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Geospatial approach to spatio-temporal pattern of urban growth in Benin City, Nigeria

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This study examines 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. It also analysed 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 km^2 in 1987 to 359 km^2 in 2013 with a mean annual growth rate of 1.5%. The growth of Benin City is observed to be influenced by the siting of public institutions such as schools, hospitals, government offices and industries. While this 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.

Key words: Urban growth, spatial analysis, monocentric, remote sensing, geographic information systems (GIS), Nigeria.

INTRODUCTION

The increase in population growth, especially in the developing countries of the world has brought about an increase in the rate of urbanization (Adeoye, 2012) and a concomitant growth in cities around the world. Urbanization is one of the several anthropogenic factors that result in land use and land cover changes. While urbanization is an increase in the size and proportion of the population living in urban settlements, urban growth refers to the rate, at which an urban settlement is increasing in spatial extent. Rapid urban growth has been observed to be the leading cause of social, economic and environmental challenges including loss of biodiversity, forest and agricultural resources, climate change and other issues related to the concentration of human activities (Skole and Tucker, 1993; Lambin et al., 2001; Perkin, 2013).

The internal demographic, spatial and economic growth of cities has been explained by many theories. These theories include the concentric zone theory propounded by Burgess in 1925, the sector theory proposed by Hoyt (1939) and the multiple nuclei theory advanced by

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Harriss and Ullman (1945). The concentric zone theory proposed that cities grow in zones outwards of the centre while the sector theory argues that cities grow in sectors, rather than in concen-tric zones and the multiple nuclei theory shows that cities growth are not necessarily in zones or sectors, but similar activities are grouped together in certain districts that necessitate the growth. The growth of some cities in some parts of world may follow any of the theories above while others may be the combination of two or the interlink of the three theories.

Urbanization in Nigeria is divided into four phases and they include: the pre-colonial (before 1900), colonial (1900-1960), post-colonial (1961-1995) and contemporary (1996-to date) phase (Omuta, 2005). Although urban growth has been on in Nigeria since the pre-colonial period, the last four decades have particularly been characterized by rapid rate of urbanization in Nigeria. Several studies have noted the rapid growth rate of Nigerian cities in the recent past (Opoko and Oluwatayo, 2014). For instance from a total of less than 8 million in 1960, the urban population in Nigeria has risen to over 80 million by 2006 according to the 2006 National Population Census data. Urban development studies in Nigeria, as in most African countries, have largely been related to the establishment of European colonial administration (Onokerhoraye, 1995; Ikhuoria, 1999). The establishment of colonial rule is noted to have influenced urban growth and development in sub-Saharan Africa. It has also been observed that rural-urban migration is a key factor influencing the rate and pattern of urban growth in most African cities (Onokerhoraye, 1995; de Jong et al., 2000).

In spite of the rapid rate of urban growth in sub-Saharan African cities, the dearth of relevant data for urban planning and management has remained a major challenge (Onokerhoraye, 1995). The consequences of uncontrolled urban expansion include overcrowding, housing shortages, inadequate or sometimes non-existing infrastructure, environmental degradation, pollution and other ecological and environmental problems (Ayedun et al., 2011 and Jiboye, 2011). These problems need consistent monitoring and management for a sustainable environmental management and control. The need for relevant and up-to-date data, therefore calls for the use of modern technologies, such as remote sensing and geographic information systems (GIS), for the acquisition of data and other information necessary for planning and monitoring of urban growth and environmental conditions.

Though studies have examined urban growth patterns in several cities in Nigeria (Fabiyi, 2006; Balogun et al., 2011; Fanah et al., 2011), it appears that no empirical study has been conducted in the recent past aimed at evaluating the rate and determinants of urban growth in Benin City. This study is therefore aimed at analysing the spatio-temporal pattern of urban growth in Benin City between 1987 and 2013. The specific objectives of the study are to analyze urban growth pattern in Benin City between 1987 and 2013, and determine the factors responsible for the observed pattern of growth in the City.

MATERIALS AND METHODS

Benin City, the capital of Edo State, is located in the southern part of Nigeria. It is geographically defined by latitudes 6°11´ and 6°29'N and longitude 5°33' and 5°47'E (Figure 1). The origin of the city dates back to the 12th century when it was the seat of the king in the ancient Benin Kingdom, the seat of the Portuguese Foreign Mission, the centre of slave trade, the focus of international commerce (Ikhuoria, 1984) and now the capital of Edo State with a population of 1,147,188 according to the 2006 National Population Census. The metropolis cuts across four local government areas: Egor, Oredo, Ovia North-East and Ikpoba-Okha. The city has remained a major commercial hub linking the western, eastern, northern and southern parts of Nigeria. The general topography of Benin City can be described as low and sloping gently from about 105 m above sea level in the north-east to about 55 m in the south-west part.

