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An assessment of spatial pattern of urban sprawl in JOS metropolis of plateau state, Nigeria: Using remote sensing and GIS techniques

BOYI MAIRIGA [1,*], Murna Joy Dawarga [2], Mustapha Yusuf [2], Taimanda Keren Ezekiel [2], Frichi Bilham [2] and Kabati Danjuma Madaki [2]

[1] *Zonal Advanced Space Technology Applications Laboratory (ZASTAL), P.M.B 47, Pajat, Langtang North, Plateau State, Nigeria.*
[2] *National Centre for Remote Sensing (NCRS) ,P,M,B 2136,Jos Rezek Village after Laminga Golf Club Fobur Road,Jos-East L. G. A. Plateau State, Nigeria.*

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Abstract

In Jos metropolis, urban sprawl debate has closely paralleled on urban growth trends over the past few decades. These studies indicate that it is the pattern, types, density and rate of new urban growth that creates the appearance of sprawl. Population dynamics are often cited as a driving force behind urban sprawl. This paper uses Geographic Information Systems (GIS) mapping and land cover change analysis, neighbourhood statistics, cross change detection techniques, field work on Urban sprawl areas in Jos metropolis. The paper also highlights the characteristics, types, rates, pattern and density of sprawl to examine the spatial pattern of sprawl in Jos North and Jos South. Linear sprawl pattern can only be visually seen by the road, the roads in Jos play important role in linear pattern of urban sprawl formation through road data, it helped to visualize clearly the areas of linear sprawl in Jos metropolis. An example can be visually seen in Naraguta area, part of a large high residential development of Jos north. Cluster types of urban sprawl settlement development in Jos metropolis. From the map, it shows that cluster types of sprawls in study area are found in the core city of Jos metropolis like Jos city and Bukuru in the study area. Cluster type of urban sprawl also appeared to grow out of what was once a leapfrog pattern of development in some area in the study area. Leapfrog patterns of urban sprawl appeared to be somewhat disconnected from other areas of existing developed settlement land. Leapfrog types of urban sprawl in Jos metropolis can be seen in Kuru North, Dan Miangu, Barakin Kuru and Kuru Hills.After the map of the densities urban sprawl for new growth areas has been created. The study reveals that settlement area has increase from 125.45 to 208.16 sq.km between 2002-2022 in twenty years period. It also revealed that water bodies have also drastically reduced by 3.33 sq.km and open space land use contributed about 127.57 km2 land converted to settlement within the time under study. Further analysis reveals that the urban settlement land of the area increased approximately 82.71 km2 in the twenty years' time period of the study (2002 to 2022). Next, the patterns of urban expansions were analyzed by using mapping capabilities within the GIS and neighborhood statistics in order to show the density and connectivity of patches of new growth. Based on the density and connectivity of new growth areas, the patterns of growth were classified as: linear along highways, cluster, and leapfrog. The threshold densities are; 0 to 2000 as 30-meter pixels per km2 for low density, 2000 to 25000 for medium density, and 25000 to 130000 for high density. The results indicate that Jos metropolis did experience an increase in urban growth from 2002 to 2022 and that urban growth in the study area can be classified as urban sprawl. The density of new development is more in Jos North, but the pattern and character with which development has occurred in Jos North is synonymous with sprawl in Jos South. the type, rate and patterns of urban expansions were analyzed by using mapping capabilities within the GIS and neighborhood statistics in order to show the density and connectivity of patches of new growth in the study area.

* Corresponding author: BOYI MAIRIGA.

Keyword: Sprawl Rate; Sprawl type; Sprawl pattern; Sprawl density; Land use Land cover

1. Introduction

As urban growth occurs, that growth is often confused with urban sprawl. However, there is a distinction between urban growth and urban sprawl [1]. Cities often experience growth either physically, by population, or by a combination of both. Urban sprawl is much more complicated because it may or may not qualify as urban growth. How a city grows can create the appearance of urban sprawl. Such urban growth may appear as a low-density leapfrog pattern, a linear or strip development pattern along highways, or a tightly condensed pattern of new development around pre-existing built-up landscapes [16]. Without urban growth there would be no appearance of urban sprawl [2].

Urbanization is the process by which large numbers of people become permanently concentrated in relatively small areas, forming cities. Internal rural to urban migration means that people move from rural areas to urban areas [11]. In this process the number of people living in cities increases compared with the number of people living in rural areas. Natural increase of urbanization can occur if the natural population growth in the cities is higher than in the rural areas. This scenario, however, rarely occurs. A country is considered to urbanize when over 50 per cent of its population live in the urban areas [23].

Urbanization is spatial concentration of people who are working in non-agricultural activities. The essential characteristic here is that urban means non-agricultural. Urbanization can also be defined as a fairly complex concept. Criteria used to define urbanization can include population size, space, density, and economic organization. Usually, however, urban is simply defined by some base line size, like 20, 000 people. Any way this definition varies between regions and cities [22].

[7] defines urban sprawl as "the scattering of new developments on isolated tracts, separated from other areas by vacant land." [12] characterizes urban sprawl as "leapfrog land use patterns, strip commercial development along highways, and very low-density single-use developments." [25] states that "urban sprawl results from poorly planned, large scale new residential, commercial and industrial developments in areas previously not used for urban purposes."

1.1. Types of Urban Sprawl

Sprawl is urbanization that takes place in 3 types namely cluster, linear and leapfrog direction around a well-established city or linearly along the highways over a given period of time [4]. [4] state that to understand the complexity of urban sprawl, land use change analyses and urban growth pattern recognition must be determined**.** Linear are type of urban sprawl that occurred and always found along a highway or road. Cluster sprawl are found in an area of new growth occurred around existing areas of urban settlement. Leapfrog sprawl are area of new growth that is sparsely distributed type of settlement. It is much more feasible to define sprawl after the formulation of necessary data into useable results. Example of those result include spatial data such as land use land cover data along with a determination of the density and connectivity of new patches of growth [6].

1.2. Pattern of Urban Sprawl

The patterns of urban sprawl are represented by sprawling landscapes are aligned with the definition of the word sprawl. Because urban sprawl involves unplanned development, inefficiency use of land and haphazard type of development [24]. This idea coupled with urban development gives a good visualization of what urban sprawl pattern may look like [24]. A formal entity reads this way: "Sprawl sit spread out in a relaxed or awkward way sprawling position" [4] definition coupled with the phrase urban growth is one example of the difference between simple urban growth and urban sprawl. Urban growth may have more of a planned appearance while the pattern of urban sprawl often appears awkward, uncontrolled, and haphazard.Perhaps there is a new development very similar to an urban landscape in the middle of a seemingly rural area broken up by many other rural landscapes such as farmland or forested areas. Perhaps the timing of this development closely follows the completion of a new road network or major highway [3].

The most pressing problem is the substantial loss of fertile agricultural land in many coastal cities because of short-term economic considerations [20]. [21] argues that suburbanization as we know it is not the issue, but rather the wasteful form of development known as sprawl with which many critics have a problem. [17] list a plethora of ills related to sprawl: the loss of open space, urban decay, unsightly strip mall developments, the loss of a sense of community, patchwork housing developments in the midst of agricultural land, increasing reliance on the automobile, the separation of residential and work locations, and the spreading of urbanized developments across the landscape. **What direction**

does a city sprawl out the furthest? In which direction does a city sprawl out to its greatest extent? How far? This includes exurbs, and open land between sprawled communities. For this thread, sprawl ends when the last strip mall and suburban division ends. The direction in which sprawl take place in any community is been determine by some factors like access roads, social amenities, land tenure system, nature of the land and development policy [15].

