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Land Use-Land Cover (LULC) and Vegetation Change in Sokoto Settled–Close Zone Sokoto State, Nigeria

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ABSTRACTS

This study examined the Land Use-Land Cover (LULC) and Vegetation Change in Sokoto Settled–Close Zone of Sokoto State. Using combined methods of Reconnaissance Survey, Remote Sensing (RS), Computation of Normalised Difference Vegetation Index (NDVI), Land Use-Land Cover (LULC) classification, post classification computation (PCC), and Change Detection by maximum likelihood classifier (MLC). The finding reveals that, Farmlands and built-up LULC are the predominant land uses in the study area. The highest Land use change increase is built-up with 17.5%; with 8257.9 hectares converted to 13282.2 hectares, while the lowest land use change is bare surface with 0.69%; with 1411.1 hectares decline to 1212.3 hectares between the dates. The trend of LULC change from 2006-2026 shows that built-up has increased by 17.65% while, vegetation declined by 3.22%, and water body rises by 0.03% over the two decades. On the other hand, farmlands loss 13.77%, and bare surface diminishes by 0.69%. Recommendations in the light of this research are: There is need for a policy framework on sustainable urban green infrastructures in the study area. Land Use and Forestry Laws of Sokoto State should be revisited by legislators with a view to enacting stiffer penalties for indiscriminate felling of trees. Finally, formulate an action plan using expertise from SURPB, Sokoto State Ministry of Lands and Housing, Sokoto State Ministry of Environment, Non-Governmental Organizations (NGO's) and Academia from tertiary institutions in the state

Keywords: LULC, MLC, PCC, Sokoto Settled–Close Zone

INTRODUCTION

It is becoming clear worldwide that urban areas grow at the expense of forests and other land cover whereby, most land surface on earth is affected by human activities with related positive and negative land use changes. However, urban ecological systems are characterized by multifaceted interactions among built up, vegetation, water bodies, farmlands and bare surface that often generate complex human-dominated sceneries affecting land use land cover as in the case of Sokoto Settled–Close Zone (Metropolis) in Sokoto State. Earlier studies conducted by Susan *et al.,* (2010) and Elmqvist *et al*., (2015) submit that, Land Use-Land Cover (LULC) changes is a process in which the society and the environment are interrelated in space and time, different economies respond to LULC change with an example of urban settings infill development on land, this response is growing in importance as countries at local and national level seek to protect increasingly scarce agricultural and forested plans for economic development. Similarly, the reasons for the Land Use Land cover and vegetation change range from natural (geographical, soil characteristics, etc.) to human induced factors of urbanization and population growth (Isah, 2023). In Sokoto state, the prevalence of vegetation change is due to climate change with attending consequences of desertification, flood, soil erosion, pollution and drought which are all cyclical and interwoven (Isah, 2024).

This research derives basically from the idea that there is a strong positive correlation between urbanization, pressure of population, land use, land cover and vegetation change that may lead to adverse environmental consequences on the study area. The observations by the authors reviewed above serve as allusions to how precarious the vegetation change could be on the study area and beyond; So, the research will attempt to contend the apprehension technologically and scientifically by employing Landsat Imageries data and observations to produce an accurate and incontestable result on the Land Use-Land Cover (LULC) and Vegetation Change in Sokoto Settled–Close Zone of Sokoto State,

Many Scholars (e.g. Hails and Ormerod 2013, Uprety, *et al.,* 2017, Isah, 2020) opined that universally, several regions undergo vegetation change: the study area is at the frontline of severe environmental degradation, thus, may not be an exception. Human land use affects the environment and increases the potential for soil erosion, land pollution and flood. On their part scholars like, Swindell *et al* (1982) and Adamu *et al.,* (2017) have examined environmental issues in the West African Sahel that report the original vegetation in Sokoto State (North-western Nigeria) has been changed by anthropogenic activities. In recent decades' vegetation change is alarming at 3.5% per annum in Nigeria and ironically, there is refusal of replacement of the converted vegetation, causing gradual loss of vegetation to built-up, open spaces thus, rendering the state more vulnerable to environmental threats. Adamu *et al.,* 2017; Isah, 2020 revealed that vegetation alteration is one of the most serious environmental challenges facing Sokoto state, for instance, a study on vegetation conducted by the authors shows that vegetation covers in Sokoto metropolis alone in 1986 occupied 3,426 hectares but reduced to 621 hectares in 2019.

