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Geospatial Analysis of the Spatio -Temporal Growth of Kwali Area Council, Federal Capital Territory, Abuja

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ABSTRACT

This study analyzed the spatio-temporal growth of Kwali Area Council in Federal Capital Territory Abuja, Nigeria from 1998 to 2017. The study used Landsat Thematic (TM) of 1997, Landsat Enhanced Thematic Mapper Plus (ETM+) of 2007 and Landsat 8 Operational Land Imager (OLI) of 2017 all with a spatial resolution of 30 meters. Those data sets were accessed from United States Geological Survey (USGS) website Supervised Classification-Maximum Likelihood Algorithm was used to establish the land use-land cover situations for 1997, 2007 and 2017; subsequently the extent and rate of the urban growth of the study area between 1998 and 2017 were determined. The findings revealed that urban landuse covered 265.9 hectares in 1998, 304 hectares in 2007 and 1100.3 hectares in 2017. The urban landuse increased by 38.2 hectares from 1998-2007 which represent 14.3% growth in 9 years and corresponds with 4.24 hectares increase per year. The aforementioned growth rate was the lowest recorded in the period (1998-2017) of study as 2007-2017 showed that the urban landuse increased by 796.1 hectares which represent 261.8% growth in 10 years, this gives a corresponding growth rate of 79.61 hectares per year. The study recommends that there is the need for ecosystems restoration for areas that have suffered terrible degradation especially bare lands and local ingenuity, indigenous technology and know-how, and local community-centered efforts should be made and supported to restore the environment. That Government should as a matter of urgency embark on landuse /land cover mapping in the region in order to facilitate accurate base map production of Kwali Area Council as well as digitize and update all analogue maps of the area of study for effective planning for all physical developments. Land use is a term indicating the use to which a portion of land is put. Land is used for all of man‟s economic activities, and so the use of a portion of land determines the economic productivity of the land. Therefore, it is necessary to regulate and coordinate land use for optimum productivity and benefit of all people whose livelihood depends on the land.

INTRODUCTION

The world is becoming an increasingly urban place. Some 65% of the world's population is expected to be urban by the year 2025 (Schell & Ulijaszek, 1999). As a result of rapid urbanization, natural ecosystems are increasingly replaced by urban development. Urbanization, which means a population shift from rural to urban areas, is often accompanied by urban expansion and land use change. With worldwide land use land cover change, biogeochemical cycles, hydrologic systems and climate and biodiversity change driven by urbanization, increasing numbers of ecologists have accepted that urban areas are hot spots that drive environmental change on multiple scales (Grimm et al, 2008). These hot spots are estimated not only to be current threats for ecosystems but also will probably last for a long period in developing nations. The global urban population will reach 5 billion by 2030 (UN-HABITAT, 2006) and will increase by 2.7 billion by 2050 (United Nations, 2010), which indicates that the dramatic urbanization phenomenon will continue.

Urbanization is the dynamic process and it is one of the more important indicators of development. Though it is happening rapidly, in developing countries like Nigeria, the process of urban expansion is underestimated, due to use of traditional administration boundaries to demarcate urban area. But in the developing countries the urban growth is happening beyond the traditional boundaries and without proper planning (United Nations, 2010). Therefore the identification of urban expansion and direction of urban expansion are important for urban planning and to measure the level of urban growth. Statistical information alone is difficult to measure urban growth because, it is physically observable phenomena on the earth surface, both horizontally and vertically. Therefore, spatial and temporal analysis is important to understand urban growth, and for this both RS (Remote Sensing) and GIS techniques provide unrivalled opportunity to analyze urban growth.

Spatial information of land use over time is an important means for city planning and undertaking development activities. Analyzing the spatial and temporal changes in land use is one of the effective ways to understand the current environmental status of an area and ongoing change. Urban expansion is a major cause of land use changes (Singh and Kumar, 2012).

Urban growth indicates a transformation of the vacant land or natural environment to construction of urban fabrics including residential, industrial and infrastructure development. It mostly happens in the fringe urban areas (Shenghe and Sylvia, 2002).

