

Modeling the Relationship between the Land Use/Land Cover Change and Land Surface Temperature in Ibadan, Oyo State, Nigeria

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Abstract

This study was designed to model the spatio-temporal pattern of Land Use/Land Cover (LU/LC) indices and its relationship with Land Surface Temperature (LST) in Ibadan Metropolis from 1988 to 2018. Four Landsat images of Ibadan metropolis for 1988, 1999, 2013 and 2018 were used in this study. Land surface temperature values of vegetation, open surfaces and built-up Land Use/Land Cover (LU/LC) analysis was carried out using ERDAS IMAGINE 9.2 in order to ascertain the areas covered by each land use type. The results of the study revealed that as the size of Built-up land use type increases and the size of the vegetation land use type decreases, the value of land surface temperature increases in relation to the increase in the size of built-up land use type and the decrease in the size of vegetation land use type from 1988 to 2018 in Ibadan Metropolis. This study can be useful in designing Urban Green Belts (UGB) and parks within the metropolis in order to mitigate problem of urban thermal discomfort in Ibadan, the state capital of Oyo State, Nigeria.

1. Introduction

Vegetation are good measure of the health and quality of our environment, they provide social, economic and ecological benefits. Their beauty inspires writers and artists while their leaves and roots clean the air we breathe and water we drink among other things ^[2]. The greater the vegetation cover and the less the impervious surfaces, the more ecosystem services are produced in terms of reducing storm, water runoff, increasing air and water qualities, storing and sequestering atmospheric carbon and reducing land surface temperature ^[3]. A situation where the vegetation were being cleared off and being replaced by concrete surfaces, asphalt roads and building, the resultant effect is environmental degradation such as abnormal increase in land surface temperature causing thermal discomfort ^[19]. Several published works have established the link between the urban land surface materials and the urban temperature characteristics. For example, ^[5] reported that land surface temperature was highest in urban residential areas where there were low vegetative covers while the lowest land surface temperature occurred in farmlands where there were high vegetative covers. According to ^[23], settlement growth reduces vegetative cover, thus, adds heat absorbing surfaces such as rooftops, asphalts and other concrete surfaces. Besides, greenhouse gases emissions from industries and automobile systems make the land surface temperature in residential and industrial land uses higher than that of vegetation and agricultural land uses ^[5]. Studies have reported that vegetation provide shade which helps lower land surface temperature, they also release water to air through evapotranspiration processes which helps in the cooling system ^{[3],[13]} and ^[27]. Land surface temperature can be reduced even when there is settlement growth through planting of trees, because trees have cooling effects on the environment. Over the past three decades, Ibadan, the State Capital Metropolis of Oyo State in South-Western Nigeria is experiencing conversion of vegetation and agricultural land uses to residential, transportation and industrial land uses due to explosive population growth, industrialization etc, thus, resulting in changes in the land surface temperature. We therefore set out to investigate the relevance of tree planting and the creation of many urban green belts in Ibadan in order to reduce the problem of thermal discomfort in the Metropolis.

Land Surface Temperature (LST) is the temperature of the skin surface of a land. It is the surface radiometric temperature emitted by the land surfaces which can be derived from satellite information or direct measurement and observed by a sensor at instant viewing angle ^[21] Cited in ^[20]. Land Surface Temperature (LST) is an important parameter in urban climatology; it can be derived from data sources such as Landsat. The thermal band of these sensors enables data collection on thermal properties of the land surface based on the amount of emitted energy. These data can be used to monitor land use/land cover change and land surface temperature over time ^[10]. In this way, modeling the relationship between land use/land cover change and land surface temperature becomes possible.

1.1. The History of Settlement Growth in Ibadan

Ibadan, historically acknowledged as the largest traditional city in West Africa, has grown rapidly from a modest population of 70,000 inhabitants in 1856 to a cosmopolitan and densely populated city. The rapid development and spatial expansion of the city became pronounced during the period of Nigeria's oil boom in the 1970s ^[12].

The Open Surfaces with natural land cover surrounding houses in the traditional core areas were change to built-up artificial land cover to provide more dwelling houses within the traditional family compounds as family units grew larger ^[6]. Over the years, the inner core of the city grew by the process of densification which resulted into the emergence of informal settlements ^[16].

