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RESEARCH ARTICLE

Monitoring Land Cover Change in Katsina Urban Area, Nigeria (1999 -2017) Associated with Urbanization: A Pixel-based Individuality Forms of Image A nalysis

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Abstract

Objectives: To study the rapidly changing urban area of Katsina in Katsina State; Nigeria, to track Land Cover Changes (LCC) and to identify possible impacts of urbanization. **Methods**: Landsat thematic mapper (TM), enhance thematic mapper (ETM +) images 30m resolution from the United States Geological Survey (USGS) acquired from Jos National Centre for Remote Sensing (NCRS). Satellite images from 1999 and 2017 were used to create a past and current picture of the LCC in the urban area of Katsina. The images were classified using the pixel identity forms of the digital organization of the monitored images with a maximum-likelihood classifier algorithm based on the multispectral image to understand the spectral data presented in the image of the urban area of Katsina. These images were then compared with the modifications that occurred among the dates of images. **Findings**: The findings on study area showed that the built-up area had increased and added 4.99 square kilometres (percentage change of 22.22) between 1987 -1999. The class of vegetation/agricultural land cover also increased and added 10.4 square kilometres (percent change of 165.8) between 1987 -1999. The Bare-soil had decreased and lost 15.39 square kilometres (percent change of 25.29) between 1987 -1999. **Conclusion**: Land cover changes exist, either legal or illegal, which indicate the rapid rate of population growth and urbanization in the urban area of Katsina. It also revealed the capability of RS/GIS for managing large information that made it suitable for these types of study.

Keywords: Analysis; Based on the pixel individuality; Land Cover Changes (LCC); Monitoring and Urbanisation

1 Introduction

Urbanization is the increase in both the urban footprint and the increasing rate of urban population that is seen among the anthropological activities that have a significant influence on the environment. The growth rate of urbanization in the world is terrifying, particularly in Third World nations like Nigeria,[1] causing many urban problems, including land-cover changes. This made it a central factor to be considered in the aspects of human or global changes in the first quarter of the twenty second century[2]. Societies are transforming as socio-economic structures are made and remade based on different models and circumstances[3,4].

Recently, cities around the world have experienced rapid growth owing to fast population growth and increased rural-urban migration.[3,5]. Thus, an average growth of the world's city dwellers from 1950 - 2005 was 2.6% and in Africa was 3.67% at the same time. Regionally, an average growth of city dwellers in West Africa was 4.3%; in Nigeria 4.4%; and in Katsina 4.5% from 1950 – 2005[6–8]. In Nigeria, urbanization is not a new phenomenon. It started three decades ago, but Nigeria's current urbanization problem is the cumulative failure of urban centres to meet the expectations of residents [5,2.6].

The urban area of Katsina has become one of the fast growing towns in the region because it provides socio-economic opportunities for communities in the surrounding area. The population of the Katsina towns ranged from less than 123,418 in 1975 to more than 378,000 in the year 2015[6].

These changes in functionality resulted to modifications in the physical appearance of the urban area of Katsina making it a major worry to planners and many government organizations. This is because this development has a greater impact on the economy, water resources, farming and recreational land and other land uses[4]. Therefore, if these environmental assets and services are left unchecked, they are either unrecognized or inadvertently sacrificed[4].

These problems had worsened due to the state creation in September 1987, which makes its development to be characterized by rapid urban growth through both natural growth and migration[3,9]. The environmental, economic and ecological problems in the urban area of Katsina are yet to received due attention. This has led to land cover change, environmental degradation and the destruction of infrastructural facilities necessary in maintaining a functional urban environment in the future[10,11].

Therefore, good diagnostic tools are needed for effective management of urban population problems. Reliable data is also needed to measure the present state and forecast the upcoming tendencies. Data on land-use designs is an example, but basic data on the populace, with its spatial spreading and growth rate is another example[12].

In view of the above, ten-year interval was selected to examine the land cover change during the successive leaders that govern the Katsina state for almost thirty years.

