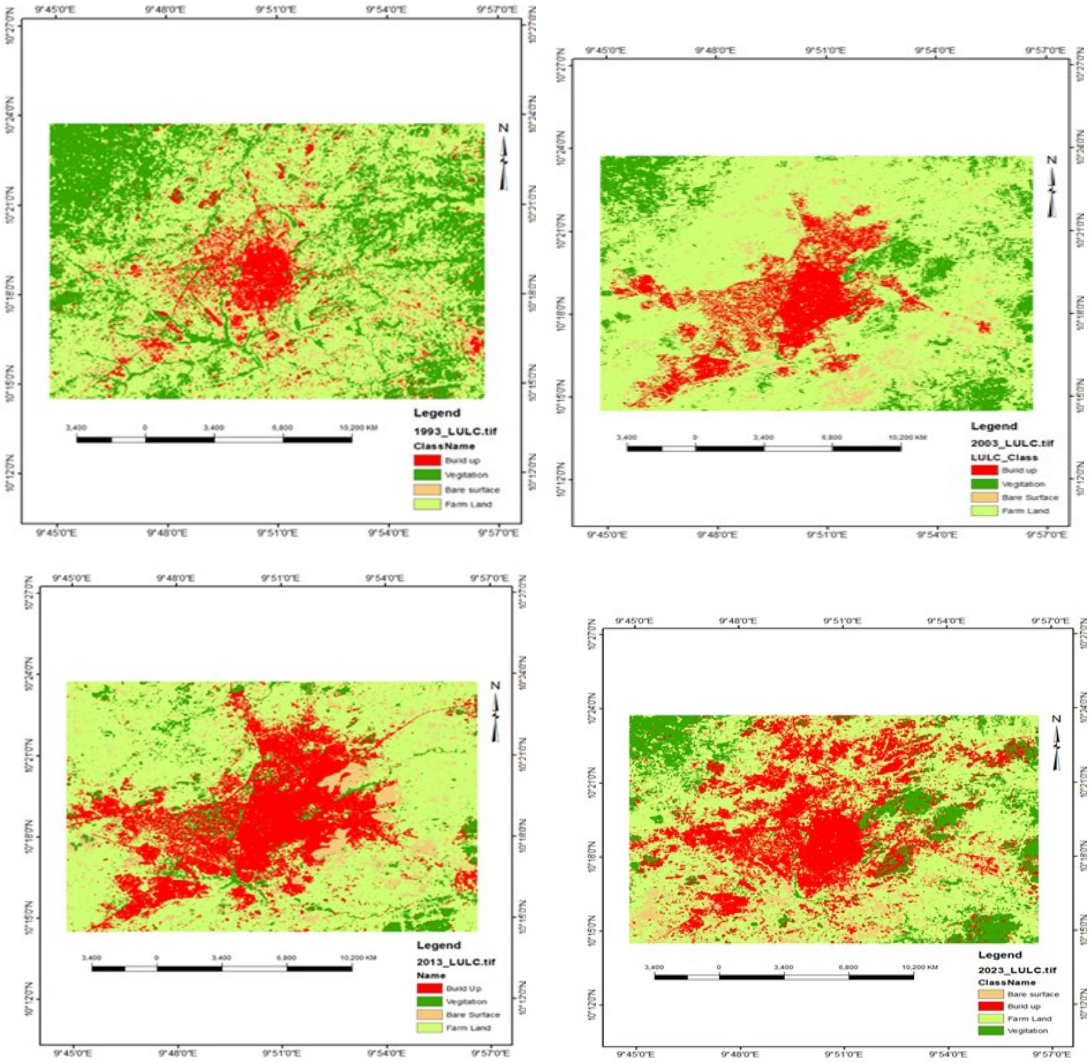

Figure 2: Spatial Extent of LULC Classes: (A) Year 1993, (B) 2003, (C) 2013 and (D) 2023.

The spatial extents of the four LULC classes derived from the images for each of the study epochs are presented in Table 2.

Table 2: Spatial Extents of LULC Classes in Bauchi Metropolis

LULC Class	1993		2003		2013		2023	
	Area(Ha)	%	Area(Ha)	%	Area(Ha)	%	Area(Ha)	%
Built -up	359.277	9.757	468.981	12.737	946.332	25.702	1003.113	27.244
Bare Surface	138.015	3.748	144.261	3.918	252.576	6.860	198.576	5.393
Farmland	2116.220	57.475	2583.19	70.157	2223.828	60.97	1953.783	53.063
Vegetation	1068.490	29.019	485.568	13.188	259.263	7.041	526.527	14.300
Total	3682.002	100	3682.002	100	3682.002	100	3682.002	100

