Urban Studies and Public Administration
Vol. 4, No. 1, 2021
www.scholink.org/ojs/index.php/uspa
ISSN 2576-1986 (Print) ISSN 2576-1994 (Online)

Original Paper

Estimating Per Capita Land Use/Land Cover Change (LULCC) in Makurdi, Northcentral Nigeria

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Received: January 1, 2021 Accepted: January 19, 2021 Online Published: February 4, 2021
doi:10.22158/uspa.v4n1p97 URL: http://dx.doi.org/10.22158/uspa.v4n1p97

Abstract

The study estimated annual and temporal variation in per capita Land Use/Land Cover Change (LULCC) in Makurdi, Northcentral Nigeria. A total of four Landsat TM/ETM+ images were acquired in April of 1991, 1996, 2001 and 2006 for the study. A total of five LULC types namely water, forest, undergrowth/wetland, cultivated land and built-up land were derived from the Landsat images using supervised classification method. The per capita LULCC was derived by dividing the areas of LULC types by the actual population data. The result showed that built-up land recorded the highest long-term gain in area by 179km^2 (130%), with an increment of 8.7% per anum, and undergrowth/wetland lost 119km^2 (32%) in area with a decrease of 2.1% per annum from 1991 to 2006. The per capita LULCC of built-up land has increased from 575m^2/person (1991) to 1059m^2/person (2006), representing an increment of 481m^2/person (83%). The undergrowth/wetland recorded the highest decrease in per capita LULCC from 1542m^2/person (1991) to 836m^2/person (2006), representing a decline by 706m^2/person (46%). The study concludes that undergrowth/wetland is the most vulnerable LULC type due to urbanisation, and sustainable urban planning should be practised to conserve the natural cover materials in the study area.

Keywords

urbanisation, footprint, land use/land cover change, per capita, landsat images

1. Introduction

One of the consequences of ecological footprints of urbanisation is the radical and irreversible changes in land use/land cover (Grimmond, 2007). Land use/land cover, which refers to the biophysical state of the earth's surface and immediate subsurface (Weng, 2001a), is the combination of land cover and human activities, which is the physical material of the land's surface.

The LULCC, associated with the replacement of natural surface materials such as soil, litter, humus, vegetation and water by impermeable, non-evaporating and non-transpiring materials such as asphalt, concrete, brick and stone used in the construction of roads, buildings and other infrastructure (Schmid, 1974; Carlson & Arthur, 2000; Grimmond, 2007), has several implications in cities. The LULC change alters the local/micro climate (Li et al., 2017), influences surface temperature and urban heat island (Chen et al., 2006; Yuan & Bauer, 2007; Gaylan, 2017; Roy & Parial, 2019), contributes to urban flooding (Weng, 2001b) and global warming (James & Mundia, 2014) and is fundamental in understanding the global ecological footprints of urbanising areas and the dynamics of urbanisation impact on temperature (Jo et al., 2000; Weng, 2001a; Musoaglu et al., 2006). Urban LULCC also influences pollution sources and characteristics (Fameli et al., 2013), and the deposition of some air pollutants such as ozone and particulate matter and their precursors (Wu et al., 2012).

The per capita LULCC, derived from dividing the areas of LULC types by the actual population data, is used as a proxy of ecological footprint of urban growth and development (Wilson & Lindsey, 2005; Fenta et al., 2017). The per capita LULCC measures the change in areas of LULC types per individual and thus relates LULCC directly to human population, a major driver of LULCC in urban areas (Wilson & Lindley, 2005). The increase in population in cities has created insatiable demand for infrastructure, services and investments to accommodate the myriads of urban needs at the expense of natural surface cover and materials. According to Newman (2006), increase in population, based on economies of scale and density, can stimulate financial investment in cities, which might lead to urban growth and consequently a decrease in natural land surface cover. The major objectives of the study are to 1) classify land use/land cover types, 2) estimate change in the areas of LULC types and 3) estimate the per capita LULCC in the study area. Estimating per capita LULCC is crucial in sustainable urban planning and conservation of natural land resources in Makurdi, one of the fastest growing urban areas in northcentral Nigeria.

2. Method

2.1 Study Area

Makurdi, Benue State capital, is the largest city in the state. It is located between latitudes 7^{o} 35^{l} - 7^{o} 53^{l} N and longitudes 8^{o} 24^{l} - 8^{o} 42^{l} E. Makurdi lies entirely in the River Benue flood plains of Northcentral Nigeria and serves as a link between the southern and northern Nigeria (Figure 1). Makurdi urban area covers a land area of $800km^2$.

