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Research Article

Keywords: Spatio-temporal, Built-up, Expansion, Suburb and Land use

Posted Date: April 23rd, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9212863/v1

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Additional Declarations: No competing interests reported.

SPATIO-TEMPORAL ANALYSIS OF BUILT-UP AREA EXPANSION IN SOUTH-WESTERN NIGERIAN CITY SUBURBS

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Abstract

This study analysed the spatiotemporal changes in the suburbs of South-Western Nigerian cities from 1998 to 2024, with the aim of informing land use management and enabling stakeholders to address associated physical planning challenges. Three state capitals and their suburbs were purposively selected for the study: Akure (Ilara-Mokin), Osogbo (Owode-Ede), and Ado-Ekiti (Iyin-Ekiti).The study employed ArcGIS Desktop 10.3, Erdas Imagine 2014, and ENVI 5.0 for Land use/land cover classification and change detection, and least square techniques were employed to analyze trends in land use/land cover changes.The results revealed a notable increase in built-up area expansion across all the suburbs: Ilara-Mokin (4.75km², 59.45%). Owode-Ede (8.68km², 84.03%), and Iyin-Ekiti (5.25km², 75.14%), while other land uses declined, negatively affecting agricultural land and farming. The least squares model revealed a positive linear relationship between year (x) and built-up area expansion(y) as follows: Ilara-Mokin, y=1.63 + 0.155x, y=1.35 + 0.326x. and Iyin-Ekitiy= 1.17 + 0.155x,indicating an increasing trend in built-up area expansion between 1998 and 2024.The study concludes that the built-up expansion in the suburbs is happening at an unprecedented rate, resulting in the decline of other land uses, which may affect the livelihood of suburban dwellers who depend on agriculture. Therefore, proactive planning procedures are recommended to mitigate the potential negative consequences of the built-up area expansion in the suburbs.

Keywords: Spatio-temporal, Built-up, Expansion, Suburb and Land use

1 Introduction

Urbanization is unprecedented around the globe [1, 2]. It has caused noticeable changes in various land uses and, consequently, built-up expansion in the suburbs of both developed and developing nations. One of the major underlying factors of suburban expansion is the rapid influx of people or migrants from rural or urban areas into cities or suburbs.The growth of cities has influenced land uses in the suburbs. Traditionally, suburban land use was known for being agricultural, vegetative, and less populated, but it has changed to include land uses like

commercial and residential areas, coupled with a rapid increase in population.One of the important forces driving urbanization is migration. Rapid migration and urbanization have impacts on infrastructural facilities, economic activities, employment, security, and land, among others [3]. Land is one of the resources that suffer the most as a result of urbanization, because demand for land tends to be high in suburban areas, often surpassing supply [4]. People migrate from rural areas to seek a better life in the city and often resolve to reside in the suburbs, where accommodation is cheaper and land is affordable [5]. Therefore, built-up expansion is the consequence of the complex interactions between humans and their physical environment over time[6].As revealed by Landsat imageries over the years by several authors [7, 8,9, 10], in most cases, vegetative land, farmland, and forests were converted to built-up lands, such as housing, road construction, and commercial purposes, among others.Furthermore, the expensive lifestyle in the city has forced middle and low-income earners to relocate to the suburbs, where land is available, affordable, and the cost of living is relatively low [11]. This relocation to the suburbs has a potential impact on built-up area expansion, social, economic, and environmental sustainability in the suburbs. Therefore, this study analysed built-up area expansion in relation to time in the suburbs of South-Western Nigerian Cities with the view of determining the impact of the expansion on suburban dwellers and other land uses. This will inform policy-making decisions on physical planning in the suburbs of south-western Nigerian cities, which will protect the interests of suburb dwellers as well as promote sustainable development in the suburbs.

2 Literature Review

2.1 Central Place Theory

Central place theory was given by [12]. Central Place Theory is a highly regarded concept that explains the spatial organisation and distribution of human settlements based on population size and distance between them. Christaller's 1932 dissertation, 'The Structure of Settlements in Southern Germany,' submitted to the University of Erlangen and published in 1933, revealed a regular pattern in settlement distribution despite their seemingly random placement. He identified a relationship between settlement size, distribution, and number, coining it a 'spatial economic geographical law' or 'the laws of geography of settlements'. His research, focused on Southern Germany, analysed the connections between settlements of varying sizes, their

economic activities, and population. Central Place Theory explains: i. the correlation between city size, number, and geographic distribution; ii. a central place's role in supplying goods and services to its market area; iii. the concept of range, which dictates that high-order settlements support unique activities. This theory remains crucial in urban planning, forming the basis for various modern theories.

The central place theory explains the hierarchical structure and functional relationships between urban centers and their surrounding suburbs. In this context, Akure, Osogbo, and Ado-Ekiti serve as central places, providing essential services such as markets for higher-order goods and job opportunities to suburban residents. The theory's traffic principle is evident in the study area, where suburbs like Owode-Ede and Ilara-Mokin are strategically located along major roads connecting important towns. Furthermore, the theory highlights the functional interdependence between cities and suburbs, with cities offering administrative functions, markets, and employment opportunities, while suburbs provide accessibility to land, affordability, and lower costs of living. The road network facilitates this interrelationship, enabling seamless interaction between urban centers and their surrounding suburbs. The good transportation and nearness of the suburbs to the city encourage migration to the suburbs subsequently resulting into built-up area expansion in the suburbs.

