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Population Estimation of Ovia North-East Local Government Area using Geographic Information System (GIS) and Remote Sensing

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Abstract

This study was done to carry out the population estimation of Ovia North-East Local Government Area in Edo State, Nigeria, using GIS and remote sensing techniques. The goal was to produce visual maps such as land use land cover, population density, and dasymetric mapping to show the population distribution. The study used a binary dasymetric method, which is a spatial interpolation technique that incorporates ancillary data on land use land cover, settlement, and road network. Binary dasymetric map separates the study area into habitable and inhabitable zones, based on the presence or absence of features such as buildings, roads, and settlement data. Census data was obtained from Nigeria Population Commission (NPC, 2006) and the land use and land cover results were obtained from the supervised classification of Landsat 7 C2 EMT + obtained from USGS earth-explorer database. The research revealed that the population of Ovia North-East Local Government Area has grown at an average rate of 14.78% per annum in five (5) year interval, with an estimated annual growth rate of 3.4%. The population for the years 2006, 2011, 2016 and 2021 were estimated to be 155344, 178909, 203425, and 234706 respectively. The results of this study demonstrate that the use of GIS and remote sensing techniques, in conjunction with ancillary data, can improve the accuracy of population estimates and provide a more comprehensive understanding of population distribution. The resulting population estimates and maps will provide valuable information for planning and resource management in the Ovia North-East Local Government Area and other tiers of Government such as the State and Federal Government respectively. It will also make it possible for policy makers to have a better understanding of the spatial distribution of the population within the study areas, and to identify areas that may be in need of additional resources or support.

1. Introduction

A country's population is its most valuable resource on a worldwide and international scale. Growth and urban expansion in the past decades have occurred at magnitudes unprecedented in human history producing considerable impacts on socio-economic development, availability of resources, and environmental protection at the local, regional, and global scales [1].

A population is described as a count of the inhabitants or people who live inside a political or geographic limit, a city, a country, or the entire world, depending on the region of interest. These numbers or figures are in no way constant. They change or diminish because of the interaction of three demographic processes namely; birth, death, and migration [2]. In understanding these interactions, population estimates are essential to provide accurate information about the size and demographics of the human population. These estimates are important because they give us a thorough understanding of the world around us and make it possible for us to address a wide range of social, political, economic, and environmental challenges that may arise in a specific area [3].Population estimates can indicate the size of the entire population as well as demographic details like age, sex, or level of education. While a projection specifies these qualities in the future, an estimate calculates the size or distribution of a population or another aspect of the population for the present or past. Both calculations aim to determine the number of people in an area and are valuable for urban management, decision-making, and socioeconomic and environment-related studies [4].

Conventionally, surveys like head counts and censuses, which are enumerations of people, residences, businesses, or other significant items in a country or region at a certain period, were the traditional techniques of population estimation [5]. In the ancient world, great empires like Egypt, Babylon, Persia, India, and China, as well as several Greek city-states, performed head counts which is the act of counting the number of individuals at a location, event, etc. Censuses in most of the developing world did not occur until the second half of the twentieth century. The United States (required by its constitution) held its first census in 1800, followed by those for England and France in 1801, Ireland in 1813, and more than 20 other nations by the 1860s.

Recently, various alternative census approaches have been developed, making use of register data combined with field data collection and other sources, as well as partial annual field data collection and other sampling methodologies [6]. Over the decades, census taking around the world has faced major challenges, including cost pressures, concerns about intrusiveness, privacy and response burden, reduced cooperation, difficulties in accessing secure apartments and enumerating unsafe areas, more complex living arrangements, numerous uncertainties, and timeliness concerns [7]. [8] focused on pycnophylactic interpolation, a spatial interpolation method that aimed to redistribute areal data into smaller and more homogenous units. The study introduced novel approach that combines pycnophylactic interpolation with the dasymetric mapping method, which allocates data from one geographic unit set to a finer set of units. The authors provided a comprehensive explanation of their methodology and formulas, which involved merging the areal weighting method with the dasymetric mapping technique. To assess the accuracy of their approach, the study compared it to traditional pycnophylactic interpolation and other spatial interpolation methods using a sample dataset. The approach involved integrating the areal weighting method with the dasymetric mapping method.

