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Geospatial Analysis of Vegetation Health Response to Urbanisation and Land Use/Land Cover Changes in Lokoja, Nigeria Using NDVI

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Abstract

Urbanization-driven changes in Land use/Land Cover (LULC) represent humanity's most pervasive alteration of terrestrial ecosystems. These changes have a direct influence on vegetation health, a critical determinant of ecological resilience. The city of Lokoja has seen tremendous population expansion because of its strategic situation at the confluence of Rivers Niger and Benue, its historical significance and its economic potential. Using geospatial techniques and NDVI, this study investigates the how vegetation responds to urbanization and changes in Land Use/ Land Cover. This study also assessed the relationship between urban growth and vegetation cover in Lokoja, Nigeria between 1990 and 2019. The mapping of LULC changes was done by analyzing Landsat (5 TM, 7 ETM+ and Landsat 8 OLI) images of 1990, 1999, 2009 and 2019. LULC was divided into 5: built-up areas, bare surfaces, forest, water and scrub/shrublands. This study's findings revealed that while built up areas grew by 505.5% during the study period, forest cover decreased by 75.99%. A highly significant negative correlation (R^2 = 0.9562) between built-up areas and forest cover was found at 0.05 level of significance indicating that there is a decrease in vegetation as the city grows. On the contrary, there is a significant positive linear correlation between the built-up areas and low NDVI values (R2 = 0.8991, p > 0.05). In conclusion, this study revealed that there was great decrease in vegetation cover (forests and scrublands), while built-up areas increased in multiple folds, during the study periods. Recommendations include integration of green infrastructure and land use zoning, reforestation and afforestation programs, strengthening environmental regulations and enforcement, and public awareness and community engagement.

Keywords: Land use/Land cover, vegetation, Urbanization, Geospatial techniques, NDVI.

Introduction

Urbanization, a dynamic process reconfiguring physical landscapes, economic systems, and social hierarchies (Punyamurthy & Bheenaveni, 2023), remains inextricably linked to global modernization (Murayama & Estoque, 2020). Characterized by rural-to-urban migration and

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industrial advancement, urbanization has propelled over half of the world's population into cities (United Nation-HLPF & UN, 2018;). Projections suggest this figure will surge to 6.3 billion urban dwellers by 2050, with Africa and Asia accounting for 90% of this growth (United Nation-HLPF & UN, 2018; Kosoro et al., 2021). While urbanization fosters economic opportunities, its unmanaged progression in developing nations often manifests as an ecological crisis, marked by unsustainable land conversion and biodiversity loss (Nuissl & Siedentop, 2021).

Africa epitomizes this paradox. The continent's urban population, growing at 3% annually—the fastest rate globally (Rana & Sarkar, 2021)—is projected to double from 36% in 2010 to 60% by 2050, housing 1.34 billion people (Dangulla et al., 2021; Cobbinah et al., 2015). Nigeria, a pivotal contributor, exemplifies this trend: its urban population is expected to swell by 212 million by 2050 (UN, 2014), necessitating a near-doubling of urbanized zones. Such expansion invariably transforms vegetated landscapes into impervious surfaces, disrupting hydrological systems, fragmenting habitats, and intensifying urban heat islands (Appiah et al., 2017; Gao et al., 2020).

Land use and land cover (LULC) changes, driven by urbanization, represent humanity's most pervasive alteration of terrestrial ecosystems (Liping et al., 2018). These changes, whether through land-use conversion or intensification directly impact vegetation health, a critical determinant of ecological resilience (Degife et al., 2018; Gondwe et al., 2021). Vegetation sustains biodiversity, regulates microclimates, and provides ecosystem services such as carbon sequestration, air purification, and soil stabilization (Wu et al., 2015; Emiru et al., 2018). However, Nigeria loses 350,000–400,000 hectares of vegetation annually due to anthropogenic pressures, including urban sprawl, infrastructural development, and mineral extraction (Akpu et al., 2017; Ahmed et al., 2023). Between 1990 and 2005 alone, deforestation erased 21% of the nation's forest cover, underscoring the urgency of monitoring these changes (Ahmed et al., 2023).

Traditional methods of assessing LULC changes, such as field surveys and aerial photography, have proven inadequate for large-scale, rapidly urbanizing regions due to cost and logistical constraints (Fonji & Taff, 2014). Advances in remote sensing (RS) and Geographic Information Systems (GIS) now enable precise, spatiotemporal analysis of urbanization's ecological footprint

(Haleform et al., 2018; Mohammed et al., 2020). Supervised classification algorithms, including maximum likelihood and machine learning techniques, coupled with indices like the Normalized Difference Vegetation Index (NDVI), have become indispensable for quantifying vegetation health and LULC dynamics (Bid, 2016; Kafy et al., 2021). NDVI, derived from the differential reflectance of near-infrared and red light, serves as a proxy for photosynthetic activity, enabling researchers to map vegetation degradation and urban encroachment with unprecedented accuracy (Liping et al., 2018).

Despite these technological advancements, critical gaps persist in the Nigerian context. Lokoja, a strategic confluence city straddling the Niger and Benue Rivers, exemplifies Africa's urbanization challenges. Rapid population growth, fueled by its historical significance and economic potential, has triggered extensive LULC changes, including deforestation, wetland reclamation, and soil degradation (Alabi, 2009; Ifatimehin et al., 2020). While prior studies have mapped LULC shifts in the region (Oluseyi, et al., 2009; Adeoye, 2012; Ukoje et al., 2017; Olatunde, 2019), none have systematically analyzed the interplay between urban expansion and vegetation health. This omission obscures the ecological costs of development and hampers evidence-based policymaking.

This study addresses this gap by interrogating vegetation health responses to urbanization in Lokoja between 1990 and 2019. Employing Landsat satellite imagery, supervised classification, and NDVI analysis, the research pursues two objectives: (1) to analyse the spatiotemporal patterns, rate, and magnitude of LULC changes, and (2) to evaluate the correlation between urban expansion and vegetation health decline. By integrating multispectral data with demographic trends, the study advances a methodological framework for reconciling urban growth with ecological sustainability in rapidly developing regions.

