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SPATIAL ANALYSIS OF URBAN GREEN SPACES IN AN INDIGENOUS AFRICAN CITY

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ABSTRACT

Green spaces are vegetation areas in urban landscapes, including forests, parks, gardens, wetlands and street trees. Their loss has great consequences for the aesthetic, recreational, economic and human health value and sustainability of urban environments. The literature on urban green spaces has focused on locations and effects on human well-being with limited attention to the spatio-temporal patterns of green spaces. Ibadan is Africa's largest traditional city with a long history of green spaces which has reduced over the years, thus providing a suitable environment for this research. This study was, therefore, designed to analyse the spatio-temporal patterns in Ibadan metropolis, Nigeria. Cloud free Landsat Imageries (LI) of 1972, 1984, 2000 and 2015 were obtained from www.Glovis.com. Normalised Difference Vegetation Index threshold of 0.2-0.8 was used in identifying green spaces from the processed LI. The map of Oyo State, Nigeria sourced from the State Valuation Department was superimposed on the LI to identify a total of 104 localities. The change detection method was used to map the changes in green spaces, while Global Moran's-I was used to analyse its temporal pattern. The green spaces declined by 38.0%, 62.2% and 61.5% between 1972-1984, 1984-2000, and 2000-2015, respectively. In 1972 ($I: 0.348091$), the green spaces were principally clustered in Bodija, Elewura and Academy neighbourhoods. In 1984 ($I: 0.452642$), 2000 ($I: 0.313010$) and 2015 ($I: 0.229712$). There is an uneven spatial distribution of green spaces in the city. There is a need for policy intervention to reduce the adverse loss of green spaces and consequent effect on the environment.

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INTRODUCTION

Green space is a vital part of the complex urban ecosystem. It benefits urban communities environmentally, aesthetically, recreationally and economically (Swanwick and Woolley 2003; Alberti 2008; Dadvand *et al.*, 2015). The loss of urban green space as a result of urbanization threatens the general biodiversity of urban areas, prompting the consideration of existing urban nature more carefully (Bastian *et al.*, 2012; Crouse *et al.*, 2017). The growing demand for land for residential development will increase the pressure to develop un-built urban areas like urban green spaces (Boone-Heinonen, and Casanova *et al.*, 2010). There is no single definition of green space but, rather, provided examples of what was meant by green space. The foremost common definition delineated greenspace as vegetated areas (Carbo-Ramirez and Zuria 2011; Taylor and Hochuli 2017). The second commonest definition considered explicit examples of what is considered 'green space' for example "urban green spaces include forests, trees, parks, allotments or cemeteries" (Bastian *et al.*, 2012).

Land uses, like recreational areas or undeveloped land, are the next most common definitions provided (Carbo-Ramirez and Zuria 2011). Furthermore, green space is defined as 'natural' environments, together with parks, woods, gardens and coastal areas (Chong *et al.*, 2013). In a study regarding the physical activity and design of communities, Almanza *et al.*, (2012) referred to green space as 'greenness exposure' that is measured via normalized difference vegetation index (NDVI), focusing on all live vegetation.

In the literature, urban green spaces have already been worked out in various ways covering the environmental, economic and social perspectives of urban green spaces (e.g., Burgess *et al.*, 1988; Morgenstern, 1999, Stephen *et al.* 1995; Taylor *et al.* 2,001; Jim 2004; Boone *et al.* 2009; Chiesura, 2004; Swanwick *et al.* 2003; Tzoulas *et al.* 2007; Alberti, 2005, Wendel *et al.* 2011; Ekkel and de Vries 2017). Studies have also been carried out on the perception of the urban residents of trees in low, medium and high-density residential areas (Ekanade 2006). Other studies have been carried out on factors

and processes behind the destruction of urban green spaces both at local and regional scales (Chiesura 2004; Ali and Malik 2010; Mensah-Bonsu and Owusu-Ansah, 2011; Feng and Astell-Burt T 2017; Bell, Hamilton, Montarzino, Rothnie, Travlou, Alves, 2008; Maller, Mardie, Brown and Lawrence 2002; Guerry *et al.* 2015; Kuehler, Hathaway, Tirpak 2017). However, limited studies have considered the spatio-temporal effects of green spaces especially in an indigenous African city. This study therefore investigates the spatio-temporal pattern of urban green spaces in Ibadan metropolis, Nigeria from 1972 to 2015. The first hypothesis states that Urban green spaces is randomly distributed in Ibadan metropolis from 1972-2015. The second hypothesis states that urban green spaces decrease significantly with time.

Literature Review

Undoubtedly, the urbanization factor is still the major driver of studies on urban green spaces. Urbanization is experienced in all countries of the world and is expected to continue in the coming decades, especially in the developing world where the United Nations Population Fund (UNPF-2007) anticipates that 80% of urban communities in the world will be recorded by 2030 (Beardsley *et al.*, 2009). Cities are confronted with a mix of growing challenges from population growth that outpaces infrastructure development, growing slums and informal settlements, changing demographic characteristics, social inequality, economic fluctuations, local changes in climate and other stressors. A study of several European cities observed a reduction in the coverage of green spaces and attributed urbanization as a major cause of this problem with many of the cities increasing in size (population and land area) to cover lands reserved for green spaces (Fuller and Gaston, 2009). In the USA, McDonald *et al.* (2010) observed a loss of about 1.4 million hectares of green spaces due substantially to rapid urbanization taking place in most cities. Similar is the story in most developing countries and Africa in particular where the rate of urbanization has been identified to be high and expected to continue into the future (United Nations, 1992; Chiesura 2004; Mensah-Bonsu and Owusu-Ansah, 2011, Ali and Malik, 2010). Studies in several African countries revealed that there is intense pressure on green spaces for different human activities resulting in persistent deterioration of these spaces (Djibril, 2012; Abbasi *et al.*, 2016; Gren and Andersson 2018). Fanan *et al.*, (2011) observed that urbanization and urban sprawl have caused Abuja (the capital city of Nigeria) to increase the loss of its green space from about 21 per cent in 2001 to 61 per cent in 2006. A study on some selected African cities such as Abidjan (Cote D'Ivoire), Lagos (Nigeria) and Freetown (Sierra Leone) found rapid urbanization causing the conversion of many reserved green space lands to infrastructural development to meet the needs of the booming urban population (Fuwapu and Onyekwelu, 2011).

Although several land planning regulations on green spaces are available in various African countries, the operation of such regulations has been problematic. Certain factors hinder the effective operation of urban planning regulations on green spaces in Africa such as the dysfunctional nature of urban planning regulations; the bureaucratic processes involved in issuing development permits; and lastly, the weakness of the planning institutions due to insufficient resources to work with (Kironde, 2006; Mensah, 2014). The dysfunctional nature of the urban planning regulations in most countries of the world especially in Africa can be linked to the outdated nature of

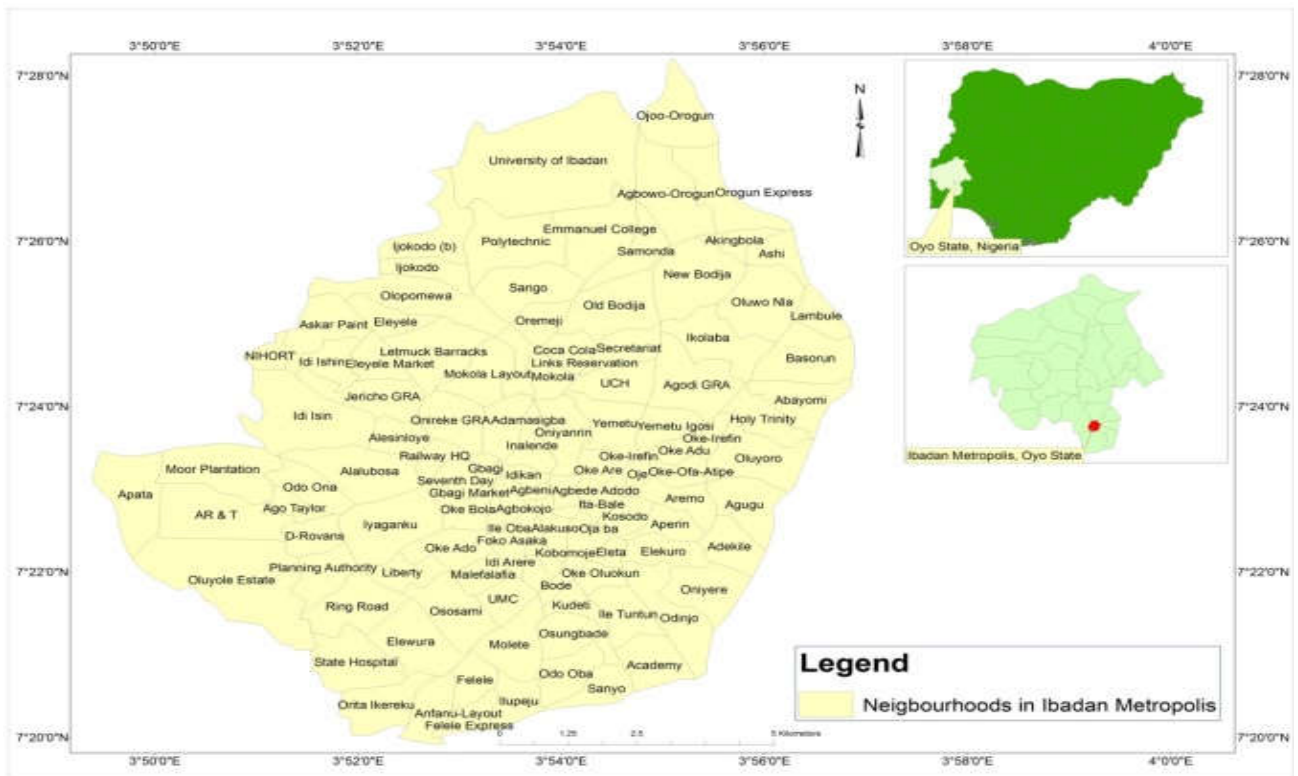
some of these regulations. Majority of the urban planning regulations operating in some countries in Sub-Saharan Africa were made about 60 years ago along the lines of the planning regulations of their colonial masters at that time like the British, French and Germans (UN Habitat, 2009; Mensah, 2014). The uncooperative attitude of urban dwellers towards the management of green spaces also emerged as a predominant challenge. This was found to be the result of a lack of involvement of the local people in decision making on green spaces and poor awareness of the benefits of green spaces on the part of the local people (Southern African Development Community, 2006; Mensah, 2014). The high rate of urban poverty in the developing countries of the world has been linked to the depletion of the green environment as many of the poor tend to over-rely on these resources for their survival (Cilliers, 2012). Also, in a study in South Africa, it was found that many poor communities relied much on the green environment for additional income or to improve their livelihood (UN Habitat 2010). The resultant effect has been excessive destruction of green spaces in many urban areas in Africa by the poor to satisfy their needs. The degradation of green spaces in cities is one of the ecological threats with attendant consequences on human health and environmental safety. Urban areas have to maintain an internal equilibrium or balance between socioeconomic and environmental conditions in such a way that the urban system and its dynamics evolve in harmony, internally limiting, and as much as possible, ensuring low impacts on the natural environment (Barredo and Demicheli, 2003; Guariguata *et al.*, 2017).