Land Use/Land Cover Changes in Ibadan became more rapid when it was made the headquarters of the defunct Western Region of Nigeria in 1946. It became a major Centre for attraction of many more expatriates and other Yoruba sub-ethnic groups due to the increasing range of job opportunities that abound in the Metropolis. Consequently, more residential areas were needed to accommodate the teeming inflow of people and the settlement began to grow rapidly ^[7]. Ibadan, the State Capital Metropolis of Oyo State in South-Western Nigeria have changed from small, isolated rural areas to large, interconnected economic urban areas. This may be as a result of migration of people from rural area to it, in search of "greener pasture". The establishment of University College in Ibadan in the year 1948 contributed enormously to the conversion of vegetation and open surface land uses to built-up land use.

1.2, Review of Similar Studies

The Land Surface Temperature before a settlement becomes urban area differs from what is obtainable when it becomes urban area. These differences are caused by the alteration of the earth's surface by human activities such as construction which causes concrete, asphalt, metals and aluminums to replace natural vegetation. As a result of all these activities, changes occur in local weather and climate, one of the most familiar being the Urban Heat Islands (UHI) phenomenon ^[14] Cited in ^[27]. The urban heat island is defined as the characteristics warmth of both the atmosphere and land surfaces in cities (urban areas) compared to their non-urbanized surroundings ^[28]. Most cities are experiencing increase in temperature

when settlement growth changes the characteristics of the earth's surfaces to artificial concrete and impervious surfaces.

A lot of studies have been reported on the use of Remote Sensing and GIS to study the relationship between land surface temperature and land use/land cover changes. For example, [9] analyzed land surface temperature changes in response to land use/land cover change in Sangong River Basin in China. The author selected two images of Landsat TM/ETM+ which belong to 1990 and 1999. Mono-window algorithm was used to get land surface temperature of 1990 and 1999, then changes of LST from 1990 to 1999 were gotten by using Arc/info 9.0 (ESRI, Arc GIS Desktop). The author also got the average LST through the weight and Standard Deviation of pixel by pixel in each land use in 1990 and 1999. Based on mean LST values, he calculated LST change rate per land use between 1990 and 1999. He found that land surface temperature is in remarkable response to land use/land cover change and that land surface temperature rose about 10°C within 1990 and 1999. Another example is that of [29] who reported an investigation into the application of Remote Sensing and GIS on how land surface temperature responded to urban growth. The authors retrieved spatial patterns of land surface temperature and land use/land cover for 1992 and 2006 from Landsat images dated 16th August, 1992 and 19th May, 2006. They classified TM images into five land use types, including built-up land, water, barren land, forest land and agriculture land. Then, they characterized the land use types with remote sensing indexes. Normalized Difference Built-up Index (NDBI) is an indicator for urban area, Normalized Difference Vegetation Index (NDVI) as greenness indicator and Modified Normalized Difference Water Index (MNDWI) was selected to represent water areas. They overlay classified land use maps and derived LST layers to recognize their spatial pattern to do correlation analysis. To examine the effect of land use/land cover change on land surface temperature pattern, land use change detection was performed. Changed areas were then overlaid with LST layers to calculate the LST differences between 1992 and 2006. Correlation analysis between land surface temperature and three mentioned indexes separately was done and then used two global and local multivariate regression to model LST based on indexes. Some of their results showed that land surface temperature increased by about 3.4°C and 1.9°C respectively for forest and agricultural land uses that were converted into built-up areas.

[24] reported an investigation into the application of the integration of Remote Sensing (RS) and Geographic Information Systems (GIS) for detecting urban built up growth for the period 1961–2002, and evaluated its impact on surface temperature in Baghdad city. Surface temperature, land cover pattern and Normalized Difference Vegetation Index (NDVI) were extracted from Landsat7 ETM+ data. Land surface temperatures was linked to land use data of Baghdad region for further investigations of the relationship between temperature behaviour and urban structures. The Normalized Difference Vegetation Index (NDVI) was used to examine the relation between thermal behaviour and vegetation cover amount. The results showed that the negative average correlation more than 85% was identified by the results from the correlation and regression analysis of the extracted surface temperature from Landsat data image with NDVI. Also this research proved that the distribution of urban surface temperature depends on various

land cover type of surrounding areas. Water and forest cover types show lower day temperature differences compared to residential, commercial cover types.

[17] employed the use of Remote Sensing and GIS techniques to identify the various land uses, their various transformations between 1986 and 2006 and measures the rate of urban expansion and loss of vegetation cover in Abuja, Nigeria. The study also analyzed the changes in Land Surface Temperature over Abuja area using Landsat TM and ETM + satellite data for 1986, 2002 and 2006. The emissivity per pixel was retrieved directly from satellite data and estimated as narrow band emissivity at the satellite sensor in order to have the least error in the surface temperature estimation. Strong correlations were obtained between high surface temperature and negative NDVI values. The study also revealed that the built up area has expanded by 17.88% of the total land area of Abuja in 1986 to 27.02% in 2006, vegetation covers reduced from 47.23–37.79%.

