Land use/cover change and urban sustainability in a medium-sized city

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Abstract: This study examined the trend in urban growth and vegetation loss and the implication of this on the sustainability of medium-sized cities, using Osogbo, south-west Nigeria as a case. Using multi-temporal Landsat^{TM} images that span 30 years (1986 to 2016), the study employed supervised classification to categorise the land cover into the built-up area, vegetation and water bodies. Findings revealed that the city grew axially along major transportation corridors in the early stage but experienced in-filling, densification and radial outward growth subsequently. The built-up area increased at annual rate of 14.7%, more than the population growth rate of 2.2% while vegetation cover and water bodies recorded an annual change of –2.5% and –3.5% respectively. Rapid city growth and the resultant land use/cover conversion contribute to the depletion of wetlands and vegetation, thereby constituting a threat to sustainable urban development. Controlled urbanisation is suggested as a panacea to the unsustainable urban expansion which threatens the city's ecological equilibrium.

Keywords: urbanisation; medium-sized city; sustainable growth; vegetation; land use; land cover change; supervised classification; ecological equilibrium; urban expansion; wetlands; sustainable urban development; controlled urbanisation.

Reference to this paper should be made as follows: Samuel, K.J. and Atobatele, R.E. (2019) 'Land use/cover change and urban sustainability in a medium-sized city', *Int. J. Sustainable Society*, Vol. 11, No. 1, pp.13–28.

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This paper is a revised and expanded version of a paper entitled 'Land use/cover change and urban sustainability in a medium size city' presented at the Ibadan Sustainable Development Summit, Ibadan, Nigeria, 24 August 2017.

1 Background to the study

Cities are known worldwide as melting pots of cultures, centres of innovation, manufacturing and services and as such, they have become the engine room for human development (UN-HABITAT, 2015). The United Nations Human Settlement Programme has noted, "cities create wealth, generate employment and drive human progress by harnessing the forces of agglomeration and industrialisation" [World Cities Report, (2016), p.4]. Because cities offer opportunities for self-actualisation and development, people continue and will continue to move into them, thereby fuelling the demographic change and physical growth of the cities. Rapid urbanisation, together with the limited capacity to plan and mobilise resources to match the needs of the burgeoning urban population, remains a critical challenge facing cities globally. Already, 50% of the six billion world population live in cities, while the percentage is likely to increase to 69.6% by 2050 (O'Neill et al., 2012; Liu et al., 2012).

While urban population continues to grow exponentially worldwide, the trend in the past two decades shows that cities in low and medium income countries have higher momentum for growth than their counterparts in the developed countries (Muggah, 2012; UN-HABITAT, 2015). It is projected that by 2030, about half of African population will live in urban centres (UN-HABITAT, 2004; Sharma et al., 2012), and the locus of this growth will be found in small and medium-sized urban centres of a million population or less (UN-HABITAT, 2015). Although definitions of medium-sized cities vary from one country to another, the United Nations Department of Economic and Social Affairs, Population Division (UNDESA, 2014) describes medium-sized cities as urban agglomerations with a population of 1 million inhabitants or less while small size cities are cities with five hundred thousand inhabitants or less.

Incidentally, cities of the developing world, especially small and medium-sized ones, lack necessary resources to deal with the quantum of urbanisation as currently being witnessed, and this problem will likely project into the future. Hence, most of these cities grow demographically and expand physically in an unsustainable manner, thereby throwing up a myriad of problems including, but not limited to, uncoordinated expansion, slum development, overcrowding, dearth of public services, and inefficient use of energy, climate change, pollution and greenhouse gas emission (Musakwaa and Van Niekerk, 2013). Whereas medium-sized cities in developed and emerging economies such as Vancouver, Nantes, Copenhagen and Curitiba (Brazil) are competing in reducing commuting distance, increasing urban greening, adopting renewable energy, and improving on climate resilience (Eberlein, 2012); their counterparts in the developing countries are yet to find their footings in planning and implementation of sustainable development programmes (Akbulut and Ozcevick, 2015).

Bradbury (2009) has noted that the process of urbanisation intensifies pressure on resources, environment and its ecosystems. Urban growth and its associated alteration in land use/cover patterns have significant impacts on the ecosystem, vegetation, water, trace gas emission, and other biogeochemical processes (Riebsame et al., 1994; Yuan et al., 2005; Bhatta, 2010; Sandhya and Joshi, 2013). According to Farmer (2012), the impact of land use/cover change can be seen in form of uncontrolled development, deteriorating environmental quality, loss of forestlands, and destruction of wetlands, among others. These indicators negate the tenets of sustainable growth and development. It has also been observed that rapid urbanisation and related land cover modifications have influenced the radiative, thermodynamic, and hydrological processes that could trigger a change in the climatic regime of the local areas (McCarthy et al., 2010).

With the prevailing situation in the small and medium-sized cities of the developing world, the prospect of achieving goal 11 of the 2030 Agenda of sustainable development goals (SDGs) which aims at making the cities in particular and the human settlements in general inclusive, safe, resilient and sustainable (Schreiber et al., 2016), remains gloomy. Sustainable development is a multidimensional concept, involving the maintenance of natural resources and spatial patterns of land use that are ecologically, socially and economically beneficial (Foley, et al., 2005; Nwokoro and Dekolo, 2012). Therefore, sustainability planning represents an opportunity for city managers to address problems facing their cities in a 'more innovative, cost-effective way' and 'create a vision for the future they want to see in their cities [Sustainable Cities International, (2012), p.6]. It does appear that cities in the developing countries are ill-prepared and under-equipped to face the challenges of rapid urbanisation, especially as it relates to environmental sustainability. Low-density developments along transportation corridors and city periphery have led to the loss of agricultural land, open space, water bodies, and ecologically sensitive habitats (Bhatta, 2010; Sandhya and Joshi, 2013). It has also elongated commuting distances that peri-urbanites need to cover on daily basis, thereby exacerbating the growing problem of auto-dependency and consequent greenhouse gas emission (Bhatta, 2010).

