ASSESSING URBAN SPRAWL IN MILLENNIUM CITY KADUNA: A MULTI-TEMPORAL CHANGE DETECTION ANALYSIS.

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Abstract:

The rapid expansion of urban areas, particularly in developing regions, presents significant challenges for sustainable development and resource management. In the context of the Millennium City of Kaduna State, the dynamics of urban sprawl have become a focal point due to its burgeoning population and economic activities. This paper presents a comprehensive multi-temporal change detection analysis aimed at assessing the extent and patterns of urban sprawl in Kaduna State. Utilizing remotely sensed imagery spanning multiple years, specifically the moderate resolution Landsat 5, 7, 8, and 9 of 1989, 2002, 2011, and 2022 respectively were combined with Geographical Information Systems (GIS) and advanced machine learning algorithms. The spatial and temporal dynamics of urban expansion were analyzed. The methodology encompasses the extraction and classification of land cover changes, focusing on key indicators of urban sprawl such as changes in built-up areas, vegetation loss, and infrastructure development. Results from an interactive supervised classification using the Maximum Likelihood Classifier (MLC) in ArcGIS 10.2 and subsequent change detection analysis indicated a significant distortion in the planned areas of the city. The result shows a progressive increase in built-up areas of the Kaduna Millennium City and environs from 1989 to 2022. Built-up areas slightly decreased from 2.4527 % in 1989 to 1.6322 % in 2002 and a slight increase of 1.6322 % in 2011. However, the built-up areas surged to 13.612 %, in 2022 which is attributable to the sudden expansion of development in the government's new layouts with the attendant haphazard development and proliferation of unplanned and illegal settlements, particularly around the buffer zones of the old cities of the millennium city and varying changes in the other classes of land cover including Vegetation, Water bodies, and Open spaces. The findings provide valuable insights into the rate, direction, and drivers of urban sprawl in Millennium City, facilitating informed decision-making for sustainable urban planning, environmental conservation, and socio-economic development initiatives. This research contributes to the broader discourse on urbanization dynamics in rapidly growing cities, emphasizing the importance of employing remote sensing, GIS technologies, and machine learning algorithms for effective urban sprawl assessment and management.

KEYWORDS: Urban Sprawl, Change Detection, Maximum Likelihood Classifier, Spatial Metrics; GIS, Remote Sensing; Millennium City Kaduna.

1. Introduction

Urbanization is one of the most pressing environmental issues of the present millennium. It is a natural phenomenon that involves changes in the physical and functional components of the built environment and presently cuts across all countries at an unprecedented rate (Chen & Shi, 2020). Urban growth occurs globally as a result of population increase and socioeconomic development leading to the transformation of non-urban land into urban land (Kanga & Singh, 2017). According to (Tariq & Mumtaz, 2023a), the global urban land increased at an annual rate of 3.5 % between 1992 and 2016 which culminated in a total increase of 346,000 km^2 and is expected to reach 58.3 % and 67.1 % by 2030 and 2050 respectively (Tariq & Mumtaz, 2023a). This translates to about 10-fold expansion of cities which has been largely unplanned and uncontrolled. As a result, urban areas in Nigeria face problems such as; inadequate housing and infrastructure, slum proliferation, widespread poverty and unemployment (Tariq & Mumtaz, 2023a), as well as alteration of natural land surface temperature, changes in urban drainage morphology, and increased surface runoff and flood events (Chen & Shi, 2020).

Detection of Changes in Land Use and Land Cover (LULC) is the most common phenomenon associated with urbanization (Vivekananda et al., 2021). These are changes associated with the manner and purpose through which humans exploit the earth's natural resources. Rapid urbanization and changes in land use & land cover play a significant role in eco-environmental changes and deterioration. Analyzing and understanding urban LULC changes is thus crucial for the assessment of human-environment interactions, efficient use and management of resources, urban planning and sustainability, and monitoring of environmental problems.

Traditionally, changes in LULC were assessed using field studies, census data, and aerial photography which are cumbersome, time-consuming, and expensive (Enoh et al., 2023). Recently, advances in Remote Sensing, GIS, and other geospatial techniques and technology have made it possible to generate; real-time, dynamic, repeatable, accurate, and reliable land-based information on wider spatial and temporal scales (Viana et al., 2019). These invaluable tools have thus become increasingly useful for studying and monitoring urban growth and LULC changes accurately and cost-effectively. Many previous urban studies were merely carried out using classification over given periods without much focus on modeling the future trends of the changes (Viana et al., 2019).

This study aims to carry out a multi-temporal change detection analysis to assess urban growth in the Millennium City of Kaduna State using geospatial techniques. The study evaluated the applicability and performance of satellite multispectral remote sensing data, particularly the Landsat 5, 7, 8, and 9 imageries, for mapping land use land cover alterations and changes over an epoch period to identify the trends and analyze the implications of these changes in the planning strategies in Kaduna State especially as it relates to the Government's recent drive towards urban renewal of the metropolitan areas. Moreover, the ArcGIS software and ENVI Raster software were employed in the analysis to test the usability and versatility of some algorithms and their accuracies in the change detection analysis.

The growth of urban areas has become a global phenomenon. Cities and towns are continuously growing and blooming with changes in land use along the highways and in the immediate vicinities and outskirts (Sundarakumar et al., 2012). Such growth is known as sprawl and is described as a response to a combination of socio-economic and political forces and the physical geography of an area (Sundarakumar et al., 2012). Urban sprawl is also caused by improper planning and enforcement, inadequate policy decisions, and lack of good governance, population growth, and patterns of infrastructure initiatives like the construction of roads and the provision of infrastructure which in turn encourage development (Lunetta et al., 2022).

Kaduna was once the capital of the northern region and presently the capital of Kaduna state. Consequently, it serves as the nerve center for administrative, economic, industrial, and commercial activities (Nasir et al., 2022). The metropolitan areas of Kaduna State have therefore experienced rapid urban expansion due to the influx of people from all over Nigeria and the resultant population explosion, urban growth, the need for more space, and attendant issues including; traffic congestion, housing problems, and slums/ squatter settlements (Nasir et al., 2022).Hence this brings about the need for a proactive approach for assessing urban expansion which could play a significant role in the sustainable development of the urban centers.

The government has over the years made concerted efforts and attempts at curtailing haphazard development and expansion resulting in the construction of new bridges across the river Kaduna and the creation of new layouts to minimize the need for more space. This has led to the creation of new satellite towns such as the New Millennium City. However, the lack of proper planning and enforcement of plans has further worsened the situation.

Given the aforementioned issues and problems, there is a need to evaluate, assess, and analyze Land Use Land Cover Changes in the millennium city using the latest geospatial techniques to help in identifying and investigating the pattern of urban growth and its consequential issues to find sustainable solutions. The study also evaluated the versatility and effectiveness of some change detection methods and algorithms to help improve the techniques of sieving out relevant spectral information from multispectral data for change detection investigations. The use of the latest geospatial tools has become imperative for gathering accurate and reliable data and information to guide the decision-making process.

2. Materials and Methods

2.1 Study Area: Kaduna Millennium City

The city of Kaduna was established in 1912 during the British colonial administration and was headed by Lord Frederick Lugard. It was initially recognized as a garrison town and subsequently, the regional capital of the then-British Colonial Protectorate of Northern Nigeria (Manonmani & Suganya, 2010). The state as a whole covers a land area of 46,053 square kilometers (Tini & Light, 2020), representing about 4.6% of the total land area of Nigeria, making it the twelfth largest state in Nigeria (Manonmani & Suganya, 2010). The city of Kaduna has a unique political history of being at various times, the seat of the defunct government of Northern Nigeria, then of the former North-Central state, as well as the capital of the old Kaduna State when it comprised of the defunct Zaria and Katsina provinces. Kaduna is also one of the most industrialized urban centers in Northern Nigeria, having most of its industries, particularly the garment and textile industry in existence since the colonial and early independence periods (Nasir et al., 2022). Other industries within Kaduna urban areas include; the refinery and petrochemical plants, vehicle assembling plants, fertilizer processing plants, breweries industries, defence industries, and divisions, among others. It is evident that since the creation of Kaduna, the city has had the attribute of an urban area with many opportunities and as such, has attracted much populace.

