Monitoring and Prediction of Land Use in Enugu Urban, Nigeria, Using GIS and Remote Sensing

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ABSTRACT

Enugu Urban (The Coal City) traditionally serves as the capital of the South-East geopolitical zone in Nigeria. It is one of the fastest developing cities in Nigeria, thus the need to monitor and predict changes in land use of the city. The purpose of this study is to conduct an appraisal of the rate at which Enugu urban have developed over the recent decades with a focus on land use and to present an analysis of possible land use changes in the next few decades based on current city growth rate; from the results of the study, recommend strategies for the mitigation of the anticipated challenges. In this study, remote sensing and GIS techniques were applied in the monitoring of Enugu urban for a period of 30 years (1989 to 2019) and predictions made for two decades (2029 and 2039) using Statistical Regression Analysis. The predictions were made based on assumptions that all other socio-economic impact factors remain unchanged. Supervised (Full Gaussian) classification was applied on four LandSat archive satellite imageries using the Maximum Likelihood Algorithm in ILWIS Academic 3.2. The five land-use classes that were studied were built-up areas, farmlands, forests, bare lands, and rivers. A study area of approximately 24,500hectares covering Enugu Urban was used as a test-bed, the land use for built-up area in 1989, 1999, 2009 and 2019 were 3,741hectares(15.4%), 4,100hectares(16.8%), 8,268hectares(34.4%), and 11,055 hectares(45%) respectively while the predicted results for 2029 and 2039 were 15,119 hectares(61.7%) and 21,361 hectares(87.1%) respectively. Consequently, significant changes are evident in the land use of Enugu Urban within the study and forecast periods. The results are verified statistics with which the Enugu state government will plan and make policies to mitigate the looming slum challenges and harness revenue that will come as a result of the predicted changes in land use in the state.

Keywords: Land Use; Monitoring; Prediction; GIS; Remote Sensing

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1.0 Introduction

Land is a fundamental factor of production, while Land Use is the vital factor of sustainable development. Nations who have effective and efficient land governance systems are more prosperous than nations who do not have the same.

The term - Land Use, depicts the running and alteration of the natural environment and the transformation of same into greeneries, farmlands, urban areas sub-urban areas and villages based on demand and use by humans. Human activities on land are represented by diverse land uses.

Land Use is a key term in the language of city planning. Commonly, political jurisdictions will undertake land-use planning and regulate the use of land in an attempt to avoid land-use conflicts. Land use plans are implemented through land division and use ordinances and regulations, such as zoning regulations. (Albert Guttenberg, 1959)

The present administration of Enugu state, led by His Excellency, Rt. Hon. Ifeanyi Lawrence Ugwuanyi, the Executive Governor of the state, has set sustainable development as a priority, this is why it has set out to review the administrations of Lands and Urban development of the state. To this end, the Governor has constituted a cabinet of a formidable team of professionals with a mandate of assessing the strength and weaknesses of the existing systems and coming up with a blueprint for the transformation of governance in the state. The vision of the Government is hinged on sustainable urban development of the state, hence this scientific study is conducted to monitor and assess changes in land use and development of the city, as well as predicting same in few decades, with a view to identifying and forestalling the factors which may adversely affect land use and urban development in the state in future.

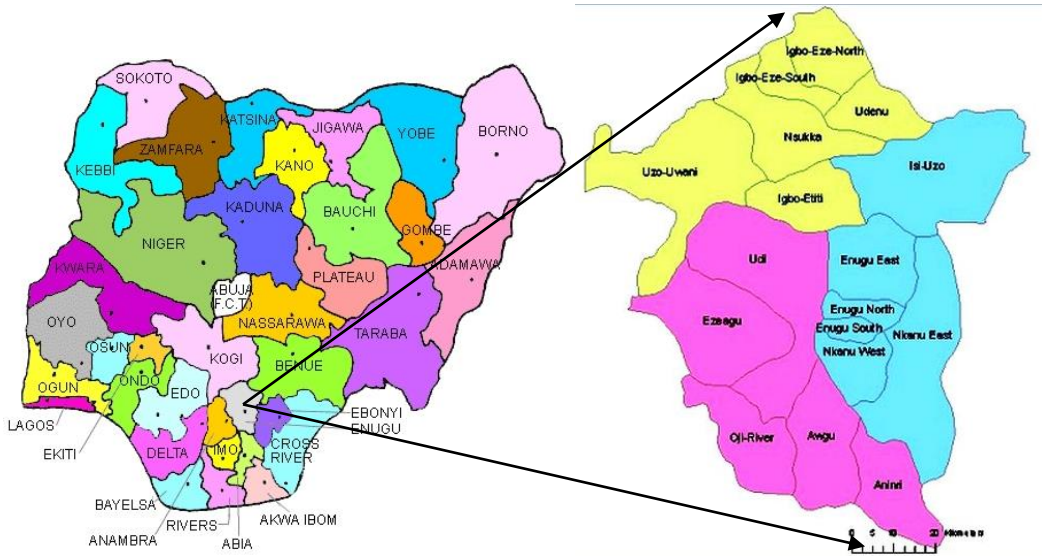
Globally, 55% of the population lives in urban areas today. By 2045, the number of people living in cities will increase by 1.5 times its present number, adding 2 billion more urban residents.

