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Research Article

Assessment of Population and Urban Growth Using Exponential Growth Model: A case study of Ibeju-Lekki Local Government Area, Lagos State.

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Abstract

The rapid population growth in Ibeju-Lekki, Lagos State, Nigeria, has caused many challenges such as infrastructure pressure, environmental degradation and social unrest. A geospatial assessment investigated the relationship between population growth and urban expansion in Ibeju-Lekki, Lagos state from 1991 to 2022.
According to the study, the population of Ibeju-Lekki experienced an average annual growth rate of 4.5% from 1991 to 2022. This growth can largely be attributed to migration from rural areas and natural population increase. Interestingly, the study also revealed that the population growth rate was higher in urban areas than in rural ones. Additionally, the research found that the urban expansion in Ibeju-Lekki was swift, with the built-up area increasing by an average of 10% annually.
Overall, these findings suggest that the government should adopt measures aimed at managing population growth and promoting sustainable development such as investing in infrastructure, improving environmental management and promoting social inclusion to mitigate the negative impacts of population growth in Ibeju-Lekki, Lagos state. These measures can help alleviate the strain on the region's resources and infrastructure caused by rapid population growth and urbanization.

Keywords: Population Growth, Urban Expansion, Exponential Model, Geospatial Assessment

Introduction

This first Nigeria population census was conducted during the colonial era in the days of the Lagos colony which includes present-day Lagos Island and some portions of the Lagos mainland, which later became a territory of Nigeria in 1866 (National Population Census, 2023). The British held decennial censuses in 1871, 1881, 1891, and 1901, and all of these were restricted to the colony alone before the formation of the nation called Nigeria, which was founded 63 years after the first census.

(National Population Census, 2023) shows that Nigeria, one of the developing countries in Africa, is a good example of a country where population growth is increasing by 2% or more yearly. There were 7.9 billion people on the planet in 2020, up from 1 billion in 1800 (WorldoMeter, 2023). According to estimations, the world's population will reach 8.6 billion by the middle of 2030, 9.8 billion by the middle of 2050, and 11.2 billion by the end of 2100, as predicted by the UN (United Nations, 2022). However, some scholars outside of the UN have increasingly created human population models that take further declining pressures on the population growth; in such a scenario the projected population increase at its peak before 2100 (Roser and Rodés-Guirao, 2019). To avoid other population impacts like increased crime rate, pressure on social amenities, land degradation, erosion, and flood, there is a need to manage the human population.

Reliable and accurate data are required for the development of urban plans. However, such data cannot be easily obtained without using efficient technology such as satellite imagery (Ramadan and Effat, 2021), which is a powerful tool in the change detection of the land surface. Therefore, urban growth is highly involved in geospatial analysis and geographic information system (GIS) Applications.

However, it is unclear from the literature how significant the human population and urban growth between 1991, 2006 and 2022 since the last population census was conducted in the year 2006 by the National Population Commission. This information is crucial, which now leads to the problems to be investigated.

The increasing human population has over time had a serious influence on urban growth, which emanates from the need for shelter (Benomar, Biant, & Abdolaziz, 2006). The overall and spatial coupling between urban growth and population growth is influenced by several factors, including the expansion rate of construction land. In other words, the higher the expansion rate of construction land, the higher the overall and spatial coupling between urban growth and population growth (Qingyao and Yihua; 2021). In Nigeria, many people move from rural areas to urban areas in search of greener pastures. Among the major Centre that many Nigerians prefer is Lagos in which Ibeju-Lekki local Government is situated it is one of the major local governments in Lagos State that receives much influx of people due to its commercial nature of the environment, which has numerous economic and commercial opportunities in terms of employment for the growing population.