Geospatial technologies had been applied to investigate the effects of urbanization on expansion variables and

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to quantify urban growth in different parts of the world. Remote Sensing and Geographical Information Systems (GIS) as modern technologies are increasingly used due to their cost effectiveness and technological soundness to develop useful sources of information and to support decision making in connection with a wide array of urban applications (Lo and Yang 2002). Due to the rapid influx of people in search of affordable lands and accommodation as when compared with expensive and high cost of housing in Abuja, Kwali Area, as a result of the proximity to Abuja attracts people and due to pressure on lend development is extending into prime agricultural land resulting to various environmental and social problems.

this research work proposes the following research questions; What are the land use and land cover classes in the areas?, What is the extent of urban land use in the study area between 1998 and 2017? And What is the rate of urban growth in the study area between 1998 and 2017?

Aim and Objectives

The aim of the study is to analysis the spatio-temporal growth of Kwali between 1998 and 2017. The aim is achieved through the following objectives which includes to; Examine the landuse and landcover classes into areas , determine the extent of urban Landuse in 1998, 2007 and 2017 and determine the extent and rate of the urban growth of Kwali Area Council between 1998 and 2017.

LITERATURE REVIEW

Urban places include areas within or near a city considered to share broad characteristics such as population concentration; shared and distinct employment pattern, lifestyle and land use; as well as the existence of different institutions that coordinate the use of public facilities (Hartshorn, 1991). According to Week (2010), urban centre refers to the concentration of people who are engaged in non-agricultural activities.

Opeyemi (2006) examined Change Detection on Land use and Land cover Using Remote Sensing Data and GIS (a case study of Ilorin and its environs in Kwara State). The study made use of multi-temporal satellite imageries and secondary data to map LandUse and Land- Cover in Ilorin between 1972 and 2001, using GIS techniques and statistical analysis to detect the changes that have taken place in its status between these periods.

Ishaya, Ifatimehin and Okafor (2008) carried out a study on urban expansion and loss of vegetation cover in Kaduna town, deployed the use of GIS and Remote sensing techniques with survey to identify the various land use and their transformations over time, recorded significant increase in the built-up area between 1990 and 2000. Such expansions were mostly at the fringe of the town area and are mainly due to population growth and development in its formal and informal sector of the economy.

Ojanuga and Ekwoanya (2008) studied Spatio-Temporal Changes in Land use Pattern in the Benue River Floodplain and the Adjoining Uplands at Makurdi, Nigeria. Makurdi and its environs were studied to assess the land use changes that occurred between 1967 and 1980’. The material and method used were two sets of panchromatic (black and white) aerial photographs for 1967 and 1980 at scales of 1:40,000 and 1:10,000 respectively. The landforms and land use patterns were interpreted and mapped with the aid of the mirror stereoscope. Detailed ground truthing was done in a sample area of 18.8km2 to characterize the component soil units, and document the cultural land use that has occurred between 1980 (representing the most recent aerial photograph of the area) and the present. The result has shown that the amount of land converted to non-agricultural uses in Makurdi increased from about 21% in 1967 and 32% of the total land area in 1980. Presently, substantial part (estimated at more than 50%) of the land in the Makurdi environs has been converted to urban use.

Akpu and Tanko (2012) examined the rate and pattern of the spatio-temporal Growth of Kaduna Metropolis, Kaduna State Nigeria, using GIS and Remote Sensing techniques. Visual interpretation method was used to sort the various datasets into land use and land cover classes. The result of the study showed that the built-up area increased from 6,410.4Ha in 1973 to 19,611.5Ha in 2009. The was growing at a rate of 5.72% annually and the areas towards the southern part of the River Kaduna were growing at a higher rate of 11.24% while the growth rate of the northern part was 3.71%.

Aguda and Adegboyega (2013) evaluated spatio-temporal dynamics of urban sprawl in Osogbo, Nigeria. The research made use of remotely sensed satellite images of 1962, 1972 and 2013, using GIS techniques of classification, overlay and area calculation. The study shows that the spatial extent of the total urban built-up areas of Osogbo city in 1962 was estimated at 3.95 km2. The total urban built-up areas increased to 6.61km2 in 1972. This indicates that urban expansion has engulfed 2.66km2 of rural areas between 1962 and 1972. Thus, the rate of urban expansion within the period was estimated at 4.0 % with land consumption rate and land absorption coefficient estimated at 0.0036 and 0.0076 respectively. This rapid rate of urban expansion has been found to have encroached on agricultural lands thereby accounting for a total loss of 57.01 % in agricultural land.