Another related study was a research done by [9], the author used a high resolution satellite imb2agery to estimate the population of Akure South Local Government Area, Ondo State, Nigeria. The methodology and data sources used in the study by the author was the dwelling unit method, a high resolution satellite imagery, 1991 and 2006 population data from NPC and an on field data. Sufficient field sample information about the number of people living in different types of residential buildings was collected using close questionnaire method. In the study area, a total of twenty-six locations were visited for sample collection. However, one of these locations was found to fall outside the designated study area. From the sample collection, five houses were randomly chosen, and relevant information was gathered for each of these locations Therefore, twenty-five areas were used for the calculation of the average number of people living in the study area. The acquired image was then taken to ArcGIS environment, where it was georeferenced and digitized. The coordinates of the twenty-five places where the samples were taken was acquired using Hand-held GPS receiver. Shapes and locations of buildings were used to determine whether a building is a residential one or not. For example, buildings around an open field, were classified as schools. Other examples are buildings located in business areas, which are classified as non-residential buildings. Since the interest of this study was on residential buildings, these non-residential buildings were not digitized nor counted. The ArcGIS software was used alongside with visual interpretation to visualize and digitize the image so as to determine locations of areas, occupied or directly utilized by the occupants of the area. It order to estimate using dwelling unit counts, ArcGis 9.3 software was used to extract the dwelling units from the satellite imagery.

2. Materials and methods

2.1 Study Area.

Ovia North-East Local Government Area is one of the eighteen (18) serving Local Government Areas in Edo State Nigeria, and thus falls within the Southern Senatorial District, also known as Edo South District, alongside Ovia South-West, Egor, Oredo, Orihionmwon, lkpoba Okha, and Uhumwode. Ovia North-East is located in the northern part of the state within longitude 5°14'20." E, latitude 5°50'34.80" E and longitude 5°54'42.10.8"N, latitude 6°46'58.80" N (CRS: WGS84). It has its headquarters in Okada, The LGA is divided into several towns and villages, including Adolor, Iguoshodin, Isiuwa, Kokhuo, Oduna, Ofunm-Wengbe, Oghede, Okada, Oluku, Uhen, Uhiere, and Utoka. It has a total area of 2,301 km^2 and a population of 153,849 people according to the National Population Census, [8] with members of various tribal affiliations such as the Ijaw and Bini ethnic groups, primarily inhabiting the area but the local language of Bini and Edo are widely spoken. Notable landmarks in the LGA include Igbinedion University, Okada, and the Okomu Oil Palm Company.