The review of related research shows that the increasing human population as a result of rapid urbanization and improved social amenities has influenced the migration of people to Ibeju-Lekki LGA, and this development has also increased its built-up area. This needs to be correlated and assessed for planning. This research will look into the population growth in the Ibeju-Lekki area concerning urban expansion for the periods of 2006 to 2022 as no official human population census within this period. The study will produce the following dataset such as projected population census data using an exponential growth model and urban growth using Landsat imagery in conjunction with existing administrative boundaries which will serve as a master plan to assess the population growth that has resulted in various challenges, such as the influx of people and its impact on green space areas and structures, a comprehensive study was conducted in the Ibeju Lekki local government. The significant factor contributing to this phenomenon has been the rapid industrialization and infrastructural development in the region between the years 2006 and 2022.

This brings a fresh viewpoint for investigating how population increase and urbanization are linked, as well as a fresh method for researching their interactions. Therefore, this research intends to proffer solutions to some of the problems mentioned above by using geospatial tools to ensure sustainability and proper planning within the limited time given and available resources. This gap in knowledge leads to the aim of this project.

The focus of this research is to carry out a geospatial assessment of the population and urban growth of the Ibeju-Lekki Local Government Area, Lagos state using an exponential growth model and analysis of results by geospatial techniques.

To achieve the aim, these are the set-out objectives:

i. To review the documented years 1991 and 2006 census data obtained from the Nigeria Population Commission (NPC).
ii. To determine the projected human population census between 2006 and 2022 using an exponential growth model
iii. To design and implement data acquisition procedures for image classification and built-up extraction from the land use of Ibeju-Lekki for the years 2006, and 2022.
iv. To perform an asymmetric analysis of the population strength and built-up land use of Ibeju-Lekki LGA for the years 2006, and 2022.
v. To apply relevant statistical techniques to test for any significant difference in the results, draw conclusions and make recommendations based on the outcome of the study.

The study area of the project is Ibeju-Lekki LGA, which lies between latitude 6°22'11.85" N and 4°16'56.54"E, 6°31'57.73"N, longitude 3°40'4.49"E. It is about 75km long and 20 km at its widest point and is spread over 646 km2 or a quarter of the total land mass of Lagos state, according to (Ibeju-Lekki Local Government Authority, 2021). Some of the major towns in Ibeju-Lekki include Ibeju-Agbe, Magbon-Alade, Iberikodo, Igando-Oloja, Aiyeteju, Awoyaya, Bogoje, Akodo, Elerangbe, Eleko, Elemoro, Idi-Orogbo, Lakowe, Orimedu, Abijo, Mopo-Ijebu Eputu and Badore. It is located along the coastal plain of Nigeria which has many creeks and Lagoons, and it's mainly populated by Ijebu-speaking people of the Yoruba tribe in Nigeria. The LGA is bounded by Eti-Osa East LCDA on the west, Epe on the north and east, and the Atlantic Ocean on the south.