2.2 Empirical Review

In recent decades, the suburban growth is not onlyrelated to the population increase, socio-economic condition, but also the built-up area expansion, availability of urban facilities and accessibility to infrastructure[13]. Through development and spatial expansion, suburban expansion is the process of suburb becoming bigger by spreading outward to rural and urban areas alike. Wherethe expansion is towards the urban area conurbation mostly occurred [14]. The suburb expansion is influenced by many factors of which migration play an important role.The scholar [15] defined migration as a phenomenon that includes the simultaneous change of three major parameters; change of domicile that involves the crossing of a political or national border; change of the place where they carry out their professional activity (even if they practice the same profession); andchange of social relations (the entry into a new community). The definition of Sulima suggests that people change their location by moving to other areas where they work and do their business. This is the happening in the suburbs, people migrate to the suburb build

homes and carry out their businesses, all these activities taking place on land changes the landscape of the suburb, thereby expanding the built-up in the suburb. This expansion of the suburb can have both positive and negative effect in the suburbs. According to Xiaodong et al[16]the expansion is accompanied with considerable losses of biodiversity. Zhixi[17]opined that migration improve the economy of the receiving suburb while the effect also bring setback in some areas. The improvement is visible in area of trade, transportation businesses, among others while the setback areas are agricultural land loss, reduction in food production from the suburb, among others.

3 The Study Area

The study area is South-Western Nigeria. It comprises six states, namely Lagos, Ogun, Oyo, Osun, Ondo, and Ekiti States (Figure 1). It is also known as the South-West geographical zone of Nigeria. The region comprises both the western uplands and western coastal areas. South-Western Nigeria is located approximately between latitudes 6°2'0'' and 10°20'0'' north of the Equator and longitudes 2°30'0'' and 6°00'0'' east of the Greenwich meridian [18].

South-Western Nigeria has a total land area of 77,818 square kilometers and is bounded in the east by Edo and Delta States, in the north by Kwara and Kogi States, in the west by the Republic of Benin, and in the south by the Gulf of Guinea [19]. For this study, three out of the six South-Western states of Nigeria were purposively selected as the sampling frame.This is because of the large scope of the region, which may be difficult to capture in its entirety for the research. The selected states are Osun, Ondo, and Ekiti States, while the state capitals and selected suburbs of each was considered for the research work, specifically: Akure (Ilara-Mokin); Osogbo (Owode-Ede); and Ado-Ekiti (Iyin-Ekiti).

The locational attributes of the selected state capitals and their suburbs are as follows: Osogbo, the state capital of Osun State, is located at the following coordinate for its suburb: Owode-Ede: 7°04'39"N and 4°02'39"E. Akure, the state capital of Ondo State, has the following coordinate for its suburb: - Ilara-Mokin: 7°02'53"N and 5°00'52"E. Ado-Ekiti, the state capital of Ekiti State, has the followingcoordinate for its suburb:-Iyin-Ekiti: 7°03'94"N and 5°09'53"E (Author's work, 2024).

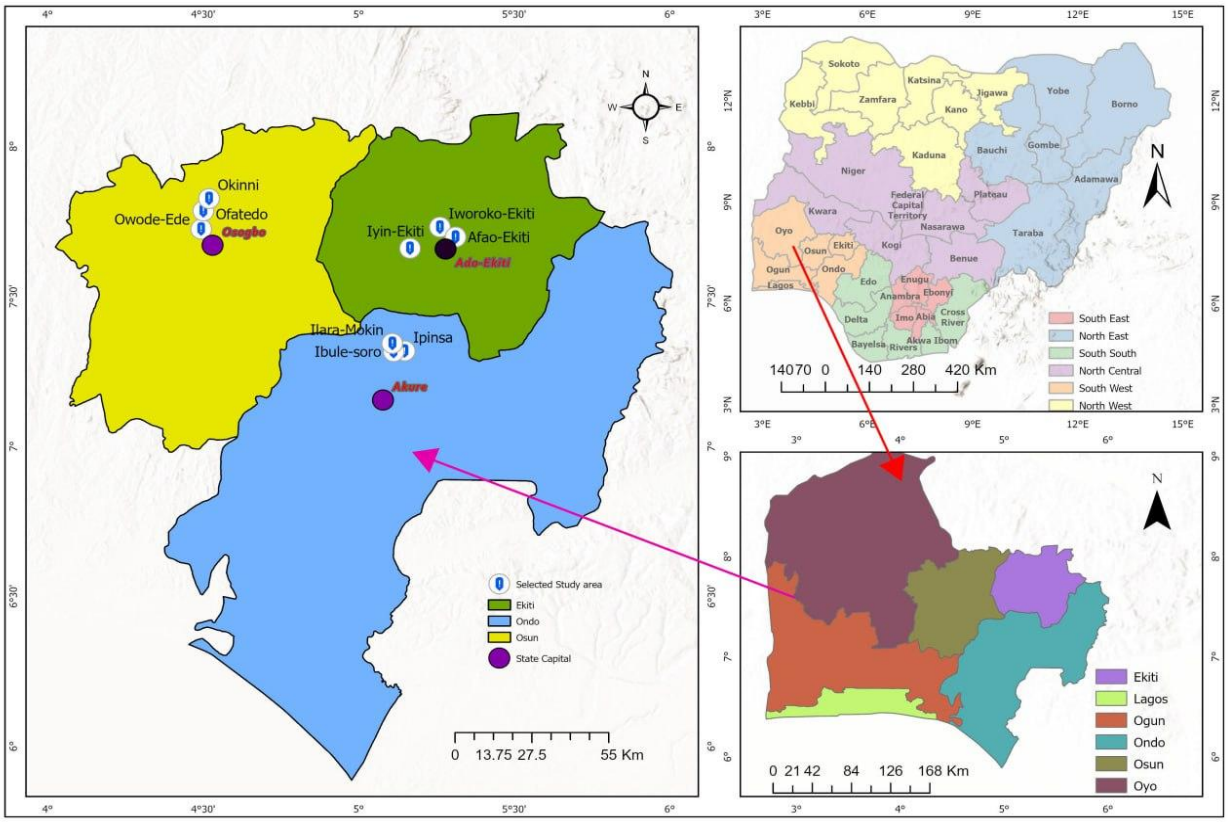


Figure 1 The Selected State, their Capital and Selected Suburbs
Inset: South-Western States within the Context of Nigeria
Source: Generated by the Author, 2025

4 Methodology

4.1 Sample frame and size

The sampling frame consists of the suburbs of South-Western Nigerian cities. Three states (Osun, Ekiti, and Ondo) were randomly selected from the six western states (Osun, Ondo, Ekiti, Lagos, Oyo, and Ogun) using balloting method. one suburb from each of the capitals of the three selected states (Osun, Ekiti, and Ondo) were used for this study. The state capitals and their corresponding selected suburbs are as follows: Akure (Ilara-Mokin), Osogbo (Owode-Ede), and Ado-Ekiti (Iyin-Ekiti). The suburbs were selected because of their proximity to the capitals and the intense migration they have experienced due to this closeness.

