

## Spatio-Temporal Trends of Urban Sprawl in Lokoja, Kogi State, Nigeria, Using Geospatial Techniques.

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### ABSTRACT

*Lokoja, like many African cities, has been experiencing rapid population growth in recent years due to mass immigration and economic growth. However, the growth is taking place in an unplanned manner creating sprawling, low-density development and uneconomical use of land and environmental resources with adverse effects on the environment. This paper analyzes the spatio-temporal trends of urban sprawl in Lokoja, using geo-spatial techniques. The objectives of the study were to map and quantify land use/land cover changes, determine the rate of urban expansion and examine the pattern of urban sprawling between 1998 and 2018. Landsat images of 1998, 2008 and 2018 of 30m, TM 30m, ETM and 30m OLI resolutions were used for the study. The data obtained is summarized using descriptive statistics. The study found that the built-up areas doubled in size between 1998 and 2008 and almost tripled by 2018 while the city was expanding at 18.73% per annum between 1998 and 2018. The major change in land use land cover was in the vegetation areas which decreased by 96.34% and 91.21% respectively. The characteristic leap frog nature of development results in excessive use of land with dire consequences for the environment. The study recommends the need to monitor urban expansion, ensure strict compliance with the Master plan, land suitability assessments and proper management of land resources to avoid the depletion of natural vegetation and agricultural lands.*

**Keywords:** Changes, geo-spatial, land use, urban sprawl, trend.

### 1. INTRODUCTION

Urban sprawl may be defined as the scattering of new development on isolated tracts, separated from other areas by vacant land (Lata, *et al.* 2001). It has also been described as leapfrog development (Torrens and Albert, 2000). Omole (2000) defined urban sprawl as a formless dispersal of congested urban areas with little or no regard for the inter-relationships of such factors as transportation, employment, health and recreational needs. Urban sprawl is characterized by an unplanned and uneven pattern of growth, driven by a multitude of

processes leading to inefficient resource utilization (Theobald, 2001; Nwafor, 2006).

The rapid expansion of urban areas due to rise in population and economic growth is increasing additional demand on natural resources thereby causing land-use changes especially in cities and towns (Theobald, 2001; Nwafor, 2006). Assessing and monitoring the state of the earth surface is a key requirement for global change research (Committee on Global Change Research, National Research Council, 1999; Lambin *et al.* 2001). Urban sprawl is one of the foremost threats facing agricultural lands in Nigeria (Nwafor, 2006). Sprawl has been criticized

for eliminating agricultural lands, spoiling water quality, and causing air pollution. Other frequently mentioned consequences are green space consumption, high costs of infrastructure and energy, increasing social segregation and land use functional division (Nwafor, 2006). Furthermore, the need to travel, dependence on private cars and consequently increased traffic congestion, energy consumption and polluting emissions are associated with sprawl (Allen and Lu, 2003).

Characterization of urban sprawl is of immense significance considering the profound implications it has for economic efficiency, social equity and environmental sustainability (Theobald, 2001; Nwafor, 2006). The direct implication of urban sprawl is the change in land use and land cover (LULC) of the area involved. Patterns of sprawl can take place either in radial direction, around a well-established city or linearly along the highways (Theobald, 2001). However, the identification of the patterns and analyses of spatial and temporal changes would help immensely in the planning for proper infrastructural facilities. This could be done effectively and efficiently with the help of spatial and temporal technologies such as GIS and remote sensing, along with other ancillary data such as survey data and existing maps (Barnes *et al.*, 2001).

Recent advancement in GIS and Remote sensing tools and methods has enabled researchers to model and predict urban growth more efficiently (Barnes *et al.*, 2001; Akubia and Bruns, 2017). Several modeling approaches have also been developed to model and forecast the dynamics of urban features. According to Akubia and Bruns (2017), Geographic Information Systems and remote sensing methods when used to analyze and assess spatio-temporal dynamics of land-use change and urban expansion, produce information for land use planning and development.