Furthermore, the study area records high temperature, depletion of green space and increase in built up and barren surfaces as the main drivers of LULC (Abdullahi, *et,* al. 2025) however, most of the vegetation changes are found in urban centres witnessing many of environmental and social problems. The vegetation conversion emanates from the core of the city and gradually coalesces into suburbs. Conceivably, there has been a persistent fall in trend in vegetation and land use type. LULC patterns showed that, the vegetation is disappeared, the built up expands at an outstanding level bringing about LULC change (Isah and Shehu, 2024). Hence, filling the research gap on the LULC and vegetation change will be necessary for sustainable environment aimed at a balanced ecosystem in the study area. In addition, this research derives basically from the idea that there is a strong positive correlation between pressure of population growth, urbanization and LULC conversion that may lead to adverse environmental concerns in Sokoto state

The aim of this research is to assess Land Use-Land Cover (LULC) and Vegetation Change in Sokoto Settled–Close Zone

The specific objectives are to:

i. Detect vegetation change in Sokoto Settled–Close Zone (Metropolis) in Sokoto State

ii. Assess the vegetation change between 2006-2026 in the study area

METHODS

Combined methods of Reconnaissance Survey, Remote Sensed (RS) data, Landsat data: Several authors (Ulbricht and Heckendorff, 1998; Michael. 2009; Li et al.2013. Eniolorunda, *et al.,* 2015 and Isah, 2020) concede that Landsat images are able to identify numerous surface phenomena better than ground-based investigations (EIA). In view of its significant advantages, Ground Truthing (GT) at the site, LULC Classification, and development of level I (5 class scheme) of Anderson *et al.,* (1976); the study area was delineated following the steps of Michael (2009); Equally, following the method of (Isah, 2020) Pre-field oral interview with urban planners, environmentalist and land agents was done with a view to obtain first-hand information on the scope of the study correspondingly, observation and inquiry via phone calls with local people around the study area was carried out..

Data Types and Sources

The satellite data used and cited for scrutiny are; Satellite images of Landsat 5 Thermal Mapper (TM) band 4 of 2006 (19-4-2006), Landsat 8 Operational Landsat Imager Infrared Sensor (OLIS-TIRS) of 2016 (13-3-2016) and Landsat 9 Operational Land Imager Thematic Infrared Sensor (OLI-2/TIRS-2) of 2026 (6-1-2022), were selected for this study. These are all near-anniversary and dry season images. Surviving dry season vegetation in a semi-arid environment composed mainly of trees. Thus, the selection of the images at irregular intervals was done to avoid cloudy images; the multispectral data with a spatial resolution of 30m correspond to Path/row of Sokoto: path 188/row 052 in the active archive centre of the United States Geological Survey (USGS) downloadable via glovis.usgs.gov was used. Also, the images selected are expectedly cloud free but likely to be affected by haze as the images were captured in dry season when the atmosphere is dusty in the region. The data are in Level 1T (precision and terrain corrected) format.

Image Radiometric Correction

Image radiometric correction was done on haze being the only error observed on the obtained Landsat data. The data were haze corrected using the PANCROMA software with the dark object subtraction (DOS) algorithm. As already geo-referenced data sets from source, both images-were co-registered and-overlaid using two hundred and seventy 270 GCPs that were derived via simple random sampling techniques. The GCPs were used for supervised image classification and classification accuracy assessment. A useful rule of thumb is 30×n (n = number of bands). In this study, this rule was applied, but the task was designed to collect more samples such that the excess could be used for classification accuracy assessment. Image classification involved the development of LULC Scheme and Digitizing of Pixel.

Computation of Normalised Difference Vegetation Index (NDVI)

The NDVI Serves as an index of choice for characterizing vegetation phenology, capable of differentiating between vegetated and non-vegetated surfaces and this informs its application in this study. The NDVI is an index of choice for vegetation mapping and change detection. The computed NDVI was also subjected to image classification first using unsupervised classification method. The method partitioned the image pixels into classes as; thus, it was unsupervised.