Olusegun (2013) carried out a study on urban expansion in Ado Ekiti, Nigeria, using GIS and Remote sensing techniques. The results showed the expansion that has resulted over the years. It was discovered that Ado-Ekiti had an area of 2.5 square kilometres in 1956, which increased to 6.9 square kilometres in 1996, and 36.7 square kilometres in 2006. The study suggested that if nothing is done to stem the uncontrolled expansion, the area may increase to 134.7 square kilometres in 2030.

Odjugo, Enaruvbe & Isibor (2015) examined the spatio-temporal pattern of urban growth in Benin City, Nigeria for a period of 26 years (1987-2013) using remote sensing data and geographic information systems techniques. The studies also examine the factors driving the observed pattern of growth in the city. The results show that Benin City is growing more towards the north, east and south along the major transportation routes. The land use pattern in Benin City is compact and radial from the city centre while the growth pattern makes Benin City a monocentric city. The settlement expanded from 220 km2 in 1987 to 359 km2 in 2013 with a mean annual growth rate of 1.5%. The growth of Benin City was observed to be influenced by the siting of public institutions such as schools, hospitals, government offices and industries. While the study demonstrates the importance of using geospatial technology in the acquisition of data for urban planning and management, the results highlight the influence of infrastructure development on urban growth pattern.

Wakirwa (2015) analyzed Urban Sprawl in Gombe Metropolis using geospatial techniques between 1991 and 2014. The data used for the study were Landsat 5 Thematic Mapper (TM) of 1991, Landsat Enhanced Thematic Mapper plus (ETM+) data of 2005 and Enhanced Thematic Mapper plus (ETM+) of 2014.The extent of urban land use was determined by using the attribute and statistics data generated from the classification result and used for post-classification comparison among the years. The built-up was also extracted for each of the periods and the extent of the built up area was calculated in hectares. The extent of the urban sprawl was analyzed by subtracting the reference year of land cover of 2014 from the base year 1991. The study explored urban sprawl in terms of the spatial extent of urban landuse, spatial extent of urban sprawl and, the rate and pattern of urban sprawl in the study area between 1991 and 2014. It was found that urban landuse occupied: 12.78km^2 (13.55%); 33.02km^2 (35.01%) and; 48.49km^2 (51.43%) in 1991, 2005 and 2014 respectively. Annual growth rate of 1.45km^2 (11.31%), 1.72km^2 (5.21%), 1.55km^2 (12.15%) were witnessed between 1991 and 2005, 2005 and 2014, 1991 and 2014 respectively. making. The results obtained from this study revealed that there has been a continuous increase in build-up areas throughout the study period.

Al Mashagbah (2016) quantified the urban growth and trend in Zarqa city during between period 1990 and 2014 using GIS and Remote Sensing techniques with Shannon's Entropy statistical method. Three Landsat images for 1990,2005 and 2014 were used for land use classification by using supervised maximum likelihood classification techniques to extract and assess the changes of urban lands. The result indicated that the urban areas in Zarqa city increased by 22.15% in the period from 1990 to 2005 and 14.86% from 2005 to 2014, with the entropy value for the NE, NW, SE and SW zone showed high values, which confirmed that urban expansion and sprawling had existed in the past twenty-four years in the study area.

Bununu (2017) simulated urban expansion using Kaduna in North-West Nigeria as a case study. Hybrid model that integrates the similarity-weighted instance-based machine learning algorithm for transition potential modelling and the Markov chain model to quantify and allocate land-use change was used to overcome the identified weaknesses of known modelling techniques such as the cellular automata, Markov chain and standard logistic regression models. Environmental and urban physical variables that act as constraints and/ or incentives to urban expansion were operationalized to create transition potentials for spatio-temporal states of built-up land use for the year 1990 and 2001. Model evaluation and validation was carried-out using the relative operating characteristic and Kappa index of agreement statistics.