The rapid rate of urbanization being experienced in Lokoja, Kogi State has created serious environmental problems in the form of unguided and uncontrolled expansion without due consideration to interrelated factors such as transport, employment, health and other livable factors. The city is experiencing expansion in all directions resulting in large scale urban sprawl and changes in urban land use. As a matter of fact, Lokoja has significantly grown during the past decades, especially since the creation of the state in 1991 merging with its surrounding settlements, exhibiting several patterns of urban growth. Adeoye (2012) observed that the natural environments (vegetation, wetland resources, water bodies and mountainous terrain) in Lokoja and environs were being threatened, as they reduced in areal extent while the built up areas expanded tremendously. Observations also showed that urbanization processes were majorly responsible for land use/cover changes in Lokoja (Adeoye, 2012). Therefore, there is need to map and monitor the trend of urban sprawl in Lokoja continuously.

Therefore, this study analyzes the spatio-temporal trends of urban sprawl in Lokoja, Kogi State. The specific objectives of the study are to map and quantify land use/land cover changes, determine the rate of urban expansion and examine the pattern of sprawl of urban land uses using spatio-temporal data.

## 2. MATERIALS AND METHODS

### 2.1 Study Area

The study area is located between Latitudes 7° 45'N and 7° 51'N and Longitudes 6° 41'E and 6° 45'E, within the lower Niger- Benue trough in Central Nigeria (see Figure 1). Kogi State is the 20th populous state in Nigeria, with about 129 persons /km<sup>2</sup> and an annual population growth rate of the state of 2.93% per annum (National Population

Commission, 2006). It has an estimated landmass of 63.82 sq. km. (National Population Commission, 2006). It shares common boundaries with Niger State in the northeast, Kwara State in the northwest, Nasarawa State and the Federal Capital Territory to the north, Kogi Local Government Area to the East, Adavi and Okehi Local Government Areas to south and Kabba-Bunu Local Government Area to the south. The major urban settlements are

Felele, Army Barracks, Zango-Daji, Nataco, Phase II, Otokiti village and Ganaja.

The annual rainfall in the area is between 1016mm and 1524mm with a mean annual temperature of about 27°C. Lokoja is drained by the Niger and Benue rivers and their tributaries. The confluence of the Niger and Benue rivers which could be viewed from the top of Mount Patti is located within the study area (Adeoye, 2012). The general relief is undulating and characterized by high hills.