Urban Sustainability is the active process of synergetic integration and co-evolution between the subsystems making up a city without compromising the possibilities for the development of surrounding areas and contributing by this means towards reducing the harmful effects of development on the biosphere (Zhang and Li, 2018). Brundtland (1987) described sustainable development as one that meets the needs of the present without compromising the ability of future generations to meet their own needs. It, therefore, means that any decision or action taking within the context of the urban environment that does not attain to, or reinforce the principles of continuity, controlled growth and consumption, environmental friendliness and social cohesion can be said to be unsustainable. Controlled urbanisation, a top-down socialist instrument of planning, is often used to enforce the restriction of rural-urban population flow, which has implications on city growth, rural development and regional industrialisation (Han, 1994). Controlled urbanisation captures state-sponsored planning and programmes that prevent the city from becoming disorderly and ensure that population growth and expansion keep pace with the city's economic base.

The problems associated with unsustainable growth in cities of the developing countries has brought to the fore the need for deeper understanding of the pattern and processes of land use/cover alterations. An in-depth understanding of these patterns and processes is capable of informing policies on urban development and environmental conservation in order to achieve the goal of improving the liveability of small and medium urban centres in developing countries. New developments around cities are becoming less compact, which fosters sprawl, congestion and segregation, conditions that could further exacerbate the precarious social and environmental situations in these cities.

In Nigeria, as in many other developing countries around the world, medium-sized cities face peculiar challenges of managing rapid population growth and unrestrained urban expansion as well as implementing green development due to dearth of requisite information, human and material resources. In most cases, these cities have expanded into multiple local jurisdictions, making coordinated planning and efficient provision of municipal services difficult (Samuel and Adagbasa, 2014). In recent times, urban expansion and its associated land use/cover changes have received significant attention globally (Riebsame et al., 1994; Liu et al., 2012; Farmer, 2012; Sharma et al., 2012; Hassan and Nazem, 2016) and at continental and nationally levels (Mundia and Aniya, 2006; Abiodun et al., 2011; Musakwaa and Van Niekerk, 2013; Atobatele, 2016). Few of these studies, however, focus on the sustainability implications of these land use/cover changes in these urban centres, while still fewer, if any, have addressed the issue of land use/cover changes and sustainability effects in the context of a medium-sized city of a developing country. Yet, these cities remain the loci of growth in terms of population concentration and physical expansion. Understanding land use change and evidence-based information on land use dynamics are essential for monitoring city growth and formulating appropriate policies targeted at the sustainable growth of urban centres. There is, therefore, the need for an up-to-date and accurate land cover information that can be utilised in the production of sustainable land use policies. Over time, remotely sensed data and geospatial methods of analysis have proven efficient in analysing the earth-system function, patterning, and change at local, regional and global scales (Rajeshwari, 2006). It has particularly been found useful in evaluating environmental impacts, delineating growth boundaries, developing land use zoning plans and estimating the expansion rate of a city growth (Aguda et al., 2012).

This study, therefore, analyses the trajectory of land use/cover changes in a medium-sized city with a view to quantifying urban expansion, vegetation and wetlands loss and the implications on the sustainability of the city. Specifically, the objectives of this study are to:

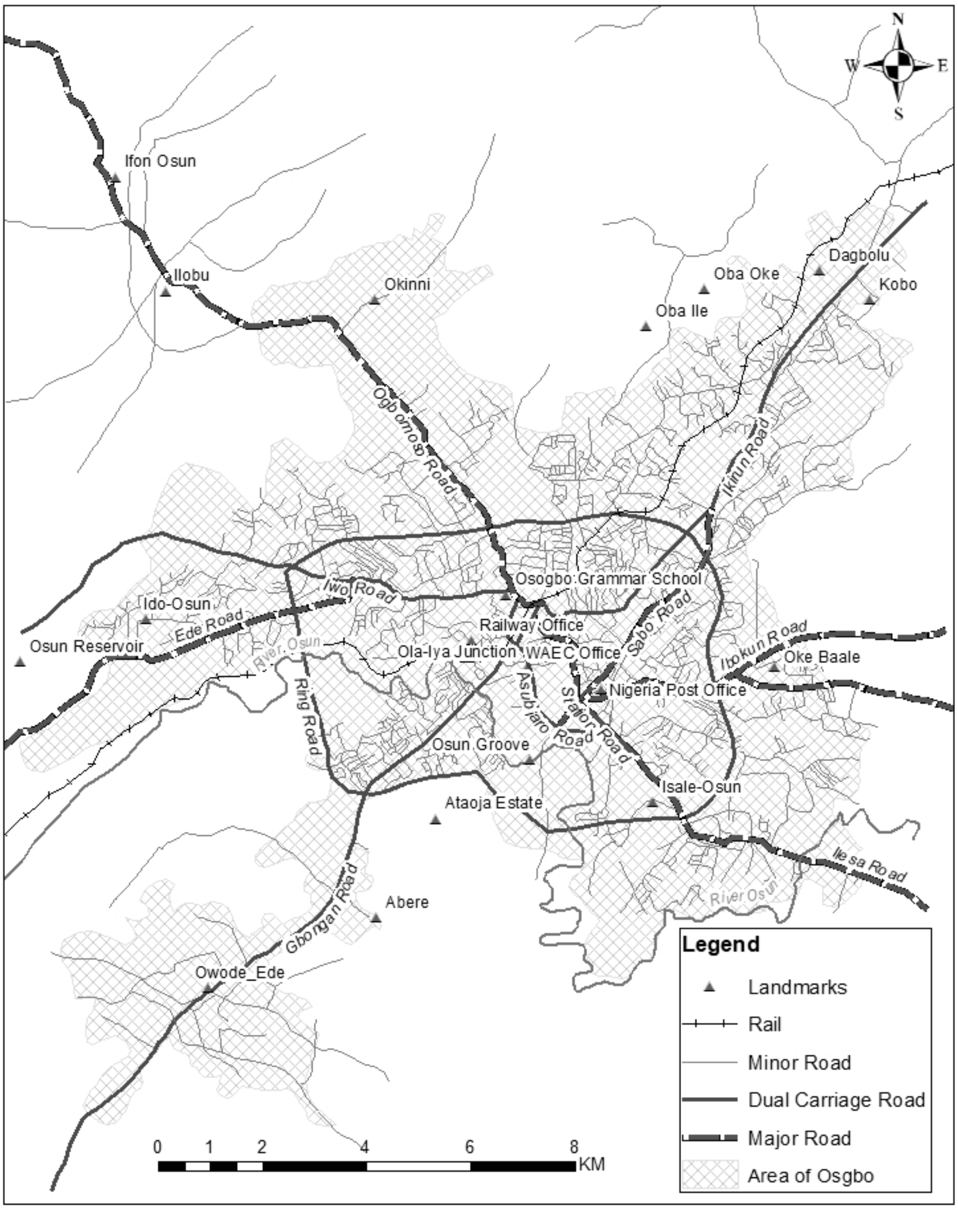
1 identify the major land use types in the study area