LULC Classification

LULC classification was supervised and was preceded with Ground Truthing (GT), where representative points were selected from the unsupervised classified map. NDVI was computed with the Red (RED) and Near-Infrared (NIR) bands of each image selected using: NDVI = (NIR-RED)/(NIR+RED): Where: NIR is the Near Infrared band while RED is the Red band of the Landsat data considered. For the Landsat TM and ETM+, band 4 is the same for Landsat ETM+ and NIR for the OLI-TIR. The LULC supervised image classification was carried out on each of the NDVI epoch data based on the extracted signatures. The maximum livelihood algorithm was used to accomplish this task. Z-scores were computed for each of the NDVI data, after which it was classified using 1 standard deviation to the mean ($\mu \pm \sigma$) algorithm. The area coverage of each classified NDVI was calculated, and Post Classification Comparison was used to detect vegetation changes from one date to another

Development of Land use Land Cover Scheme

On land use cover scheme selection the 5 class scheme of Anderson *et al*., (1976) was adopted for LULC classification in this study. The coverage values of the classes were recorded in hectares, changed to corresponding percentages and computed per decade (2006-2016 and 2016-2026) for comparison. The area coverage of each class in the LULC map was calculated, after which those classes were compared from one date to another. The classes' categorized: Built up: (urban areas, roads, buildings), Vegetation: (forests grasslands, scrubs), Water body: (rivers, lakes, reservoirs), Farmlands: (cropland and pasture) and Bare surfaces: (exposed soil, rock sand and desert) of the three epochs of 2006, 2016 and 2026 years respectively

Classification Accuracy Assessment

Classification accuracy assessment of the classified NDVI for 2026 was tested by computing the error matrix. This involved cross tabulating the ground truth data with the classified map of 2026. In this study the

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classification of image was performed with an overall accuracy (OA) of 94%, and Kappa was calculated at 0.93; a measure of classification accuracy that shows the study area was well mapped. The algorithms used for image processing of other Landsat data as in the case of that of 2026 guarantee to put that LULC classification of other years are reliable.

Study Area

Location of the Study Area

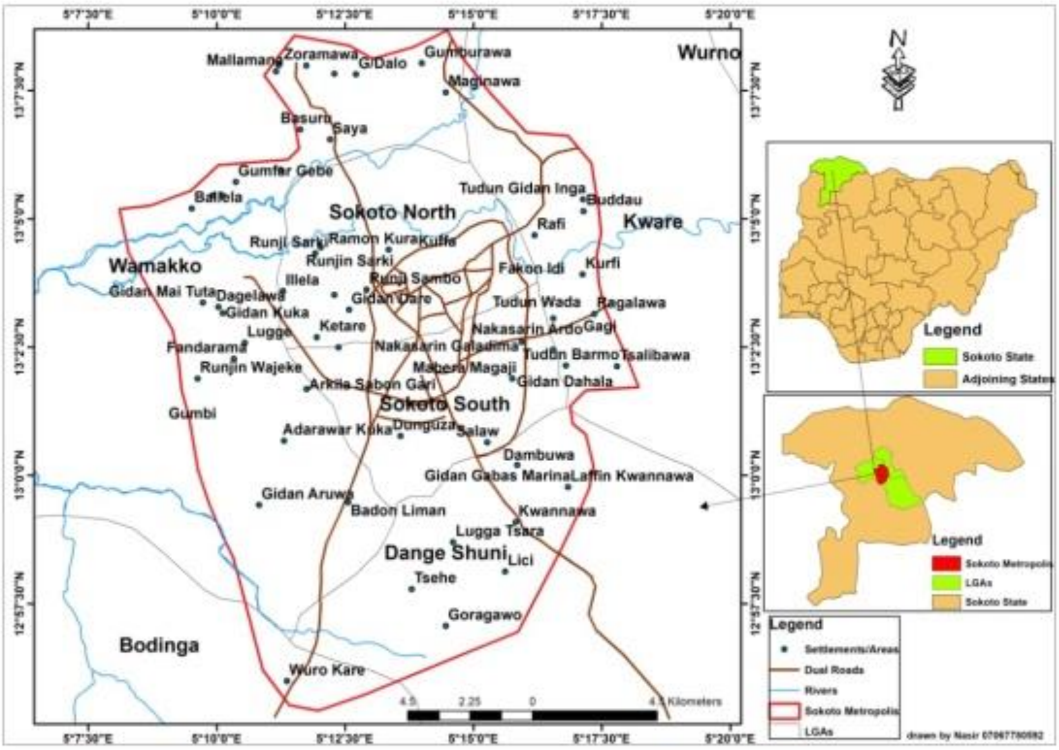

Fig 1 Map of Sokoto Settled–Close Zone: Author's Compilation, (2026)