Temperature is usually high with an annual mean of 28°C and a low annual range of 3°C. The city experiences an annual rainfall of above 2000 mm with mean relative humidity of above 80%. The soil is ferralitic and agricultural production is a major occupation of the indigenous people. The city lies within the tropical rainforest belt of Nigeria and is therefore home to several forest products including timber, oil palm and rubber. Several institutions such as the University of Benin, the University of Benin Teaching Hospital, the Benin Museum and the Palace of the Oba of Benin are some important features within the city.

Data acquisition and analysis

We obtained Landsat TM image of 21 December 1987, Landsat ETM+ images of 28 January 2002, and Landsat 8 image of 10 January 2013 covering the study area from the United States Geological Surveys website on Earth Resources Observation and Science (EROS) center. The study area was subset from the scene and unsupervised classification of the images was carried out using cluster analysis (Yang and Lo, 2002; Alo and Pontius, 2008). This operation yielded fifteen clusters. Supervised image classification analysis was conducted using the dominant classes obtained from the cluster analysis. We conducted a field survey between late February and early March of 2013 to obtain reference data for post-classification accuracy assessment of the remotely sensed image of 10 January 2013 for four categories: cultivation, settlement, forest and water. These categories were the dominant land cover types observed in the study area. We selected 16 parcels, where each parcel is predominantly one category on the ground. There were five parcels of cultivation covering 42 pixels, six parcels of settlement covering 110 pixels, three parcels of forest covered 252 pixels and two parcels of water covered 33 pixels. We obtain ground information at regular intervals of 30m apart within each parcel in most places. However, because of physical and social barriers, some of the points could not be accessed. The points that could not be accessed on the ground were determined using the authors' familiarity with the area and confirmed by looking at Google earth images and aerial photographs.

Settlement category include settlements, exposed surfaces and open-space, other man- made structures, cleared forest and rock outcrops; cultivation includes farmland, bush-fallow and abandoned farmlands, secondary vegetation and degraded forests; water include streams, rivers, wetland and waterlogged areas; while