The population of Kaduna according to the 2006 National Population Commission (NPC), stood at 6,113,503, making the state the third most populous state in Nigeria after Kano and Lagos. With an assumed population growth rate of 3.18 percent as estimated by the National Population Commission, the population of the state grew to about 8,103,075 in 2016, and by 2020, the state's population is expected to be around 9,476,053 with a further rise to 12.96 million by 2050. There is a high rate of urbanization and urban agglomeration in Kaduna state, where over 21 % of the population is expected to live in urban centers by 2020, this further reiterates the need for urban renewal projects to curtail the expected pressure (Nasir et al., 2022). *Figure 1* shows the Study Area of the Millennium City within the metropolitan areas of Kaduna City and the focused areas of the research in Chikun Local Government. The Millennium City was well planned as shown in *Figure 2*, however, there have been so many distortions as people have encroached into the planned areas through illegal acquisition of plots of land through traditional village heads who engaged in speculation and sale of government lands without authorization (Nasir et al., 2022).

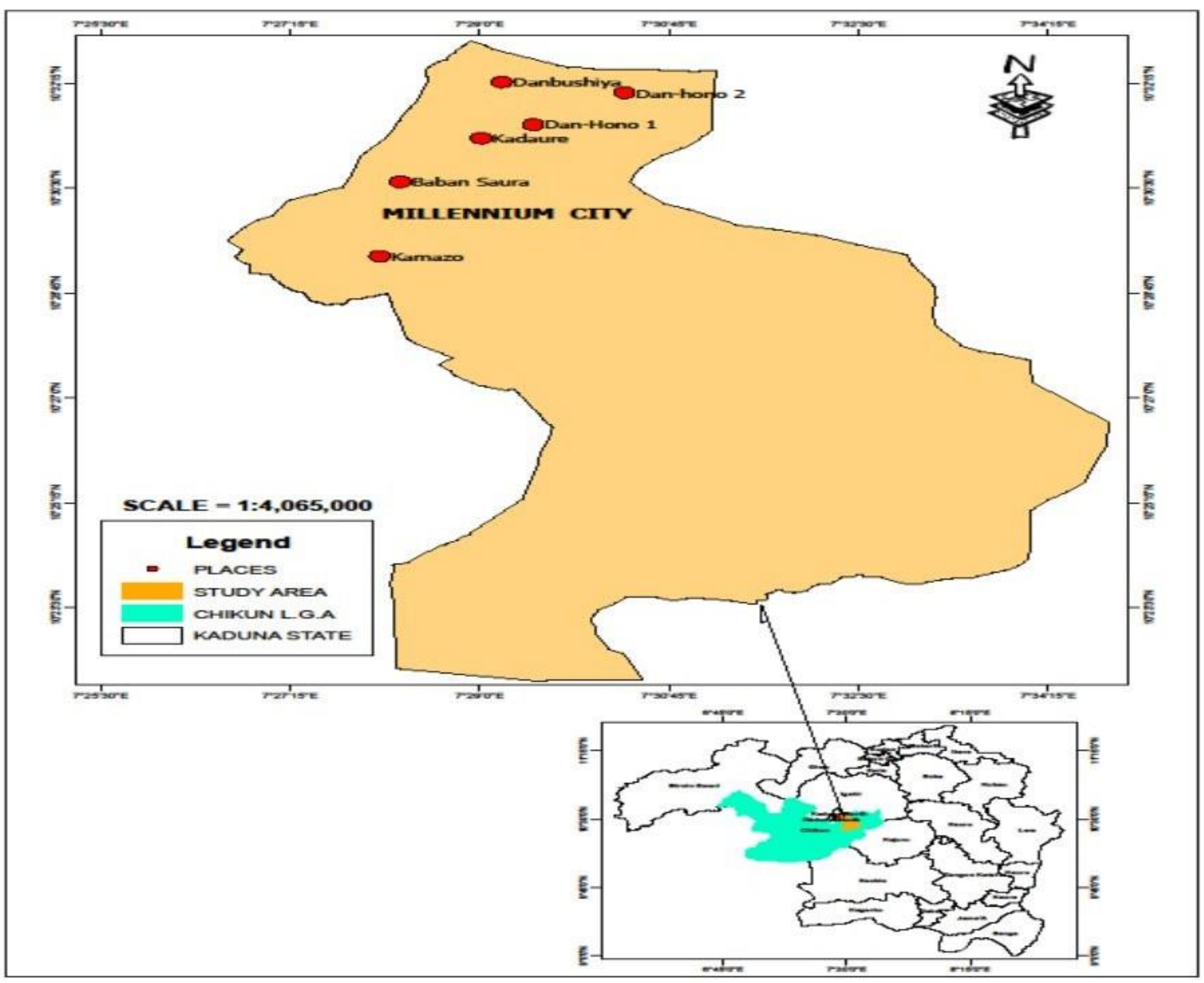

Figure 1: Study area map of Millennium City Kaduna

2.2 Location

Kaduna City is located between latitudes 10 and 11 degrees North and longitudes 7 and 8 degrees East at an altitude of 645 m above sea level (Sundarakumar et al., 2012). The city is uniquely and strategically situated almost at the geographic center of Nigeria. Kaduna State is the seat of the state government service other Northern states in Nigeria and the Federal Capital Territory (F.C.T). Consequently, the city has become a major transportation hub and a trade center in Nigeria (Zaki et al., n.d.). In playing this role, it has a network of roads that link it with other parts of Nigeria. The major roads include; the Kaduna to Abuja Road (linking the Kaduna to the Southern parts of Nigeria), the Kaduna to Zaria to Kano Road, and Kaduna to Saminaka to Jos Road.