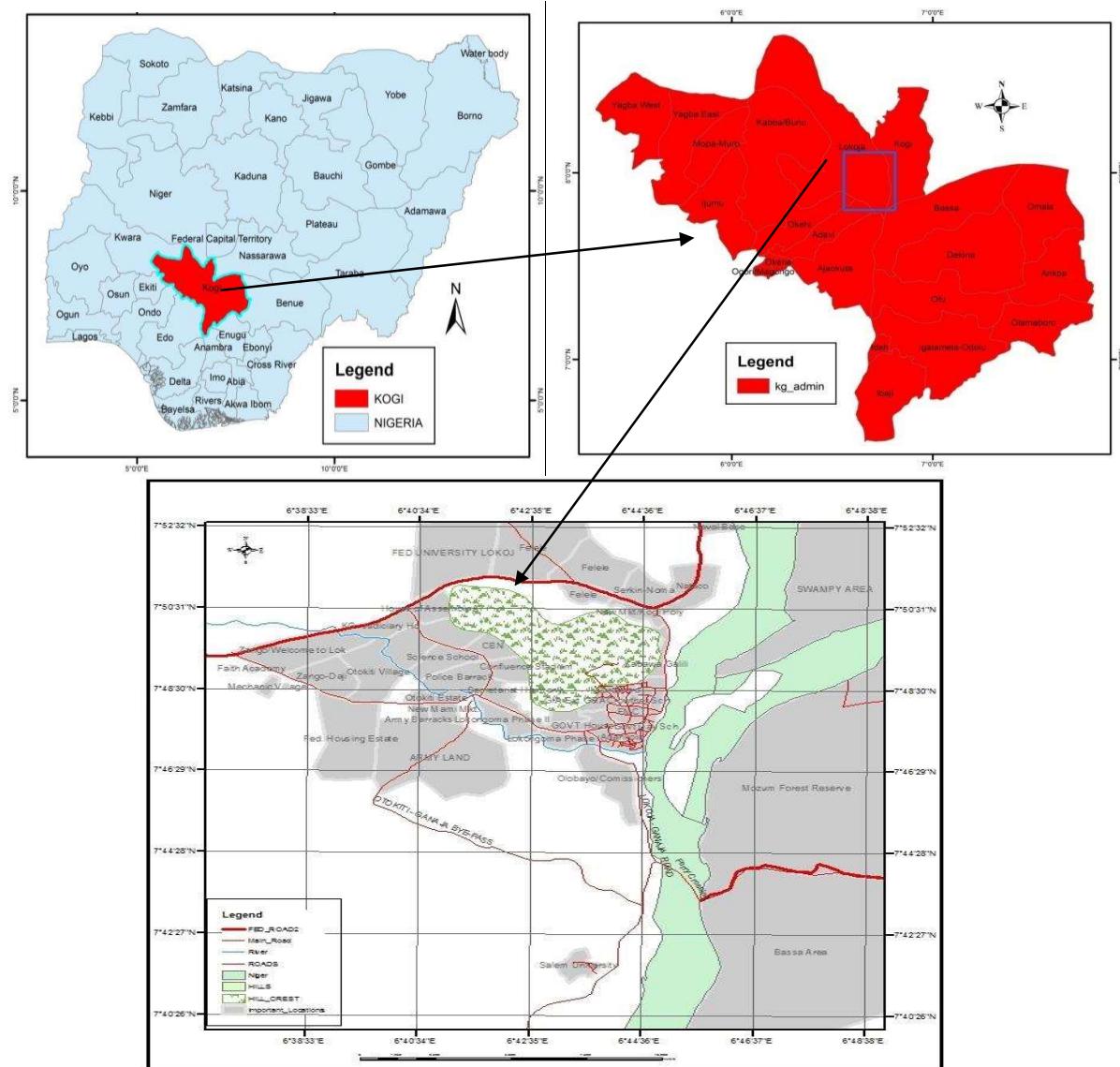


Figure 1: Geographical Location of the Study Area

The Niger-Benue trough is a Y-shaped lowland area which divides the sub-humid zone into three parts. It has been deeply dissected by erosion into tabular hills separated by river valleys. The major means of transportation is by road. However, other means of transport is by water especially when goods are to be distributed to locations that are not motorable. The ecological problems in Lokoja include leaching, erosion and general impoverishment of the soil.

A typical Landsat scene covers an area of about 170km by 185km ([www.usgs.gov](http://www.usgs.gov)), therefore it is required that the area of interest be cut from the entire imagery to simplify analysis and focus on the portion of the scene that is of primary interest. Subset covering the area of interest was extracted from the larger scene of, Landsat TM, Landsat ETM+ and Landsat 8 OLI, using the Clip tool in Arctool box. ENVI 4.5 software was used for the pixel-based classification. Supervised

**Table 1:** Types of Satellite Imageries Used for the Study

S/N	DATA TYPE	DATE OF ACQUISITIONS	RESOLUTION	SOURCE
1.	Landsat image	13 <sup>th</sup> November, 1998	30m TM	USGS
2.	Landsat image	13 <sup>th</sup> November, 2008	30m ETM	USGS
3.	Landsat And operational imager	21 <sup>st</sup> October, 2018	30m OLI	USGS

These problems are compounded by the annual bush burning of the savanna which exposes the top soil to more erosion. The study area is also flood prone during the rainy season, while aridity is a problem to several areas at short distances from the rivers during the dry season. Agriculture serves as the main occupation of the people. Other major land uses in the study area are administrative, educational and commercial. However, the increasing human population and rapid urban development have resulted in modifications of land use pattern in the area (Adeoye, 2012).

## 2.2 Methodology

### 2.2.1 Assessment of Land Use and Land Cover Change (LULC)

The Land use and land cover changes (LULC) in Lokoja between 1998 and 2008 and 2018 was determined using remotely sensed data and GIS for changes of the three time periods. Table 1 summarizes the characteristics of the imageries used for the study.

classification was performed using parallel piped classifier which was employed to categorize the four images into different land cover types, such as built-up areas, bare surface, island, water body and vegetation. The land use classification scheme used for the study is presented in Table 2.