Study area and Methodology

Study Area

Location: Ibadan metropolis, covering an area of 129.65km², is located in south-western Nigeria, 128 km inland northeast of Lagos and 530 km southwest of Abuja, the federal capital. It lies between latitudes 7^o3'N and 7^o 10'N and longitudes 3^o 2'E and 4^o40'E. The study area map (see Figure 1) for this research consists of 104 neighbourhoods which were identified by the Valuation Department of Oyo state in the 1990s.

Growth of the city: Ibadan was established in 1829 as a war camp for warriors coming back from Oyo, Ife, and Ijebu. A forest site and several ranges of hills, varying in elevation from 160 to 275 meters, offered strategic defense opportunities. Moreover, its location at the fringe of the forest promoted its emergence as a marketing center for traders and goods from both the forest and grassland areas. Ibadan therefore began as a military state and remained so till the last decade of the nineteenth century. The economy of Ibadan primarily rested on agriculture (yam, maize, vegetable etc.), manufacture (mainly weapons, blacksmith, cloth and ceramics industries) and trade (slaves, palm oil, yam, kola for export, shea butter, salt, horses, weapons from outside). The colonial period strengthened the position of Ibadan town within the Yoruba urban network. After a small boom in rubber business (1901-1913), cocoa became the main produce of the region and attracted European and Levantine firms, as well as southern and northern traders from Lagos, Ijebu-Ode, and Kano among others. The railway to the North reached Ibadan in 1901 and all road traffic from Lagos to the North converged in Ibadan. The city became a significant zone of bulk trade. By 1979, the economic landscape was still dominated by small-scale industrial



Source: Valuation Department of Oyo state, Nigeria.

Figure 1. Ibadan Metropolis showing neighbourhoods

activities though a few large-scale firms had been established in the newly developed industrial estates. The importance of Ibadan was additionally increased in 1948 by the founding of the University College that later became the University of Ibadan. Ibadan also had a well-equipped teaching hospital, at that time the only one within the country. Until 1970, Ibadan metropolis was the largest city in sub-Saharan Africa. In the nineteen eighties, the Ibadan-Lagos expressway generated the largest urban sprawl (east and north of the city), followed by the Eleyele expressway (west of the city). Since then, the city has expanded further into the neighboring Akinyele and Egbeda Local Government Areas in particular.

METHODOLOGY

Types and Data Sources: Data for this study were obtained from two sources namely primary and secondary sources.

Primary Source: Primary data were collected through focus group discussion (FGD) on activities and causes of green space reduction in each neighbourhood between 1972 and 2015.

Secondary Source: Secondary data for this study were obtained mainly from remotely sensed data and GIS-based sources for extracting the green areas. The data collection commenced fully in 2015. The initial intention was to use a ten year- interval; however, since the data were not available at that interval, a 15-year interval was applied in the selection of the Landsat satellite imageries. A backward count from 2015 resulted in the following years: - 2015, 2000, 1985, 1970. There was however one main exception on the Landsat satellite imagery for 1970 and 1985. The earliest satellite imagery for the study area was captured in 1972 while the closest for 1985 is the 1984 Landsat imagery; the study

a proxy for 1970 while the Landsat satellite imagery for 1984 was a proxy for 1985. The specifications are as follows:

- Landsat- 4 Thematic Mapper of 8 Nov 1972 with 7 spectral bands, where the bands 1 -7 have a spatial resolution of 60 meters obtained from United States Geological Survey (USGS). EarthExplorer<https://earthexplorer.usgs.gov/order>
- Landsat 5 Thematic Mapper (TM) of 18 Dec 1984 with a spatial resolution of 30m and 7 bands obtained from USGS. EarthExplorer<https://earthexplorer.usgs.gov/order>
- Landsat Enhanced Thematic Mapper plus (ETM+) of 28th May 2000 with 8 spectral bands where bands 1-7 have the spatial resolution of 30 meters and band 8 (pan chromatic band) has a higher spatial resolution of 15 meters were obtained from USGS. EarthExplorer<https://earthexplorer.usgs.gov/order>
- Landsat Enhanced Thematic Mapper plus (ETM+) of 15th June 2015 with 8 spectral bands were obtained from USGS. EarthExplorer<https://earthexplorer.usgs.gov/order>

Data Collection

Land use /land cover classification (LULC) approach : The first step in the collection of the Landsat images involved the ordering for the images from USGS EarthExplorer, <https://earthexplorer.usgs.gov/order>. The other steps included (i) Image Processing; (ii) Computation of the Normalized Difference Vegetation Index (NDVI) to derive a threshold for identifying green areas; (iii) Image classification – Green space extraction; and (iv) Green space are calculation in square meters per neighbourhood. To achieve accurate change

detection mapping, multispectral images must be pre-processed both geometrically and radiometrically to correct errors arising from imaging sensors, atmospheric effect, and earth's curvature. Pre-processing operations sometimes referred to as image restoration and rectification, are intended to correct for sensor and platform-specific radiometric and geometric distortions of data. However, since the images had been ortho-rectified by USGS Earth Explorer, there was no need for radiometric and geometric corrections. The false color composite of these images were obtained by the combination of bands 4, 3, 2 (Infrared, red, Green) using Idrisi Selva 17.0 software.

Normalized Difference Vegetation Index (NDVI): The Landsat images for 1972, 1984, 2000 and 2015 were subjected to NDVI analysis to derive a threshold for identifying green areas in each neighbourhood using the Image Analysis tool of ArcGIS. The Normalized Difference Vegetation Index was introduced by Rouse *et al* (1974) in order to produce a spectral Vegetation Index (VI) that separates green vegetation from its background soil brightness using Landsat multispectral digital data. It is expressed as the difference between the near Infrared and red bands normalized by the sum of those bands i.e. $NDVI = \frac{NIR - RED}{NIR + RED}$. NDVI is the most commonly used VI as it retains the ability to minimize topographic effects while producing a linear measurement scale. In addition, division by zero errors is significantly reduced. Furthermore, the measurement scale has the desirable property of range of -1 to +1 with 0 representing the approximate value of no vegetation. Very low values of NDVI (0.1 and below) correspond to barren areas of rock, sand, or snow. Moderate values (0.2 to 0.3) represent shrub and grassland, while high values (0.6 to 0.8) indicate temperate and tropical rainforests. For the purpose of this study, the greenness brightness threshold is from 0.2 to 0.8 (Almanza *et al.*, 2012).

Green space extraction/mapping: The mapping covers the greenness brightness between 0.2 - 0.8 measured via normalized difference vegetation index (NDVI) (Rouse *et al* 1974; Almanza *et al.*, 2012), focusing on all live vegetation cover. The process of extraction is called *digitization*. Digitization is the process of converting information into a digital format for further analysis. For the extraction, two major land use/ land cover classes were of interest; green areas and built up areas. The green areas included forests, grasses, street trees and parks, gardens and backyards, farmland and waterlogged areas. The built up areas, on the other hand, included buildings and bare ground. To achieve this, the shape file of Ibadan metropolis was superimposed on the Landsat NDVI Images using ArcGIS 10.4.1. The green areas were therefore mapped using the vegetation brightness threshold of 0.2 – 0.8 as specified in the literature.