Materials and Methods

Study area

Lokoja is the capital city of Kogi state. It is located on latitude 7° 45ꞌ N - 7° 51ꞌ N and longitude 61° 41ꞌ E - 6° 45ꞌ E of the equator. Lokoja is at an altitude of 45 - 125m above sea level. It is in the western bank of the River Niger, close to its confluence with the Benue River. The geology of Lokoja falls within the Precambrian age that has the presence of various sedimentary rocks. Basement Complex Rocks and Cretaceous Sedimentary Rocks are the two primary rock types in Lokoja. Its elevation ranges from 1,500 meters to 300 meters, with Mount Patti and Agbaja hills as notable relief features.

The area is also drained by two major rivers, Rivers Niger and Benue. There are also minor rivers like Meme among several others (Ocheja, 2005). The climate is that of Aw type of climate as classified by Koppen with a distinct wet and dry season. (Oluseyi, 2007). Rainfall ranges from 1016 to 1524 mm annually, peaking in June and continuing through September, with the dry season starting around November. Relative humidity is 30% during the dry season and 70% during the rainy season, with an average yearly temperature of around 27.7^{o}C (Udo et al., 2021).

Because of human activities like bush burning, bush clearing, and logging, the study area – which is in the southern Guinea savannah vegetation zone of the country, is now more of a derived savannah with resistant vegetation still predominating. Consequently, the majority of the study area is made up of secondary regrowth of short grasses like *Andropogon tectorum*, *Bambusa vulgaris*, *Panicum laxum*, *Cynodon dactylon.* The trees like *Carapa procera*, *Elaeis guineensis*, *Enantia chloranta* may be found in the region, while shrub like *Sida acuta*, *Chromolaena odorantum*, *Mimosa pudica, Cassia tora* can be found as well. There are also gallery forests along water courses as well as secondary and reserve forests in the study area (Ocheja, 2005). Lokoja had 77,516 residents in 1991, with a population density of 7 persons per hectare. The National Population Commission reported that as of 2006, the population had grown to 195,261 (National population commission 2006) and projected to be about 643,000 in 2019.

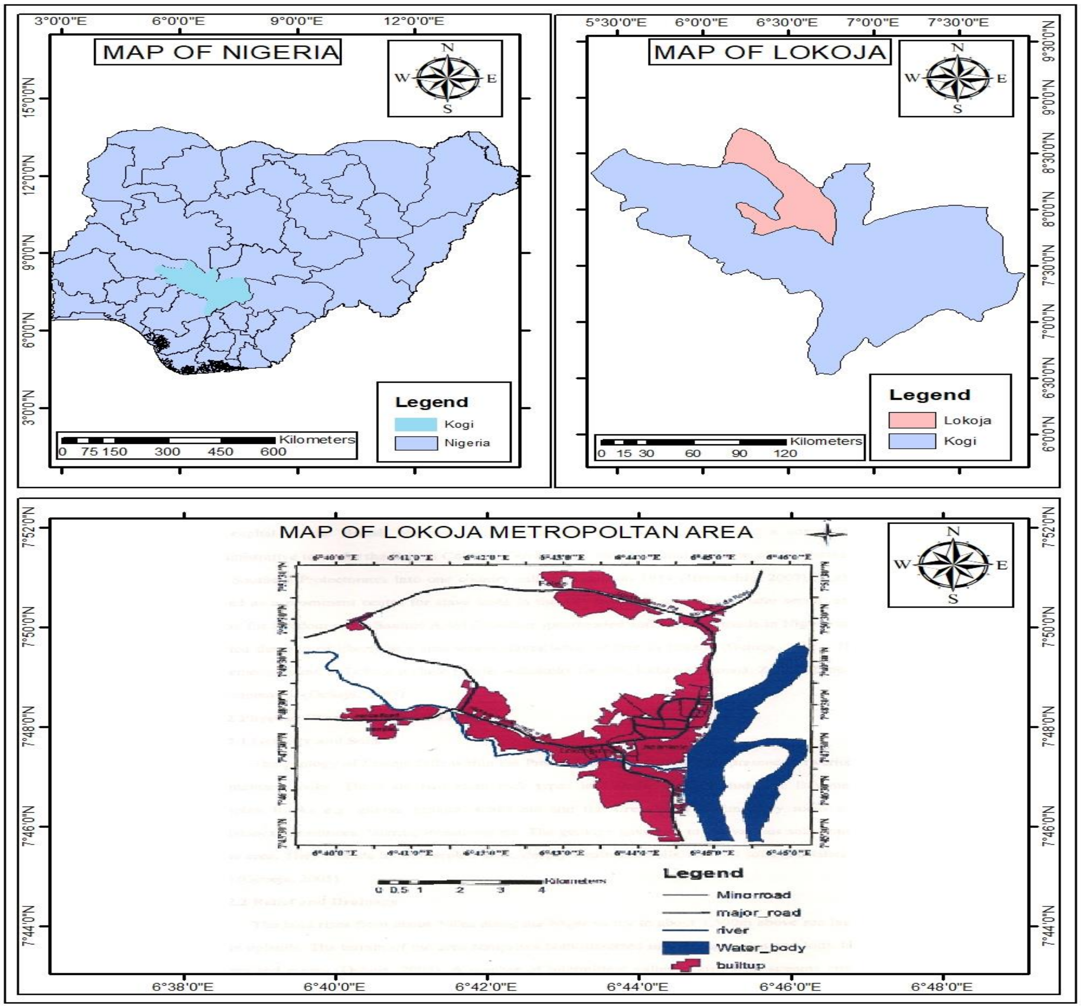

Figure 1: Map of the Study Area

Methods

For this study, Landsat 4-5 TM 1990, Landsat 7 ETM+ 1999, Landsat 7 ETM+ 2009 and Landsat 8 OLI 2019 were all obtained in the same season, and at 30m spatial resolution. The images were obtained from the United States Geological Survey (USGS), Earth Explorer (eathexplorer.usgs.gov), which is part of the United States Department of Interior. The imageries were obtained in the same season in order to minimize seasonal variation effects on the result.

Digital image processing for LULC

The downloaded satellite images for this study were ortho-rectified, georeferenced LIT (terrain corrected) product from source (United States Geological Survey). Radiometric correction was executed on the thermal bands by transforming the digital number (DN) to at-sensor radiance via the raster calculator in Arc GIS alongside the associated metadata present in the header file. Furthermore, the satellite imagery employed was improved using histogram equalization to facilitate image interpretation. The geometric precision was substantiated through the superimposition and comparative analysis with contemporary cartographic representations. The validation of the coordinate system and its projection to UTM zone 32, WGS 1984, Minna Datum was also ascertained.

