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Research Article

Geospatial analysis-based approach for assessing urban forests under the influence of different human settlement extents in Ibadan city, Nigeria

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Abstract

Urban forests are an essential component of urban areas as they provide many environmental and social services that contribute to the quality of life in cities. Urban forests in most cities of Nigeria are gradually becoming bitty as a result of urbanization activities, thereby posing adverse effects. In this study, we assessed the changes in the urban forests cover under the influence of different human settlement (HS) extents across the urban area of Ibadan city using remotely sensed data. The pattern of change(s) in the urban forests cover over 20 years were examined by analysing and manipulating Landsat and Sentinel-2 datasets using Google Earth Engine, ArcGIS 10.1, and Erdas 2014 software. The extents of human settlement (for the year 2000, 2005, 2010, 2015, and 2020) were extracted (from Landsat datasets), analysed, and mapped to evaluate the status of the urban forests cover under different human settlement extents. The result reveals a substantial land cover changes within the urban area of Ibadan. The urban forest cover decreased from 24.14% to 7.99%. Also, there is a significant decrease in the urban forests cover as a result of a substantial increase in human settlement extent (102,806 to 122,572 pixels). The study provides an opportunity to map the status of urban forest cover and extents of HS in a developing city using remotely sensed data and applications of GIS tools.

Keywords: GIS; human settlement; remote sensing; remotely sensed data; urban forests

Introduction

Urban forests are ecosystems characterized by the presence of trees and other vegetation in association with the people and their developments (Nowak *et al.*, 2001; Adelusi *et al.*, 2002). They are also considered as the sum of all woody and associated vegetation in and around dense human settlements from small communities to large metropolitan cities (Gann, 2003). According to Clark *et al.* (1997), a sustainable urban forest is defined as the naturally occurring and planted trees in cities, managed to provide the inhabitants with a continuing level of economic, social, environmental, and ecological benefits today and into the future. Comprehensively, urban forests are viewed as trees on the land that fulfil the requirements of forest and other wooded lands except that the area is less than 0.5 ha (Larinde, 2010).

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Urban forest significantly influences the sustainability and environmental quality of a city. A large, healthy urban forest can increase local urban air quality and mitigate carbon dioxide emissions (McPherson and Rowntree, 2016; Nowak *et al.*, 2007); decrease temperature elevated by the urban heat island (UHI) effect and decrease associated energy costs (McPherson and Simpson, 2001); increase city walkability (Wolf, 2008); provide stormwater retention services including decreased peak flow and increased water quality (McPherson, 2006); contribute to economic prosperity through increased job opportunities and increased retail sales in urban areas with trees (Wolf, 2005a, 2005b); as well as many other benefits that increase the overall quality of the urban environment and the quality of life for urban residents (McPherson, 2006).

Recently, urban forests within Ibadan city are gradually becoming more fragmented due to urbanization causing ripple effects such as the expansion of human settlement, increased infrastructural development, change in the city's landscape pattern, and design. The impact of their continuing disappearance is manifested through increased UHI effect, changes in microclimate, and rainfall pattern. Also, the city lacks proper and comprehensive knowledge of the status and performance of its urban forests thereby making it difficult to preserve and enhance it. Therefore, there is a need for an evaluation of these urban forests. We assess here the changes in the landscape pattern occurring over assessment years as it relates to the extents of human settlement.

Assessment of changes in the landscape pattern using remotely sensed data and geographic information system (GIS) help to depict, quantify, and map, among other factors, the change in landform (on a large scale) from permeable to impermeable surfaces with urban development (Booth *et al.*, 1989; Booth, 1990; Masek *et al.*, 2000; Klemas, 2001; Hayden, 2004; Lunetta *et al.*, 2004; Kulash, 2009; Tan *et al.*, 2010; Banai and DePriest, 2014; Chen and Guinness, 2014; Kumar *et al.*, 2019; Savita *et al.*, 2019). Urban forest managers and city planners require this information to direct future patterns of growth and green space development and also to prepare an effective and efficient urban forest management plan.

How degraded are these urban forests as a result of urbanization (in terms of human settlement extent) pressure is one of the key questions for forest policymakers and city planners? To address this question, here we assess the impact of the trend in human settlement spatial extent on urban forests cover across the urban area of Ibadan city in the south-west region of Nigeria using remotely sensed data. We focused more on the exploitation of Landsat data potentials in assessing urban forest cover and also in extracting consistent human settlement extent layers at a 30m spatial posting and time series. The specific objectives of the study are to (1) delineate and classify the urban forests using Landsat and Sentinel datasets to understand the pattern of change over 20 years (at an interval of 5 years) and; (2) extract human settlement extent from Landsat data (at an interval of 5 years, for 20 years) and evaluate the status of the urban forests under different human settlement extents.

