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Analysis of the Impacts of Urbanisation on Land Cover Change in Gombe Local Government Area, Gombe State Nigeria

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ABSTRACT: Like many other Nigerian capital cities of newly created states in the 1990s, Gombe the capital city of Gombe State in the North-eastern geopolitical zone has experienced tremendous change in the land cover which is primarily driven by urbanisation. However, little is known on the extent of this urban expansion, how it has affected other land cover types or the dynamics of demographic change as a function of urban growth in the area. This spatial information is highly needed for effective planning and development. This paper, therefore, attempts to answer these questions by firstly, processing LandSat5 images of 1998 and Landsat 8 images of 2016 both of November of Gombe Local Government Area where the state capital is situated. Image processing is then carried out using the semi-automated classification plugin in QGIS 2.18. A supervised classification scheme was used to classify the 1998 and 2016 Landsat Image scenes into four land cover classes (water bodies, built-up area, bare-surface and vegetation) using the spectral angle mapping algorithm. Secondly, the paper analysed population data of Gombe Local Government Area for the same period to understand the dynamics of population change in the area. Based on the findings, urban land cover type increased from 13.02 Km^2 (25.14% of the total land cover) in November 1998 to 25.98 km^2 (50.17% of the entire land cover) in November 2016. As a result of this change in land cover, all other land cover types decreased in areal coverage. A Kappa index of 0.82 and 0.81 suggest that that the error margins during the supervised classification process of the 1998 and 2016 Landsat images are relatively small. The implications of rapid changes in land cover and population change in the area over a short period of 18 years on planning and management are also discussed.

KEYWORDS: Land cover change, image analysis, population change, QGIS

INTRODUCTION

Rapid urban growth and development have been noted as an essential driver of environmental change resulting from population growth, especially in developing countries (Abebe, 2013). The problem has been associated with several ecological, social, and economic consequences, including climate change, depletion of agricultural resources and deforestation ((Bhatta, 2010). Globally, there are more than 400 cities with a population of over a million people (Braimoh and Onishi, 2007). By implication, the large population in the cities means demand for more infrastructural amenities. Because as population increases, so does the need for new housing, schools, transportation and other civic amenities increases. Associated with rapid expansion, a lot of lands has been converted from rural to urban. From the land use and land cover change point of view, development of urban areas is of greater importance because of its strong effect on other land cover classes, such as agricultural lands, non-built areas, forests and others. Thus land use and land cover pattern of a region is an outcome of natural and socio-economic factors and their utilisation in time and space (Sajjad and Iqbal, 2012).

Furthermore, this rising demand for urban land tends to be reflected primarily in the congestion of the central areas of cities, rise in land values and the conversion of rural land at the peripheries of cities to urban use. One of the implications of uncontrolled population growth is its impact on residential land use, particularly in urban areas. Urbanisation and high population density have caused land degradation, especially in most parts of the developing countries (Sadiq, 2016).

Since accurate and timely information on land use and land cover change is highly necessary to many groups, remotely sensed data could be used as it provides the land cover information. It is also essential for estimating levels and rates of deforestation, habitat fragmentation, urbanisation, wetland and soil degradation and many other landscape-level phenomena (Adeniyi, and Omojola, 1999).

The creation of Gombe State and the subsequent sitting of the capital in Gombe Local Government Area (L.G.A.), resulted in the rapid urbanisation of the city. Gombe is one of the rapidly expanding cities in Nigeria (Ikusemoran et al., 2016). The expansion and growth of Gombe have impacted the socio-economic and environmental landscape of the area, leading to the conversion of farmland and other ecological resources to urban use (Gadiga and Galtima, 2017; Maina et al., 2018; Idris and Dharmasiri, 2016). Urban growth generally leads to transformations in the hydrological, ecological, geomorphological and socio-economic systems (Basawaraja et al., 2011). Both rural and urban administrations often neglect these issues. Thus, special attention and continuous assessment of the magnitude of the change are required for monitoring, urban development planning and decision making.