1.3. Rate of Urban Sprawl

The rate of urban sprawl involves the area of extent in which sprawl has taking place in a particular time. So, the rate of sprawl at a particular time can be high, low and medium dependent on land use activities taking place in the area. The rate at which a sprawl takes place determines the rate of urban sprawl in a particular place [5]. An important question on urban sprawl maybe, how long is required for sprawl to compact as opposed to whether or not compaction occurs at all. The concept of time span is important in the identification and measurement of urban sprawl. The application of static measures to dynamic areas can easily result in the misidentification of an area as sprawl when it is really a viable, expanding, compacting portion of the city [14].

However, the rate of urban sprawl does show a great deal of promise in calculating the relative accessibility of destinations for different areas of the city [19]. In this way, the relative level of residential accessibility might be measured. Equally, the level of accessibility between homes could be calculated by any rate of sprawl, serving as an indicator of destination accessibility. Both of these urban sprawl rate characteristics can give us an empirical idea of the relative degree of compactness and sprawl in a city, with inferences to scatter, spatial structure, and density of an area [18].

1.4. Density of Urban Sprawl

The fundamental criticism of urban sprawl density is that it led to inefficient and costly pattern of development. The burden of proving that density sprawl with social amenities is not inefficient has fallen on those who, by virtue not attacking density urban sprawl, have been place in the position of defending the density urban sprawl. Density urban sprawl is called inefficient because it generates low, medium and higher density development that is sprawled over landscape [13]. A primary justification in interfering in the land market is a presumption that the public good is served by reducing density sprawl through policies aimed at preventing discontinuous density urban sprawl development. This is not a new notion, other authors, notable [9]. [8] have also suggested that discontinuous development led to higher densities than will occur if discontinuous development where prevented. The impact of discontinuous development on density is important because uniformly low, medium and higher density urban development is inefficient. It increases transportation cost, consumes excessive amount of land, and adds to the cost of providing and operating public utilities and public services [12].

1.5. Statement of the problem

The influx of people into Jos town since the designation of the Jos as state capital in 1976 has been on the increase till date [9]. This goes with the antecedent's consequences of congestion and pressure on social infrastructure. Since the creation of Plateau State, the daily influx of people in to the state capital has put a high demand on land. As a result, there is seems to be significant change in land use within Jos town and its environs leading to increased urban Sprawl, traffic problems. This could have a resultant effect on local resources and destruction of open space particularly at the city centre and peripheral areas which has translated into socio-economic and political problems hence imposing great challenges to urban planners, city administrators and the public settlements.

The implications of urban sprawl are not only on the surrounding public settlement, but with loss of agricultural land, ecological habitats, and on the basic amenities like, transportation, water supply, sanitation facilities within the inner core of the city. The type, rate, direction, density and the pattern of urban sprawl in Jos metropolis has a great consequence on the environment, because it is not the urban sprawl that is the problem but the type, rate, direction, density and pattern of the urban sprawl that could determine the nature of its environmental consequence. Hence, this study seeks to assess the spatial pattern of urban sprawl in Jos town metropolis with the view to understanding and quantifying the causes, drivers and consequences of urban sprawl as a result of the type, rate and pattern of urban sprawl in Jos town and its environs [10].

It is estimated that in many third world cities, more than half of their population live in the peri urban areas. In Nigeria, the share of the urban population has increased from 10% in 1932 to about 20% in 1963 when Nigeria became independent. After independent in 1960, the rate of urbanization and urban growth has been unprecedented as urban areas offered better standard of life than the rural areas, and then policy of industrial location, provision of infrastructure and jobs opportunities has favoured the urban areas against the rural areas (urban bias). In the1991

census, the urban population has risen to 37% of the total population, with the average rate of growth at about 5% per annum. The 2006 population and housing census showed that the country had a population of about 140 million people with about 45% living in towns and cities of over 20,000 inhabitants. Rapid urbanizations have changed the urban landscape of most Nigerian cities. There has been the processes of concentration and congestion in inner cities and the opposite process of suburbanization and dispersal at the urban fringes, the urban areas [10].

1.6. Scope and the study area

The scope constitutes the study area Jos North and Jos South. These were selected because there is a great deal of similarity among these jurisdictions concerning land cover, land use, urban sprawl type, pattern, rate, density, land area and land use practices. [16]. Urban Sprawl is urbanization that takes place in either a radial direction around a well-established city or linearly along the highways over a given period of time [4]

Jos the capital of Plateau State is located almost in the geographical centre of Nigeria. It is about 1000km North-East of Lagos, 400km South of Kano, 900km North of port-Harcourt, 600km South-West of Maiduguri,1000km South-East of Sokoto and 300km away from Abuja. Geographically, Jos lies between latitude 9.53 N and 9.56 N and longitude 8.52 E and 8.56 E of the Greenwich meridian. It is located at the northern point of the plateau which bears its name at an elevation of about 1,200m above mean sea level. The town it is most asymmetrically placed state capital in a whole of Nigeria, located at the extreme northern end of Plateau State. Except on its northern part, the town is almost surrounded by hills. To the East are Dagon Dutse and Shere hills which rise to over 1300m and 1400m respectively, on the West side are the Jentar hill which also rise to over 1280m above sea level [19].

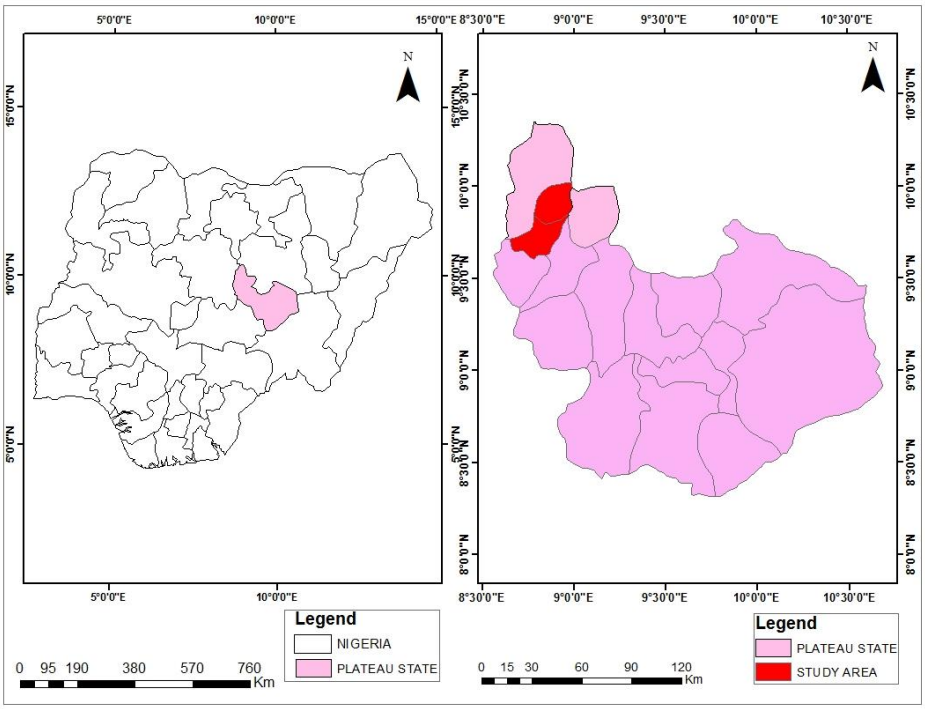

Figure 1 Location of the study area

(Source: GIS Analysis Settlement map of Nigeria, 1996)

1.7. Aims and Objective of the Study

The aim of this study is to assess the spatial pattern of urban sprawl in Jos metropolis between 2002-2022 with the view to quantifying the urban sprawl types, sprawl rate, sprawl pattern and sprawl density. To achieve the stated aim the following specific objectives are targeted;

- To determine the types of urban sprawl in Jos metropolis.
- To characterize the pattern of urban sprawl in Jos metropolis.
- To assess the rate of urban sprawl in Jos metropolis.
- To evaluate urban sprawl density in Jos metropolis

1.8. Data and Methods

1.8.1. Data and Source

The data used to achieve the research objectives and their source are presented in table.