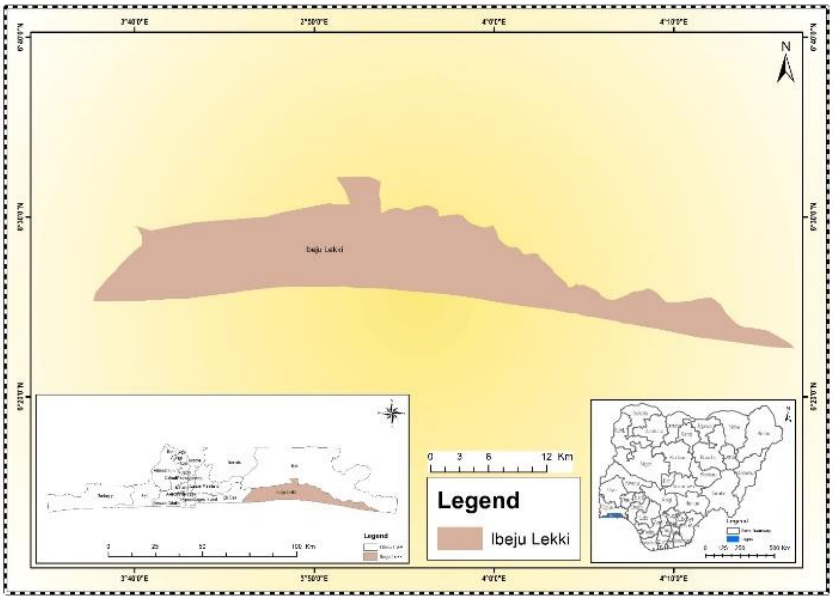

Fig 1: Map of the Study Area

Materials and Methods

The exponential growth model of population projection is a straightforward mathematical approach that assumes a constant growth rate for the population. It is commonly employed for short-term predictions of population growth due to its ease of calculation and interpretation (Keyfitz, 1977).

The equation represents the model: $\boldsymbol{P_t = P_{o(e)}^{r*t}}$ (Eq. 1)

Therefore, the exponential growth model was used to calculate the projection population data of Ibeju-Lekki for the years 2006, and 2022 as shown below;

$\boldsymbol{Pt = P_{o(e)}^{r*t}}$ Where:
Pt = Future or Present population value
Po = Past or Present Population value s
e = base of the natural logarithms
r = growth rate
t = Time interval (in years)

: $P_{2022} = P_{2006}e^{rt}$ (Eq. 2)

e = 2.718281828459045(Natural Logarithm)

$P_{2022} = 117793*2.718281828459045^{3.2*17}$
$P_{2022} =$ **174,400 peoples**

The population data for 1991 and 2006 were sourced from the National Population Census Commission, while the derivation of the projected 2022 human population from the 2006 population data was achieved using the above model and at a growth rate of 3.2%.

Comparative analysis of Population Growth (UG) in Percentage from 1991 to 2006.

Population Growth (UG) from 1991 to 2006 for the 2006:
$UG = P_{2006} – P_{1991}$ (Eq. 3)
UG = 64,445.85-31,378.67

Percentage Population Growth (PPG) = ((64,445.85-31,378.67)/ 64,445.85) *100
PUG =51%

Population Growth (UG) from 2006 to 2022 for the 2022:
$UG = P_{2006} – P_{2022}$ (Eq. 4)
UG = 64,445.85 - 174,400

Percentage Population Growth (PPG) = ((64,445.85 - 174,400)/ 64,445.85) *100
PPG = 34%...

The exponential growth model is a useful way to estimate population growth over a given period. However, it's important to keep in mind that this model assumes a steady growth rate throughout the projection period, which may not always be the case. Changes in fertility, mortality, and migration can cause growth rates to vary (Bongaarts and Bulatao, 2000). Despite these limitations, the exponential growth model is still an effective tool for making short-term projections because it's easy to calculate and interpret. It can be used to estimate population growth for different timeframes (United Nations Population Division, 2019).

Image Acquisition, and Processing

Digital Image process of the Landsat satellite images; Landsat 4(1991), Landsat 5 (2006), and Land 8 OLI/TIRS (2022). The selection of the Landsat satellite image dates was influenced by the quality of the image, especially for those with limited or low cloud cover for the census most current period in Nigeria (1991 and 2006) and projection for 2022. Each Landsat was georeferenced to the Universal Transverse Mercator Zone 31 North coordinate system. The image stacking was used to ortho-rectify the satellite images. The stacked satellite image of the study was extracted by clipping the area within the Ibeju-Lekki boundary in the form of a shapefile.