Green space calculation in square meter: After the process of digitization, the green spaces were saved as *shapefiles* and thereafter subjected to measurement. The goal here was to measure the area extent of the green spaces for each neighbourhoods for the respective years. Using the measure tool of ArcGIS the green spaces were calculated in hectares (see Table 1 below)

Focus Group Discussion (FGD): The target respondents were the elders of each neighbourhood mainly because the elders were well informed about developments and the disappearance of green spaces as far back as pre-independence days.

No.	Zone name	ha. 1972	ha.1984	ha. 2000	ha.2015
1.	Mokola	59.9	51.6	17.65	13.59
2.	Jericho GRA	11.67	64.68	32.45	11.27
3.	Gbagi	0.61	0.09	0.07	0.03
4.	OdoOna	70.78	55.01	49.89	44.15
5.	Oja'ba	6600	0.04	0.02	0.01
6.	Agbowo	81.23	29.05	3.61	1.04
7.	Liberty	8.77	5.06	3.48	2.09
8.	Sanyo	46.87	36.06	21.31	4.48
9.	Felele	60.03	51.47	28.54	2.88
10.	Apata	139.09	129.11	121.03	65.39
11.	Yemetu	11.66	8.59	6.32	5.04
12.	Adamasingba	88.71	6.54	3.12	0.09
13.	Oniyanrin	71.63	32.53	22.33	12.57
14.	Oje	0.07	0.05	0.05	0.04
15.	Agbeni	12.71	1.07	4.91	0.01
16.	Agugu,	68.95	16.76	5.39	0.01
17.	Oke Bola	3.14	0.14	0.89	0.51
18.	Aperin	1.88	0.94	0.37	0.24
19.	Eleta	1.14	0.04	0.04	0.01
20.	Molete	76.96	48.37	31.59	38.16
21.	Elewura	47.68	37.69	24.78	13.42
22.	Ojoo-Orogun	92.08	12.60	0.66	0.25
23.	Ashi	36.63	13.51	7.51	3.51
24.	Ijokodo	127.49	70.50	0.47	0.39
25.	Samonda	45.65	15.47	8.26	4.57
26.	Old Bodija	107.62	33.95	7.44	0.11
27.	New Bodija	32.24	26.84	5.42	3.01
28.	Abayomi	123.86	78.81	33.12	1.13
29.	Onireke GRA	109.15	43.65	19.79	7.02
30.	Inalende	65.04	31.52	14.31	6.54
31.	Elekuro	4.33	1.89	0.74	0.23
32.	Uni of Ibadan	380.28	76.01	54.12	49.50
33.	Oniyere	57.93	25.95	17.73	6.71
34.	Academy	33.26	24.84	19.11	8.48
35.	Sango	102.12	66.06	17.96	2.11
36.	Oremaji	32.35	22.35	7.43	4.49
37.	Ikolaba	113.00	75.38	25.21	9.54
38.	Eleyele	57.44	21.22	15.81	11.32
39.	UCH	62.24	18.04	11.72	7.43
40.	Idi Isin	248.63	30.64	17.73	8.43
41.	Alesinloye	31.82	13.04	5.11	3.21
42.	OkeIrefin	34.78	17.08	9.73	5.64
43.	Alalubosa	68.23	28.21	19.11	11.23
44.	UMC	0.66	0.66	0.37	0.29
45.	Kudeti	2.05	2.02	1.03	0.89
46.	Odo Oba	15.41	13.12	7.35	9.22
47.	Oritalkereku	59.39	39.41	15.81	14.23
48.	Ago Taylor	33.63	6.31	3.74	1.72
49.	Labiran	117.74	11.45	6.78	3.21
50.	Iyaganku	22.59	10.06	7.81	7.45
51.	Alekuso	0.81	0.51	0.39	0.31
52.	Oke Ado	17.71	4.05	3.65	2.06
53.	Ring Road	92.28	42.85	36.91	22.12
54.	The Polytechnic	155.23	146.39	131.34	124.37
55.	Akingbola	9.38	4.67	2.77	1.06
56.	State hospital	55.55	51.67	54.65	58.23
57.	Holy Trinity	96.28	50.28	47.96	22.11
58.	Akobo	196.50	19.50	61.22	11.39
59.	Arema	5.48	3.80	0.89	0.02
60.	FokoAsaka	1.04	0.43	0.01	0.01
61.	Adekile,	43.46	12.36	4.47	1.05
62.	Kobomoje	5.60	4.34	1.83	0.33
63.	Oloyoro	156.75	64.48	13.95	3.45
64.	Odinjo	58.65	12.49	2.49	1.48
65.	OluwoNla	120.39	15.20	3.16	0.87
66.	Agodi GRA	38.39	33.99	15.76	2.38
67.	Olopomewa	103.42	52.82	44.18	39.15
68.	Yambule,	6830	14.01	4.82	0.96
69.	Ososami	33.90	22.86	15.76	7.32
70.	Askar Paint	45.26	43.96	38.91	29.54
71.	Coca Cola	46.27	31.38	14.86	3.71
72.	Letmu Barracks	96.68	60.65	34.91	22.31
73.	Secretariat	41.76	28.85	19.32	12.34
74.	Eleyele Market	7358	20.11	7.21	6.99
75.	Anfanu Layout	74.23	19.67	11.98	14.74
76.	Moor Plantation	204.20	152.11	79.43	49.57
77.	Ile Tuntun	33.06	1.88	1.88	0.66
78.	Popoyemoja	0.04	0.04	0.04	0.02
79.	Idi Arere	0.02	0.02	0.02	0.02
80.	OkeOluokun	1447.44	0.14	0.14	0.02
81.	Bode	1.20	1.20	1.20	0.06
82.	Ile Oba	0.03	0.03	0.03	0.01
83.	Ayeye	0.51	0.51	0.51	0.21
84.	Kosodo	0.04	0.04	0.04	0.03
85.	Oranyan	0.03	0.03	0.03	0.02
86.	AgbedeAdodo	0.04	0.04	0.04	0.03
87.	Idikan	21.41	2.23	1.71	1.40
88.	Ilupeju	72.70	16.94	9.94	8.75
89.	Railway HQ	9.75	8.11	6.14	2.07
90.	AR & T	178.70	171.42	154.71	123.11

91.	Seventh day	0.04	0.04	0.04	0.03
92.	LinksReservation	54.57	34.54	29.31	22.31
93.	NIHORT Qts	30.24	23.08	21.34	21.30
94.	Osungbade	16.39	2.34	0.75	8.75
95.	PlanningAuthority	40.27	15.72	11.65	10.02
96.	Imalefalafia	0.03	0.03	0.03	0.01
97.	D-Rovans	51.88	23.45	19.78	3.12
98.	IsaleOsi	0.03	0.03	0.03	0.02
99.	Agbokojo	0.71	0.63	0.32	0.02
100.	Ita Bale	0.76	0.54	0.39	0.01
101.	OkeOfaAtipe	9.81	7.05	5.74	2.17
102.	OkeAdu	24.54	2.34	0.88	0.33
103.	Oke Are	0.07	0.07	0.04	0.02
104.	Basorun	56.63	23.51	8.51	4.51

The elders also have information passed on to them by their fathers or forefathers through *oral history*. The age limit for an elder for this research study is 65 years old as adopted from United Nations report on ageing in 2019. A typical FGD consisted of representatives from each neighbourhoods and total numbers of participants ranged from 4 to 8. The participants included aged men and women that were 70 years old and above, aged men and women that were between 65 and 70 years old. The leaders of the landlords' associations and community heads were present at the discussion. The age limit was 65 years old. The starting point was to regroup the 104 neighbourhoods into smaller number for the purpose of detailed focus group interviews. Twenty – one groups emerged by considering the proximity/distance of neighbourhoods from one another. More importantly their similarity and homogeneity in terms of their physical/ spatial characteristics also informed the groupings.

Data Analyses: The specific method of data analyses were based on the objective and hypotheses of the study. They included the following:

- 1) *Change Detection Analysis* of land use/land cover data
- 2) Global Moran's I analysis of spatial pattern of green spaces
- 3) Trend Analysis (Slope of trend)

The *main objective* seeks to analyze the spatio-temporal patterns of green spaces in Ibadan metropolis. The area extent of green spaces in the 104 neighbourhoods for 1972, 1984, 2000 and 2015 respectively were mapped and measured using the ArcGIS 10.4.1 software (*the measure tool*). The maps were put in their final stage of map production (i.e. inserting the map element; scale, grid legend etc.). The spatial trend of green spaces from 1972 to 2015 was carried out to show the changes over time. This method of analysis is a GIS technique known as *change detection analysis*. Change detection refers to the process of identifying changes in the state of land features by observing them at different times. Using the GIS symbology tool, the green space variation in sqm for the study period (1972-2015) was superimposed as bar graphs on each neighbourhood respectively.

Testing Spatial Patterns of Green Spaces: Furthermore, global Moran's I analysis was used to test if the spatial pattern of green spaces in Ibadan metropolis was random. Global Moran's I statistic determines the degree of spatial autocorrelation of a given phenomenon. It measures the degree to which a given phenomenon is clustered in space. The global Moran's I value generates a single summary value (*I*) and a z score with its associated probability value (p-value) indicating the presence or absence of concentration or dispersion. The Moran's I ranges approximately from +1 (positive) to -1 (negative) and any value close to zero does not show where the

clusters or outliers are located. The global Moran's I is expressed as:

$$I = \frac{N}{W} \frac{\sum_i \sum_j w_{ij} (x_i - \bar{x})(x_j - \bar{x})}{\sum_i (x_i - \bar{x})^2}$$

Where *N* is the number of spatial units (104 neighbourhoods) indexed by *i* and *j*;

X is the variable of interest (Green space in sqm per year)

\bar{X} is the mean value (Green space in sqm per year)

W_{ij} is an element of a matrix of spatial weights which expresses the degree of proximity between neighbourhoods *s* and *j*.