Materials and Methods

Study area

The study was conducted in the urban area of Ibadan city, an ancient city of the Nigerian western region that has witnessed rapid urbanization in the recent past era. Ibadan is the capital city of Oyo state in Nigeria having it extent between latitude 7° 2' N - 7° 44' N and longitudes longitude 3° 30' E - 4° 9' E (Figure 1). It is located at a distance of about 120 km East of the border with the Republic of Benin in the forest zone, close to the boundary between the forest and the Savanna. The city is naturally drained by four rivers (Ona river, Ogbere river, Kudeti river, and Ogunpa river) with many tributaries: It covers an area of 3,080 sq. km.

The elevation of the city ranges from 150 m - 275 m above sea level. The climate of the city is a tropical wet and dry climate with a lengthy wet season and relatively constant temperatures throughout the year. The wet season runs from March through October, though August seems somewhat of a lull in precipitation, while November to February forms the city's dry season, during which it experiences the typical West African harmattan. It receives a mean total rainfall of 1420.06 mm, falling in approximately 109 days. There are two peaks for rainfall, June and September. The mean minimum and maximum temperatures are 21.42 °C and 26.46 °C, while the relative humidity is 74.55%.

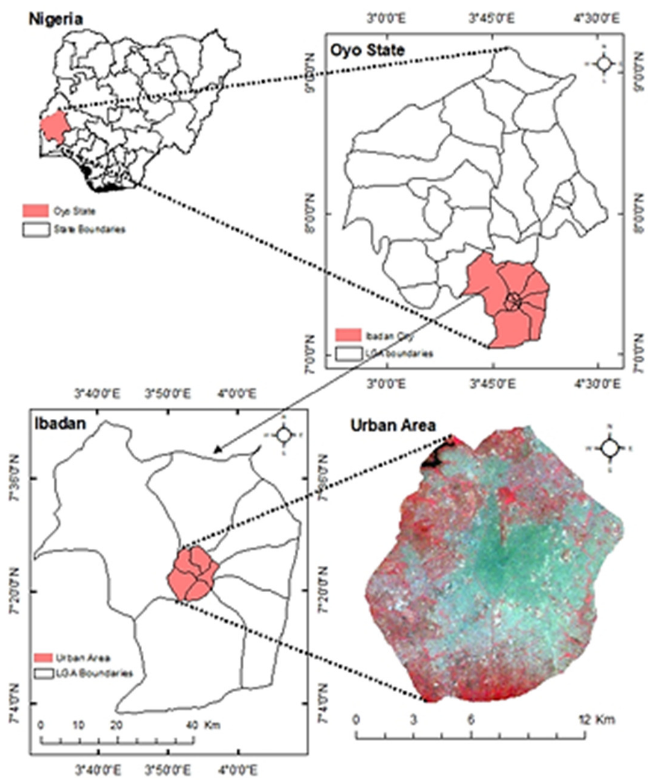

Figure 1. Location map of the study area, Urban area of Ibadan (showing a satellite image) in Oyo State, Nigeria

Geologically, the study area lies within the basement complex rocks of metamorphic origin of the Precambrian age (Figure 2). The rocks are divided into two groups; quartzite of the meta-sedimentary series and the migmatite complex consisting of banded gneiss, augen gneiss and magnetite; and other ones include pegmatite, quartz, aplite, diorite, amphibolites and zenoliths (Amanambu, 2015). The rock types are a major factor controlling the characteristics of the groundwater resource in the study area. Basement complex rocks (consisting of metamorphic and igneous rock types) are fairly low in groundwater yield when compared with sedimentary rock areas to the south

lbadan urban area (Figure 3) had four forest reserves (Popoola and Ajewole, 2001). Alalubosa forest reserve (constituted in 1916), a land area of 308.53 ha destroyed and converted to residential quarters and 'Aiesinloye' market. On the other hand, Oke Aremo reserve (constituted in 1935) with a total land area of 57.67 ha, also de-reserved with greater part ceded for the development of the new King's (Olubadan) palace and associated projects. Ogunpa dam forest reserve (constituted in 1931, but later declared a game reserve in 1952) over an area of 81.27 ha, also destroyed and larger portion of it has given way for the construction of the cultural center, Premier hotel, and public schools. Eleyele forest reserve (acquired in 1941 and formally constituted a reserve in 1956) with an area of 325.2 ha, is gradually been converted into a residential area.