4.2 Sources of Data

The data used in this study comprised land cover change-related data sourced from Landsat. Landsat data from 1998 to 2024 were used to measure land cover changes and expansion variability between 1998 and 2024.The data collected comprised land cover imageries between

1998 and 2024, covering an area of km^2.The land cover imageries between 1998 and 2024 (in km^2) were downloaded from the United States Geological Survey (USGS) website (http://www.earthexplorer.usgs.gov). The details of the imageries and their properties are presented in Table 1.

Table 1: Data Images and Properties

Years of Images	Source	Path/row	Year/Date	Spatial Resolution
Landsat 8 OLI and TIRS	www.earthexplorer.usgs.gov	191 and 54	2024/ 30 March	30m Thermal
Landsat 8 OLI and TIRS+	www.earthexplorer.usgs.gov	191 and 54	2019/ 06 February	30m Thermal
Landsat 7 ETM+	www.earthexplorer.usgs.gov	191 and 54	2012/ 01 November	30m Multi Spectral
Landsat 7 ETM+	www.earthexplorer.usgs.gov	191 and 54	2005/ 05 August	30m resolution
Landsat 5 MSS	www.earthexplorer.usgs.gov	191 and 54	1998 08 August	30m resolution

Source: Author's Compilation (2024)

Note: The disparities in the imageries used are based on their technological advancement. The updated versions have better resolution, necessitating the change in the image used

4.3 Sampling and Analytical Technique

Landsat imageries were obtained to ascertain the land use/land cover changes that have occurred over time.ArcGIS Desktop 10.3, Erdas Imagine 2014, ENVI 5.0, and Microsoft Office were used for classification and change detection, and the results were presented in images. The results were also presented in tables for easy interpretation.

4.4 Image Classification and Analysis

The Landsat images were classified into feature classes based on the land-use/land-cover classification system (Level 1) proposed by Anderson [20]and modified by Salam [21]as described in Table 2. Hence, the Landsat images were classified into five modified classification categories: bare ground, water bodies, forests, vegetation/agriculture, and built-up areas, which were used for the study. The classification was done to identify various land-use/land-cover (LULC) classes relevant to the study. The images were classified using composite bands 5, 4, and 3. From the foregoing, LULC layers were digitised for change detection. This raster layer

was quantified using ERDAS Imagine's statistical tool. Additionally, the maximum likelihood supervised classification system was employed, as it facilitates the selection of pixels representing LULC relevant to the study. Consequently, this statistical analysis was performed on the five selected years of satellite images of the study area to determine land-use/land-cover changes over the 26-year period. However, the assessment of agricultural land/vegetation health was carried out with the aid of the Normalized Difference Vegetation Index (NDVI). This analysis is noted as one of the vegetation indices commonly employed for change detection in vegetation. The purpose of using NDVI was to determine the level of vulnerability and state of vegetation to anthropogenic activities. Thus, NDVI analysis was conducted using ERDAS Imagine, raster-based software.

Table 2: Land-Use/Land-Cover Classification System

Classes	Land use/cover	Color Code
Bare ground	Sandy area, transitional area, bare/expected, bare exposed rock, beaches and open land	Gray
Water body	Stream, lakes, reservoirs, bays, canals, ponds and estuaries	Dark blue
Vegetation/Agricultural land	Cropland, pasture, vineyard, farmland	Yellow
Forest	Forest land, shrub and mixed forest land	Green
Built-up	Buildings and roads, commercial, industrial, transport and communication infrastructure and utilities	Red

Source: Anderson, (1972)

4.5 The Exponential Smoothing

The exponential smoothing and least squares regression technique were employed for the analysis of the trend of built-up area expansion in the study area from 1998 to 2024. Time-series data are usually arranged in regular time periods e.g on monthly or quarterly or yearly basis. The mathematical characteristics of the exponential smoothing trend analysis are given as:

$$\mathbf{Tp = k\,(Ø) + (1- k)\,(\beta)} \qquad \mathbf{(i)}$$

Where:

Tp = new trend or predicted trend value.

K= smoothing constant.

Ø = actual value for current period.

β = trend value for the last period. (1)

In this technique, the trend value for the first data is the same as the value for the first raw data. For subsequent data, the trend value is calculated using the formula. The commonly used smoothing constant ranges from 0.3 to 0.5, and a smoothing constant of 0.3 was used in this study, the exponential smoothing technique actually helped to smoothen pattern of built-up area expansion trend (bring out the increase or declining trend of built-up area expansion).

4.6 The Least-Square Technique

This geo-static was used in establishing the nature (fluctuation pattern and trend) of built-up area expansion. It was used to obtain regression line that gave the clearest picture of the increase or declining pattern of built-up area. It was, therefore, used in determining the linear relationship between yearly built-up area expansions. The mathematical characteristic of the least-square technique is given as:

Y= a + bx **(ii)**

Where:

Y = Predicted future built-up area expansion

b = Regression coefficient, constant, r depcting the amount of change in y corresponding to a change of one (7) units in x (the years).

X = Year

a = the slope intercept, the valus of Y when x = 0

5 Result and Discussion

This section discusses the result of the findings on built up area expansion in South-Western Nigeria Suburbs. It covers area such as, trend in built-up area expansion over time as well as changes in other land uses, couple with the effect of these changes on the suburb dwellers.

5.1 Land-Use/Land-Cover Distribution of Ilara-Mokin from 1998-2024

The statistics of the land-use/land-cover distribution for each study year of Ilara-Mokin are presented in Table 3 and Figure 2.

