Analysis of Trend and Dynamics of Urban Sprawl in Minna Niger State Nigeria

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Abstract—*Urban Sprawl in Minna is a phenomenon that is quite pronounced with many unsustainable impacts, consequently raising concern for environmental sustainability. This research evaluates Urban Sprawl dynamics in terms of its magnitude, direction and nature of occurrence by integrating Remote Sensing, GIS tools and Shannon's Entropy. The Landsat images of the study area acquired for the years 1990, 2000, 2010 and 2017 were processed and classified, the result shows that land use land cover is rapidly being transformed into built up area. The images were further divided into concentric buffer zones easily adoptable by relative Shannon's entropy, due to its high flexibility and the fact that it is unrestricted by the number of divisions used, the relative Shannon's entropy was calculated, It revealed that in 1990 and 2000 urban sprawl has low magnitude with compact form of settlement, while in the year 2010 and 2017 it became evenly dispersed with higher magnitudes and directed towards the south-western part of the study area, it shows that urban sprawl had always increased in its rates of dispersal throughout the period of the study, it is gradually becoming compact, as indicated by changes in its pattern from 2010 to 2017, showing increasing signs of environmental problems and decaying urban infrastructure. This research provides information about the pattern of urban sprawl which will help environmental managers in decision making. It is recommended that the rate of urban sprawl and increasing environmental decay should be matched with proportionate economic growth and environmentally friendly development practices.*

Keyword—Environment, GIS, Relative Shannon's Entropy, Remote Sensing, Urbanization.

1 INTRODUCTION

Urbanization is a "process of human agglomeration in multi-functional settlement of relatively substantial size" (Jiboye, 2011). According to Ujoh, Kwabe and Ifatimehin, (2010), it is the process that refers to the growth both in size and numbers of urban centre. This process is responsible for the transformation of towns, cities and metropolitan areas, while at the same time increasing the process of direct rural-urban migration.

Increased population growth has led to massive urbanization and concentration of socioeconomic and physical activity, resulting in the creation of environmental issues and concentrate problems and vulnerabilities (Dawson, *et al.*, 2014).

Urbanization has become not only a manifestation but also an engine of change on how humans use and view the environment, Nigerian Cities are witnessing high rate of environmental deterioration and are rated among urban areas with the lowest livability index in the world (Adedeji and Eziyi, 2010), this is due to attempt by Nigerians to adjust their seemingly endless wants and desire for food, shelter, recreation, transportation, infrastructural facilities and so on to the land and other environmental resources available to them, as a result Urban infrastructures such as roads/streets, housing, electricity, water supply and waste management systems are depreciating and this has compounded the way the cities are sprawling.

In Minna urban sprawl is exceptionally rapid, such rapid urban growth has had many unsustainable impacts, it has consumed significant amounts of resources, produced waste, pollution and degrades the environment in the form of loss of agricultural land, green spaces and natural land, increased energy consumption and therefore, greater environmental pollution. Increased need for more infrastructure like water, electricity, roads and health care facilities, the degradation of peri-urban ecosystems and valuable habitats within the city. It has lead also to increased traffic and high automobile dependency, as a result exacerbates global warming.

Currently these problems are major urban challenges in Minna, consequently raising the point that the cost of sprawl is borne by all of us not just those creating it. This opens up the field to investigate and understand its dynamics, with the aim of evaluating the trend and dynamics of urban sprawl in Minna.

1.1 Objectives

- To analyze Land use Land cover trend in Minna from 1990-2017.
- To Evaluate urban sprawl dynamics in Minna from 1990-2017.

1.2 Study Area

The study area is located about 150 kilometers from Abuja the Federal Capital Territory of Nigeria; Minna lies between latitudes 9°24'N- 9°48'N and longitude 6°25'E - 6°45'E, it is the State capital of Niger state (figure 1). It has a total population of approximately 506,113 with an average population density of about 3448 persons per km^2 (NISEPA, 2009). The population growth in the city is among the highest in the country and faster than the national average because of its proximity to the Federal Capital Abuja, it is occupying a land area of about 6,789 square kilometers and lies on a geological base of undifferentiated basement complex of mainly gneiss and magnetite (NISEPA, 2009).