Table 1 Data used and their Sources

Data Type	Date of Production	Resolution	Source
Land-sat imagery	2002	30m	GLCF
Land-sat ETM	2012	30m	GLCF
Land+sat 8	2022	30m	GLCF
Study area map	1996		NCRS

2. Methodology

Following the geo-referencing of all GIS data layers, a boundary map was incorporated into each land use and land cover data set in the ArcGIS environment to determine urban sprawl spatial pattern from 2002 to 2022. After clipping the classify land use land cover data for each year to the study area, a classify data of 2002, 2012 and 2022 land use land cover for those classes that represent a particular land use that have change to another land use between 2002-2022. The result was used to determine the rate of urban sprawl based on land use change from one land use to another land use from 2002 to 2022.After the reclassification of the land use land cover, neighbourhood statistics method was used on new growth areas in order to show pattern and direction of connectivity of new growth areas thereby classifying those new patterns of urban sprawl as one of three types of urban sprawl: linear, cluster and leapfrog urban sprawl. Road network data was used to create a 1km buffers around those roads to assist in determining the extent of the linear nature that urban sprawl can take along highways and other major roads. Based on the density of new growth areas, the classify map was used to visually assess the types, pattern, density and rate of urban sprawl distribution on build-up land in 2002, 2012 and 2022, then to classified those new areas of growth as one of the three types of potential urban sprawl: linear, cluster and leapfrog urban sprawl.

Linear urban sprawl was classified as new growth areas that occurred along a highway and exhibited high to medium density.

On the other hand, those areas of new growth that occurred around existing areas of urban land and exhibited high rate of sprawl were then classified as cluster urban sprawl.

While those areas of new growth that were describe as medium to low density and were sparsely distributed throughout the study, were classify as leapfrog urban sprawl.

The techniques used to classify areas of new growth are based on research done by (Wilson et al., 2003). It was however, important to isolate areas of new growth in all the areas of existing growth in 2002, 2012 and 2020 in order to create a layer to enable the overlay of the classify area of developed settlements in the years under investigation. The developed settlement land in 2002, 2012 and 2022 were classified, and then the addition operation in ArcGIS was used to form a map which showed the area of new growth. In calculating neighborhood statistics, filtering techniques was used to incorporate a window of pixel approximately one kilometer by one kilometer across the entire study area to calculate the density of developed settlement pixel within that window. The result of the techniques was used in adding up to show the new values that are attributed to the center of the neighborhood statistic density of developed settlement in 2002, 2012 and 2022. Within the GIS one kilometers by one kilometer equal to approximately 36 by 36 cells given that each cell was 30 meters by 30 meters resolution of the satellite images used. Urban density maps for developed settlement in 2002, 2012 and 2022 and new development over the twenty-year time period based on the given window in order to compare densities for each classification of developed settlement land that was created.

Furthermore, a statistic table for land use and land cover changes in Jos metropolis (2002-2022) was produced using the analyse image in the ArcGIS window which show format for land use and land cover change in Jos (2002-2022 (area km2). A spatial GIS analysis modelling technique called cross analysis change detection was used to produce a gain in settlement from water bodies, farmland, vegetation, open space and rock outcrop in the study area from the already

classified land use and land cover change map of the study area. This helped to visualize the trend of land use and land cover changes that have occurred from 2002 to 2022 and the gain in settlement in the study area. A land use conversion maps was created to show the dynamic process of the spatial characteristics of settlement development during 20 years from 2002 to 2022 in Jos metropolis. As this helped in analyzing and improved our understanding about the gain in settlement on spatial pattern of urban sprawl in the study area on the bases to find out the driving force for settlement land use increases in Jos metropolis, so that a suitable land utilization practice will be used to overcome the causes, drivers and the consequence of the spatial pattern of urban sprawl experiencing in the study area. Cross analysis change detection analysis using Arc GIS was used on the already classify land use and land cover change to detect where water body, farmland, open space, vegetation and rock outcrop convert to settlement land use and which types of land use has been transformed to settlement land use? A statistic table was produced from the cross-analysis change detection methods in Arc GIS window to show the percentage of settlement land use conversion from 2002 - 2022. The vertical column of a table shows the total amount of land used for a particular class from 2002 to 2022 and the horizontal line show the land conversion that have occurred in a particular class within 20 years period and what type of land use has contributed for this conversion to settlement land use.

More to that, land conversion or transformation in Jos metropolis (2002-2022) statistics table and map showing the land conversion to settlement which form the basis of the study. The conversion map showed how new settlement has developed through the conversion of farmland, water body, Rock outcrop, Open space and vegetation in 2002 is converted to settlement in 2022.

2.1. Data Analysis, Presentation and Interpretation

The results are presented inform of maps, charts and statistical tables. They include the statistic, change land use land cover and gain in settlement which form the basis of the study and all other classes used in the study. This chapter also shows the classified images and the area coverage of each class. The classified images are analyzed and they show changes in the area of all land use land cover types, rate density and pattern of urban sprawl during the period under study.

2.2. Types of Urban Sprawl in Jos Metropolis

A GIS analysis of urban sprawl growth and distribution in Jos metropolis involve the manipulation of GIS data that revealed the main basic types of urban sprawl over the time from 2002-2022. The result of supervised classification with the appropriate feature class was clipped to study area. After this was done, it helps to classify the data into applicable classes that represent developed settlement land use. As shown in Fig 2, urban sprawl around major roads in Jos metropolis was created to help in easy identification of linear types of urban sprawl in the study area. That was the first step in quantifying the type of urban sprawl within the study area.

The second step involve the calculation of the rate of new growth areas that was used to create relevant maps thereby showing the connectivity of areas of new urban sprawl growth based on neighborhoods statistics in other to show the types and direction of urban sprawl. However, at this stage of the research work it was important to assess the types of urban sprawl in order to see whether or not the study area was sufficient to use for the purposes of the research work. Whether or not those areas could be classified as sprawl areas was based not only on the spatial distribution of the rate of growth, but also on the neighborhoods statistics method. Clearly, it appears that the data used was appropriate for the research at this stage because it allowed the location of new type of urban sprawl growth (**see Fig. 2**). Then based on the spatial patterns and the rate of sprawl, the result can be used to classify new growth areas as one of the three types of urban sprawl: cluster, leapfrog, and linear urban sprawl which measure the rate and direction of the patches of sprawl growth, to classify new sprawl growth areas as one of three types of urban sprawl.

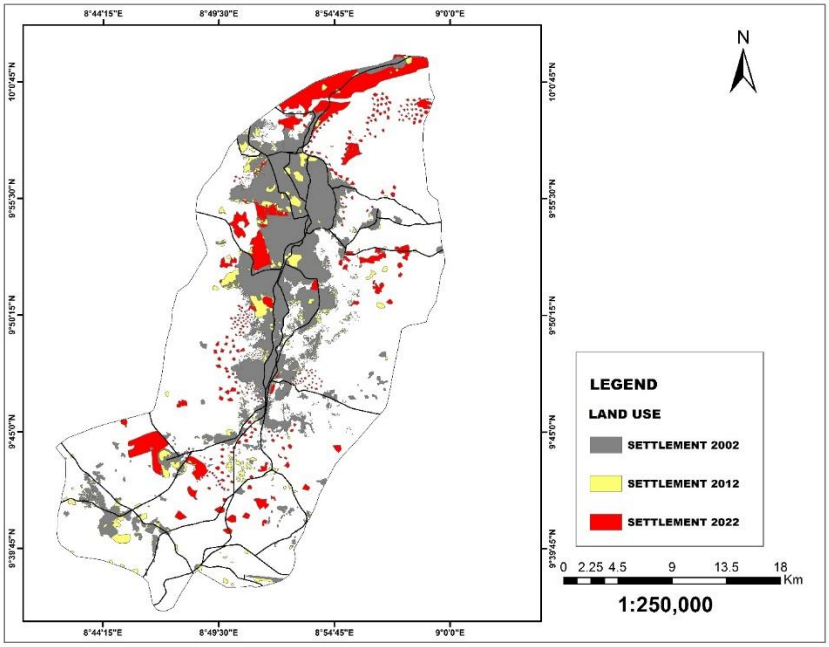

Figure 2 Urban Sprawl around major road in Jos and environs

(Source: Author GIS Analysis, 2022).