With more than 80% of global GDP generated in cities, urbanization can contribute to sustainable growth if managed well by increasing productivity, allowing innovation and new ideas to emerge (World Bank, 2018).

Geographic Information System (GIS) is a computer-based system composed of software and hardware designed to capture, store, manipulate, analyze and manage geographically related data in order to solve land-related problems of humans; while remote sensing is the acquisition of spatial/geographic information about an object on the earth's surface without making direct physical contact with the object. In this study, GIS and remote sensing techniques were applied to assess, monitor and predict Land Use in Enugu Urban (The Coal City), Nigeria.

2.0 Study Area

The study area is approximately 24,500Hectares of the Enugu Urban (The Coal City). Enugu State is located in the South Eastern geopolitical zone of Nigeria. Enugu State is bounded by Ebonyi state to the East, Anambra state to the west, Abia state in the south and Kogi/Benue states in the North. Figure 1.0 shows the spatial location of the state within Nigeria and the administrative boundary of the state respectively.



Nigeria Enugu State

Figure 1.0: Location maps showing the study area.

3.0 MATERIALS AND METHODS

3.1 Materials

The following archived remotely sensed satellite imageries were openly sourced from Global land cover facility (GLCF) and used in this study; Land sat 5 Thematic Mapper (TM) with 30 meters resolution, Land sat 7 Enhanced Thematic Mapper (ETM) 30 meters resolution, Land sat 7 Enhanced Thematic Mapper Plus (ETM+) image with 30 meters resolution and Land sat 8 with 30meters resolution. The path and row of the study area are P188 and R55 respectively.

3.2 Data Processing

Requisite GIS and remote sensing software were utilized in this study. The software used for the data processing are ArcGIS 10.1, ILWIS Academic 3.2and Erdas imagine 9.2. Supervised (full Gaussian) classification was applied, using the maximum likelihood classifier to generate five main land use classes, namely, built up area, farm Lands, forest, bare land and river. These land use classes were derived from satellite images taken at a ten yearly interval between 1989 – 2019 (1989, 1999, 2009 and 2019) for the study area.

Three spectral bands (band “7”, “4” and “2”) were used in to produce a false color composite. Based on the given spectral combination, band 7 was assigned to color red in order to display the built up area in red color, band “4” was used to display the spatial distribution of the vegetation in green color and band “2” was used to display the water body in color blue. The primary color RGB (Red Green Blue) was used as the panel to display the LandSat scene information in their various natural colors. The color composite image was resampled using the maximum and minimum coordinate of the study, the pixel size was defined (30m) for the both LandSat TM and ETM^{+}. The same reference system was used in resampling process. The output image was the subset image to the study area. The image resampling operation enabled registration of multi-date image of the same area.

The pixel based supervised classification scheme was employed where spectral signatures of the classes was adopted and the software assigned each pixel in the image to the cover type. The stages employed in the supervised classification are as following.

i. Location of the 'training sites' in the image and selection of sample set.

ii. Maximum likelihood classification in the analysis of the classification in which the output image was displayed. A sample set was used as input in the Classification operation.

3. 3 Change Detection

The method of change detection used in this study was the Cross tabulation method. The Cross Operation performs an overlay of two raster maps. Pixels on the same positions in both images are compared. The occurring combinations of class names, identifiers and/or values of pixels are stored. These combinations give an output cross map, and a cross table. The cross table of land use land cover change for the study areas shows combination classes in the change matrix. The analysis is area-based comparison, so that recorded changes from one class to another represents the actual.