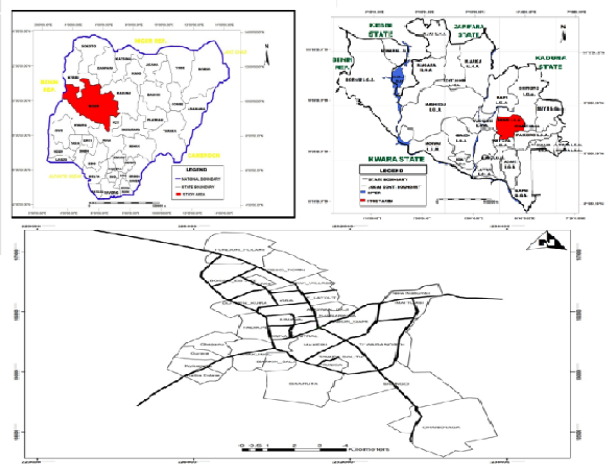

Figure 1: The location of the Study area
Source: Niger State Geographical Information System

2 METHODOLOGY

The data sets utilized were Landsat images of the study area for the years 1990, 2000, 2010 and 2017. The Landsat Images were acquired and classified as secondary data with their characteristics presented in table 1.

Table 1: Details of secondary data used and their characteristics

Data	Bands	Date	Resolution	Path/Row
Landsat TM	7 Bands	1990	30M	189/053 1990
Landsat ETM+	7 Bands	2000	30M	189/053 2001
Landsat ETM+	7 Bands	2010	30M	189/053 2011
Landsat OLI/TIRS	10 Bands	2017	30M	189/053 2017

2.1 The analysis of Land use Land cover trend in Minna from 1990 to 2017.

The rate of Land use Land cover (LULC) change in Minna between 1990 and 2017 was analyzed at a decade interval, the four landsat images were preprocessed and classified. The spectral bands of the images were stacked and masked in Erdas imagine 9.0 and ARC-GIS 10.3 environment. Supervised raster classification was carried using training samples obtained from the field, with maximum likelihood algorithm in the ARC-GIS environment to identify the homogenous groups of pixels, which represent various land use classes of interest; this was verified with a ground truth of the area. The land use were classified into four; Built up area, Bare-ground, Water and Vegetation which were computed and presented in a graph.

2.2 Urban Sprawl Dynamics in Minna 1990-2017

In other to evaluate urban sprawl dynamics in Minna, the classified landsat images were divided into concentric circles as buffer zones, from a point about the center of the study area as employed by Srimanta, *et al* (2013), the approach used in this research involves the division of the study area into 15 zones, which is easily adoptable by the model used (relative Shannon's entropy), due to its high flexibility on how the study area is divided and the fact that it is unrestricted by the number of divisions used.

The major variables are relative entropy (En) as well as change in relative entropy, which were calculated using equation one (1) and three (3) respectively with the results presented in graphs, the value for relative entropy ranges from zero (0) to one (1), where a value of one indicates even dispersal of the variable and a value of zero (0) indicates minimal dispersion (compactness), half way between zero (0) and one (1) is used as a threshold to determine whether the variable can be described as moderately dispersed or concentrated, the relative entropy was calculated using the formula given by Pedro *et. al.* (2013)

$$En = \sum^{n} Pi \log\left(\frac{1}{Pi}\right) / \log(n) \quad (1)$$

Where n= 15 which is the number of zones

$$Pi = XI / \sum XI \quad (2)$$

Where Pi = the density of land development, XI = built up land in ith zone and ∑XI. = total amount of land in ith Zone.

Change in relative entropy between two time periods indicate the magnitude, direction and nature of urban sprawl occurrence between the time periods. Therefore, changes in relative entropy values were calculated by subtracting the relative entropy value of the base year from that of the terminal year, using the formula given by Thomas (1981):

$$\Delta En = En(t+1) - En(t) \quad (3)$$

Where, t and t + 1 respectively indicate the base year and the terminal year.

The values below one (1) indicates low magnitude, higher concentration and inward direction of sprawl, while values at one exactly is an indication that sprawl has remained constant from the previous year., and values above one is an indication of high magnitude, increased dispersion and outward direction of sprawl.