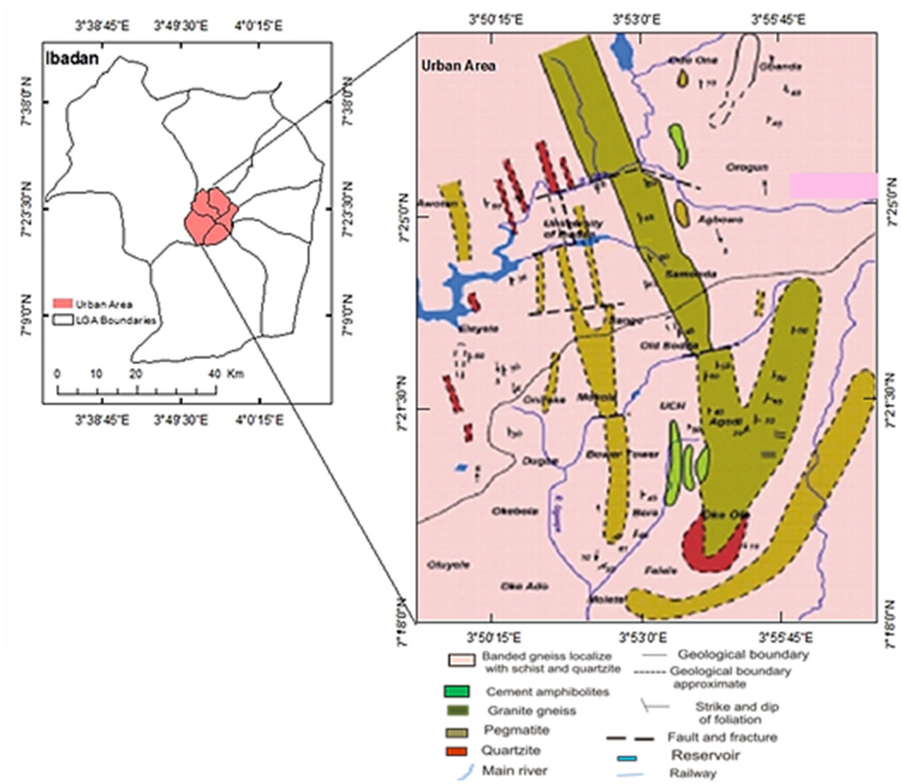

Figure 2. Geological map of the urban area of Ibadan (After Amanambu, 2015)

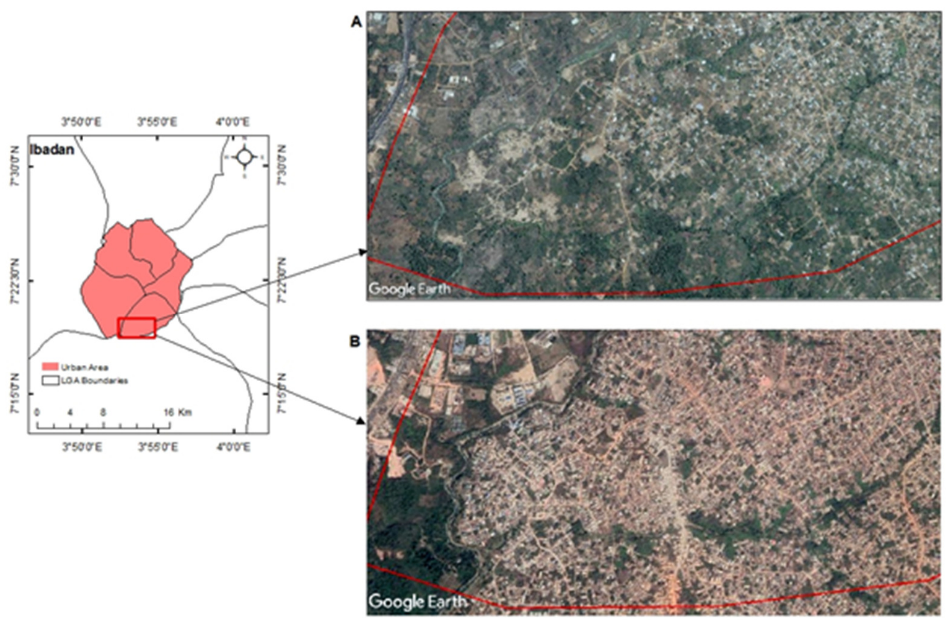

Figure 3. Map of urban area of Ibadan (showing a satellite image covering Challenge/Olomi Area), Nigeria: (a) year 2000; (b) year 2020

Data source and analytical tools used

In this study, remotely sensed data (satellite images) were primarily used. Multispectral satellites (Landsat-5, 7 & 8, and Sentinel-2) datasets were extracted using Google Earth Engine (GEE). The GEE (*https://earthengine.google.com/*) provides planetary-scale geospatial analysis through large scale cloud computing to extract various archived geospatial layers to perform scientific analysis (Gorelick *et al.*, 2017; olokeogun and Kumar 2020). The manipulation, processing, and handling of the remotely sensed data involved the use of GEE, ArcGIS and ERDAS EMAGINE software as shown in Figure 4.