2 quantifies the changes that have taken place over time

3 analyse land consumption and land absorption rates

4 examine the implications of the land cover changes on the sustainability of the city.

Figure 1 The areal extent of Osogbo (2016)



Source: Authors' compilation (2016)

2 The study area

The study was carried out in Osogbo, the capital of Osun State, South-West Nigeria. The choice of Osogbo as the study area was due to its strategic importance as an emerging industrial and commercial hub with significant administrative functions. These characteristics make Osogbo representative of most medium-sized cities in sub-Saharan Africa with increasing momentum for population growth and environmental change. The city occupies a land area of about 230 square kilometres with a projected population of 650,000 people in 2015 (United Nations, 2014), translating to a density of 2,826 persons per square kilometre. Osogbo is about 190 kilometres by road northwest of Lagos, the nation's commercial hub. Arguably one of the fastest growing medium-sized cities in Nigeria, the elevation of the Osogbo to the status of divisional headquarters of the then Osun Division and the capital of Osun State in 1952 and 1991 respectively has had a profound impact on the population growth as well as the physical expansion of the city (Figure 1). Hitherto, an agrarian town with the predominance of the native population, Osogbo has grown over time to become a regional commercial and industrial centre. The rapid spatial expansion of the city is attributable to population growth, industrial development and political influence (Agbola, 1992; Aguda et al., 2012). The city owes its industrial development to favourable government policy which designated it as one of the regional Industrial Development Centres in 1970 (Agbola, 1992) and the impact of the railway line which facilitated the movement of bulky goods. The establishment of Osogbo Steel Rolling Mills and Osogbo Machine Tools are a direct consequence of this political decision which led to further expansion of industrial land use in the northern axis of the city. The rapid urbanisation coupled with poorly regulated urban development has resulted in accelerated but uncoordinated outward expansion of the city into its periphery, thereby causing unprecedented loss of vegetation, eating up farmlands, and fuelling climate change through wanton conversion of forest and wetlands into residential, commercial, administrative and other urban land uses (Atobatele, 2016; Taiwo et al., 2014).

3 Material and methods

3.1 Data collection and processing

The data used in this research included remotely sensed images, administrative maps, population data and the ground control points captured within the city of Osogbo. Remotely sensed data were mainly satellite images: LandsatTM (1986), (1996) and Landsat (2006) and (2016) downloaded from EarthExplorer® website https://earthexplorer.usgs.gov/. Administrative maps of Osogbo were obtained from the State's Ministry of Lands and Physical Planning. Population figure for the city for 2006 was obtained from National Population Commissions' 2006 Census Figures while population estimates for other years were obtained from United Nation's Department of Economic and Social Affairs, Population Division (2014). Table 1 shows the summary of the data acquired and their sources. The coordinates of 22 ground control points were taking through field observation using global positioning system (GPS) for the purpose of ground-truthing and geo-referencing to improve the geometric accuracy of the images.

The Landsat images were subjected to various pre-processing operations. Atmospheric changes were rectified using atmospheric and topographic correction (ATCOR3) method (Balthazar et al., 2012). Furthermore, false colour composites of images were processed from Landsat images by selecting bands 4.3.2 which conform to near infrared red (NIR), red (R) and green (G) planes respectively. Training areas were identified and sampled in order to obtain the spectral characteristics of the different land-use classes (Zeng et al., 2002; Enaruvbe and Atedhor, 2015).