3 RESULT AND DISCUSSION

3.1 Analysis of Land use Land cover trend in Minna 1990- 2017

The changes in Land use Land cover in Minna from 1990 to 2017 appeared not to have maintained a consistent pattern, built up area in 1990 was 2.4% of the total land area and 3.8% in 2000, it then rapidly increased to 19.1% by the year 2010 and 48.2% in 2017, covering almost half of the total land area as depicted in figure 2, this is as a result of the rapid migration of people to Minna due to the better

economic opportunities being a state capital and its proximity to the Federal Capital Territory Abuja.

Bare ground covered 4.2% of the total land area in 1990 and then decreased to 3.5% in the year 2000, which may be due to reduced human activities in some areas where it existed and the ability of vegetation to regenerate, by 2010 it rapidly increased to 9.6% due to increased population and human activities, mostly illegal mining around Chanchaga area indicated in figure 2, dramatically it reduced to 1.8% of the total land area in 2017, largely due to reduced mining activities, the ability of the vegetation to regenerate and conversion into built up area.

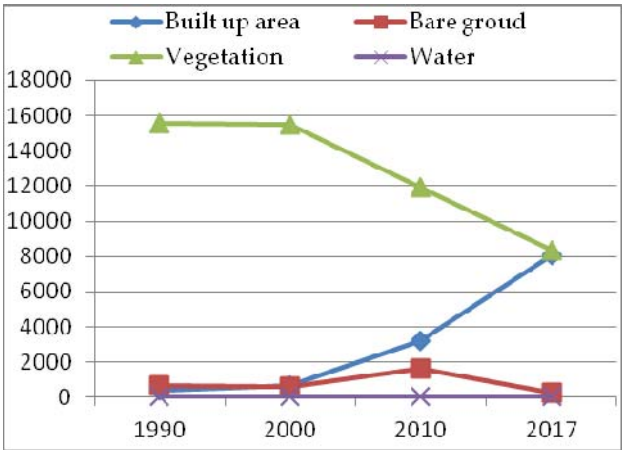

Figure 2: Land use Land cover trend in Minna 1990-2017.

Water in Minna was covering 0.5% of the total land area in 1990 and decreased to 0.3% in 2000, this is mainly due to drying up of most surface water in Minna as a result of building constructions and dumping of refuse in stream channels. It have remained constant through 2010 to 2017 at 0.3% of the total land area as indicated in figure 2, surface water left are concentrated to particular locations which have witnessed very little human activities.

The vegetation of Minna from 1990 to 2017 have being decreasing, it is inversely proportional to built up area as indicated in figure 2, it covered 92.9% of the total land area in 1990 by 2000 it reduced to 92.3, it rapidly decreased to 71% in 2010 and by 2017 it is covering 49.7% of the total land area, due to its conversion into built up area as can be seen in figure 3 and figure 4.

Figure 3: The classified image of 1990 and buffer zones

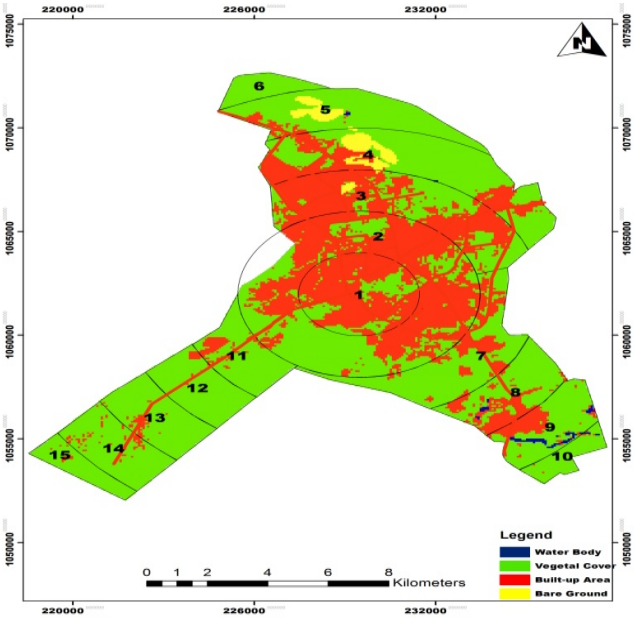

Figure 4: The classified image of 2017 and buffer zones

3.2 Urban Sprawl dynamics in Minna 1990-2017

The figure 5 depicts variations in urban sprawl and changes in its occurrence from 1990 to 2017, it is indicating that in 1990 and 2000 the rate of urban sprawl occurrence is low and is concentrated to some parts of Minna town, which indicates a compact form of settlement as displayed in figure 3, while in the year 2010 and 2017 the rate of urban sprawl occurrence became very high and evenly dispersed as can be viewed from figure 4, an indication that the town is approaching high rates of dispersal from where it will gradually become compact, generally urban sprawl have being increasing in its rates of dispersal throughout the period of study.