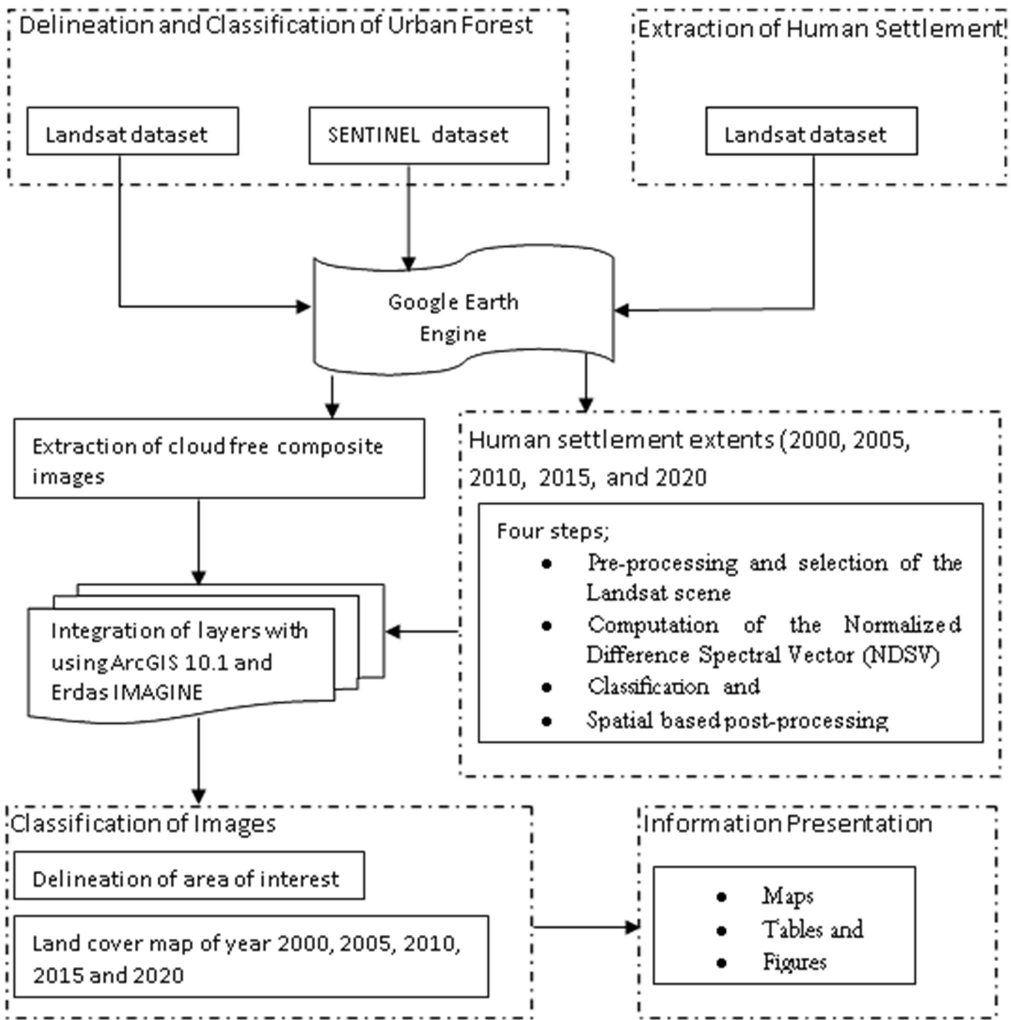

Figure 4. Schematic representation of steps involved in the study

Delineation and classification of the urban forest using remotely sensed images

The GEE was used for creating a cloud-free composite image for five time periods (2000, 2005, 2010, 2015, and 2020) by utilizes imagery from Landsat-7, Landsat-8, and Sentinel-2 datasets. Methodology, as suggested by Zhu *et al.* (2015) was adopted for the extraction of composite images in an automated manner that incorporates a sophisticated cloud and shadow masking algorithm; an algorithm based on the spectral and thermal properties of clouds. It finds pixels that are bright and cold but do not share the spectral properties of snow. Further description can be referred to in the work done by Huang *et al.* (2010), Goodwin *et al.* (2013), Housman *et al.* (2015), and Tsai *et al.* (2018).

The script for obtaining cloud-free image composite for the period 2000, 2005, 2015, and 2020 was implemented in GEE. The images were saved in Google drive and later downloaded from the drive for its manipulation and handling in ArcGIS and ERDAS EMAGINE software. The boundary indicating the extent of the study area was extracted from an existing topographic map sheet covering the area using ArcGIS software. Furthermore, the downloaded images were imported into ArcGIS software and utilized with the extracted boundary to define the area of interest (AOI) for each period.

The images of the defined AOI for each period were used to develop land cover maps for the years 2000, 2010, 2015, and 2020 in ERDAS software using supervised classification with the Maximum Likelihood Classifier. Dominant categories of land cover, viz., Built-up area, urban forest, water bodies, and open space were mapped (Table 1). A change matrix to see categorical changes of one land cover type in 2000 to another cover type in the years 2005, 2010, 2015, and 2020 was done using ERDAS. This thus provides an estimate of proportionate land cover changes from one category to another for five (5) years.