The supervised image classification methodology was employed, utilizing a false colour composite due to its superior visual discrimination capabilities. The selected colour composite for Landsat 5 TM, 7 ETM+ (comprising bands 4, 3, and 2), and Landsat 8 OLI (encompassing bands 5, 4, and 3) was integrated with training sample sites for the purpose of land cover classification. This composite facilitated enhanced visualization and recognition of Land Use and Land Cover (LULC). The training sites formulated for this investigation were derived from reference data and ancillary information amassed from diverse sources.

Upon the determination of the training sites, the Maximum Likelihood Classification (MLC) algorithm, which has been previously recognized for yielding the most precise results, was employed to classify the LULC. The five categories of LULC identified include built-up areas, bare surfaces, forest regions, water bodies, and shrubland (Table 1). The satellite imagery was processed utilizing the ERDAS Imagine 2014 software.

Table 1: Land Use/Land Cover classes.

LULC Classes	**Description**
Built up areas	This encompasses all urbanised lands including those used for residential, administrative, educational, industrial and commercial purposes.
Bare surface	It encompasses any open grounds that are neither vegetated nor built-up, un-tarred roads and footpaths. It also includes sand bars on the river.
Forest	This is made up of forest
Water body	All aqueous surfaces, including but not limited to: fluvial systems, tributaries, lentic bodies, and reservoirs.
Scrub	Made up of Shrub lands and agricultural land.

The overall accuracy was measured by calculating commissions and omission errors in the error matrix. Also, the Kappa coefficient was computed to illustrate the discrepancies between the agreement and reality changes. In order to assess the accuracy of the satellite images from 1990 to 2019, 100 random points were constructed for each image using the ERDAS Imagine software.

Year	1990	1999	2009	2019
Accuracy	69.48	75.09	72.05	76.37
Kappa statistics	0.6170	0.6903	0.6712	0.7035

Normalised Difference Vegetation Index (NDVI)

A common tool for detecting variations in vegetation health and characteristics is the NDVI, a spectral vegetation indicator that is obtained using remote sensing. The NDVI can estimate the state and changes of vegetation due to the index being related to photosynthetically active radiation (Ivanova, et al., 2019). NDVI works on the principle that healthy vegetation has low reflectance in the visible portions of the ElectroMagneticSpectrum (EMS) due to chlorophyll and other pigment absorption and has high reflectance by the mesophyll spongy tissue of green leaf (Campbell, 1987). Hence, the index is predicted on the observation that RED is very absorptive while NIR is highly reflective in healthy vegetation. Both RED and Near-Infrared (NIR) bands are used to calculate NDVI (Herrero et al., 2020). Thus, mathematically, the NDVI is calculated by dividing the difference between RED and NIR by their total.

$$NDVI = (NIR - RED)/ (NIR + RED)$$

Where NIR represents the spectral reflectance in near infrared band
RED represents red bands (Herrero et al., 2020).

The range of NDVI values falls within -1 to 1. The existence of healthy vegetation is signified by enhanced reflectance within the near-infrared region of the electromagnetic spectrum, yielding NDVI values that span from 0.1 to 1 (Alemu et al., 2024). Conversely, surfaces devoid of vegetation, such as bodies of water, exhibit negative NDVI values due to water's electromagnetic absorption characteristics. Areas covered by bare soil display NDVI values approaching 0, as a consequence of their high reflectance in both the visible and near-infrared sections of the electromagnetic spectrum. (Bid, 2016). For this study, the classification framework outlined below was used to categorise and scrutinise the images. The range of values used in the table was obtained from the NDVI imageries used for this work.

Table 2: NDVI range classification scheme

Vegetation Cover Type	Range of Value	Interpretation
No Vegetation	-1 - 0.00	This are basically the water bodies, built up areas, rock outcrops and bare surfaces
Sparse Vegetation	0.01 - 0.50	Comprises basically of areas with scattered cultivation, grasses and farmlands
Dense Vegetation	0.51 - 0.1	Areas that are highly vegetated, areas like forest, shrubs and fadama regions.

Source: Laboratory Analysis, 2021.

Stated differently, the NDVI is a biophysical metric associated with the photosynthetic capacity of plants. If time series photos are analyzed, this characteristic can yield useful information on the dynamic changes in plant cover. Because of this, the NDVI is a useful tool for predicting dynamic seasonal or sporadic changes in the state of the vegetation (Muavhi, 2021). to investigate the relation between vegetation moderators and built-up areas, multiple regression analysis was employed. Test for significance was carried out at 0.05 probability level. All statistical analysis were done using SPSS version 25.0.

Results

Area-specific Coverage of LULC at different periods

According to the analysis's findings, the total land area was 371.46 km². Table 3 provides a summary of each LULC's percentage and area coverage for 1990, 1999, 2009 and 2019 evaluation periods. In 1990, forest and shrub dominated most of the region covering 153.21km^2 (41.25%) and 181.77km^2 (48.93%) respectively. While bare surfaces covered 6.5km2 (1.75%), built-up areas as well as water covered 13.25km2 (3.57%) and 16.71km2 (4.50%), respectively. (Table 3).

Land use/Land	1990	1999	2009	2019

	Area (km²)	(%)	Area (km²)	(%)	Area (km²)	(%)	Area (km²)	(%)
Shrub	181.77	48.93	192.92	51.94	210.09	56.55	183.11	49.29
Forest	153.21	41.25	135.67	36.52	107.60	28.97	36.82	9.91
Built-up Area	13.25	3.57	15.91	4.28	25.48	6.86	80.21	21.59
Bare Surface	6.52	1.75	5.62	1.51	6.22	1.68	46.45	12.51
Water	16.71	4.50	21.34	5.75	22.07	5.94	24.87	6.70
Total	371.46	100	371.46	100	371.46	100	371.46	100

Table 3: Total Area Covered by LULC classes between 1990 and 2019

Shrubland accounted for the largest portion of LULC in 1999, rising somewhat to 192.92km2 (51.94%). The area covered by forest and bare surface decreased to 135.67km^2 (36.52%) and 5.62km^2 (1.51%) respectively, whereas the aerial coverage of built-up area and water slightly increased to 15.91km^2 (4.28%) and 21.34km^2 (5.75%) respectively. Shrub area, built-up area, bare surface and water all increased in 2009 (210.09km^2, 25.48km^2, 6.22km^2 and 22.07km^2 respectively) while forest area decreased significantly to 107.60km^2. The LULC result for 2019 experienced the most significant change as a result of increased urban activities. Coverage area of Built-up area, bare surface and Water increased significantly to 80.21km^2, 46.45km^2 and 24.87km^2 respectively. On the contrary, the area covered by shrub and forest decreased tremendously, accounting for 183.11km^2 (49.29%) and 36.82km^2 (9.91%) respectively (Table 3 and Figure 2). This is in accordance with a study by Alemu at el., (2024) where it was discovered that shrubs and forest decreased significantly between 1985 and 2024 in the Amhara region of Ethiopia.