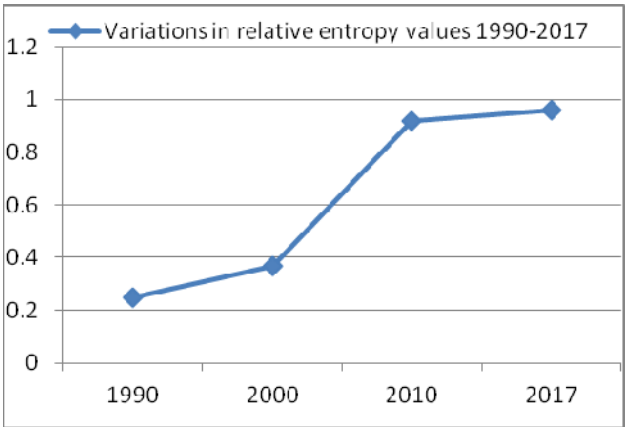

Figure 5: Variations in relative entropy values 1990-2017

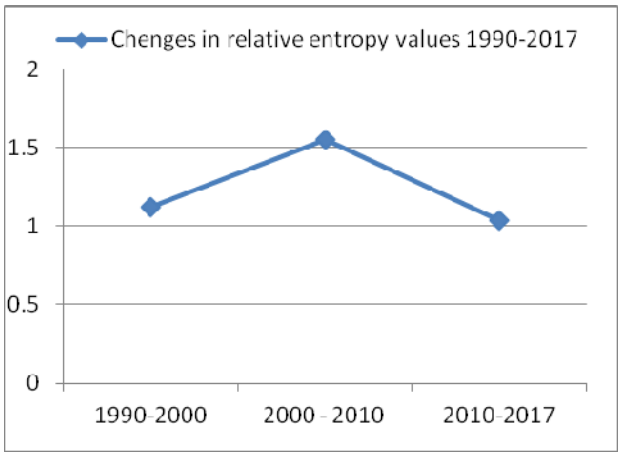

Figure 6: Changes in relative entropy values 1990-2017

Figure 6 shows changes in relative entropy values between the time periods under study which is indicating changes in urban sprawl behaviour; implying low magnitudes from 1990 to 2000 and from 2010 to 2017, while it has a high magnitude from 2000 to 2010 signifying the highest urban sprawl occurrence rate of the period under study. It can also be observed, that the variation indicates changes in urban sprawl behaviour from 1990 to 2000 and its behaviour from 2000 to 2010 which shows rapid rates of dispersal, high magnitude and an outward direction of sprawl occurrence, while its behaviour from 2010 to 2017 indicates compactness, lower magnitude and an inward direction of sprawl occurrence, an indication that urban sprawl occurrence slowed down from 2010 and 2017.

4. CONCLUSION

From the findings Urban sprawl in the study area was earlier compact with low magnitude from 1990 to 2000, it gradually became dispersed with high magnitude from 2000 to 2010 and is becoming compact with low magnitude from 2010 to 2017, it is directed towards the south western part of the study area with emerging environmental issues and rapidly decaying urban infrastructure such as roads/streets, housing, electricity, water supply and waste management system. It is quite important to note that this research is limited to the dynamics of urban sprawl; it is therefore recommended that the scope of subsequent researches should include the effects of urban sprawl on environmental sustainability.

Attainment of Environmental sustainability in Minna will remain a mirage, if the current rate of urban sprawl and increasing environmental deterioration are not proportionately matched with economic growth and environmentally friendly development practices. Therefore the need for Proper environmental management is paramount to the sustainability of the environment, as this research provides information about the dynamics of urban sprawl occurrence, which will help environmental managers in decision making.

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