1.3. Sustainable City

Sustainability has become a much-needed target, especially when considering the rapid settlement growth and the subsequent exacerbation of social, economic and environmental problems [1]. The notion of sustainable city emerged as a political initiative in response to the degradation that occurred in the urban environment throughout the twentieth century. Therefore, the issues related to the planning and management of human settlements were top priority of the United Nations Conference held in Stockholm in 1972 [22].

The UN sustainable city programme defined sustainable city as one that is able to retain the supply of natural resources while achieving economic, social and physical progress and remaining safe against the environmental risks that can undermined any development achievement. One of the global environmental problems is climate change. Combining sustainable development and urbanization issues together has become important because sustainable city is a prerequisite to sustainable development [19].

In sustainable city development, the primary goal is to make cities and their ecosystems healthy and sustainable over time in terms of their environmental, economic and social dimensions. This perspective gives birth to the concept of sustainable city [26]. A sustainable city is a city that improves and enhances its natural, social and economic capital in ways that allow current and future inhabitants of the city to have healthy, productive and happy lives [11]. A city designed with consideration of environmental impact, inhabited by people dedicated to minimization of heat and building city for healthy future.

As this metropolis is growing to meet the present needs, the needs of the future generations must also be put into consideration. Thus, a better understanding and practice of sustainable city can go a long way to preserve the natural landscapes of this city, even in the phase of urbanization. To achieve this, there should be an attempt to bridge the gap between nature and cities through what is called 'Green Urbanism' [19]. Green urbanism is a practice of creating communities beneficial to human and the environment, an attempt to shape the cities and lifestyles that consume less of the world's resources [8]. A city with high

air quality, moderate land surface temperature and minimize pollution of any type that will not totally eradicate the natural phenomenal in the environment because of settlement growth.

2. Methodology

2.1. Data Required and Sources of Data

The variables that were investigated in this study include as well as Land Use/Land Cover (LU/LC) Land Surface Temperature (LST) of Ibadan from 1988 to 2018. The main source of data for Land Use/Land Cover and Land Surface Temperature were remotely sensed imageries from Landsat of the city for 1988, 1999, 2013 and 2018. All these Landsat images were collected from the website of the U.S. Geological Survey (USGS) of the National Centre for Earth Resources Observation and Science (EROS) (Table 1). The Land Use/Land Cover and Land Surface Temperature in the State Capital Metropolis of Oyo State in Nigeria for thirty (30) years were investigated from 1988 to 1999, 1999 to 2013 and 2013 to 2018 respectively.

Table 1

The Description of Satellite Imageries used in the Study.

Acquisition Date	Source	Path/Role	Resolution	Landsat Series
04 Dec. 1988	USGS	190/55	30M.	L5
17 Dec. 1988	USGS	191/55	30M.	L5
21 Jan. 1999	USGS	190/55	30M.	L5
18 Dec. 1999	USGS	191/55	30M.	L5
14 Dec. 2013	USGS	190/55	30M.	L7
27 Dec. 2013	USGS	191/55	30M.	L7
16 Jan. 2018	USGS	190/55	30M.	L8
03 Jan. 2018	USGS	191/55	30M.	L8
Source: USGS, 2018.				

In order to estimate land use/land cover of the study area, three classes of land use which include Vegetation, Open surfaces and Built-up land uses were selected from the Landsat imageries of the study area (Table 2). Geographic link of ERDAS IMAGING 9.2 were used to investigate the Land Surface Temperature values for vegetation, open surfaces and built-up land use types. The percentage of changes in the size of each class of land uses with its corresponding land surface temperature values from 1988 to 2018 in the State Capital Metropolis of Oyo State in Nigeria were compiled and tabulated in order to

understand the rate of Land Use/Land Cover changes and how it affects the land surface temperature in the study area.

Table 2
Description of Land Use/Land Cover.

Land Use Types	Description
Built-Up	Residential, Commercial, Roads and other Urban Features
Vegetation	Forest, Cash Crops and Urban Green Belts
Open Surfaces	Exposed Soil and Rock surfaces
Source: [19]	

2.2. Image Pre-processing

Landsat images of Ibadan between 1988 and 2018 were used in this study. All the images were retrieved from the U.S. Geological Survey (USGS) of the National Centre for Earth Resources Observation and Science (EROS). All the bands were utilized at a spatial resolution of 30m. These spectral bands were layer stacked to produce a composite image of the study area for each year (1988, 1999, 2013 and 2018) for the purpose of Land Use/Land Cover classification and image analysis. Thermal band for Landsat images were used to extract the Land Surface Temperature from all the periods under consideration. The composite images and thermal bands were clipped with a rectangular area of interest in ERDAS IMAGING 9.2.

