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MONITORING AND MODELLING OF URBAN SPRAWL IN OSOGBO METROPOLIS, USING GIS AND REMOTE SENSING

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Abstract

Rapid urbanization in the world is a major and concerning issue, particularly in emerging nations such as Nigeria, and this has resulted in various environmental issues which urban sprawl is one of. The existing built-up area, land and housing policies, accessible empty land area, existing number of households, demographic parameters, and the nature of the economy, among other factors, all influence urban area expansion. Using Landsat imagery, this study assessed urban sprawl in Osogbo Metropolis, Nigeria; which is in a bid to have a clear understanding of the direction of uncontrolled urban growth in the study area, with a view to proffering best solutions to its evaluation and monitoring. Data obtained through supervised classification were categorized into pre-processed images using different land cover classes. Change detection analysis was used to determine the urban growth areas between the study years (1989-2021) and make a projection for 2029. Findings revealed that the built-up area in 1989, 2002 and 2021 were 6.04%, 21.67 % and 36.42% of the study area, indicating a steady increase in the extent of the built-up area. The study estimated that the built-up area of Osogbo by the year 2029 will be about 75.28km2; an increase of 26.48km2 from the present area of 48.80km2. This study also revealed that the direction of growth in the projected year 2029 is towards the western periphery and the remote pockets located in the southern outskirts of Osogbo. These findings have implications for re-modelling urban sprawl. This study provides a basis for decision makers by enforcing planning standards, constant monitoring exercise, effective land administration and management and involvement of technology at all levels of planning.

Keywords: GIS, Landsat, Osogbo Metropolis, Remote Sensing, Urban Sprawl

INTRODUCTION

The radical population shift of human societies from rural dwellings into the urban space amongst other human and natural activities has made the monitoring and management of these urban areas germane on all fronts of environmental and developmental agendas all over the world. This transformation has led to an increase in population of urban dwellers than ever before, and this has in turn resulted in an unprecedented growth rate, further causing a space outburst in these urban centres over the years (United Nations, 2018). It has been widely observed that in most countries of the world, land is the major contributor of revenue and income. It contributes immensely to a nation's wealth. Efficient management of this vital resource is therefore essential for the overall sustenance and development of man and his environment (World Bank, 2018). However, over the years there has been a serious increase in population in many urban centres around the world and this has resulted to one environmentally related problem or the other. As the outburst of population is being experienced in developed nations of the world, so it is in developing nations. Overpopulation has led to increased pressure on existing infrastructure and public utilities, further resulting in urban periphery migration and uncontrolled developments along the outskirts and margins of these urban centres (Makinde, 2020). These uncontrolled developments are usually characterised as unorganized, unattractive, and scattered, which entirely describes the phenomenon of Urban Sprawl.

Karakayaci (2016) opined that following the rapid increase in population, urban growth which is a result of increased demand for dwelling units, industry, and business is expanding towards city boundaries and causing the occupation, and total eradication of agricultural lands and forests. This uncontrolled and unplanned growth, which is amongst other influencers, is defined as Urban Sprawl (Zhang, 2004; Sudhira & Ramachandra, 2007). Urban sprawl, which is asserted to be produced by urban growth, is in fact not suitable, either for urban growth itself or for the rural environment in the real sense, since it is carried out in a disorganized and uncontrolled way, and it has effects which hinder the regional and sustainable development of an area (Bhatta, 2010). Donk (2006) was of the view that the increase in urban sprawl in most cities of developing nations continue to attract attention from both national and international agencies, but the efforts have not achieved much results in checking the sprawl.

African cities in particular produce miseries that are often difficult to comprehend (Olurin, 2003). Most of the big African cities are faced with the problem of rapidly deteriorating physical and human environment. The deterioration manifests in the form of slums, urban sprawl, and squatter settlements; increasing traffic congestion, flooding, and erosion, deteriorating infrastructure and short falls in service delivery among others. Due to uncontrolled urbanization and increased population, one conspicuous feature linked to Nigerian cities is Urban Sprawl. Urban Sprawl in Nigeria describes the development of informal housing units along the outskirts of cities and urban centres. This is characterised by haphazard housing development in the urban suburbs, where majority of the structures are without planning permit in uncoordinated layouts. Often, these structures are products of squatters that choose to settle at the suburbs, because of their inability to afford suitable residential accommodation in the city centres. Ago (2001) stated that, unfortunately, there is hardly a Nigerian city that is exempt from the experiences of urban sprawl and the menaces that have arisen from it. Hence, the pressing need to address the issue of the phenomenon Sprawl.

In about 50 years, Nigeria's urban population increased rapidly and is projected to continue to increase relatively faster in the coming decades. With the urbanization rate in Nigeria being estimated at 50 percent, it is projected that in the next 30 years, the overall population will likely double the present figure of 170 million people (Ujoh, Kwabe, & Ifatimehin, 2010). Bloch et al. (2015) is of the opinion that the growth of Nigeria's urban population in both absolute and relative terms has been accompanied by the expansion of existing built-up areas and the emergence of new and identifiably 'urban' settlements. Furthermore, while reporting the study of Urbanization and Urban expansion in Nigeria, Bloch et al (2015) observed that in the South-Western part of Nigeria, there is a conurbation stretching from Lagos in the south to Ilorin in the north to Akure in the east.

Meanwhile, being a State capital, Osogbo has experienced a serious rise in the influx of people over the past years. This is not surprising, considering the various centripetal forces of attraction that have become prevalent in the study area in these years. Increased presence of economic and social infrastructure has increased employment opportunities, business opportunities, leading to high rate of urbanization in the state capital (Aguda & Adegboyega, 2013). The city has witnessed a lot of uncontrolled developments within the city centre, the urban periphery and along the city margins, and this has raised serious concerns for the government and related agencies. However, as much as there is a yearning for increased urban development within the city, there is also a great need to monitor, regulate developmental activities, and enforce planning standards, to reduce the effects uncontrolled developments will have in the city.

Aguda and Adegboyega (2013) evaluated the Spatio-Temporal Dynamics of Urban Sprawl in Osogbo, using satellite imagery and GIS techniques. In this analysis, the dynamism of land use, the extent and rate of urban expansion were quantitatively compared, where the annual rate of land use change is used to determine the extent of urban expansion. In addition, the study determined the Population Growth Rate (PGR), Land Consumption Rate (LCR), Land Absorption Coefficient (LAC) and Percentage Agricultural Loss of the study area over a certain period of time. Measuring urban sprawl in a particular location over a period of time assists decision makers in understanding the pattern of growth in such areas, as well as having a deep understanding of the direction of such growth. This enables administrators and agencies alike to make certain decisions that will enhance the overall growth and development in a place. In establishing the realities of urban sprawl, the magnitude of the changes in built-up areas reveals the sharp increase in the extent of the area under study, while the pattern of growth of the peri-urban areas also establishes the reality of urban sprawl (Idowu et al., 2018)

It is with this view that this paper describes the spatio-temporal change that has occurred in Osogbo metropolis over the years, by examining the pattern and extent of land use, and land cover change that has taken place in the city; the research also focused on determining the areas of high, low, and medium growth probabilities using Logistic Regression Model. Though the years, there have been series of research carried out to find solutions to the phenomenon of sprawl; however, relevant to the study area, there has not been much of research carried out with the Logic Regression Model to determine the growth probabilities throughout the study area. This study also investigated the relative impacts of the proximity of some urban area features closely clustered around the centre of Osogbo on the rate of growth of the whole of the town. All these analysis and assessments will enhance various administrative decision-making processes. It will also help in establishing various developmental strategies geared towards achieving a liveable, workable, and sustainable city.