Source: DIVA GIS and Open Street Map

The study area lies between latitude 12 55 30N to 13 8 45N and longitude 5 8 5E to 5 18 30E. Physically, the study area covers the following Local Government Areas (LGAs) of Sokoto State namely; Sokoto South, Sokoto North, Wamakko, part of Kware, and Dange-Shuni

RESULTS

LULC Change Detection by Post Classification Comparison (PCC)

The area coverage of each class in the LULC map NDVI was calculated, after which those classes were compared from one data to another. Therefore, The Post Classification Comparison (PCC) was used in this research to assess vegetation change of 2006-2016, 2016-2026. The character of each image was improved separately for merging the Landsat imageries. This was to ensure perfect overlay or image merging between the Landsat images, and was followed by the sub-mapping of Sokoto closed-zone from each of the scenes. Thus, size covering of the study area was sub-mapped from each of the Landsat scenes Image. The maps were overlaid on one another for comparison. Likewise, LULC Change Detection by Cross Map Tabulation (CMT**)** was carried out by cross tabulating the classes of the land use maps of 2006, 2016 and 2026

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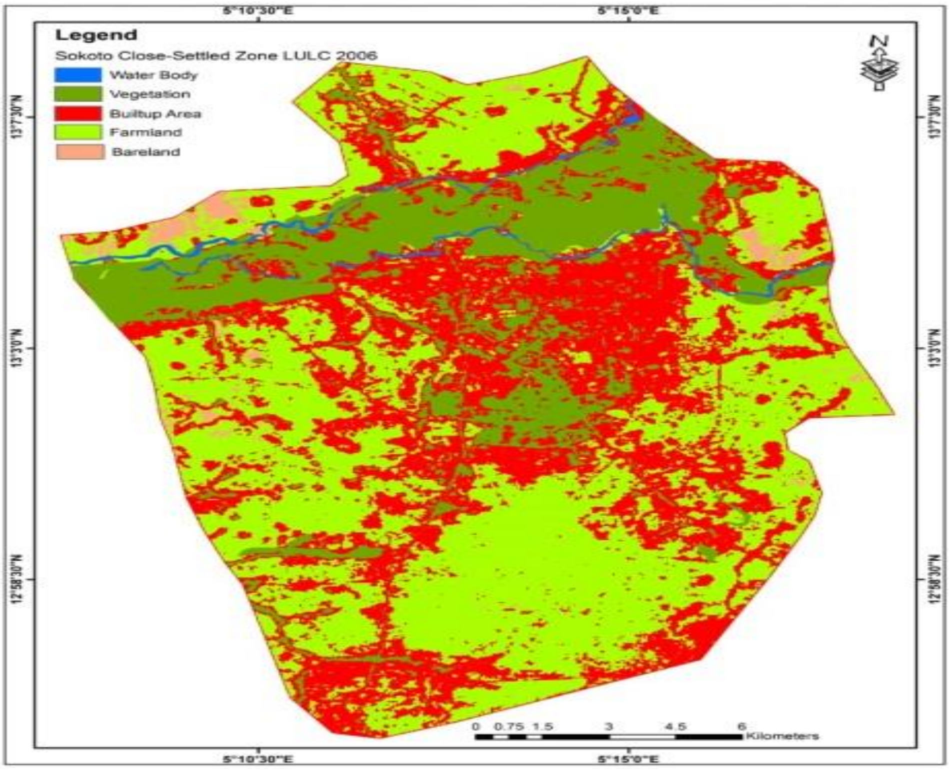

Figure 1 LULC Map (2006)

Source: Authors Compilation (2026)