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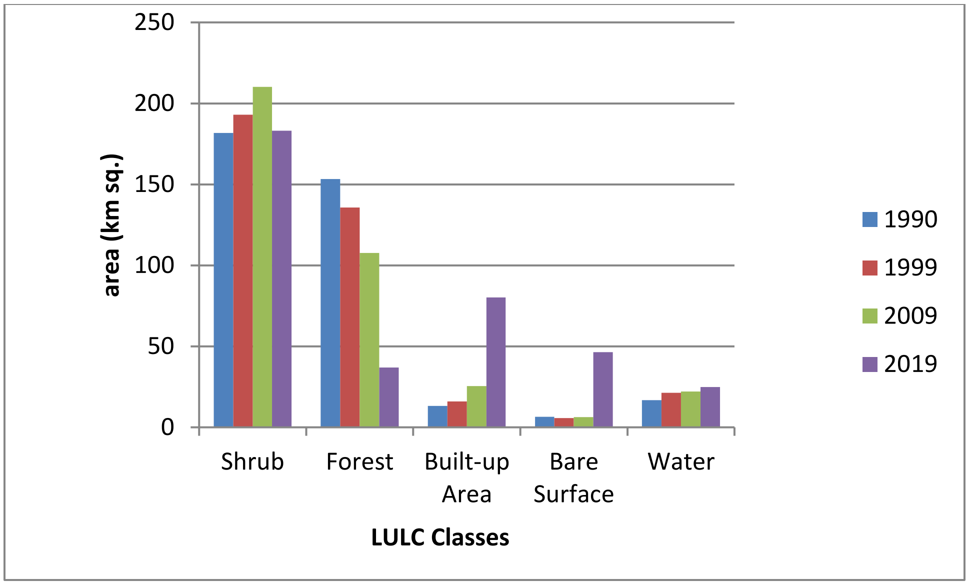


Figure 2: Area coverage of LULC

Pattern of Land Use/Land Cover (LULC) changes

A summary of the spatial and temporal changes of each Land Use and Land Cover for all the epochs studied are presented on Table 4 and Figure 3. There has been considerable variation in LULC change rate over these years. Considering the pattern of changes in LULC from 1990-1999, water changed the most as it increased by 27.71% at 2.7%/year. This was followed by built-up area and shrubs as they increased by 20.08% (2.74%/year) and 6.13% (0.67%/year) respectively. In contrast, forest area showed a reverse trend, reducing by 11.45% (1.40%/year) while bare surface diminished by 13.80% (1.01%/year) (Table 4). From 1999 to 2009, the area covered by built up areas grew by 60.15%, bare surface increased by 10.68%, shrub by 8.90% and water also increased slightly by 3.42%. Conversely, forest continued to decline as it decreased by 20.69% at a rate of 4.0%/year from 1999 to 2009. Scrubland eventually began to experience decline from 2009 till 2019 as it decreased by 12.84% while forest also witnessed decline by 65.78%, whereas, built-up areas, bare surfaces and areas covered by water experienced increment in multiple folds (Table 4)

Table 4: Pattern of Land Use/Land Cover change

LULC	1990-1999		1999-2009		2009-2019		1990-2019	
	(km²)	(%)	(km²)	(%)	(km²)	(%)	(km²)	(%)
Shrubs	11.15	6.13	17.17	8.90	-26.98	-12.84	1.34	7.62
Forest	-17.54	-11.45	-28.07	-20.69	-70.78	-65.78	-116.39	-75.99
Built-up Area	2.66	20.08	9.57	60.15	54.73	214.80	66.96	505.5
Bare Surface	-0.9	-13.80	0.6	10.68	40.23	38.46	39.93	612.43
Water	14.63	22.71	0.73	3.42	2.8	12.69	8.16	48.83