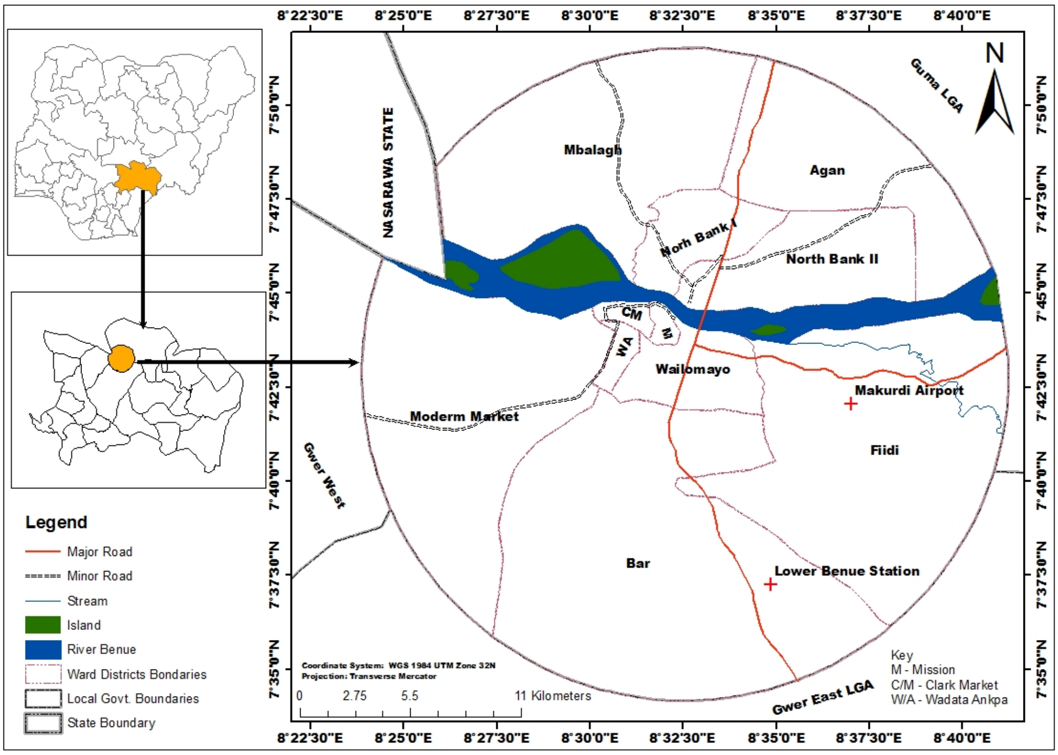

Figure 1. Location of Makurdi Urban Area

Makurdi started as a small river port at the south bank of River Benue, in the present Mission and Clark/Market council wards, in the 1920s. Makurdi became the provincial headquarters of former Benue Province in 1927, headquarters of Makurdi Local Government Area in 1970, and capital of Benue State on February 3, 1976. The changes in the administrative status have contributed to the tremendous growth and spatial expansion of Makurdi southwards and northwards of River Benue, into rural and suburban areas of Kanshio, Yaikyo, Apir, Adaka, Adeke and Poor (in the south bank) and Anter, Akiki and Agan (in the north bank).

According to national population census data, the population of Makurdi was 239 889 people in 1991 and 300 096 people in 2006, representing an increase in population density from 300 to 375 persons/km^2. The projected population of Makurdi in 2020 is 460,000 people based on 3.0% growth rate per annum. Makurdi urban area is subdivided into eleven political divisions known as council wards. The council wards that cover the metropolitan area are Mission, Clark/Market, Wadata/Ankpa, North Bank I and Wailomayo. Fiidi, Modern Market and North Bank II constitue the suburban councl wards and the rural council wards comprise Bar, Mbalagh and Agan (Figure 1). It is widely believed that in Makurdi urban area, 60%, 30% and 10% of the population live in metropolitan, suburban and rural areas.