Table 1. Land cover classification scheme and their general description

Classes	Description
Built-up area	Residential, commercial, industrial, facilities and settlement
Urban forest	Evergreen forest and mixed forests with a higher density of trees; including mangrove, sparse vegetation, etc. and all types of crops.
Water bodies	Areas covered by water such as rivers, ponds, lagoons, dams, and waterlogged areas.
Open space	Open land and non-vegetated land

Extraction of human settlement extent using remotely sensed images

The human settlement (HS) extent for each period (2000, 2005, 2010, 2015, and 2020) were extracted from Landsat data using GEE based on a processing chain referred to as spectral-based analysis (coupled with a spatial regularization) as suggested by Trianni *et al.* (2014). The approach for the extraction requires spatial and spectral processing. The processing chain consists of four steps; pre-processing and selection of the Landsat scene, computation of the Normalized Difference Spectral Vector (NDSV), classification, and spatial based post-processing. The graphical representation of the steps regarding the processing chain can be found in Figure 4.

Landsat 7 scene (for 2000, 2005, 2010) and Landsat 8 scene (for 2015 and 2020) were selected and scripts for creating variable representing a single image (for each scene) and for obtaining cloud-free images were implemented in GEE. The NDSV was used to detect urban area pixels from the obtained cloud-free images. Urban areas exhibit an NDSV spectral signature that is flat across all bands. Support Vector Machine (SVM) classifier was then utilized to characterize the HS. SVM classifier is a non-parametric classifier developed for hyperspectral data and able to manage high-dimensional spaces. Also, morphological operators aimed at getting rid of isolated pixels and at improving the homogeneity of the extracted settlements concerning their spatial distribution was applied as a post-processing step. Furthermore, the images of the extracted HS extent were exported and downloaded from Google drive for its manipulation and handling in ArcGIS software. The AOI shapefile and the downloaded images were used to define the extent of HS (for the year 2000, 2005, 2010, 2015, and 2020) within the study area. In addition, to further reveal the relationship between urban forest pattern of change and extent of HS pattern of change, the percentage change of urban forest and extent of HS in 2000-2005, 2005-2010, 2010-2015, and 2015-2020 were calculated.

Results

Land cover pattern between 2000 and 2020

The land cover (of the urban area of Ibadan city) mapped for the corresponding years of 2000, 2005, 2010, 2015, and 2020 is presented in Figure 5. Four prevailing categories of land cover identified in the study area are water bodies, built-up area, urban forest, and open space. A substantial change in the alteration of one land cover category into another was observed during the comparison years. The water bodies, urban forest, and open space classes noticeably decreased from 0.31% to 0.01%, 24.13% to 7.99%, and 14.14% to 7.86% respectively while the built-up area class increased significantly from 61.42% to 84.14%. The distribution of land cover within the urban area of Ibadan city during the years 2000, 2005, 2010, 2015, and 2020 is depicted in Table 2.

Water Bodies with the lowest land cover (0.31%) in year 2000, decreased to 0.22%, 0.18%, 0.13%. 0.01% in the year 2005, 2010, 2015 and 2020 respectively. Built-up area with the largest land cover (61.42%) in the year 2000, decreased to 53.51% in the year 2005, then increased to 67.71%, 74.32%, and 84.14% in the year 2010, 2015 and 2020 respectively. Furthermore, Urban forest with 24.13% land cover in the year 2000, decreased to 23.67% in the year 2005 but increased to 27.34% in the year 2010, and then decreased to 18.46% and 7.99% in the year 2015 and 2020 respectively, while Open Space with 14.14% land cover in the year 2000, increased to 22.61% in the year 2005, but decreased drastically to 4.77% in the year 2010, and then increased to 7.09% and 7.86% in the year 2015 and 2020 respectively.