To determine the percentage of land use change, the study period 1989-2019 was divided into three sub-periods and the land use changes of the two sub periods were compared. The first sub-period was from 1989 to 1999 and the second sub period was from 1999 to 2009 and the third one is from 2009 to 2019. The comparative analysis in land use change is focused on the three sub-periods. The spatial distribution of the average (annual) rate of land use land cover change between two periods was computed by a slightly modified formula used by Long *et al.* (2007).

Percentage change to determine the trend of change was calculated by dividing observed change by sum of area of the particular land use in that period multiplied by 100.

$$(\text{Trend})\text{percentage }(\%)\text{change} = \frac{observed\ change \times 100}{total\ area} \qquad (1)$$

Where:

The observed change = (Area of the previous year – Area of the current year)

The Total Area = Sum of area (both years).

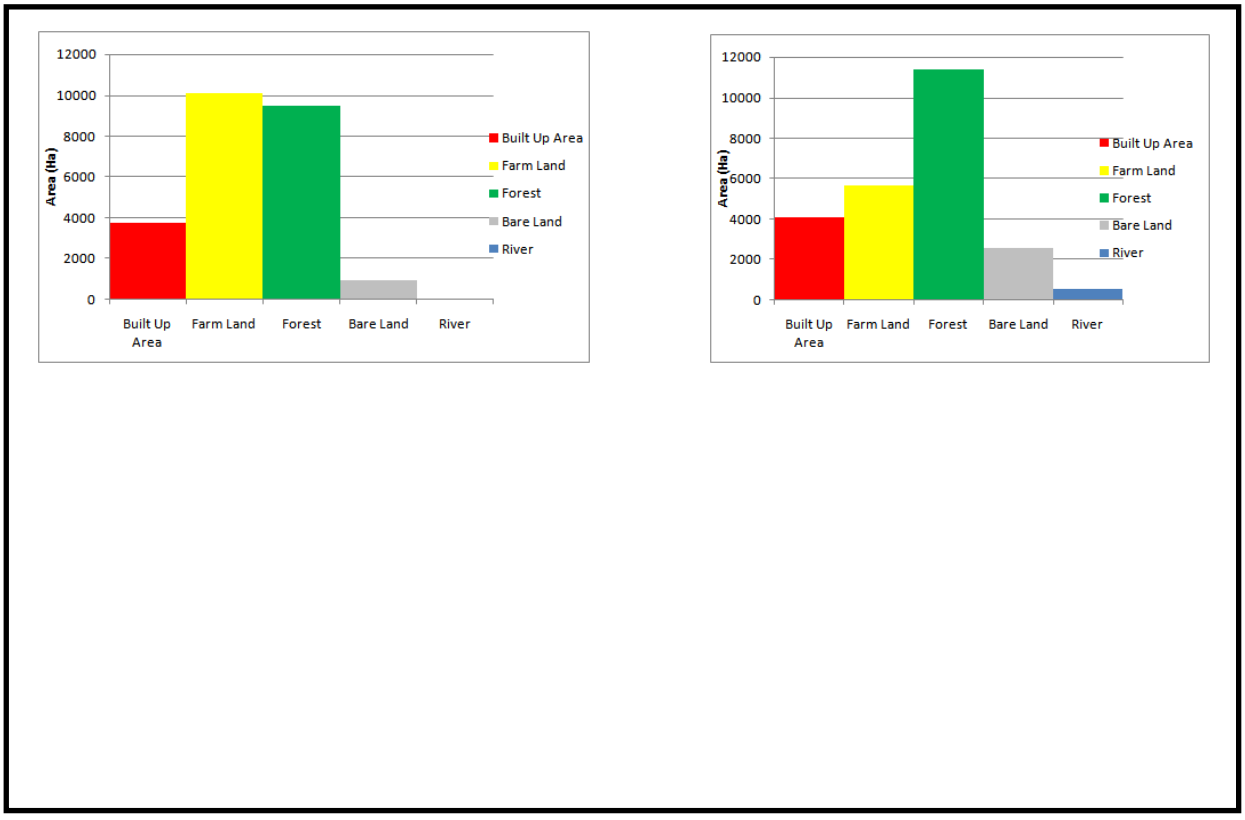
The predictions were made based on assumptions that all other socio-economic impact factors remain unchanged.