MATERIALS AND METHODS

Study Area

Osogbo, the capital city of Osun state is located between latitudes 7º46'N and 7.767ºN, and longitudes 4º34'E and 4.567ºE, (see Figure 1) Southwest of Nigeria, with a total land area of about 2,875 sqkm as at the time it became the State capital (Akinola, 1998; Osun State Ministry of Information 1992). It was founded in the late 18th century, and originated as a traditional and cultural town which derives its name from the proclamation by the goddess of Osun River. The town is known for her very rich arts and cultural heritage (Awe & Albert, 1995). Osogbo is largely dominated by the Yoruba ethnic group and unified by the Yoruba language. Other tribes such as Hausa, Igbo, and Fulani are also found in the city.

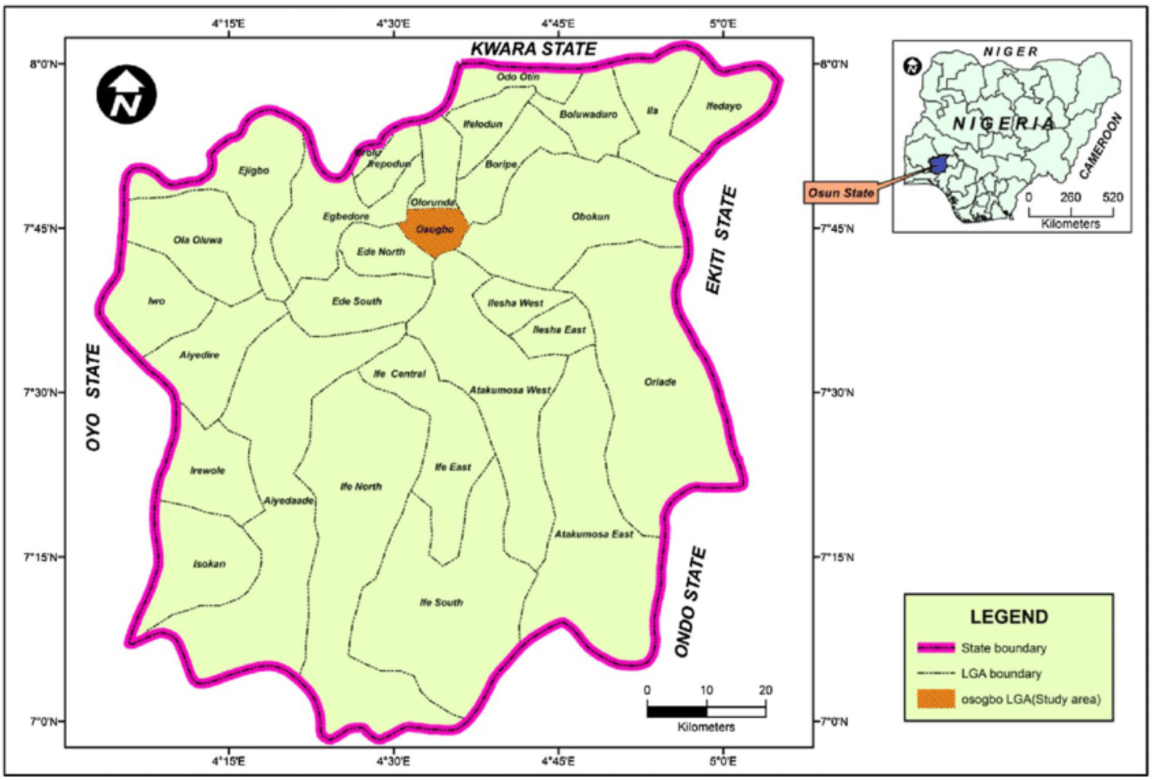

Figure 1: Map of the study area
Source: Cooperative Information Network (COPINE), 2021

According to the 1963 census results, the population of Osogbo was 152,424. In 1991, when Osun State was created with Osogbo as the state capital, the population increased to 250,951. In 2006 the population of Osogbo was 381,405. Based on this figure, the population of Osogbo was estimated to be 527,954 in 2017 (see Table 1) at the official rate of 3% annual growth rate (National Bureau of Statistics, 2016). The growth in the population of Osogbo over time is largely related to the introduction of modern technology and administration, as Osogbo became a growth centre that pulled population from its neighbouring settlements (Agbola, 1992; Osogbo.info, 2013).

Table 1: Population Growth of Osogbo, 1963 - 2017

Year	Population	Percentage Change
1963	152,424*	24.1
1991	250,951*	64.6
2006	381,405*	52.0
2017	527,954**	38.4

*Source: *Census figures (National Population Commission of Nigeria, 1991; 2006)*
***Projection at official 3% annual growth rate for urban centres in Nigeria (National Bureau of Statistics, 2016)*

Osogbo is situated on a raised land which is well over 500 metres (800 feet) above sea level. There are many rivers and streams in Osogbo of which the most permanent is River Osun (Faniran & Jeje, 1983; Osun State Government, 2016). As a result of these geographical attributes of Osogbo, farming is the major traditional occupation of inhabitants. The tropical climate of the area favours the cultivation of cash crops such as cocoa, cotton, and kolanuts, as well as food crops such as yam, maize, and vegetation. Apart from farming, cloth dyeing is another traditional activity of the people of Osogbo. The town is a major dyeing centre, thus, it is often referred to as "Ilu-Aro" (home of dyeing). The people of Osogbo are also famed for their commercial activities in handmade traditional weaving of cloth (Aso-Oke) and Batiks, same with embroidery, pottery and gold-smiting (Agbola, 1992; Murphy & Sanford, 2001; Osun State Government, 2006).

The phenomenal growth and development witnessed in Osogbo can be linked to improved style of administration and governance and population influx from neighbouring towns and states. Such urban derivatives as social infrastructure, rail stations, roads, establishment of institutions, location of industries e.g. The Steel Rolling mill, Machine tools and the likes gave rise to developments and growths the town witnessed in the past. Road transport allowed for dispersal of developments in all directions from the traditional core of the town. As the population kept increasing, further developments in housing and related services also increased. Over the years, Osogbo has become a capital with several cores and business districts located around the town.

Data Acquisition

This study utilized a variety of data in order to accomplish its objectives. The details of the data used are shown in Table 2.