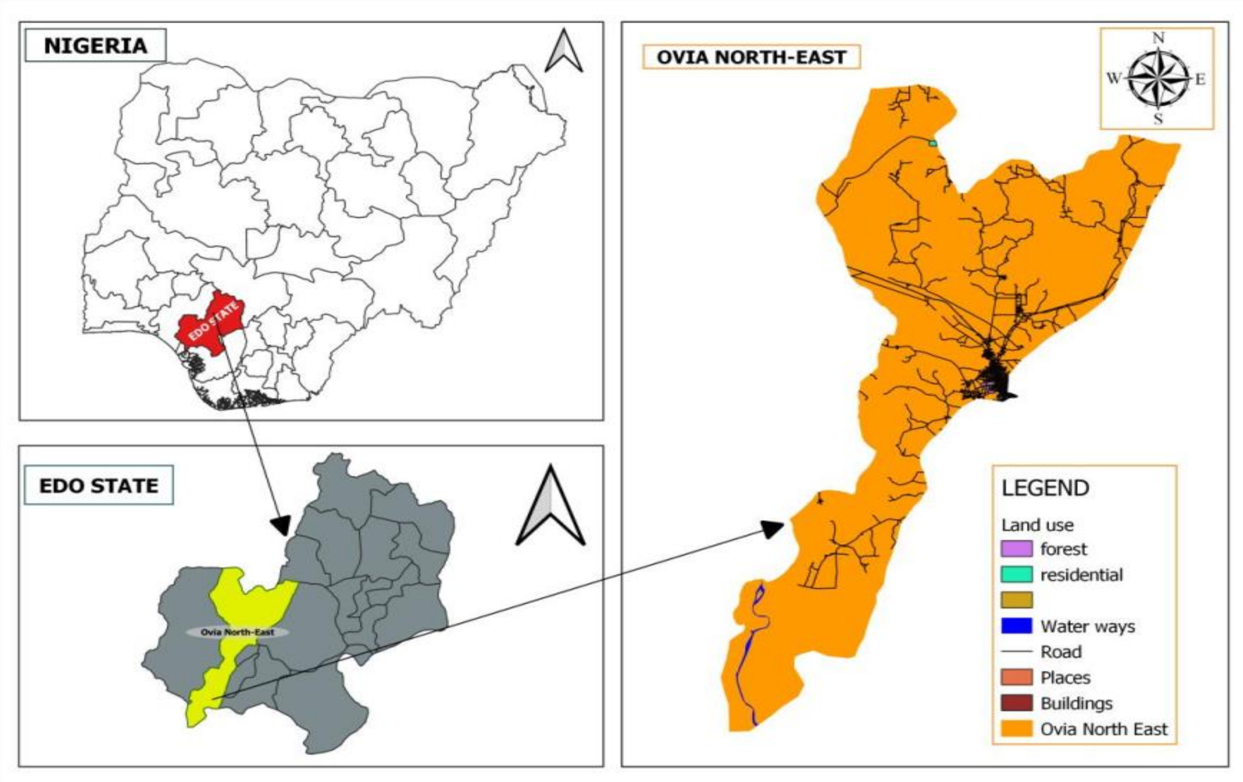

Figure 1: Map of the Study Area

2.2 Methods

This section enumerates the methods adopted for achieving the aim of this study. It includes the series of steps and the critical considerations involved in selecting the procedures to be applied. These steps include:

1. Data Acquisition
2. Integration of Population Counts and Landsat Images
3. Image Processing and Map Production

a. **Data Acquisition**: Obtain datasets such as administrative boundaries shape files of Ovia North-East Local Government Area. Gather population census data for Ovia North-East Local Government Area. Access Landsat ETM+ satellite imagery with the thermal band for the study area. Nigeria Population Commission (NPC) is the official source for population data in Nigeria and it is responsible for conducting periodic censuses. Hence, the 2006 population data was obtained from this NPC agency to ensure the accuracy and reliability of the data
b. Integration of Population Counts and Landsat Images: Perform a spatial join operation, using GIS software, to link the population census counts with the administrative boundaries shape files. This step associates the population data with their respective administrative units.
c. Image Processing and Map Production: This includes processing the Landsat imagery to get the Land Use Land Cover information and generate map outputs which includes dasymeteric and population density map based on analysis of the processed imagery each of these stages plays a crucial role in achieving the project aim and contributes to the overall workflow.