2 Methodology

2.1 Description of Research Area

The urban area of Katsina is located at latitude 12 ° 60'N to latitude 12 ° 75'N on the equator; and between 07°, 35'and 08°, 10'east longitude of Greenwich[13]. It covers an area of about 40 km^2. The urban area of Katsina is bounded by Batsari and Jibia Local Governments to the west and the Batagarawa Local Government area to the south. In the north, the urban area of Katsina is bounded by Kaita and the Jibia Local Government while to the east by Tsagero town[14]. (Figure 1 Map of the Katsina urban area).

The urban area of Katsina is mainly covered with crystalline rocks of the underground complex. However, in the north and east of the region, several feet of weathering material cover the hard rocks, which are commonly accumulated in drier climatic conditions[15]. The river basin is formed by the Abdallawa river that serves as the main water sources of the urban area of Katsina. The river basin is supplied from the southern part of the city. It collects water supplied by the Ginzo and Tille rivers that formed the main catchment and divides the urban area of Katsina into two. The north-western part is the Tille River basin and the south-eastern part is the Ginzo River basin. They are seasonal and almost dry in the dry season, if not due to domestic sewage. Their flow varies significantly over time throughout the rainy season[15].

The climate type is hot because it is located in a dry tropical area, with the characteristics of dry and rainy seasons, with an average annual temperature of about 27°C, which is high throughout the year. The average monthly temperature varies between 24 and 31 degrees Celsius, reaching approximately 36°C in March. The average annual rainfall in the area was recorded as 879 mm. The rainy period starts in May and ends in October, with great changes in intensity and duration[15,16].

The main vegetation features of the state (Sudan-Sahel) are shrubs and grasses, which are usually high during summer rains and usually straw-like or clustered during dry seasons. The trees are small and scattered. They shed their leaves in the cool dry season. The soils are class of entisols using the USDA 1975 system and xerosols using the FAO/UNESCO system. These soils are described as fine sand and slight acidic with Ph. 5.5 - 6.5. It is also, a low leaching soils with high alkali saturation

Fig 1. Map of the study area (The Katsina urban area), Sources: Map of Nigeria showing Katsina Metropolis, accessed October 2019, https://www.google.com/maps/search/map+of+nigeria+showing+katsina+metropolis/@12.9848928,7.5534067,12z/data=!3m

originating from complex rocks in the basement and aeolian drift. They are low in organic matter with total nitrogen content rarely exceeding 0.2%, while available phosphorus is usually less than 10ppm. The population is mainly Hausa-Fulani by the tribe and Hausa has become the lingua franca of the local people. According to the 2011 forecast based on 2006 population census data, the population of the urban area of Katsina is 438,826 persons. In terms of population density, an average of 245 people lives per square kilometre(7,14). The main livelihood activity of people in the urban area of Katsina is agriculture (crop production, livestock, food processing). Trade and other micro-entrepreneurship are also important in the socio-economic life of the populace(14).

The urban area of Katsina is a centre of tourism because of its wall which is surrounded by seven gates. The city walls (Ganuwa) was built about 903 years ago during the reign of King Ali Murabus. The Emir's Palace is also a tourist attraction due to the unique design of its architectural arrangement. The first citadel of learning, Katsina College was constructed in 1922, which is the firstborn education formation in Northern Province of Nigeria. Its key fascination is the red-baked-mud with which it was constructed. There is also, Gobarau minaret which was built about 300 years ago which still serves as a significant tourist attraction place. It was built with a baked-clay which is a very magical thing for the residents of this city. Legend has it that at that time, it was used for surveillance purposes due to its height, as soldiers can see opponents coming to the ancient city from a far place(14).

2.2 Data Sources

Effort was made to select data set free from cloud and near to similar date and season to avoid the impact of seasonal differences on the images were to be classified and changes identified detection. Cloud-free satellite images were will be collected in the Katsina urban area from March to May in the same season. Landsat, 30m resolution images (TM5, 1987 and ETM+ 7, 2017) full or obtained from the (USGS) were processed and projected onto the WGS 84 Earth Spheroid Zone 31. Images are acquired from the National Space Research and Development Agency (NASRDA), Abuja. (Table 1 , features of images used in LCC drawing for the urban area of Katsina) below shows the characteristics of the image.