Table 2: Details of data sets utilised for this study

S/N	Data type	Acquisition Date	Actual Spatial Resolution/Scale	Acquisition Source
1.	Landsat TM	1989	30m	USGS Earth Explorer
2.	Landsat ETM	2002	30m	USGS Earth Explorer
3.	Landsat OLI p199r055	2021	30m	USGS Earth Explorer
4.	Topographic Map	1967	1:50,000	Federal Surveys Department, Lagos
5.	Google Map	2021	-	Google Earth Application
6.	Administrative map	2021	ESRI Shapefiles	Office of the Surveyor General of the Federation (OSGOF)
7.	Co-ordinates of points	2021	$\pm$ 5m	Field survey/GPS Receiver

TM – Thematic Mapper; ETM+ - Enhanced Thematic Mapper plus; OLI – Operational Land Imager

Assessment of the spatio-temporal pattern of urban expansion

The year 1989 was chosen to be the start year for the assessment, being the period shortly after the oil boom in the nation, and the period before the creation of Osun state. Also, the choice of 2002 was for the representation of the beginning of the 21st century. In order to achieve the objectives of this study the following steps which include: development of classification scheme, image pre-processing and image classification, the generation of land use map and statistics, reclassification of land cover maps, and overlay of urban areas, were taken and all these processers were executed within the ArcGIS 10.3 software environment.

Step 1: Development of classification scheme

Studies of land use and land cover change usually needs development and definition of homogeneous land use/land cover units before the analysis is started. The land cover classification scheme used in this study is that of Anderson et al. (1976). In developing the Anderson classification system, every effort has been made to provide compatibility, as much as possible, with other classification systems currently being used by the various Federal agencies involved in land use inventory and mapping.

The Anderson classification scheme consists of Level 1 to Level 4 land use/cover classes depending on the scale of mapping and the type of data used. Level 1 classes are usually extracted from moderate resolution images e.g. LANDSAT which was used in this study. The classification scheme developed is shown in Table 3.

Table 3: Land cover classification scheme

Level 1	Description
Cultivation and tempered vegetation	Farmlands, crop fields, golf courses, and fields (football field).
Bare ground	Bare rock outcrop, Bare fields, bare lands.
Built-up	Residential land uses range from high density, represented by the multiple-unit structures of urban cores, to low density, where houses are on lots of more than an acre, on the periphery of urban expansion
Semi-Natural vegetation	Savannah and wet land vegetations, deciduous forest land, mixed forest land, orchards, nurseries

Source: Modified from Andersonet al., (1976)

Step 2: Image pre-processing and image classification

The Image Pre-Processing of the Landsat images was carried out in three stages:

i. Image Composition,
ii. Image Rectification, and
iii. Image Enhancement

The Colour Infra-red composite was used. For image rectification, the coordinate system used was the UTM Zone 32. The enhancement procedure applied to image data to effectively display the data for visual interpretation is histogram equalization for the purpose of increasing the visual distinction amongst the features in a scene.

The objective of image classification is to replace visual analysis of the image data with quantitative techniques for automating the identification of features in a scene. This involves the analysis of multispectral image data and the application of statistically based decision rules for determining the land cover identity of each pixel in an image. The intent of classification process is to categorize all pixels in a digital image into one of several land cover classes. The supervised maximum likelihood classification was employed for this study due to the prior knowledge of the study area. Also, the maximum likelihood classification was used because;

i. it provides a consistent approach to parameter estimation, and;
ii. it has desirable mathematical and optimality properties due to normal distribution and sample variance utilized in the algorithm (Jensen, 2004).

Filtering and boundary cleaning were carried out thereafter to eliminate “bad” pixels, i.e. isolated pixels to aid classification accuracy. Land cover maps from satellite images have errors due to various factors. Evaluating the accuracy is crucial, and one common method is using an error/confusion matrix. This matrix compares the assigned categories to the actual ground truth. It provides statistics like overall accuracy, omission and commission errors, and the kappa coefficient, which considers the influence of chance. Omission errors are pixels that should belong to a category but were not classified as such, while commission errors are pixels wrongly placed in a category. These errors are assessed using known land cover samples. The accuracy assessment of land cover classification included 80 stratified random sampling points and comparisons with other images and existing maps.

Step 3: Land cover map and statistics

To determine the extent and rate of change in the land cover dynamics in the region, the total area and area of change between two years were computed. The classified data was used to produce thematic maps giving a pictorial representation of how the land use, and land cover of the area, have changed over the years of study.

Step 4: Reclassification and overlay of built-up classes

The main analysis used to determine the rate of urbanization was the change detection analysis. GIS overlay operations were used to join up the areas built up during the years under study, using the reclassification and combine tool which computes a geometric intersection of the built-up area of the study years. The result is a thematic layer showing urbanization categories.

Determination of areas of high growth probabilities using logistic regression model

This section comprises the mapping of the variables of urban expansion in the study area, preparation of variables for Logistic Regression (LOGISTICREG), and computation of the Logistic Regression Model. First, the variables of urban expansion were mapped; the variables consist of points, and lines having unique characteristics that are responsible for land use change. This dataset was then created in shapefile coverage polygon by importing field survey data, which was corroborated with field survey, and ground trothing, using Global Positioning System (GPS). The data digitized include roads, hospitals, banks, hotels, markets, and the built-up areas.

Secondly, the variables for logistic regression were prepared, using the Euclidean Distance Tool of ArcGIS Spatial Analyst tool to compute the distance to each of these features which were later divided by the value of the highest distance to obtain the variables from 0 to 1. The prepared dichotomous layer contained values 1 and 0 showing the presence and absence of built-up growth, respectively. The constraints consist of the built-up patch, water body and forest areas which remained constant with due course of time except for the built-up land which increased from 2002 to 2021. The prepared layer was dichotomous in nature and therefore held the value 1 and 0, showing the presence, and absence of a constraint feature. This binary thematic layer was used to train the model that no built-up growth can take place in an already urbanized area or protected land. The built-up layer for the year 2002 was used for regression and that for 2021 for future probability prediction.

The distance to built-up area shows the proximity to the already built-up area of a point on the map. The prepared raster layer was normalized and continuous in nature such that pixels closest to the built-up patch held highest value, i.e., 1, and the pixel at a maximum distance from the built-up patch in the raster layer held the value 0. The built-up patch of the year 2002 was replaced by the built-up patch of 2021 from regression to future growth probability prediction. The proximity to all the features were normalized in such a way that the pixel nearest to the feature holds a value 1 and the farthest one holds 0. The distance to the roads were prepared using the line road vector layer whereas medical facility and hotels were generated in terms of vector points in the GIS environment. Same layers were used during the model calibration and future prediction.

Finally, the Logistic Regression was performed in IDRISI Taiga software, an integrated geographic information system. The procedure involved the indication of independent variables which includes the image file of Distance of hospital, security, road, market, finance, built-up, and Dependent variable which is the area of expansion between 2002 and 2021. The numeric regression and test results show a summary template after the LOGISTICREG module analysis and were written to a text file in the working directory with the same name as the output prediction file, but with a '.txt' extension.