Table 3: Land-Use/Land-Cover Distribution in Ilara-Mokin from 1998-2024

Land-use/Land-cover class	Year 1998		Year 2005		Year 2012		Year 2019		Year 2024	
	Area (km^2)	Area %	Area (km^2)	Area %	Area (km^2)	Area %	Area (km^2)	Area %	Area (km^2)	Area %
Built – Up area	0.59	7.38	1.58	19.78	1.67	20.90	3.53	44.18	4.75	59.45
Vegetation/ Agriculture	3.21	40.18	0.28	3.50	1.00	12.52	2.30	28.79	0.54	6.76
Forest	1.54	19.27	4.43	55.44	5.30	66.33	2.05	25.65	2.70	33.79
Water Body	0.38	4.76	0.01	0.13	0.00	0.00	0.02	0.25	0.00	0.00
Bare ground	2.27	28.41	1.69	21.15	0.02	0.25	0.09	1.13	0.00	0.00
Total	**7.99**	**100.00**	**7.99**	**100.00**	**7.99**	**100.00**	**7.99**	**100.00**	**7.99**	**100.00**

Source: Author's Work (2024)

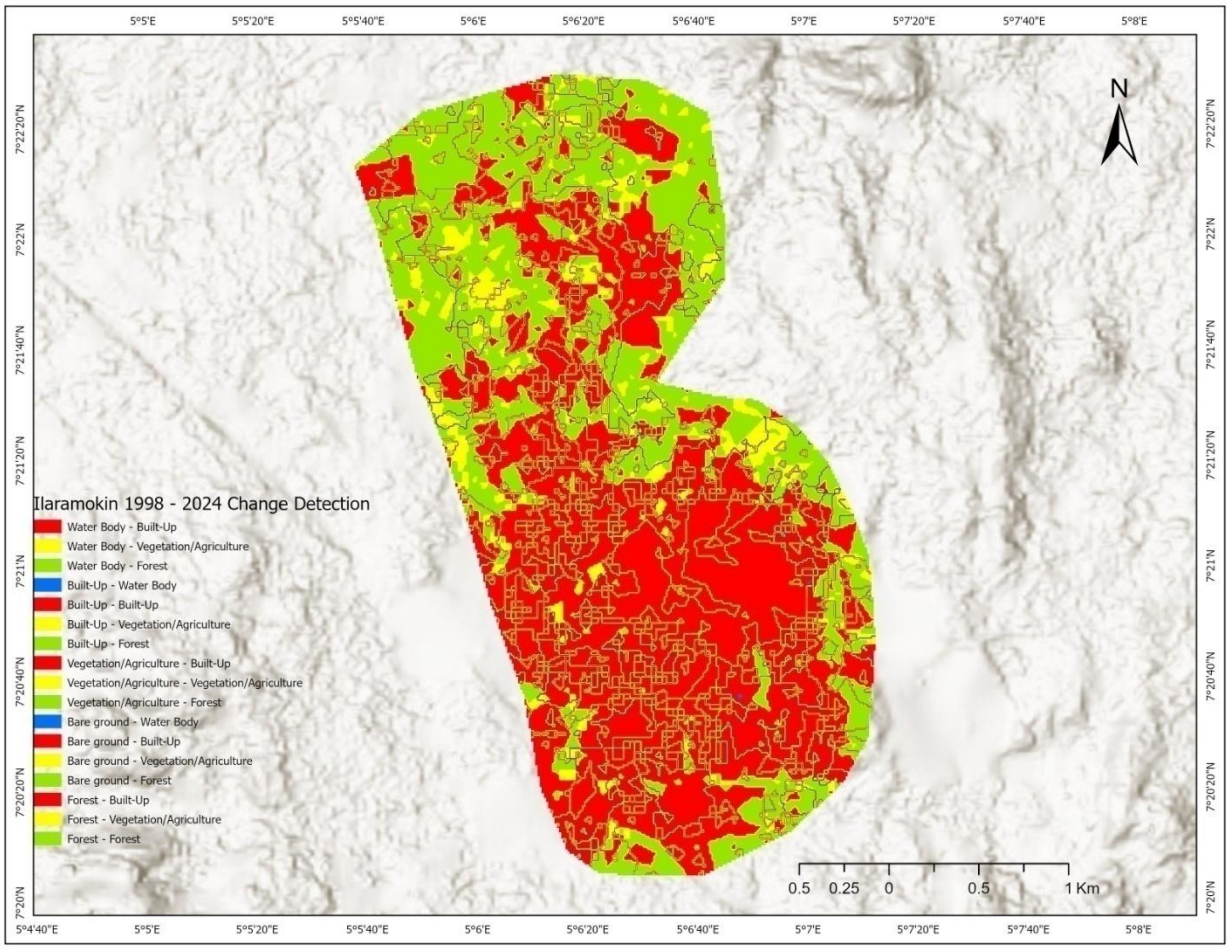


Figure 2: Change Detection Analysis Map at Ilara-Mokin 1998-2024
Source: Author's Work (2024**)**

5.2 Trend in Built-Up Area Expansion at Ilara-Mokin 1998-2024

The analysis employed an Exponential Smoothing and Least Squares Regression to examine built-up area expansion trends over time as revealed in Figure 3. The result indicates a distinct increase trend in built-up area expansion within the Ilara-Mokin. This upward trend is reflected in a positive regression coefficient (r = 0.996), indicating a direct relationship between time and built-up area expansion, this suggests that as time progressed, the built-up area expansion increased (see Figure 3 for trend lines). The coefficient of determination (r^2=0.992) further indicates that 99.2% of the variation in built-up expansion in Ilara-Mokin can be attributed to the passage of time. As time passes, a major contributing factor to built-up expansion is the increase in population, resulting in an increased demand for land for different purposes, and subsequent built-up area expansion. The remaining 0.8% of the variation is likely to be influenced by other factor, such as planning policies, technological advancement, government initiatives, among others. This indicates that built-up area expansion in Ilara-Mokin is occurring at an unprecedented rate, resulting in ecosystem encroachment. If this trend continues, it may lead to the loss of all vegetation/agricultural land, potentially affecting the livelihoods of farmers. These findings align with the study by Mohd*et al*., [22]which reported a rapid increase in built-up areas in suburban regions, often at the expense of other land uses. The field survey revealed widespread clearance of vegetation, including grasses and trees, to make way for alternative land uses such as residential and commercial development. The least square model that represents the trend of built-up expansion over time is expressed by the equation y=1.63 + 0.155x. the equation suggest a positive linear relationship between x and y, as x increases, y tends to increase at a rate of 0.155 units per unit increase in x, the intercept suggest that even when x is 0, y has a baseline value of approximately 1.63.