METHODOLOGY

Kwali Area Council is located between Latitudes 80 30' and 80 55' North of the Equator and Longitudes 60 47' and 70 13' East of the Greenwich Meridian as shown in Figure 1. It is bounded on the North by Gwagwalada LGA, the West by Abaji LGA and to the East Kuje LGA. Kwali LGA consist of 10(ten) political wards, namely; Ashara, Dafa, Gumbo, Kilankwa, Kundu, Kwali, Pai, Wako, Yangoji, Yebu wards. Kwali Area Council experiences annually both the rainy and dry season. The rainy season begins in April and end in October when daytime temperature reaches 28-30ºC and nighttime lows over around 22-23ºC. According to National Population Commission (NPC) (2006), Kwali Area Council has population of 86,174. Using Exponential population

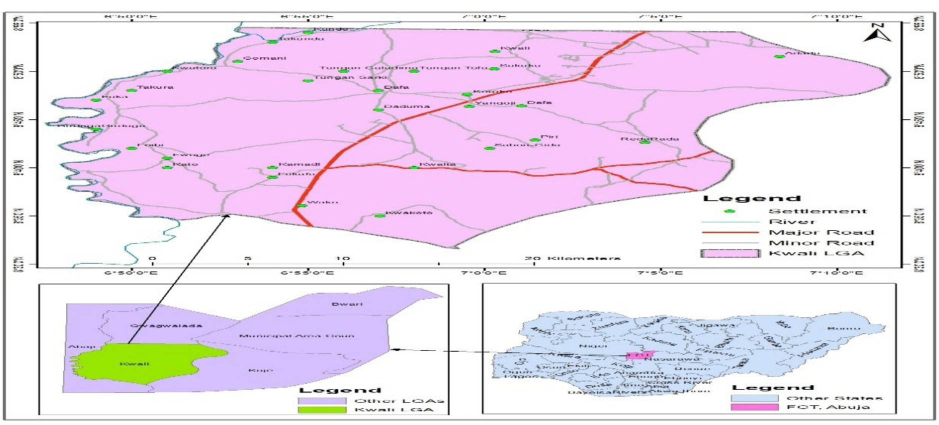

Fig.1: Kwali Area Council

Source: Administrative map of the study Area (2019) projection formula, at annual growth rate of 6.11%, the population of Kwali Area Council is estimated to about 179, 391.

Research Protocol

The first step, a researcher to was carried out reconnaissance survey for enable the researcher get a general knowledge of the study area. This knowledge was very useful during selection of training site and visual image interpretation process before and after classification.

The second step involve data collecting and data processing, Landsat imageries for 1997, 2007 and 2017 was downloaded from the United States Geological Survey (USGS) website at www.glovis.usgs.gov. They include the following:

1. Landsat Thematic Mapper (TM), 1998 with spatial resolution of 30 meters.
2. Landsat Enhanced Thematic Mapper Plus (ETM+) of 2007 with spatial resolution of 30 meters.
3. Landsat 8 Operational Land Imager (OLI) of 2017 with spatial resolution of 30 meters.

Data Processing

Image Pre-processing

Image processing techniques of layer stacking and sub setting were performed on the three sets of satellite images. To produce a composite image for each set of Landsat image, bands 1,2,3,4,5,7 of ETM+ and bands 2,3,4,5,6,7 of OLI will be stacked together respectively. A subset covering the area of interest will be extracted from the two composite images of the study area.

Image Classification

The satellite images were classified into land use classes. Anderson et al (1976) land use/ land cover Classification Systems was modified to classify the images into three land use classes: built-up (impervious layers such as residential and commercial services, office blocks, educational centres, hospitals, manufacturing industries, motor roads, rails etc); green areas (all cultivated areas such as farmlands, crop fields including vegetable gardens, plantations, fallow plots, protective forests, timber forest, economic forest, firewood forest and forests of special use), bareland (rock outcrop, bare surfaces or places with scanty grass) and water (river, stream, dam, pool and lake). Supervised classification system using maximum likelihood algorithm was performed on the images.

Classification Scheme

Code	Class Name	Description
1	Built-up	Residential, commercials, transportation and communication.
2	Water body	Rivers, stream and lakes
3	Vegetation	Natural forest, natural vegetation like grasses, shrubs, grass-like plant, farmlands, deforested area and clear forest land.
4	Bare land	Exposed soil and rock outcrops

Source: Modified from Anderson, Hardy, Roach, and Witmer (1976)

Data Analysis

Rate of Change Analysis

Post-classification comparison change detection algorithm will be applied to determine the changes in built up land use that has taken place from each classified image of the study area. In order to determine the extent and rate of change in built up in the study area, the following variables will be computed:

Total area (Ta), Changed area (Ca), Change extent (Ce) and Annual rate of change (Cr)

These variables can be described by the following formula:

$Ca = Ta\ (t2) - Ta\ (t1)$

$Ce = Ca\ /\ Ta\ (t1)\ x100\%$

$Cr = Ce\ /\ (t2 - t1)$

Where t1 and t2 are the beginning and endin g time of the land cover studies conducted.