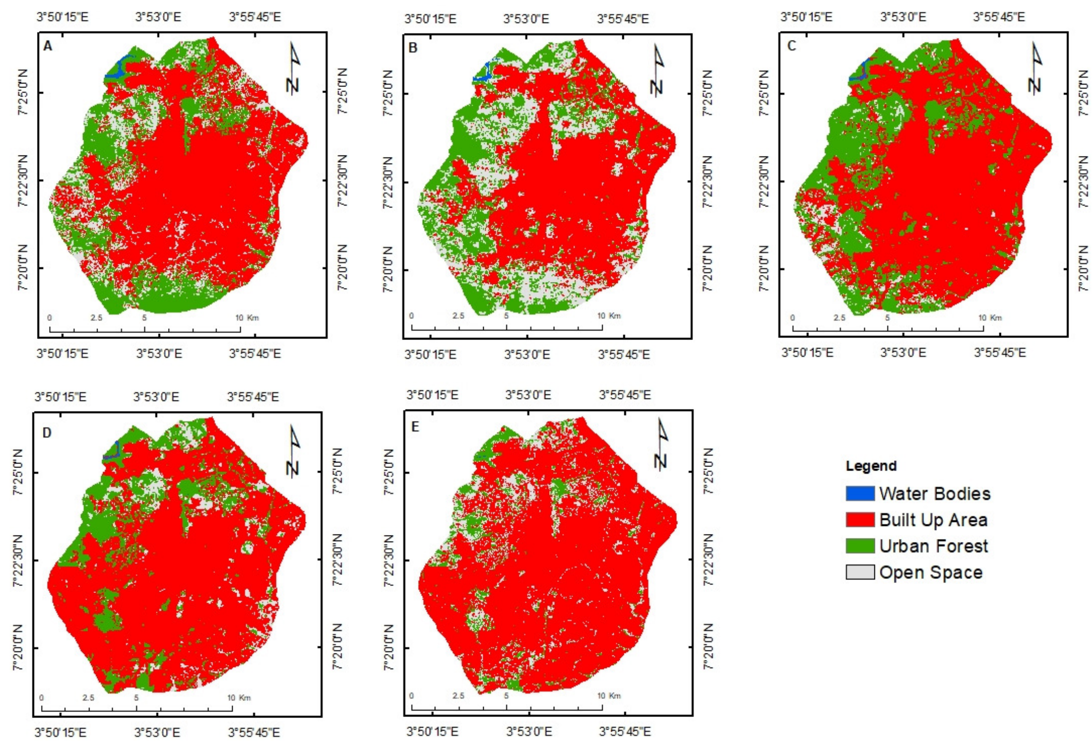

Figure 5. The land cover map of the urban area of Ibadan city, Nigeria: (a) year 2000; (b) year 2005; (c) year 2010 (d) year 2015 (e) year 2020

Table 2. Land cover distribution of the urban area of Ibadan during the year 2000, 2005, 2010, 2015, and 2020

Land cover class	2000		2005		2010		2015		2020		Percentage change
	A (Km^2)	P (%)	A (Km^2)	P (%)	A (Km^2)	P (%)	A (Km^2)	P (%)	A (Km^2)	P (%)	(2000-2020)
Water bodies	0.46	0.31	0.29	0.22	0.25	0.18	0.18	0.13	0.02	0.01	- 95.65
Built up area	77.83	61.42	72.75	53.51	92.06	67.71	101.04	74.32	114.4	84.14	+ 46.99
Urban forest	36.36	24.13	32.18	23.67	37.17	27.34	25.1	18.46	10.86	7.99	- 70.13
Open space	21.31	14.14	30.74	22.61	6.48	4.77	9.64	7.09	10.68	7.86	- 49.88
Total	135.96	100	135.96	100	135.96	100	135.96	100	135.96	100	

Note: Area (A) and Percentage (P)

Evaluation of urban forests cover under different human settlement extent between 2000 and 2020

The extent of HS within the urban area of Ibadan city generated for the corresponding years of 2000, 2005, 2010, 2015, and 2020 is presented in Figure 6. A significant increase in the extent was detected during the comparison years. The extent of HS during the years 2000, 2005, 2010, 2015, and 2020 with their corresponding urban forest cover for the urban area of Ibadan is presented in Table 3. The urban area of Ibadan had 24.14% urban forest cover under 102,806 pixels of HS extent in the year 2000, 23.67% urban forest cover under 80,833 pixels of HS extent in the year 2005, 27.34% urban forest cover under 102,290 pixels of HS extent in the year 2010, 18.46% urban forest cover under 112,271 pixels of HS extent in the year 2015, and 7.99% urban forest cover under 122,572 pixels of HS extent in the year 2020.

The pattern of change between urban forest cover and extent of HS at 5 years interval (2000–2005, 2005-2010, 2010-2015, and 2015-2020) for the urban area of Ibadan is presented in Figure 7. The pattern of changes in the urban forest and the extent of HS are both positive and negative. From 2000 to 2005, the negative change accounted for 1.91% and 21.37% in urban forest and extent of HS respectively; from 2005 to 2010, the positive change accounted for 15.50% and 26.54% in urban forest and extent of HS respectively; form 2010 to 2015, the negative change accounted for 32.48% (in the urban forest) while the positive change accounted for 9.76% (in the extent of HS); and from 2015 to 2020, the negative change accounted for 56.72% (in the urban forest) while the positive change accounted for 9.18% (in the extent of HS).