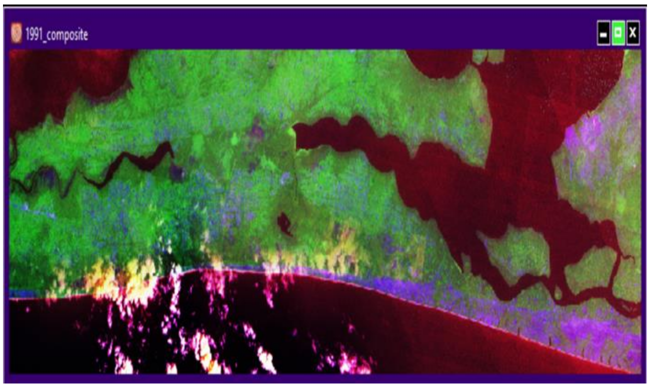

Figure 2: 1991 Landsat 4 MSS Satellite Imagery
*The figure which the 1991 Landsat satellite imagery with plate number 4 MSS.

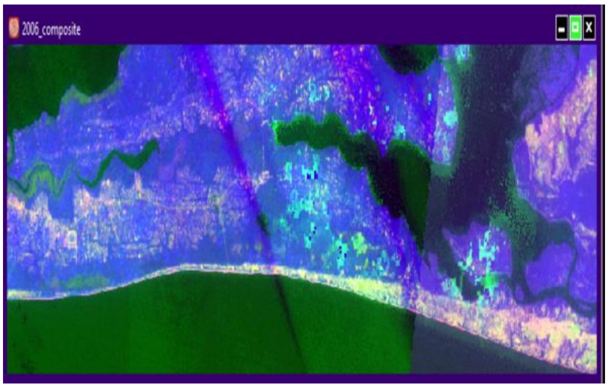

Figure 3: 2006 Landsat 5 TM Satellite Imagery
*The figure displays the 2006 Landsat 5 TM Satellite imagery.

Figure 4: 2022 Landsat 8 OLI/TIRS Imagery
* Figure 4 displays the exceptional Landsat 8 OLI/TIRS imagery for 2022, providing valuable insights into the natural features of Ibeju-Lekki.

Image Classification

Image classification is the art and science of recognizing meaningful patterns in data by spatially and spectrally enhancing an image. The supervised Maximum Likelihood Image classification is used with Erdas Imagine tools for analyzing input data and creating training samples and signature files for the classification.

Land Use	1991 (Acres)	2006 (Acres)	2022 (Acres)
Built-up	10086.2063	20715.159	31276.5139
Waterbody	28030.2121	38917.9265	36070.7604
Vegetation	61489.1129	21403.5059	28444.8602
Bare ground	3114.21765	1001.0189	6910.46275

The images are clipped to reflect only the parts of the Ibeju-Lekki Local Government Area necessary for this study which is of the densely populated areas of Lagos state.

The classification process used is broken down into two parts: training and classifying.

After the training site (AOI) is digitized, the next step is to create statistical characterizations of each piece of information. These are called Signatures editors in ERDAS Imagine 2015. In this step, the goal is to create a signal (SIG) file for every informational class. The SIG files contain a variety of information about the land cover classes described. After the entire signature is created, then the SIG file is saved as dialogue.
Based on the Created training signature, the computer system is then instructed to identify pixels with similar characteristics.

Table 1: Land use area in Acres of Ibeju-Lekki for the years 1991, 2006, and 2022
******The table displays changes in land cover between 1991, 2006, and 2022.*
The supervised classification was applied after defined training classes. One or more than one training area was used to represent a particular class. During the supervised classification process, the entire Signature editor was selected to be used in the classification process. Then the classify was selected from the Editor Menu bar, classify/supervised. A non-parametric rule was used in this classification. The Image was classified into five classes namely; Waterbody, Built areas, Barren/bare land, and vegetation. Reclassification was done to get the built-up area of the land use, this built-up was extracted for the study periods to assess and evaluate the urban expansion in the study area.