2.3. Supervised Image Classification

A Land Use/Land Cover classification is necessary in order to detect Land Use/Land Cover changes as a result of settlement growth from 1988 to 2018 in Ibadan, Nigeria. The classes of Land Use/Land Cover that were considered are vegetation, open surfaces and built-up land uses. A supervised classification with the maximum likelihood algorithm was conducted to classify the Landsat images using bands 2 (green), 3 (red) and 4 (blue). Visual image interpretation was done with reference to Landsat images of the study area.

2.4. Accuracy Assessment

Land Use/Land Cover maps derived from classification of images usually contain some sort of errors due to several factors that range from classification techniques to methods of satellite data capture. Therefore, assessment of classification results is an important process in the classification procedure to avoid these errors. The accuracy assessment was done by generating equal random points for the

classified images, using the accuracy assessment tool in ERDAS IMAGING by comparing the randomly selected pixels with corresponding referenced data.

2.5. Land Use/Land Cover Change Detection Analysis

The change detection algorithm employed for detecting land use/land cover change was image differencing. Image differencing is one of the widely used change detection approaches and is based on the subtraction of images acquired in two different times. In the process, the Digital number (DN) value of one date for a given band is subtracted from the DN value of the same band of another date^[25]. Change detection analysis was carried out to evaluate the changes in Land Use/Land Cover from 1988 to 2018 in the study area.

2.7 Estimation of Land Use/Land Cover and Land Surface Temperature

In order to estimate Land Use/Land Cover of the study area, three classes of land use which include vegetation, open surfaces and built-up land uses were selected purposefully from the Landsat imageries of the study area. Geographic link and enquire tools of ERDAS IMAGING 9.2 were used to investigate the land surface temperature value for each of the land use type that was selected. The percentage of changes in size of each class of land use from 1988 to 2018 with its corresponding land surface temperature value were compiled and tabulated in order to understand the rate of land surface temperature response to the changes in Land use/Land Cover in the study area.

3. Results And Discussion

3.1. Land Surface Temperature Variation in Ibadan from 1988 to 2018

The Land Surface Temperature variations in Ibadan from 1988 to 2018 were investigated and the values obtained were presented in Table 3.

Table 3
LST Obtained for Different Years in Ibadan

Years	1988	1999	2013	2018
LST (°C)	23.0	24.7	27.2	29.7
Source: Obtained from Landsat Images of 1988, 1999, 2013 and 2018				
LST - Land Surface Temperature				

From Table 3. It is obvious that there is a noticeable increase in LST value from 23.0⁰C in 1988 to 29.7⁰C in 2018. It seems that the increase in LST value from 23.0⁰C to 29.7⁰C is majorly driven by the change in land use/land cover in Ibadan. That is, from vegetation land use to built-up land use.

Land Surface Temperature dynamics in Ibadan from 1988 to 2018 is presented in Figure 1.

From Fig. 1, the areas with high Land Surface Temperature represented with red colour indicate built-up areas while the areas with low Land Surface Temperature represented with green colour indicate vegetated areas.

3.2 Investigation of Land Use Change in Ibadan

In this study, built-up areas which includes all impervious surfaces such as concrete land cover, asphalt roads, residential and commercial buildings and all other urban features are referred to as Built-up while dense forest, tree crop- lands and urban green belts are referred to as vegetation and also open surfaces are used to represent exposed soil and rock surfaces. The areas covered by each land use types in Ibadan from 1988 to 2018 are clearly shown in Table 4. Also Landsat maps showing the built-up, open surfaces and vegetation land uses in Ibadan were produced and presented in Figs. 2a, 2b, 2c and 2d respectively.

