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ASSESSING THE SPATIO-TEMPORAL PATTERN OF LAND USE AND LAND COVER CHANGES IN OSUN DRAINAGE BASIN, NIGERIA

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Abstract

Over the years, Osun drainage basin has witnessed tremendous increase in population, and urbanization that have changed the landscape of the area. This study evaluated the spatio-temporal pattern of land use/land cover change (LULC) in the study area, and made hydrological inferences. Landsat imageries were acquired from USGS-EROS satellite image database for the period 1984, 2000 and 2015, while the Digital Elevation Model (DEM) was obtained from Shuttle Radar Topography Mission (SRTM) of the National Aeronautics and Space Agency (NASA). Supervised image classification using the Maximum Likelihood Algorithm in Erdas Imagine was adopted to classified the land use/land cover of the study area into seven classes. Elevation, aspect and slope of the study area were processed from DEM using ArcGIS. Modules for Land Use Change Evaluation (MOLUSCE) plugin in QGIS was used to simulate the basin future LULC change, using change driving factors of population, elevation, aspect and slope of the study area. There was about 234% increase in built up areas and 89.22% in crop/shrubs between 1984 and 2015. The most significant decrease in LULC occurred in forest (58.75%) and wetland (84.69%) during this period. The predicted future LULC change suggests that only about 12% of the basin will remain under forest cover by the year 2046. The results underscored the increasing anthropogenic activities in the basin that influenced recharge rate, surface runoff, incidences of soil erosion, etc., in Osun drainage basin. The planting of the lost native trees was recommended for the sustainability of the basin's ecosystem.

Keywords: Land use/land cover, spatio-temporal, change detection, Osun drainage basin

INTRODUCTION

The existing land use/land cover (LULC) in a region and the previous impacts of the earlier LULC change still operating in the system determines the response of the ecosystem to disruption in LULC (Martin et al. 2011). The change in LULC of a region, particularly increase in built up areas advertently or inadvertently alters the hydrological processes which include change in runoff pattern, modification of peak flow characteristics, alteration of water quality, etc. (Noorazuan et al., 2003). In fact, changes in land use may have unintended negative impacts on the hydrological regime of a drainage basin, thereby increasing the chances of flood occurrence and also reducing the dry season flow (Lorup et al., 1998). Studies have reported that change in land use and land cover can influence surface runoff, infiltration, groundwater recharge, water quality and supply in a drainage basin. Depending on the degree of change, overland flow can be increased or reduced, infiltration and recharge can also increase or reduce (Ziegler and Giambelluca, 1997; Turner et al., 2001; Butt et al., 2015; Ashaolu, 2018).

In the views of Ashraf (2013) and Butt et al. (2015), land use/land cover change in a drainage basin include rapid urbanization, deforestation and afforestation which endlessly influence the water budget; and the type and magnitude of surface and subsurface water exchanges. Thereby affecting drainage basin ecology and their various benefits to man. Nevertheless, enhanced water preservation schemes can be articulated through the appropriate identification of the spatio-temporal variation taking place in a drainage basin and the relationship between the various components of the basin (Ashraf, 2013; Butt et al., 2015). Therefore, assessing the spatio-temporal pattern and changes of land use and land cover at drainage basin level is essential to the management and planning of the drainage basin water resources (Butt et al., 2015) and land use allocation that will not jeopardize the basin ecosystem in particular.

Over the years, Osun drainage basin which is one of the two major drainage basins in the southwestern Nigeria has witnessed tremendous increase in population, farm settlements, urbanization and emerging cities which have changed the landscape of the drainage basin. The land use pattern within Osun drainage basin include land use for residential/settlements, built up areas, bare rocks, soils surfaces, farmlands (annual crops/shrubs and agroforestry/secondary regrowth), vegetation and water bodies. Over two decades ago, Salami (1995) reported that the increasing population density coupled with the long history of agricultural colonization of some parts of the basin has resulted to substantial alteration of the basin's natural environment. Salami et al. (1999) also reported that the natural vegetation of so many parts of the basin has been replaced by secondary forest or perennial and annual crops.

Therefore, the vegetation of the area can be described as derived savannah characterized by gallery of forest along stream sides and tall grasses with scattered perennial trees over land. The basin is covered by secondary forest and the derived savannah mosaic predominates in the northern part. Originally, almost all parts of the basin had a natural lowland tropical rain forest vegetation; but this has however, been replaced by secondary forest regrowth as a result of years of anthropogenic activities. However, relics of the old rainforest species are still found in some isolated areas. Some of the reasons for this change in vegetation are fuel wood production, road construction, clay and sand quarrying and traditional farming practices (Ifabiyi, 2005).

In recent years, studies on LULC in Osun drainage basin were carried out to understand the changing pattern of LULC in settlements therein and were for the purpose of urban planning (Salami, 1995; Salami et al., 1999; Akinyemi, 2005; Mengistu and Salami, 2007; Gasu et al., 2016) and not with the aim of understanding the implications of such LULC changes on the hydrology of the entire basins. These studies have suggested changes in LULC all over the basin which will no doubt influence the water budget. For example, Akinyemi (2005) discovered that the greatest percentage change in land use/land cover of the part of the basin that includes, Ilesha, Ijebu Ijesa, Imesi Ile, Otan Aiyegbaju, Igbajo Efon Alaiye and Oke-Messi, etc. were recorded on built up areas/roads (88.41%), while Agro-forestry/secondary regrowth decreased by 49.06% between 1986 and 2002. Similarly, Gasu et al. (2016) discovered that the urban/built-up areas in Osogbo, one of the major towns in the basin have increased by about 415% between 1986 and 2012.