2.3. Linear Urban Sprawl in Jos Metropolis

The result of the analysis presented in **Fig 3** shows a map of developed settlement land representing a linear urban sprawl type in some areas in Jos metropolis. Because linear sprawl pattern can only be visually seen by the road, the roads in Jos play important role in linear pattern of urban sprawl formation.

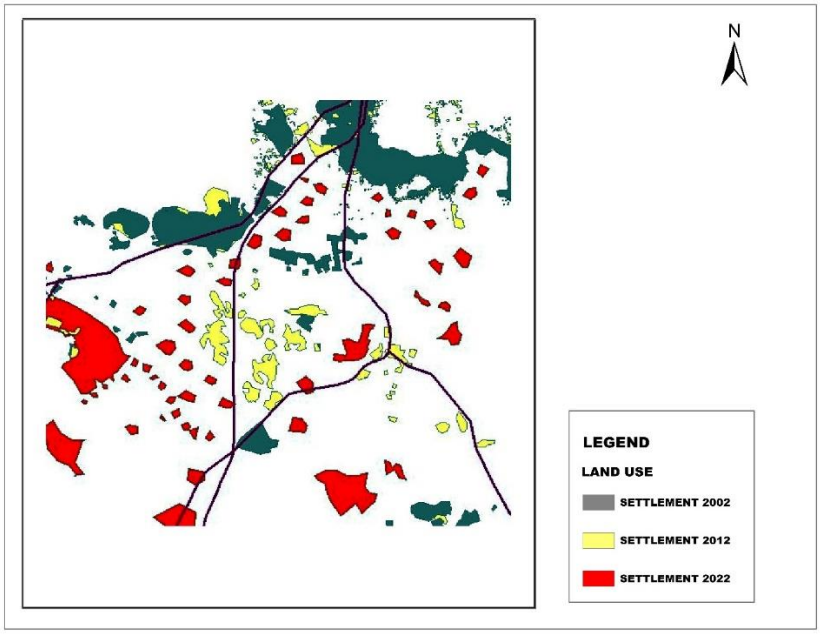

Figure 3 Linear sprawl type in Jos metropolis

(Source: Author GIS Analysis, 2022)

By including road data, it helped to visualize clearly the areas of linear sprawl in Jos metropolis. An example can be visually seen in Naraguta area, part of a large residential development of Jos north. (Fig 3)

2.4. Cluster Urban Sprawl Type in Jos metropolis

The result presented in Fig 4 shows the map of cluster types of urban sprawl settlement development in Jos metropolis. From the map, it shows that cluster types of sprawls in study area are found in the core city of Jos metropolis like Jos city and Bukuru in the study area.

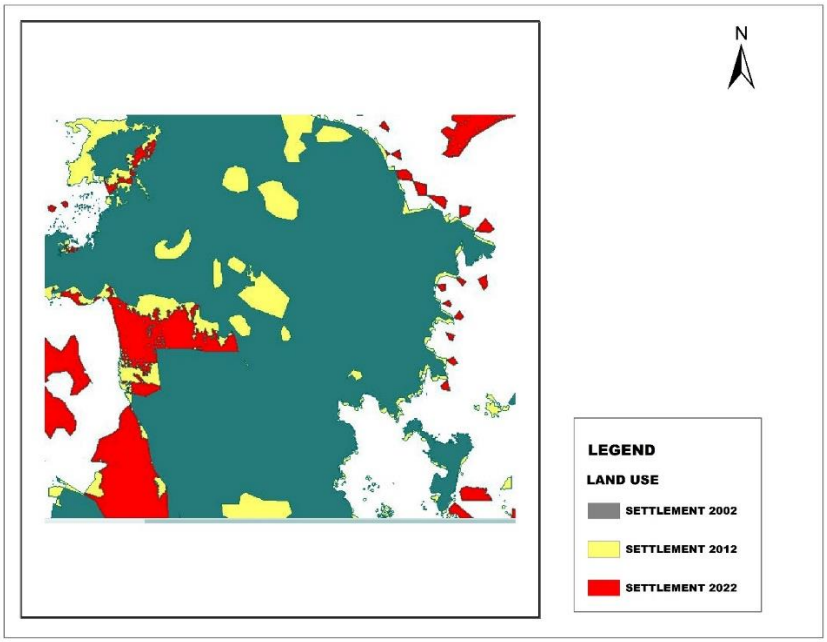

Figure 4 Cluster Urban Sprawl type in Jos metropolis

(Source: Author GIS Analysis, 2022)

Cluster type of urban sprawl also appeared to grow out of what was once a leapfrog pattern of development in some area in the study area. However, the patterns of sprawl type represented in the research work are not exclusive of neighborhoods' statistic calculation that give measurements of the rate of density in the growth areas and display the direction of sprawl type in those new growth areas in (figure 4).

2.5. Leapfrog Urban Sprawl type in Jos metropolis

Figure 5 shows map of leapfrog sprawl type pattern of developed settlement land in Jos metropolis. So, the map shows that the emerging of new developed settlement land called leapfrog is a new settlement development that constitutes a big problem of urban sprawl in Jos metropolis. Leapfrog patterns of urban sprawl appeared to be somewhat disconnected from other areas of existing developed settlement land. Leapfrog types of urban sprawl in Jos metropolis can be seen in Kuru North, Dan Miangu, Barakin Kuru and Kuru Hills. After the map of the densities urban sprawl for new growth areas has been created. The maps help in locating each type of sprawl within the study area. In Jos city and Bukuru, the urban sprawl areas were all residential development with cluster urban sprawl. The example of cluster urban sprawl is found within the core Jos city, part of some residential areas like polo field, Jaruwa, Janta hill, Geri gad, Farin gada, gwong.

This area is been identify as urban sprawl area because it falls within a one-mile buffer of a road around Naraguta settlement a major road in the study area. The leapfrog sprawl development can be seen in Barakin, marin area of Jos north. Barakin marin in Jos north is also a residential development. However down barakin marin is entire development is leapfrogging urban sprawl away from a cluster developed areas. The urban sprawl area in Bukuru was also all residential development. Bukuru is been identify as one example of cluster urban sprawl because it forms the core city of Jos metropolis, Von as an example of linear urban sprawl, and Tudun- Wada as another cluster sprawl.

Through neighborhoods statistics calculation, it helps in describing why a new growth of settlement will be called linear, cluster and leapfrog urban sprawl (table 2). This is because it is not only the patterns of development that create the appearance of urban sprawl, but also the density, rate, types and density direction of the connectivity of development to existing areas of developed settlement land. More densely and compact areas of developed settlement land was

classified as cluster, while medium density areas with low-rate connectivity indicated leapfrog patterns (table 2). Classified areas of new growth that exhibited high, medium and low rate as high, medium and low residential area base on the density of the pixel each represent in developed settlement land between2002-2022. It was also used in calculating the rate of densities of developed settlement land in 2002, 2012 and 2022 (figure 2 and table 2) which is used as Settlement or developed settlement lands inter changeable in this research work for comparison with new growth areas.