Neighbourhoods that share boundaries with others were considered to be contiguous and therefore assigned a value of 1 whereas non –contiguous neighbourhoods have zero value assigned to them. The result of the Global Moran's I included the following values: Moran's Index, Variance, Z- score, P- Value (significance level).

Testing temporal trend of green spaces: Lastly on objective one, the hypothesis which was to test if green spaces significantly decreased with time was achieved by plotting the temporal trend of green spaces between 1972 and 2015 using the trend line tool of Microsoft Excel. Here, the overall temporal trend of green spaces (sqm) for Ibadan metropolis as a whole and the temporal trend of green spaces (sqm) at the neighbourhood level from 1972 – 2015, were plotted.

FINDINGS AND DISCUSSION

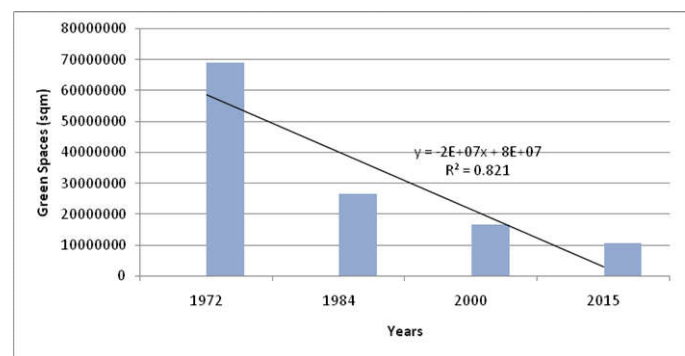
Spatio-Temporal Patterns of Green Spaces: This section presents the results of the analyses of the spatio - temporal patterns of green spaces in Ibadan metropolis. Results and findings are provided for the following: (1) Temporal trend of green spaces from 1972- 2015; and (2) Spatial pattern of green spaces from 1972 – 2015.

Temporal trend of green spaces FOR Ibadan Metropolis from 1972- 2015: The total area of green spaces in square meters for each periodic year was plotted on a graph to derive a trend line. The result showed the total green spaces as follows:

1972: 68,610,542sqm. (6,861.05ha.)
 1984: 26,086,573sqm (2,608.66ha.)
 2000: 16,219,748sqm (1,621.97ha.)
 2015: 9,985,743sqm.(998.57ha.)

The slope of the trend for Ibadan metropolis is negative (i.e. $y = -2E+07X+8E+07$) indicating a decreasing trend in the extent of green spaces from 1970 to 2015 (Figure 2). Therefore, the test of hypothesis which says green spaces decreased significantly with time is supported by the trend analysis. Remarkably the years 2000 and 2015 marked critical turning points in the fortunes of greening. Information gathered from the FGD showed that the late 90s and early 2000s were characterized by controlled urban development in Ibadan metropolis. In other words, as construction works and other human activities increased, there was a greater awareness of the importance of green spaces, hence; green spaces were deliberately accommodated in the physical development

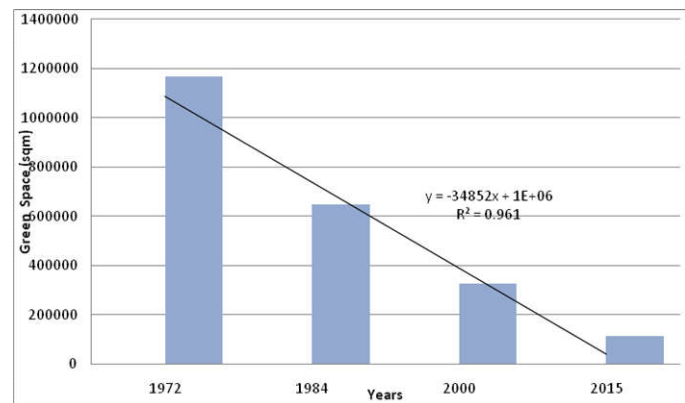
process. The increase in greening was, however, not universal as many communities, particularly in the traditional core of the city continued to suffer rapid de-greening. Some respondents believed that the climatic conditions were favorable between 1985 and 2000 and as such regardless the pressure on green spaces there was quick regrowth that minimized the effects of the de greening process going on. Furthermore, the year 2015 was almost in all cases a turning point for the worse. This indicates that, in Ibadan metropolis, greening is rapidly losing out to de-greening in this third decade of the 21st century. The year 2015 was a year of drastic development motivated by people’s eagerness to own their personal houses and businesses (FGD 2019). Some attributed the drastic reduction in this period to population pressure and the need for land for accommodation and commercial purposes.



Source: Author Analysis

Figure 2. Total Temporal Trend of Green Spaces in Ibadan Metropolis (1972 -2015)

Temporal trend in green spaces for selected neighbourhoods (1972 - 2015): The neighbourhoods selected had some unique characteristics. In addition, the selected neighbourhoods reflect the differences between the traditional core/ semi modern areas (Adekile, Mokola); institutional/Government Reserved Areas (University of Ibadan, Jericho GRA); and the more recent and suburban areas of the city (Apata, Molete). The green spaces in square meters for each neighbourhood were plotted for the study period to derive a trend line. The slope of the trend for Adekile is negative ($y = -348520x + 1E+06$; $R^2=0.9617$) indicating a decreasing trend in the spatial coverage of green spaces from 1972 to 2015. Green spaces in Adekile neighbourhood, for instance, started to decrease from about 450, 000 m² (45ha.) in 1972 and then to about 120,000m² (12ha.) in 1984 (Figure 3).

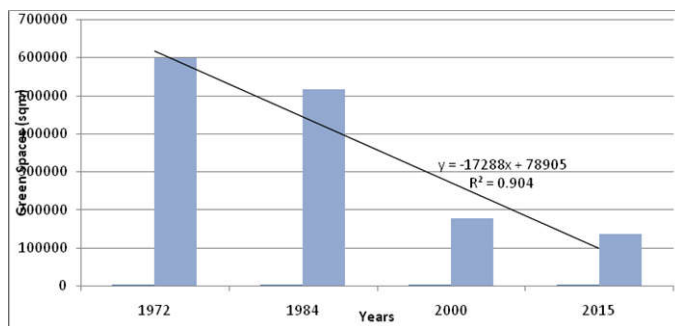


Source: Author Analysis

Figure 3. Temporal Trend of Green Spaces in Adekile Neighbourhood (1972 -2015)

Then, a drastic decline occurred in 2000 when the coverage dropped to only about 50,000m² (5ha.). Thereafter, there was a drastic decline to less than 20,000m² (2ha.) in 2015. Findings from the FGD 2017 support this trend in that it was reported that in the 1980s there was significant physical development which brought about reduction in green spaces. Furthermore, findings from the FGD 2017 also confirm the trend depicted in the graph (Figure 3) showing the drastic reduction between 2000 and 2015. According to the FGD report, the years since 2000 are characterized by rapid physical development such as road construction, siting of petrol filling stations etc.

Another distinct pattern was observed in some neighbourhoods where the size of green spaces started to decline gradually and then there was a sharp decline which later readjusted to a slower rate of decline. For example, Mokola area today is known as a mixed land use area comprising residential and commercial land uses. It is one of the major transition zones in Ibadan. Therefore, it is not surprising that the green space had reduced from 600,000m² (60ha.) in 1972 to 520,000 m² or (52ha.) in 1984 though the decline was gradual. The rate of decline became very rapid between 1984 and 2000 in which Mokola was left with a green land mass of less than 200,000m² (20ha.). Thereafter, the decline gathered speed and has continued until the present. The transition years can be observed in the graph in Figure 4. The slope of the trend for Mokola is negative ($y = -172880x + 789050$; $R^2 = 0.904$) indicating a decreasing trend in the size of green spaces from 1972 to 2015. Findings during the FGD analysis showed that green spaces gave way to urban development such as filling stations, parks, shops, houses etc. One of the characteristics of an institutional land use is green spaces made up of a variety of lawns, sports fields, hedges, parks, and gardens. The University of Ibadan is characterized by trees, wetlands, gardens, farmlands and grass lawns in large numbers. However, the graph in figure 5 shows that between 1972 and 1984, the University had minimal loss of green spaces. This was a period marked by a lot of physical development and expansion of farming activities by students in the Faculty of Agriculture (FGD 2017).