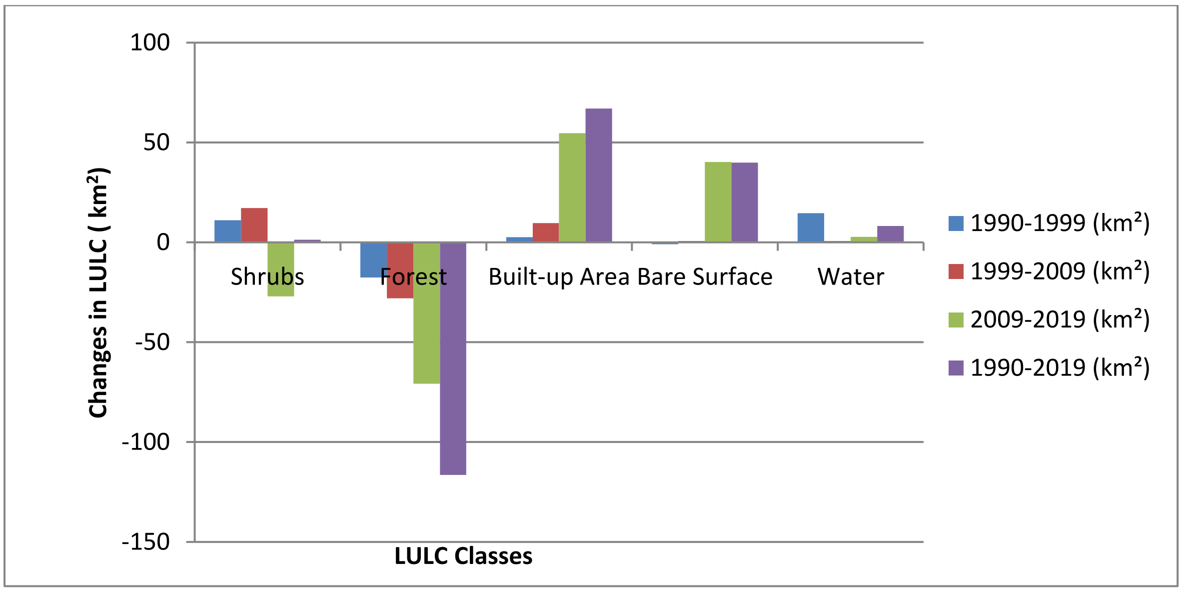


Figure 3: Changes in LULC from 1990 to 2019

The pattern of change generally indicated more vegetated lands are continuously cleared and built upon indicating that built-up area and bare surfaces continued to increase at the expense of forest and shrubs. From 1999 to 2019, forest areas decreased significantly by 116.29km^2 (76%) while built-up area and bare surfaces increased by 66.96km^2 and 39.93km^2 respectively. Even though shrub area only started to decline in 2009, analysis has shown that it slightly gained 1.34km^2 from 1999 – 2019, water also gained 8.16km^2 in the same period.

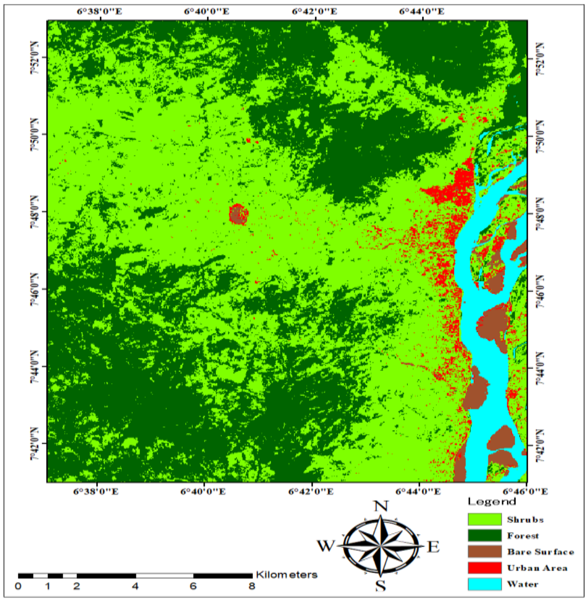
Therefore, the study's findings showed a number of changes in LULC during a 30-year period (1990 - 2019) in Lokoja. The findings demonstrated that built-up areas have expanded significantly while more land is still being cleared for urban expansion and logging. As a result, majority of the forest areas and shrublands have changed into other Land use types and witnessed drastic decline. The expansion of built-up areas at the expense of forest cover was found to be consistent with LULC changes reported by Dangulla, et al., (2023).

Table 5: Annual Change (Percentage %)

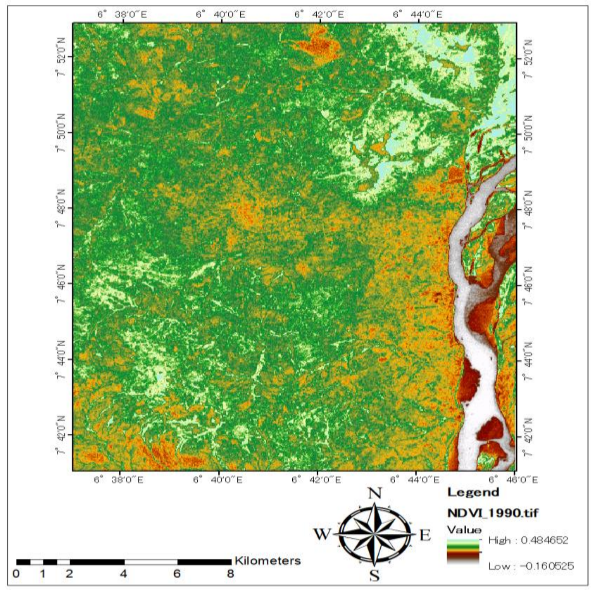
LULC	1990 - 1999	1999 - 2009	2009 - 2019
Shrubland	0.67	0.85	-3.49
Forest	-1.40	-4.0	-6.89
Built-up Area	2.74	3.63	12.38
Bare Surface	-1.01	1.06	64.71
Water	2.7	0.34	1.2

Normalized Difference Vegetation Index (NDVI) dynamics

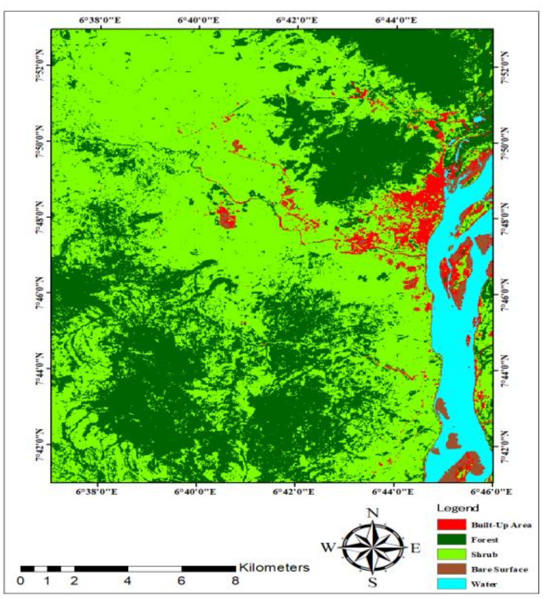
The NDVI analysis showed that NDVI values have declined over the four periods under study. During the 1990s, the quality of vegetation was high with the lowest NDVI value of -0.16. The blue areas indicate regions with high NDVI values. The central and northern parts of the map are predominantly blue, meaning they had dense and healthy vegetation in 1990 (Figure 3b). The areas around Lokoja and Adavi showed a mix of green and blue suggesting moderate to dense vegetation in these regions. The red areas around the western part of the map which corresponds with urban areas and barren lands indicate low NDVI values. It signified poor vegetation cover or no vegetation at all. In 1999, the western regions of the study area, denoted by red, had the lowest NDVI values (-0.3) (Figure 3d). These areas are the developed areas and bare lands around the river with minimal vegetation. Central areas especially around Lokoja metropolis and Adavi had moderate vegetation cover with a value of about 0.4. Healthy and dense vegetation was recorded in the northern and eastern regions, having a value of 0.7. The analysis of 2009 NDVI map showed that areas with high vegetation density and high vegetation health reduced as the highest NDVI value was 0.49, areas with poor vegetation health (-0.5) became more extensive while areas with moderate and healthy vegetation (0.2) reduced indicating increased urbanization and deforestation. NDVI map of Lokoja in 2019 (Figure 5b) clearly shows a noticeable decline in vegetation health from 2009 to 2019. Central areas of Lokoja had a low value of -0.92 indicating sparse and unhealthy vegetation. Areas along the River Niger also showed significant red shades indicating very low vegetation cover, most likely due to the presence of water and bare surfaces. Similarly, the eastern and southern areas as well as the northern have shown more red and yellow colors compared to 2009 map, indicating a decrease in vegetation health and density as a result of increased human activities, deforestation and other environmental factors.