Predictive modelling of urban sprawl

Cellular Automata modelling was carried out for the prediction of the future pattern in the study area using Quantum Geographic Information System (QGIS) Software. The urban transition probability had been predicted from the previous section used. Cellular Automata (CA) was used to add spatial character to the model in QGIS software. The tool made use of the output from the Logistic Regression to apply a contiguity filter to "grow out" urban areas from time two to a later time. In essence, the CA will develop a spatially explicit weighting showing, more heavily, areas that proximate to existing built-up area. This will ensure that built-up area occurs proximate to existing built-up and not wholly random. In summary, the model generates a set of spatial coverages (maps) reflecting the future pattern of urban sprawl in the area.

RESULTS AND DISCUSSION

Spatio-temporal analysis of urban expansion

The results of the accuracy assessment revealed overall accuracy and kappa index of 80% (0.733), 78% (0.7), 80% (0.767) for 1981, 2001 and 2021 respectively, a suggestion of low classification errors which some degree of confidence in proceeding with the analysis in the study after generalizations (majority filtering) have been made. The Tables 4, 5, and 6 present the details of the user's accuracy and producer accuracy for each land cover class in the study years.

Table 4: User's accuracy versus producer's accuracy for each land cover class in year 1989

	BUA	B	CTV	SNV	Classification Overall	User's accuracy (Precision)
Built-up Area (BUA)	16	1	0	3	20	80%
Bareland (B)	2	15	1	2	20	75%
Cultivation/Tempered Vegetation (CTV)	1	1	17	1	20	85%
Semi-Natural Vegetation (SNV)	1	2	1	16	20	80%
Truth Overall	20	19	19	22	80	
Producer's accuracy (Recall)	80%	79%	89%	73%		
Overall accuracy	80%					
Kappa	0.733					

Table 5: User's accuracy versus producer's accuracy for each land cover class in year 2002

2002	BUA	B	CTV	SNV	Classification Overall	User's accuracy (Precision)
Built-up Area	14	2	1	3	20	70%
Bareland	0	17	1	2	20	85%
Cultivation/Tempered Vegetation	0	2	17	1	20	85%
Semi-Natural Vegetation	2	2	2	14	20	70%
Truth Overall	16	23	21	20	80	
Producer's accuracy (Recall)	87%	74%	81%	70%		
Overall accuracy	78%					
Kappa	0.7					

Table 6: User's accuracy versus producer's accuracy for each land cover class in year 2021

2021	BUA	B	CTV	SNV	Classification Overall	User's accuracy (Precision)
Built-up Area	18	0	1	1	20	90%
Bareland	1	17	2	0	20	85%
Cultivation/Tempered Vegetation	1	0	16	3	20	80%
Semi-Natural Vegetation	1	1	3	15	20	75%
Truth Overall	21	18	22	19	80	
Producer's accuracy (Recall)	86%	94%	73%	79%		
Overall accuracy	83%					
Kappa	0.767					

Analysis of land use/cover change patterns was conducted in this study using the approaches adopted in the methodology. Individual class area and change statistics for the three years (1989, 2002, and 2021) are summarized in Table 7. It is noted from this table that Semi-Natural Vegetation constituted the predominant land cover class in the year 1989, but built-up land cover class constituted the predominant class in 2021. A look at the Built-up Area which this research work focused on shows that the Built-up Area was 6.04% in 1989, 21.67 % in 2002, and 36.42% in 2021. Though Osogbo used to be a small town in 1989, the study area has gradually emerged as a big city. This portrays an increase in built up area signifying increased rural-urban migration. Spurred by the nationwide oil boom of the 1980s and the massive improvements in roads, infrastructure, institutionalisation, and the availability of vehicles amongst other factors, many rural dwellers started migrating to Osogbo. Osogbo has become an increasingly urbanized and urban-oriented society because of these factors.

Table 7: Total area of land cover classes in study years

Land Cover	Year 1989		Year 2002		Year 2021	
	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
Built-up Area	8.09	6.04	29.03	21.67	48.80	36.42
Bare land	13.42	10.02	53.49	39.92	44.86	33.48
Cultivation/Tempered Vegetation	35.23	26.79	15.25	11.38	24.38	18.65
Semi-Natural Vegetation	76.59	57.16	36.22	27.03	15.12	11.45
Total	**133.99**	**100.00**	**133.99**	**100.00**	**133.99**	**100.00**

From 1989 to 2021, increased urbanization, socio-economic factors, and human activities such as construction, deforestation, and agriculture greatly contributed to produce different types of land-use/land-cover change in the study area, thereby altering the natural environment. From the analysis of change in built-up areas in 1989, 2002, and 2021, there was evidence of an increase in the built-up area by 20.94km2 between 1989 and 2002, and 19.77km2 between 2002 and 2021 (Table 8). The pattern of political changes, shift in economy, and an increase in population has resulted in an increased built-up area. This pattern of urban expansion affects prime agricultural farming areas, and limits the potential of farming in the study area. Thus, the change of agricultural areas in the urban and peri-urban areas to urban status continues due to the process of urbanization. This problem has become more pronounced, being driven by government's developmental activities. These have led to the taking over of large expanses of agricultural land for different urban development activities as road construction, schools, hospitals, and other projects.

Table 8: Area Change in Land Cover Classes between study years

Land Cover	1989-2002	2002-2021
Built-up Area	20.94km^2	19.77km^2

Using the approach adopted in the methodology, land cover maps were generated for all the three years and the projected year 2029. Land cover maps for Osogbo for years of 1989, 2002 and 2021 are shown in Figures 2, 3 and 4 respectively.