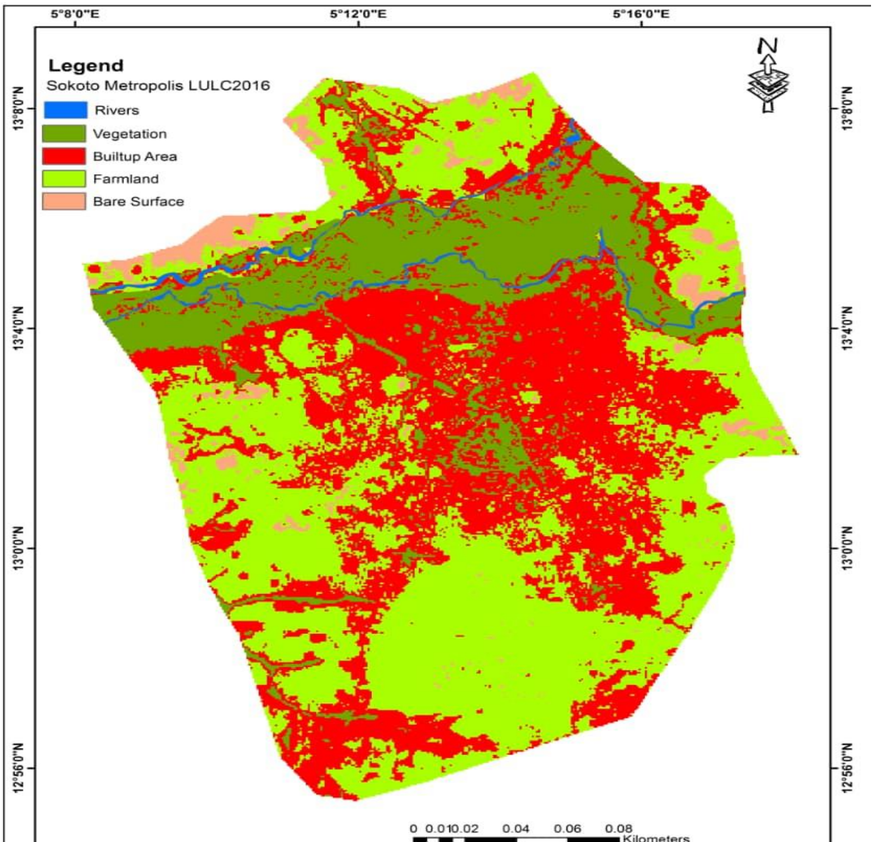

Figure 2 LULC Map (2016)

Source: Authors Compilation (2026)

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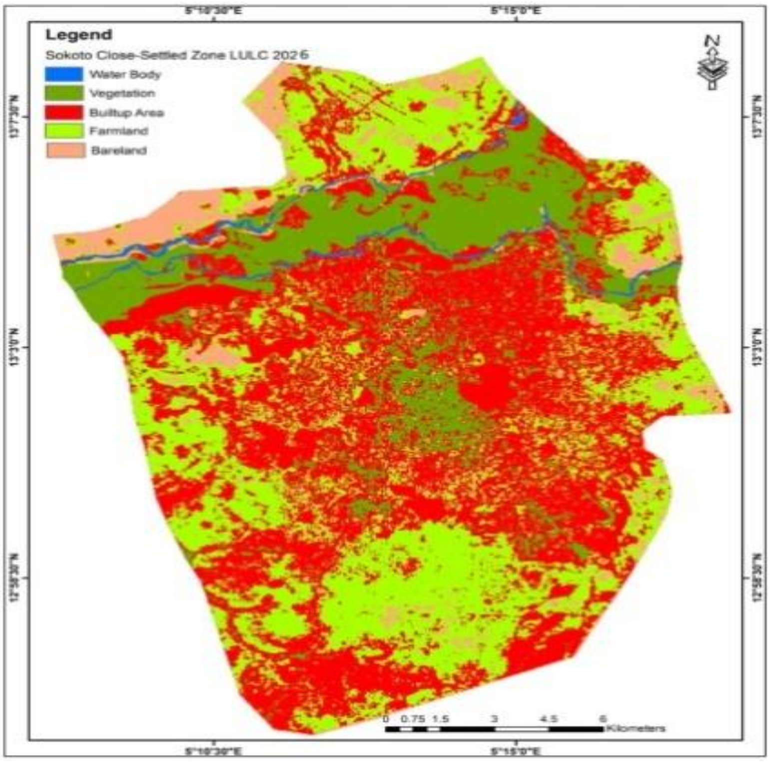