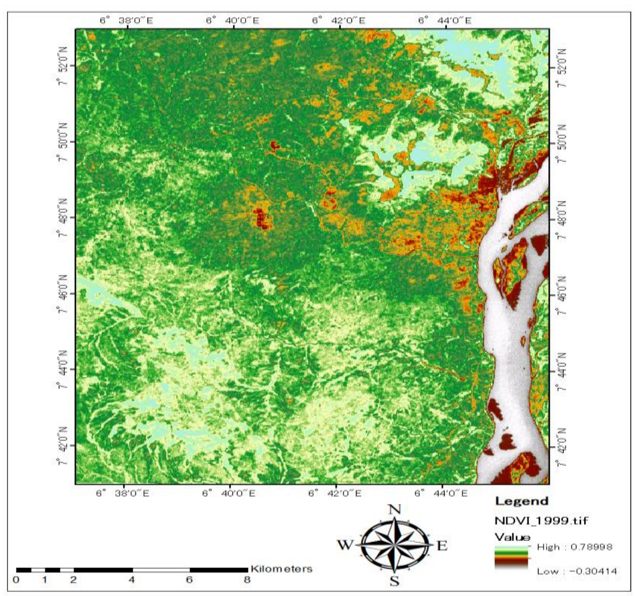
(a) LULC 1990



(b) NDVI 1990

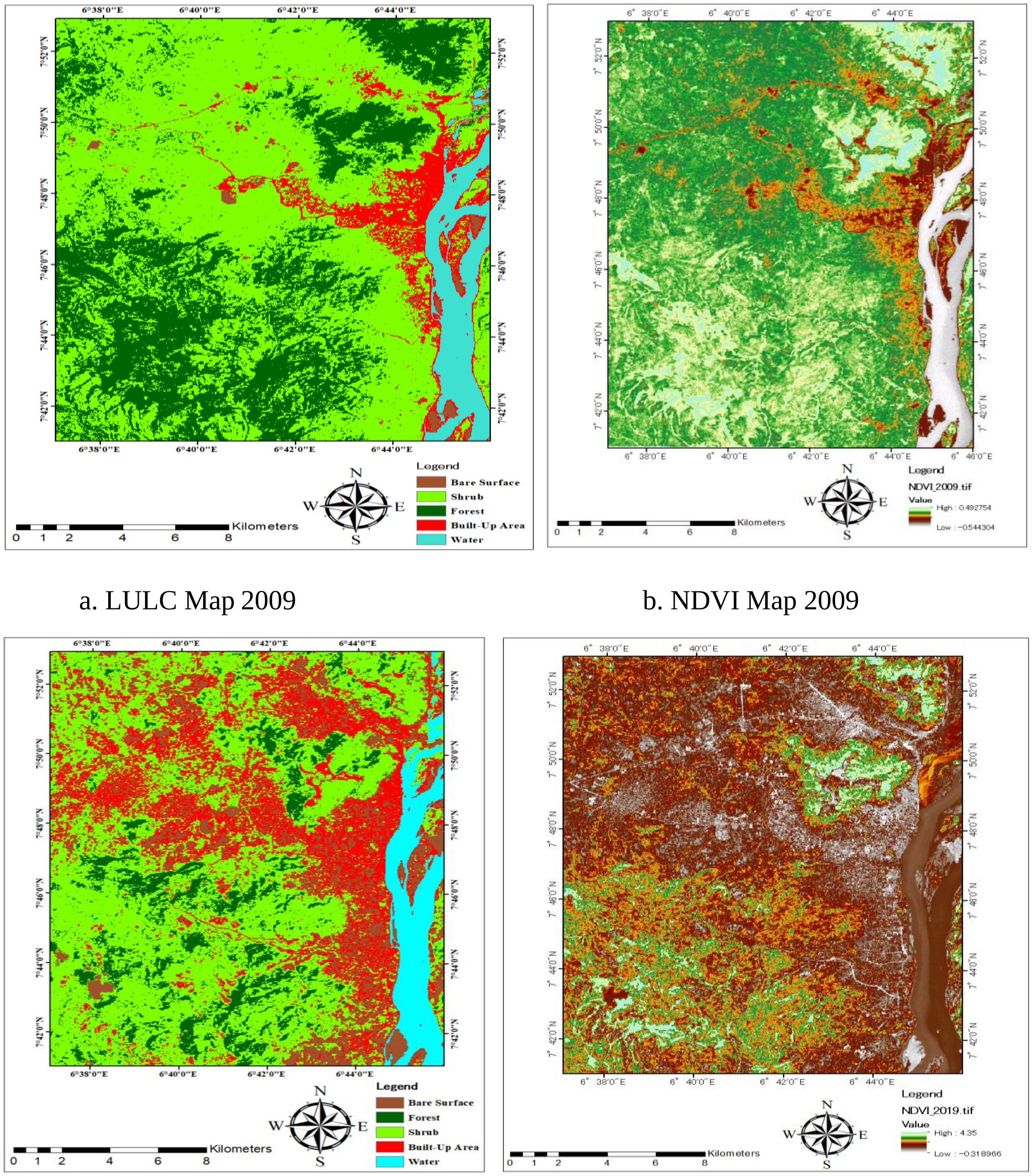


(C) LULC 1999



(d) NDVI 1999

Figure 4; Maps showing LULC changes and NDVI in different years



a. LULC Map 2009

b. NDVI Map 2009

c. LULC 2019

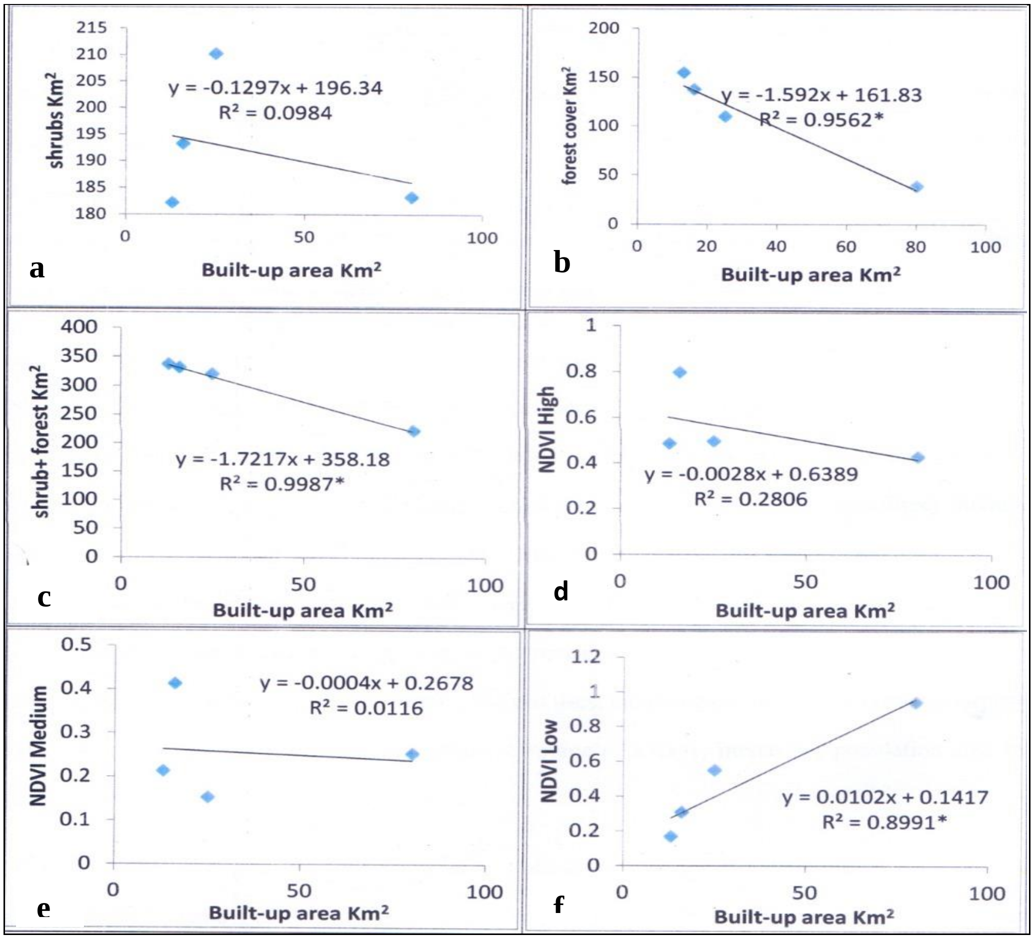
d. NDVI Map 2019

Figure 5: Maps showing LULC changes and NDVI in different years

Relationship Between Urban Expansion and Vegetation

The Land Use and Land Cover (LULC) analysis has shown considerable rise in the extent of built-up areas over the studied periods, resulting in a reduction in vegetation cover, namely shrubland and woodland. The scatter plots derived from the regression analysis, depicted in Figure 6b, demonstrated a highly significant negative correlation ($R^2 = 0.9562$) at a 0.05 level of significance between built-up areas and forest cover. This suggests that as the city expands, there is a substantial reduction in vegetation. Additionally, Figure 6a shows that there was a rather weak linear correlation seen between the built-up area and shrub coverage ($R^2 = 0.0984$, < 0.05). Nevertheless, there was a highly significant association ($R^2 = 0.9897$, < 0.05) between the total area of forests and shrubs and the extent of built-up regions (Figure 6c). This suggests that with the expansion of built – up environment, there is a substantial drop in shrublands and forest areas, combined.

Nevertheless, Figure 6f clearly shows a strong positive linear correlation between the built-up areas and low NDVI values (R2 = 0.8991, $p > 0.05$), whereas a marginally negative linear relationship is observed between the built-up area and high NDVI values (0.2806). A weak positive correlation is shown between medium NDVI values (R2 = 0.0116, $p > 0.05$) and built-up areas, suggesting that as the built-up area rises, there is a minor and inconsequential increase in medium NDVI values (Figure 6e). Overall, the total