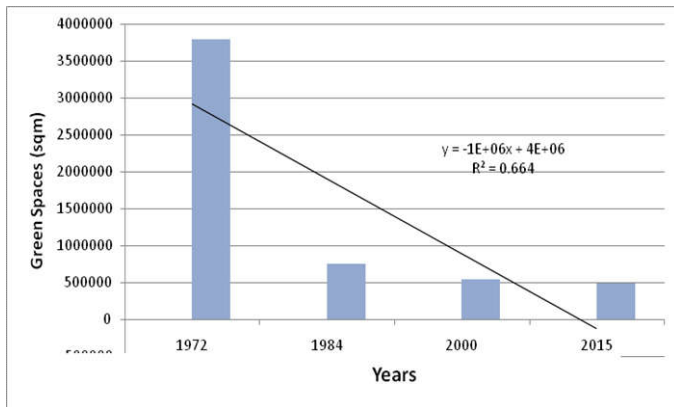


Source: Author Analysis

Figure 4. Temporal Trend of Green Spaces in Mokola Neighbourhood (1972 -2015)

The decline continued but less steeply after 1984. Indeed, there was only a comparatively slight decline of about 100,000m² (10ha.) between 2000 and 2015. The gradual decline could be explained in terms of the abandonment of University farmlands which reverted to bush, and poor maintenance of open spaces which became overgrown with bush. But the University also planted exotic tree species in some areas, which increased the green spaces. However, there are physical developments today such as research centers, institutes, and the international conference center among others, which have

encroached further into the existing green spaces. The slope of the trend for the University of Ibadan is negative ($y = -1E+06x + 4E+06; R^2 = 0.6646$) (Fig 5)

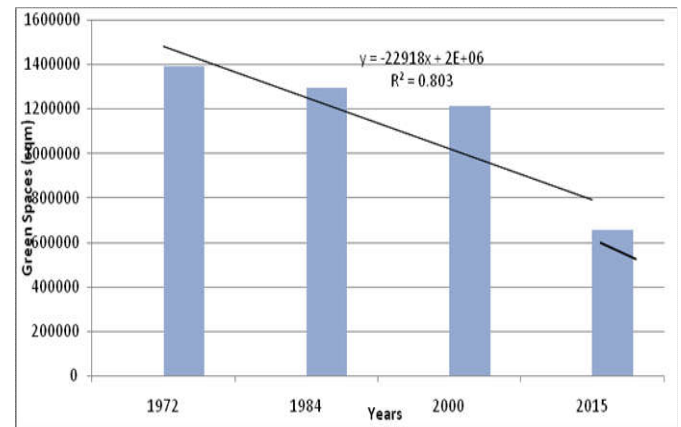


Source: Author Analysis.

Figure 5. Temporal Trend of Occurrence of Green Spaces, University of Ibadan (1972 -2015)

Also, a unique temporal pattern of green spaces observed is clearly depicted by the graph for Apata locality shown in Figure 6. Apata is located at the urban fringe of the city, that is, at the outskirts of the city. Therefore, development in most cases is driven by population pressure from the city center. Pressure came from the desire of the average Nigerian, particularly, the Yoruba, to build their own houses (FGD 2017). Therefore, Apata is one of the areas in Ibadan that have attracted the influx of people in search of land for residential buildings. But, in spite of this influx of people, de-greening was very slow for a long time. The area is surrounded by hills and this might have been responsible for the minimal reduction in green spaces as some areas are not suitable for development. Green space reduction was observed to be 1,200,000 m² (120ha.) between 1972 and 1984. The green land mass declined only slightly to about 1,000,000m² (100ha.) in 2000. However, there was a drastic decline between 2000 and 2015. This sharp decline could be as a result of increasing demand for land for commercial and residential purposes (FGD 2017). Therefore, the slope of the trend for Apata is negative ($y = -229160x + 2E+06; R^2; 0.8032$) (Fig 6).

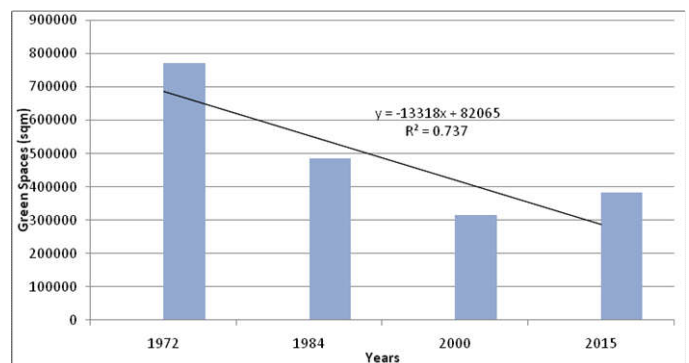
was a long period characterized by a steep drastic decline before there was a turnaround. Moleteneighbourhood is known as a residential area but with light commercial activities. Between 1972 and 1984, farmlands were noticeable in Molet area as people were still concentrated in the core parts of Ibadan.



Source: Author Analysis

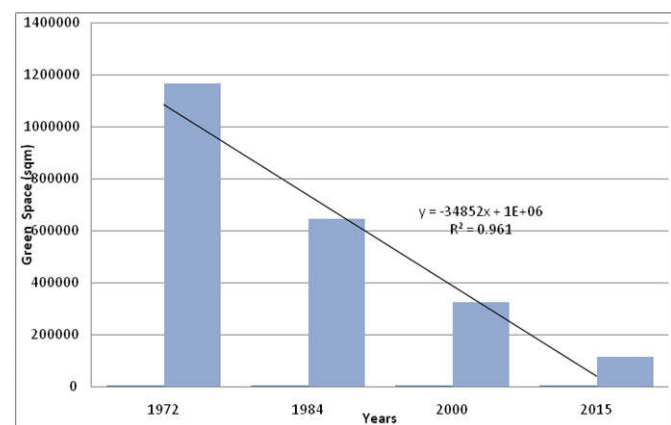
Figure 6. Temporal Trend of Green Spaces in Apata Neighbourhood (1972 -2015)

But then, people began to relocate to Molet for two main reasons: (i) to be close to their farms; and (ii) to escape the increasing housing congestion in the traditional core of the city (FDG 2017). Between 2000 and 2015, the pressure from the core areas of the city allowed physical development in the form of schools, residential houses, shops, markets etc. and this led to an alternating fall and rise of green spaces of about 300,000m² (30ha.). Reports from FGD showed that people's ties with the core areas of Ibadan were very strong due to commercial reasons and social engagements, hence the alternating rise and fall of green spaces. However, the slope of the trend for Molet is negative ($y = -133180x + 820650; R^2 = 0.7375$) from 1972 to 2015 (Fig 7).



Source: Author Analysis

Figure 7. Temporal Trend of Occurrence of Green Spaces, Molet Neighbourhood (1972 -2015)



Source: Author Analysis

Figure 6. Temporal Trend of Green Spaces in Jericho GRA Neighbourhood (1972 -2015)

Interestingly, there were also temporal patterns of green space occurrence that displayed a rather slow decline for a long period and suddenly the rate of decline picked up and there

Spatial Patterns of Green Spaces: Table 4.1 presents a summary of Global Moran's I analysis carried out for 1972, 1984, 2000 and 2015 respectively. There was a significant clustering of green spaces in 1972 ($I: 0.348091; z: 6.365863; p: 0.000000$), 1984 ($I: 0.452642; z: 8.099308; p: 0.000000$), 2000 ($I: 0.313010; z: 5.781242; p: 0.000000$) and 2015 ($I: 0.229712; z \text{ score}; 4.355389; p: 0.000013$). The implication is that given the Moran's Index value and the z-score of 6.365863 for 1972, there was a less than 1% likelihood that a clustered pattern could have occurred by a random chance. In

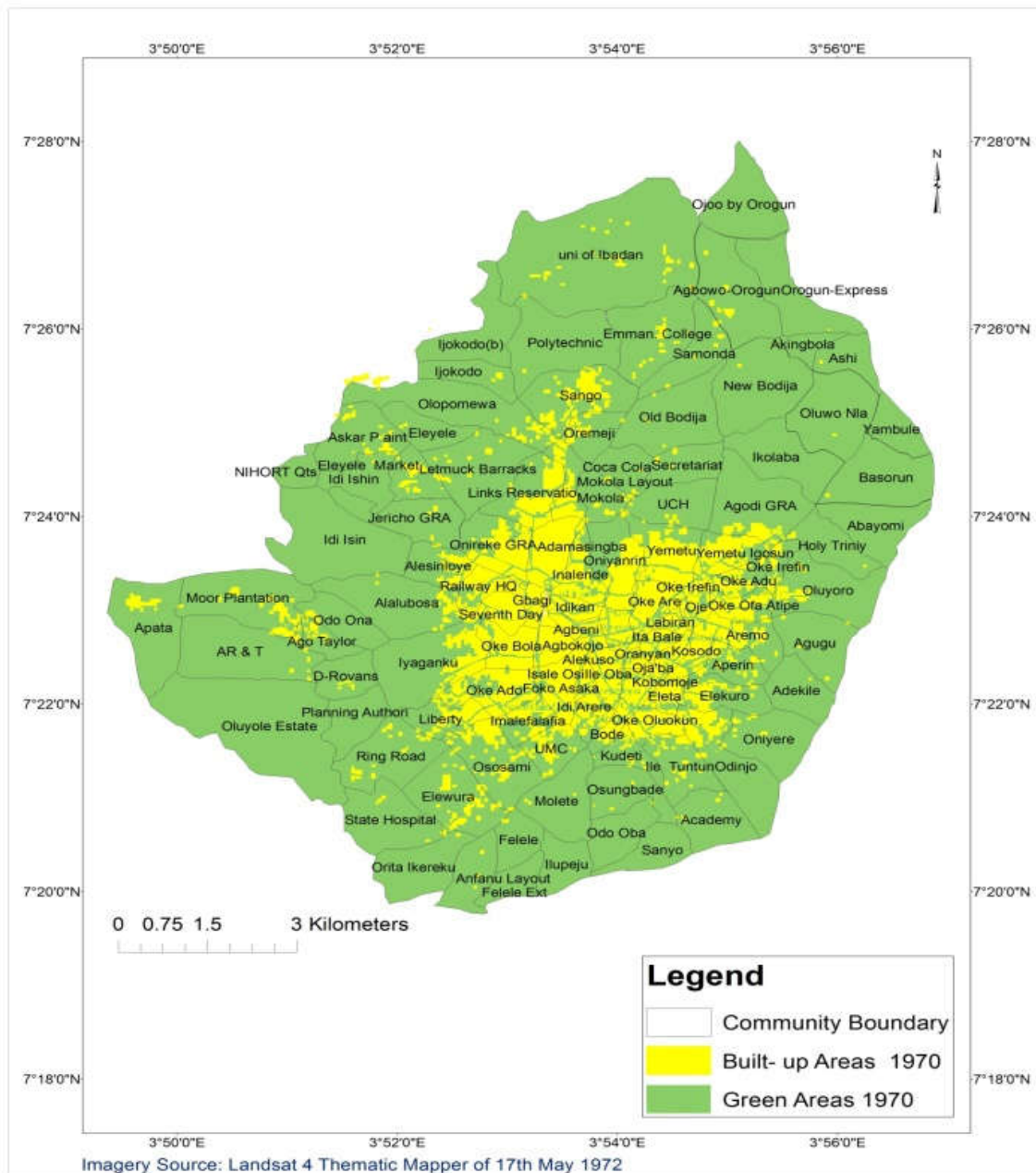
other words, localities with more green spaces were found together and localities with little or no green spaces also occurred together. However, from the cartographic mapping, clustering patterns were obvious for 1984, 2000 and 2015 only. This justifies Tobler’s first law of geography which states ‘everything is related to everything else but near things are more related than distant things (Tobler, 1970; p236).