2.2 Data Acquisition and Processing

A total of four Landsat TM/ETM+ images were acquired for a 15-year period (1991-2006). These comprised Landsat 5 TM images (April 11, 1991 and April 25, 1996) and Landsat 7 ETM+ images

(April 13, 2001 and April 12, 2006) respectively. The starting (1991) and terminating (2006) years were chosen to coincide with years the National Population Census was conducted in Makurdi. The actual population census figure is required in estimating the per capita LULCC (Wilson & Lindley, 2005). Since 1991, National Population Census in Nigeria is conducted every 15 years and the next census is scheduled to hold in 2021.

All the raw Landsat images were geo-referenced to a common Universal Transverse Mercator (UTM) co-ordinate system using a 1:50 000-scaled topographical map of the study area. The Landsat TM/ETM+ images of the study area were retrieved from Landsat scenes of paths 187-188 and rows 054-055. National Population Census data of 1991 and 2006 were acquired at the National Population Commision (NPC), State Office, Makurdi.

2.3 Classification of LULC

Classification of LULC is a prelude to estimating annual and temporal change in the per capita LULCC in any geographical region. The supervised classification (SC) method was used to classify LULC in the study area. The supervised classification of satellite images is an effective tool to quantify current and to detect changes in LULC (Degife et al., 2018). Using the SC method, the LULC types of the study area were first detected and classified based on their spectral emittance. Secondly, field work was conducted and the coordinates of the LULC types on the ground were taken. Two or more different cover materials may have same spectral signature and may thus be classified as a single LULC type. Field work is necessary because different cover materials with same spectral signature can easily be detected and separated. Thirdly, the coordinates of LULC types obtained during filed work were then superimposed on the initial LULC map to identify the actual LULC types. Lastly, the area of each of the LULC types was computed in square metres (m^2) and then converted to square kilometres (km^2). The classification and computation of areas of LULC types were conducted using Integrated Land and Water Information System (ILWIS) 3.3 and ArcGIS 9.2 software.

3. Result

3.1 Classification of Land Use/Land Cover

A total of five LULC types were classified in the study area namely water (blue), forest (light green), undergrowth/wetland (green), cultivated land (oval green) and built-up land (gold). The water surfaces covered open water surfaces, streams and rivers, and natural and man-made forest were categorised under forest. Undergrowth/wetland comprised grassland, marshy areas and wetlands while cultivated land covered all arable farm sites. The built-up land comprised buildings, roads, high ways, parking lots and other infrastructure.

3.2 Annual Changes in Land Use/Land Cover Types

The result of land use/land cover change analysis from 1991 to 2006 is presented in Figures 2-5 and Table 1. In 1991, the undergrowth/wetland has the largest area of 370km^2, representing 46%, and water has the least area of 21km^2, representing 3% of the total land area. The areas of other land use/land cover types are forest (133km^2 or 17%), cultivated land (138km^2 or 17%) and built-up land (138km^2 or 17%) respectively (Figure 2 and Table 1). However in 1996, the areas of undergrowth/wetland, forest and cultivated land have decreased to 268km^2 or 34%, 116km^2 or 14% and 118km^2 or 15%, while water and built-up land have increased in sizes to 147km^2 or 18% and 151km^2 or 19% of the total area (Figure 3). The increase in area of water cover in 1996 is attributed to increase in surface water in wetlands and marshes as the result of rainfall.

In 2001, cultivated land occupied the largest area of 280km^2 or 35%, followed by undergrowth/wetland (253km^2 or 31%), and built-up land (144km^2 or 18%), forest (102km^2 or 13%) and water (21km^2 or 3%). However, all the land cover types experienced decrease in sizes relative to 1996 except cultivated land (Figure 4 and Table 1). Increase in area of cultivated land in 2001 is related to improved government incentives and inputs to farmers to boost agricultural production of arable crops in 2000. In the same vein, government's policy on demolition of illegal structures on streets, parks and open spaces, and other reserved areas is responsible for the decline in area of built-up or developed land in 2001.

The area of built-up land experienced a tremendous increase in size by 179km^2 (40%) from 138km^2 in 1991 to 317km^2 in 2006. Conversely, the areas of other LULC types including water, forest, undergrowth/wetland and cultivated land have declined by 251km^2, 119km^2, 96km^2 and 17km^2 (Figure 5 and Table 1). The sharp increase in built-up land in 2006 is attributed to the housing development in new areas of Makurdi including Judges' quarters, Nyiman layout and New GRA.