The rate of urban sprawl was determined by comparing the resulting value generated from the classified images of the data set for 1998, 2008 and 2018. The total extent of the sprawl in hectares was divided by the number of years within the period studied (1998 – 2018).

$$R = \frac{E_T}{\text{Numbers of Years}}$$

Where R = Rate of urban sprawl. ET = Total Extent of urban sprawl.

$$\text{To get the Percentage; } R = \frac{E_T}{\text{Numbers of Years} \times 100}$$

**Table 2: Land use Classification Scheme**

<b>Code</b>	<b>Land Use Categories</b>	<b>Description</b>
1	Built-up Areas	Land used for residential , transportation and communication purposes.
2	Water body	Areas covered by body of water (rivers, streams, ponds and dams).
3	Wetlands	Land within the river that is not covered by water.
4	Vegetation	Land covered with natural vegetation that is Predominantly grasses and shrub.
5	Bare surface	Exposed soils, lands devoid of vegetal cover, rock Out crops.

*Source: Modified from Anderson *et al.*, (1976)*

Pattern indicators which include the shape change of built-up area, fragmentation and open space efficiency, was used to determine the pattern of urban sprawl (Theobald, 2001). Data obtained from the study are summarized using descriptive statistics.

### 3. RESULT AND DISCUSSIONS

#### 3.1 Pattern of Land use/ Land cover change from 1998-2018

The results of land use and land cover changes within the study period are presented in Figure 2, 3 and 4 while Table 3 shows the statistics.

The results show a progressive increase in the built-up land use throughout the study period occupying 616.26Ha (0.73%) in 1998, 3,398.39Ha (4.04%) in 2008 and 8,109.49Ha (9.65%) in 2018. This result reflects a rapid population growth and conversion of other land use types such as forest areas to residential and commercial land uses (Adeoye, 2012).

Water body, which occupied 5,328.44 Ha (6.34%) in 1998 decreased to 4,436.28 (5.28%) in 2008 and 6,483.38 (7.71%) and 2018 respectively. The area occupied by wetlands increased from 348.99Ha (0.42%) in 1998 to 1,378.70Ha (1.64%) in 2008 but decreased again in 2018 to 517.01Ha (0.62%). There is a major change in areas occupied by vegetation land use as the land

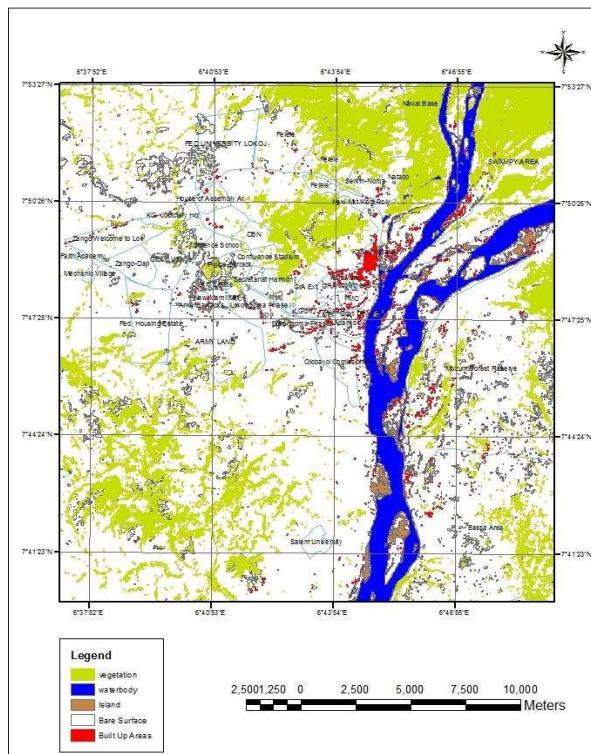
use decreased from 73,415.34 Ha in 1998 to 70,628.26Ha in 2008 and 64,886.771Ha in 2018.

Bare surfaces decreased progressively from 4,373.62Ha (5.20%) in 1998 to 4,241.02Ha (5.04%) in 2008 and 4,085.99Ha (4.86%) in 2018. This could be due to the conversion of bare surfaces to built-up areas or quarrying in some parts of the study area, which reduced the areal extent occupied by rock outcrops.