Table 1 Data and their sources

S/N	*Type of data*	*Date/year*	*Image resolution*	*Source*
1	Landsat.TM	1986/11/15	30 metres	www.usgs.gov
2	Landsat.TM	1996/12/18	30 metres	www.usgs.gov
3	Landsat ETM	2006/12/16	30 metres	www.usgs.gov
4	Landsat ETM	2016/11/17	30 metres	www.usgs.gov
5	Population of Osogbo	1986–2016		United Nations (2014)
6	GPS coordinates of 22 control points	May 2016		Acquired via field observation

Source: Authors' compilation (2016)

3.2 Data analysis

Supervised classification method using the maximum likelihood classifier was employed to generate three land cover classes: the built-up areas, water bodies and vegetation cover. Supervised classification has been adjudged the best method for classifying multi-spectral images (ITC-ILWIS, 2001) while Maximum Likelihood Classifier was chosen because it returns a higher level of accuracy than other classifiers (Sandhya and Joshi, 2013). To further aid classification of change in vegetation cover, a normalised difference vegetation index (NDVI) was computed using the Landsat red and near-infrared bands in order to separate vegetated surface from a non-vegetated surface. Classification accuracy assessment was conducted for each of the images to ascertain the level of correspondence between pixels of the classified images and the reality on the ground. The overall percentage accuracy ranged from 90.7% to 94.9% (see Table 2). These values were higher than the minimum of 85% suggested by Eastman (2009) for land use classification. The land cover maps were produced and the areal extent of each of the land cover types was calculated using ArcGISTM 10.3 and the result tabulated. land consumption rate (LCR) was computed and used as an estimate of the compactness of the city that indicates a progressive spatial expansion of the city. Land absorption coefficient (LAC) was used to measure the change in consumption of new urban land by each unit increase in urban population (Sharma et al., 2012; Herold et al., 2005). Following Yeates and Garner (1976) LCR was calculated by dividing the change in the extent of the built-up area by the population of the area for the same period. LAC, on the other hand, was computed by finding the ratio between the change in population and change in the size of the built-up area as given by Yeates and Garner (1976):

$$LCR = A \div P \tag{1}$$

$$LAC = \left(A_2 - A_1\right) \div \left(P_2 - P_1\right) \tag{2}$$

where

LCR	is urban land consumption ratio
LAC	is land absorption coefficient
A	is the extent of the built-up area in (km^2)
P	is the population of the urban centre
A_1	is the extent of the built-up area in $time_1$ (km^2)
A_2	is the extent of the built-up area in $time_2$ (km^2)
P_1	is the area of the urban centre in $time_1$
P_2	is the area of the urban centre in $time_2$.

Table 2 Accuracy assessment of classified maps

Year	*Land cover type*	*No. of classified pixels*	*Correct no. of pixels*	*Wrongly classified pixels*	*% accuracy*	*% reliability*	*Overall average*
1986	Built-up	64	60	4	94.7	90.0	90.7
	Vegetation	55	50	5	90.9	91.0	
	Water	30	26	4	86.7	90.0	
1996	Built-up	60	57	4	95.0	95.7	93.1
	Vegetation	55	51	4	94.0	95.5	
	Water	31	28	3	90.3	91.0	
2006	Built-up	45	43	2	95.6	95.5	94.9
	Vegetation	65	63	2	96.9	97.0	
	Water	39	36	3	92.3	93.1	
2016	Built-up	59	57	2	96.6	96.0	93.2
	Vegetation	37	35	2	94.6	95.2	
	Water	26	23	3	88.5	89.0	

Source: Authors' computation (2016)

4 Results and discussions

4.1 Pattern of land use/cover changes in Osogbo (1986–2016)

The city of Osogbo witnessed tremendous growth over the 30-year period (1986 and 2016), in both population and built-up area with associated substantial effects on the land use/cover configurations. As shown in Table 3, the built-up area of Osogbo in 1986 was about 20.5 km^2 while vegetation and water bodies occupied 474.9 km^2 and 19.7 km^2 respectively. The city form was largely axial in its spatial expression, growing along major arteries of transportation. These axes of growth were separated by undisturbed forest, secondary vegetation and wetlands. By 1996, the urban extent had grown by 6.9% to 21.9 km^2 while water bodies and vegetation recorded –25.2% and –21.8% growth in areal coverage respectively. The increase in spatial coverage of urban land use between