Table 1. Features of Satellite images for LCLU mapping in the urban area of Katsina.

Date	Type of imagery	Landsat No.	Spatial Resolution	Year	Path/Row
April- May,2020	TM	Landsat-5	30	1987	147/47
April- May,2020	ETM+	Landsat-7	30	2017	147/47

The land-use map for the urban area of Katsina was obtained in hard copy from the KURPB and MLS produced prior to 1987, with an update to the current information on urban land cover changes. After that, it was scanned at a resolution of 100 dots per inch (dpi). It was geometrically corrected during scanning; digitized for computer handling and then digitized to make a G.I.S databank. The land use maps of the urban area of Katsina was as a guide for collecting and identifying areas suitable for reference data.

2.3 Image processing

In the absence of satellite images with high-resolution, urban land cover categorization in remote sensing is challenging[17,18], because of the characteristics an urban area is formed. Another problem with the classification of urban land cover in developing countries is that cities do not distinguish between materials covering different land cover types. For example, untarred roads, children's playgrounds, open spaces, landfills, agricultural land, etc. which belong to diverse types of land use, but have similar covering material and similar spectral reflectance. More specifically, because most city features are larger than 1m, this leads to misclassification of fixel[19].

2.4 Image pre-processing

The data was imported band by band and opened to ERDAS image software 8.7 version and then was transformed to the data imagine (img) image format. Bands 1-5 and 8 are then layer stacked on both Landsat TM5-1987 & ETM+7-2017. A consistent set of geometric and radiation measurement images were used to perform LULC change analysis**.** Geometric corrections were targeted for map scale and projection properties to avoid geometric distortion of the image[20,21]. Relative geometric correction methods were adopted to maintain the geometrical consistency of all images. A recent Landsat (TM) imagery was used as a reference for simultaneous image co-registration. An RMSE value less than 0.5 was set as the basis for the geometrically modified image, reducing the impact of inherent errors on the accuracy of the map product. The RMSE is determined using the below equation,

RMSE = $\sqrt{(xr - x2)\,2\, + (yr - y2)\,2}$ equation -1

Where, Xi &Yi = imputes source coordinates while Xr & Yr = retransformed coordinates.

After geometric correction, all images are taken to the common three-dimensional reference system (UTM/WGS84) in order to better align geographical features. After that, it was based on the pre-established geodetic control, projection, scale and grid positioning; and registered to the geodetic coordinates[20,21]. Later was compare the scene to scene through a single pixel for change detection.

Afterwards, different remote sensing data sets are radio metrically corrected to obtain suitable atmospheric conditions, solar angles, sensor observation angles and phonological characteristics[20,21]. In this research, images were obtained from diverse sensors (TM5 1987 & ETM+2017) and due to the spectral appearances of a specific land use feature and its representation in the data might differ over a period. Therefore, a simple approach is used, where the spectral response of the LCC features of a similar set of sensors, prior to image classification, are visually evaluated. The favourite images are obtained from April to May 2020 in the dry season that are related with vigorous, vegetative growth, cloud-free and fully cultivated farmland.

Image enhancement and transformation for spatial, spectral and radiometric, that includes contrast improvement through flattening histogram, the image transformation by a principal component analysis (PCA, de-correlation & HIS) and filtering method (low-pass-smoothing, upper-pass-sharpening, haze and noise decreasing) was performed. Spatial enhancement was use multiplicative spatial enhancement techniques, built on simple arithmetic integration and makes it easy to define urban features. The data was subjected to radiometric enhancement through a turbid reduction with ERDAS Imagine (V8.7) based on a cap and tassel conversion. Noise reduction was performed, removing the amount of noise in the input raster layer and in flat areas to preserve fine details in the image. (Figure 2, Diagram of Image Pre-processing, improvement and data extraction, Adopted from Matthew, 2007).