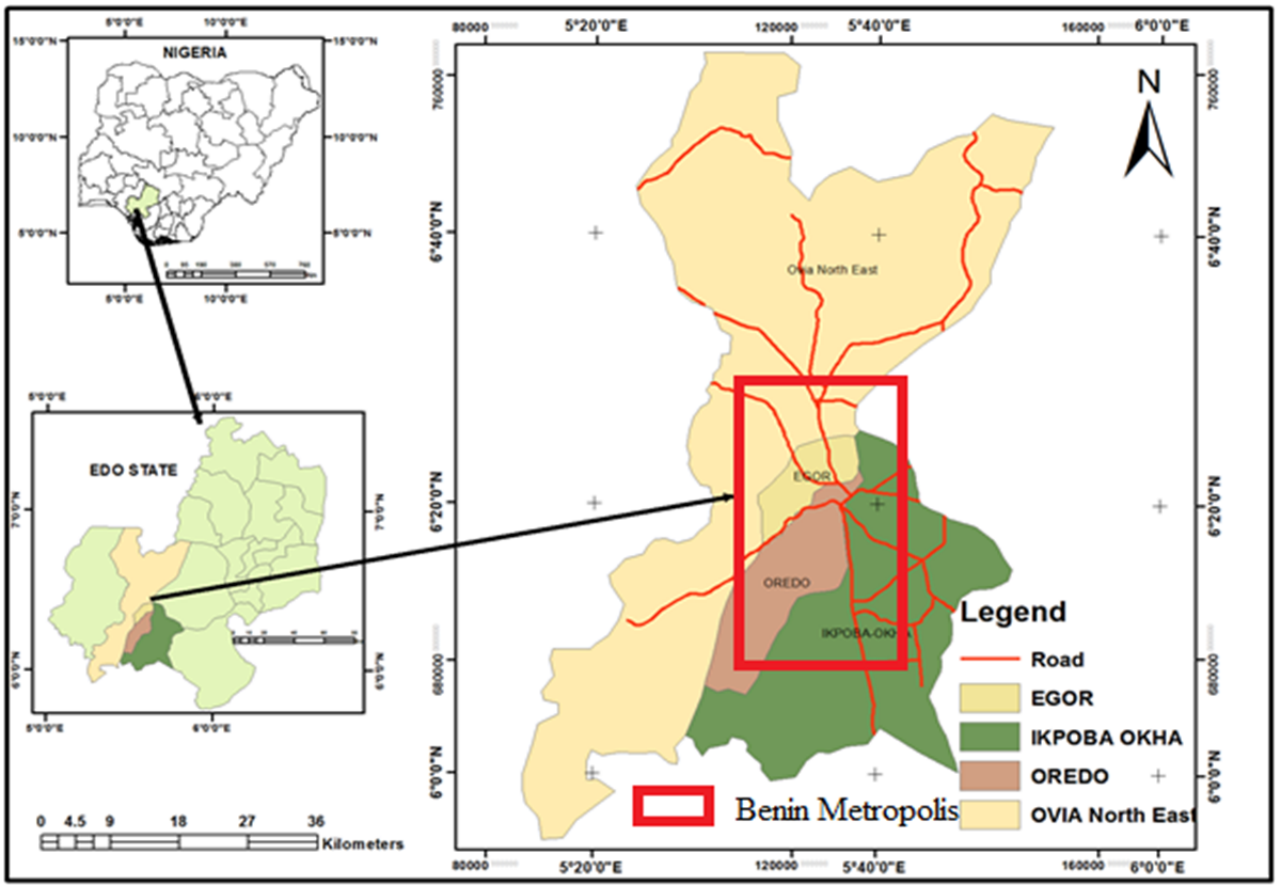

Figure 1. The study area.

forest are dense forest with canopy cover of 60% or more or old grown secondary vegetation and plantations. While Figure 2 shows the methodological workflow diagram of the study, the accuracy assessment of the classified images is shown in Table 1.

A hundred and fifty copies of a structured questionnaire were administered using the stratified sampling techniques. The city was stratified based on the four local government areas and the major quarters in each local government area were identified. Questionnaire administration was based on the population size of the local governments; hence more locations were selected from Oredo LGA for the purpose of questionnaire administration. Respondents were randomly selected in each of the identified locations. The retrieved copies of the questionnaire were analysed using simple percentages.

RESULTS AND DISCUSSION

The pattern of urban growth of Benin City

Table 1 shows the accuracy analysis of the classified remote sensing images and it reveals the accuracy level of 100% for 2013 map, 83% for 2002 and 71% for the 1987 maps. The 2013 land use map is highly accurate because the field survey was conducted a few months after the image was acquired. Accuracy analysis is an indication of the level of agreement between the classified image and land cover categories on the field.

Figure 3 shows the land use pattern in Benin City in 1987. It shows a rather compact and radial pattern from the city centre with growth occurring mostly in a north-south direction. Table 2 shows that settlement accounts for about 220 km² (25%) of the study area, cultivation 223 km² (25.3%), forest 322 km² (36.6%) and water 115.5 km² (13.1%). It is observed that forest was the most extensive land cover class in the study. This may be due to the fact that the city was just moving away from the traditional setting where farming seems to form the basis for living. In 2002, however, (Figure 4) land cover pattern indicates that settlement and cultivation increased by 13.5 and 17.6%, respectively to 339.2 and 377.5 km^2 while forest and water lost 22.5 and 8.6% respectively between 1987 and 2002. This shows that the city is expanding at the rate of 0.9% per annum during the 1987-2002 period. The expansion of urban boundary and changes in land use was also observed by (Tayyebi et al., 2014, 2015). The high rate of growth could be attributed to the increase in demand for social and economic infrastructure and housing resulting from the influx of people from different parts of the countryside in