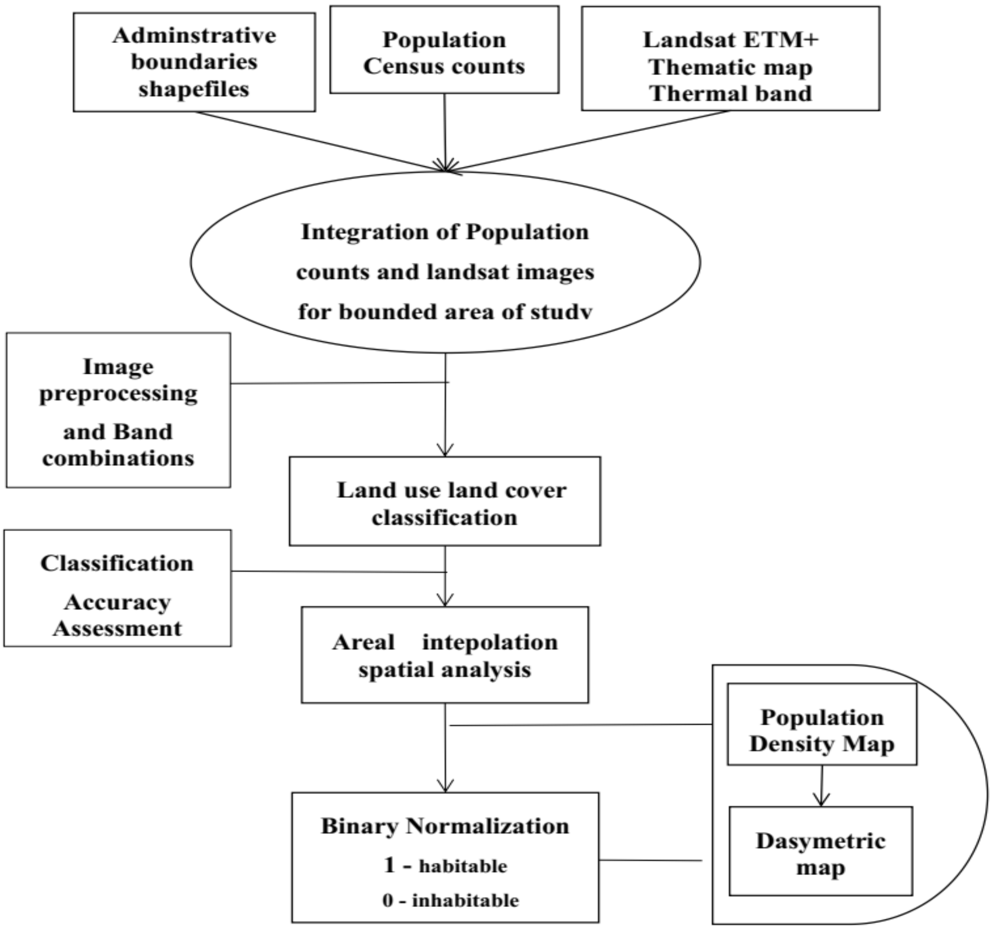

Figure 2: Study Work Flow

2.3 Landsat 7 Enhance Thematic Mapper Plus (ETM+)

Landsat 7 ETM+ is a satellite sensor that collects data in multiple wavelengths of visible and infrared light. It has a total of 15 bands, including 8 bands in the visible and near-infrared (VNIR) range, 2 bands in the shortwave infrared (SWIR) range, and 5 bands in the thermal infrared (TIR) 51 range. Each of these bands has a different wavelength range and is sensitive to different types of information about the surface of the Earth. For example, the VNIR bands are useful for mapping vegetation and land cover types, while the SWIR and TIR bands are useful for mapping minerals and detecting temperature differences. The panchromatic band (Band 8) has a higher spatial resolution than the other bands and can be used to create detailed, high-resolution images of the Earth's surface. Landsat 7 ETM+ imagery is provided by the US Geological Survey and is available for free, but there is need for one to create an account to access it. To obtain Landsat 7 Enhanced Thematic Mapper Plus (ETM+) imagery for Ovia North-East Local Government Area in Edo State, Nigeria, a visit was made to the Visit the USGS Earth Explorer website (https://earthexplorer.usgs.gov/), and the area of interest which is the administrative boundary shape file for Ovia North-East was uploaded.

2.4 Binary Interpolation Process

The binary dasymetric method, is a specific type of dasymetric mapping technique that involves the use of binary ancillary data, which was used in the study. The following include the procedure taken to for binary interpolation. The obtained datasets for population counts by census block was imported as vector layer, and the ancillary data used to clearly differentiate between densely and sparsely populated areas. The results were two categories such as inhabited (1) and unhabitable zone (0). Each census block is assigned to a category based on the ancillary data. A census block may be classified as habitable if it is within the boundaries of an habited built-up zone, and inhabitable zone if it is not. The population density for each census is was calculated by dividing the population count by the area of the block, given as:

$$Population\ Density = \frac{Population\ Count}{Area\ of\ Block}$$

The population density values for each category on the map are displayed using appropriate visualizations such as shading or color. The final mapping products include the population density and dasymetric map

2.5 Image Preprocessing

Image preprocessing helps to correct for various sources of error and distortion in the images. This includes correcting for atmospheric effects, such as scattering and absorption of light by atmospheric gases, and removing sensor-specific artifacts. Preprocessing also helps to improve the overall quality of the image by enhancing its contrast and sharpness. This process was carried out with the following procedure using ArcGIS Pro, where the Landsat 7 ETM+ imagery was imported into ArcGIS Pro and add the imagery as a raster layer. Atmospheric correction was performed on the imagery to remove atmospheric artifacts, such as water vapour, aerosols, and scattering. This was done using the Atmospheric Correction tool in the Image Analysis toolbox in ArcGIS Pro. A cloud mask was created to identify and remove clouds and shadows from the imagery. This was done using the Cloud Mask tool in the Image Analysis toolbox in ArcGIS Pro, also by manually identifying and masking clouds and shadows using the mask tool in ArcGIS Pro. Spectral information was extracted from the imagery by creating spectral bands or indices.

This involve creating color composites or using mathematical equations to combine the different spectral bands

2.6 Land Use Land Cover (LULC) Classification

After the image preprocessing, the following procedure were carried out to obtain the land use land cover map:

i. Identifying and Labeling Distinct Land Cover Classes: This was done by visually inspecting the imagery and assigning classes using the Image Classification tool in ArcGIS Pro. The Image Classification Wizard in ArcGIS Pro was used to perform classification using supervised methods.

ii. Creating of Training Samples: Training samples are used to teach the classification algorithm which pixels in the image correspond to different land cover classes. To create training samples, ArcGIS Pro "Training Samples" tool was used to draw polygons around areas in the image that represent different land cover classes.