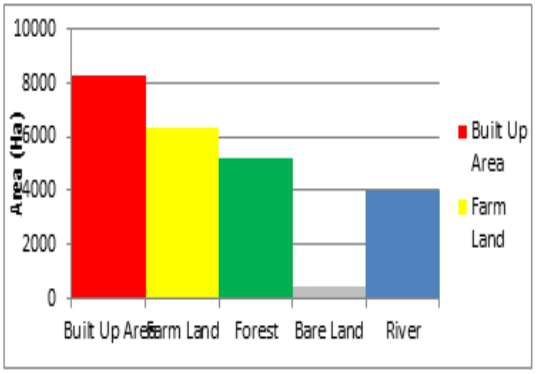
4.0 Results and Analysis

The spatial change pattern of the various Land Uses within the study area from 1989 - 2019 was assessed and monitored through land-use change classification of the study area. The results obtained for the spatial distribution of the analyzed land use classes are shownand discussed below. Table 1.0 and further corroborated by Figure 2.0(a – d) show the percentage of urban land utilized for the various identified uses across Enugu Urban within the study period.

Table 1.0: Evaluation of land use of the Study Area in 1989

	1989		1999		2009		2019	
Classes	**Area (Ha)**	**Percentage (%)**	**Area (Ha)**	**(%)**	**Area (Ha)**	**(%)**	**Area (Ha)**	**(%)**
Built-Up Area	3741.3	15.40	4100.04	16.88	8268.21	34.04	11055.87	45.52
Farm Land	10072.26	41.47	5659.74	23.30	6363.54	26.20	4747.5	19.55
Forest	9502.02	39.12	11391.66	46.90	5211.18	21.46	3132.36	12.90
Bare Land	917.19	3.78	2580.48	10.62	420.93	1.73	806.76	3.32
River	54.63	0.22	555.48	2.29	4023.54	16.57	4544.91	18.71
Total	**24287.4**	**100.00**	**24287.4**	**100.00**	**24287.4**	**100.00**	**24287.4**	**100.00**





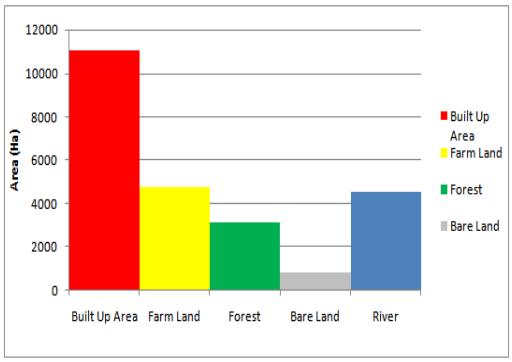


Figure 2(a) Top left: Histogram of Land uses within the study area in 1989
2(b) Top right: Histogram of Land uses within the study area in 1999
2(c) Bottom left: Histogram of Land uses within the study area in 2009
2(d) Bottom right: Histogram of Land uses within the study area in 2019