Table 4
Areas Covered by Land Use types from 1988 to 2018 in Ibadan

Land Uses	Areas in 1988 (km ²)	Areas in 1999 (km ²)	Areas in 2013 (km ²)	Areas in 2018 (km ²)
Built-Up	188.29	382.74	423.45	578.69
Open Surfaces	118.23	245.39	468.94	425.33
Vegetation	1095.71	774.01	550.84	398.20
Total	1472.23	1402.14	1443.23	1399.22
Source: Obtained from Landsat Images of 1988, 1999, 2013 and 2018				

The total area of built-up, open surfaces and vegetation land use types from 1988 to 2018 were calculated and are clearly presented in Table 4. During the last 30 years in Ibadan, the built-up land use type covered a total area of 188.29km² in 1988, 382.74km² in 1999, 423.45km² in 2013 and 578.69km² in 2018. Open surfaces land use type covered a total area of 118.23km² in 1988, 245.39km² in 1999, 468.94km² in 2013 and 425.33km² in 2018. Vegetation land use type covered a total area of 1095.71km² in 1988, 774.01km² in 1999, 550.84km² in 2013 and 398.20km² in 2018. From Table 4, it can be observed that there was a drastic increase in built-up land use type from 188.29km² in 1988 to 382.74km² in 1999 and from 382.74km² in 1999 to 423.45km² in 2013 and from 423.45km² in 2013 to 578.69km² in 2018. Table 4 indicates that built-up land use type has increased from 188.29km² in 1988 to 578.69km² in 2018 indicating an increase of 390.40km² over the last 30 years. The reason for the

increase in the built-up land use type may be attributed to indiscriminate felling of forest trees as a result of population growth. Open surfaces has a drastic increase from 118.23km² in 1988 to 425.33km² in 2018 showing an increase of 307.10 km² over the last 30 years and the reason for this drastic increase is not unconnected with the conversion of tropical forest to farmlands. Vegetation land use type decline drastically from 1095.71km² in 1988 to 398.20km² in 2018 indicating a decrease of 697.51km². The reason for this drastic decrease may be attributed to rapid settlement growth in Ibadan.

Landsat maps showing the built-up, open surfaces and vegetation land uses in Ibadan were produced and presented in Figs. 2a, 2b, 2c and 2d for 1988, 1999, 2013 and 2018 respectively.

It is apparent from the findings of this study that area covered by the built-up land use type is increasing rapidly while the area covered by the open surfaces and vegetation land use types is reducing in the study area (Table 4 and Figs. 2a, 2b, 2c and 2d). The movement of people into this metropolis may be because of the presence of employment opportunities, social amenities and government patronage, being the seat of Government. As population increases due to influx of people into this metropolis, there is a necessity to build more houses, commercial centres, roads, educational and health facilities to accommodate the ever increasing population.

3.3. Settlement Growth and Corresponding Land Surface Temperature in Ibadan

The land use maps of Ibadan generated in this study revealed a steady growth in the built-up land use type (Figs. 2a, 2b, 2c and 2d). Percentage of changes in built up land use with their corresponding LST values for the investigated areas were presented in Table 5.

Table 5
Percentage of Changes in Built-up Land Use and their Respective Corresponding LST Values in Ibadan

Metropolis	Years	% of Changes in Built-up Land use	% of Changes in LST
Ibadan	1988–1999	103.27	7.1
	1999–2013	10.64	10.4
	2013–2018	36.66	8.9
	1988–2018	67.46	22.4
Source: Obtained from Landsat Images of 1988, 1999, 2013 and 2018			

From Table 5, built-up land use value was directly proportional to the LST value. This implies that changes in land use/land cover can bring about significant increase in land surface temperature values. The percentage increase in built-up land use from 1988 to 1999 was 103.27% and the LST percentage of

increase was 7.1%. From 1999 to 2013, the percentage of increase in built-up land use was 10.64% and the LST percentage of increase was 10.4% while the percentage of increase in built-up land use from 2013 to 2018 was 36.66% and the LST percentage of increase was 8.9%. Then from 1988 to 2018, the percentage of increase in built-up land use in Ibadan was 67.46% with LST percentage of increase of 22.4%. According to ^[15] afforestation can decrease land surface temperature by about 1.1⁰C. On other hand, conversion of vegetation land cover into impervious surfaces can significantly increase Land Surface Temperature.

4. Conclusion

This study has demonstrated the usefulness of Remote Sensing (RS) and Geographic Information System (GIS) approaches to retrieve Landsat images and estimate land use changes using ERDAS IMAGING 9.2. The analysis of the data obtained from the Landsat imageries of Ibadan, the State Capital Metropolis of Oyo State in South-Western Nigeria showed that the areas covered by the built-up land use type in the study area from 1988 to 2018 experience steady growth and this brought about the alteration of the micro climate of the environment leading to significant increase in the Land Surface Temperature of Ibadan, Nigeria.