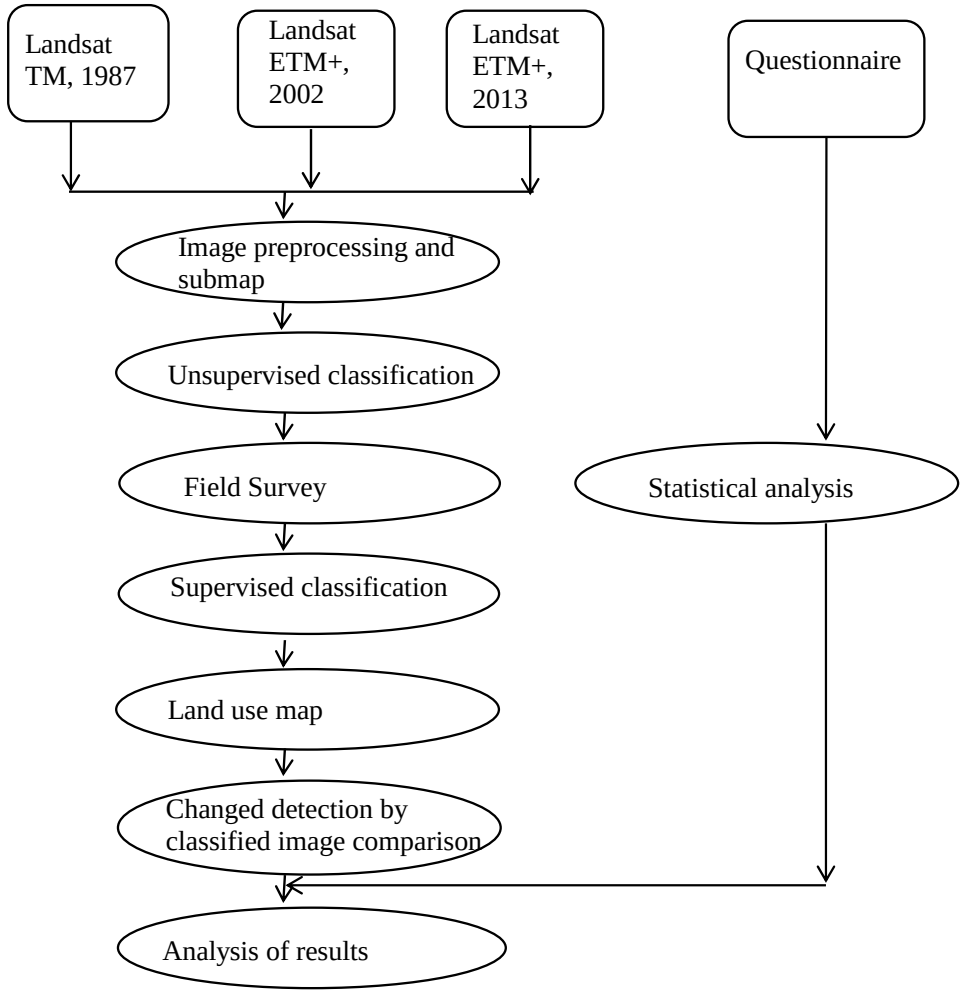

Figure 2. Methodological workflow for the study.

Table 1. Accuracy assessment of image classification; (a) accuracy assessment, 2013; (b) accuracy assessment, 2002; (c) accuracy assessment,1987.

Accuracy assessment, 2013					
Parameter	**Reference total (pixel)**	**Classsified total (pixel)**	**Number correct (pixel)**	**Producer's accuracy (%)**	**User's accuracy (%)**
Settelement	110	110	110	100	100
Cultivation	42	42	42	100	100
Forest	252	252	252	100	100
Water	33	33	33	100	100
Column total	437	437	437		
Overal accuracy	100%				
Accuracy assessment, 2002					
Settelement	102	112	90	80	88
Cultivation	97	43	37	86	38
Forest	233	274	230	84	99
Water	29	32	27	84	93
Column total	461	461	384		
Overal accuracy	83%				

Table 1. Contd.

Accuracy assessment, 1987					
Parameter	**Reference total (pixel)**	**Classsified total (pixel)**	**Number correct (pixel)**	**Producer's accuracy (%)**	**User's accuracy (%)**
Settelement	85	112	80	71	94
Cultivation	42	43	22	51	34
Forest	264	274	210	77	80
Water	47	32	33	50	34
Column total	461	461	328		
Overall accuracy	71%				