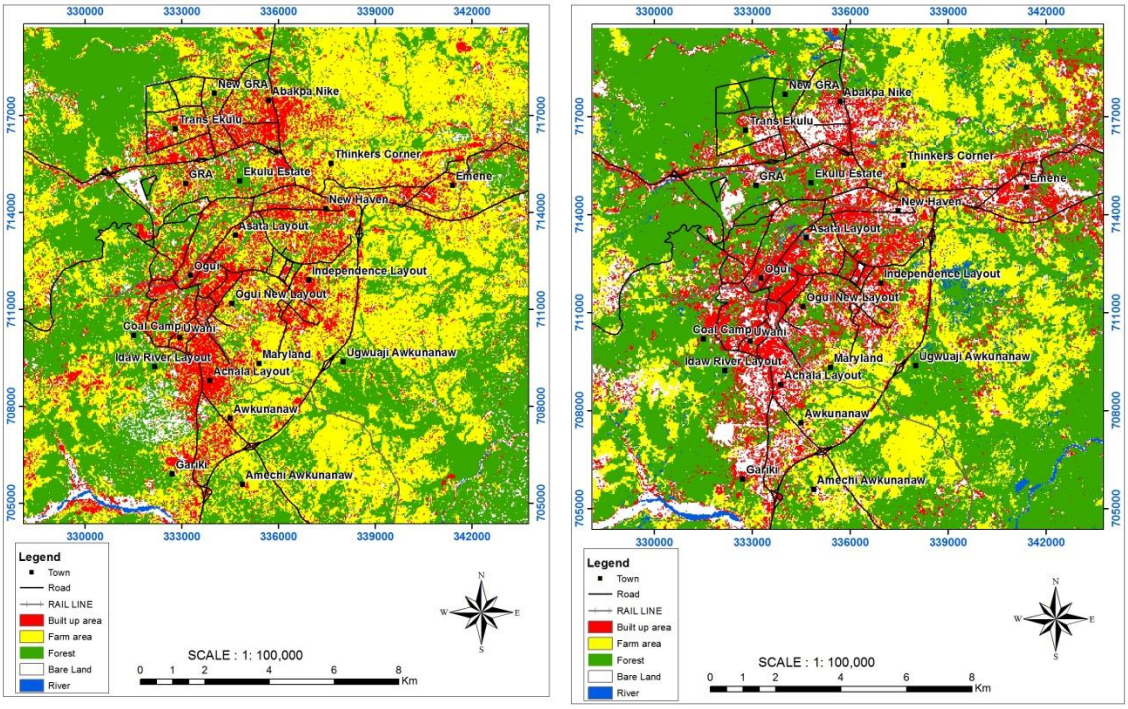
As seen in Table 1 and further supported by Figure 2.0, there is a continuous increase in percentage of land space occupied by built-up areas Figure 2.0 from 15.4% to 45.5% across the study period. However, a leap-frog pattern is observed between the Farm land and Forest land uses. This observed trend of an interchanging rise and fall between the forest and farm land areas could be associated with the fluctuating agricultural policies and practices within the study area. Further scientific analysis would however be required to substantiate the actual cause for such observed fluctuations. Similarly, fluctuating values of bare land and rivers/water bodies could be associated to the drying up of seasonal rivers during dry season and reactivation of such rivers during the rainy season. Since multiple images were used for the study and the images taken at various times of the year, this is a likely cause for the fluctuating value observed in the rivers and bare land.

However, of all the identified classes, the built-up area is the only factor associated with urban growth. Hence, this study utilizes the results obtained for the built-up area for predicting urban growth for 2029 and 2039.Figure 3.0 presents a plot of the spatial sprawl of the urban development across Enugu urban area during the study period. As seen in the Figure, urban development continues to densify from the city center to the fringes. This development pattern/trend is common with most cities across the world in accordance with the well-known

central place theory (Openshaw and Veneris, 2003). A trend/correlation analysis of the spatial behavior of the changes in land uses across the study area within the study period is given in Table 2.0.

Table 2.0: Trend/correlation change within the study area

Years	**Built-Up area**					
Period	**The area in Ha (Previous Year)**	**The area in Ha (Later Year)**	**The difference of Change in Built-Up area (Ha)**	**Rate of Change (%)**	**Trend of Change**	**Correlation**
1989-1999	3741.3	4100.04	358.74	4.57	Increased	
1999-2009	4100.04	8268.21	4168.17	33.70	Increased	
2009-2019	8268.21	11055.87	2787.66	14.43	Increased	
Period	**Other Classes**					-1
1989-1999	20546.1	20187.36	-358.74	-0.88	Decreased	
1999-2009	20187.36	16019.19	-4168.17	-11.51	Decreased	
2009-2019	16019.19	13231.53	-2787.66	-9.53	Decreased	