In Nigeria, the local government often referred to as the third tier of government is the smallest unit of administration and policy formulation (Ibietan and Ndukwe, 2014). Therefore the local government is significant in the development and management of urban areas. However, the ability of local governments to efficiently perform its role depends among several issues the ability to generate and have timely access to information on growth and changes taking place within its domain (Ibietan and Ndukwe, 2014). Analysing and modelling modifications, therefore, provide better information for urban planners and decision-makers to design strategies and solutions to manage the impacts of land use and land cover changes in both spatial and temporal scales.

The main focus of this study is, therefore, detecting and analysing the impacts of urbanisation on land cover changes in Gombe L.G.A. by integrating remote sensing and Geographical Information System (G.I.S.) tools.

Previous studies covering parts or the entire study area have used similar methods to determine urban change (Maina 2018; Gadiga and Galtima). Others include its effect on agricultural land (Oboh, 2018), hydrology (Idris and Dharmasiri, 2016), analyse conflicts caused by resource use (Whanda et al., 2016) and model topography (Ikusemoran et al. 2016). However, the previous studies mentioned fell short of using the L.G.A. as a unit of studying land cover change and did not consider the role of population change as the primary driver of urbanisation leading to overall changes in the land cover. Therefore, this study aims at producing a land cover map of Gombe L.G.A. at a different significant period to detect the changes that have taken place between the years 1998-2016 and to analyses the land cover changes that occurred. The specific objectives of the study are to analyse the pattern and rate of land cover changes in and around the study area using remote sensing data. Furthermore, to determine the impact of urban land cover growth on other land cover types and changes in population as a function of urban expansion in the area.

2.0 MATERIALS AND METHODS

2.1 Study Area

Gombe L.G.A. is located in the centre of Gombe State. The L.G.A. lies between latitudes 10^{O}15'00''to 10^{O}21'00 `` north of the equator and longitudes 11$^{O}$06'00 `` to 11^{O}12'00 `` east of the Greenwich Meridian (Figure 1). Gombe L.G.A. is bounded by Kwami L.G.A. in the North and almost surrounded by Akko Local Government Area in the Southeast and south-west. Gombe Metropolis is linked to other regions by roads like Gombe-Yola Road, Gombe to Biu – Maiduguri Road and Gombe to Bauchi Road.

Most parts of the larger Gombe Metropolis fall within Gombe L.G.A. The metropolis is divided into different residential quarters which include, G.R.A., Federal Low Cost, Arawa, State Low Cost, Kumbiya-kumbiya, Pantami, Jekadafari, Tudun Wada, Madaki, Dawaki, Bolari, Yalanguruza, Shamaki, Tumpure etc. (fig. 1). Some of these quarters belong to the neighbouring L.G.A.s of Akko and Kwami.