by 1972. The decrease was spreading outwardly from the traditional core areas of Ibadan. Physical development experienced in this period was characterized by modern structures. From the area measurements, twenty (20) neighbourhoods each had less than 10,000m² (1ha.) of green spaces in 1972. Examples include Idi Arere, Ile Oba, Oranyan, Imalefalafia, IsaleOsi, Popo Yemoja, Kosodo, Agbede, and

Table 4. Summary of Global Moran's I Analysis

Year	Moran's Index	z-score	p-value	Remark
1972	0.348091	6.365863	0.000000	Clustered
1984	0.452642	8.099308	0.000000	Clustered
2000	0.313010	5.781242	0.000000	Clustered
2015	0.229717	4.355389	0.000013	Clustered

Source: Author



Source: Author Analysis

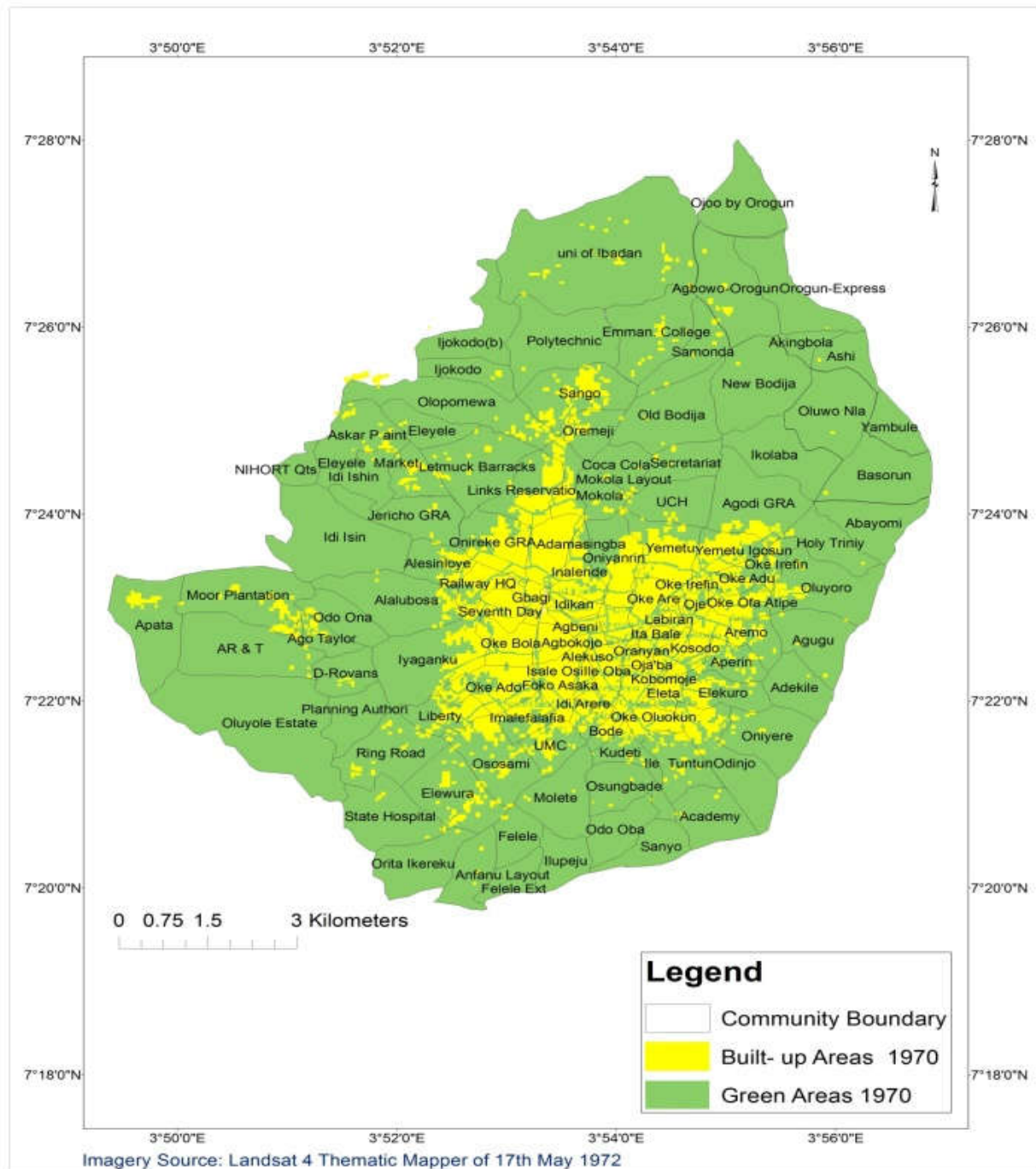
Figure 8. Spatial Distribution of Green Spaces in Ibadan Metropolis for 1972 (proxy for 1970)

Pattern of green spaces in 1972: The spatial pattern of green spaces for 1972 is presented in Figure 8. From the image analysis, there had been a significant decline in green spaces

Adodo. Some neighbourhoods are in the core areas of the metropolis. Twelve (12) neighbourhoods had green spaces between 10,000m² (1ha.) and 100,000m² (10ha.) in size as of

1972. Examples are Bode, Aperin, Kudeti, Oke Bola, Elekuro, Aremo, and Kobomoje, etc. Furthermore, Fifty-three (53) neighbourhoods were in the category 100,000m² - 1,000,000m² (i.e. 10 -100ha.) while nineteen (19) neighbourhoods were in the

spatial distribution of green spaces in 1984. From the green space area measurements, the number of neighbourhoods with less than 10,000 m² (1ha.) of green spaces had increased from twenty (20) as in 1972 to twenty-three (23) neighbourhoods by



Source: Author Analysis

Figure 8. Spatial Distribution of Green Spaces in Ibadan Metropolis for 1972 (proxy for 1970)