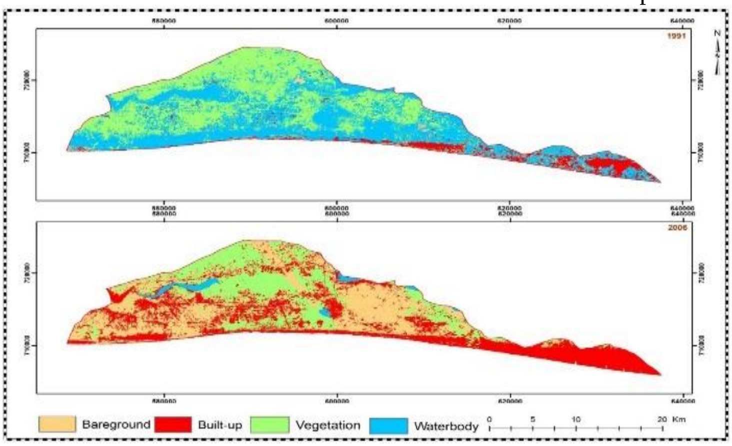

Fig. 5: Land use/land cover of Ibeju-Lekki for the years 1991 and 2006.

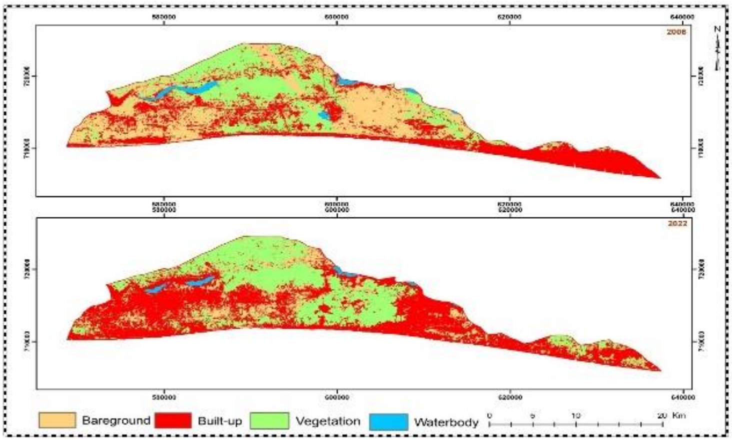

Fig. 6: Land use/land cover of Ibeju-Lekki for the years 2006 and 2022

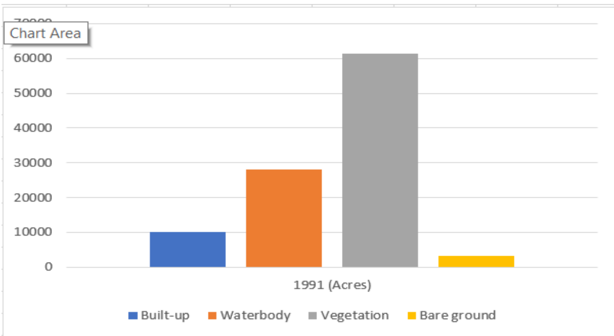

Fig. 7: Bar Chart of Ibeju-Lekki for the year 1991

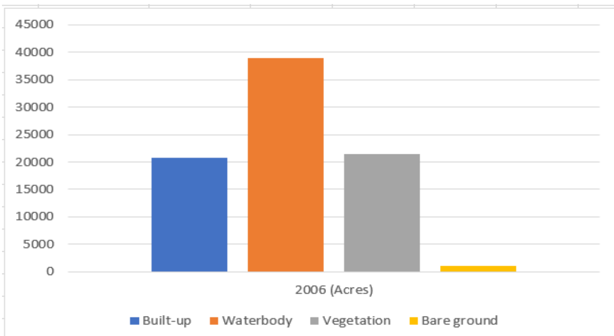

Fig. 8: Bar Chart of Ibeju-Lekki for the year 2006

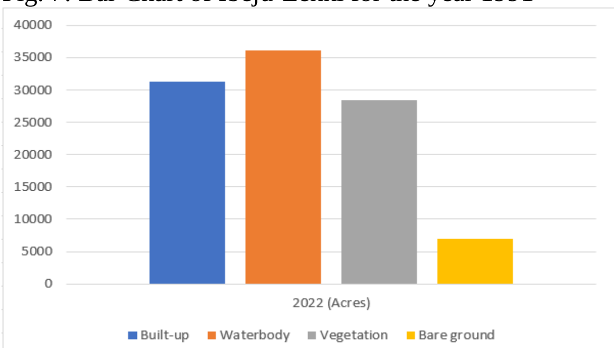

Fig. 9: Bar Chart of Ibeju-Lekki for the year 2022