After Landsat TM 1987 and ETM+ 2017 images were corrected and enhanced, the individual pixel based forms of digital image classification were used to classify the image. A clustered class is purposefully established from the multispectral image to understand the spectral data presented in the image of Katsina urban area. This image was compared with the changes that have occurred between the date of the image. Thereafter, Landsat TM 1987 and ETM+ 2017 images was classified as including land cover types. At this level, satellite images are classified into four major types of land cover, considering the land-cover material of research at larger scale; (i) Urban/Built-up (ii) Forest/Agriculture (iii) Roads (vi) Bare-Soils/ landfill.

Assessment of the Accuracy

Error Matrix method is seen as the most appropriate for User's, Producer's and Overall/ Kappa accuracy assessment of data and maps used. First, the current land use map of the Katsina urban area was measured for its accuracy using location information collected through site visits. This should be very accurate as most places or areas were visited. This map was used together with the collected ground trough reference data to assess the classification precision in the land-use/ land cover maps that will be formed from satellite imagery. Thus, given the availability of data for this study, a satisfactory level of user's accuracy of 90%, 74% and 79% for Built-Up Land Cover Class, Vegetation/Agriculture Land Cover Class and Bare- Soil Land Cover Class were

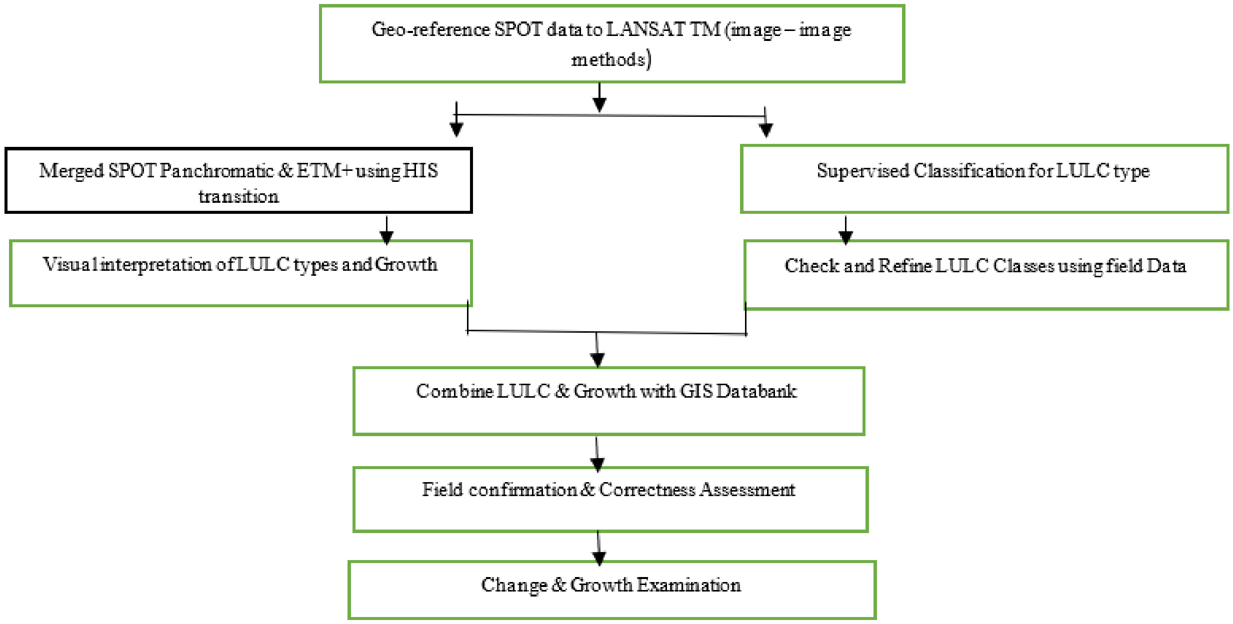

Fig 2. Diagram of Image Pre-processing, improvement & data removal, Adopted from Matthew, 2007.