Table 1. Changes in Land Use/Land Cover Types in Makurdi from 1991-2006

Land use/land cover types	1991		1996		2001		2006	
	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
Water	21	3	147	18	21	3	17	2
Forest	133	17	116	14	102	13	96	12
Undergrowth/wetland	370	46	268	34	253	31	251	31
Cultivated area	138	17	118	15	280	35	119	15
Built up area	138	17	151	19	144	18	317	40

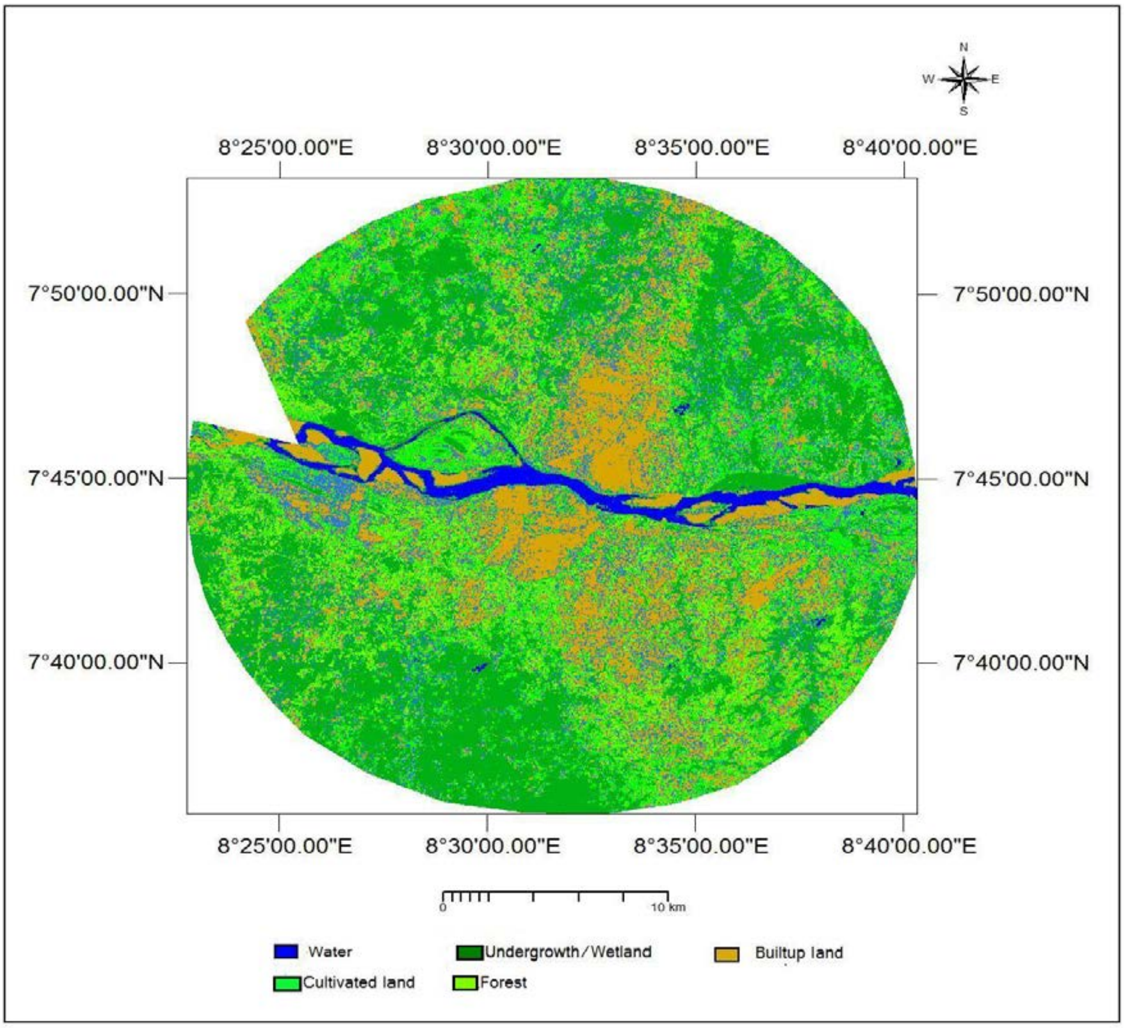