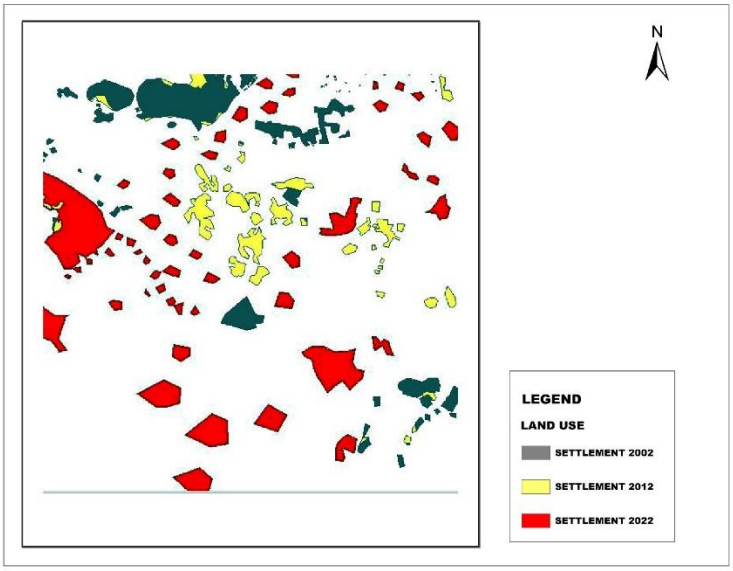

Figure 5 Leapfrog sprawl type in Jos metropolis

(Source: Author GIS Analysis, 2022)

2.6. Pattern of Urban Sprawl in Jos Metropolis

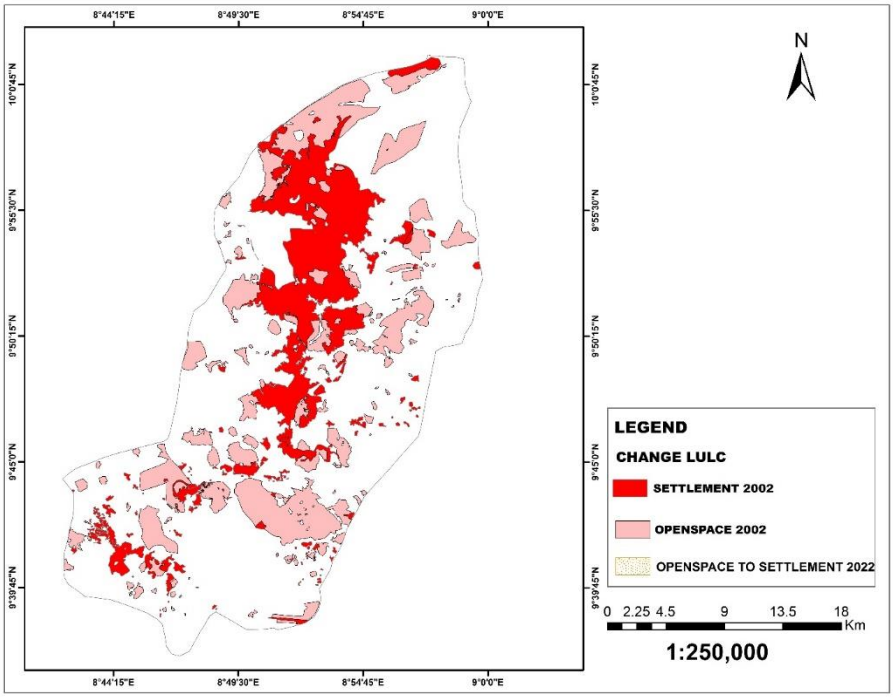

Figure 6 Open space 2002 convert to settlement land 2012

(Source: Author GIS Analysis, 2022)

The new areas of growth were described in the methodology section (Figs 6,7.8 and 9) which showed the areas of various land use 2002 converted to developed settlement land 2022. Isolating new growth areas enabled the quantification of urban sprawl pattern based on rate of new growth areas. It was also used to determine areas that remained the same land use and those land use areas that change from one land use to developed settlement land from 2002 to 2012. This was used in assessing those areas that have strong impact on the study and those areas that have little impact on the results of the study between Jos north and Jos south.

Figure 6 showed the areas of open space land 2002 converted to settlement land 2022. It was also used to determine areas that remained open space land (figure 6) and those land use areas that change from open space land to developed settlement land from 2002 to 2022.This was used to analyse and show the pattern of urban sprawl in Jos town and its environs.

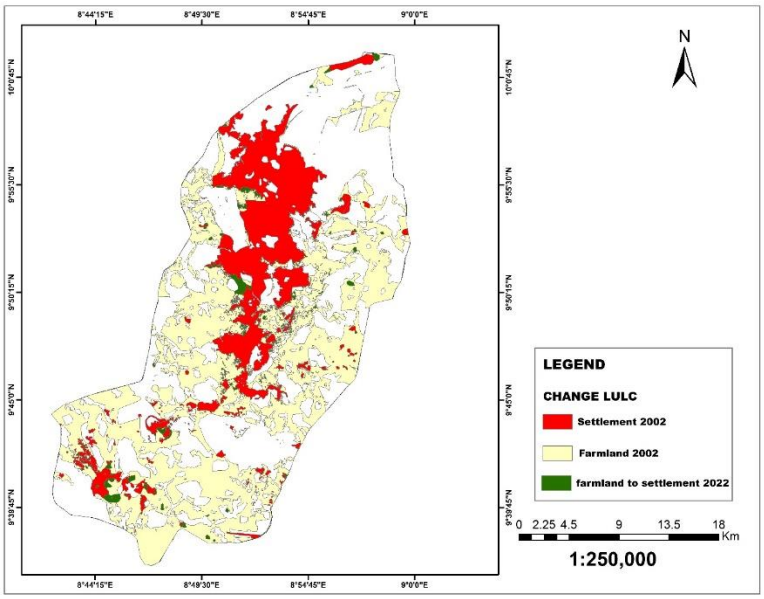

Figure 7 farmland 2002 convert to settlement 2022

(Source: Author GIS Analysis, 2022)

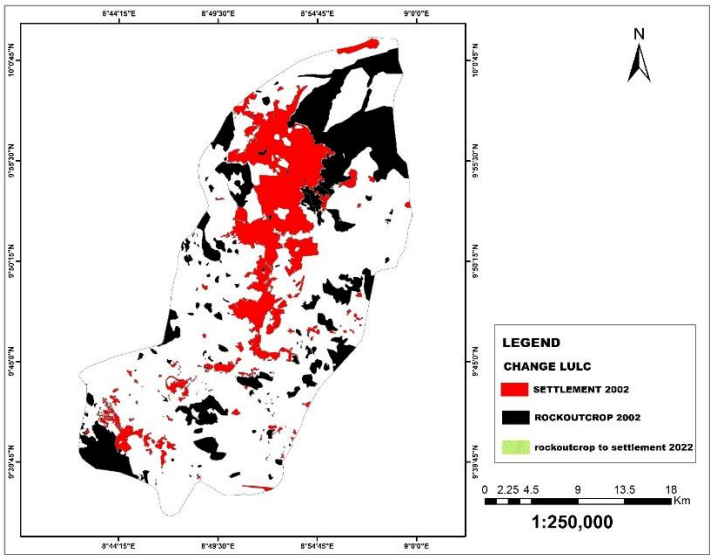

Figure 8 Rock outcrop 2002 convert to settlement 2022

(Source: Author GIS Analysis, 2022)

Figure 7 Map showing what settlement 2002 was, farmland in 2002 and farmland that have change to settlement in 2022. So, the map above is showing the pattern of land use change pattern of urban sprawl in around Jos and environs from 2002-2022. Map showing what was farmland 2002 and settlement 2022 presently in the study area as a result of land use land cover changes pattern in Jos and environs.

Also figure 8 shows how rock outcrop 2002 and settlement 2002. The map is showing sprawl pattern in the study area as how rock outcrop in 2002 converted to settlement 2022.This is displaying the urban sprawl pattern in the study area in terms of how rock outcrop is contributing to urban sprawl development.