amount of plant cover loss and the total areas covered by shrubs and forest is clearly and highly correlated with growth There is a moderate to significant correlation between high and low NDVI values and built-up regions. Low NDVI values rise and high NDVI values fall as the built-up areas grow. Furthermore, there is a little link between the extent of shrub covering and medium NDVI values with the built-up area.



r- Value significant at 0.05 level

Figure 6: Relationship between vegetation moderators and built-up area

Discussion

From the analysis on the LULC maps (Figure 4a and 4c, Figure 5a and 5c), it is clear that the vegetation cover of Lokoja has shrunk significantly between 1990 and 2019. Conversely, the built up areas, barren surfaces and water-covered regions increased greatly. In 1991, Kogi State was created, and as the administrative capital of the State, Lokoja witnessed massive influx of people from neighbouring States like Benue, Kwara and Niger States. Prior to this time, as shown on the LULC map of 1990 (Figure 4a), Lokoja was in an early stage of growth as urbanization was yet to intensify. Urban development was limited and scattered all over the town with most of these developments concentrated along transportation routes, historical settlements and near the river confluence. In addition, the prominence of vegetation cover (forests and scrublands) and water aligns with Lokoja's role as a riverine city and these ecosystems supported biodiversity and local livelihoods such as agriculture and fishing. Between 1990 and 2019, built up areas have continued to increase and this increase is attributed to the swiftly growing population of Lokoja and then increased urban growth leading to the rise of construction of structures for various purposes. This is in line with the findings of Ifatimehi et al., (2020) as it was stated that built-up areas in Lokoja increased 2667.6% between 1987 and 2001.