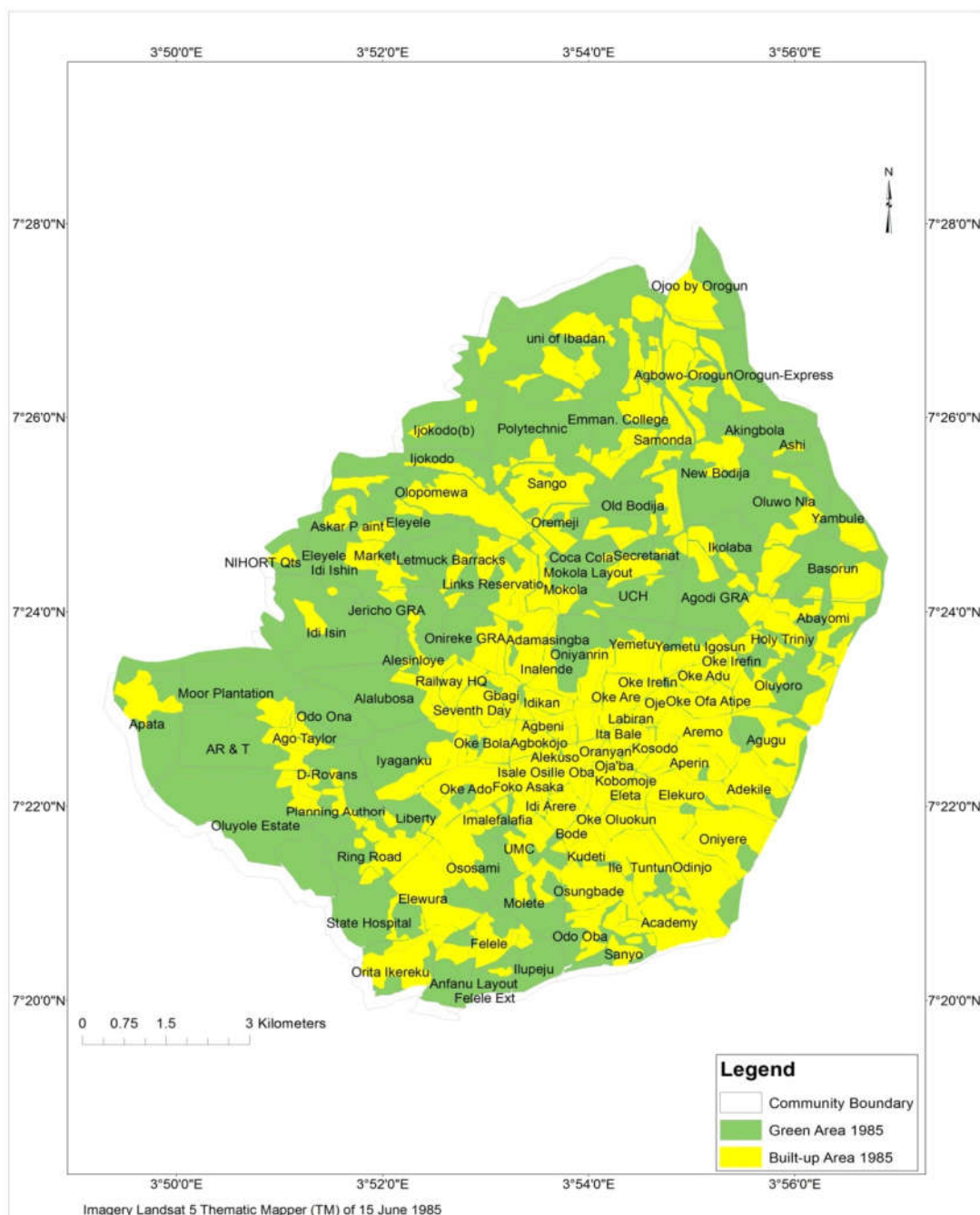
category 1,000,000m² - 3, 900,000m² (i.e. 100 – 390ha.). Some of these neighbourhoods included Old Bodija, Onireke GRA, Ikolaba, Jericho, etc. The major changes to green spaces were noticed in the core areas and their surroundings except for areas that have landmark like institutions and offices. Furthermore, by 1972, it was observed from the map analysis that the city center was getting congested which meant that people would have to migrate to other areas for shelter and work.

Pattern of green spaces in 1984: By 1984, there had been a significant reduction in green spaces. Figure 9 shows the

1984. The additional three (3) neighbourhoods were Agbokojo, UMC and Aperin. Twelve (12) neighbourhoods had their green spaces between 10,000 m² and 100,000 m² (i.e. between 1ha. And 10ha.) as of 1984. For instance, Bode which was estimated at 31,400 m² (3.1ha.) in 1972 had reduced to 12000 m² (1.2ha.) by 1984; Kudeti which was estimated at 54,800 m² (5.48ha.) had reduced to 20,200m² (2.02ha.) and Osungbade which was estimated at 93,800 m² (9.38ha.) had reduced to 23,400m² (2.34ha.). Also, fifty-nine (59) neighbourhoods were in the category 100,000 m² - 1,000,000 m² (10 -100ha.) in 1984 as compared to the 53 neighbourhoods counted for 1972. This shows a reduction in green spaces in some neighbourhoods

between 1972 and 1984. Some of these neighbourhoods included Ashi, Odo-oba, and Orogun-Ojoo. Furthermore, only four (4) neighbourhoods were in the 1,000,000 m² - 3,900,000 m² (100-390ha.) category as compared to the 19 neighbourhoods

Oniyanrin, Foko, Asaka, Onireke etc.; (ii) some neighbourhoods were government reserved areas, for instance, Letmuck Barracks, Iyaganku GRA, Jericho GRA; and (iii) low-density areas like housing estates, institutions,



Source: Author Analysis, 2019

Figure 9. Spatial distribution of Green Spaces in 1984 (proxy for 1985)

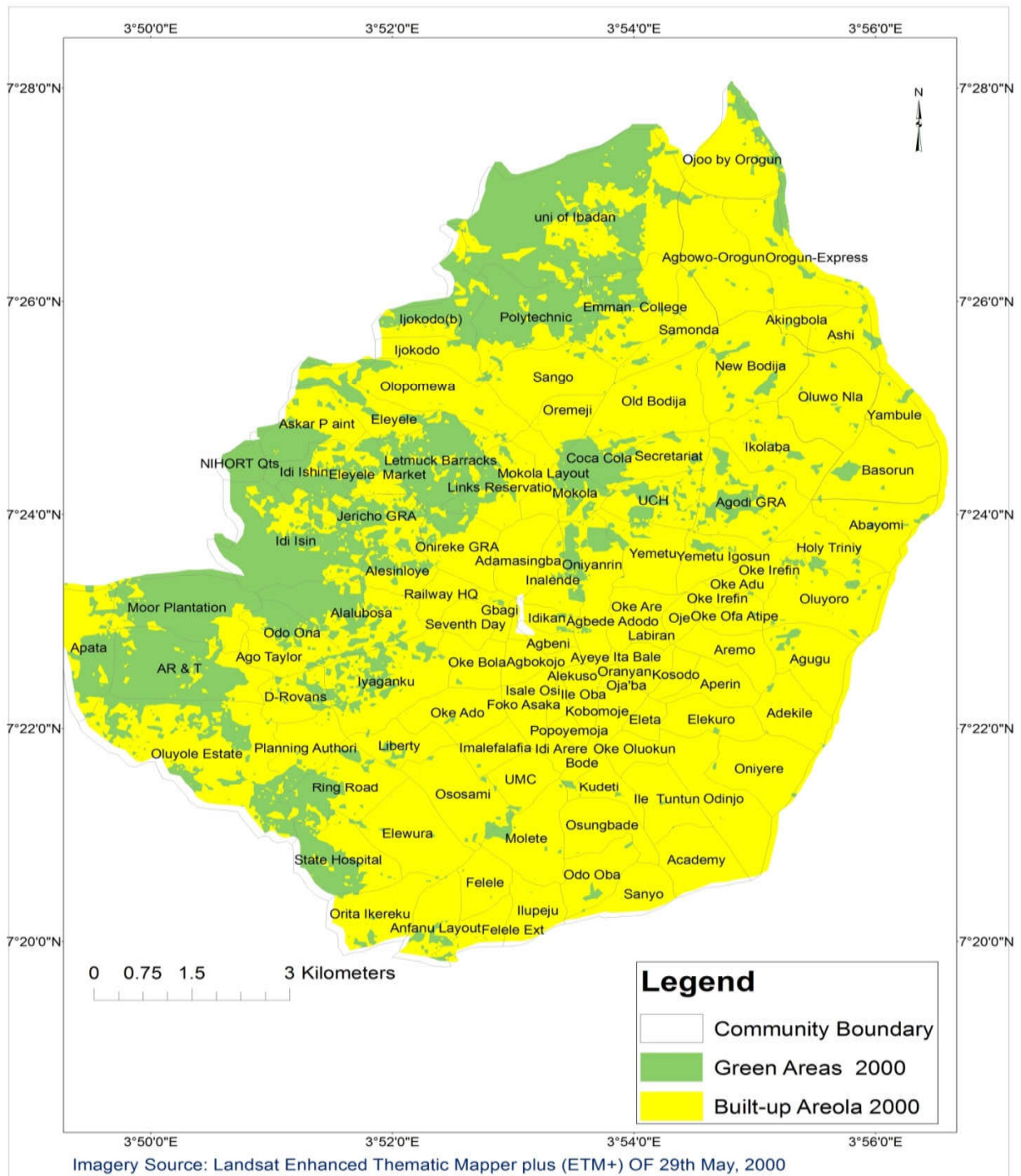
recorded in 1972. Findings from the FGD revealed that the period between mid-1970s and mid-1980s was a period of economic boom for the country as well as for the people of the metropolis then in terms of trade and commerce. As such accelerated physical developments were experienced in this period which led to a significant reduction in green spaces (FGD 2019). However, some areas still maintained their green spaces or experienced insignificant depletion of their green spaces between 1984 and 2000. According to findings from the FGD this was partly due to (i) the presence of the Ogunpa water canal along certain neighbourhoods contributed to the greenness of those areas still date for example, Arere,

and government offices still experienced very slow pace of green space depletion.

Pattern of green spaces in 2000: One expected a drastic reduction in green spaces between 2000 and 2015 in the metropolis and from the map in Figure 10, this was the case in some areas. For instance, there was an increase of neighbourhoods that had less than 10,000 m² (1ha.) from twenty-three (23) in 1984 to thirty (30) by 2000. By 2000 there were two other neighbourhoods added to those in the range between 10,000m² and 100,000m² (1ha. and 10ha.). It is,

however, important to note here that while some neighbourhoods continued to decline in green space area, some increased over the years particularly those along the wet Ogunpa canal. Findings from the FGD showed that increase in the upgrading of residential areas into estates brought about

with the largest expanse of green spaces, forexample, IAR& T, Moor Plantation etc. But such green spaces occupied a small portion of the city landscape in 2000 as compared to the situation in1985 (Figure 12). The city traditional core center continued to experience de-greening in the year 2000.