In addition, Mengistu and Salami (2007) reported a significant conversion of natural vegetation cover to farmland and settlements between 1986 and 2002 in the upper part of the basin. The area covered by Savanna and high forest declined by 71.9 and 8%, respectively, while shrubs/farmlands and settlements/bare surface increased by 413.6% and 192.4%, respectively. All these studies attributed the change in the land use/land cover of the area to the rapid expansion of agricultural land as a result of change in socioeconomic system of the region, population growth, expansion of settlements, gold mining activities, fuelwood extraction, intensive biomass burning and illegal logging. It is noteworthy, that a study that attempted a LULC classification of Osun drainage basin was limited to the upper part of the drainage basin basically in the portion that falls within Osun and Ekiti States (Akinwumiju, 2015), and there is need to cover the entire drainage basin in order to fully understand the LULC change scenario in Osun drainage basin, Nigeria. The changes in LULC experienced in Osun drainage basin over the years will no doubt influence the hydrology of the basin. Therefore, understanding land use and land cover change in the basin will enhance planning and management activities within the study area. This study therefore evaluated the change in LULC of Osun drainage basin over the years and made hydrological inferences from the results of the change detection.

STUDY AREA

Osun drainage basin is located between latitudes 6°25′58.79″ and 8°21′3.6″ N and longitudes 3°47′34.8″ and 5°10′55.2″ E in the southwestern Nigeria (Fig. 1).

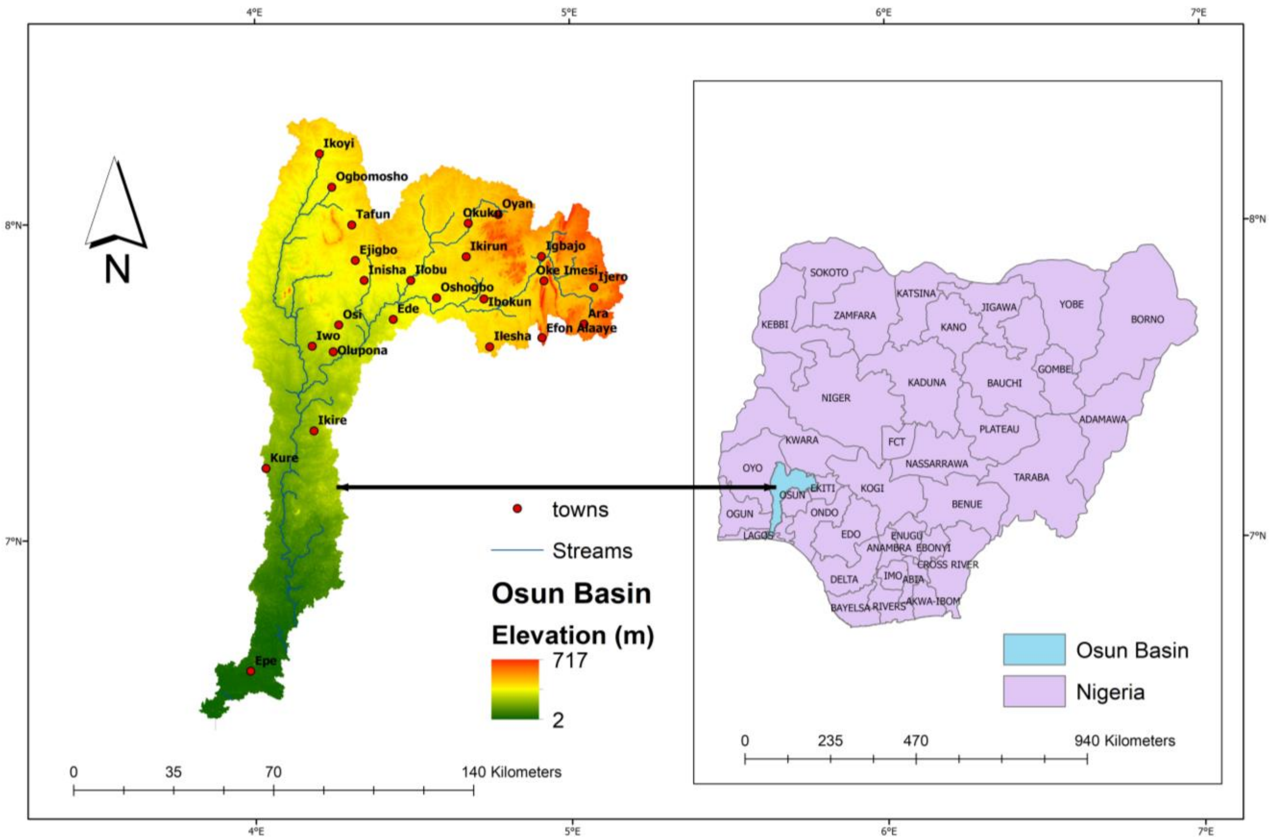

Fig. 1 Location and position of Osun Drainage Basin, Nigeria. Source: Modified form Ashaolu (2016)

River Osun which is the major river in the drainage system accents in Oke-Mesi ridge, about 5 km North of Effon Alaiye and flows North across the Itawure gap to latitude 7°53″ and then deviates westwards via Osogbo, Ede and southwards to flow into Lagos lagoon (Ogun-Oshun River Basin Development Authority (OORBDA, 1982; Oke et al., 2013; Ashaolu, 2016). The basin climate is influenced by the movement of the Inter-tropical Convergence Zone (ITCZ), the quazi-stationary boundary that distinguishes the sub-tropical continental air mass over the Sahara and the equatorial maritime air mas over the Atlantic Ocean (OORBDA, 1982). The climate of the basin can be described as the tropical continental climate of Koppen Aw type humid tropical rainforest climate (Ifabiyi, 2005).