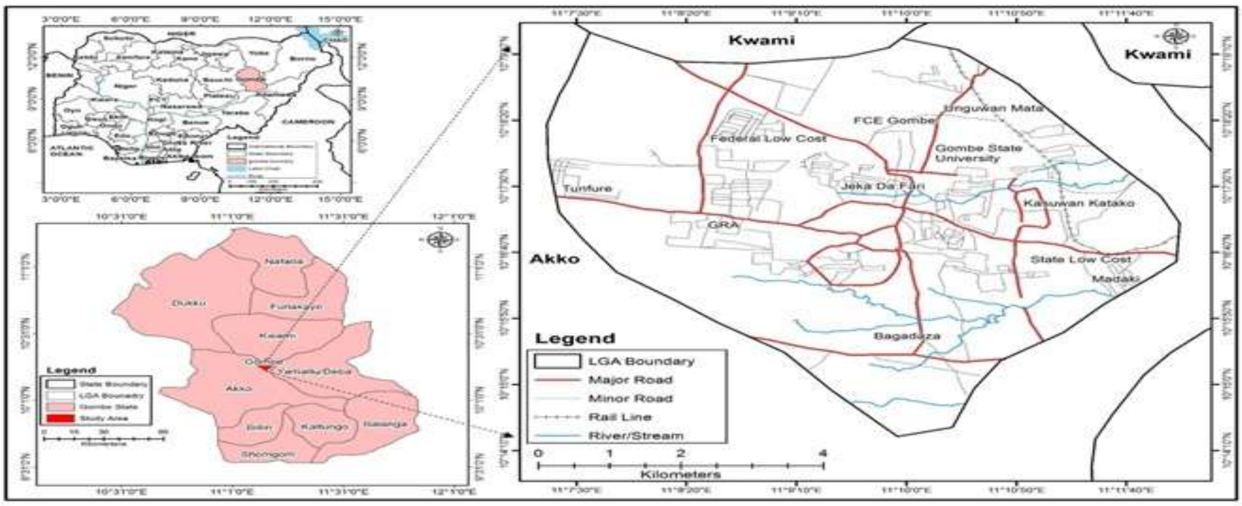

Fig. 1 Map of Nigeria of Gombe L.G.A. (primary right) with Gombe State (bottom left) and Nigeria (top left)

Source: Adapted and modified from the administrative map of Gombe State

2.2 Data types and analysis techniques

The data used in this research include shapefiles of Gombe State and local government areas in the state. Others are Landsat 5 and 8 image scenes of November 1998 and 2016, google earth images of the same period, population data from the National Population Commission (N.P.C.) and the National Bureau of Statistics, G.P.S. recordings, field observation; published and unpublished articles.

Table 1: Image Characteristics

S/No.	Satellite platform	Sensor Type	Spatial Resolution	Date Captured	Date acquired
1	Landsat 5	T.M.*	30M	4 November, 1998	11th June, 2017
2	Landsat 8	TIRS*	30M	6 November 2016	11th June 2017

* Note:
TM: Thematic Mapper (and Multi-Spectral Scanner)
TIRS: Thermal Infrared Sensor (and operational land imager)

Landsat 5 and 8 image scenes of November 1998 and 2016 (Table 1) were used to classify the study area into four distinctive land cover classes using the semi-automatic classification plugin (S.C.P.) in QGIS 2.18 software. QGIS is an open-source G.I.S. and Remote Sensing software with additional applications and plugins (Congedo, 2016). The four land cover classes include water bodies, urban built-up area, vegetation and bare surface. Image classification was carried out using a supervised classification technique based on the spectral angle mapping algorithm (Dennison *et al.*, 2004). The algorithm for the spectral angle mapping is as follows:

$$\theta(x,y) = cos^{-1}\left(\frac{\sum_{i=1}^{n} x_i y_i}{(\sum_{i=1}^{n} x_i^2)^{\frac{1}{2}}(\sum_{i=1}^{n} y_i^2)^{\frac{1}{2}}}\right)$$

Where: Eq. 1

x = spectral signature vector of an image pixel;
y = spectral signature vector of a training area;
n = number of image bands.
Therefore a pixel belongs to the class having the lowest angle that is:
x∈Ck⇐⇒ θ(x,yk) < θ(x,yj)∀k≠ j
Where:
Ck = land cover class k;
yk = spectral signature of class k;
yj = spectral signature of class j.

Simple random sampling technique was adopted in selecting the location of ground-trothing points. A total of 50 ground points were used across the study area in the ground-trothing process. Verification of image classification was carried out on locations on the ground and using google images. To determine the degree of error of the supervised classification accuracy assessment was carried out for the users and producers accuracy of each land cover class. Similarly, the overall (Total) accuracy and Kappa index were calculated to determine the accuracy of the image classification. The Kappa index is calculated as follows:

$$\widehat{K} = \frac{N\sum_{i=1}^{r} xii - \sum_{i=1}^{r}(x_{i+} \text{ x } x_{+i})}{N^2 - \sum_{i=1}^{r}(x_{i+} \text{x } x_{+i})}$$

Where, Eq. 2

$\widehat{K}$is the Kappa hat index,
N is the total number of pixels (observed),
r is the number of rows in the matrix,
xii is the number of observations in row i and column$i$,
$x_{i+}$and x_{+i} are marginal totals of row i and column i.

Population density of the study area was calculated using the N.P.C.'s census data for 2006. Also, population projections of the study area were obtained from the same source for 1998 and 2016, respectively.