Since the 1900s, urbanization has spread around the world, impacting every region (Dangulla et al., 2023). The reason has been attributed to the global urban population growth and in particular, migration of people to urban centres (Dangulla et al., 2023). Urban growth and the rise in infrastructural developments to cater for the population growth also accounted for the slight decrease of 13.8% for bare surfaces between 1990 and 1999 in Lokoja. However, since 1999 bare surfaces have continued to increase as vegetated lands are constantly being cleared and fenced for infrastructure development. In addition, some of these lands are neither used for urban development of agricultural purposes, rather the land owners await increase in land values so that they can make more profit when the lands are sold. The increase in agricultural areas and shrubland between 1990 and 2009 was brought on by the need to grow more food crops to feed the teeming population. The work of Ifatimehin and Ufuah (2006) further corroborate this finding as it was reported that cultivated land increased by 109.6% between 1987 and 2005.

The changes in the extent of coverage of the other LULC were at the detriment of vegetation cover. In order to provide space for homes, infrastructure, and commercial activity, this population boom has made it necessary to turn vegetated lands into built up areas. As a result, vegetation cover has decreased as built up areas have grown. From 2009 to 2019, the entire vegetation cover of Lokoja (forest and scrubland/agricultural land) experienced massive decline attributed to the massive clearing of lands for the development of numerous urban facilities and infrastructure such as the Specialist hospital, Federal University, ultra-modern international market, access roads and so many others. According to Hussein et al., (2024), vegetation cover decreased by 2.7% between 2000 and 2021 in Punjab, Pakistan as vegetation/forest areas were converted to built-up areas and roads. Molla et al., (2024) emphasized that the conversion of agricultural land and forest for urban and infrastructure reasons has been associated with significant vegetation loss, posing great danger to the surrounding environment.

From the analysis of the NDVI maps from 1990, 1999, 2009 and 2019, the results revealed the distinct trends and significant changes in vegetation health during these periods. These results reflect both natural and anthropogenic factors that have influenced vegetation in Lokoja and its environs. In 1990 (Figure 4b), the eastern and southern parts of Lokoja exhibited high NDVI values, indicating dense, healthy vegetation. This was because of the low level of urbanization and human activities at that time; hence, natural forest and grassland ecosystems remained relatively untouched as urban development was mainly around the town. Gradually, urban infrastructure started to be developed after Kogi State was created in 1991, thereby encroaching on vegetated areas. By 1999, only pockets of dense vegetation that persisted in the southern and remotes areas had high vegetation health (NDVI values). Fragmentation began to emerge due to agricultural activities, deforestation and urban sprawl, formerly vegetated areas were encroached into leading to the reduction and division of large, continuous vegetated areas.

Accelerated rate of urbanization with increased settlement and infrastructure development continued till 2009 which led to the massive conversion of vegetation to farmland and bare surfaces for construction. Isolated patches of forest appeared scattered in the south eastern parts which were either inaccessible or in protected areas. This accounted for the significant expansion of low NDVI areas around the town, the River Niger and northern area. Low vegetation health that has continued to exist in the centre, as well as the western areas of Lokoja, its surroundings and the riverine areas has been as a result of urban sprawl which was at its peak in 2019. Therefore, urbanization is a major factor influencing vegetation changes in Lokoja. Lokoja's growth as a regional capital has spurred significant land conversion for settlements, roads, and industry. The expansions of these urban areas have consistently reduced the vegetation, and reflected in lower NDVI values over time. High rates of population growth and economic activity have led to the expansion of farmland, shifting cultivation, increased logging and over exploitation of land which have further degraded vegetation health.

The relationship between NDVI data and LULC analysis provides a full understanding of how human activities and natural processes affect vegetation health. Urban growth frequently results in reduced plant cover and more impermeable surfaces, resulting in lower NDVI values. The weak negative correlation seen between shrubland and built-up areas suggests that while the increase in the areas that are developed has caused loss of shrublands, its impact is not so pronounced. Scrubland and agricultural lands persists around Mount Paati and in the urban fringes such as the Adavi area and Ajaokuta area where massive farming activities are carried out. Remnants of vegetation are also present within the town particularly on vacant lands where residents now practice subsistence agriculture. The significant negative relationship between forest cover and built up areas reflects the fact that urban expansion has significantly reduced forest cover. The relatively flat terrain of the forest areas, accessible lands and the presence of infrastructure in the north and west regions of Lokoja brought about for the expansion of the town in these directions, resulting into massive forest cover loss in those areas. This is in line with the findings of Bunyangha, et al (2021).

Therefore, the results from the scatter diagram aligned with observed LULC changes derived from NDVI maps. Urban growth primarily replaces forests and shrublands, resulting in significant vegetation loss. The increase in low NDVI areas further confirms the degradation of vegetative health because of the rapid growth of the built-up areas. These changes are a result of population growth, infrastructure development, and economic activities that prioritize urban expansion over environmental conservation.

Conclusion and Recommendation

Using NDVI, this study demonstrates a notable change in Lokoja’s LULC between 1990 and 2019 and its implication on vegetation health. The investigation showed the significant reduction in vegetation cover (forests and scrublands) and the increase in developed areas. Forest area decreased from 153.21km^2 (41.25%) in 1990 to 36.82 km^2 (9.91%) in 2019. Scrubland area increased from 181.77 km^2 (48.93%) in 1990 to 210.09 km^2 (56.55%) in 2009 while it decreased slightly to 183.11 (49.29%) in 2019. Built-up area, water and bare surfaces all increased between 1990 and 2019 by 505.5%, 612.43% and 48.83% respectively. The NDVI analysis highlights a progressive decline in vegetation health in Lokoja from 1990 to 2019, largely driven by urbanisation, agriculture, and deforestation. The values in 1990 were significantly higher, representing healthier vegetation, but by 2019 NDVI values had declined, particularly in the central areas of Lokoja and the suburbs, suggesting increased land degradation. These results highlight how urgently sustainable urban planning that minimises vegetation loss is required.

Therefore, this research advocates for integration of green infrastructure and land use zoning within urban development strategies that prioritize the conservation of existing vegetation and incorporate green spaces into the urban landscape. Initiatives aimed at reforestation and afforestation should be given precedence, emphasizing indigenous species to restore ecological equilibrium and enhance long-term vegetation health. Policies designed to mitigate deforestation and combat land degradation must be thoroughly reviewed and rigorously enforced. Regulatory frameworks should mandate that agricultural expansion and construction activities undergo comprehensive environmental impact assessments prior to their execution. Furthermore, public awareness and community involvement should be promoted through campaigns and participatory initiatives that highlight the benefits of vegetation conservation.

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