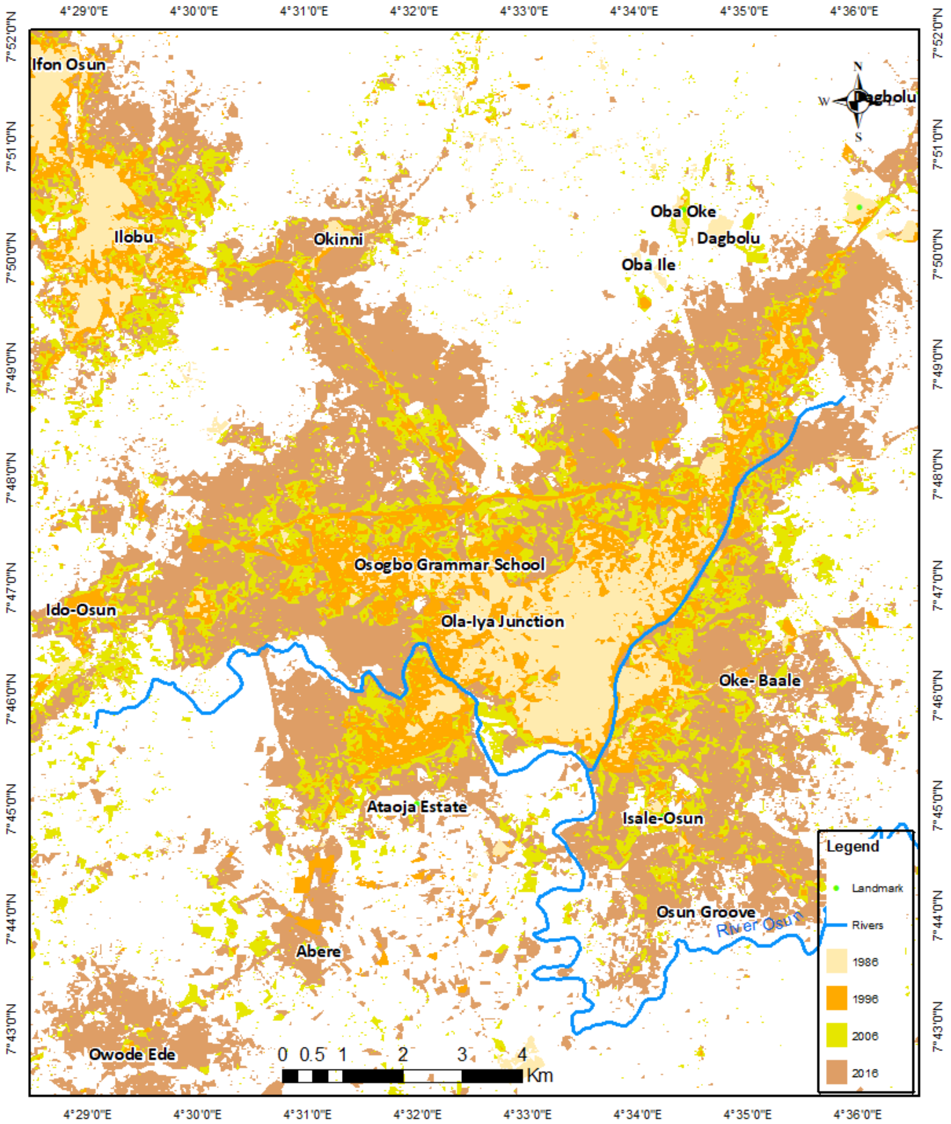
1986 and 1996 was due in part to the designation of the city as the capital of the newly created Osun State in 1991 (Atobatele, 2016). These developments attracted people from within and outside the State to Osogbo. Another important contribution to the urban spatial expansion at this period was the establishment of multi-million dollars Osogbo steel rolling mills and machine tools companies which increased the volume of economic activities in the city and caused development along the northern axis of the city. During this period, the city developed a scorpion-shaped pattern, extending linearly in the northern directions.

The rate of growth of the built-up area between 1996 and 2006 snowballed, rising from a paltry 6.9% in 1996 to 166%, with actual areal expansion increasing from 21.9 to 58.5 km^2. Conversely, the rate of conversion of vegetation and water bodies recorded a slight slowdown to 21.8 and 25.2% respectively (Table 3). By 2006, the transition to civil rule had started yielding economic dividends which further intensified urban expansion, with concomitant accelerated loss of both vegetal cover and water bodies. This period also marked the implementation of a wage increase of 15% in the country, a development that afforded workers the opportunity to build their own houses. In a country where housing provision is mainly done by informal actors, the economic fortunes of the people have a significant effect on the trajectory of urban development. Added to this was the influx of people from the rural areas and surrounding urban areas in search of government jobs and contracts in the newly created State of which Osogbo was the capital as the full bureaucracies of the second tier of government were fully established at this period. The sustained growth of urban land use in this period, partly a result of the economic boom, also contributed to the incipient 'metropolitanisation' of the city (UN-HABITAT, 2004) that led to the annexation of the surrounding lower-order settlements such as Kelebe, Ofatedo, Okinni, Abere and Ido Osun. From this time on, the city began to fill up gaps between the developments along the transportation corridors, thereby giving it a radial shape. At the same time, the vacant land and wetlands within the urbanised areas were being developed, in response to increased demand from the government workers (both State and Federal) who had to move to the State capital as result of the creation of the State. Expectedly, the appreciable gain in urban expansion caused a concomitant reduction in both vegetation cover and water.

After 2006, new urban developments, mostly spearheaded by the government as reflected in the building of a new government secretariat, House of Assembly Complex and Central Bank Branch along Gbongan-Ibadan axial road also contributed to land use change in the area. Private residential and commercial developments were also springing up in response to the burgeoning population of mostly government workers and their dependants, resulting in low-density development towards the periphery. Elsewhere, Federal Housing Estate, Police Command Headquarters and Government Reserved Area were built on the eastern axis of the city.

By 2016, the city appeared to have expanded to its traditional and administrative limits, as the development of hitherto undeveloped plots (mostly bare ground and wetlands) within the built-up areas which had started earlier intensified (Aguda and Adegboyega, 2013). Water bodies contracted by over 8.5% from the previous period while vegetation recorded a moderate contraction of 43.1%. The interval between 2006 and 2016 saw the built-up area grow by 266% from 58.5 km^2 to 214.5 km^2, with new densification of the existing urban land use and further filling up the open spaces and conversion of wetlands and vegetation. It was at this period that the conversion of wetlands and vegetation reached its peak, with the consequent deleterious effect on the ecosystems services. The continued 'metropolitanisation' of the city had caused a spill over into other autonomous smaller urban centres that were not considered as part of the city. However, adjoining towns such as Ifon Osun and Ilobu (on the western axis), Oba-Ile, Oba-Oke and Dagbolu (northern corridor) and Ido Osun, Owode Ede and Ede (south-western axis) continued to receive the spill over population and development from Osogbo. The implication of this is that these autonomous towns are expanding in the direction of Osogbo, while few of them have linked, forming a continuous zone of urban development (Figure 2).