iii. Supervised Classification. To perform supervised classification, the ArcGIS Pro "Classification" tool was used. This tool uses the training samples created to classify the pixels in the image into different land cover classes. In this case, five (5) different classes where classified. They are:

a. Built-up areas
b. Water
c. Thick vegetations
d. Light vegetations
e. Bare land

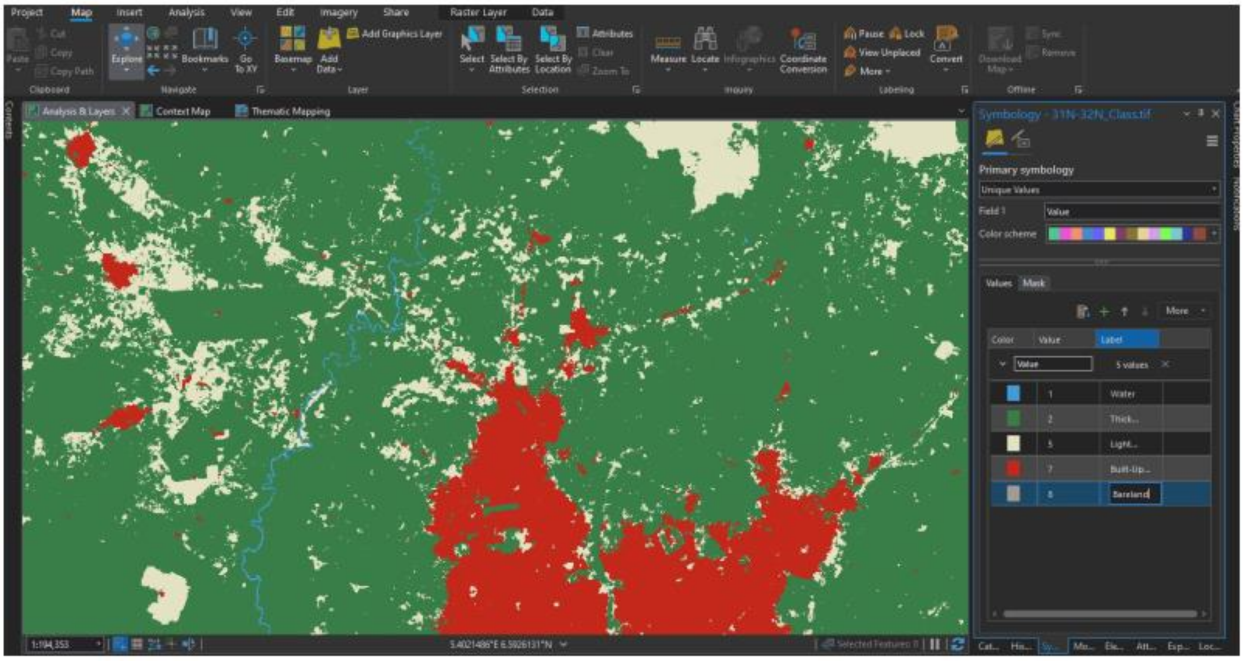

Figure 3: Supervised classification Land Use Land Cover Classes

3.0 Results and Discussion

3.1 LULC Classification Result for year 2006

The analysis of Land Use Land Cover (LULC) offers valuable insights into the distribution and composition of land cover classes in a particular region. This study focuses on the LULC outcomes for Ovia North-East in 2006. Table 1 presents the identified land cover classes, their respective areas in square kilometers (km²), and percentage coverage.

Class	Area (km²)	Percentage (%) Covered
Built-Up Area	64.66	2.81
Water	14.06	0.61
Thick Veg	2039.20	88.71
Light Veg	180.11	7.84
Bare land	0.60	0.02
Total	**2298.63**	**100**