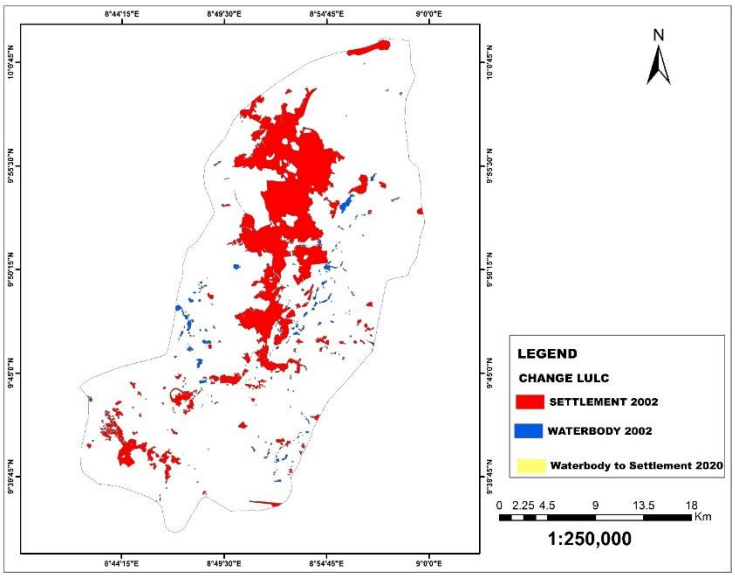

Figure 9 Waterbody 2002 convert to settlement 2022

(Source: Author GIS Analysis, 2022)

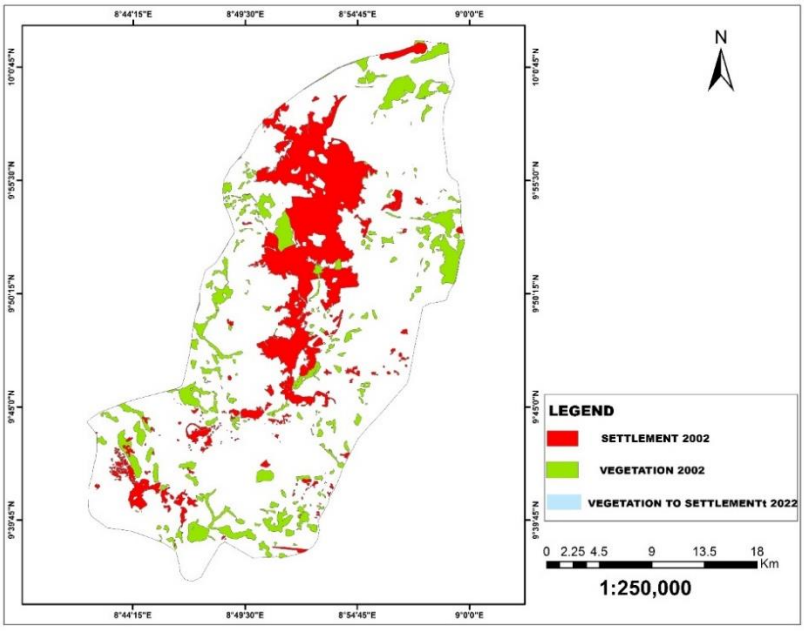

Figure 10 Vegetation 2002 convert to settlement 2022

(Source: Author GIS Analysis, 2022)

Figure 9 in the year 2002 the total surface of water body was 7.88 area km2, 2012 is 4.74 area km2 and in 2022 is 4.56 area km2 (table 2). So, there is 3.33 area km2 changes in water body from 2002 -2022. Therefore 3.33 area km2 of water

body has been converted to settlement which show the pattern of urban sprawl in the study area in terms of water to settlement.

Fig 10 shows that settlement in 2002 is 125.45 area km2 (table 2). For the rapid increase in settlement in 2022 is as a result of open-space land that converted to settlement land development. Open=space land has contributed 127.57 area km2. This shows changes that occur in the area in the year 2002-2022 that is the conversion of opens=pace to settlement. In figure 10 one can easily identify exactly where the open=space was transformed to settlement. New settlement such as Kuru, turu, Barakin mari and Naraguta were developed within open-space. The increase in settlement development have reduced open=space land area in the study area between 2002-2022.

2.7. An Assessment of Urban Sprawl Rate in Jos Metropolis

Assessing the rate of urban sprawl between2002-2022 was done through the assessment of approximate area hectare of developed settlement land for each year 2002, 2012 and 2022 was calculated and presented in table 2.

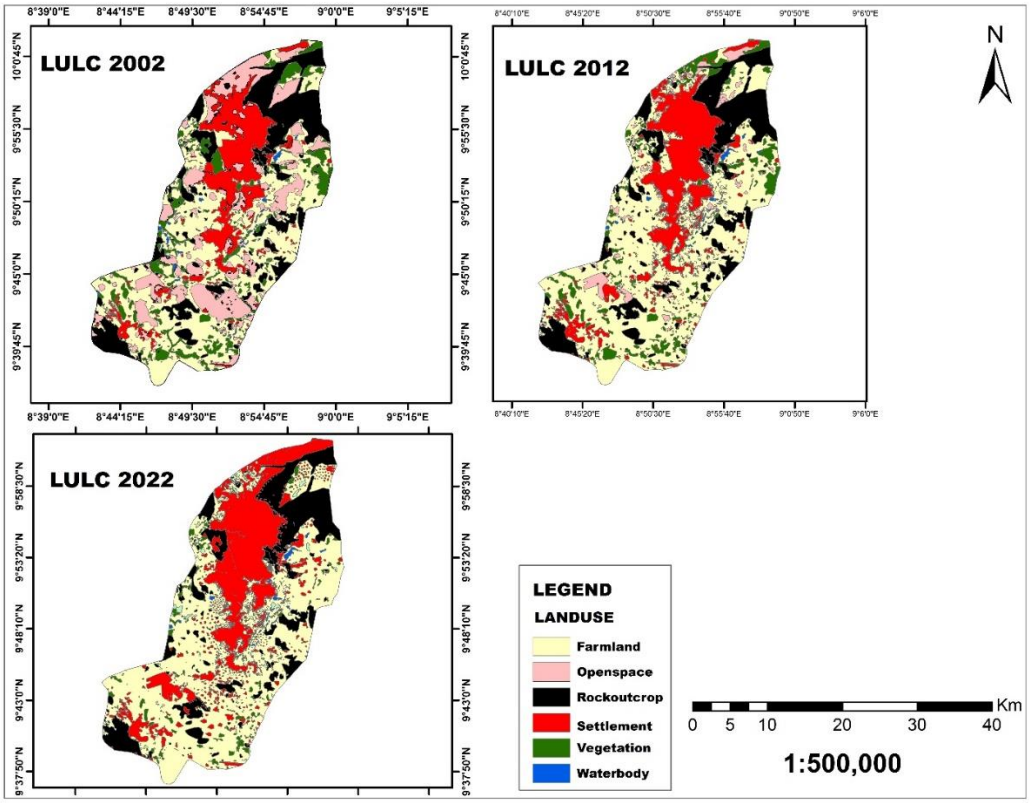

Figure 11 Land use land cover 2002,2012 and 2022

(Source: Author GIS Analysis, 2022)

This was used to conclude that there was a clear increase in the amount of developed settlement land over the given time period (Figure 11). In 2002 area km2 is 125.45 and 2022 the area in km2 increase to 208.16 area km2 of developed settlement land within the study area respectively. In 2020 developed settlement land increased to 208.16 area km2 of developed settlement land indicating a large increase in the extent to which urban sprawl occurred between 2002-2022.Also between 2002-2022 there is a great change in settlement development of about 82.71 area km2 (Table 2) Assessing urban sprawl help in recognizing urban growth by performing an overlay of the land use change analysis from open space land to developed settlement land. Then based on the techniques used to measure the rate of urban sprawl, view the direction and the spatial distribution of new pattern of growth areas with the GIS application, it was used in calculating the rate of patch of new growth areas in order to classify some of those areas as urban sprawl. For the purpose of this research work ARCGIS is used to calculate the rate of patches of new growth, create maps and statistical table to show the rate of urban sprawl in Jos metropolis.