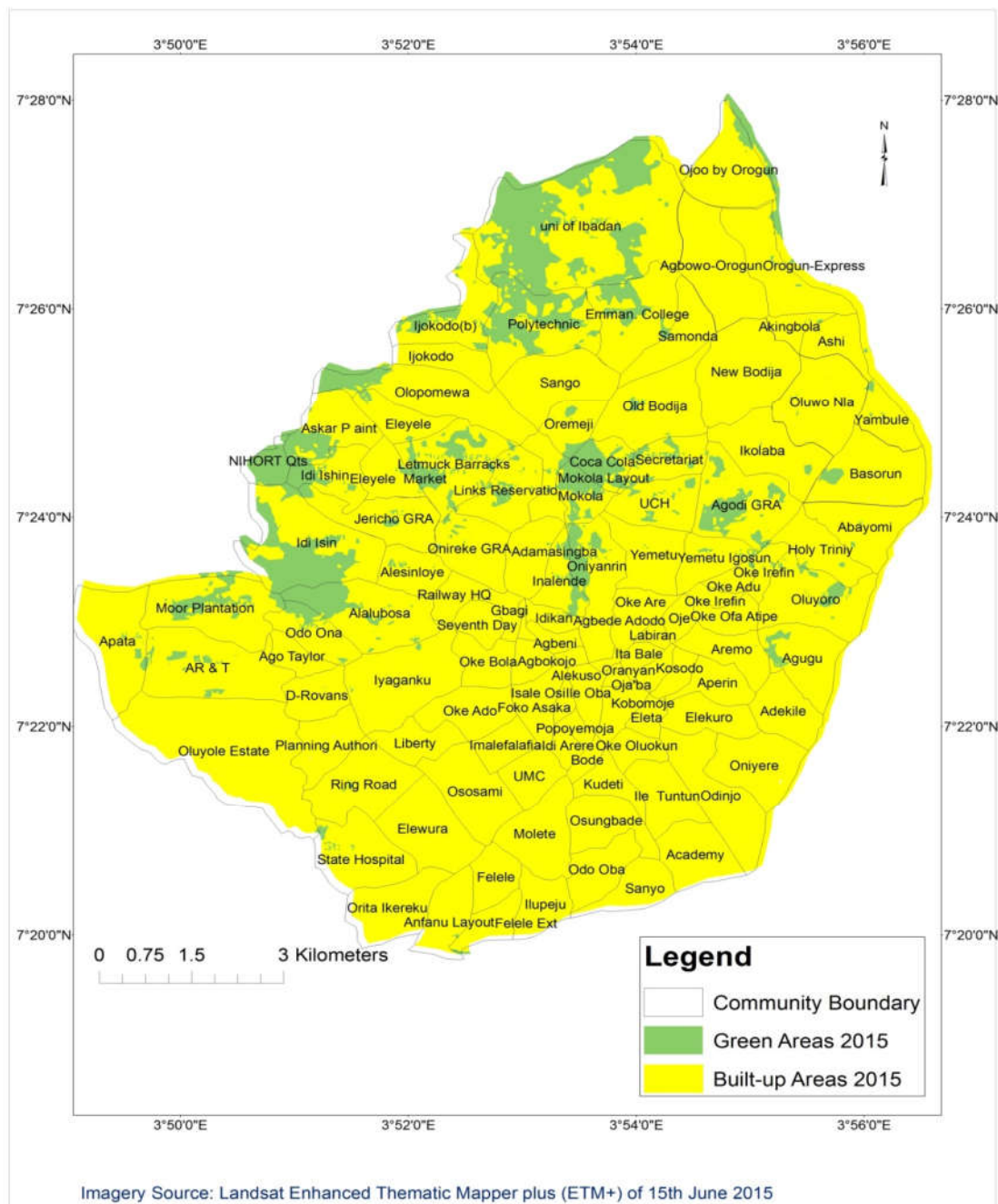
Source: Author Analysis, 2019 **Figure 10. Spatial distribution of Green Spaces in 2000**

Furthermore, there was a drastic decrease in the number of neighbourhoods in the green space range 100,000m² and 1,000,000m² (10 -100ha.) from fifty-nine (59) in 1984 to thirty-nine (39) in 2000. It was observed from the image analysis that open spaces in some neighbourhoods reduced significantly even though they were still within this category. As can be seen in Figure 10 institutional land use accounted for neighbourhoods

Pattern of green spaces in 2015: Figure 11 shows that green spaces remained sparsely distributed as of 2015 while areas with large volumes of green spaces were still linked with government reserved areas (GRA). But, significantly, some new areas emerged with small pockets of green space that were not there before. Could it be that the green movement had started by 2015? Or could it be that residents had become more

aware of the benefits and importance of green spaces? From the FGD conducted in these neighbourhoods, it is clear that the metropolis is now congested and green spaces are found in fenced areas, in compounds and in the interior parts of the neighbourhoods which are not suitable for construction. However, findings also showed that a number of single lane

however, exceptions in certain areas. For example, areas close to the river channels (e.g. Ogunpa canal, Ona River etc.) and Government Reserved Areas remained green over the years. The GRAs suffered repeated deregulation especially under the military governments but, they still have a relatively higher proportion of green spaces compared to other sections of the



Source: Author Analysis, 2019

Figure 11. Spatial distribution of Green Spaces in 2015

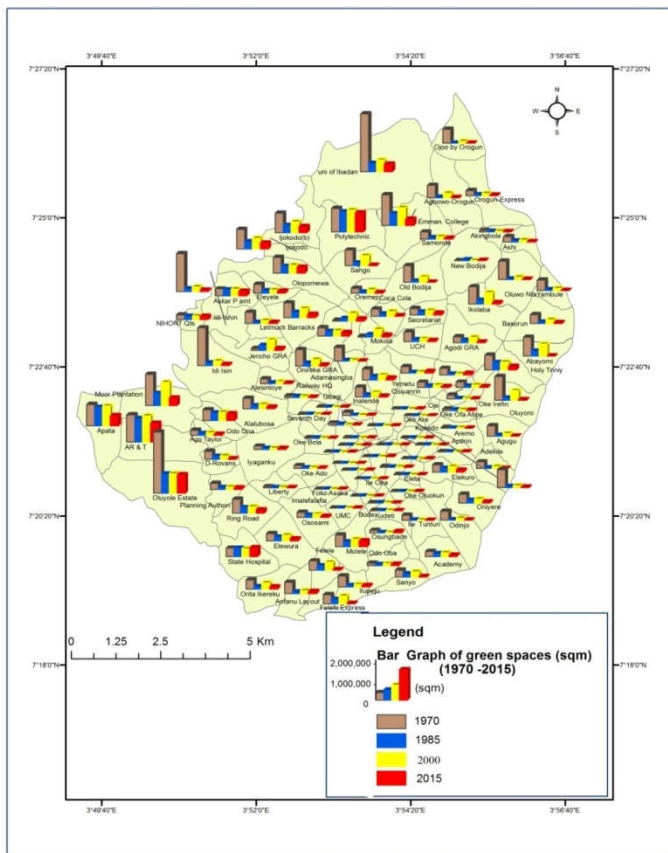
and dual carriage roads were constructed between 2000 and 2015 during the Alao-Akala and Ajimobi administrations. The road construction cleared some erstwhile green spaces. From the green space measurement carried out the majority of the neighbourhoods now have green spaces within the range 10,000m² to 100,000m² (1ha. – 10ha). In other words, small sized green spaces now predominate in the metropolis. In summary, therefore, the spatial pattern of green spaces clearly portrayed a declining trend in coverage from 1955 to 2015. The main factor responsible was urbanization characterized by the construction of residential, commercial and industrial buildings, roads and other social infrastructures. There were,

city up till today. Another crucial observation was the impact of the establishment of an institution, the University of Ibadan, and the Government Secretariat in shaping the green space distribution. For instance, as early as the 1950s, areas around Agbowo, Orogun, Ojoo, and Samonda were already under significant pressure for expansion. Areas along Old Bodija began to spring up fast in the 60s which could be attributed to the presence of major landmarks such as the Secretariat and the University institution. Lastly, decreases in green space sizes between intervals were as follows:

- 1972-1984: 42,420,000sqm (4,242ha.);
- 1984-2000: 9,880,000sqm (988ha.); and

2000-2015: 6 230,000sqm (623ha).

Thus, the 1984 - 2000 period experienced the most significant reduction in green space. Figure 12 shows a graphical depiction of variations in neighbourhood green space losses, 1972- 2015.



Source: Author Analysis, 2019

Figure 12. Changes in Green Spaces from 1972 – 2015

Summary and Conclusion

Today, the unplanned traditional core areas of Ibadan show more scanty distribution of green spaces as compared to the outer areas because of the densification of buildings. Neighbourhoods such as Moor Plantation, IAR & T, Iyaganku, Oluyole estate still have open spaces with dense green vegetation. These areas were once either Government Reserved Areas or parts of the modern core city fringes that could still accommodate settlers at that time and so reduced the number of people migrating far to the rural fringes of the metropolis. The presence of Ogunpa River channel contributed immensely to the preservation of green spaces in such areas as Oranyan, Foko, Asaka and Inalende. Lastly, it could be inferred from the FGD reports that the green space distribution pattern was more a function of the pattern of physical developments than a deliberate effort by the people to maintain the green spaces.

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