Table 3. Urban forest and human settlement extent for the urban area of Ibadan during the year 2000, 2005, 2010, 2015, and 2020

Time period (Year)	Urban forest (%)	Human settlement extent (No of pixels)
2000	24.13	102806
2005	23.67	80833
2010	27.34	102290
2015	18.46	112271
2020	7.99	122572

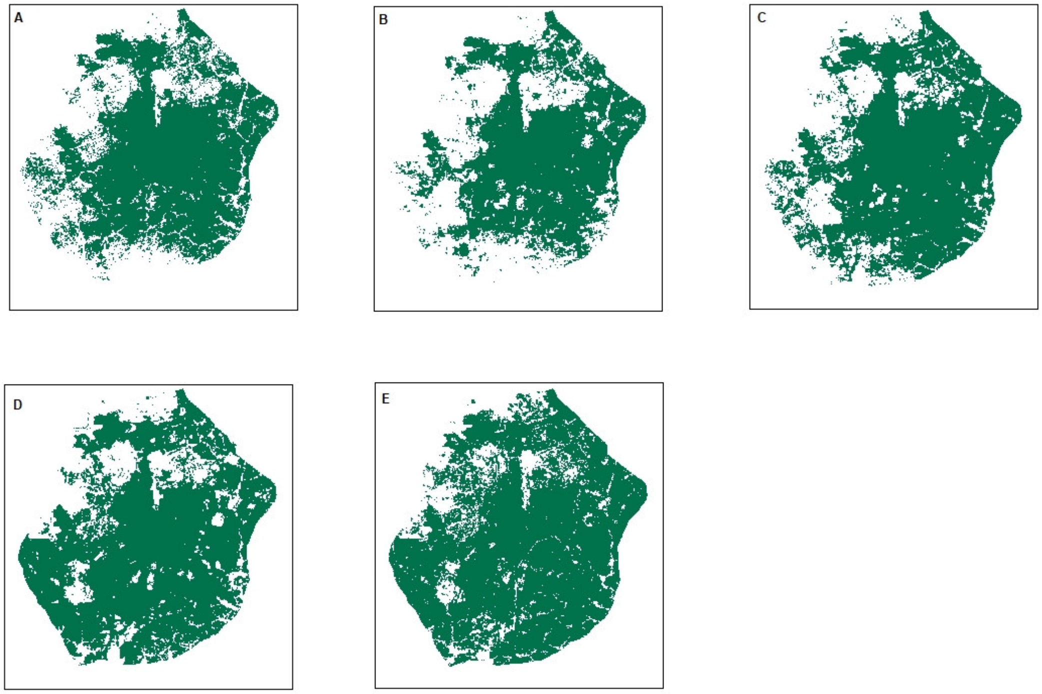

Figure 6. Reference GIS layer of human settlement extent extracted for the urban area of Ibadan city, Nigeria: (a) year 2000; (b) year 2005; (c) year 2010 (d) year 2015 (e) year 2020

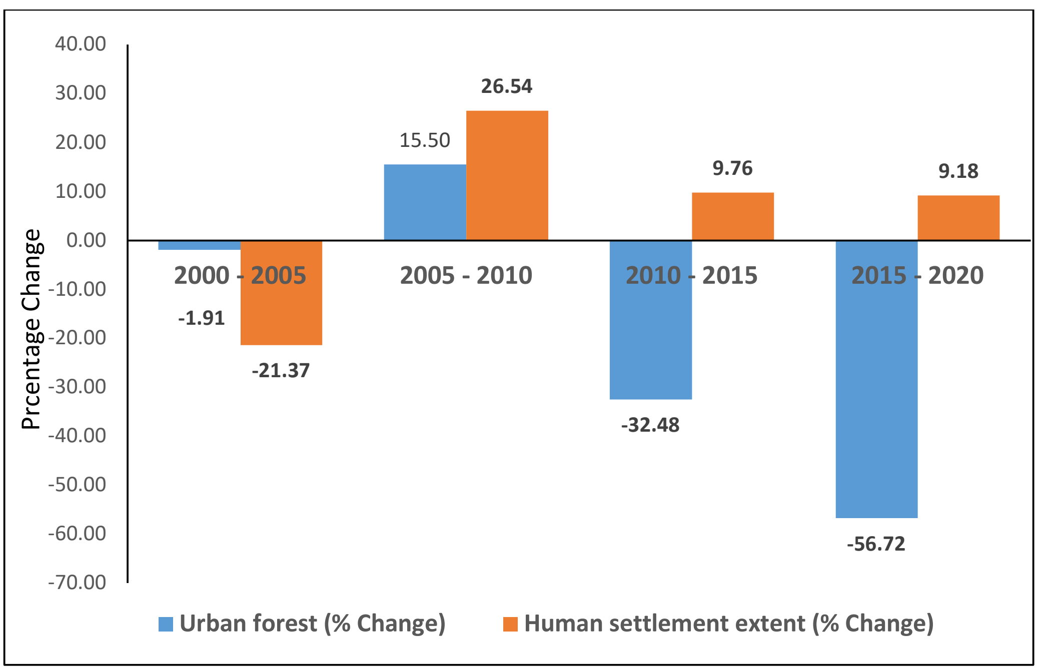

Figure 7. Pattern of change (in percentage) between urban forest and human settlement extent at 5 years interval for the urban area of Ibadan