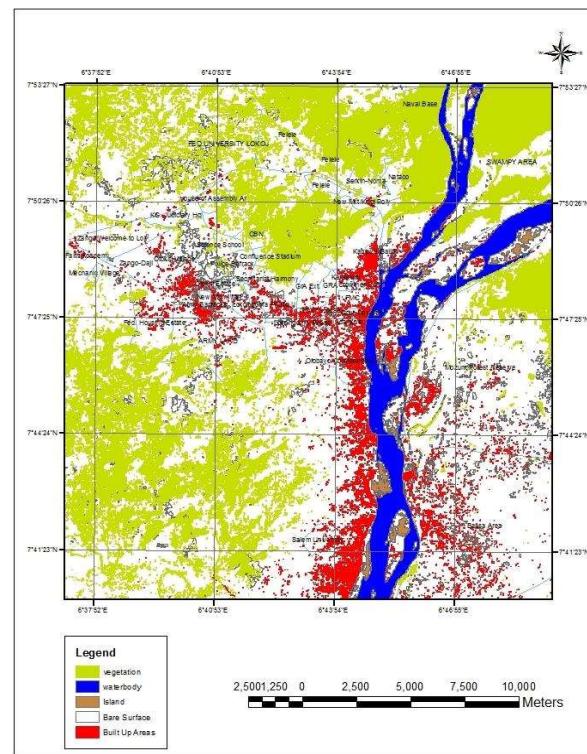
#### 3.2 Extent and Rate of Urban Sprawl in the Study Area

The extent and rate of urban sprawl in Lokoja is presented in Figure 5 (a, b, and c) and Table 4.

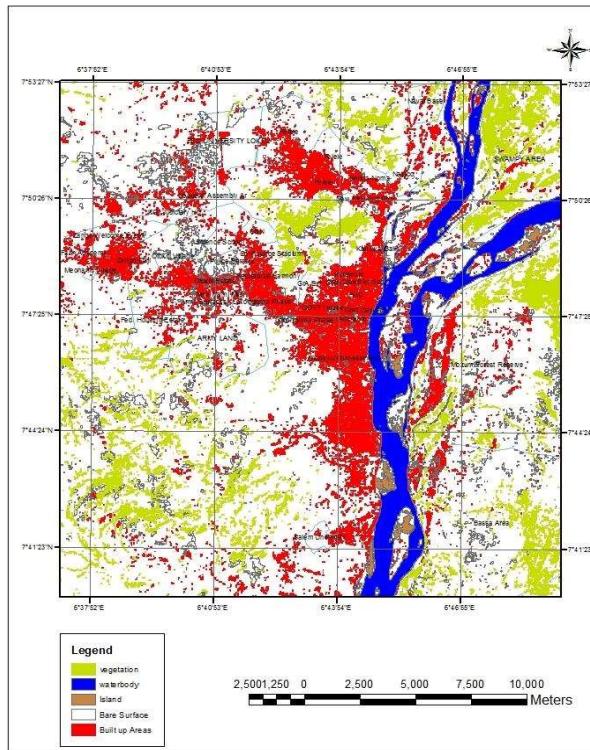
The results showed an overall urban land sprawl of 1,215.92 hectares, at an annual rate of 15.48% within the period studied. As indicated in Figures 5 (a, b and c), major areas like Phase II, Barracks and Otokiti Village started out as linear settlements along the Lokoja - Kabba road which is a major road. However, the urban sprawl extended eastward and westwards from the central business district. The implication is that, some land use/land cover types such as vegetation areas have been and are still being converted to residential and commercial land uses (Adeoye, 2012). In 1998 the pattern of