The months of February and March are the hottest in the basin and temperatures are high over the entire basin during this period. The mean annual temperature is about 30°C, which can varies depending on the location and time of the year (Ifabiyi, 2005). The basin is underlain by two types of rocks which are the Basement Complex rocks and the sedimentary basins (OORBDA, 1982; Oke et al., 2013). About 93% of the basin is underlain by the Basement Complex rocks, while the remaining 7% is sedimentary rock found in the southern part of the basin close to the Atlantic (Ashaolu, 2016). The soils in larger part of the study area belong to the highly ferruginous tropical red soils associated with Basement Complex rocks (Ifabiyi, 2005). The relief of the basin is generally undulating and descends from an altitude of about 700 meters in Oke lmesi area to 50 meters and below in areas around Epe and Ibeju Lekki in the southern parts of the basin (Ashaolu, 2016). The land use pattern within the drainage basin includes land use for residential/settlements and built up areas, bare rocks, bare surfaces, crops/shrubs, vegetation/forest and water bodies. The population distribution pattern of the basin is quite uneven. The urban population in the basin is larger than the rural population. Based on the 1963 population census of western Nigeria, the estimated population of the basin made by Ogun-Oshun River Basin Development Authority in 1980 was 4,281,000 and was estimated to be 12,046,145 in 2015 from 1991 population census using 3.0 percent growth rate for areas that comprises of rural and urban settlements in Nigeria (Ashaolu, 2018).

MATERIALS AND METHODS

Landsat imageries of the study area were acquired from USGS-EROS satellite image database for 3 epochs (1984, 2000 and 2015). Table 1 shows the type, path/row, date and characteristics of the satellite images acquired. The images of the years 1984 and 2015 were captured in December, while that of the year 2000 were captured in February. The disparity in the months was because February year 2000 was the closest month to December with all the four satellite scenes that covered the study area. It is important to note that vegetal cover from December to March in the study area are quite similar, hence it cannot affect the reality of the change detection registered in this study. The satellite images of 2015 are pansharpened using the panchromatic 15m band of Landsat 8 and all the other images were resampled into 15m pixel size from their original 30m resolution. The nearest neighbor resampling method was adopted to resample the satellite images using ArcGIS 10.4. The study area falls within four different satellite scenes. The bands of each of the satellite image scenes of the three periods were first stacked in Erdas Imagine 2014. The four scenes for the years 1984, 2000 and 2015 were mosaic using the MosaicPro algorithm in Erdas Imagine 2014. The resulting images were subset using the study area shapefile to bring out the satellite images of the area of interest (AOI). The AOI images were enhanced by filtering the imageries in Erdas Imagine, resampled and projected. The images were enhanced into natural colour composite to improve the visual interpretation. All the images were projected to Universal Transverse Mercator projection of WGS84 coordinate system, zone 31N.

Table 1 Satellite image characteristics

SN	Image Type	Path/Row	Acquisition Date	Resolution
1	Landsat 8 OLI/TIRS	191/54	24/12/2015	30 m
		191/55	24/12/2015	
		190/54	17/12/2015	
		190/55	17/12/2015	
2	Landsat 7 ETM	191/54	06/02/2000	30 m
		191/55	06/02/2000	
		190/54	15/02/2000	
		190/55	15/02/2000	
3	Landsat 5 TM	191/54	18/12/1984	30 m
		191/55	18/12/1984	
		190/54	11/12/1984	
		190/55	11/12/1984	

The supervised classification method in Erdas Imagine 2014 was adopted, using the maximum likelihood algorithm. The coordinates of some identified features within the basin were recorded and used as training samples for supervised classification of the remotely sensed data. One hundred and forty distributed training sites depicting all the main land use/land cover classes were used in each of the Landsat image used for the classification. The training sites (signatures) of all images were developed by using the spectral characteristics of known to train the classification algorithm for the land use/land cover mapping of the basin, which represent various land use/land cover of interest. After classification, ground truthing was carried out to verified doubtful areas in the classified image. The classified LULC classes were corrected using the recode option in Erdas Imagine. The accuracy assessment was conducted using 250 points, based on ground truth data and visual interpretation of the images. The 250 points were randomly selected in preparing confusion matrix for accuracy assessment, which is a popularly accepted method in determining the accuracy of LULC classification (Foody 2002). The 1984 and 2000 Landsat imageries could not be checked against the ground truth data point to validate the interpretation made. Hence, Google Earth images for these two periods were adopted for references. Tilahun and Teferie 2015; and Tadele et al. 2017 adopted similar approach in their studies with reasonable results. The randomly generated points in the classified 1984 and 2000 images were imported into Google Earth images of 31/12/ 1984 and 31/12/2000, respectively to verify the accuracy of the classifications. Also, the randomly generated points in the classified 2015 image was imported into Google Earth image of 14/12/ 2015 to verify the accuracy of the classification

(Tilahun and Teferie, 2015; Tadele et al., 2017) and the generated confusion matrix derived from the image and the points collected during ground truthing was also used for the accuracy assessment (Ismail and Jusoff, 2008).Thereafter, the Kappa coefficient and overall accuracy were calculated to assess the mapping accuracy of the LULC classification.

Seven land use/land cover classes reported in various part of the study area by Akinyemi (2005), Meginstu and Salami (2007) and Gasu et al. (2016) that include bare surfaces, built up area, crops/shrubs, forest, rock outcrops, water bodies and wetland were adopted as the basis for classification in this study. The land use/land cover maps of the basin for the period 1984, 2000 and 2015 were developed and measured for each land use/land cover types. A post classification detection approach was adopted for the change detection analysis. The change information was conducted using a pixel-based comparison, this enable us to interpret the changes overtime more effectively using the "-from, -to" information. The classified image of the three period were compared using cross-tabulation which assisted us to determine both qualitatively and quantitatively aspects of the changes for the year 1984 to 2000 to 2015. The change matrix (Weng, 2001; Rawat and Kumar, 2015) was prepared using Erdas Imagine. Therefore, the quantitative areal data of the total LULC changes, gains and losses in each LULC classes between the three period of investigation were compiled.