Table 2 demonstrates that farmland has the greatest area covered throughout the study period, although it is decreasing; its dominance supports the finding of demonstrates that farming is a common activity for residents of the Bauchi metropolis. Bashir, Dasin, Bwala & Ibrahim (2019) reported that 57% of residents of the metropolis engage in farming. Farmland initially 1993 covered a maximum of 2116.220 Ha or 57.475% of the total area studied. By 2003, it increases to 70.157% covering 2583.19 Ha as a result of the reduction in farming activities. In 2013 the farmland decreased to 60.97% covering 2223.828 Ha, and in 2023 covered 1953.783 Ha equivalent to 53.063%, this is associated with an increase in buildings in the metropolis. Additionally, the table indicates that vegetation cover is decreasing every year. In 1993, vegetation covered 1068.490 Ha corresponding to 29.019% of the entire area of the study, it continuously decreased to 14.300% equivalent to 526.527 Ha after 30 years as a result of population growth, people were searching land for farming and building for residential purpose. Table 2 indicates that the built-up area increased over the study period. The built-up area in the initially in 1993 covered 359.277 Ha or 9.757%. Built-up land cover increased by 12.737%, 25.702%, and 27.244% between 2003, 2013 and 2023 respectively. The increase in built-up areas occurred to accommodate the metropolis's increasing population growth. The bare surface is the least covered land, occupying only 3.748% covering 138.015 Ha in 1993. Then it increased slightly to 144.261 Ha (3.918%) in 2003 gradually increased to 252.576 Ha (6.860 %) in 2013 and decreased to 198.576 Ha (5.393%) in 2023.

The changes in various land use and land cover classes from 1993, 2003, and 2013 to 2023 are depicted in Table 3. Significant land use and land cover changes occurred in the Bauchi metropolis and its environs over the 30-year study period. As a result, it is critical to evaluate the nature of changes in each land use and land cover class.

Table 3: Decadal and Total LULC Changes

LULC Classes	1993-2003		2003-2013		2013-2023		1993-2023	
	Area (Ha)	Annual Rate (%)	Area (Ha)	Annual Rate (%)	Area (Ha)	Annual Rate (%)	Area (Ha)	Annual Rate (%)
Built -up	109.704	0.031	477.351	0.050	56.781	0.006	643.836	0.0597
Bare Surface	6.246	0.0045	108.315	0.0751	-54.000	-0.0214	60.561	0.0146
Farmland	466.697	0.0221	-359.362	-0.0139	-270.045	-0.0121	-162.437	-0.0003
Vegetation	-582.922	-1.1983	226.305	-0.0466	267.264	-0.1031	-541.963	-0.0169

As shown in Table 3, the built-up (urban) class grew significantly during the study period, In 1993, the built-up area accounted for only 359.277 Ha that is, 0.031 % rate per annum of the total area under investigation. It increases to 468.981 Ha (0.050%) after a decade (i.e., in 2003), representing a growth of 109.704 Ha or a 0.031 % annual growth. The built-up area had increased by more than 477.351 Ha (0.050%) in 2013, implying that the urban area had more than doubled in size since 1993.

During this period, a transition to democratic governance occurred, accompanied by a slew of socioeconomic policies, including an increase in workers' salaries, which increased money circulation and sparked the construction of houses to address ever-increasing housing crises. Additionally, Table 3 indicates that the second part of the study (2003–2013) observed rapid urban growth, with the built-up area increasing by 477.31 Ha at the rate of (0.050%). Other studies (Musa, Hashim, & Reba, 2017; Aliyu, Babanyara, & Wasinya, 2024) reported significant increases in the built-up cover of the metropolis at different epochs The primary factor influencing this development is Bauchi's relatively peaceful nature in Nigeria's North East region, which is frequently afflicted by civil unrest, most notably the Boko Haram crisis in Borno, Yobe, and Adamawa states, as well as religious crisis that cause people migration from plateau states to Bauchi metropolis. The cumulative growth of over 643.836 Ha of the study period (1993–2023) indicates that the built-up area is rapidly expanding in size, with a growth rate of 0.0597% per annum. Similarly, vegetation cover shows a gradual decline in the area throughout the study period from --1.1983% to 0.0169% per annum, that is the reduction in size from 1068.49 Ha to 526.527, the decrease in size of 541.963Ha (-0.0169 %) per annum from 1993 to 2023. Similarly, Musa, Hashim, & Reba (2017) reported the loss of 91.80% of the forest in the metropolis between 1986 and 2006. This should concern the government and people given the correlation between the depletion of vegetation and increase in surface temperature, flooding, and climate change. Evidence of climate change in the metropolis shows an average temperature increase of 0.030C and an annual rainfall increase of 0.2mm (Odiana, 2009 in Yahaya, Bello,

Rukayya, & Yuguda, 2020). Kafi, Salisu, & Aliyu (2021) attributed the adverse effects of strong winds experienced in the metropolis to the significant reduction in the size of vegetated areas around the metropolis.

Conclusion

This study used remote sensing images and GIS Software to determine the changes in LULC in the Bauchi metropolis over three decades (1993-2023). The LULC of the Bauchi metropolis has undergone a lot of transitions primarily driven by land consumption for urban expansion. The built –up cover increased throughout the study epoch, while farmland, vegetation and bare surfaces exhibited decline. This trend has socioeconomic and environmental implications that threaten sustainable development and should therefore, be factored in managing the metropolis subsequently.

Recommendations

The government should;

i) Build the capacities of urban planning agencies to effectively manage the LULC changes in the town, especially in the areas of land use planning and development control

ii) Activate and prioritize control measures for the depletion of vegetation, and encourage the adoption of smart agricultural practices

iii) Embark on public awareness campaigns on the need to cooperate with the government in its drive to reduce the negative effects of the LULC changes

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