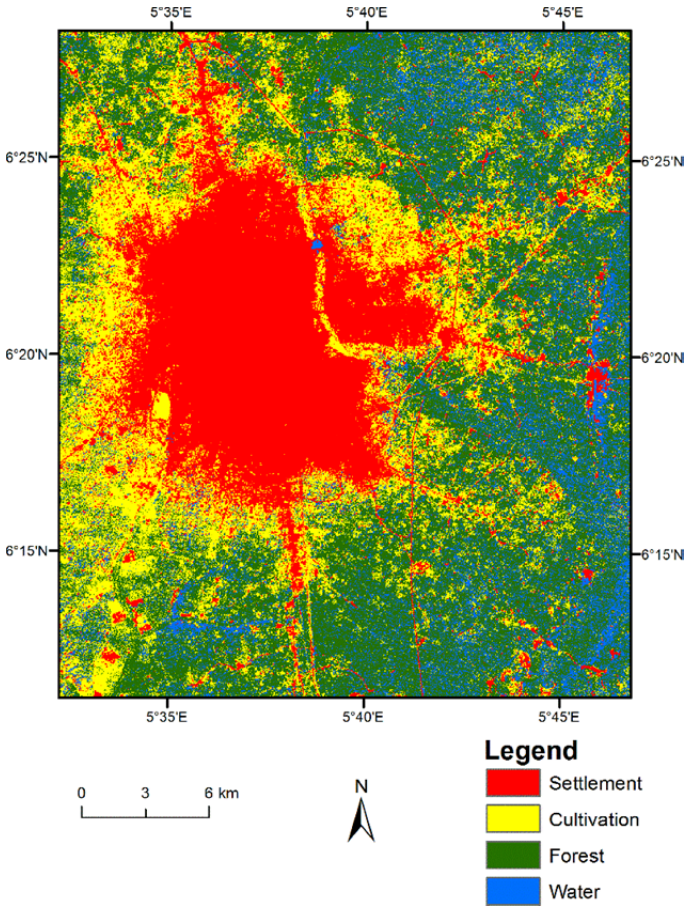

Figure 3. Benin City land use/land cover, 1987.

Table 2. Land cover change pattern, 1987-2013.

Land cover change	**1987**		**2002**		**2013**	
	km^2	**%**	**km^2**	**%**	**km^2**	**%**
Settlement	219.97	24.99	339.15	38.53	358.90	40.80
Cultivation	222.66	25.30	377.46	42.88	403.16	45.83
Forest	322.11	36.59	123.79	14.06	105.67	12.01
Water	115.47	13.12	39.81	4.52	12.03	1.37
Total	880.21		880.21		879.76	

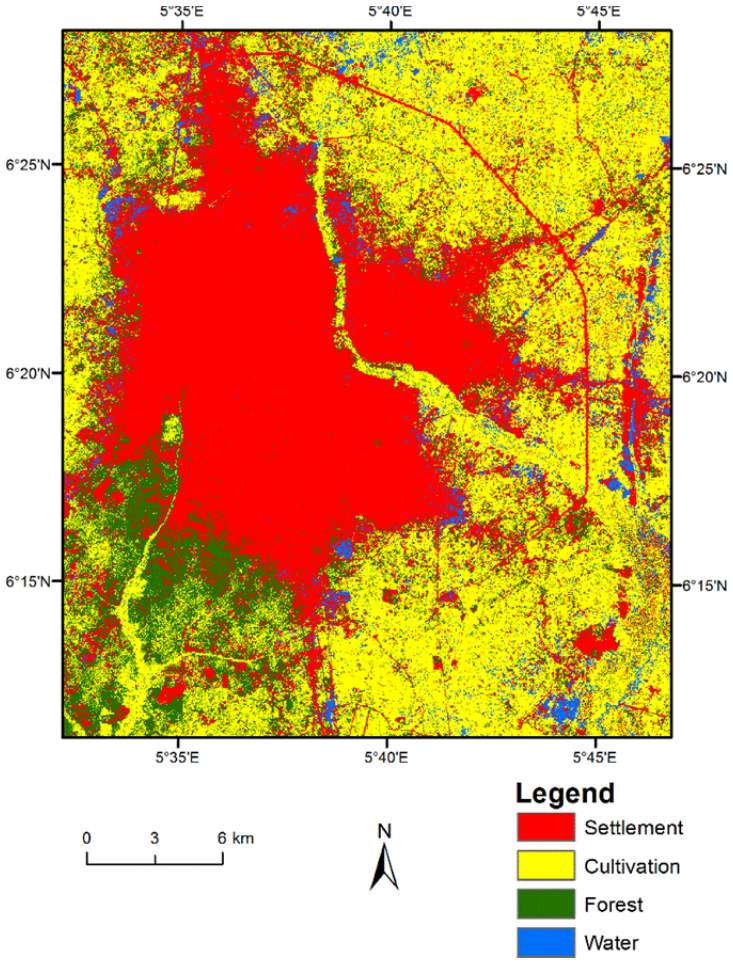

Figure 4. Benin City land use/land cover, 2002.

search of social and economic opportunities which abound in the city because it provides administrative, industrial and educational functions by virtue of its status as the state capital. Edo State was created in 1991 with Benin City being the headquarters, led to the influx of many industries such as Kada group of companies, bottling and brewing companies among others. Most importantly, the Federal and State Governments' general increase in salaries of workers in the late 1990s and early 2000s resulted in construction boom as many individuals and agencies built more residential houses and small scale industries.