Figure 2. Land Use/Land Cover in Makurdi, April 1991

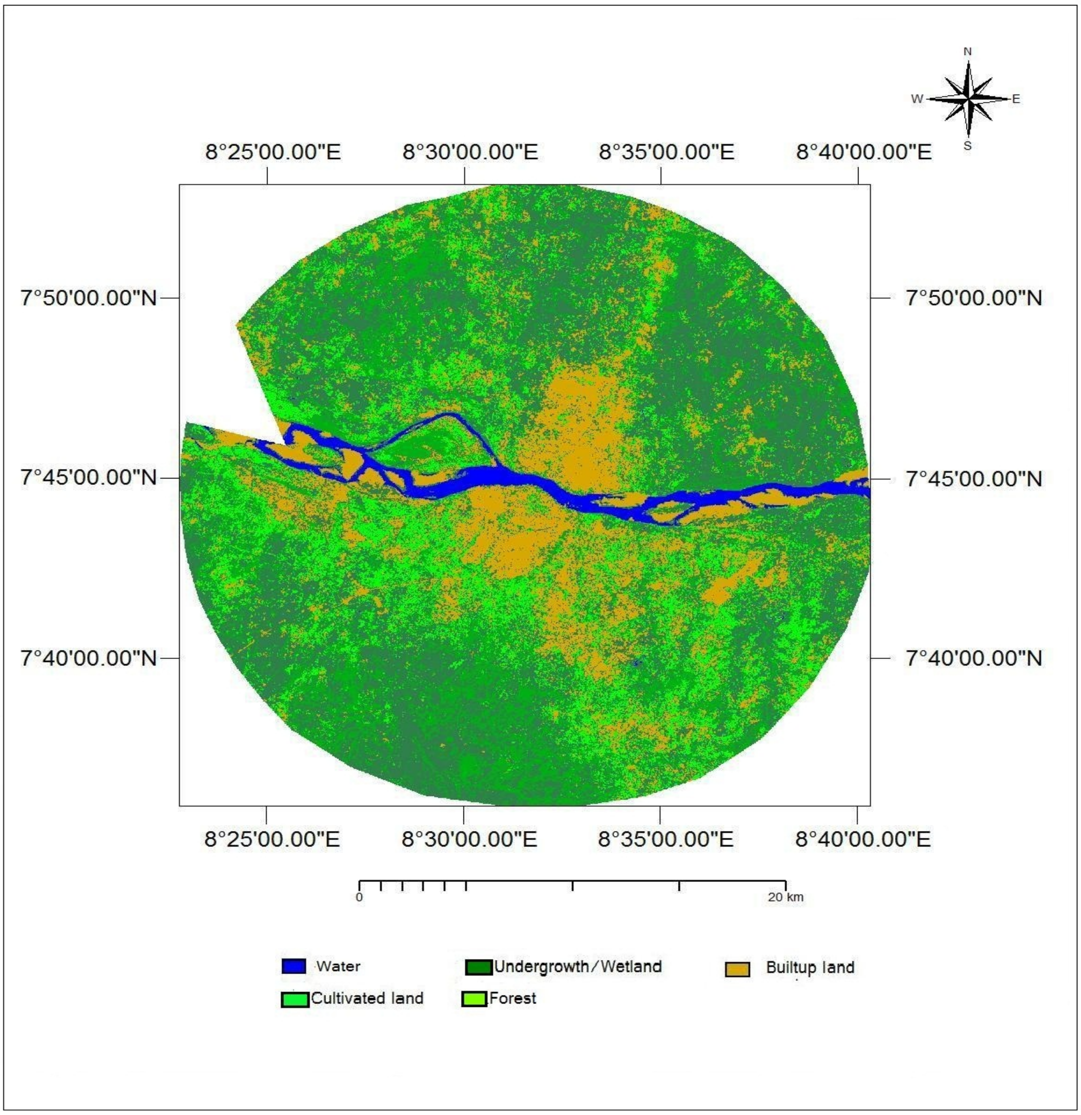

Figure 3. Land Use/Land Cover in Makurdi, April 1996

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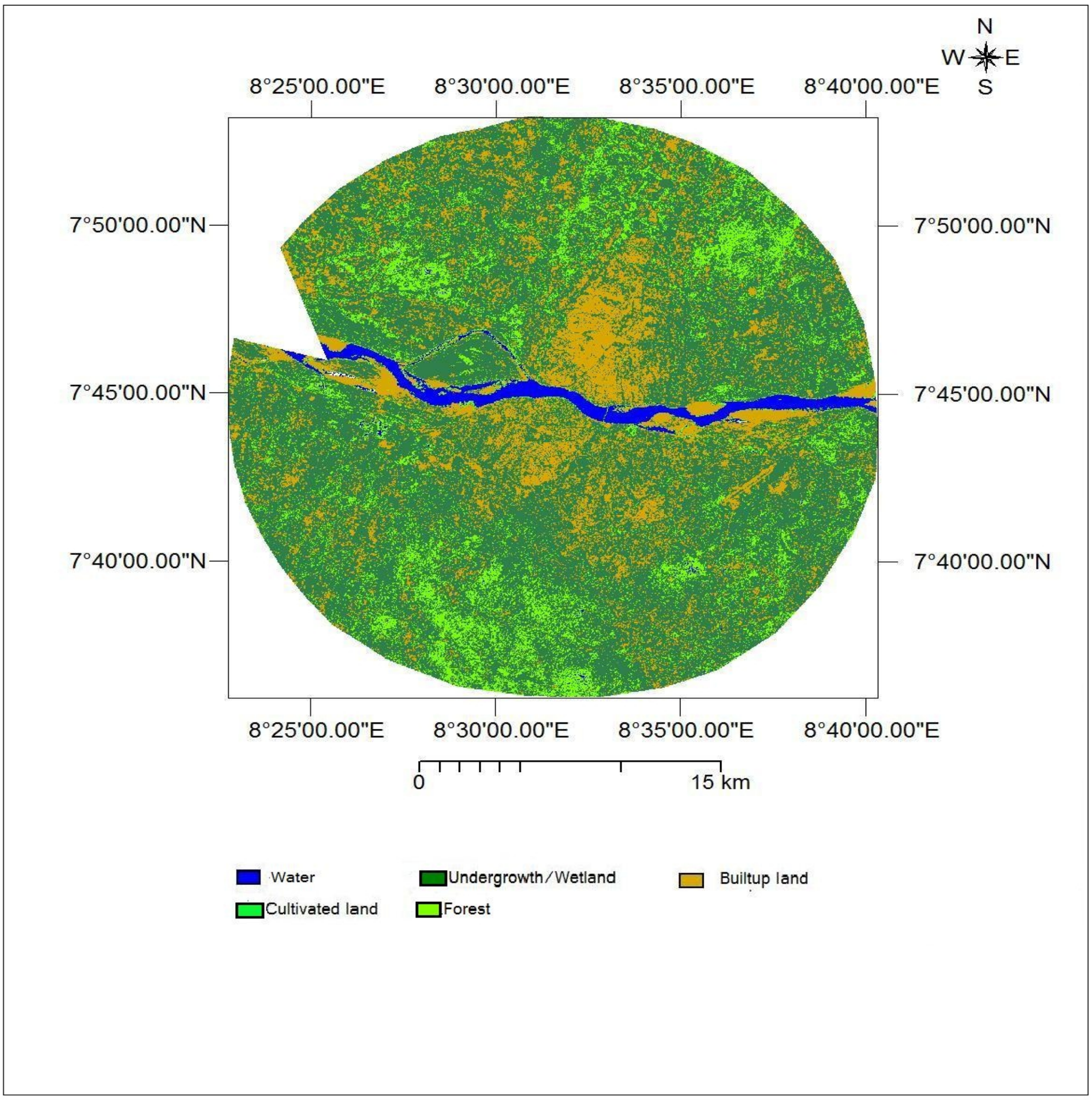