Table 1: LULC of Ovia North-East in 2006

i. Built-up Area: The built-up area expanded from 64.66 square kilometers (2.81%) in 2006 to 74.63 square kilometers (3.25%) in 2011. This indicates an increase in urban development and infrastructure within Ovia North-East during this period.
ii. **Water**: Water bodies, such as rivers, lakes, and ponds, occupied an area of 14.06 km², representing 0.61% of the total area. These water features provide important ecological habitats and play a crucial role in the hydrological cycle.
iii. **Thick Vegetation**: The largest land cover class in Ovia North-East in 2006 was thick vegetation, which covered 2039.20 km², accounting for 88.71% of the total area. This class includes dense forests, woodlands, and other areas with abundant vegetation. Thick vegetation provides numerous ecosystem services, including carbon sequestration, biodiversity conservation, and habitat for wildlife.
iv. Light Vegetation: Light vegetation, covering 180.11 km² or 7.84% of the total area, refers to areas with lower vegetation density compared to thick vegetation. This category includes grasslands, shrub lands, and areas with scattered vegetation. Light vegetation areas may have lower tree density but still contribute to ecological functions and provide important grazing lands.
v. Bare Land: The smallest land cover class in Ovia North-East was bare land, encompassing only 0.60 km² or 0.02% of the total area. Bare land typically consists of exposed soil, rocks, or areas with limited vegetation cover. This land cover class may be associated with anthropogenic activities, natural disturbances, or transitional states between different land cover types. In 2006, Ovia North-East had a total area of 2298.63 km², and the land cover classes accounted for 100% of this area. These results offer valuable information on land cover types, aiding land management, environmental planning, and conservation efforts. The research conducted in this study has led to the creation of figure 4.1, which showcases the LULC map for the year 2006.

	CLASS	LULC AREA (km²)	PERCENTAGE (%) COVERED	DENSITY	BINARY CLASS	TOTAL POP
2006	Built-Up Area	64.66	2.81	67.581	1	**155344**
	Water	14.06	0.61	14.695	0	**0**
	Thick Veg	2039.20	88.71	2131.339	0	**0**
	Light Veg	180.11	7.84	188.248	0	**0**
	Bare land	0.60	0.02	0.585	0	**0**
	TOTAL	**2298.63**	**100**	**2402.450**		**155344**

Table 2: 2006 Estimated Population of Ovia North East

	CLASS	LULC AREA (km²)	PERCENTAGE (%) COVERED	DENSITY	BINARY CLASS	TOTAL POP
2011	Built-Up Area	74.63	3.24	77.833	1	178909
	Water	14.05	0.61	14.695	0	0
	Thick Veg	1993.11	86.72	2083.351	0	0
	Light Veg	216.13	9.40	225.906	0	0
	Bare land	0.71	0.03	0.708	0	0
	TOTAL	**2298.63**	**100**	2402.450		**178909**

Table 3: 2011 Estimated Population of Ovia North East

	CLASS	LULC AREA (km²)	PERCENTAGE (%) COVERED	DENSITY	BINARY CLASS	TOTAL POP
2016	Built-Up Area	84.67	3.68	88.498	1	**203425**
	Water	15.46	0.67	16.130	0	**0**
	Thick Veg	2031.68	88.39	2123.489	0	**0**
	Light Veg	132.34	5.76	138.327	0	**0**
	Bare land	34.48	1.50	36.048	0	**0**
	TOTAL	**2298.63**	**100**	2402.450		**203425**

Table 4: 2026 Estimated Population of Ovia North East

	CLASS	LULC AREA (km²)	PERCENTAGE (%) COVERED	DENSITY	BINARY CLASS	TOTAL POP
2021	Built-Up Area	97.6926	4.25	102.107	1	**234706**
	Water	13.4681	0.59	14.072	0	**0**
	Thick Veg	1918.8549	83.48	2005.557	0	**0**
	Light Veg	236.7618	10.30	247.460	0	**0**
	Bare land	31.8571	1.39	33.297	0	**0**
	TOTAL	**2298.63**	**100**	2402.450		**234706**