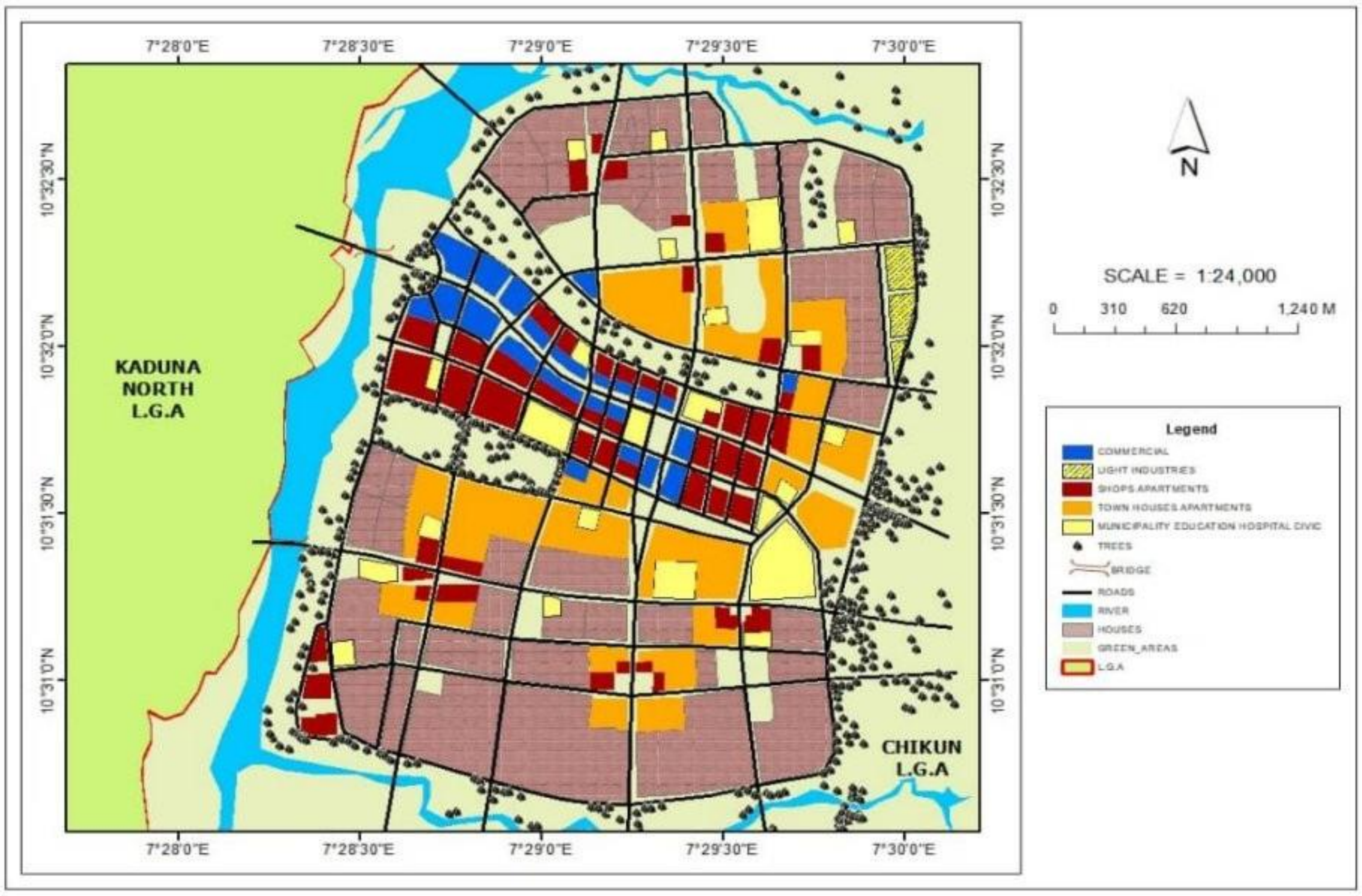

Figure 2: Millennium City Plan

2.3 Remote Sensing Data

Four cloud-free daytime Landsat level 1 data of path/raw, 189/053, covering the Kaduna Metropolis and the surrounding regions (the Shiroro Lake in Niger State is viewed in the center of all the scenes). The data were obtained from the United States Geological Survey (USGS) Earth Resource Observation System (EROS) downloaded online at (http://glovis.usgs.gov/). The images were georeferenced to UTM zone 32N with WGS-34 datum and tuned to the north-up direction as shown in Figure 3.

The acquired Landsat includes;

- Landsat 5 with scene ID; LM_51890531987011AAA03; acquisition date; January 11th, 1987.

- Landsat 7 with scene ID; LE_71890532007026ASN00; acquisition date; January 26th, 2007
- Landsat 8 with scene ID; LC_81890532014005LGN01; acquisition date; January 05th, 2014
- Landsat 9 with scene ID; LC_91890532022008LGN01; acquisition date; January 08th, 2022

The imageries used in this study are Geo-TIFF Products, which are radiometrically and systematically geometrically corrected with ground control points (Dwyer, 2006). The scenes were chosen because the acquisition dates are in the dry season of the study area to reduce the signal-to-noise ratio (SNR) effect (Kruse et al., 2003).

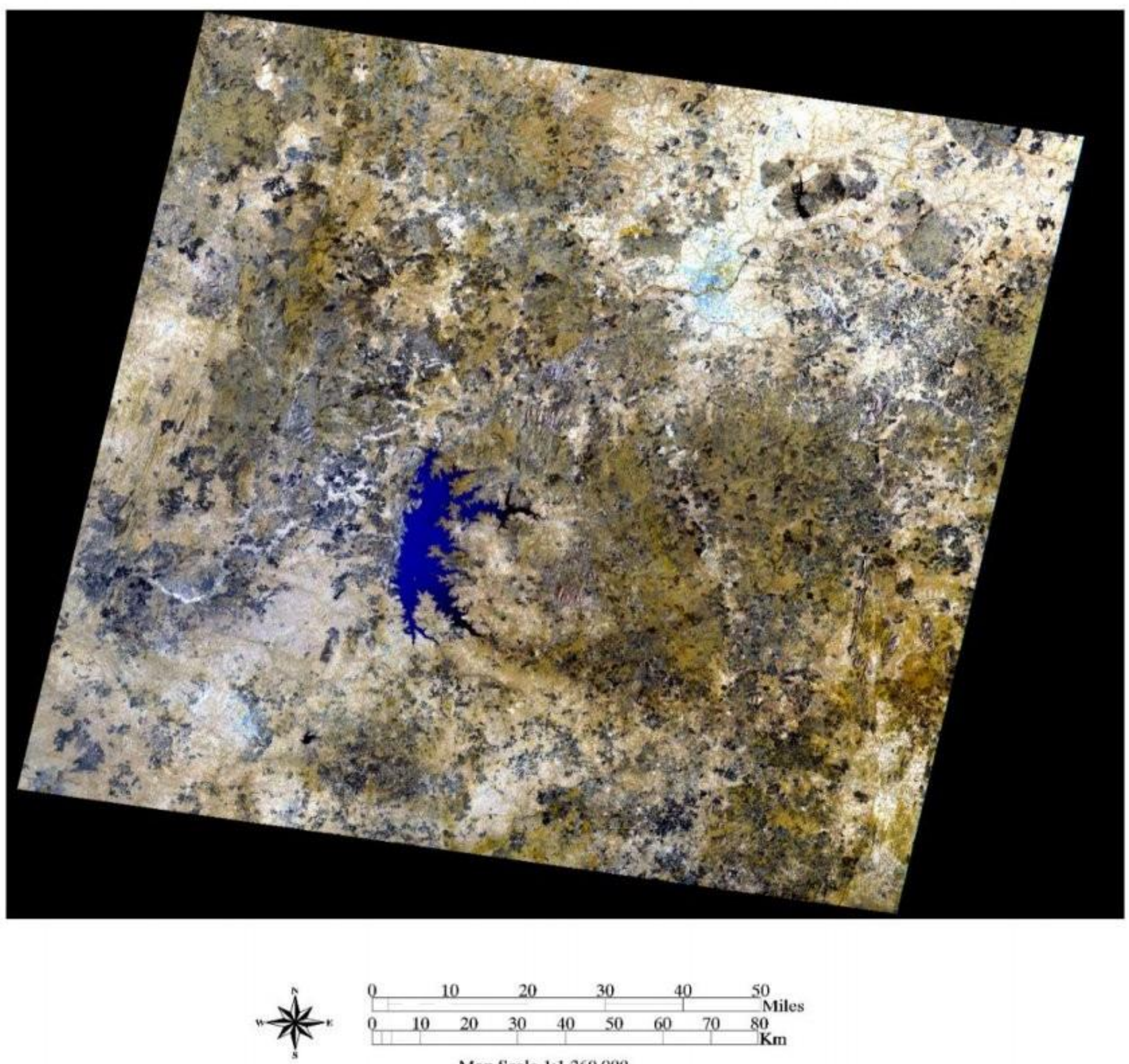

Figure 3 Acquired Landsat 8 visible bands 4, 3, 2 loaded as RGB

2.4 Methods:

The acquired satellite data including Landsat 5, 7, 8, and 9 data were preprocessed before subsequent analysis. The preprocessing was carried out depending on the unique requirements of the different data sets. The following sections explain the methods.

2.5 Preprocessing of Landsat data

The acquired cloud-free Landsat 5, 7, 8, and 9 scenes (path/raw 189/53) covering the study area were first preprocessed. The data were first imported into ENVI 5.1, viewed, and bands loaded. The scenes were observed to be free from distortions, thus the data were first layer stacked into a cube containing two spectral subsets, the first of which has VNIR bands 1-7, the other containing only TIR bands 11 & 12. Panchromatic Band 8 and aerosol band 9 were not included because they have less relevance in the subsequent analysis. The data covers the entire study area including its surrounding neighboring regions providing a regional appreciation for the study. The Landsat 8 data was pre-georeferenced and geometrically rectified and turned to a north-up Universal Transverse Mercator (UTM) 32N projection with WGS 84 Datum.