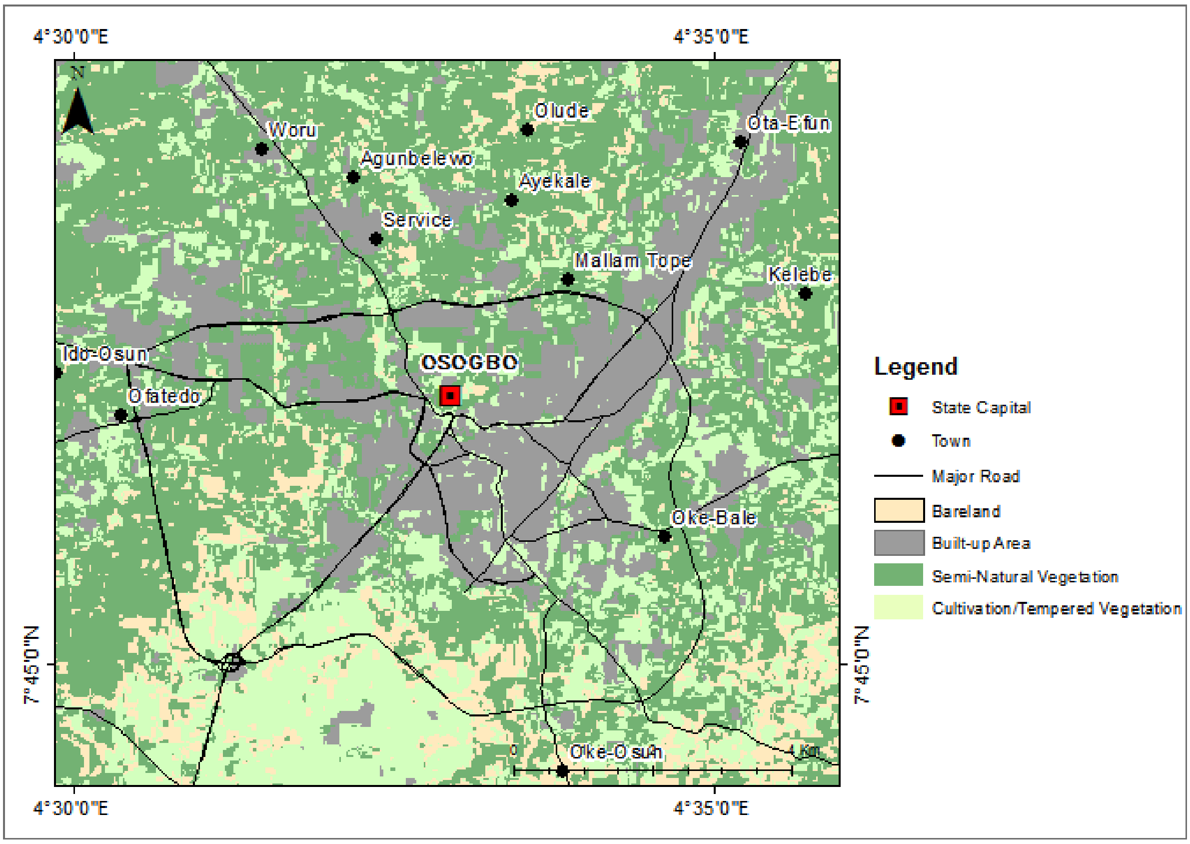

Figure 2: Land Cover Map of Osogbo for year 1989

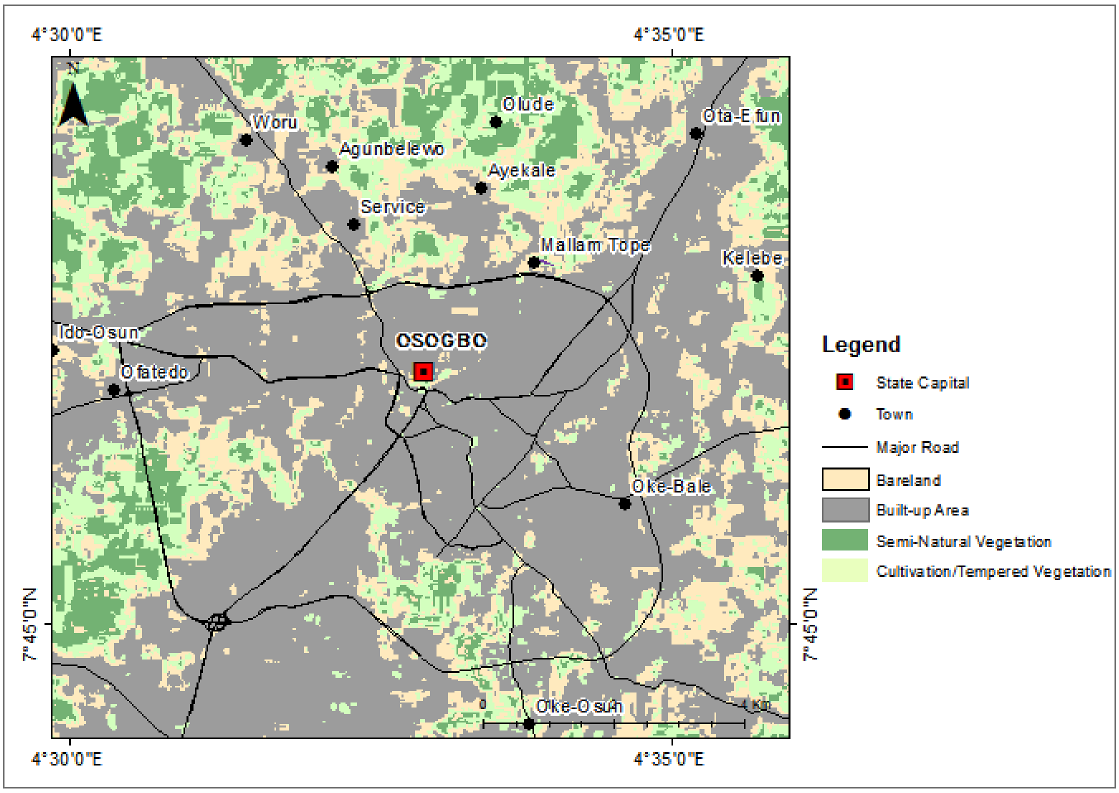

Figure 3: Land Cover Map of Osogbo for year 2002

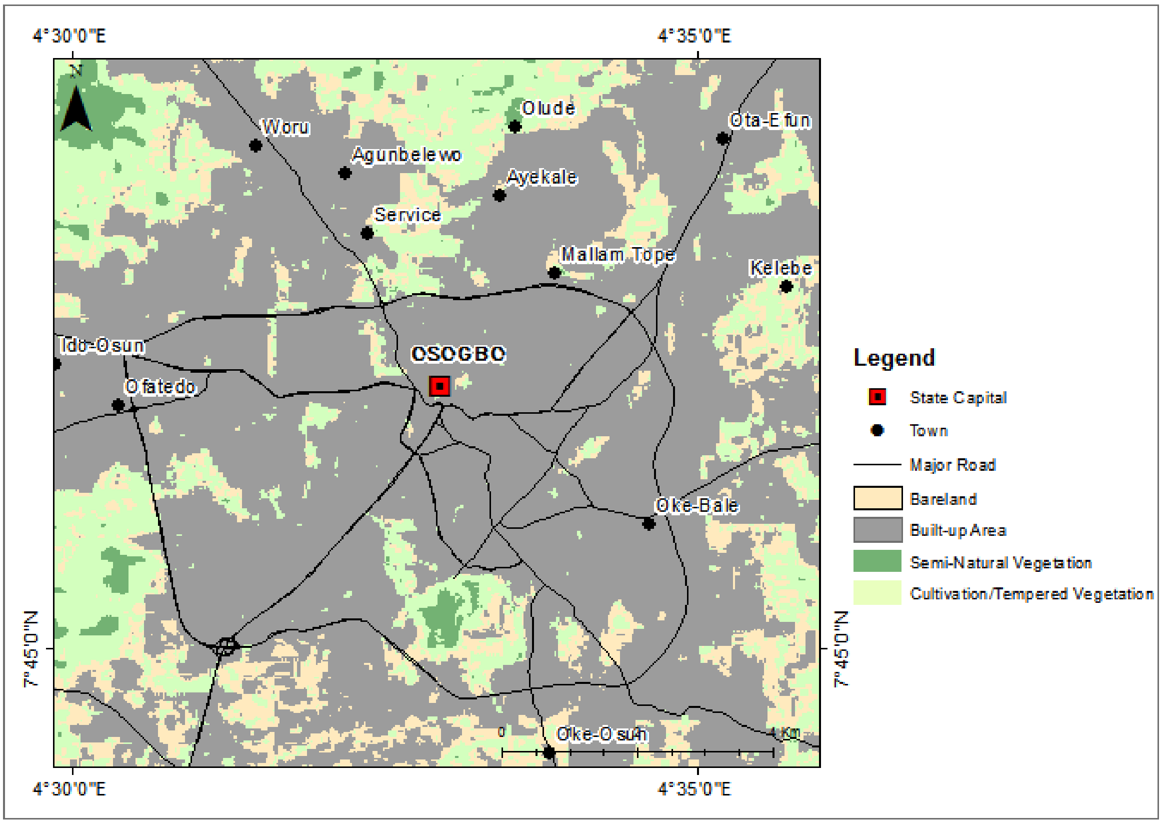

Figure 4: Land Cover Map of Osogbo for year 2021

Urban expansion of Osogbo

The change detection map in Figure 5 depicted that, rapid expansion of urbanized area within Osogbo was evident over time. The map revealed that urban expansion intensity is higher towards the outskirts of the initial area. These areas are places of increasing development