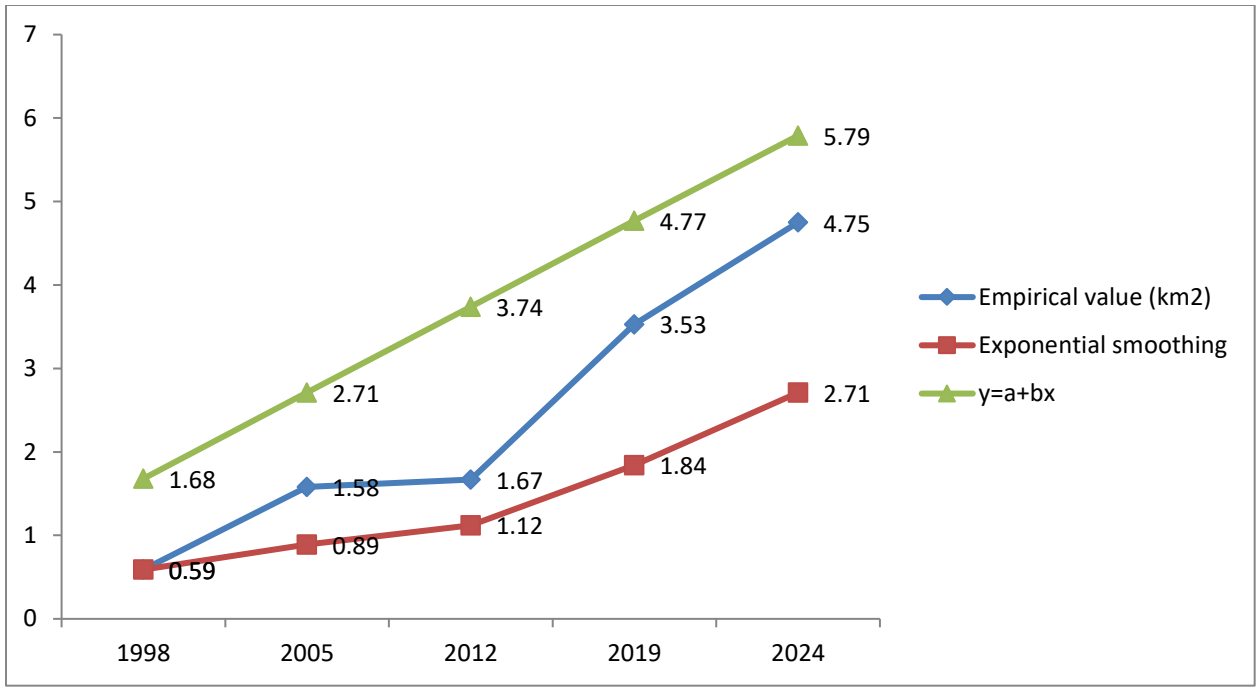


Figure 3: Trend in Built-Up Area Expansion at Ilara-Mokin, 1998-2024
Source: Author's Work (2024)

5.3 Land-Use/Land-Cover Distribution of Owode-Ede from 1998-2024

The statistics of the land-use/land-cover distribution for each study year of Owode-Ede are presented in Table 4 and Figure 4.

Table 4: Land-Use/Land-Cover Distribution in Owode-Ede from 1998-2024

Land-use/Land-cover class	Year 1998		Year 2005		Year 2012		Year 2019		Year 2024	
	Area (km^2)	Area %	Area (km^2)	Area %	Area (km^2)	Area %	Area (km^2)	Area %	Area (km^2)	Area %
Built – Up area	0.01	0.10	3.40	32.92	6.17	59.73	7.64	73.96	8.69	84.12
Vegetation/ Agriculture	8.58	83.06	6.38	61.76	0.28	2.71	0.19	1.84	0.19	1.84
Forest	1.58	15.29	0.40	3.87	3.70	35.82	1.23	11.91	1.19	11.52
Water Body	0.02	0.19	0.15	1.45	0.00	0.00	0.55	5.32	0.26	2.52
Bare ground	0.14	1.36	0.00	0.00	0.18	1.74	0.72	6.97	0.00	0.00
Total	**10.33**	**100%**	**10.33**	**100%**	**10.33**	**100%**	**10.33**	**100%**	**10.33**	**100%**

Source: Author's Work (2024)