Figure 4. Land Use/Land Cover in Makurdi, April 2001

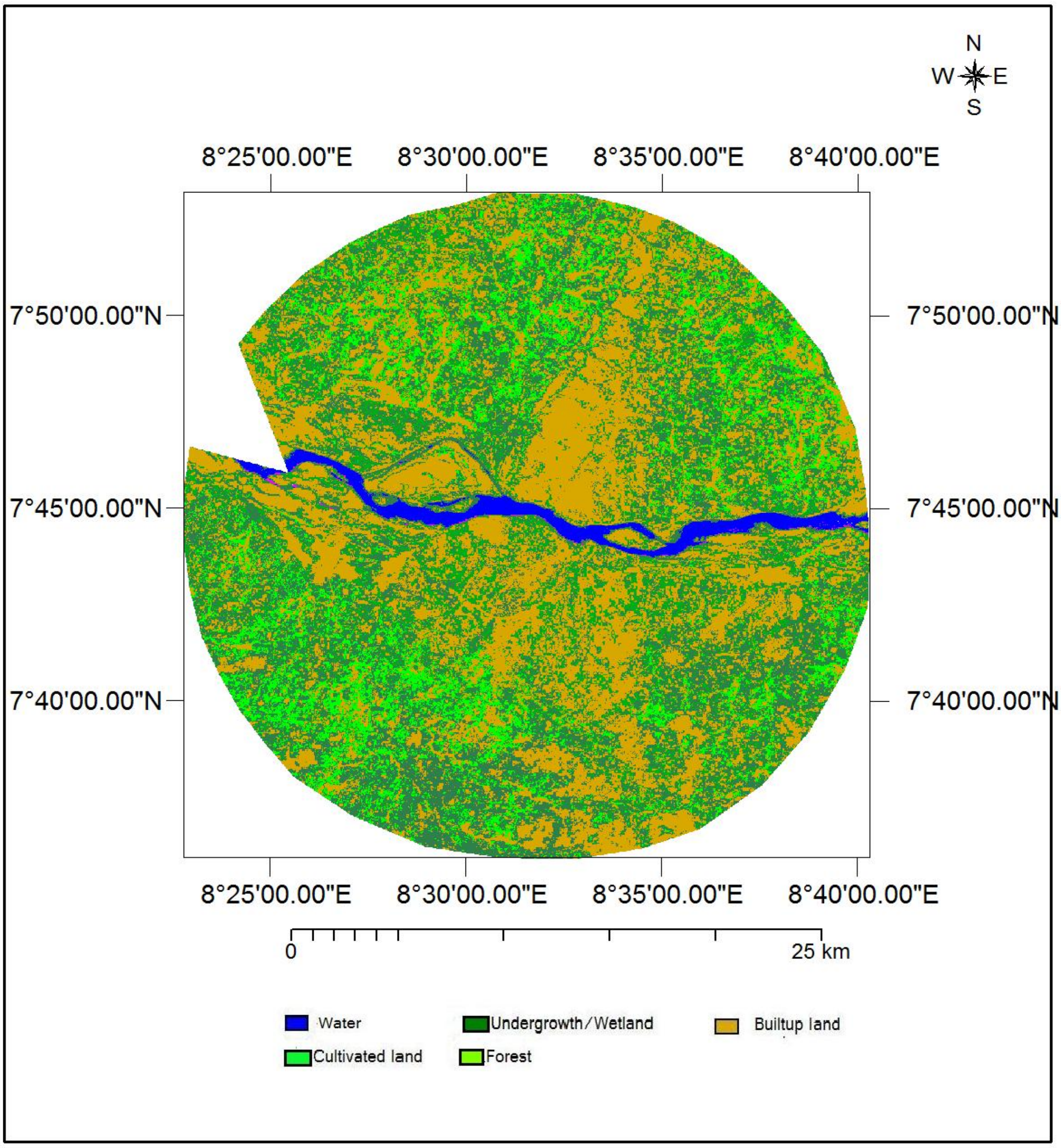

Figure 5. Land Use/Land Cover in Makurdi, April 2006

3.3 Per Capita Land Use/Land Cover Change

The result of the per capita LULC change is presented in Table 2. The result indicated that water and undergrowth/wetland have the least and highest per capita decrease in area by 31m^2/person (35%) and 706m^2/person (46%) from 1991-2006. The areas of forest and cultivated land have also decreased by 214m^2 and 178m^2 per person, representing a decrease by 39% and 31% during the same period. Conversely, built-up or developed land has increased by 481m^2/person, representing an increase by 83%, from 575m^2/person in 1991 to 1056m^2/person in 2006 (Table 2). The result suggests that as urban population increases, the need and demand for housing, infrastructure and services also increase. This leads to inadvertent increase in human-related surface cover and materials at the expense of natural ones such as vegetation, soil, wetlands, marshes, water bodies and cultivated lands. In Makurdi urban area, urban growth and development have led to an aggressive and irreversible incroachment on undergrowth/wetland, the most vulnerable land use/land cover type, in the study area.