achieved. Also, the Producer's Accuracy of 89%, 72% and 82% for Built-Up Land Cover Class, Vegetation/Agriculture Land Cover Class and Bare- Soil Land Cover Class were achieved. Whiles, the overall accuracy of 82% were achieved. The source of error was eliminated by geo-referencing the land-use map to geometrically corrected satellite images based on the acquired GPS coordinates. In addition, challenges brought by was used to assess the arrangement of image and the precision of the produced map. After that, the accuracy of the data used in the research have a high degree of accuracy. The accuracy of the land cover map formed of the Katsina urban area was evaluated and updated using the reference data obtained during the reconnaissance investigation. It solves the missing errors, challenges and difficulties in organization and comparison of urban land use types. Land cover map formed from satellite imagery and land use map formed from old-style mapping technique is resolved.

In a nutshell, the classification of urban land use is much problematic because of the composition of the materials that make-up the structure of the city. The level of accuracy of classification is to the minimum standard. Reflectance signs are much related that the more classes you try to have, the lesser level of precision of classification.

3 Result and Discussions

3.1 Change Detection

A Multi-temporal dataset method for digital change detection is adopted to distinguish between dates of imaging or the location of land cover changes between dates. This study looks at changes between classes (conversions amid land cover categories) and inside classes (changes amid land cover categories). Post-classification change detection is performed to avoid problems related to the examination of imagery obtained at diverse times of the year and sensors.

3.1.1 Land Cover Changes from 1999 to 2017

A Land area coverage for the individual's land cover category is computed from the categorized images. A Supervised organization technique is used to develop land cover maps classified in 1999 and 2017. After the classification of land cover types, comparison shows the changes in Km^2 between 1999 and 2017. (Table 2, the 1987 & 1999 land cover change obtained from post-classification assessment; Figure 3, the 1999 classified land cover image**;** figures 4, the 2017 classified land cover image). Table 2, Figure 3 and Figure 4 shows a detailed land cover type changes over time. The Built-up area increase by 31.66%, and vegetation/agriculture dropped sharply by nearly half, reaching -24.13%, from the initial land coverage to almost that of 1987 in the year 1999. This is because most of the new layouts designed for various land uses have been developed and put into use. The Bare-land cover reduces by -12.54% between the year 1999 and 2017. This is because the spatial expansion of other land cover types occurred in this land cover type and vegetation /agricultural land cover type. This is because, this land cover types show decrease in area coverage during the period under study.

Table 2. The 1999 and 2017 land cover change resulting from post-classification contrast.

LC Type	Year 1999		Year 2017		Change Year 1999-2017		Annual change rate -(Km^2)
	Area- (Km^2)	Area- (%)	Area- (Km^2)	Area- (%)	Area -(Km^2)	Area- (%)	
Built-Up Area	27.45	33.73	36.14	44.41	+8.69	+31.66	0.43
Veg. & Agric.	16.7	20.52	12.67	15.57	-4.03	-24.13	- 0.20
Bare Soil	37.23	45.75	32.56	40.01	-4.67	-12.54	- 0.23
Total	**81.38**	100	**81.38**	100	–	–	–

Source: Field Work, 2020. *+ (-) indicates the area increase / (decrease) of LULC classes

(Figures 3 and 4, the 1999 & 2017 classified land cover image), were classified images showing land cover types and their changes in the study area. This is obtained by comparing the land area (Km^2) of each class on different dates for the years 1999 and 2017. The images in 1999 and 2017 are divided into three classes of land cover classified. The purpose of this is to resolve the confusion amid bare soil with the new urban developments that have close spectral reflectance, but combined built-up and new urban development into one land-cover type for numerical analysis.