Table 5: 2021 Estimated Population of Ovia North East

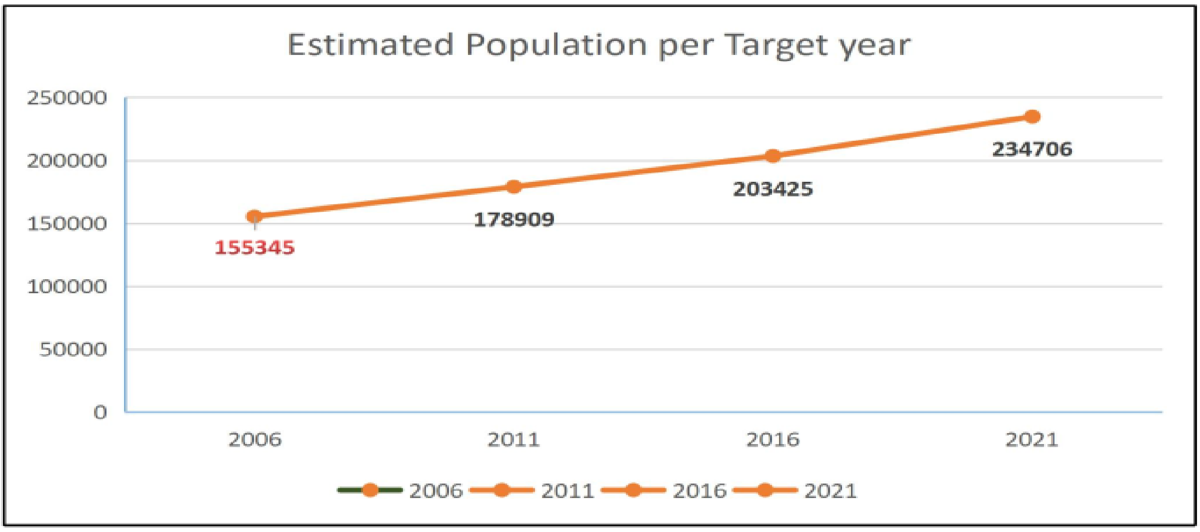

Figure 4: Chart Showing Estimated Population from 2006 to 2021

3.2 Population Distribution mapping

3.2.1 Population Density Mapping

This map that shows the distribution of population of the given area, typically by using a color scheme to indicate areas of high and low population density. These maps were created by dividing the area of interest into smaller units, such as census tracts or grid cells, and the population density was then calculated for each unit. The following processes were carried out:

i. Calculate the Area of each Census Block or Ward for the study area. This was done using the Calculate Geometry tool in ArcGIS Pro, which calculates the area of a polygon in square meters measure.

ii. Using the Field Calculator tool in ArcGIS Pro, the population density was calculated for each census block or by dividing the population count by the area.

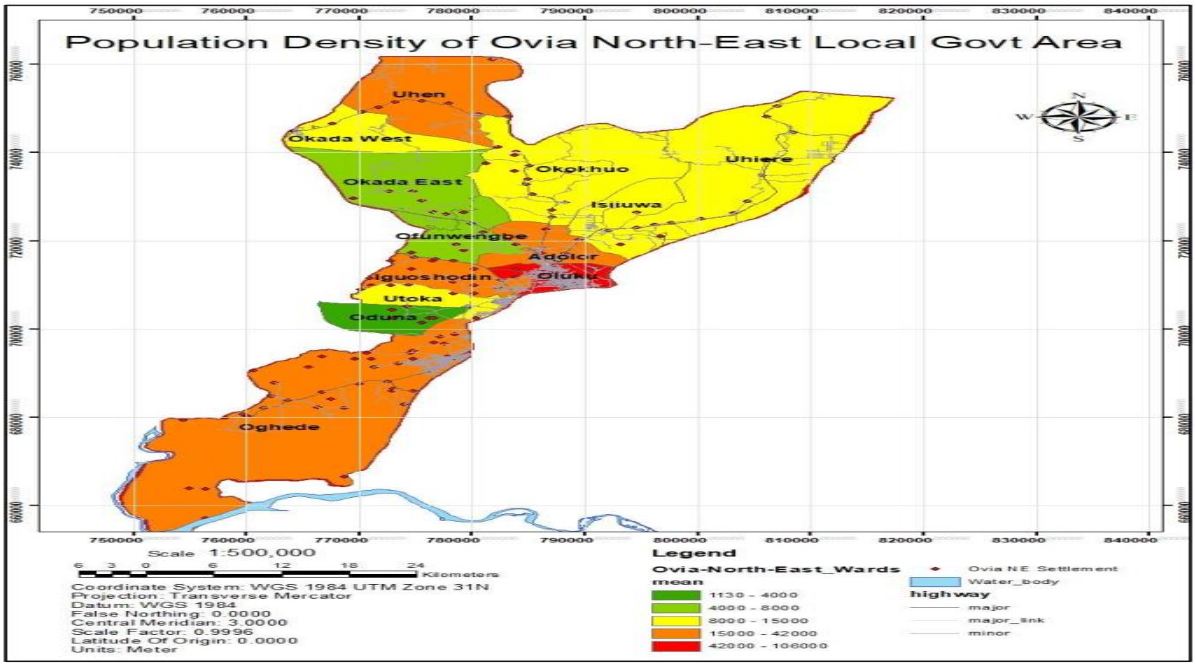

Figure 5: Population Density of Ovia North-East Local Govt. Area (Mapping Source)

3.3 Dasymetric Mapping

The mapping result of the binary dasymetric mapping technique described by [9] , is a population density map gotten by applying a spatial modeling approach used to estimate population distribution within a study area. It involves the combination of two key datasets: a land use/land cover map and a population density map. The primary goal is to distribute population counts more accurately by considering the spatial variations in the capacity of different land cover types to support human habitation.