pressure and urban expansion. Expansion of the already existing urban fabric through rapid construction of residential units, commercial and industrial units, road networks and pavements, port and leisure facilities, amongst others, lead to continuous expansion of impervious built-up surfaces at the different corners of the city.

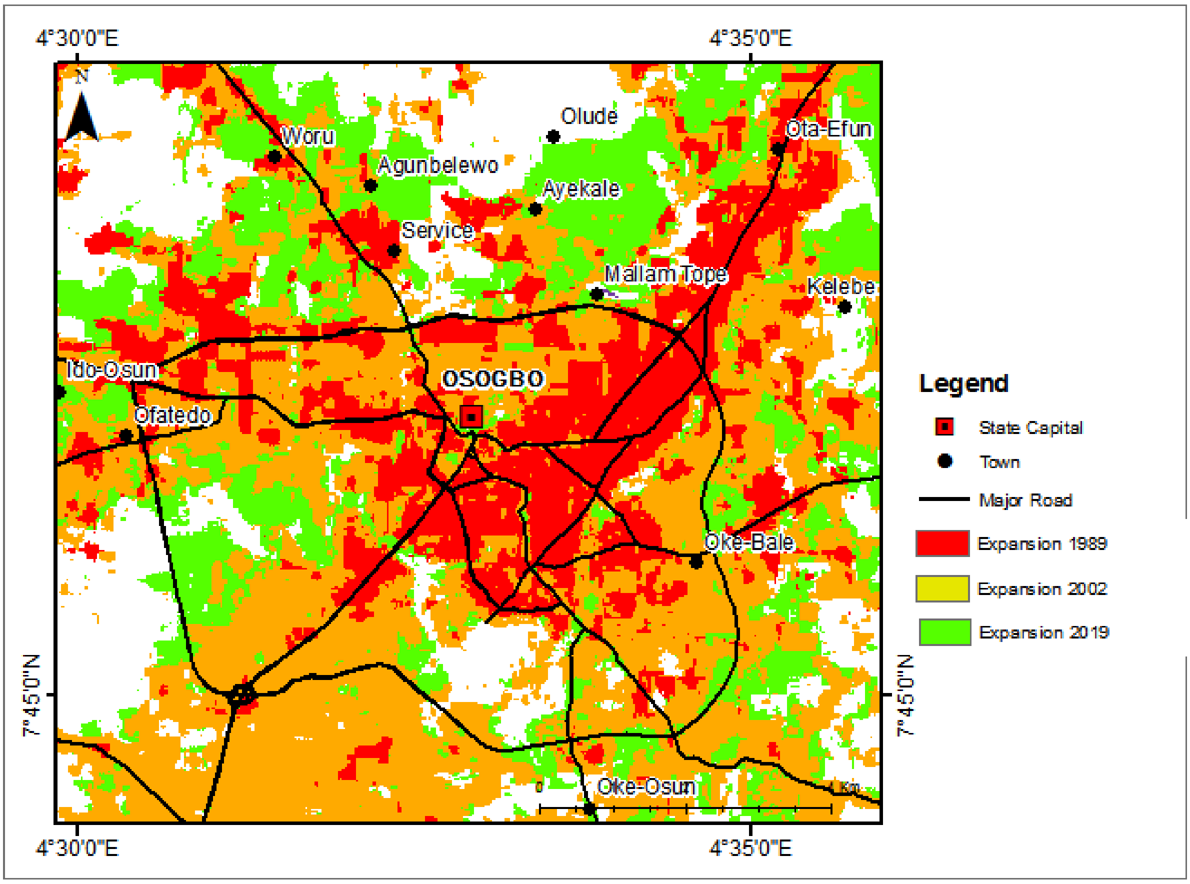

Figure 5: Urban Expansion of Osogbo (1989-2021)

The base map of Osogbo is shown in Figure 6. It is noted that most of the mapped variables are located within the central part of the study area.