Modules for Land Use Change Evaluation (MOLUSCE) plugin in QGIS was adopted in simulating the future LULC change in the basin. MOLUSCE is designed to analyze, model and simulate land use/cover changes and predict the future direction of change by using spatial change variables that include elevation, slope, aspects, distance to roads, population, etc. In this study, to simulate the future change in the drainage basin, the LULC change explanatory variables or change driving factors that include population, elevation, aspect and slope of the study area were adopted. The resulting predicted land use/land cover should be used with caution because there are other factors that can drive change in the future besides the factors adopted in this study. The Digital Elevation Model (DEM) of the study area was obtained from Shuttle Radar Topography Mission (SRTM) of the National Aeronautics and Space Agency (NASA). Elevation, aspect and slope of the study area were processed from DEM using ArcGIS 10.4. Also, the 1991 population of the study area acquired from National Population Census in Nigeria was projected using the 3.0 growth rate to get the population of the study area as at 2015. All these variables are ranked between 0 and 1 using the fuzzy membership tool in ArcGIS 10.4. The change transition matrix for the predicted 2046 LULC change was also computed.

RESULTS AND DISCUSSION

Land use/land cover classification, 1984-2015

The results of the seven (7) classified LULC for the study area are presented in Table 2 and Figure 2. In the base year, forest area constituted the most extensive type of land use/land cover of Osun drainage basin. Accordingly, it

Table 2 Land use/land cover classification of Osun Drainage Basin, 1984-2015

Land use/land cover types		1984		2000		2015	
		Area (Km^2)	%	Area (Km^2)	%	Area (Km^2)	%
1	Bare surfaces	2040.95	20.56	2709.57	27.30	3087.31	31.10
2	Built Up Areas	317.64	3.20	459.18	4.63	1063.91	10.72
3	Crops/Shrubs	1646.14	16.58	4163.35	41.94	3114.86	31.38
4	Forest	5223.61	52.62	2059.21	20.75	2154.87	21.71
5	Rock Outcrops	493.05	4.97	342.35	3.45	420.09	4.23
6	Water Bodies	50.76	0.51	61.64	0.62	61.59	0.62
7	Wetland	154.07	1.55	130.93	1.32	23.59	0.24
	Total	9926.22	100.0	9926.22	100.00	9926.22	100.00

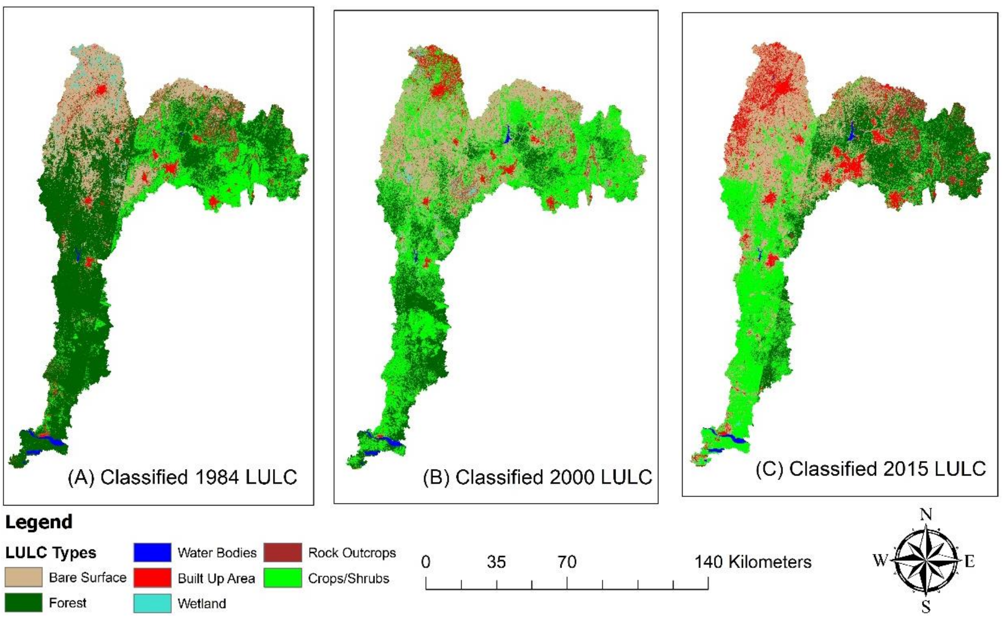

Fig. 2 The Classified Images of Osun Drainage Basin, 1984, 2000 and 2015

accounted for about 52.62% of the total drainage basin area in 1984, followed by bare surface and crops/shrubs, occupying 20.56% and 16.58% of the total drainage area, respectively (Table 2). About 0.51% of the study area was covered by the water bodies, which is the least of the seven (7) land use/land cover classified in 1984. In 2000, crops/shrubs, bare surfaces and forest covered 41.94%, 27.30% and 20.75%, respectively of the total basin area. Also, bare surface, crops/shrubs, forest covered 31.10%, 31.8% and 21.71%, respectively, while built up area accounted for 10.72% of Osun drainage area in 2015. For the LULC map of 1984, the Kappa coefficient and overall accuracy were found to be 0.71 and 0.80, respectively. The Kappa coefficient and overall accuracy were 0.80 and 0.85 for the year 2000 LULC map. Also, the Kappa coefficient and overall accuracy were found to be 0.79 and 0.82, respectively for the LULC map of 2015.

Land use/land cover change, 1984-2015

To explain the changes of one LULC class to another during the period of study, a change detection matrix was prepared and the results are presented in Table 3.

Land use/land cover change, 1984-2000

Between 1984 and 2000, bare surfaces, built up areas, crops/shrubs and water bodies gained a total land area of 668.62km^2, 141.54km^2, 2517.21km^2 and 10.88km^2, respectively. Crops/shrubs has a remarkable increase of 152.92%. It was also observed that built up area increased with about 44.56% between 1984 and 2000. This can be attributed to the increasing human population within the basin. Akinyemi (2005), Mengistu and Salami (2007) and Gasu et al. (2016) similarly reported increases in settlements/built up areas in their studies in the different parts of the basin. This confirms the fact that there is an increasing trend in the size of built up areas in the Osun drainage basin. The area covered by bare surfaces, built up areas, crops/shrubs and water bodies expanded at an annual average rate of 1.93%, 2.62%,9.00% and 1.26%, respectively between 1984 and 2000.