2.6 Atmospheric correction of the acquired Landsat data optical bands

The four acquired multispectral Landsat 5, 7, 8, and 9 data were all atmospherically corrected to facilitate subsequent change detection analysis (Pour & Hashim, 2015). This is achieved through atmospheric corrections/radiometric calibration to reduce and remove artifacts from the imagery and improve the accuracy of results. The Fast Line-of-site Atmospheric Analysis of Spectral Hypercubes (FLAASH) was used. The FLAASH atmospheric correction algorithm is developed by the Air Force Research Laboratory, Space Vehicles Directorate (AFRL/VS), and Spectral Sciences, Inc. (SSI) (Felde et al., 2003) to aid the analysis of VNIR-SWIR Multispectral and Hyperspectral imaging sensors. The algorithm derives its first-principles physics-based calculations from the MODTRAN4 radiative transfer code (Anderson et al., 2002). To perform the FLAASH absolute correction, the ENVI classic software was used. The acquired Landsat radiance data in each case was imported into ENVI, preprocessing calibration utilities and IARR was chosen and executed before subsequently applying the FLAASH option. Landsat was chosen as the sensor type. From global attributes; scene center time and date were retrieved. The Landsat Metadata file was also used to retrieve using several parameters including; Latitude and Longitude values, sensor altitude, ground elevation, pixel size, satellite flight overpass date, and time. The tropical atmospheric model was chosen because the area is in the tropical region and other variables such as aerosol model and retrieval, spectral polishing, and initial visibility were used as defaults. The FLAASH atmospheric correction was then applied and the resulting absolute atmospherically corrected image was saved for subsequent analysis. The image was then converted from radiance to reflectance to facilitate the spectral analysis.

2.7 Masking of Millennium City Area Boundary

The Masking of the study area was conducted to delineate the boundary from the overall Landsat image scene. To mask the boundary, the Landsat image scene was imported to ArcGIS 10.3 software. A shapefile of the Millennium City area was created by opening a topographical map of the area from an online data cloud source (Research Systems, 2008). A spatial reference was then given to the map using the coordinates system UTM 32N and WGS 84 to harmonize with that of the acquired Landsat image. Image on-screen digitization of the boundary was then carried out using the harmonized image and topographical boundary. The digitized Shapefile created was exported to the ENVI standard 32-bit system. Using the Mask tool in ENVI, an image mask was created from the shapefile to include only the highlighted areas of the Millennium City boundary by applying the selected areas "on" & "off" options. Subsequently, the Band Math tool in ENVI was used to create a mathematical expression e.g. Band1 x Band2, which was used to multiply the Millennium City boundary mask with the overall image scene of the area to mask out the study area

2.8 Interactive Supervised Classification using MLC

The multispectral Landsat images were first subjected to atmospheric corrections and rectification, subsequently, procedures were followed using the processed image for classification to create thematic maps. Training samples were created based on the identified four major classes namely; Built-up, Open spaces, Vegetation, and Water bodies. Supervised classification was employed, and the trained samples were used to classify the images based on the different spectral signatures of the classes in the image. Representative pixels were identified for each of the classes, the system then analyzed and classified all other pixels with similar spectral signatures of the different classes, eventually classifying the image into different themes.

The Image Classification toolbar was used to classify the Landsat satellite image visible bands. Using the toolbar, four land-use classes were defined from the satellite image as **Built-up**, **Open spaces**, **Vegetation**, and **Water bodies**. The quality of the training samples was analyzed using the training sample evaluation tools in the **Training Sample Manager**. Using the Image Classification toolbar and Training Sample Manager, it was established that, the training samples were representative of the area and statistically separate.

3. Result and Discussions

3.1 Results

The presentation and analysis of the data were carried out under the following sub-themes; Percentage of changes and magnitude of change in land use and land cover distribution covering Kaduna Millennium City. The categories of land use land cover identified in the study area are; Built-up areas, Open spaces, Vegetation, and Water bodies. Land use land cover in the area was observed to vary among classes as shown in Figure 4**.** Table 1 shows the result of changes that occurred in the study area between 1989 to 2022

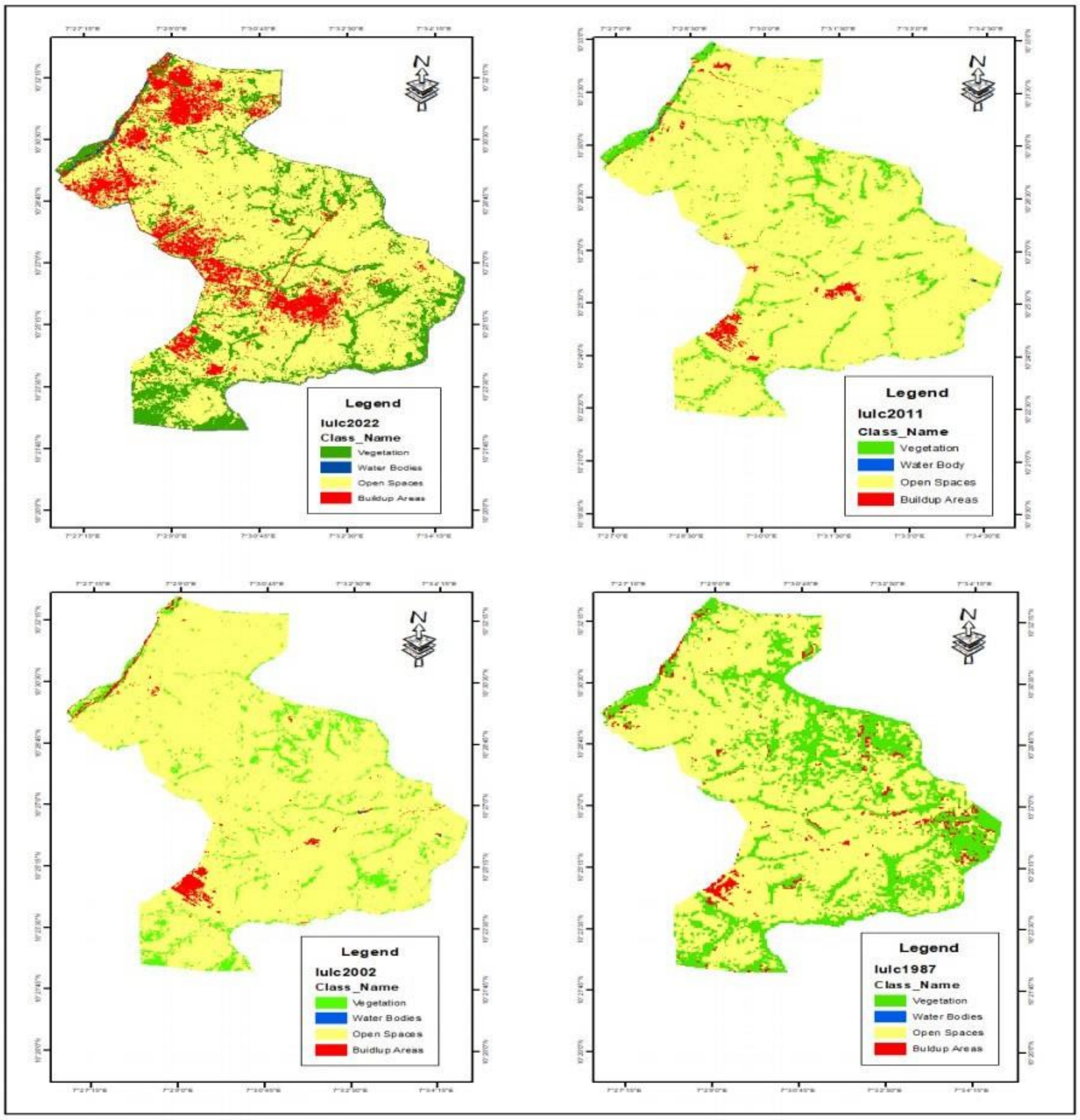

Figure 4: Land use land cover of Kaduna Millennium City from 1989 to the year 2022. (Source: Author's Analysis, 2022)