**Figure 2:** Land use/land cover map (1998)



**Figure 3:** Land use/land cover map (2008)



**Figure 4:** Land use/ land cover map (2018)

Table 3: Land use and Land Cover Changes

Land use	1998 (Ha)	%	2008 (Ha)	%	2018 (Ha)	%
<b>Built up</b>	616.26	0.73	3,398.39	4.04	8,109.49	9.65
<b>Water body</b>	5,328.44	6.34	4,436.28	5.28	6,483.38	7.71
<b>Wetlands</b>	348.99	0.42	1,378.70	1.64	517.01	0.62
<b>Vegetation</b>	73,415.34	87.31	70,628.26	84	64,886.77	77.17
<b>Bare surfaces</b>	4,373.62	5.2	4,241.02	5.04	4,085.99	4.86
<b>Total</b>	<b>84,082.65</b>	<b>100</b>	<b>84,082.65</b>	<b>100</b>	<b>84,082.65</b>	<b>100</b>

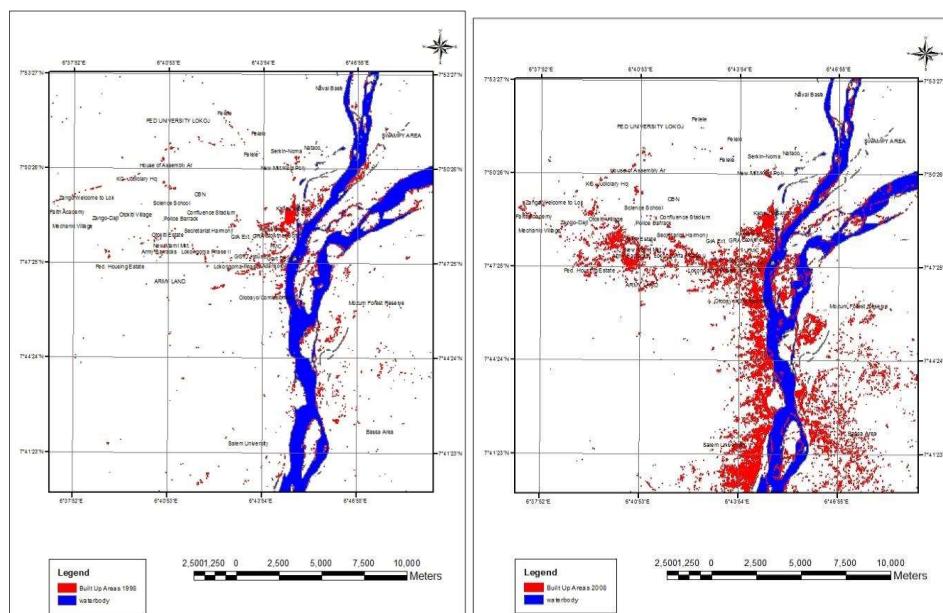
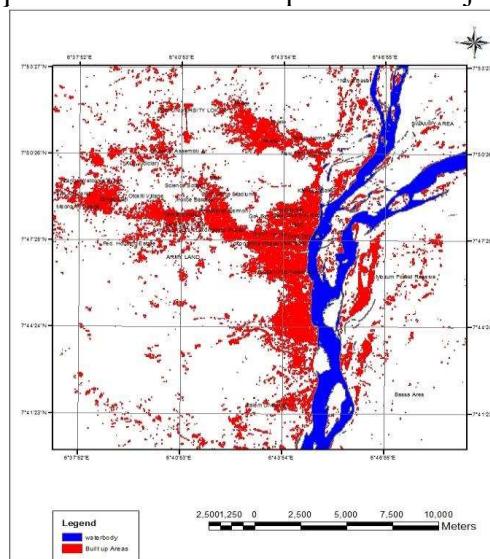