In the same period, forest, rock outcrops and wetland lost a total land area of 3164.40km^2, 150.70km^2 and 23.15km^2, respectively. The forest area decreased rapidly with a total loss of 60.58% of its initial areal coverage. The sharp decrease in the size of forest between 1984 and 2000, is due to anthropogenic activities. Similar results were observed in some parts of the basin between 1986 and 2002 (Akinyemi, 2005; Mengistu and Salami, 2007). The forest area, rock outcrops and wetland receded at an annual rate of 3.56%, 1.80% and 0.88%, respectively between 1984 and 2000.

Land use/land cover change, 2000-2015

Built-up areas increased significantly during this period. It indeed increased by131.70% from its original size of 459.18 km^2 in 2000 to 1064.91km^2 in 2015 (Table 3). This gives an average annual growth rate of 8.23%. A change largely due to increasing population and urbanization. As a matter of fact, the population of the basin that was put at 4,281,000 in 1980 by OORBDA (1982) was estimated to be 12,046,145 in 2015 by Ashaolu (2018). The increasing built-up areas can severely change the water balance of the study area, influence the rate of recharge and the microclimate of the area (Lerner et al., 1990; Jyrkama and Sykes, 2006). Also, the amount of direct groundwater recharge resulting from rainfall may reduce as a result of the increase in impervious surfaces from built up areas, while surface runoff will increase significantly (Rose and Peters, 2001). Expectedly, crops/shrubs, water bodies and wetland receded at an annual rate of 1.57%, 0.08% and 5.12%, respectively. For example, crops/shrubs lost an area of 1048.50 km ^{2} , which is about 58% of its basin coverage in 2000. The study of Akinyemi (2005) in a small section of the drainage basin, while agreeing with this finding continues up until 2015.

Land use/land cover change, 1984-2015

The greatest percentage change for the 32-year-period was recorded on built-up area with about 235% increase at an average annual rate of 7.34% (Table 3). Built-up area increased significantly from 317.64 km^2 in 1984 to 1063.91km^2 in 2015. The increasing areal extent of the built-up areas confirmed the results of early studies (Akinyemi, 2005; Mengistu and Salami, 2007; Gasu et al., 2016) in some parts of the study area. Also, crops/shrubs gained about 89.22% with an average annual rate of 2.79%. Crops/shrubs increased by an area of 1468.22km^2, from

Table 3 Area and amount of change in land use/land cover categories in Osun Drainage Basin, 1984-2015. Note: The signs + and - indicate increase and decrease, respectively

	Land use/land cover types	1984-2000		Average rate of change (1984-2000)		2000-2015		Average rate of change (2000-2015)		1984-2015		Average rate of change (1984-2015)	
		Area (Km^2)	%	Area (Km^2)	%	Area (Km^2)	%	Area (Km^2)	%	Area (Km^2)	%	Area (Km^2)	%
1	Bare surfaces	668.62	32.76	39.33	1.93	377.74	13.94	23.61	0.87	1046.36	51.27	32.70	1.60
2	Built up areas	141.54	44.56	8.33	2.62	604.73	131.70	37.80	8.23	746.27	234.94	23.32	7.34
3	Crops/Shrubs	2517.21	152.92	148.07	9.00	-1048.50	-25.18	-65.53	-1.57	1468.72	89.22	45.90	2.79
4	Forest	-3164.40	-60.58	-186.14	-3.56	95.66	4.65	5.98	0.29	-3068.70	-58.75	-95.90	-1.84
5	Rock outcrops	-150.70	-30.57	-8.86	-1.80	77.74	22.71	4.86	1.42	-72.96	-14.80	-2.28	-0.46
6	Water bodies	10.88	21.44	0.64	1.26	-0.05	-0.07	0.00	0.00	10.84	21.35	0.34	0.67
7	Wetland	-23.15	-15.02	-1.36	-0.88	-107.34	-81.98	-6.71	-5.12	-130.48	-84.69	-4.08	-2.65

1646.16km^2 in 1984 to 3114.86km^2 in 2015. The increase recorded in the percentage area of crops/shrubs conform with the work of Salami et al. (1999), which reported that natural vegetation has largely been replaced by perennial and annual crops in many parts of the basin. The changes in land use/land cover during the 32 years, especially increase in built up and crops/shrubs can be attributed to population growth and settlement expansion, these scenarios had culminated into conversion of natural vegetation to farmland. Other human activities such as fuel wood extraction, sand mining, quarrying and gold mining etc. have all contributed to land use changes.

The most notable decrease in LULC classes in the Osun drainage basin was observed in the forest area and wetland. Forest decreased from a total land area of 5223.61km^2 (52.62%) in 1984 to 2154.87 km^2 (21.71%) in 2015. This is similar to the study of Hammad et al. (2018) in the southern Syria coastal basin where forest area decreased from about 64% in 1987 to about 38% in 2017. The forest area receded at an annual average rate of 1.84% during the period under investigation. This can be attributed to the years of human occupation and interference with the tropical vegetation of the drainage basin. The long history of agricultural practices and increasing population density in the area would have resulted into substantial modification of the natural vegetation. Wetland declined from a total land area of 154.07 km^2 in 1984 to 23.59 km^{2}in 2015. Wetland area receded at an annual average rate of 4.08 km^2 during this period. This is attributable to wetland being converted to built-up area as there is need for accommodation for the teeming population in the basin. Figure 3 shows the percentage change in LULC in Osun Drainage Basin between 1984 and 2015. This shows the areal extent's increase or decrease by each LULC in percentages.