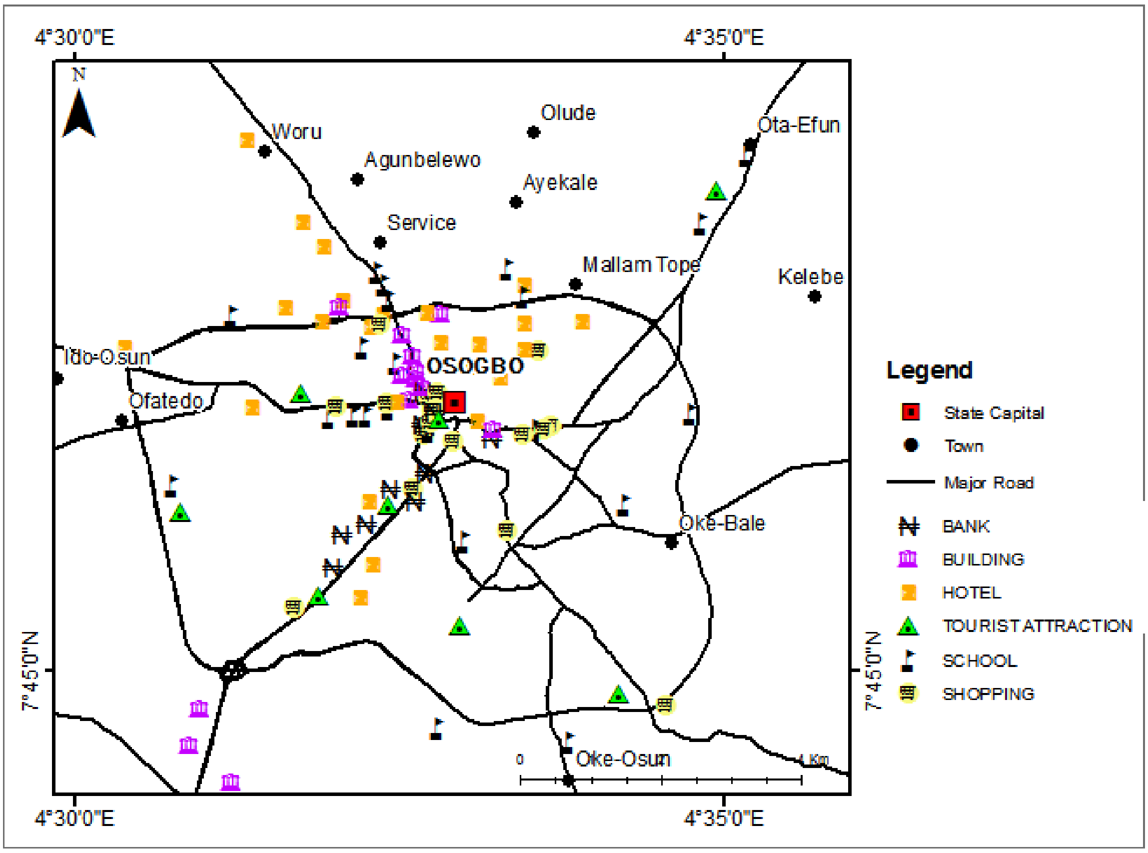

Figure 6: Base Map of Osogbo showing different features

Areas of high growth probabilities using logistic regression model

The variables for future built-up growth prediction were fitted in the Logistic Regression Model. The data type of variables was dichotomous and continuous in nature, as per the requirement. All the continuous variables were normalized between 0 and 1. The independent variables along with the sample Y was used for the logistic regression model fit. The Logistic Regression Model was used to fit the variables in a linear equation form and to derive the coefficients of independents driving the growth process.

The final equation of the logistic regression is.

$$\begin{aligned} \text{Logit (Growth)} = & -3.0391 + 0.001288*\text{Dist\_Attraction} - 0.037830*\text{Dist\_Built11} \\ & + 0.007213*\text{Dist\_Finance} - 0.002642*\text{Dist\_Hospital} - 0.003388*\text{Dist\_Hotel} \\ & - 0.006588*\text{Dist\_Market} - 0.004076*\text{Dist\_Rd} + 0.005010*\text{Dist\_Security} \\ & + 2.457883*\text{LUConstraints} \end{aligned}$$

The statistics of the variables involved is illustrated in Table 6. The coefficients of the dependent variable depict their participation level in determining the growth process. The highest coefficient value was estimated for constraint (2.457883) which indicates that the presence of water, forest and existing built-up areas shows its favouring nature in the growth process. The positive value for Distance to Attraction indicates a positive impact on urbanization while the low negative value of the coefficient of distance to built-up, finance, hospital, hotel, market, road, and security shows that it does not affect the urban growth process at all.

Table 9: Coefficients of Variables in Logistic Regression.

Variables	Coefficient
Intercept	-3.03907572
Distance to Attraction	0.00128790
Distance to Built	-0.03782964
Distance to Finance	0.00721285
Distance to Hospital	-0.00264220
Distance to Hotel11	-0.00338792
Distance to Market11	-0.00658784
Distance to Road	-0.00407583
Distance to Security	0.00500978
Constraints	2.45788345

The probability of the urban growth was computed and visually represented in continuous data in Figure 7. The brighter areas in the image indicate areas where urban growth is high. The map was reclassified into three classes of low, medium, and high as shown in Figure 8 to present areas with high, medium, and low growth probabilities.