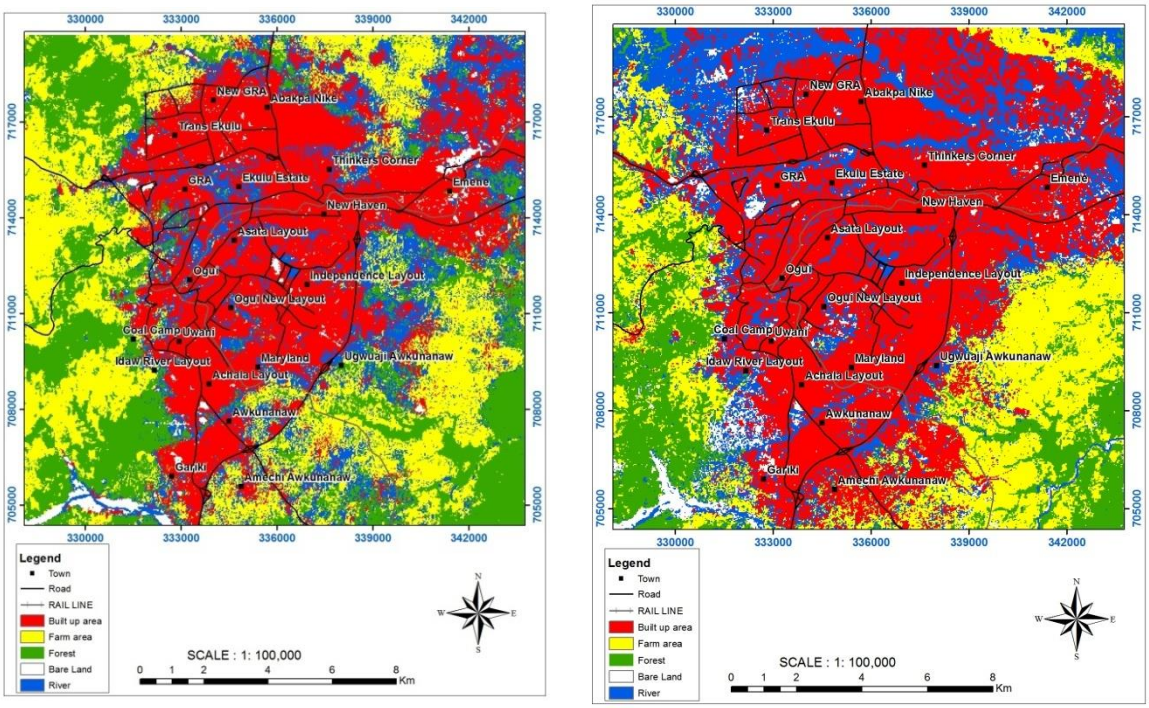


Figure 3.0 a: Land Use of the study area in 1989 (Top left)
b: Land Use of the study area in 1999 (Top right)
c: Land Use of the study area in 2009 (Bottom left)
d: Land Use of the study area in 2019 (Bottom right)

4.1Trend Analysis of Enugu Urban Land Userate of changes

As earlier presented in Tables 1.0, 2.0 and Figures 2.0, an increasing trend is observed in the built-up land use within the study area and a decreasing trend of other uses. This is further illustrated by Figure 4.0. The observed pattern suggests that other land uses continue to suffer a reduction in available land spaces for them as the need for housing, real-estates and other building related uses increase.

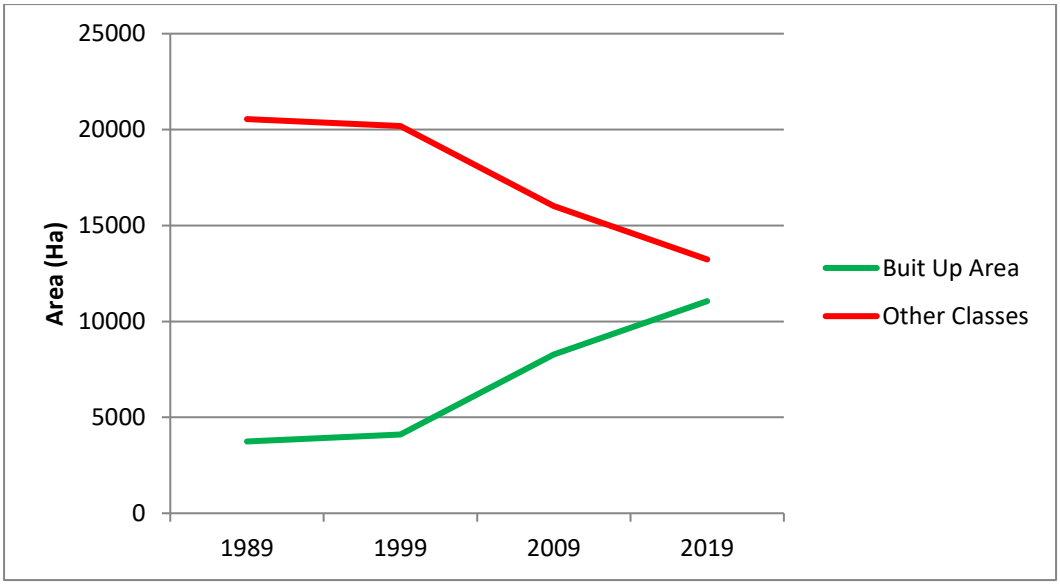


Figure 4.0: Graph Showing the Correlation between built-up area and other land Uses.