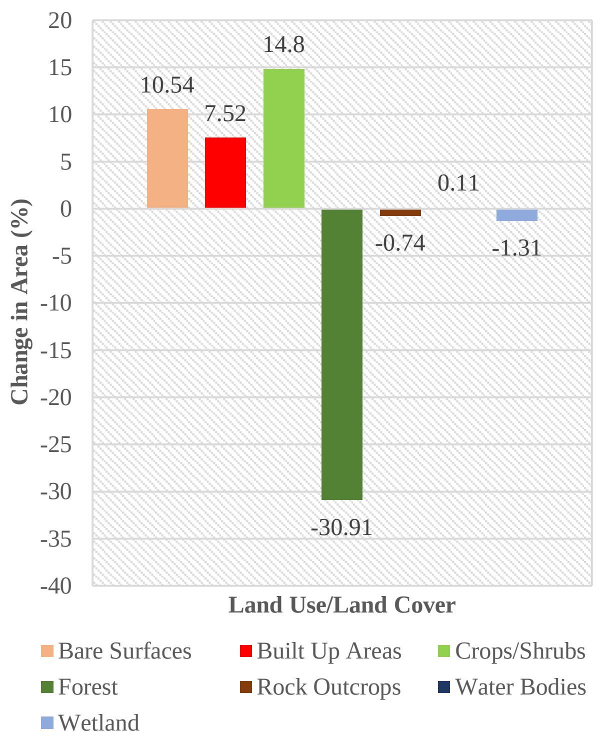

Fig. 3 Percentage change in land use/land cover in Osun Drainage Basin, 1984-2015

The socio-economic characteristics of the people in the study area has significantly influenced the changes in LULC observed. Most communities in Osun drainage basin earn their living through farming, logging and fuel wood production. The issue of climate change is another major cause of the disappearing natural vegetation in addition to the prevailing human activities. The Sudano-sahelian zone has been reported to be advancing southward of latitude 10°N resulting in loss of forest species and arable lands. All these are responsible for the rapidly changing land use and land cover in the Osun drainage basin (Fasona and Omojola, 2005; Mengistu and Salami, 2007). The implications of the changing LULC include increasing incidences of soil erosion, increasing reservoir sedimentation, soil degradation and unfavourable changes in the hydrological regime. Groundwater recharge is influenced by plant cover and land use practices. Hence, the type and nature of land cover can have a significant influence on infiltration, and on groundwater recharge (Jyrkama and Sykes, 2006). Altering the natural land surface as observed in this study will significantly alter the groundwater recharge (Lerner et al. 1990; Lerner 2002) of the drainage basin.

The results of the change detection transition matrix between 1984 and 2015 (Table 4) revealed that:

– about 25% of the area that are bare surface in 1984 has been converted into built-up area, 4.55% are crops/shrubs, 5.06% are rock outcrops, while 65.43% remained unchanged;
– about 32% of forest area in 1984 remained unchanged, while it lost 43.70% and 21.68% to crops/shrubs and bare surfaces, respectively;
– rock outcrops lost 35.12% to bare surfaces, 13.46% to built-up areas and 12.40% of its areal extent to crops/shrubs;
– no significant conversion of water bodies to other LULC class, as it maintained 89.35% of its size; and
– about 66% of wetland was converted to bare surfaces.

The forest area, bare surface and crops/shrubs LULC classes were the most significant land cover transitions during the period of investigation. Hence, spatial analysis was performed on the three classes to evaluate the spatial texture of these changes during the periods 1984 to 2015 (Fig. 4).

Predicted future land use/land cover change in Osun Drainage Basin, 2046

Based on the rate of change between 1984 and 2015, the predicted LULC change revealed that by 2046, bare surface will increase slightly by 188.01 km^2 (Table 5). Thus, bare surface would have increased from 3087.31 km^2 in 2015 to 3275.32 km^2 in 2046. Built-up area would have increased steadily from 1063.91 km^2 in 2015 to 1658.85 km^2 by 2046. This is 55.92% increase. The simulated result shows that the increase in built-up area are closely associated with the existing built-up areas. This will be more pronounced in the northwestern part of the study area, especially in the Oyo State portion of the basin, in and around Ogbomosho. The growth that will be experienced in this area is attributable to population

Table 4 Land use/land cover change transition matrix in Osun Drainage Basin (1984-2015)**.** Figures in the upper rows indicate areas of particular LULC type that remained unchanged (in bold) or converted to other LULC types in Km^2. Figures in italics in the lower rows indicate areas of particular LULC type that remained unchanged (in bold) or converted to other LULC types in percentage

Land use/land cover categories		Land use/land cover 2015 (Km^2)							
		Bare surfaces	Built up areas	Crops/Shrubs	Forest	Rock outcrops	Water bodies	Wetland	Total area
Land use/land cover 1984 (Km^2)	Bare surfaces	**1333.54** ***65.43***	493.53 *24.8*	92.93 *4.55*	15.31 *0.75*	103.37 *5.06*	0.80 *0.04*	1.48 *0.07*	2040.95 *100*
	Built up areas	3.50 *1.10*	**309.96** ***97.58***	3.25 *1.02*	0.00 *0.00*	0.70 *0.22*	0.06 *0.02*	0.17 *0.05*	317.64 *100*
	Crops/Shrubs	343.56 *20.87*	108.61 *6.60*	**667.99** ***40.58***	437.51 *26.58*	81.89 *4.97*	6.42 *0.39*	0.16 *0.01*	1646.14 *100*
	Forest	1132.32 *21.68*	41.22 *0.79*	2282.96 *43.70*	**1649.40** ***31.58***	91.07 *1.74*	7.17 *0.14*	19.48 *0.37*	5223.61 *100*
	Rock outcrops	173.21 *35.13*	66.36 *13.46*	61.14 *12.40*	51.45 *10.44*	**139.67** ***28.33***	0.43 *0.09*	0.78 *0.16*	493.05 *100*
	Water bodies	0.06 *0.12*	0.56 *1.10*	3.84 *7.56*	0.03 *0.07*	0.12 *0.23*	**45.35** **89.35**	0.80 *1.57*	50.76 *100*
	Wetland	101.12 *65.63*	43.68 *28.35*	2.76 *1.79*	1.16 *0.75*	3.28 *2.13*	1.35 0.88	**0.72** ***0.47***	154.07 *100*
	Total Area	3087.31	1063.91	3114.86	2154.87	420.09	61.59	23.59	9926.22