Figure 5 shows the land cover pattern of the city in 2013. The interval between 2002 and 2013, the city grew at about 0.2% per year. It expanded from 339 km^2 in 2002 to 359km^2 by 2013 (Figures 6, 7 and Table 2). It is observed that the city is growing at the expense of agricultural land, which is a common feature for developing countries as urban extension, industrial and other development take up the natural and secondary forest as well as farmland around cities (Zhang and Xu, 2014, Okello and D'Amour, 2008) . The rapid population growth and an increase in rural-urban migration into the city also accounted for the loss of productive agricultural lands. The expansion in the city is also observed to be encroaching into the river channels as a significant proportion of the wetland and riparian forest is converted to built-up area. Water category and forest consistently recorded losses during the period of the study.

Figures 6 and 7 show the pattern of growth of Benin City between 1987 and 2013. It is obvious from Figure 6 that much of the growth in the city took place in the north, south and the eastern axes. This pattern may be as a result of the institutions such as the University of Benin and University of Benin Teaching Hospital, Ugbowo, Igbinedion University, Okada, College of Education, Ekiadolor, the Uselu Market, bottling company, timber and plywood industries, broadcasting stations, Egor Local Government Secretariat, the trans-continental road that link the western part of Nigeria and West Africa among others are all in the northern part of the city. The south and eastern axes are major routes into and out of the city to the eastern part of the country such as Onitsha, Aba and Owerri. The eastern part of the

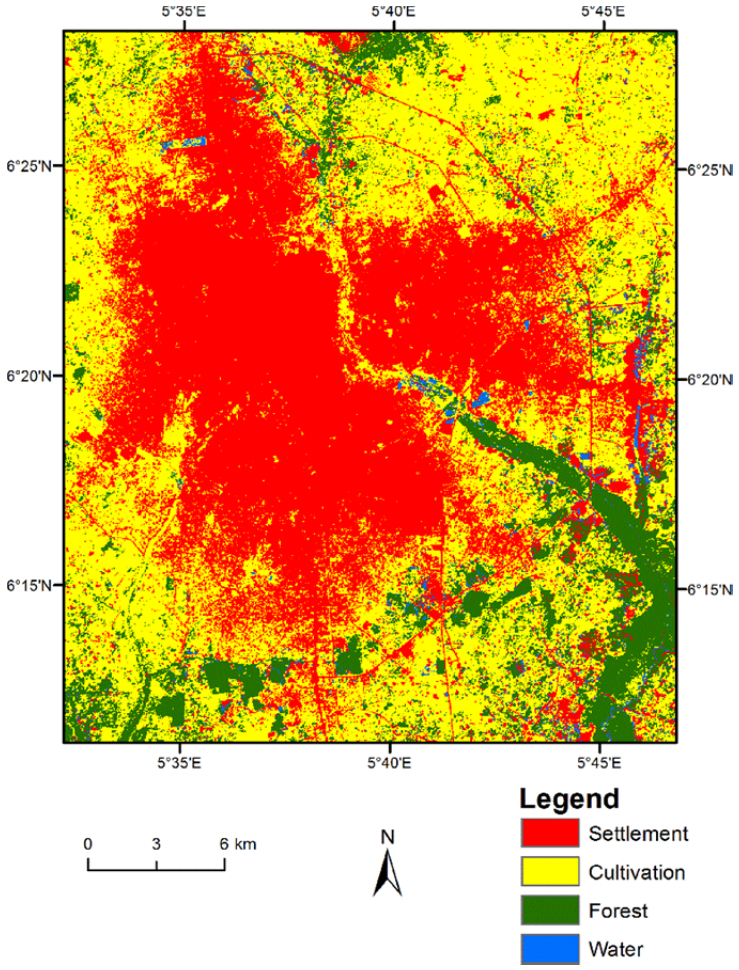

Figure 5. Benin City land use/land cover, 2013.