4.2 Regression analysis and Land use prediction model

Based on the result of the land use change pattern presented above, regression analysis was used to determine a predictive model for land use change within the study area from 2019 - 2039. Summarized result of the regression analysis is shown in Table 3.0.

Table 3.0: Summary of Regression analysis

Regression Statistics	
Multiple R	0.982
R Square	0.964
Adjusted R Square	0.891
Standard Error	1160.506
Observations	4.000

ANOVA					
	df	***SS***	***MS***	***F***	***Significance F***

Regression	2.000	35566426.948	17783213.474	13.204	0.191
Residual	1.000	1346773.860	1346773.860		
Total	3.000	36913200.809			

	Coefficients	***Standard Error***	***t Stat***	***P-value***	***Lower 95%***	***Upper 95%***	***Lower 95.0%***	***Upper 95.0%***
Intercept	23869204.199	23302557.386	1.024	0.492	-272217860.775	319956269.173	-27221786.775	319956269.173
X Variable 1	-24076.660	23256.595	-1.035	0.489	-319579.722	271426.403	-319579.722	271426.403
X Variable 2	6.072	5.803	1.046	0.486	-67.656	79.800	-67.656	79.800

Also, analysis of variance (ANOVA) was performed to determine if there is any significant difference between the predicted results by the determined predictive model and the observed land use values for the observation years. A polynomial equation as given in equation (2) was adopted for predicting spatial changes in land use across the study area for the predicted years (2029 and 2039).

$$Y = 6.072X^2 - 24076.660X + 23869204.199 \qquad (2)$$

The choice for a polynomial fit as the predictive model for built-up areas within the study area was further subjected to an empirical test as shown in Figure 5.0. Equation (2) was used to predict changes in built-up area across the study area and results obtained are as shown Table 4.0 and Figure 6.0. The polynomial second order is the best fit the for prediction with R square equal to 0.963

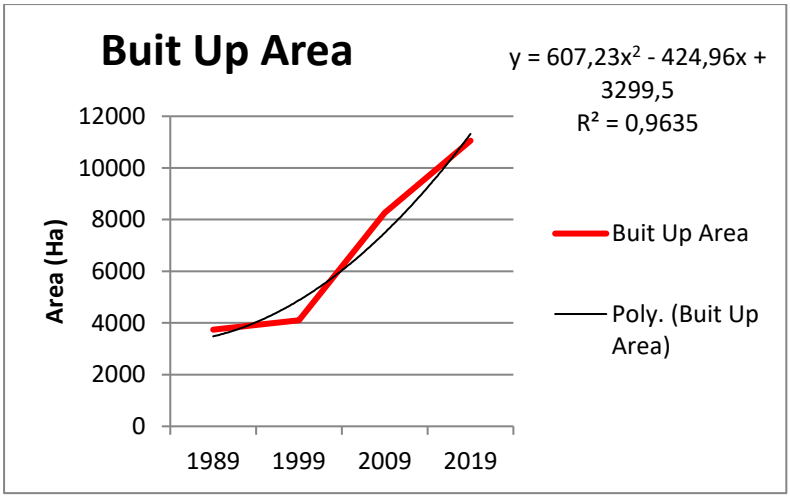


Figure 5.0: Graph showing the polynomial trend line

Table 7.0:Trend and Prediction table ofurban change

Analysis	**Years**	**Area (Ha)**
Present Change	1989	3741.3
	1999	4100.04
	2009	8268.21
	2019	11055.87
Predicted Change	2029	15119.611
	2039	21361.971

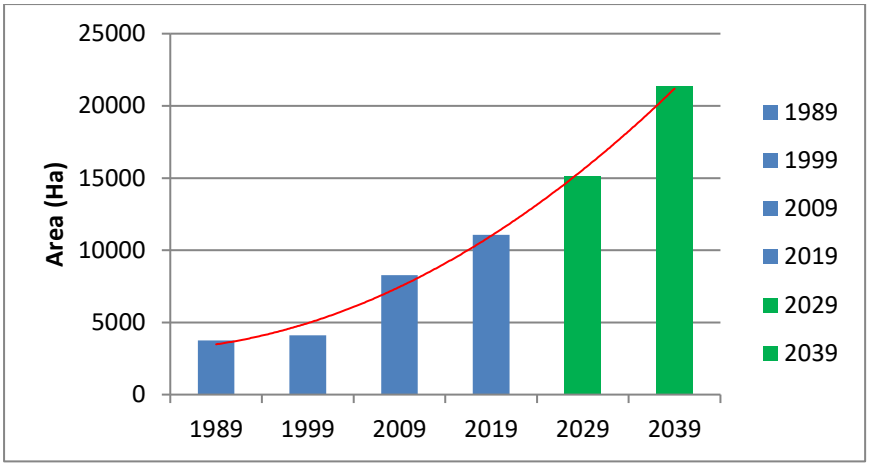


Figure 6.0: Trend and Prediction of Urban area in the study area.