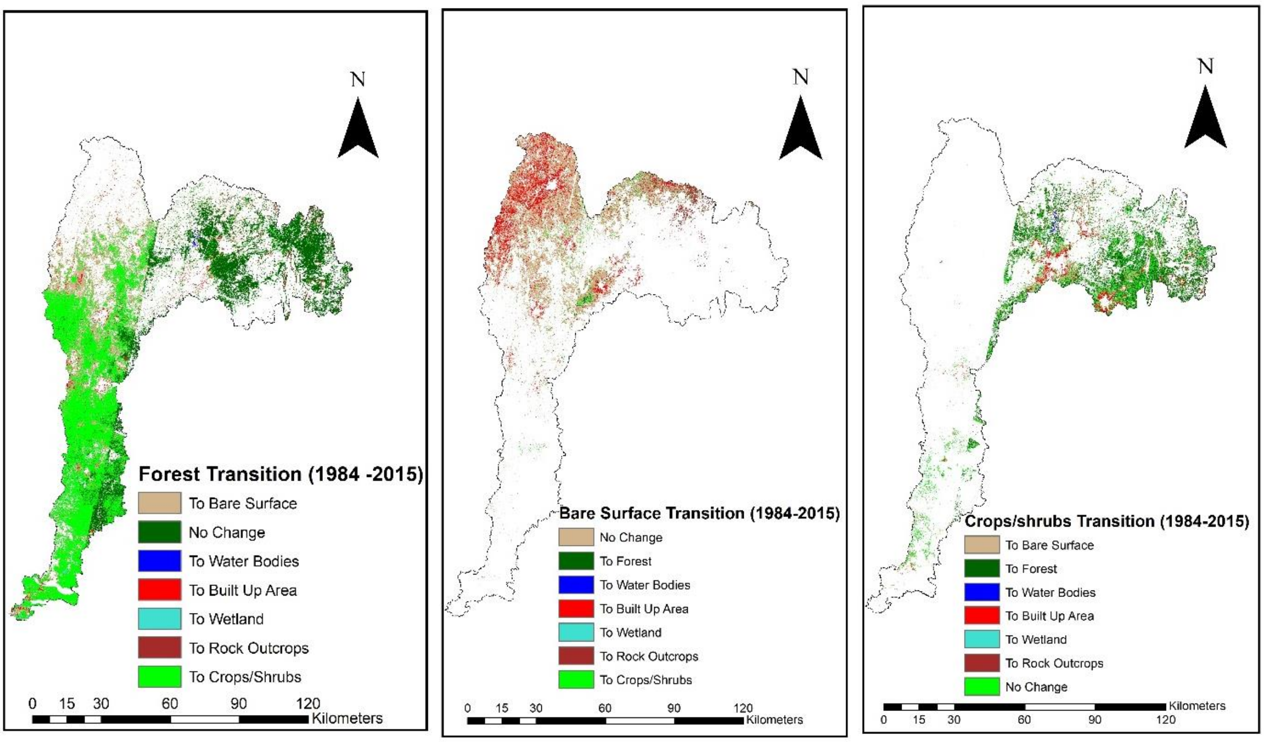

Fig. 4 Transition of forest, bare surface and crops/shrubs to other land classes (1984-2015)

increase, that will lead to the expansion of built-up areas. Also, crops/shrubs LULC class will increase slightly from 3114.86 km^2 in 2015 to 3311.11 km^2 by 2046, which is an increase of 6.30%. This suggest that farming activities in the basin will increase only slightly. There may be further increase, if the effort of the Federal Government of Nigeria to diversify the economy is vigorously pursued.

The future LULC change revealed that between 2015 and 2046, the forest area will continue to decrease. As much as 897.69 km^2 of forest land may be lost to other uses between this period. Thus, it is expected that forest area will decrease from 2154.86 km^2 in 2015 to 1257.18 km^2 by 2046. The 42% reduction in forest area, is worrisome because it reflects the unrelenting activities of wood loggers in the study area. Continuous deforestation of the forest area will certainly have significant impacts on the water budget of the study area, especially groundwater recharge. Based on this study, water bodies LULC will decrease by 2.70%. Wetland which is one of the important groundwater recharge mechanisms in a

Table 5 Predicted land use/land cover change between 2015 and 2046. The signs + and - indicate increase and decrease, respectively

	Land use/land cover types	2015		2046		2015-2046		Average rate of change (2015-2046)	
		Area (Km^2)	%	Area (Km^2)	%	Area (Km^2)	%	Area (Km^2)	%
1	Bare surface	3087.31	31.1	3275.32	33.00	188.01	6.09	5.88	0.19
2	Built up areas	1063.91	10.72	1658.85	16.71	594.94	55.92	18.59	1.75
3	Crops/Shrubs	3114.86	31.38	3311.11	33.36	196.25	6.30	6.13	0.20
4	Forest	2154.87	21.71	1257.18	12.67	-897.69	-41.66	-28.05	-1.30
5	Rock outcrops	420.09	4.23	359.79	3.62	-60.30	-14.35	-1.88	-0.45
6	Water bodies	61.59	0.62	59.93	0.60	-1.66	-2.70	-0.05	-0.08
7	Wetland	23.59	0.24	4.04	0.04	-19.55	-82.87	-0.61	-2.59
Total		9926.22	100	9926.22	100.00				

drainage basin would have decreased in size from 23.59 km^2 in 2015 to mere 4 km^2 by 2046. The predicted 2046, land use and land cover change in Osun drainage basin, Nigeria is presented in Figure 5.