CLASS NAME	1989 (%)	1989 Area(ha)	2002 (%)	2002 Area(ha)	2011 (%)	2011 Area(ha)	2022 (%)	2022 Area(ha)
BUILD UP AREA	**2.4527**	**356.2999**	**1.6322**	**237.0687**	**1.6632**	**241.6035**	**13.6127**	**1977.187**
VEGETATION	**28.3979**	**4125.19**	**8.1515**	**1183.958**	**8.8317**	**1282.893**	**17.9584**	**2608.389**
OPEN SPACE	**69.1451**	**10044.27**	**90.1959**	**12100.33**	**89.423**	**12989.57**	**68.1873**	**9903.902**
WATER BODIES	**0.0041**	**0.6064**	**0.0202**	**2.9412**	**0.082**	**11.9127**	**0.2414**	**35.0718**
SUM TOTAL	**100 %**	**14526.37**	**100 %**	**13524.3**	**100 %**	**14525.98**	**100 %**	**14524.55**

Table 1 Results of Land Use Land cover in 1989, 2002, 2011, and 2022

Source: (Author's Analysis, 2022).

Results from *Table 1* show that the land coverage of Millennium City from 1989 2002, 2011, and 2022 was consistent and found to be 14,525.98 hectares, and also, built-up areas in 1989 occupied 2.4527 % of the total land area. In 2002, it occupied an area of 1.6322 % while in 2011 there was a drift change to 1.6632 %. In 2022 the buildup Areas surged covering an area of 13.612 %. However, open spaces had the dominant coverage of 69.1452 % in 1989. In 2002, it occupied an area of 90.1952 % and in 2011, it occupied an area of 84.423 %. In 2022 there was a drastic loss of open space which dropped to 68.1873 %. Vegetated land use occupied a total land area of 28.3979 % in 1989, in 2002, it covered an area of 8.1515 %, however in 2011 the vegetation cover saw an increase of about 8.8317 % while in 2022, it occupied an area of 17.9584 %. Water bodies covered 0.0041 % in 1989, 0.0202 % in 2002 and 0.082 % in 2011 and 0.2414 in 2022. Open space is an important land cover to man, this area covered an area of about 69.1451 % in 1989, in 2002 it had a total of 90.1959 % and in 2011 it occupied a total of 87.423 % while in 2022 a total of 68.1873 % of open space was available in the study area as shown in Figure 5.

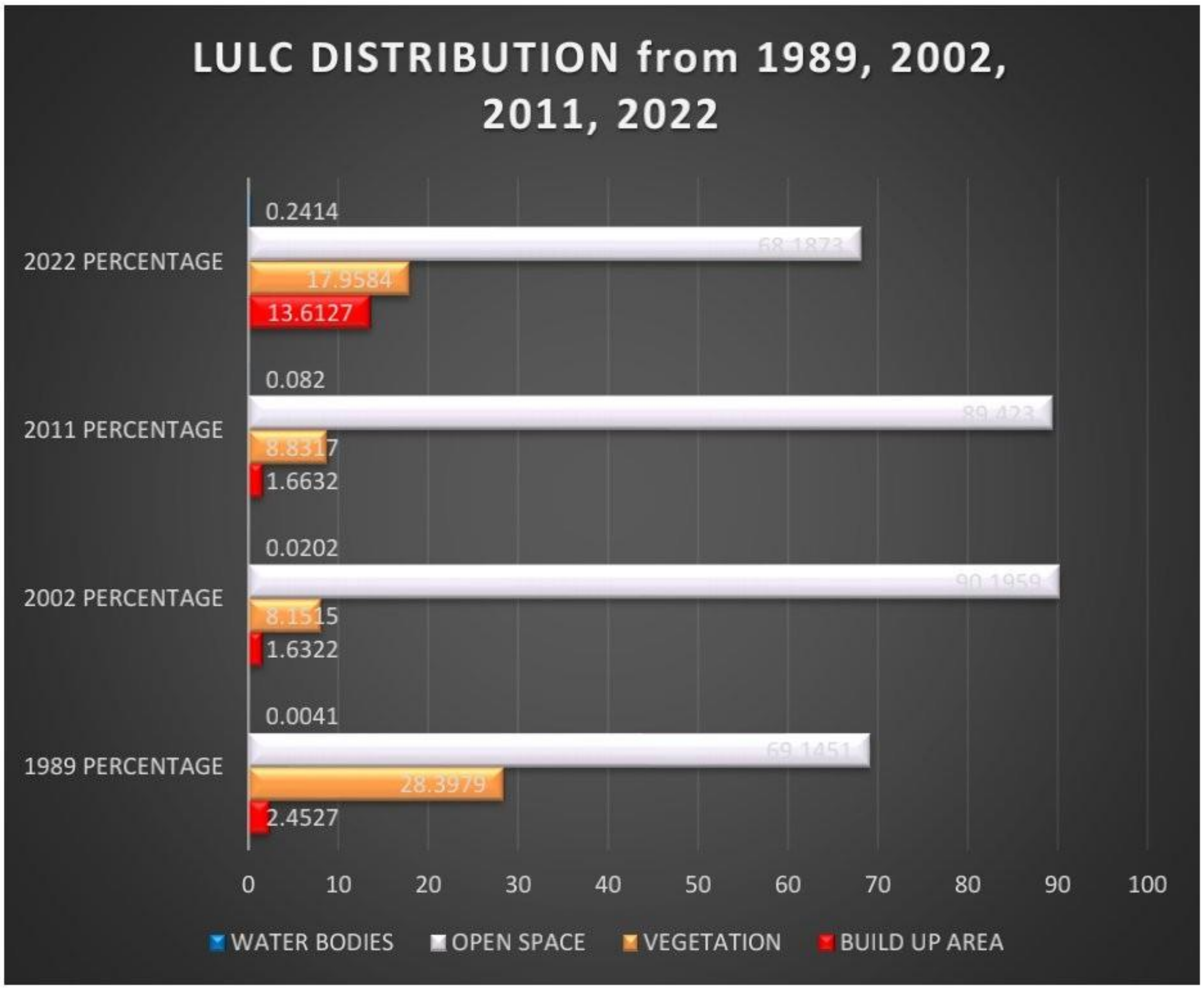

Figure 5: Bar Chart showing Land use land cover distribution from 1989 to the year 2022. (Source: Author's Analysis, 2022)

The study revealed that the water body has the lowest proportion of land coverage within the millennium city and its environment while open spaces have the highest proportion of land coverage within the periods of study as shown in Table 1.