The growth in the built-up land use type in Ibadan, Nigeria was as a result of the conversion of open surface and vegetation land use types to built-up land use type throughout the period under consideration in this study. The changes that occurred in the land use/land cover in the study area, that is, conversion of open surface and vegetation land use types to build-up land use type can be attributed to influx of people from other areas to the city in search of white collar job and other economic activities being the State capital of Oyo State, South-western Nigeria. Adoption of the concepts of Green Urbanism (GU) and Sustainable City by planting Green Belts (GB) within the city will go a long way in sustaining our cities by reducing the amount of Land Surface Temperature (LST) within the city ^[20]. Vegetation makes use of solar radiation for transpiration and release water vapour that helps in reducing the amount of air temperature and potentially decrease the amount of land surface temperature ^[4]. Hence, the more the presence of vegetation covers the more its cooling effects on land surface. In addition to evaporative cooling effects of vegetation, the shade provided by the trees can act to cool the land surface by intercepting solar radiation and preventing the increase in Land Surface Temperature ^[18]. The increment in the amount of Land Surface Temperature recorded in Ibadan, the State Capital Metropolis of Oyo State South-Western Nigeria can be attributed to the reduction in the areas covered by vegetation in the Metropolis (See Table 5).

5. Recommendations

Based on the current findings, it was presumed that increase in LST in Ibadan the State Capital Metropolis of Oyo State, South-Western Nigeria was in response to the changes of open surface and vegetation land use types to built-up land use type. This result points to the need to have focused policies

on sustainable city such as introduction of urban green belts within the cities and implementation of the concept of green urbanism by the Government and residence of Ibadan. It will be good if government will encourage the inclusion of trees, flowers and grasses around proposed building plans before approval, be it residential or commercial building instead of concrete artificial surface in order to reduce land surface temperature within the Metropolis. If it is possible, flowers and grasses should be planted around the existing buildings in Ibadan, the State Capital Metropolis of Oyo State South-Western Nigeria so as to reduce the land surface temperature within the Metropolis and also help in its beautification.

Declarations

Data Availability: The datasets generated and analysed to support the findings in this study are not publicly available because I involved in some financial and mental commitments before I could generate and analyse the Landsat Images used in this study. I can only give the data out base on reasonable request on the following platforms:

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2. www.spacelabng.com

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Figures

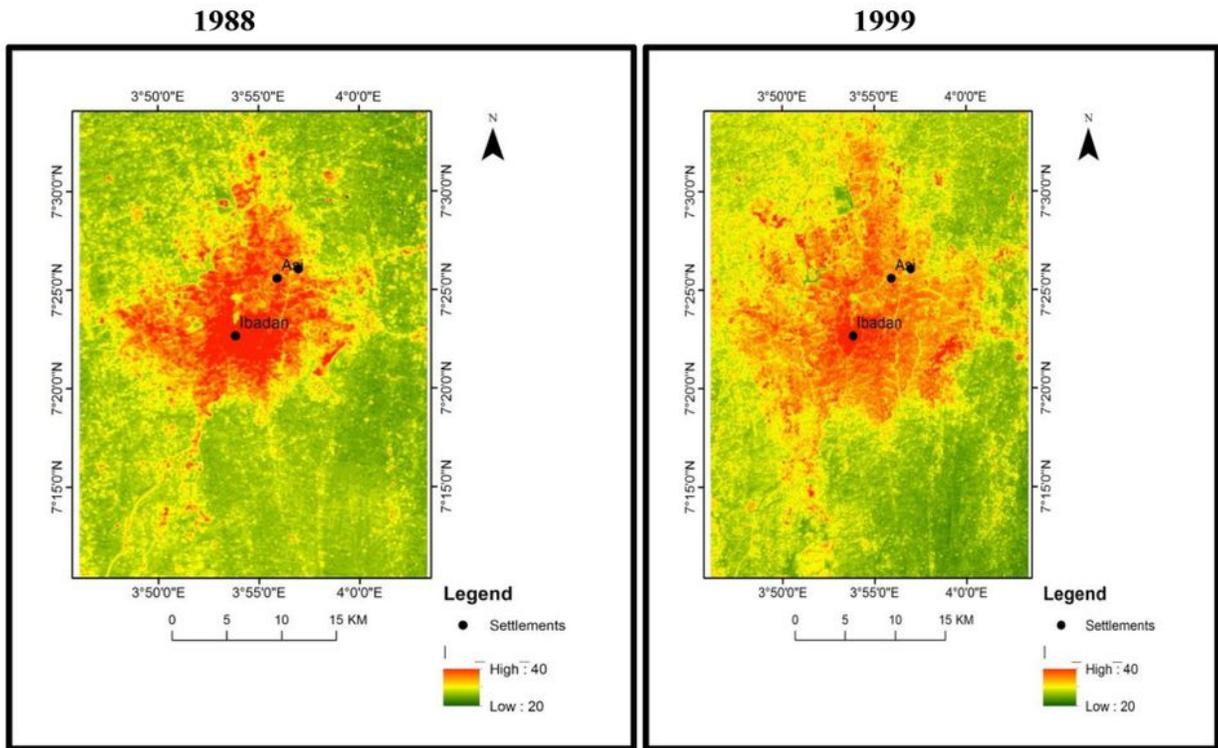


Figure 1a
2013

Figure 1b
2018

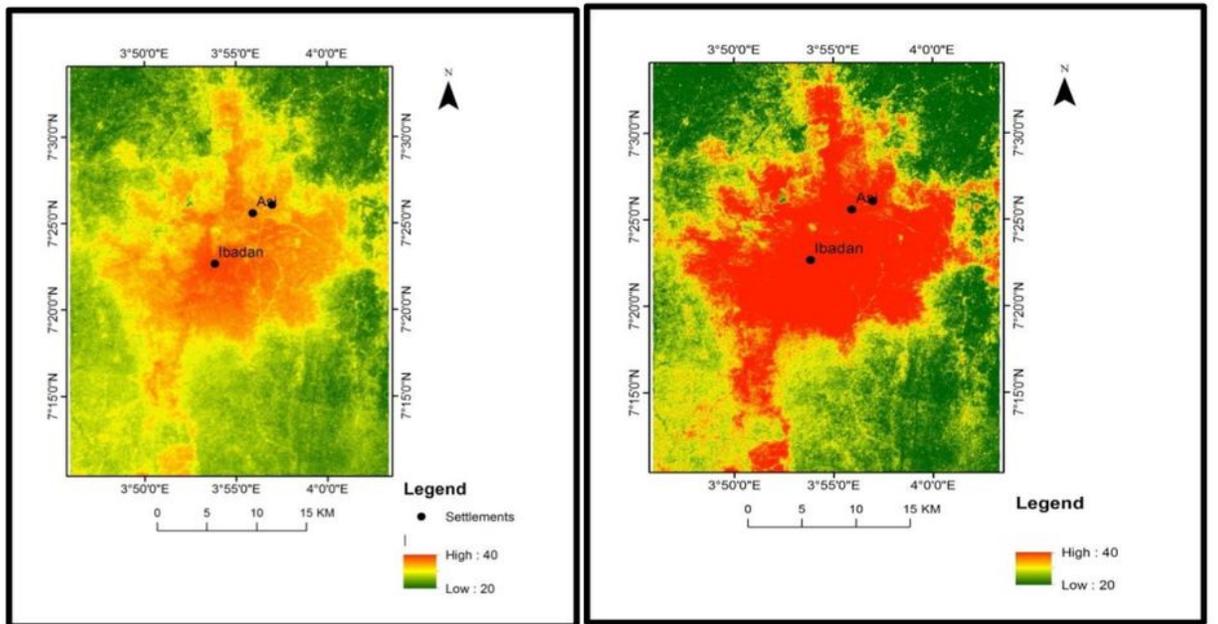


Figure 1c

Figure 1d

Figure 1

Land Surface Temperature dynamics in Ibadan from 1988 to 2018