Figure 3 LULC Map (2026)

Source: Authors Compilation (2026)

Table 1 Estimates of the Various Land Use Land Cover (2006-2026) in the Study Area

Land Use Types	2006 (Hectares)	2006(%)	2016 (Hectares)	2016 (%)	2026 (Hectares)	2026 (%)	2006-2026 (%) change
Built up	8257.9	28.99	11.195.9	39.31	13282.2	46.64	17.65
Vegetation	**3012.4**	**10.60**	**2416.3**	**8.48**	**2102.6**	**7.38**	**-3.22**
Water Body	286.3	1.00	283.0	0.99	293.7	1.03	0.03
Farmland	15507.9	54.46	13218.4	46.42	11584.8	40.69	-13.77
Bare Surface	1411.1	4.95	1362.0	4.80	1212.3	4.26	-0.69
TOTAL	**28475.6**	**100**	**28475.6**	**100**	**28475.6**	**100**	

Source; Authors' Compilation (2026)

The finding on Land Use Land Cover (LULC) change in the study area reveals that, built up stood at 28.9%, vegetation occupied 10.6%; water bodies was 1.0 %, farmlands covered 54.46%, bare surface was 4.95 in 2006. (Figure 1) On the other hand, in 2016, the built up was converted to 39.3%, vegetation had reduced to 8.4%; water bodies was 0.99 %, farmlands covered 46.42%, bare surface was 4.80%. (Figure 2) Accordingly, in 2026, the built up was converted to 46.64%, vegetation had reduced to 7.38%; water bodies has upsurge to 1.03 %, farmlands covered 40.69%, and bare surface decreased to 4.26% (Figure 3). All of these proportionate percentages changes occur within the total coverage of 100% (28475.6 hectares). However, farmlands and built-up are the predominant land uses in the study area. The highest Land use change is on built-up with 17.5%; (8257.9 hectares) converted to 46.64% (13282.2 hectares), while the lowest land use change is bare surface with 4.95% (1411.1 hectares) to 4.6% (1212.3 hectares) a decline of 0.69%; between the dates (Table

1). Specifically, vegetation suffers a sharp decline over the two decades with the existing 10.60% (3012.4 hectares) in 2006 plummeted to 8.48% (2416.3 hectares) in 2016, and further shrink to 7.38% (2102.6 hectares) in 2026 hence, depicting a loss of 2.12% from 2006-2016, and 1.1% from 2016-2026 respectively (Table 1). This finding corroborated (Isah, 2020) that opined Sokoto metropolis vegetation in 1986 occupied 32%; but it reduced to 11% in 2015

Land Use Land Cover (LULC) change trend from 2006-2026 shows that built-up has increased by 17.65%, vegetation declined by 3.22%, water body rises by 0.03%. On the other hand, farmlands loss 13.77%, and bare surface diminishes by 0.69% to other land uses. On the same vein, water body has witness an increase by 0.03% over 2006-2026, this could be attributed to the impact of climate change; with heavy storms leading to flash floods such as, the flood recorded in the year 2010 in the study area. Farmlands has declined by 13.77% indicating that, large farmland areas were converted to other uses; leading to decrease in crops output which could affect the food security of Sokoto state and hence causing inflation on crops and vegetables prices.