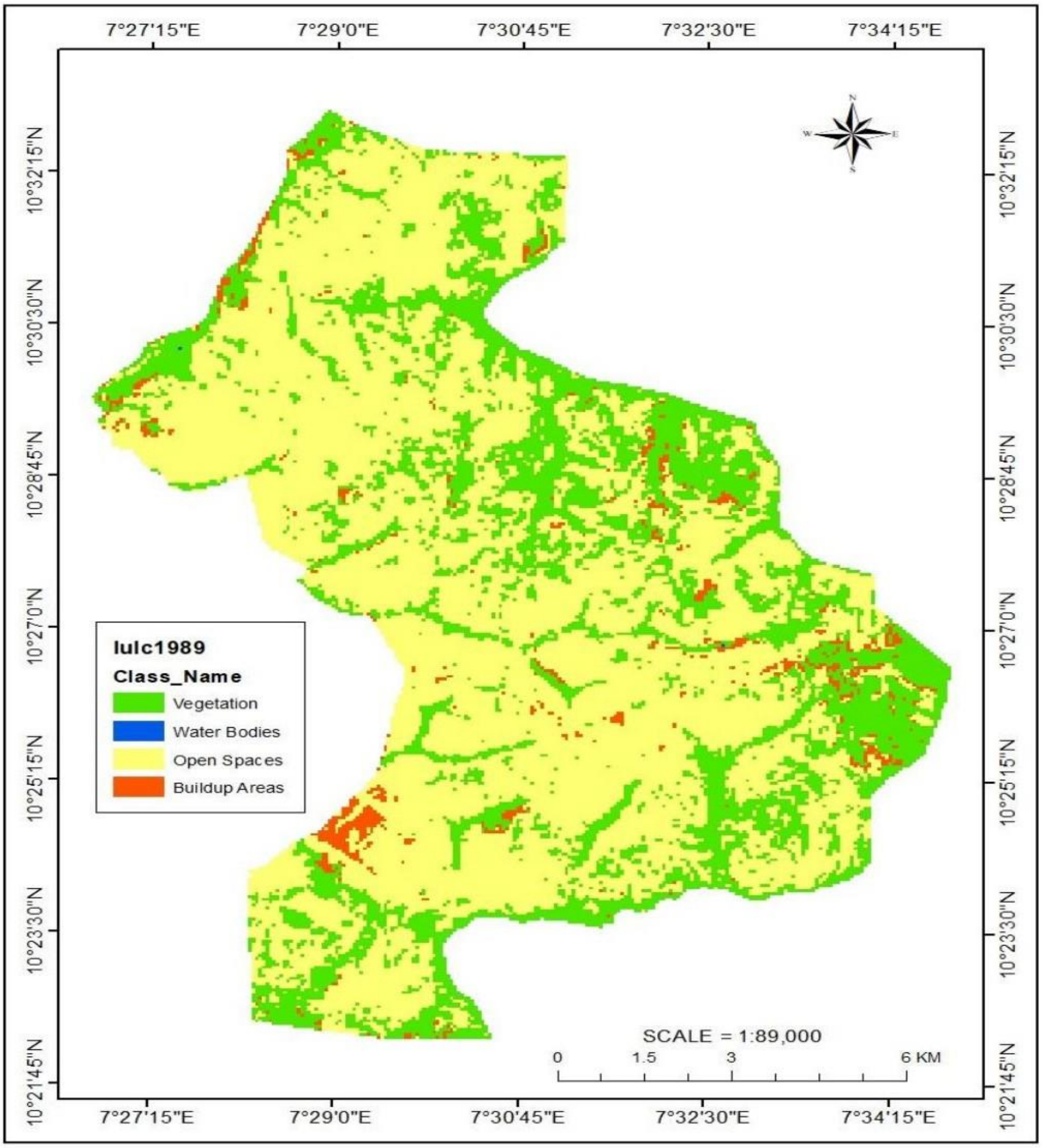

Figure 6: Land use land cover changes of Kaduna Millennium City for the year 1989 (Source: Author's Analysis, 2022)

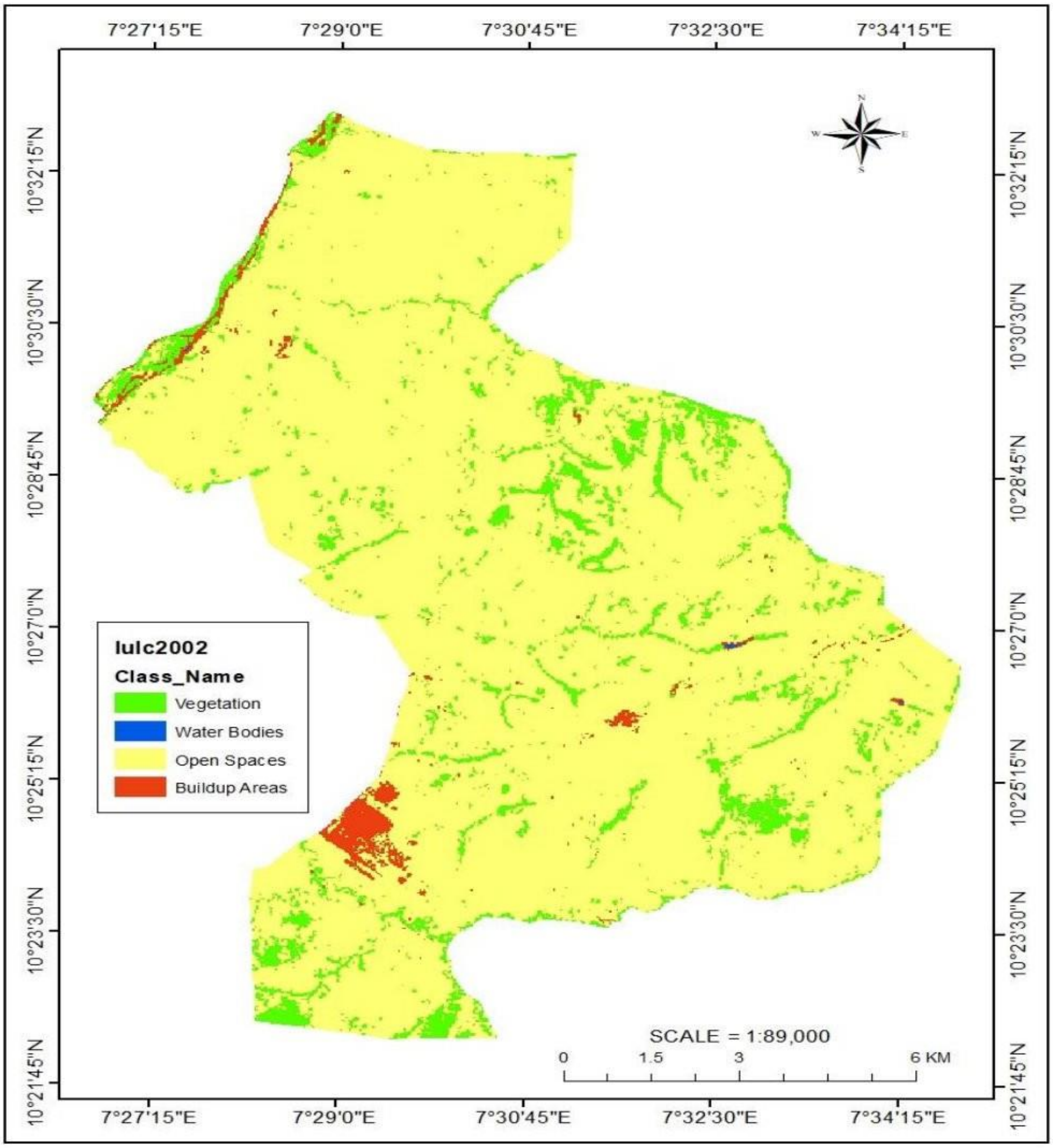

Figure 7: Land use land cover change of Kaduna Millennium City for the year 2002 (Source: Author's Analysis, 2022)