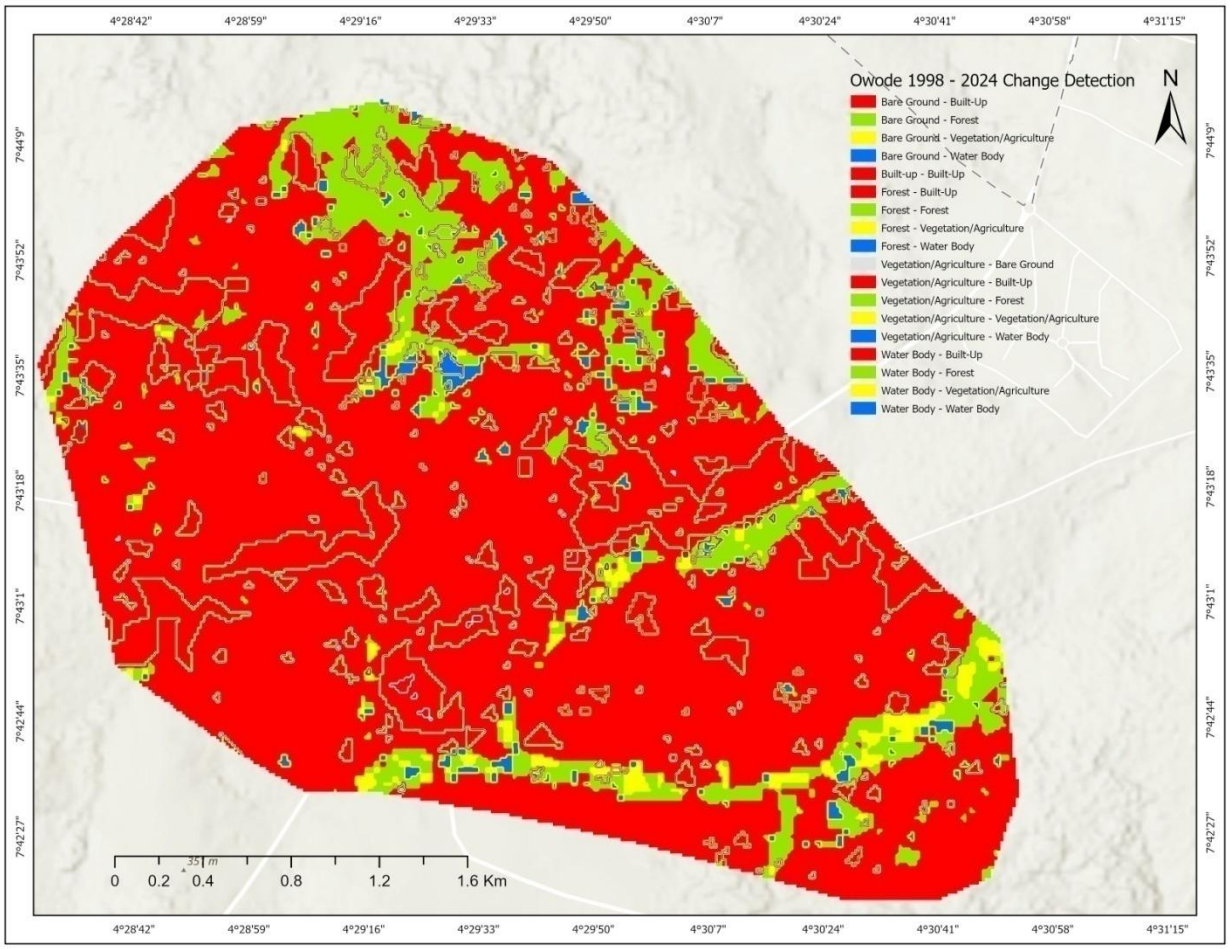


Figure 4: Change Detection Analysis Map at Owode-Ede 1998-2024

Source: Author's Work (2024)

5.4 Trend in Built-Up Area Expansion at Owode-Ede 1998-2024

The investigation into built-up area expansion trends utilised Exponential Smoothing and Least Squares Regression, as shown in Figure 5. The results indicate a significant increase in built-up area expansion within suburban areas over time. The strong positive regression coefficient ($r = 0.998$) suggests a direct relationship between time and built-up area growth. According to the coefficient of determination ($r^2 = 0.996$), approximately 99.6% of the variation in built-up expansion in Owode-Ede is explained by the passage of time. As the population grows over time, the demand for land increases, driving built-up area expansion. The remaining 0.4% of variation is likely influenced by factors such as economic factors, government initiatives and technological progress. This observation aligns with the research of Xingfen[23], which reported that continuous migration over time induces urbanisation, leading to increased costs of living,

changes in identity, and cultural infiltration by immigrants. The least square model that represents the trend of built-up expansion over time is expressed by the equation y= 1.35 + 0.326x. The equation suggest a positive linear relationship between x and y, as x increases, y tends to increase at a rate of 0.326 units per unit increase in x, the intercept suggests that even when x is 0, y has a baseline value of approximately 1.35.

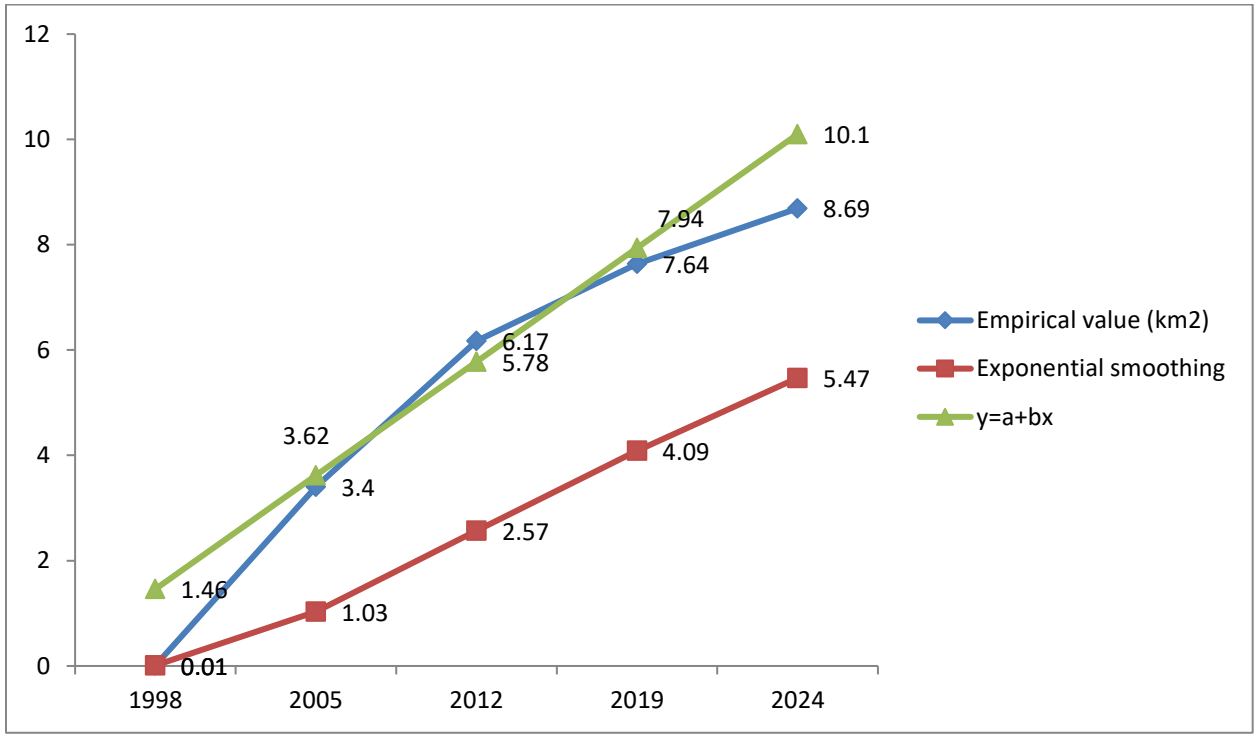


Figure 5: Trend in Built-Up Area Expansion at Owode-Ede, 1998-2024
Source: Author's Work (2024)