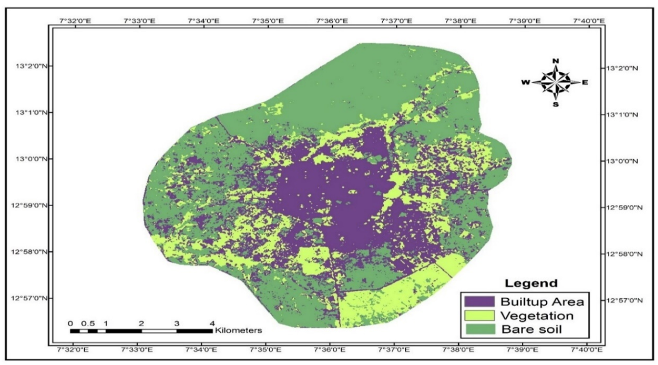

Fig 3. The 1999 Classified image (land cover) **Source: Field Work, 2020.**

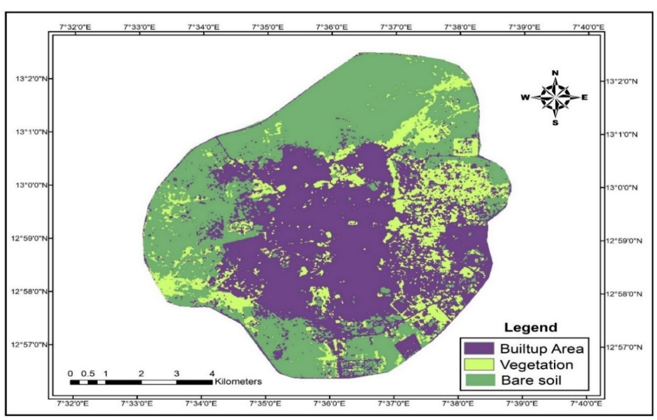

Fig 4. The 2017 Classified image (land cover). Source: Field Work, 2020.

The change in land cover types explains the dynamics of land cover changes occurrence and the upcoming trends that may follow based on present conditions. Each land cover type was compared and the proportion change is computed to define the degree of change amid diverse classes. (**Table 2** The 1999 and 2017 land cover change resulting from post-classification contrast.)

3.2 Discussion of the Findings

Land cover/ land use change has been known to be a significant driver of ecological change on all the spatial and temporal scales[20,22] and is related to human mobility, the trend of urbanization and urban-rural migration research; together they affect land use and land value and the changing shape of the urban environment[23,24]**.** The land cover/ land use change can be a conversion, that is, due to changes in the urban area, agricultural expansion or deforestation, as one type of land cover completely replaces another land cover type, resulting in an overall change in the land cover category[22,25] or modification which is just an alteration in the character of land cover without undertaking its general classification.

After classification of land cover types, comparison shows the changes in Km^2 between 1999 and 2017. (Table 3.1. The 1999 & 2017 land cover change obtained from post classification assessment) this shows the detailed information of the changes between land cover types in the study are for the during study period. Due to fast populace growing and the change of economic function of the urban area of Katsina from what it was before the state creation and the present status. The status quo highlights the land cover changes happened in the Katsina urban area.

3.2.1 Built-Up Land Cover Class

This land cover type accounted for 33.73% (27.45 Km^2) of the land cover in the urban area of Katsina in 1999. By the year 2017, this land cover category accounted for 44.41% (36.14 Km2), an increase of 8.69% during the study period. Most of the growth occurs on the outskirts of cities, where bare soil and vegetation/agricultural land cover provide many opportunities for urban growth for various land uses. In addition, the land cover in the old city has changed, and residential land has been used as commercial land. The lack of effective government policies to protect vegetation/agricultural land makes it an easy target. It is also agreed that there is no effective government policy and planning to limit and protect mixed land use. This has today reached a worrying stage because all the land assigned for this purpose in the land use map of the urban area of Katsina has been taken over or fully developed for other purposes, mainly for urban land use. This resulted in a rapid and unprecedented urban growth of 8.69%, which is not typical of cities such as the urban area of Katsina during the study period.