Figure 5: (a) Spatial extent of Built-up area in Lokoja 1998 (b) 2008



(c) 2018

**Table 4:** The Extent and Rate of Urban Sprawl

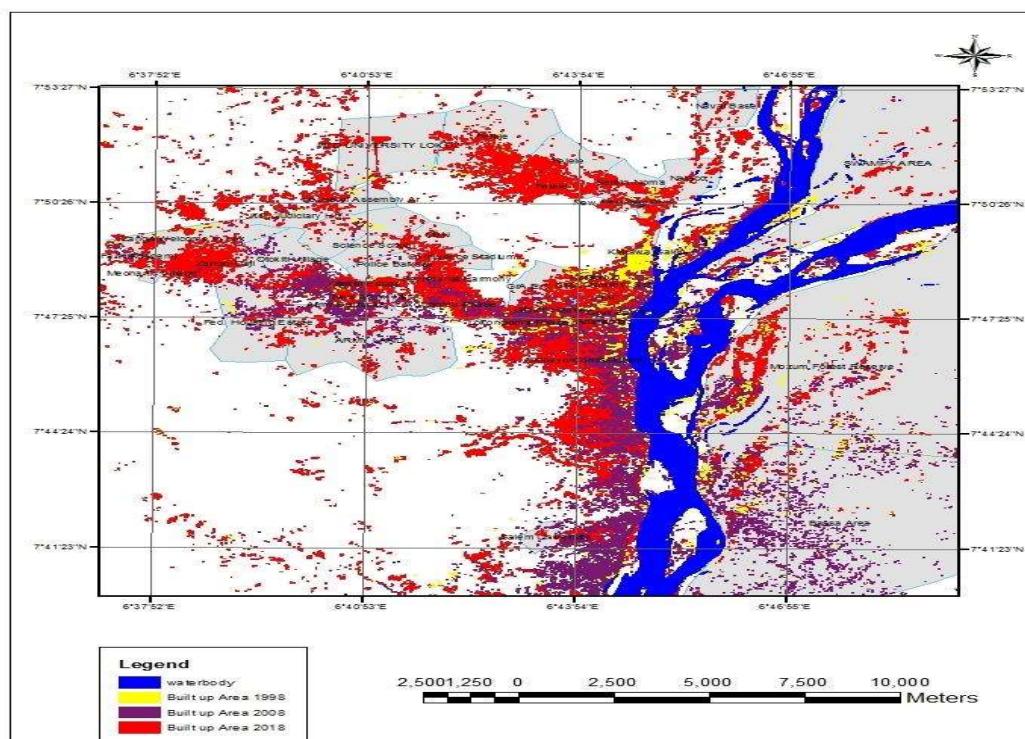
Urban Period	Year	Hectares	Extent of Urban Sprawl		Rate of Urban Sprawl	
			(Ha)	%	Ha/Year	%/Year
1998-2008 (11yrs)	1998	616.26	2,782.13	451.45	252.92	22.99
	2008	3,398.39				
2008-2018 (11yrs)	2008	3,398.39	4,711.1	138.63	428.28	38.93
	2018	8,109.49				
1998-2018 (22yrs)	1998	616.26	7,493.23	1,215.92	340.60	15.48
	2018	8,109.49				

pattern of urban expansion (Adeoye, 2012; Barnes *et al.*, 2001).

The extent of urban sprawl was derived from the overlay analysis of the sub-sets of the three classified imageries of the built-up areas of the study area for the periods (Figure 6). The results showed three patterns of urban expansion; extension, linear and leapfrog.

The period between 1998 and 2018 had the highest rate of urban expansion which could

be attributed to the fact that it was the period within which the Lokoja 16km radius master plan was established. The extent of urban sprawling shown by this study may be attributed to high cost of residential houses which low income Lokoja residents can not afford and are forced to seek alternative residence in Zango, Ganaja village and felele because of its proximity to Lokoja (Adeoye, 2012; Barnes *et al.*, 2001).

**Figure 6:** Spatial extent of urban sprawl (1998 - 2018)

#### 4. CONCLUSION AND RECOMMENDATIONS

This study analyzed the spatio-temporal trends of urban sprawl in Lokoja, Kogi State. The results from this study revealed that major changes were in the vegetation, build-up areas and bare surfaces land uses. The results show a progressive increase in the built-up land use throughout the study period occupying 616.26Ha (0.73%) in 1998, 3,398.39Ha (4.04%) in 2008 and 8,109.49Ha (9.65%) in 2018. This reflects a rapid population growth and conversion of other land use types such as forest areas to residential and commercial land uses. The results showed an overall urban land sprawl of 1,215.92 hectares, at an annual rate of 15.48%

There is therefore need to monitor urban expansion, ensure strict compliance with the Master plan, carry out proper land suitability assessments and proper management of land resources to avoid the depletion of natural vegetation and agricultural lands.

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