Table 2 Land Use and Land Cover Change Rate in Jos town and its Environ 2002-2020(area in hectare)

Land use	Area km2 2002	Area km2 2012	Area km2 2012	2002-2022	
Farmland	305.28	411.33	414.59	109.59	109.31
openspace	143.65	31.23	16.08	127.57	127.57
rockoutcrop	150.20	146.49	144.89	5.31	5.31
settlement	125.45	155.11	208.16	82.71	18.71
vegetation	74.56	58.94	19.52	55.04	55.04
waterbody	7.88	4.74	4.56	3.33	3.32
Total	807.85	807.85	807.85	383.55	

(Source: Author GIS and Statistical Analysis, 2022)

Table 2 show classified land use and land cover statistic for the year 2002, 2012 and 2022 which was drive from land use land cover of the study area respectively. The total area changed in settlement 2002-2022 is 82.71 area km2 while water body 3.33 area km2, farmland 109.31 area km2, vegetation 55.04 area km2, open space 127.57 area km2 and rock outcrop 5.31 respectively. As shown in Table 2 open space constituted the largest land use change from 2002-2022.So that show that, there is change in rate of settlement, water body, farmland, vegetation, open space and rock out crop from 2002-2022. But our main concern was to access the rate of urban sprawl, which was been show in table 2 were settlement rate change from 125.45 to 208.16 area km2 from 2002-2022.

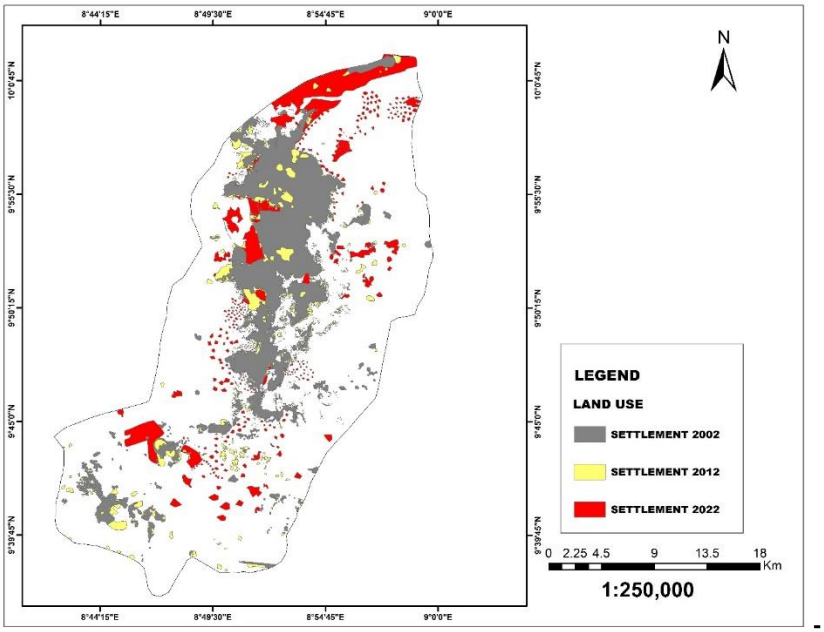

Figure 12 Map showing developed land 2002, 2012 and 2022

(Source: Author GIS Analysis, 2022)

Fig 12: show developed settlement land in 2002, 2012 and 2022 in Jos metropolis. With the analysis capabilities in the GIS, the map helps in calculating the approximate area hectare of developed settlement land for each year 2002, 2012 and 2022. The result was used to conclude that, there was a clear increase in the rate of urban sprawl over the given time period. In 2002 there was approximately 125.45 km2 area of developed settlement land within the study area, 2022 the number of developed settlements increased to 155.11 area km2 and 2022 developed settlement increase to 208.16 area km2 that is indicating a large increase in developed settlement land to an extent that shows urban sprawl has occurred between 2002- 2022 in the study area.

The map of developed settlement land cover shows the rate of new settlement growth has occurred within the study area. Without urban growth, there would be nothing to classify as urban sprawl. The percentage of developed settlement land covers change over the twenty-year time period increased by almost 82.71 km2 area (table 2). A great deal of change that provides a strong growth change that a substantial amount of urban sprawl in Jos metropolis over the period of time between 2002-2022 can be classified as urban sprawl.

2.8. An Evaluation of Urban Sprawl Density in Jos metropolis

The evaluation of urban sprawl density involves the generating of map produced with the aid neighbourhood statistics method are important in showing areas where developed settlement land show density rate of sprawl increased. There is a clear increase in the density of developed settlement land to the north, south, east and west in Jos North and Jos south in 2002, 2012 and 2022 (Figs 13, 14 and 15). However, increases in developed settlement land density rate are apparent throughout the study area.

To access the density rate of urban sprawl patter in Jos metropolis, a threshold for low, medium and high density developed settlement pattern was adopted from Wilson et al., (2003) model of sprawl density threshold was used in accessing the density rate of urban sprawl as seen in Table 3.

Table 3 Density thresholds for low, medium and high developed settlement land

Low	0-2000 pixel
Medium	2000-25000 pixel
High	25000-130000 pixel

Source: Author (GIS and Statistical Analysis 2022)

Table 3 is showing the number of pixels threshold for settlement density development from 2002-2022 that was used to analyse the density rate of sprawl from low, medium and high. So, the threshold for low, medium and high developed density settlement land on the table 3 was been used in explaining the reason behind why some settlement was been called low residential density, medium residential density and high residential density area of developed settlement land from 2002-2022. Neighbourhood statistic method was being used on the land use data in order to understand and visualize how disconnected the urban sprawl growth density is. It was clear that, the density sprawl map of developed settlement land in 2002, 2012 and 2022 show the level of increase in developed settlement land density sprawl. In addition to that, the density of developed settlement land in 2002, 2012 and 2022 show new density urban growth, these techniques allowed the examining of how disconnected areas of density urban sprawl were in 2002, 2012 and 2022 (figure 13,14 and 15). The highest density of new settlement growth occurred in North, south, east and west of Jos north in the study area. The lowest and moderate density rate occurred in Jos south from south-west to south-east of Jos south.

Neighbourhood statistics did not only help to view the density urban sprawl and connectivity of new settlement growth but it also helps to quantify the density of new developed settlement growth between 2002-2022.Putting the categories of low, medium, and high density on new growth as well as the ability to display how connected patch of density sprawl are crucial in clarifying the quantification of the density of urban sprawl for the purposes of this study. It was found that there was a mix of low, medium and high-density rate of development throughout the study area. The threshold for these sprawl densities is the density of pixel that represents a particular developed settlement growth. By creating the density sprawl maps, it helps in locating the types, direction, rate and the pattern of settlement growth in the study area. The findings with regard to the neighbourhood statistic calculation revealed that density sprawl of new growth development in the study area are variable and highly disconnected in many places in the study area.

Figure 13 map is showing developed urban sprawl density in around Jos metropolis in 2002 with low residential area falling between pixel 0-2000 with area about 25.10 km2, medium residential area falling between 2000-25000 pixel with land area of 35.20 km2 and high residential area land falling between 25000 -130000pixel value with area 65.15 km2 area.