Discussion

The results revealed the past and current land cover patterns of the urban area of Ibadan city, HS extents, and urban forests cover under the influence of different HS extent. The water bodies, urban forest, and open space classes decreased while the built-up area class increased over twenty years. This implies a substantial redistribution of the landscape pattern. As reported by Asmat *et al.* (2012), and Noor and Rosni, (2013), a developing/growing city is usually characterized by a continuous restructuring of landscape pattern. The built-up area class decrease from 61.42% to 53.51% between the year 2000 and 2005, but later continued to increase till the year 2020 with 84.14% (Table 2). The decrease between the years 2000 and 2005 is traceable to urban restructuring embarked upon by the then Oyo State government between the years 2004 and 2006 as reported by Akingbogun *et al.* (2012). Also, the changes can be largely attributed to anthropogenic activities such as urbanization activities (urban development and human settlement expansion, including road constructions, demolition, and construction of residential/non-residential buildings) and unstable government policy. According to Asmat *et al.* (2012), and Banai and DePriest, (2014), indicators of urbanization include not only the following, human settlement, land development, population, mix of residential and commercial land use, and multi-modal mobility options.

Furthermore, urban forest class decreased from 24.13% to 23.67% between the years 2000 and 2005, increased to 27.34% in the year 2010, and then continued to decrease to 18.46% and 7.99% in the year 2015 and 2020 respectively (Table 2). The decrease between the year 2000 and 2005 implies the occurrence of forest destruction, which affirm the report of Popoola and Ajewole (2001), and Agbola *et al.* (2012) concerning the trends of urban forest deforestation and its consequences in Ibadan. The increase witnessed in the year 2010 can be linked to the impact of the afforestation program implemented within the city in the year 2006, as reported by Akingbogun *et al.* (2012). The observed continued decrease in the year 2015 and 2020, indicates major loss which could be attributed to rapid urbanization which has led to a massive conversion of vegetation/forested area to residential and non-residential areas. Several studies reported that swift urbanization has momentous impact causing many unforeseen consequences including loss of natural resources (such as forests), loss of prime farmland, increased environmental pollution, and many other physical, social and economic effect (Burchell and Shad, 1999; Sierra, 2001; Adelusi *et al.*, 2002; Hasse and Lathrop, 2003; Noor and Rosni, 2013). Also, the decrease might have a great adverse influence on the quality of life within the city as reported by Popoola and Ajewole (2001). According to Kuchelmeister (2000), the conversion of forests and farmland for urban development can reduce water-permeable areas, upset natural drainage patterns, and cause serious flooding.

Also, HS extent increased from 102,806 to 122,572 pixels between the years 2000 and 2020 (Table 3). This suggests that the urban area of Ibadan city experienced urban expansion pointing to urbanization. Several studies agreed that urban expansion is an important indicator of urbanization (Nasser and Paul, 2001; Yeh and Xia, 2001; Weng, 2002; Sudhira *et al.*, 2003; Jain, 2008; Ibrahim *et al.*, 2009; Kulash, 2009; Li, 2009; Mohd Noor *et al.*, 2012;). Also, the urban forest cover was 24.14% under 102,806 pixels of HS extent in the year 2000, urban forest cover and HS extent decreased in the year 2005, both increased in the year 2010, however, in the year 2015 and 2020, urban forest cover decreased while HS extent increased (Table 3).

Conclusions

This research focused on examining the status of urban forests under the influence of different HS extents within the urban area of Ibadan city. The findings revealed considerable changes in landscape patterns within the urban area of Ibadan city for over twenty years (2000 - 2020). Furthermore, there is a significant decrease in the urban forests cover as a result of a substantial increase in HS extent. The study demonstrates the successful application of remote sensing and GIS tools for the acquisition of relevant information that can be used for mapping the status of urban forests cover and extents of HS within cities. The mapping is therefore important for proper, effective, and efficient landscape management. The study would be useful for urban forest managers and city planners who are involved in urban growth and green space development.

Authors' Contributions

Conceptualization: OS and AO; Data curation: OS; Formal analysis: OS; Investigation: OS, AO, and OO; Methodology: OS and AO; Project administration: AO and OO; Resources: OS, AO, and OO; 12

Software: OS; Supervision: AO and OO; Validation: OS, AO, and OO; Visualization: OS, AO, and OO; Writing - original draft: OS; Writing - review and editing: OS, AO, and OO. All authors read and approved the final manuscript.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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