Overlay Analysis

The built-up areas for 1998, 2007 and 2017 were superimposed on each other to analyze the pattern of urban growth in the study area. This process was done in ArcGIS 10.5.

RESULTS AND DISCUSSION

Land use land cover classification maps for 1998, 2007 and 2017 of the study were generated and presented in Figures 2, 3 and 4. Table 1 summarizes the total land area for each land use land cover class across the study area and the corresponding percentage of the total.

As shown in Table 1, the built-up has progressively increased throughout the study period from 265.9Ha in 1998, 304.1Ha in 2007, 1100.3ha in 2017 representing 0.2 %, 0.3% and 0.91% of the total landuse. This progressive increase in built-up area is in agreement with the work of Ade and Afolabi (2013), which revealed that built up areas in city(Abuja) increased throughout the study period from 78.75km2 in 1987 to 147.22km2 in 1999 and built up further increased to 416.22km2 in 2007 and an increase from 4%, 8% and 22% respectively. This growth extends not just inwards but outwards. This indicates that the continuous increase in built-up in Kwali has given rise to continuous increase in the urban expansion.

Water bodies which constituted 0.3% of the total area in 1998 increased in 2007 to 0.9% and decreased to 0.72% in 2017. The urban growth has also impacted on the water bodies negatively. Although generally, the reduction could be attributed to climate change.

Vegetation, which occupied 75400.6Ha (62.5%) in 1998 decreased to (55.5%) in 2007 and increased to 70.08% in 2017. Compared to 1998 vegetation cover has also been on the decrease. The decrease in vegetation between 1998 and 2007 in might have been caused by the increase in built-up area and other anthropogenic activities, leading to invasion of prime vegetal cover and conversion of vegetation lands to built-up land. This is in line with the work of Nwafor (2006) who also found that vegetal lands in Owerri decreased as built-up area increased. Bare land was 37.0 % in 1998, 43.3% in 2007 and decreased to 28.29% in 2018. During the epoch, 1998 to 2007, the increase in urban land use had not really been too much as the built-up area barely increased by 14.3% as shown in Figure 2-4. The increase in bare land may be attributed to clearing of vegetal cover for built-up activities, low rainfall and the people not cultivating the

Table 1: Land Use and Land Cover Statistics

Name	1998		2007		2017	
	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%
Built up	265.9	0.2	304.1	0.3	1100.3	0.91
Water	389	0.3	1077.8	0.9	866.4	0.72
Vegetation	75400.6	62.5	66969.7	55.5	84547.6	70.08
Bareland	44589.5	37.0	52293.4	43.3	34130.7	28.29
Total	120645	100	120645	100	120645	100

Source: Author's GIS Analysis (2019)

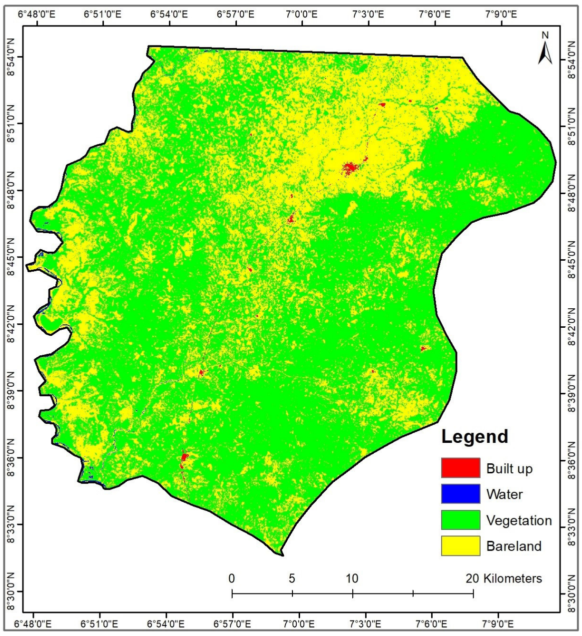

Figure 2: 1998 Land use Land Cover Classes of the Study area
Source: Author's GIS analysis (2019)