As a result of this conclusion, it can be argued that the higher the level of urbanization (the urban growth / urban sprawl), the greater the likelihood of land cover change in the Katsina metropolitan region. Thus, for a long-term urban development, the Katsina state government should prioritize land cover change studies as well as urban studies in general. It should be emphasized that increased urbanization (urbanization / urban sprawl) has an impact on land cover change because it has resulted in a shift in land cover, hence confirming the demand and supply model of land use/ cover change and the theory of ecological equilibrium.

3.2.2 Vegetation/Agriculture Land Cover Class

In 1999, this type of land cover accounted for 20.52% (16.7Km^2) of the urban area of Katsina, but the urban area of Katsina offers numerous prospects for urban expansion. The total land area of this land cover/ use type is 20.52% (16.7 Km^2) in 1999, reduced by 15.57% (12.67 Km^2) in the year 2017. Most of the built-up land cover changes (increase) occur in vegetation/agricultural land cover. The bare-soil land cover type has also made a significant contribution to the reduction of vegetation/agricultural land cover type, since most of the development areas chosen for the design of layout have been developed.

As a result of this conclusion, it can be argued that the higher the level of urbanization (urban growth / urban sprawl), the greater the likelihood of land cover change in the urban area of Katsina. Thus, for long-term urban development, the Katsina state government should prioritize land cover change studies as well as urban studies in general. It should be emphasized that increased urbanization (urbanization / urban sprawl) has an impact on land cover change because it has resulted in a shift in land cover, hence confirming the demand and supply model of land cover/ use change and theory of ecological equilibrium.

3.2.3 Bare- Soil Land Cover Class

This type of land cover is the least, and what happens in this class can't be overlooked. This type of land cover has reproduced in extent over the past two decades. The shocking truth regarding this type of land cover is that, most parts that are bare-soil in 1999 have converted to build up areas, but this type of land cover has declined from 45.75% (37.23 Km^2) in 1999 and 40.01% (32.56 km2) km2) in 2017. This is attributed to the development projects by the government and individuals in the study area from 1999-2017. Precisely, layouts are designed for different land uses to meet the increasing demand for the growing population. Most of the affected areas were on the outskirts of the city and existing roads were widened and new ones were built in some parts of the old city. This development has changed and continues to form the landscape structure of the urban area of Katsina.

4 Conclusions

The research proved the use of the image examination method based on the pixel individuality in the observation of multi-temporal LC. Numerous earth satellite imagery observation is integrated in studying the effect of urbanization on the current land cover pattern of the urban area of Katsina in Katsina State between 1987-1999 were studied. Urbanization is seen as the factor responsible for urban growth and population growth due to change in status of the study area and migration as the most common phenomena. This is reflected in land cover changes and population growth. The percentage change in built-up land cover has increased by 22.22%; the vegetation / agriculture land cover has nearly tripled from its original cover in 1987; while a 29.25% decrease in bare land cover indicates that spatial expansion of other land cover types arose directly on the bare-soil.

In land cover change, an increase of 8.69 Km^2 in the coverage built-up within the study period testifies the change in socio-economic and political activities of the study area. The bare-soil reduces its size from the original area cover in 1999 to - 4.67 Km^2 in 2017. The - 4.03 Km^2 decrease in the vegetation/ agriculture land cover shows the spatial growth in other land cover types has straight-away occupied place on the vegetation/ agriculture and bare soil, as indicated by decreased in their area coverage for the study period.

The population of the urban area of Katsina has increased from less than 123,418 in 1975 to over 378,000 in 2015. This clearly indicates the close relation between urbanization, population and urban growth.

However, these changes in land cover during the study period indicate a change in socio-economic activity of the study area. Also, it can be argued that the higher the level of urbanization (urban growth / urban sprawl), the greater the likelihood of land cover change in the urban area of Katsina. Thus, for long-term urban development, the Katsina state government should prioritize land cover change studies and urban studies in general. It should be emphasized that increased urbanization (urbanization / urban sprawl) has an impact on land cover change because it has resulted in a shift in land cover, hence confirming the demand and supply model of land cover/ use change and theory of ecological equilibrium.

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