Figure 2 Spatial expansion of Osogbo (1986–2016) (see online version for colours)



Overall, the built-up areas added an average of 9.8 km^2 translating to a yearly growth rate of 14.7%, about 12.1% higher than the population growth rate of 2.2%. This aligns with the United Nations' observation that the rate of urban expansion in most cities of the world has outpaced the rate of population growth (World Cities Report, 2016). The wide gap between urban growth and population growth would not only put pressure on the urban infrastructure but also has implications for the sustainability of the city. On the other hand, 29.7 km^2 of vegetation was lost yearly at the rate of 2.5% per annum, while water bodies recorded a yearly loss of 1.0 km^2 at the rate of 3.5% per year. These significant losses in vegetation cover and wetlands have significant implication for regulating urban climate, water supply, urban agriculture, and ecosystem services.

Table 3 Land cover changes in Osogbo (1986–2006)

Year	*Population*	*Population growth rate (%)*	*Vegetation cover (km^2)*	*Change in vegetation cover (%)*
1986	368,333		474.9	
1996	458,007	24.4	371.4	–21.8
2006	550,143	20.1	331.3	–10.8
2016	663,898	20.7	188.6	–43.1
Annual rate of change	*9,852*	*2.2*	29.7	–2.5
Year	*Water bodies (km^2)*	*Change in water bodies (%)*	*Built-up (km^2)*	*Change in built-up areas (%)*
1986	19.7		20.5	
1996	14.7	–25.2	21.9	6.9
2006	11.4	–22.2	58.5	166.7
2016	5.0	–56.4	214.5	266.9
Annual rate of change	1.0	–3.5	9.8	14.7

Source: Authors' Computations from image analysis (2016)

4.2 LCR and LAC

Land consumption is increasing rapidly with the exponential growth of population. LCR and LAC were introduced to aid in the quantitative assessment of changes in relation to urban expansion in the study area. LCR measures land availability by estimating the quantity of urban land on average that is consumed per person in a given area. LAC also gives an indication of the land that is converted into urban land use as the city expands. It measures the consumption of new urban land by each unit increase in the urban population.

As shown in Figure 3, LCR increased consistently from 0.06 km^2/1,000 persons in 1986 to 0.32 km^2/1,000 persons in 2016, translating to 433% increase, while LAC also increased from 0.02 to 1.36 km^2/1,000 persons, suggesting intensification of urbanisation within the city space. Large values of LCR suggest a significant increase in uptake of non-urban land use for urban purposes. It also is an indication of increasing low-density developments that are clearly noticeable at the outer part of the city. This reinforces the result of land use/cover analysis that revealed the consistent outward expansion of urban land use in the study area. A major implication of this is the progressive transformation of hitherto agricultural land, wetlands and forest into concrete, impervious surfaces that alter the radiation and hydrological budgets, thereby adversely affecting the climatic as well as hydrological regimes. Such a situation may trigger an urban heat island phenomenon while severely limiting surface and groundwater availability. In addition, low-density development poses a problem to infrastructure and service provision, especially in the developing areas at the urban fringe. This partly explains why many residential developments (especially Okinni and Ilobu in the western axis, Abere and Owode Ede in the southeast as well as Dagbolu in the northern axis) are not serviced with basic services like piped water, motorable road, among others. Above all, cities with a higher level of urbanisation as indicated by high values of LCR and LCR have been associated with global warming and climate change.

Table 3 LCR and LAC

Year	*Population*	*Population growth rate (%)*	*Urban extent (km²)*	*Land consumption rate (LCR)*	*Land absorption coefficient (LAC)*
1986	368,333		20.5	0.06	
1996	458,007	9.9	21.9	0.05	0.02
2006	550,143	9.6	58.5	0.011	0.04
2016	663,898	10.1	214.5	0.032	1.37

Note: *Population figures obtained from United Nations (2014)

Source: Authors' computations (2016)

4.3 Implications of findings for city's sustainability

One of the major findings of the study is the rapid growth in the areal size of the built-up areas at a rate of 3.5% which is higher than the population growth rate of 2.6%. This shows that there are other drivers of land use/cover change apart from the population, prime among which could be a change in the administrative function of the city. Conversion of vegetation and wetlands into bricks and mortals is an inexorable consequence of this unrestrained increase in the size of the built-up areas, with the likelihood of disruption in biogeochemical cycles, depletion of carbon sink and the resultant increase in global warming and increased incidence of urban heat island. As the city experienced in-filling and development of hitherto undeveloped land parcels (most of which are used for urban agriculture), arable land for urban agriculture and open spaces for recreation and community interactions are depleted. The expansion of the city into the surrounding rural lands is also creating stiff competition for agricultural land with its consequences on agricultural production and food security.

Furthermore, the exponential growth in urban land development drives competition for available land which in turn causes the land value to skyrocket, making it difficult for average urban dwellers to acquire land for housing and other uses in safe areas. The consequences of this range from people having to relocate to unsafe locations, thereby increasing their vulnerability, to the development of shanties and squatter settlements around the cities peripheries. Such developments are noticeable around Okinni, Oke Baale, Agunbe Elewo, where the unplanned, and unserviced development of poorly constructed homesteads are common sights. Urban sprawl is also evident in some sections of the outer city where there has been an extensive outward growth of urban land use into the hitherto rural lands. Sustainable growth of urban settlements favours compact, high density, smart development, as this enhances service provision and efficient energy utilisation. While shanty and slum development is capable of aggravating the already bad living conditions of a sizeable number of city dwellers, sprawl usually increases the cost of service and infrastructure provision in the suburbs and the periphery. It also increases car dependency and therefore worsening the emission problem.

Increased human population and human activities mean that more wastes are generated. In a city where more than 50% rely on unconventional methods of waste disposal, the rate of air, land and water pollution has increased tremendously.