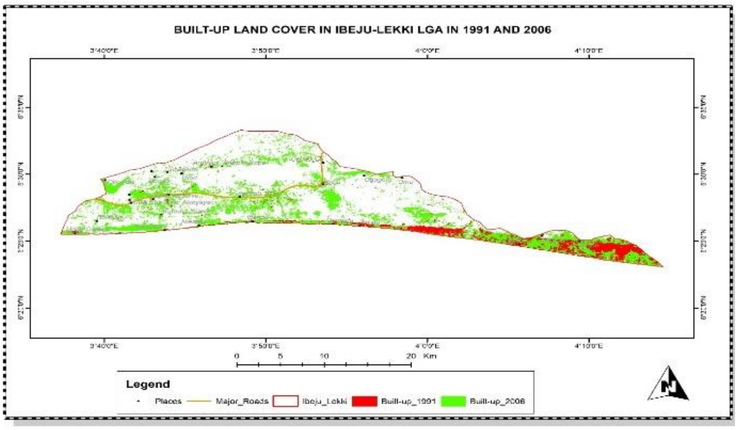

Fig. 10: Urban Land use of Ibeju-Lekki for the years 1991 and 2006

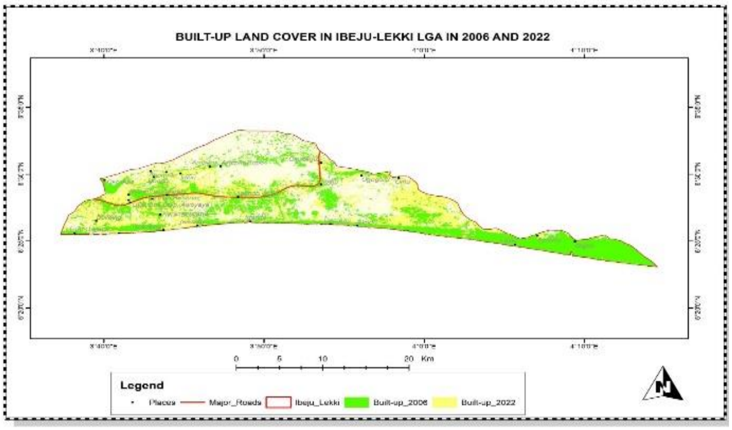

Fig. 11: Urban Land use of Ibeju-Lekki for the years 2006 and 2022

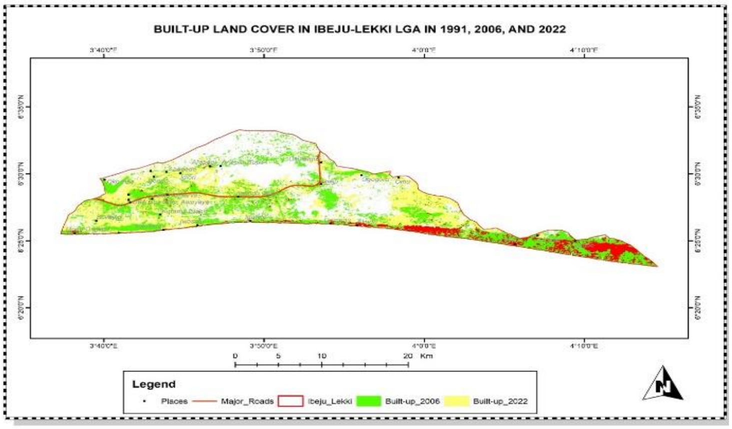

Fig. 12: Urban Land use of Ibeju-Lekki for the years 1991, 2006, and 2022

Table 2: Urban Expansion and Population of Ibeju-Lekki for 1991, 2006, and 2022

Year	Built-up	Population
1991	10086.206	24937
2006	20715.159	117793
2022	31276.514	174400