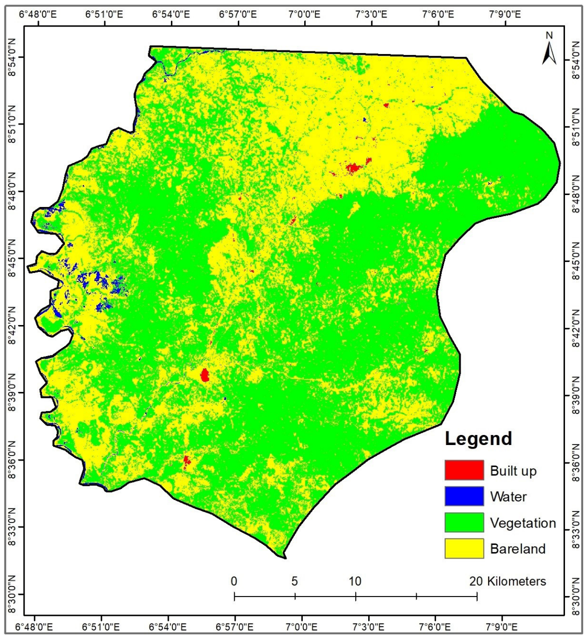

Figure 3: 2007 Land use Land Cover Classes of the Study area
Source: Author's GIS analysis (2019)

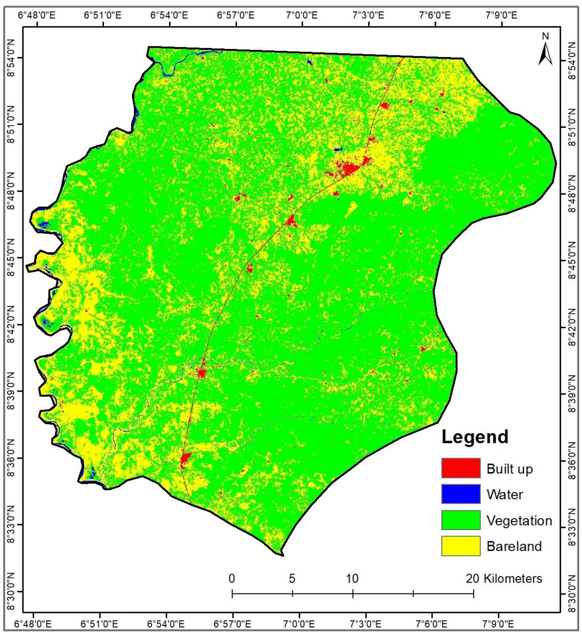

Figure 4: 2017 Land use Land Cover Classes of the Study area
Source: Author's GIS analysis (2019)

land and more anthropogenic activities. But as the urban land use increased significantly, between 2007 and 2018, it impacted on the bare land negatively decreasing to (28.29%).

Extent and Rate of Urban Growth

The extent of built-up land use for 1998, 2007 and 2017 are shown in Figure 5,6 and 7 respectively. Table 2 shows the extent and rate of the urban expansion between the various time periods.

The results as shown in Table 2 reveal that the built-up area increased by 38.2 hectares from 1998 to 2007 at an annual rate of 4.24%. The period 2007-2017 also recorded an increase in built-up (796.1 hectares) with an annual growth rate of 26.18%.

The analysis reveals that the extent and rate of urban growth in the study area increased appreciably. As shown in Table 2, the study area in 1998-2007 urban expansion by 38.2Ha (14.3%) at a rate of 1.59% each year. The period between 2007 and 2017 witnessed a urban expansion of 796.1Ha (261.8%) at a rate of 26.18% annually. Generally, from 1998 to 2017, the urban area in Kwali Area Council also increased by 834.3 hectares at 16.52% per annum.