5 Conclusions

This study employed geospatial techniques, embedded in geographic information system (GIS) and remote sensing to evaluate the urban land use changes in a rapidly expanding medium-sized city in the developing world. The study showed that fluctuations in the rate of land use/cover change synchronise with changes in demography, economic fortunes, and political status of the study area. These factors affected the level of socio-economic activities that contributed significantly to rapid expansion in urban land use observed in the city during the periods under study. The study has shown that in terms of urban land use as well as socio-political and demographic characteristics, the city is in a transition, just like many other medium-sized cities in Sub-Saharan Africa and Southeast Asia. While the city's demographic growth and physical expansion are inevitable, it is imperative that city managers evolve ways of checking the uncoordinated growth of the city to prevent further loss of vegetation and deterioration of the environment in general. The high rate of conversion of vegetation and wetlands to urban land use remains a critical challenge to the sustainability of the city. Innovative city planning that incorporates efficient land use and transportation planning, smart growth and compact development should be evolved. Such policy must be strictly implemented to create a new order in city planning and management in which city dwellers are made to embrace behavioural change required to regulate consumption pattern and change the waste generation and management orientation. The inability of small and medium-sized cities to ensure strict implementation and enforcement of planning codes and environmental standards remains the bane of the SDGs in these cities. Hence, building capacity in the areas of policy formulation, implementation and monitoring are crucial to the attainment of sustainable development of objectives.

Finally, although this work has analysed the change in land use/cover and its implication for the city's sustainability, it is necessary that further works that will provide a broader understanding of the contributions of drivers of urban expansion be carried out. Such studies will provide sound theoretical basis for developing policies aimed at mitigating the factors that drive urban land use changes, and consequently reduce the rate of vegetal loss and environmental degradation in the evolving urban areas. In order to stem the current rate of urban expansion, and foster sustainable urban growth, there is the need to strictly regulate urban development, encourage vertical growth, green development and formulate policies that promote sustainable urban growth.

References

Abiodun, O.E., Olaleye, J.B., Dokai, A.N. and Odunaiya, A.K. (2011) 'Land use change analyses in Lagos State from 1984 to 2005', *FIG Working Week 2011*, pp.1–11, Marrakech, Morocco.

Agbola, T. (1992) 'Osogbo City profile', *Cities*, Vol. 9, No. 4, pp.249–260.

Aguda, A. and Adegboyega, S. (2013) 'Evaluation of spatio-temporal dynamics of urban sprawl in Osogbo, Nigeria using satellite imagery and GIS techniques', *International Journal of Multidisciplinary and Current Research*, Vol. 1, pp.60–73.

Aguda, A.S., Farinde, T.A., Adegboyega, S.A. and Olawole, M.O. (2012) 'Spatio-temporal assessment of urban growth of medium-size and nodal towns for sustainable management: using GIS', *Management of Environmental Quality: An International Journal*, Vol. 24, No. 1, pp.94–106 [online] https://doi.org/10.1108/14777831311291159.

Akbulut, A. and Ozcevick, O. (2015) 'Sustainability indicators of land-use planning for medium-sized cities: a case study of Nigde, Turkey', *WIT Transactions on Ecology and The Environment*, Vol. 193, pp.385–396, DOI: 10.2495/SDP150331.

Atobatele, R.E. (2016) *Assessment of the Impact of Urbanization on Land Use Land Cover Changes in Osogbo, Nigeria*, Osogbo: BSc Project, Osun State University, Department of Geography.

Balthazar, V., Vanacker, V. and Lambin, E.F. (2012) 'Evaluation and parameterization of ATCOR3 topographic correction method for forest cover mapping in mountain areas', *International Journal of Applied Earth Observation and Geoinformation*, Vol. 18, pp.436–450.

Bhatta B. (2010) 'Causes and consequences of urban growth and sprawl', in *Analysis of Urban Growth and Sprawl from Remote Sensing Data*, Advances in Geographic Information Science, Springer, Berlin, Heidelberg.

Bradbury, A. (2009) 'Understanding the evolution of community severance and its consequences on mobility and social cohesion', *European Transport Conference*.

Brundtland, G.H. (1987) *Report of the World Commission on Environment and Development: Our Common Future*, United Nations.

Eastman, J.R. (2009) *IDRISI Taiga Guide to GIS and Image Processing*, Clark Labs, Clark University, Massachusetts.

Eberlein, S. (2012) *How Smaller Cities are Taking the Lead in Sustainability Innovation*, AlterNet, 23 July [online] http://www.alternet.org/print/visions/how-smaller-cities-are-taking-lead-sustainability-innovation (accessed on 10 December 2016).

Enaruvbe, G.O. and Atedhor, G.O. (2015) 'Spatial analysis of agricultural landuse change in Asaba, Southern Nigeria', *IFE Journal of Science*, Vol. 17, No. 1, p.65.

Farmer, K. (2012) *Utilizing Object-Based Image Analysis to Explore the Effect of Urbanization on Vegetation Diversity in Southeastern Duval County, Florida*, A Thesis Presented to the Department of Humanities and Social Sciences in Candidacy for the Degree of Master of Science, Doctoral dissertation, Northwest Missouri State University.

Foley, J.A., DeFries, R., Asner, G.P., Barford, C., Bonan, G., Carpenter, S.R. and Helkowski, J.H. (2005) 'Global consequences of land use', *Science*, Vol. 309, No. 5734, pp.570–574, DOI: 10.1126/science.1111772

Han, S.S. (1994) *Controlled urbanization in China, 1949–1989*, PhD Dissertation, Simon Fraser University, December [online] http://summit.sfu.ca/system/files/iritems1/6538/b16962813.pdf (accessed 1 July 2018).