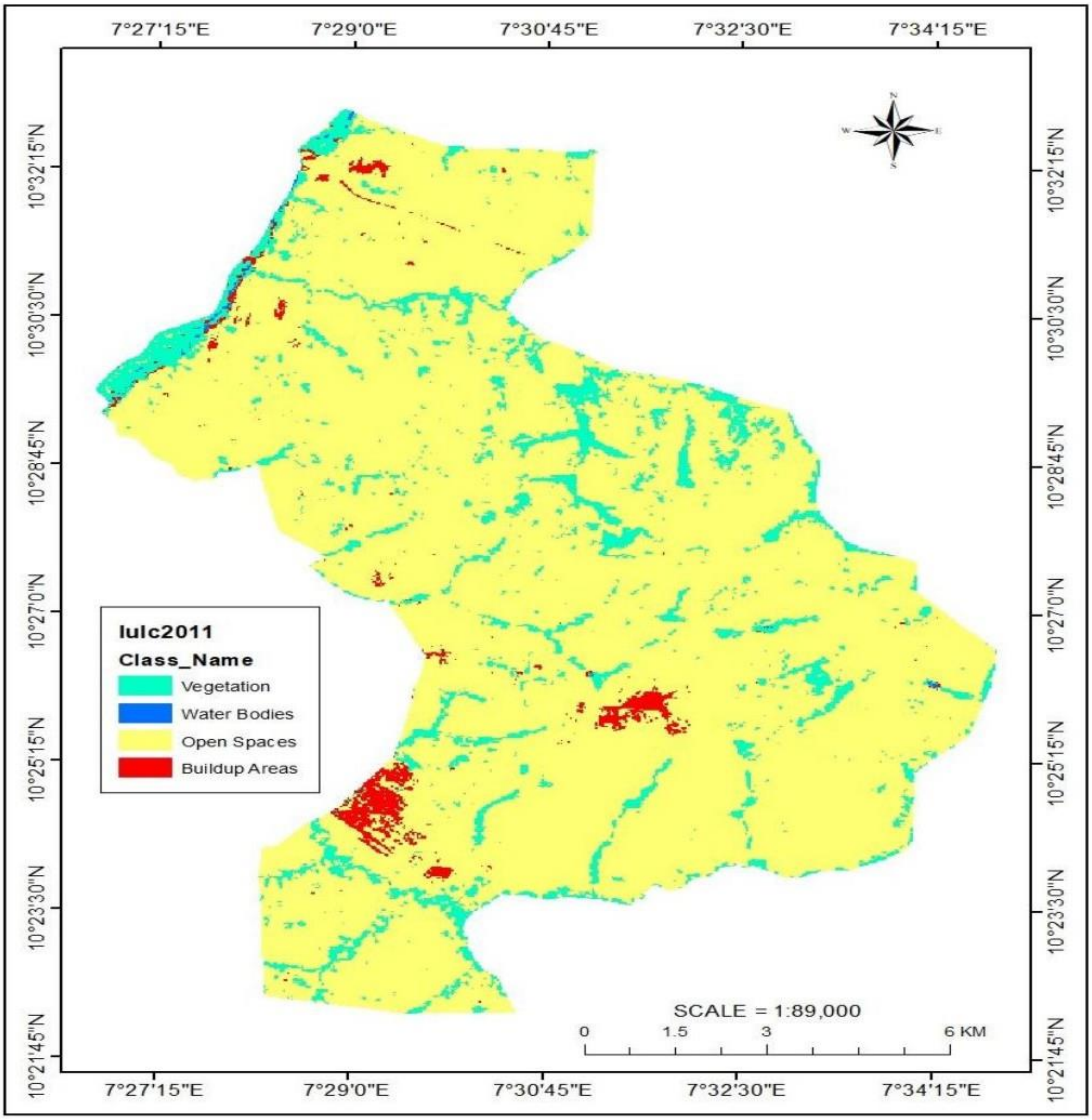

Figure 8: Land use land cover change of Kaduna Millennium City for the year 2011 (Source: Author's Analysis, 2022)

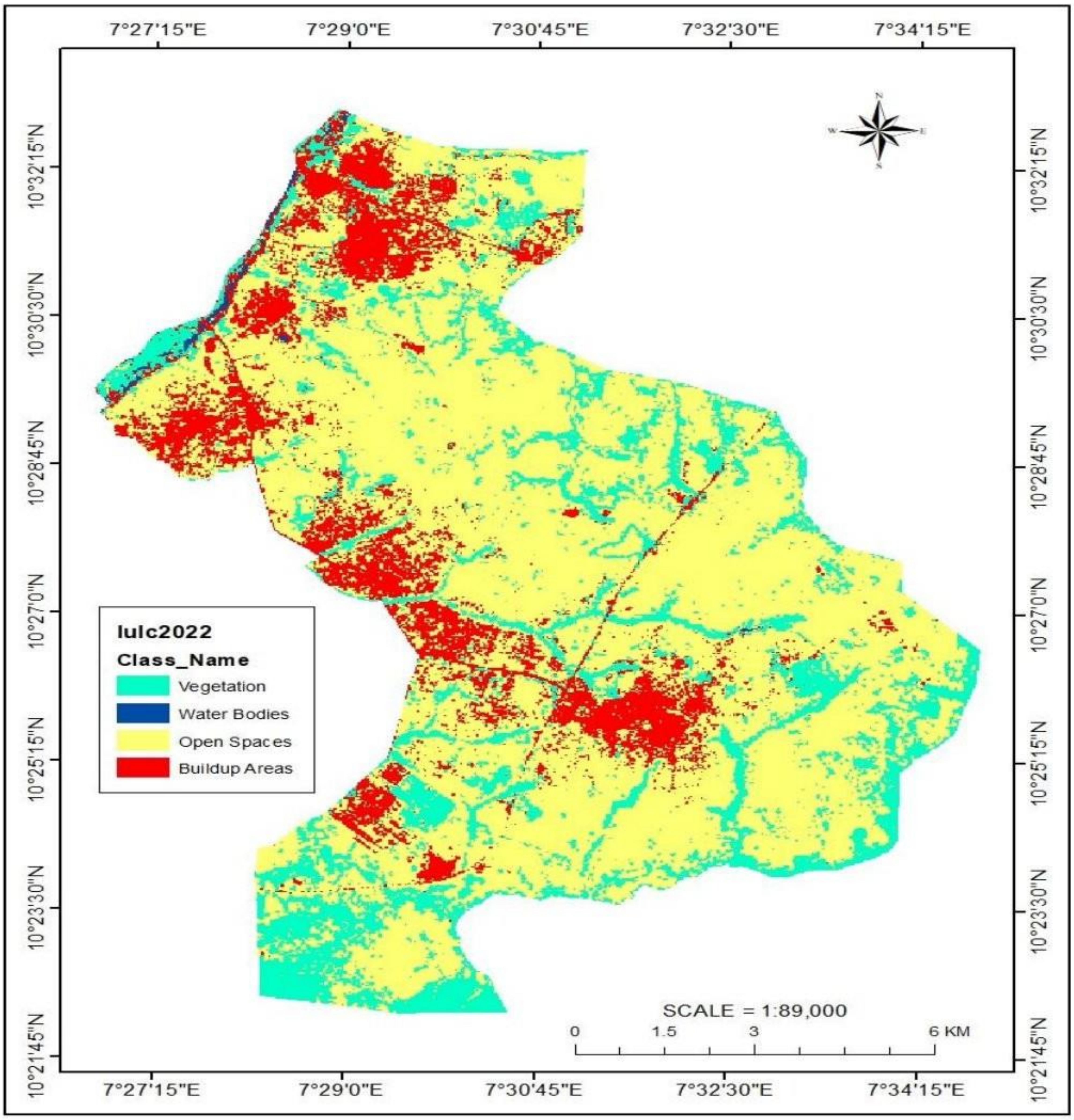

Figure 9: Land use land cover change of Kaduna Millennium City for the year 2022 (Source: Author's Analysis, 2022)

3.2 Discussion

The composite map representing the 4 epoch periods as shown in *Figures 6 to 9* will be used for the discussions to analyze and sieve out relevant inferences from the observed results of multi-temporal change detection analysis.