4.3 Discussion of Results

From 1989 to 1999(See tables 1&2), the built up areas increased from 15.4% to 16.88%, the percentage of change shows that the change was more prominent in 1999. The Farm Lands decreased from 41.47% to 23.30%, the percentage of change in farm land was negative,this shows that many Agricultural areas has been converted to built up area for human settlement and activities. The forest increased from 39.12 % to 46.90%, this may be attributed to the sensitization of Enugu dwellers by Government, to plant more trees in the early 90s.

From 1999 to 2009(See tables 2&3), the built up area has increased from 16.88% to 34.04%, the percentage of change shows that the change was not very significant between 1989 and 1999, the farm lands increased from 23.30% to 26.20% . The forest has decreased considerably from 46.90% to 21.46%. The increase in agricultural lands may be as a result of the various Government sponsored Agricultural schemes in the year 2000, while the deforestations may be due to pressure of urbanization and human activities.

From 2009 to 2019(See tables 3&4), the built up area has increased from 34.04% to 45.52%,and the percentage of change shows more human infrastructural development in the city. The Farmlands decreased from 26.20 % to 19.55%. The forest also decreased considerably from 21.46% to 12.90% due to deforestation as a result of human activity and massive urban

development. Furthermore, from the prediction (see table 7.0), Built up Areas for 2029 and 2039 are predicted to be 15,119 hectares (61.7%) and 21,361 hectares (87.1%) respectively.

From the above assessment and predictions, percentage of increase in built up areas, and the resultant decrease in farmlands and forests shows a progressive trend in the depletion of greenery in the city due to growth in population and the consequent urbanization.

5.0 Conclusion and Recommendation

5.1 Conclusion

Changes in land use which have occurred in Enugu Urban (the coal city), for the past three decades have been assessed and analyzed, a prediction has been made for the projected changes in land use for the years 2029 and 2039 respectively; the following were inferred;

1. Resultant upon the trend demonstrated in this study and its ensuing prediction, it is contingent that by 2039, the will be a total overflow of population and built-up areas; consequently, inhabitants of the surrounding suburban areas will be faced with challenges such as traffic jams, increase in crime rates, land litigations, juvenile delinquencies and more, if adequate measures of development controls are not put in place.
2. If vegetation and farmlands are depleted as the prediction in this study, it brings about the consequent negative effects of climate change. Without vegetation, the production of oxygen (O_2) and consumption of the Carbon IV Oxide (CO_2) by the trees would be impossible. Also, such decline in available spaces for Farmlands and Forested areas may result in food scarcity if not adequately managed and controlled.
3. Going by the trend predicted for 2029 and 2039 respectively, there will not just be a horizontal slum; there may also be a vertical slum.
4. Sustainable development in Enugu Urban (Coal City) can only be achieved if urban development is periodically and continuously assessed, monitored, predicted and controlled with strong urban development planning policies.

5.2 Recommendations

Consequent upon the results and analyses presented herein, the following are strongly recommended;

1. To forestall the impending slum development in Enugu Capital City, it is strongly recommended that Enugu State Government should quickly review the existing master plan for the development of the Coal City.
2. That the master plan, so designed, be used for the continuous assessment, monitoring, and development control of the area to police violations. If adequately policed, the impending loom so discovered by this study would be averted.
3. Enugu State Government and Nigeria, in general, should adopt this approach of Remote Sensing and GIS for the planning, management, and control of newly developing areas to improve the livelihood and health standards of our people.
4. Enugu State Government should re-strategize, take charge and put machinery in place to harness the land use revenues that may be wasted as a result of the predicted trend of development.
5. Since the predictions in this study were made based on assumptions that all other socio-economic impact factors remain unchanged, it is strongly recommended that the trend of variability of the socio-economic impact factors of this study area be studied and analyzed in juxtaposition with these results in order to further validate the prediction.

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