city is the location of the Federal Secretariat Complex which houses the offices of most federal government agencies and parastatals in the state. Three bottling and brewing industries, gas plant, daily markets, broadcasting stations, small scale industries and the Benin by-pass among others are other major factors attracting people to the eastern part of the city. The southern part of the city is also home to the State Secretariat, the central hospital, Evboriaria industrial estate, small and medium scale industries, daily markets and it is the major route connecting the Niger-Delta region. The growth of Benin City radiates from the Ring Road (the City centre) and extends in different directions following the major roads thereby engulfing the neighbouring villages. The growth pattern makes Benin City a monocentric city. This finding is similar to that of Abebe (2013) which reports that urban growth tends to be longitudinal from the city centre along the major transportation routes. A critical look at the growth pattern of Benin City shows that it did not follow any single theory of urban growth rather it combined features of the three major theories- concentric zone, sector and multiple nuclei.

The factors responsible for urban growth in Benin City

The satellite images analysed confirmed that the city is expanding more to the north, south and eastern directions while the questionnaire reveals that the major factors responsible for this pattern include the siting of educational institutions, like the University of Benin, University of Benin Teaching Hospital, College of Education (Ekiadolor) and Igbinedon University (Okada) apart from it being the state capital. While 28.7% of the respondents believe that the educational institutions are the major drivers of the expansion in the city, 23.3% of respondents are sure that the status of the city as the administrative headquarters of the state is responsible (Table 3). Other important factor include job opportunities (18%) provided by economic growth of the city. These three factors accounted for 70% of the reasons for the physical expansion of Benin City. Aworemi et al. (2011) also showed that some of these factors are responsible for the growth of Lagos, Nigeria. Although Benin City is growing more along the major roads of the city, only 8%

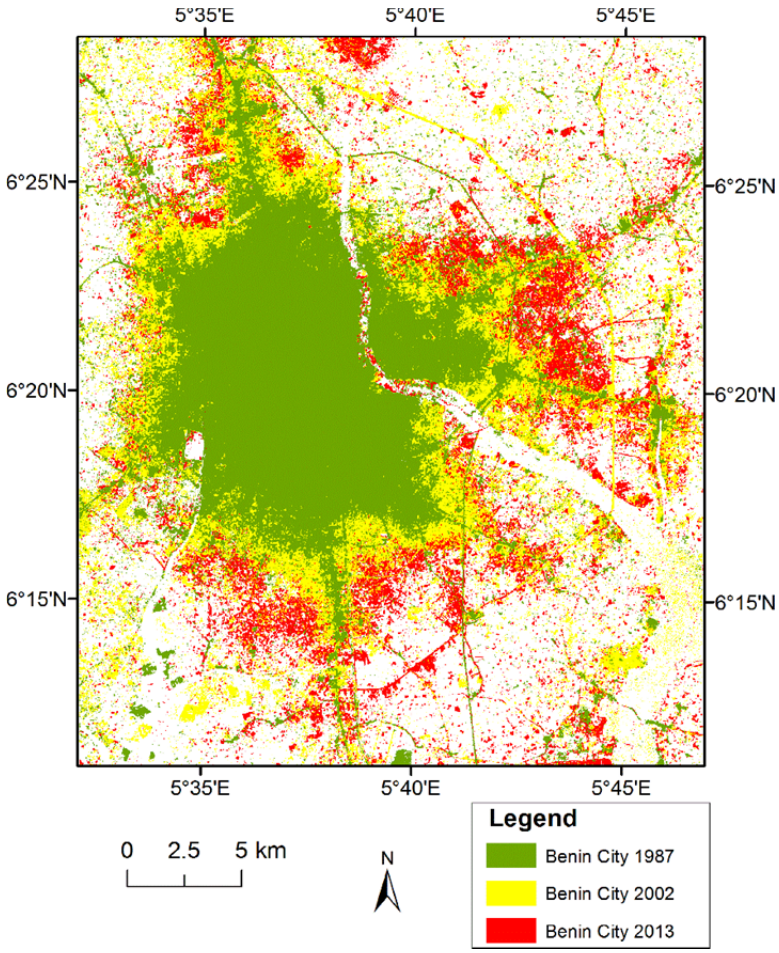

Figure 6. Overlay of settlement for 1987, 2002 and 2013.