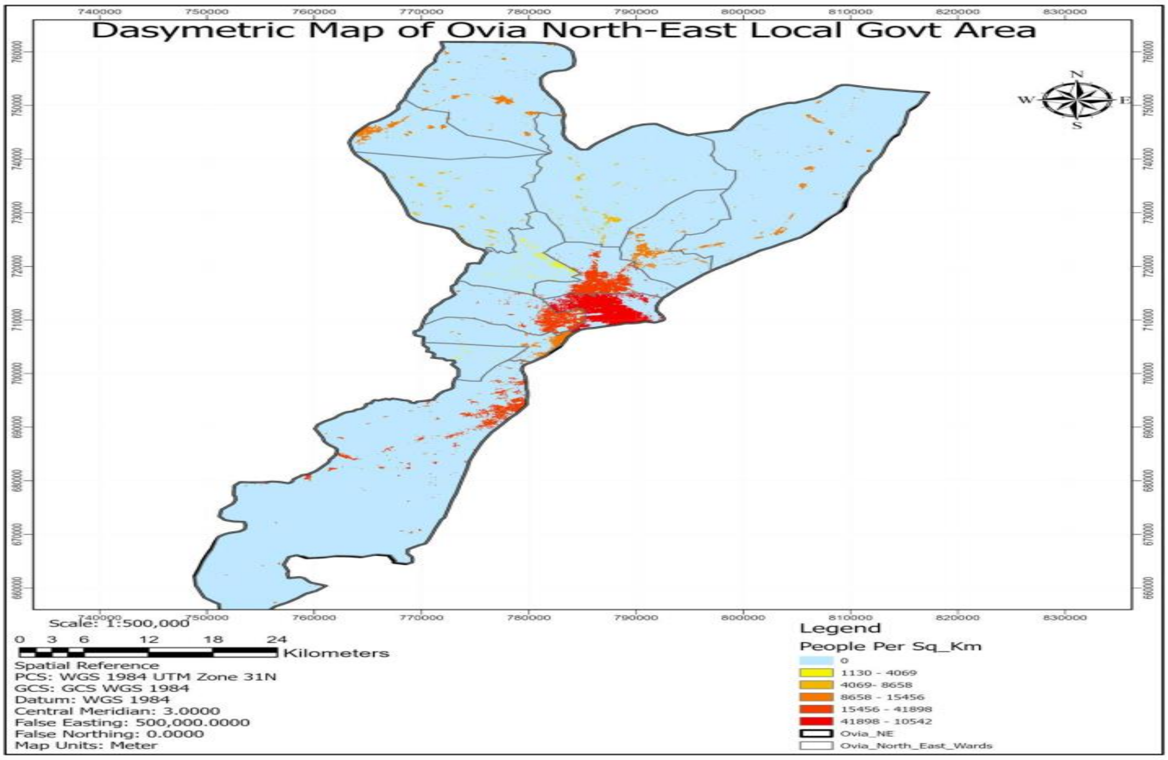

Figure 5: Dasymetric Map of Ovia North-East Local Govt. Area

4.0 Conclusion

Remote sensing and GIS techniques were used in this study in estimating the population of OviaNorth-East L.G.A of Edo State, with the objectives of producing visual maps such as land use land cover, population density, and dasymetric mapping showing the population distribution. Binary dasymetric method, which is a spatial interpolation method, was used to estimate population density at a fine scale by incorporating ancillary data on land use land cover, settlement, and road network. The method involves creating a binary dasymetric map that divides the study area into habitable and inhabitable zones, based on the presence or absence of features such as buildings, roads, and infrastructure using land use land cover, census counts, data from National Population Commission [8] road network as ancillary data which were overlaid on the binary map. The population estimates for 2006, 2011, 2016, and 2021 are given as 155345, 178909, 203425, and 234706 respectively, This indicates an average growth rate of 14.78% in 5 years interval with estimated annual growth of 3.4%. It was shown that when land use land cover data, population counts and other ancillary data are used together, the results are more accurate than when only one single data source is used. Remote sensing and GIS technologies are increasingly being recognized as cost-effective and reliable tools for population estimation. These technologies offer several advantages over traditional population estimation methods, including speed, accuracy, and low cost. Remote sensing technology, such as satellite imagery and aerial photography, can be used to obtain detailed and up-to-date information on land use and land cover, such as buildings, roads, and settlement data. This information can be used to estimate the population of an area, especially in less accessible rural communities. GIS technology, on the other hand, allows for the integration and analysis of multiple sources of data, including population data, demographic information, and land use data.

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