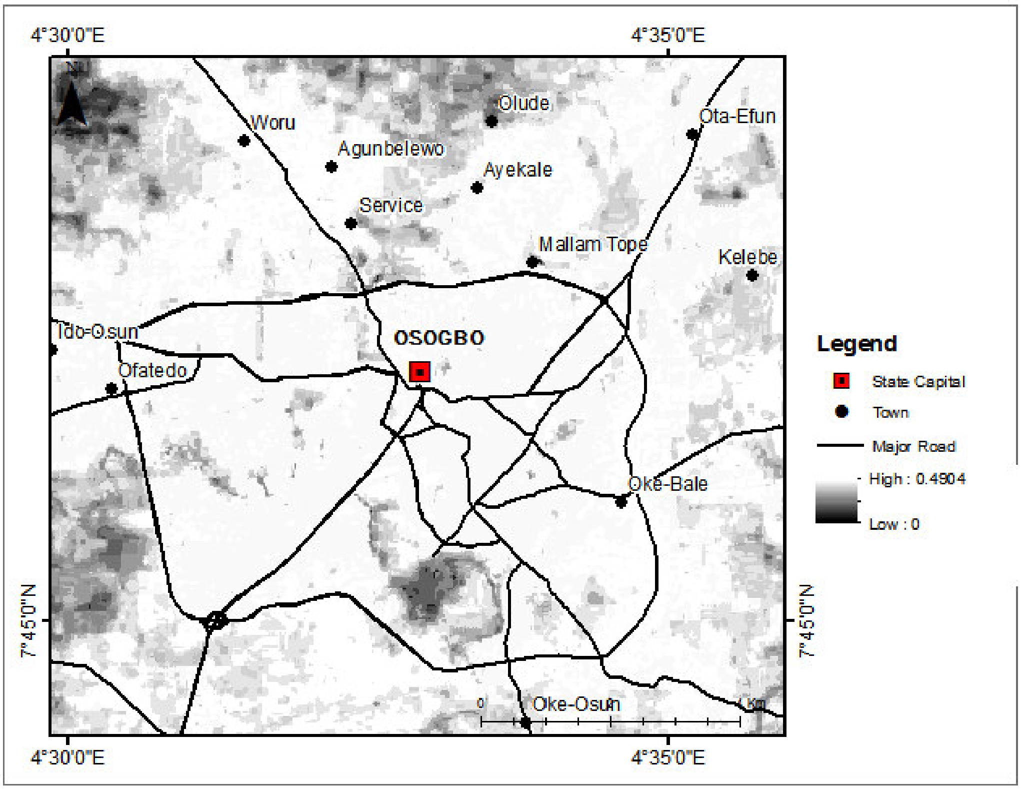

Figure 7: Built-up Map represented in continuous data

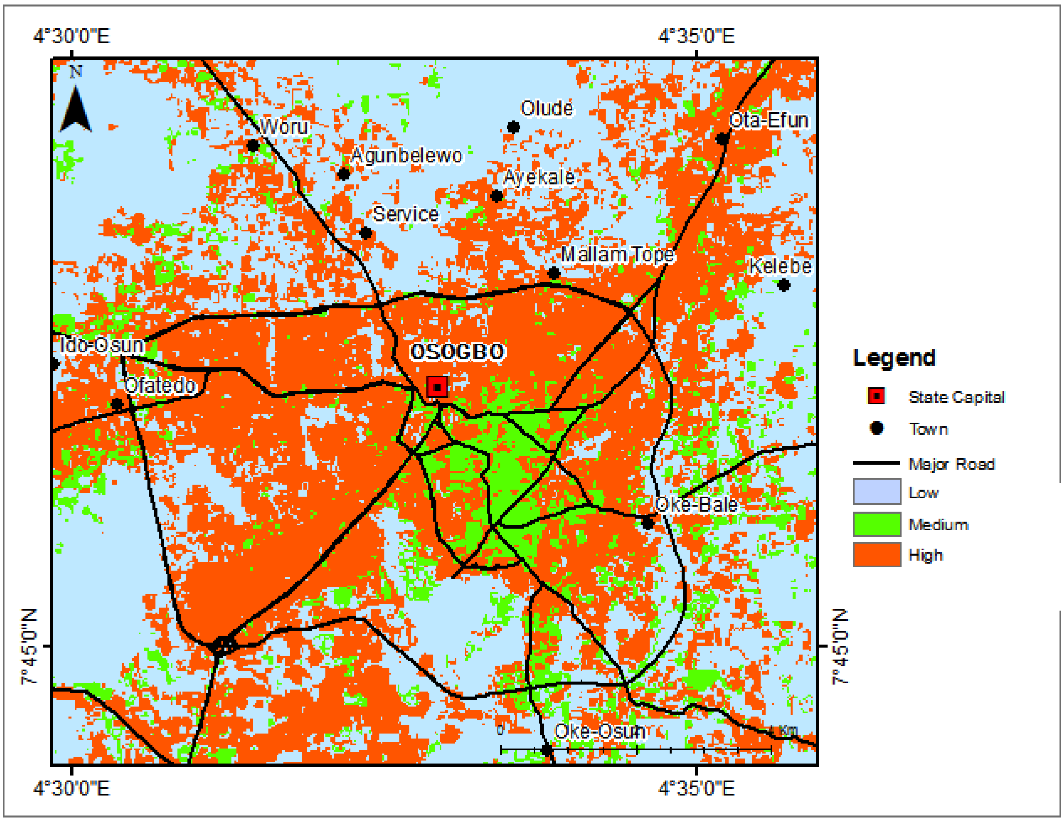

Figure 8: Built-up growth probability showing low, medium, and high growth probability areas

Projection for year 2029

It is clear from the Figure 9 that the urbanization of Osogbo is inevitable. Consequently, the estimated land area of Osogbo by the year 2029 is 75.28km2. This is an increase of 26.48km2 from the present area of 48.80km2 in 2021. Apart from being the state capital, increase in population through natural birth, siting of educational institutions, immigration, and the location of industries in the area will contribute to that. It was found that most of the growth is expected to take place in the western periphery of the built-up area, and in the remote pockets located in the southern outskirts.

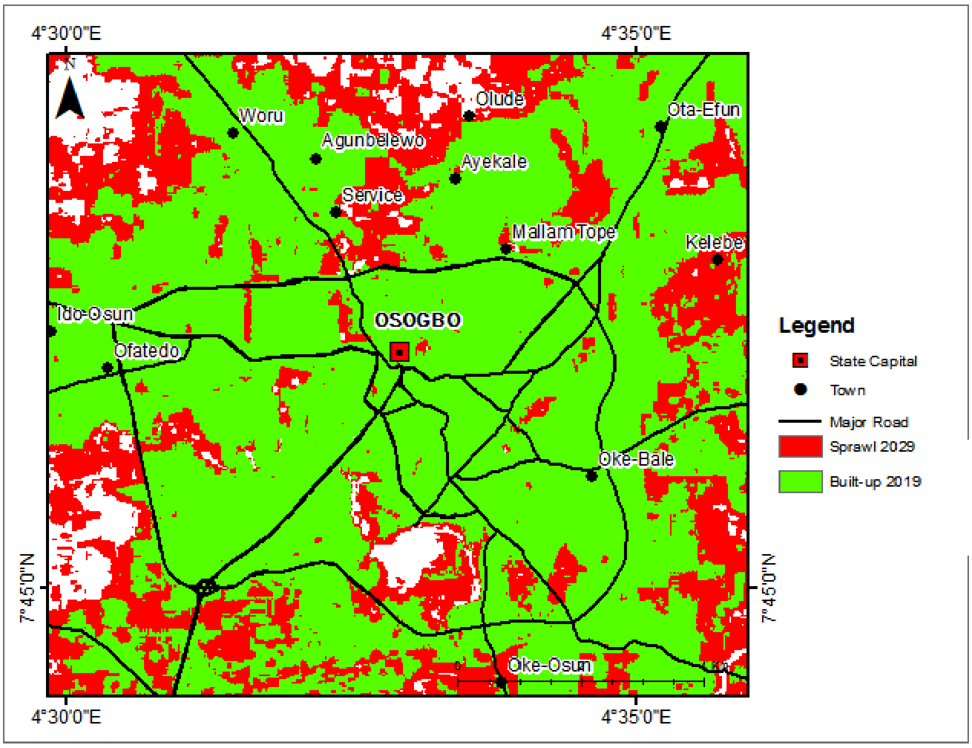

Figure 9: Urban Sprawl Map of Osogbo

CONCLUSIONS

The study addressed spatio-temporal pattern, monitoring of the dynamics of urban expansion, and prediction of built-up area in Osogbo, Nigeria, with the use remote sensing and GIS technology. The objectives were to assess the spatio-temporal pattern of urban expansion of Osogbo city between 1989 and 2021; determine areas of high growth probabilities using Logistic Regression Model and predict sprawl in the study area for year 2029. Using Landsat imageries of 1989, 2002 and 2021 covering the study area, the datasets were subjected to supervised classification using Image Classification Tool in ArcGIS 10.3. The urban land cover was subjected to change analysis to determine the urban growth areas between the study years. A Linear Regression Model was computed to understand the impact of proximity of urban growth variables such as Hospitals, Banks, Markets, Roads, Existing Built-up areas on the growth probability of the identified areas for the projected year 2029 using IDRISI Taiga software. Finally, a growth prediction map for the projected year 2029 was computed using Cellular Automata in QGIS software.

It could be deduced from this study that the urbanization of Osogbo is inevitable and will constitute an exceptionally large, urbanized area by 2029. Dramatic land use/ land cover change and adverse environmental impacts of urban expansion, and increasing built up surfaces can be alleviated by the following: enforcement of planning laws and standards, effective land administration and management, and full empowerment of planning administrators and agencies. Also, there is the need for the government to embark on a constant appraisal and analysis of various urban dynamics and developments using GIS techniques and remote sensing. This will help in earlier detection of areas that are fast growing as well as areas that need urgent administrative interventions amongst other monitoring policies and standards.

This study has shown that information from satellite remote sensing and integrated with GIS can play a useful role in understanding the nature and extent of changes in land use/ land cover, where they are occurring and monitor these changes at local scale and predict areas of different growth probability rates which help in determining the extent of urban growth of the study area in the future.

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