5.5 Land-Use/Land-Cover Distribution in Iyin-Ekiti from 1998-2024

The statistics of the land use/land cover distribution for each study year of Iyin-Ekiti are presented in Table 5 and Figure 6.

Table 5 Land-Use/Land-Cover Distribution in Iyin-Ekiti from 1998-2024

Land-use/Land-cover class	Year 1998		Year 2005		Year 2012		Year 2019		Year 2024	
	Area (km^2)	Area %	Area (km^2)	Area %	Area (km^2)	Area %	Area (km^2)	Area %	Area (km^2)	Area %
Built – Up	1.11	15.77	1.69	24.00	2.81	39.91	3.66	52.00	5.29	75.14

area										
Vegetation/ Agriculture	0.98	13.92	0.59	8.38	0.27	3.84	0.17	2.41	0.25	3.55
Forest	4.21	59.80	4.72	67.05	3.95	56.11	3.21	45.59	1.50	21.31
Water Body	0.00	0.00	0.04	0.57	0.01	0.14	0.00	0.00	0.00	0.00
Bare ground	0.74	10.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**7.04**	**100%**	**7.04**	**100%**	**7.04**	**100%**	**7.04**	**100%**	**7.04**	**100%**

Source: Author's Work (2024)

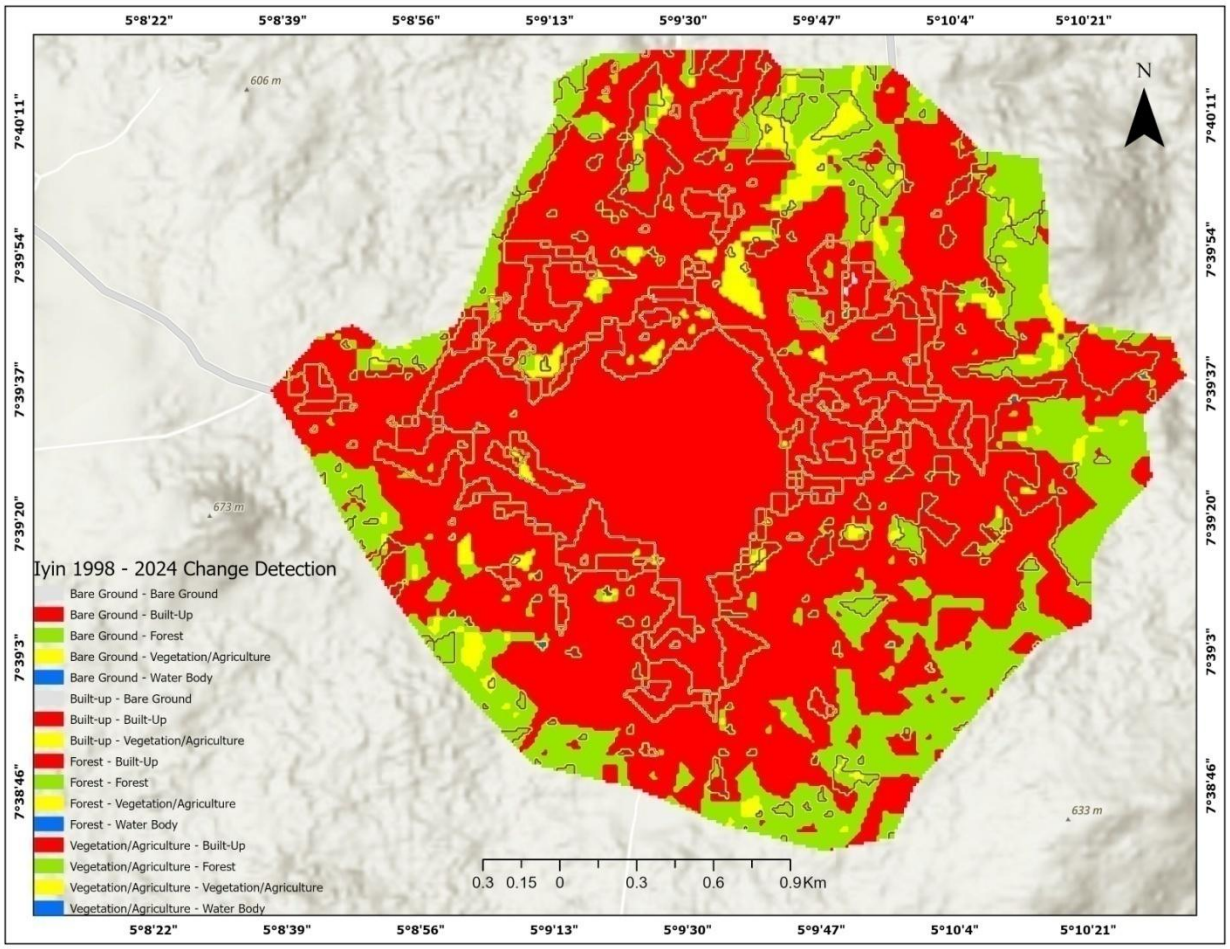


Figure 6: Change Detection Analysis Map at Iyin-Ekiti 1998-2024
Source: Author's Work (2024)