Hassan, M.M. and Nazem, M.N. (2016) 'Examination of land use/land cover changes, urban growth dynamics, and environmental sustainability in Chittagong City, Bangladesh', *Environment, Development and Sustainability*, Vol. 18, No. 3, pp.697–716.

Herold, M., Couclelis, H. and Clarke, K.C. (2005) 'The role of spatial metrics in the analysis and modelling of urban land use change', *Computers, Environment and Urban Systems*, Vol. 29, No. 2005, pp.369–399.

ITC-ILWIS (2001) *ILWIS User's Guide. International Institute for Aerospace Survey and Earth Science (ITC)*, ITC, Enschede, The Netherlands.

Liu, Y., Yin, G. and Ma, L.J. (2012) 'Local state and administrative urbanization in post-reform China: a case study of Hebi City, Henan Province', *Cities*, Vol. 29, No. 2012, pp.107–117.

McCarthy, M.P., Best, M.J. and Betts, R.A. (2010) 'Climate change in cities due to global warming and urban effects', *Geophysical Research Letters*, Vol. 37, No. 9, p.L09705.

Muggah, R. (2012) *Researching the Urban Dilemma: Urbanization, Poverty and Violence*, IDRC, Ottawa.

Mundia, C.N. and Aniya, M. (2006) 'Dynamics of land use/cover changes and degradation of Nairobi City, Kenya', *Land Degradation Development*, Vol. 17, No. 1, pp.97–108.

Musakwaa, W. and Van Niekerk, A. (2013) 'Implications of land use change for the sustainability of urban areas: a case study of Stellenbosch, South Africa', *Cities*, June, Vol. 32, pp.143–156.

Nwokoro, I.I. and Dekolo, S.O. (2012) 'Land use change and environmental sustainability: the case of Lagos Metropolis', *WIT Transactions on Ecology and The Environment*, Vol. 155, pp.157–167, DOI: 10.2495/SC120141.

O'Neill, B.C., Ren, X., Jiang, L. and Dalton, M. (2012) 'The effect of urbanization on energy use in India and China in the iPETS model', *Energy Economics*, Vol. 34, pp.S339–S345, DOI: 10.1016/j.eneco.2012.04.004.

Rajeshwari, D. (2006) 'Management of the urban environment using remote sensing and geographic information systems', *J. Hum. Ecol.*, Vol. 20, No. 4, pp.269–277 [online] http://www.krepublishers.com/02_journals/JHE/ (accessed 21 July 2017).

Riebsame, W.E., Meyer, W.B. and Turner II, B.L. (1994) 'Modelling land use and cover as part of global environmental change', *Climatic Change*, Vol. 28, Nos. 1–2, pp.45–64.

Samuel, K.J. and Adagbasa, E.G. (2014) 'A composed index of critical accessibility (CICA) to healthcare services in a traditional African City', *GeoJournal*, Vol. 79, No. 3, pp.267–278.

Sandhya, G.K. and Joshi, U.B. (2013) 'Estimation of variables explaining urbanization concomitant with land-use change: a spatial approach', *International Journal of Remote Sensing*, Vol. 34, No. 3, pp.755–758.

Schreiber, F., Kaj, F., Eleni, D. and Alexander, C. (2016) *Designing the New Urban Agenda: Lessons from International Agreements*, Delphi, Berlin.

Sharma, L., Pandey, P.C. and Nathawat, M.S. (2012) 'Assessment of land consumption rate with urban dynamics change using geospatial techniques', *Journal of Land Use Science*, Vol. 7, No. 2, pp.135–148.

Sustainable Cities International (2012) *Indicators for Sustainability: How Cities are Monitoring and Evaluating their Success*, Sustainable Cities International, Vancouver.

Taiwo, O.J., Abu-Taleb, K.A., Ngie, A. and Ahmed, F. (2014) 'Effects of political dispensations on the pattern of urban expansion on the Osogbo Metropolis, Osun State, Nigeria', *Proceedings of the 10th International Conference of AARSE*, October, pp.242–251.

UN-HABITAT (2004) *State of the World's Cities: Trends in Sub-Saharan Africa Urbanization and Metropolitanization*, UN-HABITAT SOWC/04/RB/4, Nairobi.

UN-HABITAT (2015) *Enhancing the Competitiveness of Cities*, UN-HABITAT, Nairobi.

United Nations, Department of Economic and Social Affairs, Population Division (UNDESA) (2014) *World Urbanization Prospects: The 2014 Revision* [online] http://www.un.org/esa/population/ (accessed 12 September 2016).

United Nations, P.D. (2014) *World Urbanization Prospects: The 2014 Revision, Custom Data Acquired Via Website*, Department of Economic and Social Affairs.

World Cities Report (2016) *Urbanization and Development: Emerging Futures*, United Nations Human Settlements Programme, Nairobi.

Yeates, M. and Garner, B.J. (1976) *The North American City*, Vol. 14, HarperCollins Publishers, New York.

Yuan, F., Sawaya, K., Loeffelholz, B. and Bauer, M. (2005) 'Land cover classification and change analysis of the twin cities (Minnesota) metropolitan area of new york by multi-temporal landsat remote sensing', *International Journal of Remote Sensing*, Vol. 98, Nos. 2–3, pp.317–328.

Zeng, Y., Zhang, J., Wang, G. and Lin, Z. (2002) 'Urban land-use classification using integrated airborne laser scanning data and high-resolution multi-spectral satellite imagery', *Pecora15/Land Satellite Information IV/ISPRS Commission I/FIEOS 2002 Conference Proceedings*, pp.1–6.

Zhang, X. and Li, H. (2018) 'Urban resilience and urban sustainability: what we know and what do not know?', *Cities*, February, Vol. 72 , pp.141–148.