According to the table, the population of Ibeju-Lekki has been on a steady rise over the past few decades due to urban expansion and development

Table 3: Analysis of urban growth for each epoch

Epoch	1991	2006	2022
Urban Area (Acres)	10086.206	20715.159	31276.514
Urban Growth	-	10628.953	32,856.88
Percentage Urban Growth	-	51%	34%

Table 3 shows the analysis of urban growth for each epoch

Change Detection- Image Differencing

The change detection method used in this analysis is the post-classification image differencing. Change-detection images provide information about built-up land use changes over the years. The information is extracted by comparing two of the independently produced classified images overlaid in ArcGIS 10.7. The images are registered using corresponding ground-control points then the digital numbers of one image are subtracted from the one acquired later. The resulting values for each pixel will be positive, negative, or zero (no change).

Results

Urban Expansion and Population Growth

Spatial metrics are valuable tools to quantify the dynamic patterns of ecological processes of urbanization which usually change the landscape pattern in urban regions. Changes in urban landscape patterns can be detected using tables that quantify and categorise landscape structure.

Regression Analysis

The regression analysis provides valuable statistical insights into the relationship between the population and the dependent variable. The high correlation coefficient (Multiple R) of 0.990592 suggests a strong positive correlation between the population and the dependent variable. The coefficient of determination (R Square) at approximately 98.13% indicates that a significant portion of the variance in the dependent variable can be explained by changes in population.

Table 4: Result of the regression analysis of Ibeju-Lekki LGA for 1991, 2006, and 2022.

Regression Statistics	
Multiple R	0.990592
R Square	0.981273
Adjusted R Square	0.962546
Standard Error	6379.163
Observations	3

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	2.13E+09	2.13E+09	52.39887	0.087393
Residual	1	40693714	40693714		
Total	2	2.17E+09			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	18634.75	7313.936	2.547841	0.238105	-74297.6	111567.1	-74297.6	111567.1
Population	0.432703	0.059776	7.238706	0.087393	-0.32683	1.192232	-0.32683	1.192232

**Table 4 shows the results of regression analysis comparing urban land use and populations in Ibeju-Lekki LGA for 1991, 2006, and 2022.*

Discussion and Conclusion

The Land Use Dynamics: The land use data analysis reveals some significant changes in the past few years. While there has been an increase in built-up areas due to urbanization and infrastructure development, there has also been a slight increase in waterbody areas, thanks to dam and reservoir construction. However, there is still room for improvement, especially when it comes to vegetation. Deforestation and expanding agriculture have led to a significant decrease in vegetation, which poses risks to the area's biodiversity and increases the likelihood of flooding. To address this issue, it is essential to promote sustainable land use practices that prioritize conservation efforts. Additionally, the minor reduction in bare ground is an opportunity to implement measures to prevent encroachment from built-up and vegetation areas, which can have implications for soil erosion and land stability. By working together, we can ensure that land use practices are sustainable and help maintain the health and stability of our environment.

Urbanization trends: This indicates a continuous growth of urban areas over the years. Between 1991 to 2006, urbanization was robust due to factors such as population increase, economic development, and infrastructure projects. However, from 2006 to 2022, the expansion of urban areas slowed down, suggesting a potential shift in urban development strategies. This shift could be influenced by urban planning regulations, environmental concerns, or changing development priorities.

Statistical Insights: The regression analysis provides valuable statistical insights into the relationship between the population and the dependent variable. The high correlation coefficient (Multiple R) of 0.990592 suggests a strong positive correlation between the population and the dependent variable. The coefficient of determination (R Square) at approximately 98.13% indicates that a significant portion of the variance in the dependent variable can be explained by changes in population.

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