The multitemporal land cover change detection as shown in the composite maps in *Figures 6 - 9* exhibited a widespread built-up land cover growth in the millennium city of Kaduna, this is particularly evident in the results shown in 2022 which indicates a progressive conversion of open spaces and vegetation into buildings. This can be attributed to the rapid increase in real estate markets and Developer Lease Agreements (DLAs) undertaken as a new policy by the government especially from 2017 onwards, resulting in the expansion and building of new estates and sale of mortgage houses in the city. The results of findings of the study showed that the factors responsible for growth in the study area include: an increase in urban land features, residential development, roads, and extension and the building of new linkages in the form of bridges across the major River Kaduna which connected the Millennium city with the larger metropolitan areas. The results revealed that built-up lands in 1989 occupied just about 356.2999 hectares from a total land area of 14524.55 hectares (*Table 1 and Figure 6*), which is understandable because the area was not envisaged for development yet and none of the Bridge linkages was constructed then, consequently the built-up are usually farmers settlements, which normally use ferries and canoes across the river to go to their farms and transport farm and gardening produce for sale in the main city. Vegetation and open spaces thus covered the most area at 4125.19 hectares and 10044.27 hectares respectively. Water bodies occupied only 0.6064 hectares as the areas were virgin lands & farms as of then. The results in 2002 show a slight decrease in the area covered by built-up land to about 237.0687 hectares and an increase of 241.6035 hectares in 2011, this could be a result of the Millennium Bridge which was constructed and launched on May 2008 by the Muhammad Makarfi administration and served as a Link Bridge and Approaches to the state capital. This gave rise to what has come to be known as the Millennium City. Consequently, there was a gradual development in the area, especially as a result of the then-governor of the state, Arch. Namadi Sambo's efforts towards a revised Master Plan of Kaduna and its sub-regions based on its growth, taking into consideration urban extensions around the city. The result in 2022 revealed a geometric rise in areas covered by built-up lands to 1977.187 hectares and 13.1267 % of the total land area (*Table 1 and Figure 7*). This is partly a result of Governor El-Rufai's administration which came in 2015 through 2023 and brought about reforms such as the **2018-2050** Kaduna Infrastructure Master Plan (KADIMP) leading to the consolidation and systematization approach and strategy towards a coordinated and purposeful long-term infrastructure development in the state. Thus, the Millennium City become a hub for investment in real estate and the rapid development of the Eastern Sectors. This however was not without its challenges, as the process led to a proliferation of illegal layouts and settlements, especially around the buffer regions close to old settlements such as; **Babban Saura, Kadaure, Danbushiya,** and so on. The government has made concerted efforts to regularize and register undocumented layouts through the **Systematic Property Registration Program (SPRP),** to help replan the distorted parts of the city, this is however a herculean task as the tenants in these illegal layouts find it hard to understand the implications of their actions, this requires a gradual community engagement to carry people along with the objectives of the government. The results of other classes of land cover including; vegetation 4125.19, 1183.958, 1282.893, and 2608.389, hectares respectively for 1989, 2002, 2011, and 2022 show a decrease in vegetal cover which could be a result of built-up land replacing previous agricultural lands, the slight increase in 2022 could be due to the government's policy of allocating urban lands at proximity to the major surface waters of river Kaduna to be used for urban farming *(Table 1 and Figure 8)*. Open Space 10044.27, 12100.33, 12989.57, and 9903.902 hectares respectively for 1989, 2002, 2011, and 2022 reveals a progressive increase in open space with a decrease recorded in 2022, perhaps this could be linked to the clearing of vegetated/agricultural lands in the planned layouts some of which may have been developed in 2022 thereby resulting in a decrease in open spaces in 2022 replaced by built-up lands. Water bodies covered just about 0.6064, 2.9412, 11.9127, and 35.0718 hectares respectively in 1989, 2002, 2011, and 2022.

The results of the land use/land cover classifications and relative changes as revealed from 1989 to 2022 in the Millennium City display spatial patterns of land cover; the urban built-up area showed a dramatic increase while the non-built-up area substantially decreased. Expansion of built-up areas has exhibited a consistent response from 1989 to 2022 in its areal extent. There has been a continuous conversion of non-built-up surfaces to built-up environments especially in areas adjacent to the existing urban boundaries in temporal dynamics. Millennium City has recorded a significant increase in the built-up area and the periphery of the town mainly due to population growth and development in its formal and informal sector of the economy and from the perspective of typology, Çağlıyan and Dağlı (2022) divided urban growth into three types: infilling, edge-expansion, and outlying. During infilling, a "hole" within an existing urban patch is filled with newly developed urban patches (Grover & Vadakkuveettil, 2023; Das & Angadi, 2022). An edge expansion refers to newly developed urban patches spreading out from the edge of existing urban patches (Yu et al., 2013)(Yu et al., 2013; Çağlıyan & Dağlı, 2022). New urban patches isolated from existing urban patches characterize outlying growth (Das & Jain, 2022). Infilling growth types can be confused with edge-expansion or outlying growth types. The confusion is caused by whether the existing urban patch approximates a ring-shaped built-up structure. Based on the spatial expansion pattern within the results obtained, it was observed that infilling and edge expansion are the predominant growth type patterns in Millennium City. ***Areas such as Kadaure, Danbushiya, Babban, Ungwan Maaji, Danhonu 1 & 2, and Kyauta*** are the very original settlements that existed even before the construction of the bridge linking the city with the metropolitan areas, due to the new developments in the new layouts, the old settlements are sold and new built-ups are gradually replacing the old ones which can be likened to the infilling growth pattern. Conversely, the new policies of the government since 2017 encouraged Public Private Partnerships (PPP) in real estate investments. This resulted in the engagement of several mortgage and foreclosure institutions. The Developer Lease Agreement (DLA) in which case the government provides the lands at zero premium while the developers source funding facilities to develop new and approved layouts resulting in several newly developed areas such as the Urban Shelter, Nurus Suraj Estates, Aso Savings, Family Homes and several others leading to an edge-expansion pattern of urban growth that emerged from formally agricultural lands in the millennium city area.

The socio-economic status of land owners, land speculation, and poor government intervention in housing and urban development in one way or another are responsible for the infilling pattern in the millennium city. Accordingly, Kaduna Millennium City is an example of an outlying growth type pattern because it is a new urban patch isolated from existing urban patches (Aldogom et al., 2019). Based on urban growth phase theory, spatial urban evolution can be a general temporal oscillation between phases of diffusion and coalescence (Marzialetti et al., 2023; El Garouani et al., 2017; Hegazy & Kaloop, 2015; Kisamba & Li, 2022). Diffusion is defined as the dispersion of patches, while coalescence is the fusion of patches into one patch (Tariq &

Mumtaz, 2023b). Outlaying growth corresponds with diffusion, and edge expansion and infilling represent coalescence (Enoh et al., 2023). Kaduna Millennium City is expanding in every direction but with more concentration in the south and the general growth pattern is radial as it spreads outward virtually in all directions (Tariq & Mumtaz, 2023b; Zhang & Wang, 2022).

4. Conclusion

This study investigated the multitemporal urban growth pattern and assessed the urban sprawl in Millennium City, Kaduna State using moderate resolution Landsat data for periods 1989, 2002, 2011, and 2022. The study demonstrated the efficient utilization of geospatial measurement techniques such as GIS and RS in analyzing urban sprawl. The urban growth pattern indicated a progressive rise in built-up land cover in most of the analyzed areas. The results of the analyzed data showcased a higher built-up growth rate as the years changed compared to the other land cover types. There was a significant reduction in vegetation and other land cover categories during the study period. Some of the prominent factors that led to the rapid growth of built-up areas include; illegal land speculation and sale of land in the peripheries of the old cities such as **Danbushiya, Kadaure, Danhonu 1 and 2, Babban Saura, Kyauta and Ungwan Maaji** etc. at low price leading to proliferation of unplanned built-up lands, haphazard and unchecked urban growth, and weak coordination among the multiple authorities to checkmate these excesses especially by previous governments.

Moreover, the trend indicated a continuous rise in urban sprawl from 1989 to 2022 with varying intensities. Overall, economic reforms and policies enacted after liberalization did not seek to curb urban sprawl. Instead, it encouraged indiscriminate city growth. Therefore, there is an urgent need for sustainable urban planning in the city to promote sustainable cities and communities. Urban sprawl is a complex and dynamic phenomenon; therefore, this study combined RS, GIS, and interactive supervised classification techniques. The methodology adopted in this study can be used to assess the urban sprawl in other medium-sized cities in Kaduna State Nigeria and other countries due to its significance in the coming decades. The obtained results can serve as a guide to planners and authorities to help in preparing relevant strategies for promoting urban sustainability strategies and the creation of smart cities.

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