3.0 RESULTS AND DISCUSSION

3.1 Land cover maps of Gombe L.G.A. and land cover change 1998 – 2016

Satellite image scenes for 1998 and 2016 were classified using spectral angle algorithm supervised classification techniques based on four land cove classes and is presented in Table 2 and Figure 2. In 1998 two years after the creation of Gombe State and study area becoming the state capital, the bare surface was the predominant land cover class. Based on the 1998 classified land cover map of the study area bare surface is 35.95Km^2 (69.43%) of the land surface. This land cover class was identified as open lands with barely any vegetation constituting of farmlands, rock outcrops, badlands and areas cleared for construction. The second-largest land cover type in terms of size is the urban land cover class 13.02Km^2 (25.14%). The urban built-up land cover class comprises of artificial surfaces such as buildings of various types, tarred roads and other concrete surfaces. In 1998 vegetation and surface water bodies are a small fraction of the total land surface area occupying on 2.80Km^2 (5.41%) and 0.01Km^2 (0.02%), respectively. Since the satellite image scenes were captured in November during the dry season, this explains the low vegetation cover as most grasses have dried up leaving only tree stands.

3.2 Land cover change 1998 – 2016 in Gombe L.G.A.

Comparisons of classified land cover maps of the study area for 1998 and 2016 shows a marked increase in urban land cover class from 13.02Km^2 (25.14%) in 1998 to 25.98Km^2 (50.17%) in 2016. All other land cover classes reduced in terms of area in the 2016 land cover map. Bare surface land cover class reduced from 35.95Km^2 (69.43) in 1998 to 25.13Km^2 (48.53%) in 2016. Vegetation cover in the study area reduced from 2.80Km^2 (5.41%) in 1998 to 0.67Km^2 (1.29) in 2016. There was a total loss in water surface cover 2016 (0Km^2).

Further investigation shows that within the period under study Gombe Metropolitan Area has grown and extended to areas outside the boundaries of the L.G.A. to neighbouring L.G.A.s such as Akko, Kwmai and Yamaltu – Deba. Similar results were obtained by Gadiga et al. (2017) and Maina et al. (2018) on the rapid increase in urban land cover in the study area since being designated the state capital of Gombe State. Oboh (2018) noted that the increase in urban land cover led to a reduction in agricultural land cover within the vicinity of Gombe Metropolitan.

Table 2: Land Cover change in Gombe L.G.A. from 1998 to 2016

Land Cover Code	Land Cover Type	1998		2016	
		Area in Km^2	Area in %	Area in Km^2	Area in %
1	Water Bodies	0.01	0.02	0.00	0.00
2	Urban	13.02	25.14	25.98	50.17
3	Vegetation	2.80	5.41	0.67	1.29
4	Bare/surface	35.95	69.43	25.13	48.53
	Total	51.78	100.00	51.78	100.00