Source: Obtained from Landsat Images of 1988, 1999, 2013 and 2018

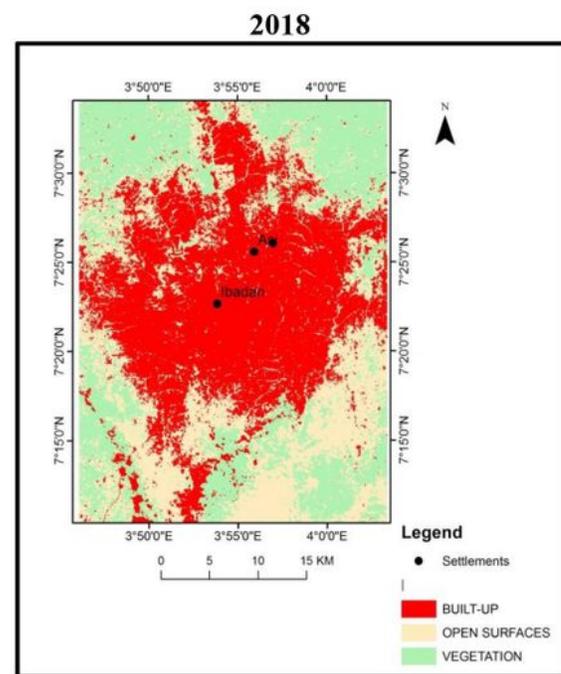
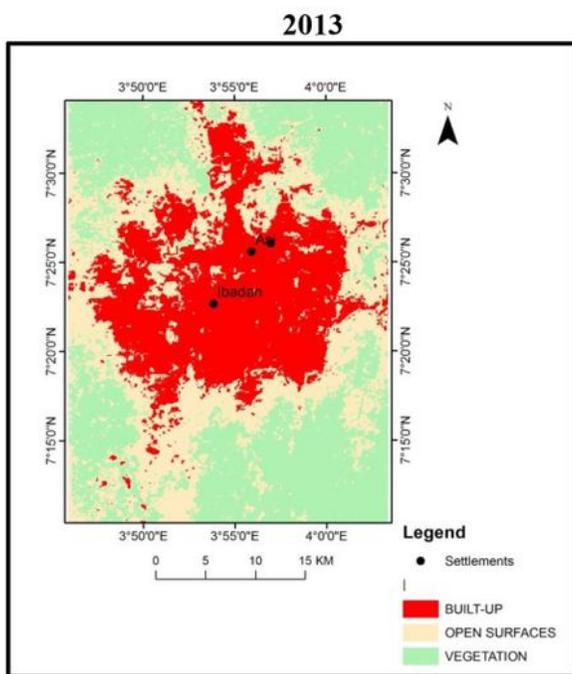
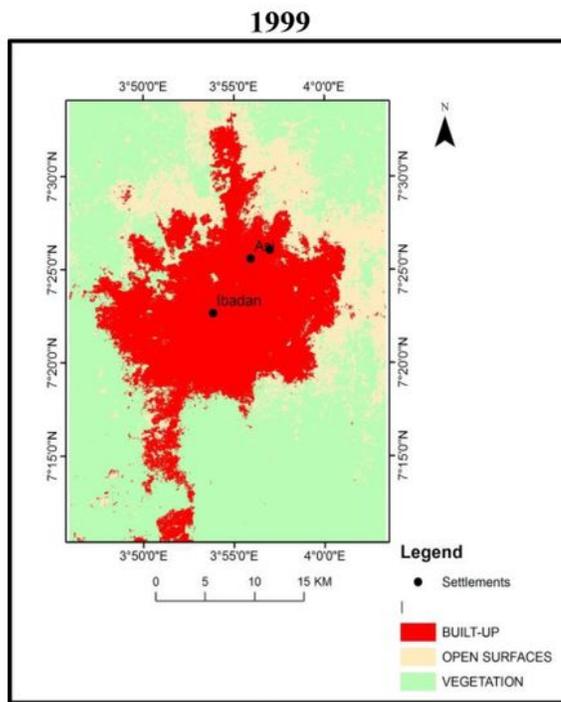
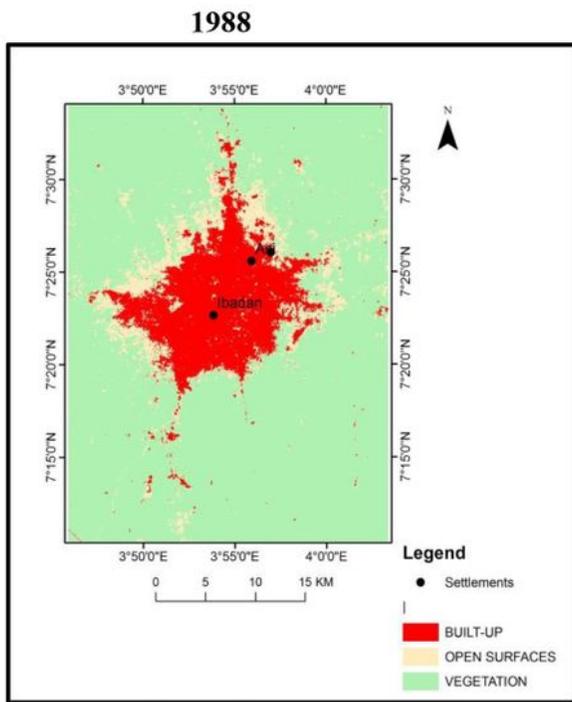


Figure 2

Landsat maps of 1988, 1999, 2013 and 2018 indicating area covered by land uses in Ibadan

Source: Obtained from Landsat Images of 1988, 1999, 2013 and 2018