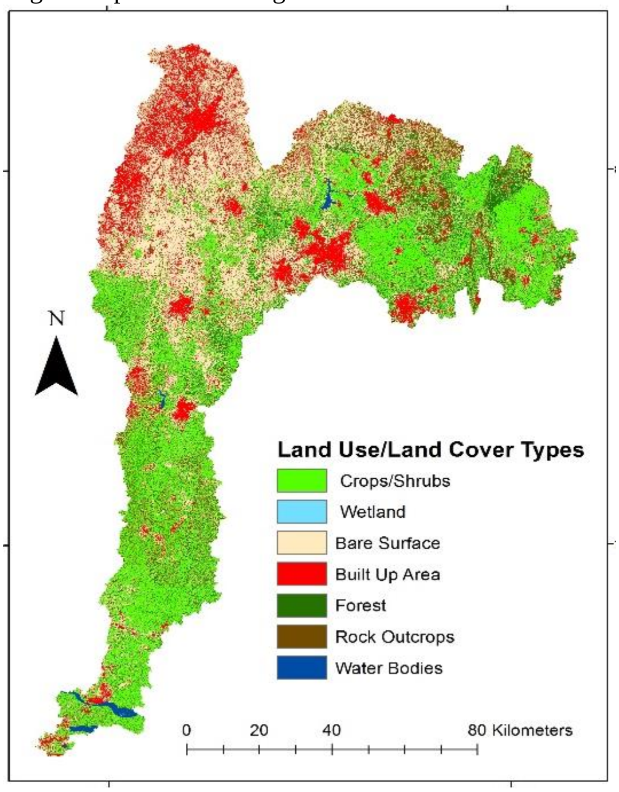

Fig. 5 The predicted, land use and land cover for 2046 in Osun drainage basin, Nigeria

In summary, the change detection transition matrix between 2015 and 2046 (Table 6) indicates that:

- about 16% of the bare surface in 2015 will be converted into built-up area by 2046;
- there will be no significant decrease in built-up areas, rather it will increase from 1063.91 km^{2}to 1658.85 km^2;
- about 34% of wetland would have been converted to built-up area;
- significant areal extent of about 1349 km^2 of forest will be converted to crops/shrubs; and
- water bodies will remain about 96.61% of its size in 2015 by 2046.

CONCLUSION

In conclusion, land use/land cover change for the period 1984-2015 were examined based on the data generated from satellite imageries. LULC change transition matrix was computed with a view to determining the percentage change of one land class to another during the period of study. Also, the future LULC change was simulated for the year 2046, to understand the level and direction of change that might be experienced in the future in Osun drainage basin. The LULC change in the basin revealed that built-up area increased by about 235% between 1984 to 2015. Forest area declined by 59% and crops/shrubs increased with about 89%, during the same period. The rate of change of LULC in the Osun drainage basin may not be unconnected to population increase and settlement expansion with their accompanying anthropogenic activities which include fuel wood extraction, wood logging, and sand mining, etc. All these anthropogenic activities resulted into the loss of the original rainforest in the basin. The land use/land cover change scenario in Osun drainage basin will influence the water budget and hydrology of the study area, with the probability of changing the rate of interception, evapotransipiration, runoff and groundwater recharge in the basin. In fact, the predicted future LULC change suggests that only about 12% of the basin will remain under forest cover by the year 2046. The results have underscored the increasing human occupation and the high rates of conversion of the natural vegetation into other land use classes. The rate at which forest cover declined in Osun drainage basin unabated is a pointer to the fact that even after the United Nations Millennium Development Goal (MDG) terminated in 2015, one of her goals to ensure environmental sustainability by reversing the loss of forests in all regions of the world was not met in Sub-Saharan Africa and Nigeria in particular. It is paramount that the rate of deforestation and unregulated land use in the larger part of the basin be discouraged for a sustainable drainage ecosystem. In addition, the planting of the lost native trees should be encouraged for the sustainability of the basin's ecosystem.

Table 6 Land Use/Cover Change Transition Matrix in Osun Drainage Basin (2015-2046) Figures in the upper rows indicate areas of particular LULC type that remained unchanged (in bold) or lost to other LULC types in Km2. Figures in italics in the lower rows indicate areas of particular LULC type that remained unchanged (in bold) or lost to other LULC types in percentag*e*

	Land use/cover categories	Predicted land use/land cover 2046 (Km^2)							
		Bare surfaces	Built up areas	Crops/Shrubs	Forest	Rock outcrops	Water bodies	Wetland	Total Area
Land use/land cover 2015 (km^2)	Bare surfaces	**2493.64**	495.55	24.56	22.90	50.49	0.10	0.06	3087.31
		80.77	*16.05*	0.80	*0.74*	*1.64*	*0.00*	*0.00*	*100*
	Built up areas	77.26	**968.01**	12.00	5.22	1.20	0.16	0.06	1063.91
		7.26	***90.99***	*1.13*	*0.49*	*0.11*	*0.02*	*0.01*	*100*
	Crops/Shrubs	352.85	107.96	**1911.06**	661.13	81.57	0.00	0.30	3114.86
		11.33	3.*47*	**61.*35***	*21.23*	2.*62*	*0.00*	*0.01*	*100*
	Forest	297.69	24.19	1348.98	**544.63**	27.99	0.03	1.37	2154.87
		9.64	*1.12*	*62.60*	**25.27**	*1.30*	*0.00*	*0.06*	*100*
	Rock outcrops	130.31	55.02	13.49	22.80	**198.34**	0.12	0.00	420.09
		31.02	*13.10*	*3.21*	5.*43*	***47.21***	*0.03*	*0.00*	*100*
	Water bodies	0.75	0.16	0.74	0.09	0.07	**45.35**	0.80	61.59
		1.*22*	0.*26*	*1.21*	*0.15*	*0.11*	**96.61**	*0.45*	*100*
	Wetland	12.82	7.95	0.28	0.41	0.14	0.01	**1.98**	23.59
		54.35	*33.69*	*1.20*	*1.74*	0.*60*	0.03	**8.*39***	*100*
	Total Area	3275.32	1658.85	3311.11	1257.18	359.79	59.93	4.04	9926.22

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