Therefore, it is observable that the loss of vegetation due to deforestation through indiscriminate felling of trees for fuel wood and other utilities in the study area, the vegetation suffered a tremendous decrease; this has impacted on the climatic condition of the area with multiple devastating environmental problems and land degradation with attending consequences such as, floods, desertification, wind erosion, heat stress, etc. Similarly, on their part Akinyemi *et*. al., (2025) pointed out that in northern Nigerian desert frontline state dense vegetation declined to light vegetation by 58% and built up areas increased substantially. Eventually, about 53.36% of dense vegetation in 1984 was converted to light vegetation by 2022. Ambursa *et, al*. (2021) in his finding on vegetation cover change of Kebbe forest in Sokoto state has alluded that LUC change is taking place at an alarming rate with the highest decrease experienced in the kebbe deep forest, with 24.89% of the decrease being from 1649.25 to 744 ha, and the least being the bare land with 8.73% decrease, which is from 406.71 to 89 ha of the total reserve area. Scholars also observed that, depletion of vegetation and increase on built up/bare surfaces are the major drivers causing the upsurge of temperature in Sokoto metropolis. Generally, several researchers indicate that built up and barren land expansion are at the expense of the dense vegetation. This was attributed to urbanization, population growth, and non-compliance to the planning control procedures by land users, others are climate change, mining and related dynamics.

Furthermore, the vegetation change in the study area has culminated to loss of plant biodiversity for instance, shrubs commonly available and easily consumed as edible vegetables leave; *Maringa oleifera, Senna occidentales, Hibiscus cannabirus*, and *Ficus glumosa* were all at the verge of extinction. Equally, threatened wildlife includes birds like migratory cattle *egret*: heron Ardeidae species and Pelican which were all drove away, largely due to destruction of their natural habitat. All these findings posed a serious environmental concerns and threat to sustainable balanced ecosystem.

Recommendations in the light of this research are: Sokoto state government should emphasize on the need for a policy framework on sustainable urban green infrastructures in the metropolis. Land Use and Forestry Laws of Sokoto State should be revisited by the legislators with a view to enacting stiffer penalties for urban and rural dwellers felling trees without replacement. Urban planning authorities in the state should be well funded, adequately staffed and retrained to monitor the manifestation of LULC conversion and growth of slums (unplanned urbanization) at the expense of vegetation cover. Urban and rural dwellers in Sokoto Settled–Close Zone (Metropolis) should be adequately sensitized on preserving and maintaining vegetation, greenbelt, and recreational facilities etc. in order to enhance the balancing of the ecosystem. Finally, there is need to formulate an action plan to protect and maintain the urban environment using proficiency from Sokoto Urban and Regional Planning Board (SURPB), Sokoto State Ministry of Lands and Housing, Sokoto State Ministry of Environment, Non-Governmental Organizations (NGO's) and Academia from tertiary institutions in the state

Limitations

The study was not without some limitations that affected its vigorous conduct these include; the satellite data sourced for the study were captured and presented with haze being dry season driven; reduces visibility and sometimes muddle the images requiring a haze free correction using the PANCROMA software with the dark object subtraction (DOS) algorithm. In addition, built-up and degraded land uses presented similar signature thus, so hard to separate the two without field data which is limited at the time of conducting this research due to insecurity. Correspondingly, fieldwork for data collection and Ground Truthing validation accuracy was constraints due to security and logistics challenges; using GPS coordinates via GPRS on the ground to ascertain the GCPs was not feasible in some parts of the study area due to bad roads, insecurity and private ownership of lands. Also, the attitudes of some land officers of poor record keeping and non-digitizing of past maps/photo by the Local Government Areas (LGAs) that constituted the Sokoto Closed-Zone was a constriction. The inadequate funding on the part of Governments at all levels to conduct allied researches was a limitation.

CONCLUSION

Sokoto state is at the frontline of severe environmental degradation due to desertification. In recent years' vegetation alteration is one of the most serious environmental challenges facing the state, turning vegetated areas into built up, farmlands bare surface etc. thereby, rendering the state more susceptible to environmental pressures. These vegetation conversions are ordinarily found in urban centres. The vegetation change emanates from the core of the town and gradually merges into the suburbs. Credibly, from the study, over the decades (2006-2026) there has been a change in the trends of LULC for instance, persistent fall in vegetation, built up areas are on the increase, water body increased, farmlands coverage has plummeted and bare surface is on decrease. Therefore, this research has recognized there is strong relation between pressures of population; urbanization, land use and land cover conversion that may lead to environmental threats and other effects/impacts in Sokoto State. Finally, the finding of this study is expected to filled-in the awareness gap on LULC and vegetation change in Sokoto state for sustainable environment aimed at a balanced ecosystem.

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