This result is in agreement with the work of Ade and

Table 2: Extent and Rate of Urban Growth in Kwali Area Council

Urban			Magnitude of Expansion		Rate of Expansion	
Period	Year	Hectares	Ha	%	Ha/Yr	%/Yr
1998-2007	1998	265.9	38.2	14.3	4.24	1.59
9Years	2007	304.1				
2007-2017	2007	304.1	796.1	261.8	79.61	26.18
10Years	2017	1100.3				
1998-2017	2001	265.9	834.3	313.7	43.91	16.52
19Years	2017	1100.3				

Source: Author's GIS analysis (2019)

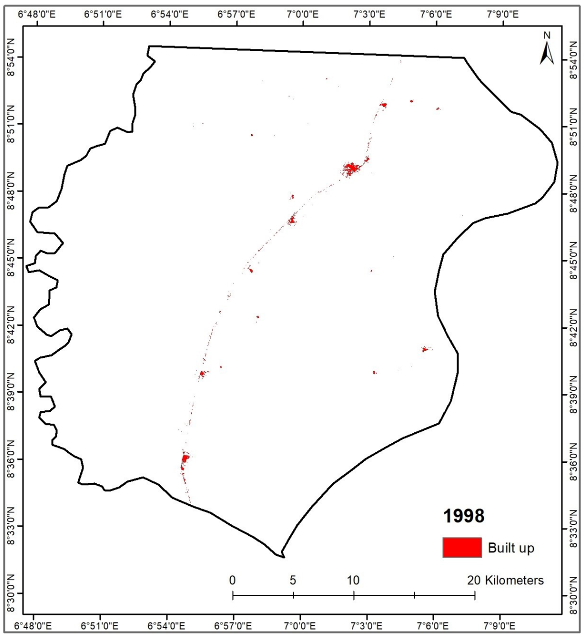

Figure 5: Extent of Built up in 1998
Source: Author's GIS analysis (2019)

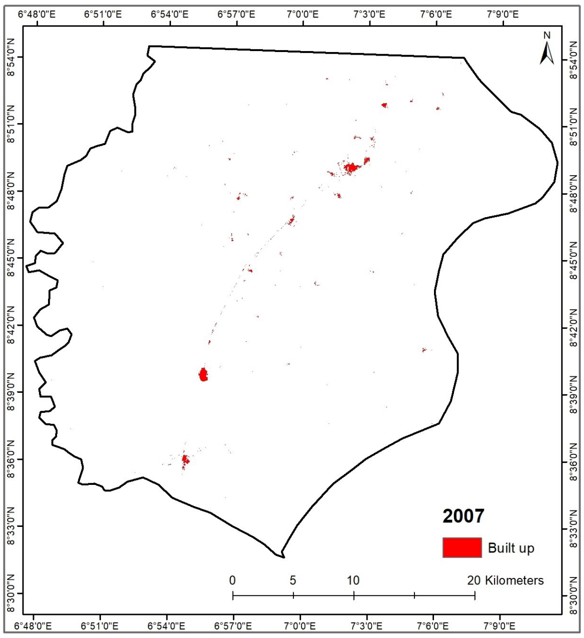

Figure 6: Extent of Built up in 2007
Source: Author's GIS analysis (2019)

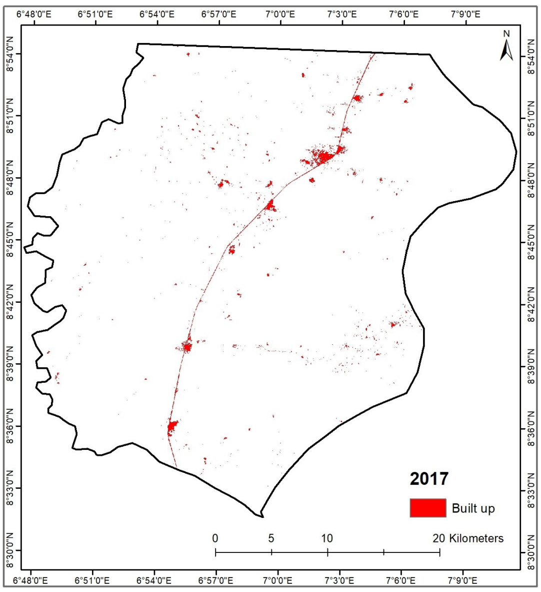

Figure 7: Extent of Built up in 2017
Source: Author's GIS analysis (2019)

Afolabi, (2013) which analyzed urban sprawl in Abuja and the result shows that the extent of growth increased not just inward but outwards. And also agreement with the work of Shittu, (2018) Spatio-temporal analysis of urban expansion in greater Karu urban area, Karu local Government area, Nasarawa state.