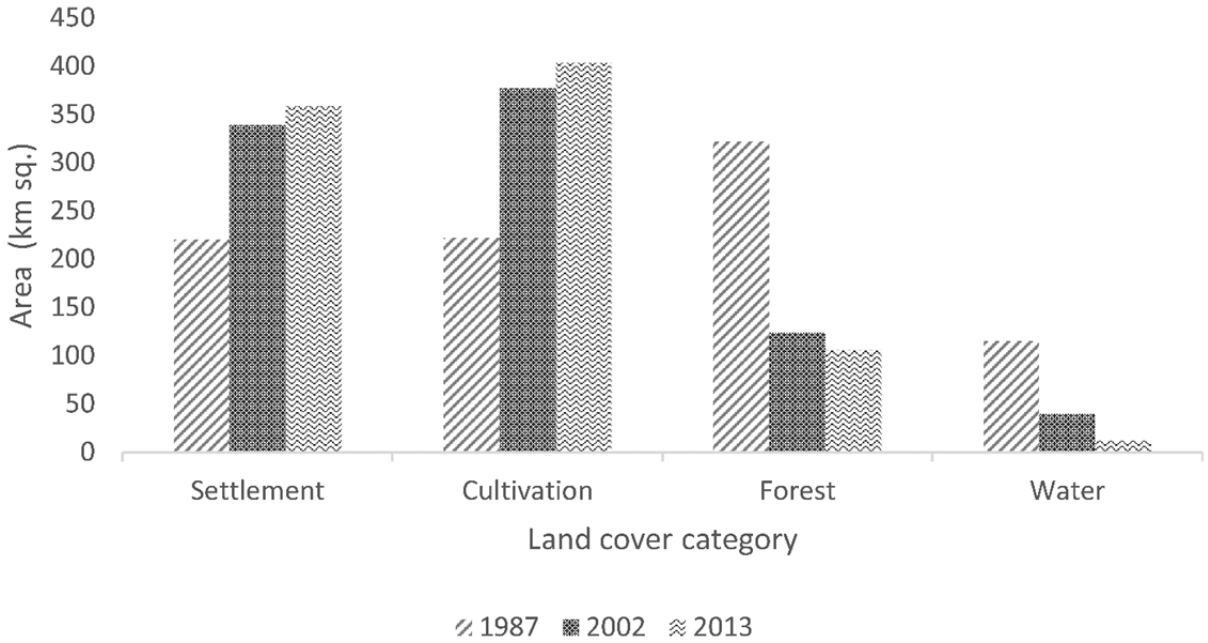

Figure 7. Land use pattern in Benin City, 1987-2013.

Table 3. Factors responsible for rapid urban growth in Benin City.

Factors	Frequency	%
Family size	10	6.7
Administration	35	23.3
Infrastructure	8	5.3
Economic growth	27	18.0
Education	43	28.7
Transportation	12	8.0
Demand for more space/personal house	15	10
Total	150	100

Source: Authors' fieldwork, 2013.

of the respondents saw transportation as a major factor responsible for the rapid expansion. Dankani (2012) reveals that the expansion of Makurdi is more along the transportation routes and the river.

Conclusion

This study has shown the pattern of urban expansion in Benin City between 1987 and 2012 using remote sensing and GIS approach. The results show that the city is growing at a rapid rate in the north, south and eastern directions majorly along the transportation routes. The growth pattern is largely influenced by factors such as siting of educational and medical institutions, the presence of government buildings and economic growth of the city through industrial establishments. These institutions and industries provide employment opportunities needed by urban dwellers and they equally attracts job-seekers mainly from the rural areas and other urban centers into the city. Transportation routes significantly influence the direction and pattern of urban growth in the city because they are the main stimulant for the establishment of the industrial, commercial, educational and medical institutions.

The results imply that apart from legislation, urban growth can be controlled through careful selection of sites for the location of facilities such as industries, schools, hospitals and recreation and tourism centres as these facilities have the capacity to attract growth and development. Similarly, infrastructure needed for urban development should be provided around such facilities as the absence of such infrastructure could result in uncontrolled development which may be difficult to correct as time goes on. Furthermore, it is important that geospatial technologies be employed at regular intervals in monitoring urban growth and development in order for the government to gather data required for urban planning and management in rapidly developing urban centers like Benin City.

Conflict of interests

We wish to state that this article Geospatial Approach to Spatio-Temporal Pattern of Urban Growth in Benin City, Nigeria is an original piece of work carried out by the authors. It has not been published anywhere neither is it under review with a view to publish it in any publishing home.

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