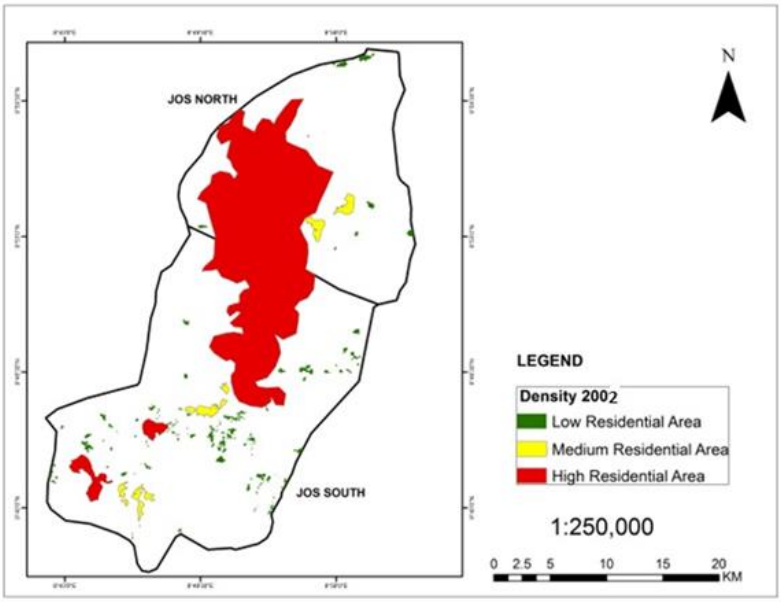

Figure 13 Map showing developed settlement land density sprawl in 2002

(Source: Author GIS Analysis, 2022).

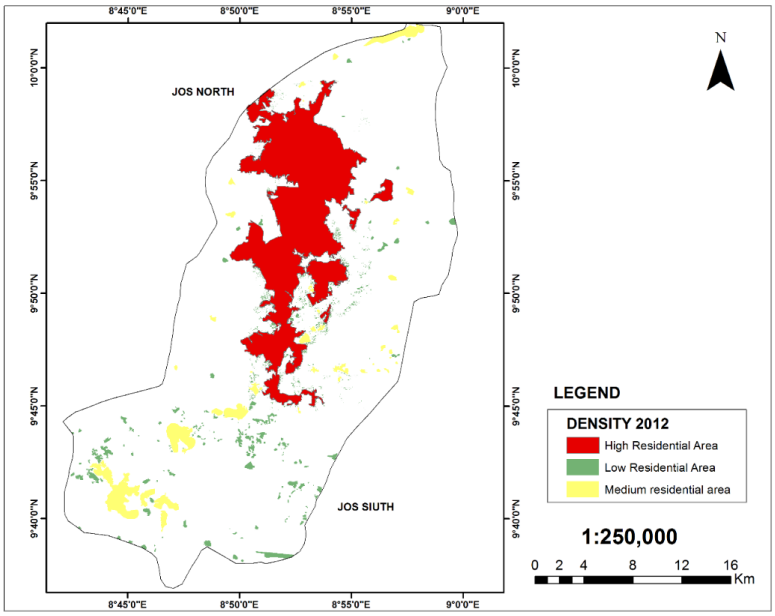

Figure 14 Map showing developed settlement land density rate in 2012

(Source: Author GIS Analysis, 2022)

Figure 14 map is showing developed settlement land density sprawl in Jos metropolis in 2012 with area of low, medium and high residential areas.2012 map shows a clear increase in all categories of settlement developed land density from 30.4 area km2 of low residential to 39.6 area km2 of medium residential area and 85.11 area km2 of high residential area in 2012(Fig 14).So in 2012 it expected that, the number of pixel of developed settlement will increased more than the number of pixel of settlement land in other years in study. This is used in quantifying the density of urban sprawl development in Jos metropolis in 2012.

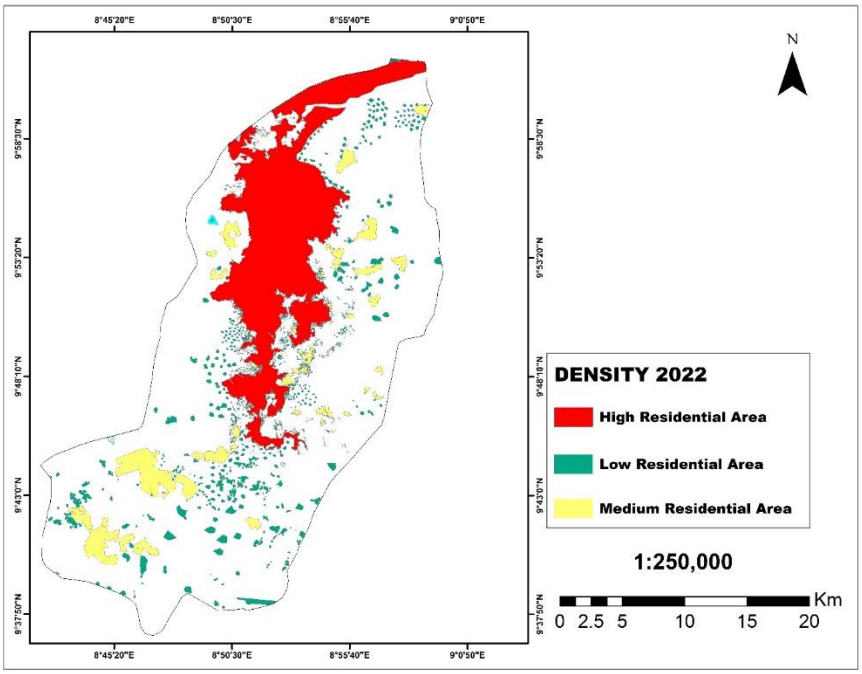

Figure 15 Map showing developed settlement land density rate in 2022

(Source: Author GIS Analysis2022)

Figure 15 map is showing developed settlement land density sprawl in Jos town and environs in 2022 with area of low, medium and high residential areas, by visually see in compare to the 2002 the 2022 map shows a clear double increase in all categories of settlement developed land from 125.45 area km2 in 2002 to 208.16 area km2 in 2022 (table 2).So in 2022 it expected that that number of pixel of developed settlement land density will increased more than the number of pixel of settlement land in 2002.The density sprawl in 2022 show a low residential area with 26.12 area km2,medium residential area of 36.38 km2 area and 145.88 km2 area of land density.

3. Conclusion

The maps showing the rate of urban sprawl was used to visually assess the spatial distribution of new urban sprawl growth areas thereby classifying them as one of three types of urban sprawl. This research conceptualized urban sprawl from a geographic perspective in order to assess the spatial pattern of development. It is done by using geographic information system (ARCGIS) it enables the quantification of development patterns of urban development that exhibited characteristics of sprawl based on the literature were classified as such. By using a geographic information system (GIS), it helps to answer the four-research objective. The answer to this research objective was based on the use of GIS analysis techniques which access the rate, type, density and pattern of sprawl and also help to identify types and direction of sprawl in Jos metropolis. So urban sprawl take place in Jos metropolis over the past 20 years based on low to high-rate density of development to the disconnected areas of new growth.

Urban sprawl creates inefficient use of land, resources and large-scale encroachment on agricultural land. The most pressing problem is the substantial loss of fertile agricultural land in many urban areas. Problems related to urban sprawl include the loss of open space, urban decay, unsightly strip mall developments, the loss of a sense of community, patchwork housing developments in the midst of farmland, increasing reliance on the automobile, the separation of residential and work locations, and the spreading of urbanized developments across the landscape.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors of the paper ''An assessment of spatial pattern of urban sprawl in JOS metropolis of plateau state, Nigeria": Using remote sensing and GIS techniques'' declare that they have no financial or non-financial conflicts of interest that could have influenced the research, analysis, or interpretation of the findings presented in this paper.

Author Contributions

- Boyi Mairiga contributed to the conceptualization of the study, data collection, interpretation of results and manuscript writing.
- Murna Joy Dawarga contributed to data analysis.
- Taimanda Keren Ezekiel provided expertise in geospatial analysis.
- Frichi Bilham contributed to the analysis of urban sprawl and laboratory work.
- Mustapha Yusuf assisted in the fieldwork, data collection and generating of urban sprawl maps.
- Kabati Danjuma Madaki contributed to the spatial analysis and mapping of urban sprawl types and pattern.

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Ethical Considerations

The research adhered to ethical guidelines and regulations relevant to scientific research, including obtaining necessary guideline for urban sprawl analysis techniques.

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