Figure 2 to Figure 4 shows the sub-sets of the urban land use in the study area for the three epoch to demonstrate how it has grown over time.

Pattern of Urban Growth in Kwali Area Council

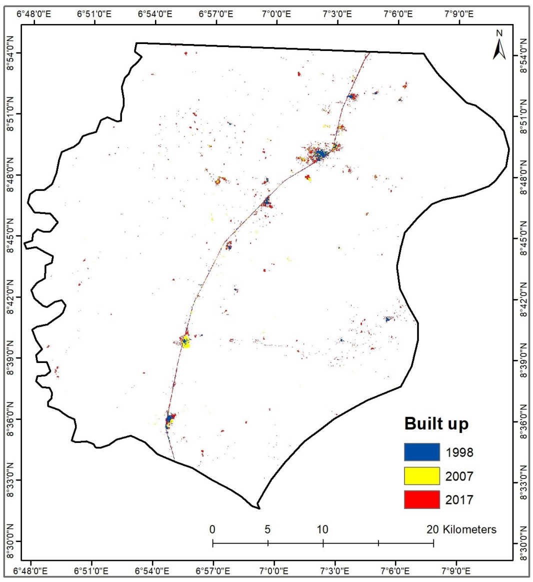

Figure 8: Pattern of Urban Growth in Kwali Area Council
Source: Author's GIS analysis (2019)

The pattern of urban growth of the study area was derived by superimposing the built up land use of 1998, 2007 and 2017 on each other and the result of the overlay analysis is presented in Figure 8. On the bases of the results obtained from the analysis, three patterns of urban growth namely; cluster, radial and leapfrog were found which varied from different study periods (1998, 2007 and 2017). Though, all of the study periods witnessed cluster in some of the villages in the study area, there is still variation within the study periods. It was found that in 1998 the pattern of the urban expansion was cluster while 2007 and 2017 witnessed both radial and leapfrog pattern of urban growth.

Summary of Findings

This project analyzed spatio-temporal urban expansion in Kwali Area Council, between 1998 and 2017 using Geospatial techniques. Landsat Thematic Mapper (TM) of 1998, Landsat Enhanced Thematic Mapper Plus (ETM+) of 2007 and Landsat 8 Operational Land Imager (OLI) of 2017 all with a spatial resolution of 30 meters of the study area were utilized. The land use land cover classes identified in the study area were built-up, water, vegetation and bare lands as the maps were generated using supervised classification. The findings revealed that urban landuse covered 265.9 hectares in 1998, 304 hectares in 2007 and 1100.3 hectares in 2017. The findings also revealed that the urban landuse increased by 38.2 hectares from 1998-2007 which represent 14.3% growth in 9 years and corresponds with 4.24 hectares increase per year. However, the period 2007-2017 showed that the urban landuse increased by 796.1 hectares which represents 261.8% growth giving a corresponding growth rate of 79.61 hectares per year.

CONCLUSION

This study reveals that there is high rate of urban expansion in Kwali Area Council. From the analysis carried out, the results obtained from this study revealed that there has been a continuous increase in build-up areas throughout the study period. There has also been a progressive increase of urban growth both in terms of spatial extent and annual rate throughout the study period. The period of between 2007 and 2018 had the highest rate of urban expansion which could be attributed to the fact that it was the period within which the restoration of FCT master-plan. It is obvious that the selected study area demands attention of planners and the FCDA to monitor and enforce land use policies to avoid urban sprawl.

RECOMMENDATIONS

Based on the identified changing nature and rate of various land-use/land-cover types identified in the study area especially from 1998 to 2017, the following are recommended:

Owing to the continual increase in urban sprawl in both extent and the rate in the study area, the following are recommended:

1. There is the need for ecosystems restoration for areas that have suffered terrible degradation especially bare lands.
2. The local communities are presently implementing the only adjustment mechanism they know which is to move away from degraded LULC. But local ingenuity, indigenous technology and know-how, and local community-centered efforts should be made and supported to restore the environment.
3. The tacit, informal and experienced based old natural community instinct needs to be rekindled to promote vegetation growth and maintain green countryside. Information, education and incentives should also be provided to stimulate the interests of the local communities in reforestation and sustainable farming activities.
4. Legislations compelling environmental protection, restoration and remediation need to be enforced.

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