5.6 Trend in Built-Up Area Expansion at Iyin-Ekiti 1998-2024

The study examined built-up area expansion trends using Exponential Smoothing and Least Squares Regression, as shown in Figure 7. The findings indicate a significant upward trend in built-up area expansion within iyin-Ekiti. The strong positive regression coefficient (r = 0.998)

suggests a direct correlation between time and built-up area growth. The coefficient of determination ($r^2 = 0.996$) reveals that nearly 99.6% of the variation in built-up expansion can be attributed to the passage of time. Population growth, primarily driven by migration, is a major contributor to built-up expansion, leading to increased land demand and subsequent urbanisation. Other factors, such as environmental factors and government initiative, may account for the remaining variation of 0.4%. This finding supports the research of Bartara*et al*.,[24]which highlights the ongoing clearance of vegetation to accommodate built-up development leading to ecosystem disruption and environmental pollution. Findings revealed that a significant proportion of agricultural lands had been converted to built-up area. The least square model that represents the trend of built-up expansion over time is expressed by the equation y= 1.17 + 0.155x. The equation suggest a positive linear relationship between x and y, as x increases, y tends to increase at a rate of 0.155 units per unit increase in x, the intercept suggests that even when x is 0, y has a baseline value of approximately 1.17.

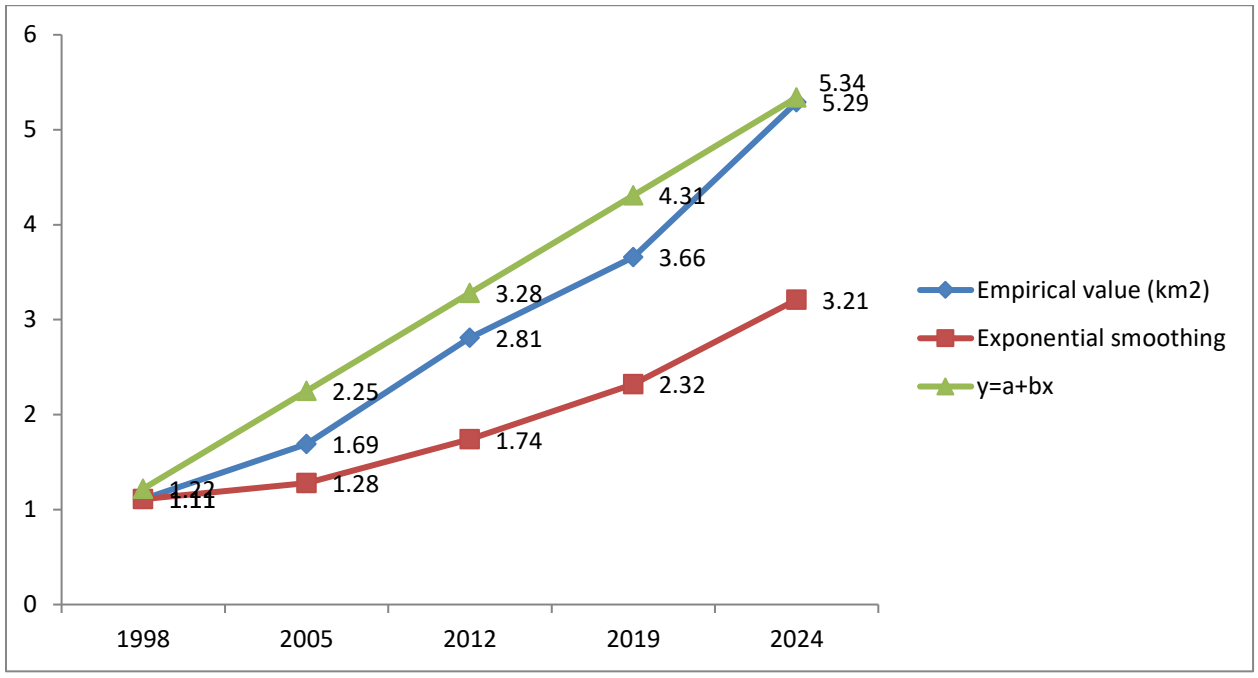


Figure 7: Trend in Built-Up Area Expansion at Iyin-Ekiti, 1998-2024
Source: Author's Work (2024)

6. Conclusion and Recommendation

The study has established that there is relationship between time and built-up area expansion, as time passes the built-up areas expands. It was also established that the built-up expansion has led

to decline of other land uses such as agricultural land, forest land, vegetation, bare ground, among others, agricultural land loss may reduce food production in the suburb as well as lead to job loss in the suburb. Unprecedented migration into the suburbs overtime is also one of the key factors that has contributed to the built-up area expansion.The migration into the suburbs may be difficult or impossible to stop, making it a necessity for town planners to make suburbs planning a priority.Since migration is inevitable, the suburb should be well-planned to accommodate rapid migration and future expansion in a sustainable manner.

7 Recommendations

The study recommends proactive planning in the suburbs to prevent planning problems like sprawl, incompatible land uses, and illegal land use changes and promote sustainable physical development. Findings shows agricultural land use has reduced due to built-up area expansion. Hence, protecting agricultural land is crucial to prevent job losses and reduced food production. Zoning regulations can help conserve agricultural land. Furthermore, as urbanization continues, constant monitoring by the Town Planning Authority can mitigate environmental issues and enforce laws.

Ethical approval and accordance

The study uses secondary data, including land cover images from 1998 to 2024, downloaded from the United States Geological Survey (USGS) website (http://www.earthexplorer.usgs.gov).. ArcGis software was used for analysis. Since the study doesn't involve human participants, Nigerian research regulations didn't require formal ethical clearance. The study followed general ethical principles for using secondary data, consistent with international guidelines

Clinical trial number

Not applicable.

Consent to participate

Not applicable

Consent to publish

Not Applicable

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Availability of data and material

The research data are available from the authors on request.

Competing interests

The authors declare no conflict of interest.

Authors' contributions

The first author, Asiyanbi Adedolapo Oloruntoba, collected the data and wrote the first draft of the manuscript. The second author, Abolade, Olajoke, supervised data collection, the third author; Adejare Jacob Ayorinde provided comments on the previous draft. The first author rewrote and revised this draft. The second author also supervised the first author's analysis

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