Table 2. Per capita Land Use/Land Cover Change in Makurdi, 1991-2006

LULC types	LULC area/person (m^2)		Change in LULC area/person	
	1991	2006	Area (m^2)	%
Water	88	57	-31	35
Forest	554	340	-214	39
Undergrowth/wetland	1542	836	-706	46
Cultivated land	575	397	-178	31
Built-up land	575	1056	+481	83

4. Discussion

The result of LULC change analysis indicated that there is a general increase in the area cover of built-up or developed land while those of water, forest, undergrowth/wetland and cultivated land have decreased from 1991 to 2006. This is attributed to increase in urban population which triggers a simultaneous increase in both financial and infrastructural investment and improvement in the quality of life of urban dwellers. Other studies have reported similar trend in Landsat TM/ETM+ derived LULC change in many urban areas and cities such as Lagos (Okude & Ademiluyi, 2006), Instanbul (Musaoglu et al., 2006), Shanghai (Zhao et al., 2006), Lokoja (Oluseyi et al., 2009) and Bahir Dar and Hawassa (Gashu & Gebre-Egziabher, 2018). However, Mills (2004) observed that urban areas in desert regions may not fit in this pattern because they are wetted through irrigation. Degife et al. (2018) also reported that government intervention has resulted in increase in the areas of marsh vegetation, water bodies and farmland in Gambella region, Ethiopia as the population of the region increases.

The result of per capita LULCC suggests that population increase is the primary driver of LULC change occasioned by urban growth and development in Makurdi. As urban population increases, there is increase in the need and demand for infrastructure and services by urban dwellers. Natural land cover and materials become scarcer as they give way to housing, roads, markets, schools and other human-related structures. In Makurdi, like most cities in developing countries without a planning ordinance, the situation is even more critical. Increase in urban population has increased the presure on wetlands, marshy areas and vegetation. The conversion of wetlands to housing for instance has tremendously increased the frequency of flooding in the city. This confirmed the result of Wilson and Lindley (2005) study of increase in per capita developed land of 6.6% in Central Indiana, USA from 1991 to 2000 due to increase in urban population. Fenta et al. (2017) also reported an increase in the per capita land consumption rate (ha per person) from 0.009 in 1984 to 0.014 in 2014 in Makelle City, northern Ethiopian as a result of urbanisation.

The result of per capita LULCC has several environmental implications in Makurdi. Urbanisation degrades the environment and destroys fragile natural ecosystems and biodiversity. In addition, the replacement of evapotranspiring land cover materials with non evapotranspiring ones will lead to a decrease in atmpsheric humidity, increase in air pollutants and surface and air heat and temperature. According to Weng et al. (2006), water has a high thermal inertia through convection and turbulence, leading to slower accumulation and subsequently cools the surface and the overlying air. Vegetation also is noted to effectively reduce the amount of heat stored in soil and surface structures through direct shading and evaporation. Conversely, buildings have lower thermal inertia, leading to a quicker heat accumulation. The increase in the size of built-up land at the expense of water and vegetation surface materials would positively affect both the surface and air temperatures in the study area.

5. Conclusion

The result of annual and temporal variation in per capita LULC change showed that the least and highest decrease in areas of the five LULC types namely water, forest, undergrowth/wetland, cultvated land and built-up land during the 15-year period were water (-4km^2 or 19%) and undergrowth/wetland (-119km^2 or 32%). The area of built-up land however has increased by 179km^2 (130%) during the same period. The per capita LULC of water, forest, undergrowth/wetland, cultvated land has decreased from 1991 to 2006 by 31m^2/person, 35m^2/person, 706m^2/person and 178m^2/person representing a decline by 35%, 39%, 46% and 31%, with undergrowth/wetland having the highest decrease both in area and percentage. Conversely, the per capita LULC of built-up land has increased by 481m^2/person (83%), during the same period. The result of the study suggests that as urban population increased, the areas of natural and human-related surface cover and materials have decreased and increased in Makurdi. Moreover, among the five LULC types in the study area, undergrowth/wetland is most vulnerable to urban growth and development. Sustainable urban planning in Makurdi should incorperate conservation of wetlands, water surfaces and natural vegatation to safeguard the natural resources from human degradation.

Ackwoledgements

The support of management and staff of National Center for Remote Sensing, Jos, Nigeria in acquisition, procession and analysis of Landsat Images is highly appreciated. The study was partially supported by Doctoral Fellowship of the African Climate Change Fellowship Program (ACCFP) Round 1. The paper is dedicated to the memory of Late Professor Raymond Nlemadim Chima Anyadike, who contributed from conceptualisation to writing of original draft.

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