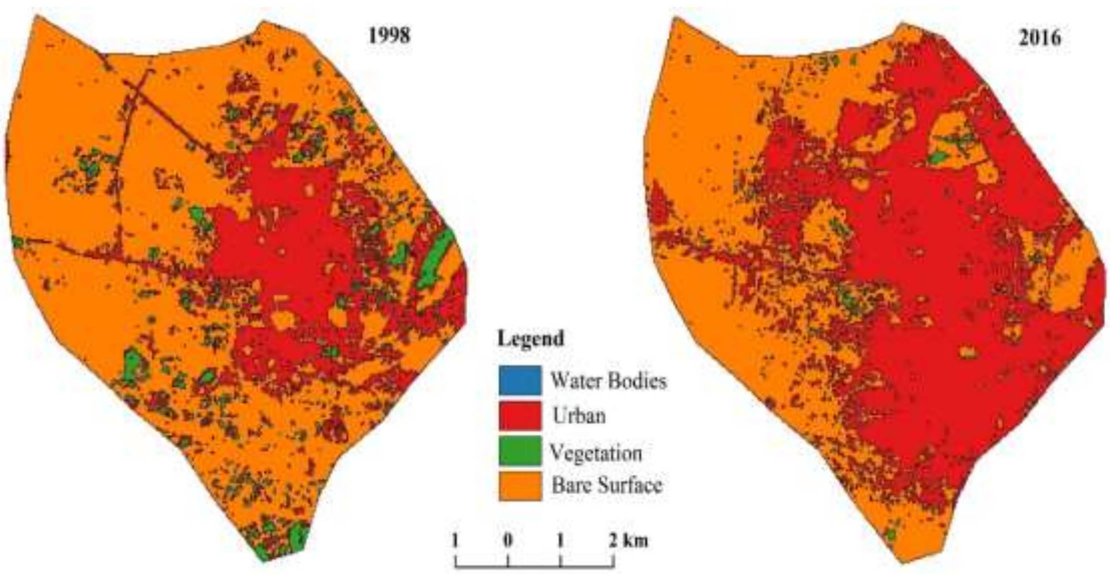

Figure 2: Classified images of the study area of November 1998 and November 2016 showing four land cover classes

3.3 Accuracy Assessment of land cover classification based on the 1998 and 2016 satellite image scenes

It is necessary to report the level of accuracy of the degree of error after classifying satellite images. The accuracy of the image classification is presented in Table 3. The overall accuracy for the two classified land cover maps of 1988 and 2016 is 88%. The Kappa index, which gives an overall agreement between the land cover classification and ground observations are 0.82 (1998) and 0.81 (2016), respectively. Therefore, both kappa index values are above 0.8 for a perfect fit, indicating an excellent classification of the images.

Table 3: Accuracy Assessment of 1998 and 2008 Classified Landsat Images

Land Cover Code	Land Cover Type	Producer's accuracy (%)		User's accuracy (%)	
		1998	2016	1998	2016
1	Water Bodies	100.00	0.00	100.00	0.00
2	Urban	85.71	92.86	85.71	92.86
3	Vegetation	80.33	90.00	100.00	90.00
4	Bare/surface	90.00	81.82	85.70	81.82
	Overall (Total) Accuracy			88%	88%
	Kappa Index			0.82	0.81

3.4 Population growth and changes in population density in Gombe L.G.A. 1998 – 2016

The population is the main driver of land cover change through changes in land use. Census data of 2006 and the estimated population of the study area for the years 1998 and 2016 are presented in Table 4. The population at different time intervals was used to calculate the population density of the study and is also presented in Table 4. The population increased from 213,714 people in 1998 to 266,844 in 2006 and 365,641 in 2016. Also, the population density of the study area increased from 4,127.35 persons/Km2 in 1998 to 5,153.42 persons/Km2 and 7,061.43 persons/Km2. As the population density in the study area increase, it provides an additional challenge to the L.G.A. in terms of urban planning and management of necessities and services such as the provision of access roads, primary health care and waste management. These services are the primary responsibility of a local government administration in Nigeria.

Table 4: Population and Areal Growth of Gombe L.G.A. (1998 – 2016)

Year	Population	% Increase in Population	Density in persons/Km^2	% Increase in Population Density
1998	213,714		4,127.35	
2006	266,844	24.86	5,153.42	24.86
2016	365,641	71.09	7,061.43	71.09

Source: N.P.C. 2018

4.0 CONCLUSION AND RECOMMENDATIONS

Considering the importance of monitoring land cover change and population increase in the formulation of policy and the decision making process in L.G.A.s this study classified satellite image scenes for the years 1998 and 2016 of Gombe L.G.A. and population change over 18 years (1998 – 2016). Results show that there is a rapid increase in urban land cover class at the expense of other land cover classes. The population also increased considerably during the 18 years, increasing the population density in the study area and pressure on land. Based on these results, the paper recommends the following:

- There is a need for local authorities and stakeholders to adopt geospatial analysis techniques for continuous monitoring of urban growth and land cover change
- There is an urgent need to look into the unplanned urban expansion not only within the L.G.A. but also in all the L.G.A. headquarters in the state. Vertical rather than lateral development should be encouraged.
- Further research is required in the future to study the evolving pattern of urban growth in the study area.

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