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Modelling Urban Sprawl along Minna Western Bye-Pass Using [illegible] Sensed Data

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Abstract:
Many state capitals today in Nigeria are witnessing unprecedented populations growth and [illegible] urbanization that are deficient in indispensable infrastructural facilities. urban planners who are [illegible] knowledge of future urban growth and the multi dimensional factors which has hitherto influence [illegible] and cities are unaware of them because of the inefficiency of the traditional surveying meth[illegible] prevailing scenario in Nigeria, this paper presents the Capability of using Remote Sensing GIS [illegible] modeling urban sprawl along Minna Western Bye-pass. Data for the study were obtained through [illegible] satettite imageries. The analysis of field survey revealed that low price of land, lack of basic [illegible] area, low level of awareness of development control and low level of education of inhabitants [illegible] factors of sprawl in these areas. The analysis of the time series spatial data such as: SPOT HR[illegible] 1993 and Landsat ETM image acquired in 2007 shows that low density sprawl and ribbon spraw[illegible] patterns identifiable and synonymous to this areas. Comparison of data set for the two dates als[illegible] 191,40 acres (77, 4571.14 sq. m.), representing 59% total landuse change over the same period, [illegible] grew by 111.61%. Spatial regression analysis was carried outto model the extent of sprawl inthe [illegible] linear regression analysis was conducted using key factors identified (independent variables) and [illegible] up (POBUILT) for each area along the Bye-Pass (dependentvariable) and results shows thatth[illegible] who relocated because of low in price of land in the study area (LOPLAND) and percentage o[illegible] white-collar job (COLLARJOB) contribute more to the explanatory power of the model. Multiple [illegible] finally done by regressing LOPLAND, population of year 2007 (Independent variable) and PO[illegible] variable) to fashion out an equation that can forecast future sprawl and it was established that [illegible] will be 3,888.23acres, which reveals excessive future spatial development along the bye-pass

Keywords: Urban sprawl, Remote Sensing/GISand Spatial modeling

Introduction

Nigeria as one of the important countries in the less developed region [illegible] (united Nation world urbanization project 1990) shares similar urban [illegible] challenges (as other countries in the region) arising from high rate of ur[illegible] study by the World Bank (1995), estimates that the population of Nigeria [illegible] doubled by the 21st century. This is reinforced by the fact that where as the [illegible] population growth rate is estimated by the Bank as being 2.9% that of urb[illegible] was 5.5% between 1980-1993. The unprecedented population growth [illegible] particularly in area along Minna Western Bye-Pass coupled with [illegible] developmental activities has had to urbanization which lacks infrastructur[illegible] The dispersed and compacted unplanned development along the Bye-Pass [illegible] country side is often referred to as sprawl (Theobald, 2001). The direct [illegible] such unplanned growth is the change in landuse and land cover of an area. Identification of level and patterns of sprawl and analysis is pertinent in the proper planning for infrastructural facilities.

Patterns of sprawl and analysis of spatial changes could be done cost effectively and effectively and efficiently with the help of spatial technologies such as Geographical Information System. The spatial patterns of urban sprawl over different period can be systematically mapped, monitored and accurately assessed and modeled from satellite data (remotely sensing data) along with conventional ground data (Leta, Sankar, Krigna, Badrinath and Reghavaswsing, 2001). Remote sensing can be used separately and combination with GIS to modeling urban growth. In the case of combined applications, even though a more complex approach is the integration of remote sensing data processing, arc analysis, database, manipulation and models into a single analysis system (Michael and Gabriel 1999). Diffusion limited aggregation, a form of fractal based modeling and a physical model used to describe aggregation phenomena, has been applied to describe urban growth (Balty and Longley 1994). Cellular Automata (CA) modeling approach tagged as a proper tool for modeling spatial dynamics is proposed by Portugali and Benson (1995) and Wu (1998).

Inspite of effort of researchers on urban growth and sprawl in Nigeria, modelling of sprawl using remote sensing/GIS and spatial statistics has not been employed. Therefore, this study used remote sensing techniques to investigate the level and pattern of sprawl along Minna Western Bye-Pass with particular emphases on Sauka Kahuta, Barkin Sale, Kpakungu and Dutsen Kura Gwari areas, identify the causal factors of urban sprawl in the study area, model the sprawl and suggest the likely future direction and pattern of sprawling growth.

Description of the Study Areas

Sauka Kahuta, Barkin Sale, Kpakungu and Dutsen Kura Gwari areas all along Minna Western Bye-Pass lie between latitude 9°30N to 9°45N and longitude 6°20E, lat. 9°457N on a geological base of undifferentiated basement complex rock of mainly gneiss and migmatites. The Bye-Pass is about 11 km west of Minna town (Fig. 1).

At the time of this study, the latest population figure for different areas within Minna township was not available, only encapsulated population figure for Minna town was and therefore the 1991 population census figure was used to project for 1993 and 2007 at 5.5% world Bank urban population growth rate for Nigeria(table1.0). Population is a driving factor of urbanization and also serves as the bases of measuring sprawl in this research

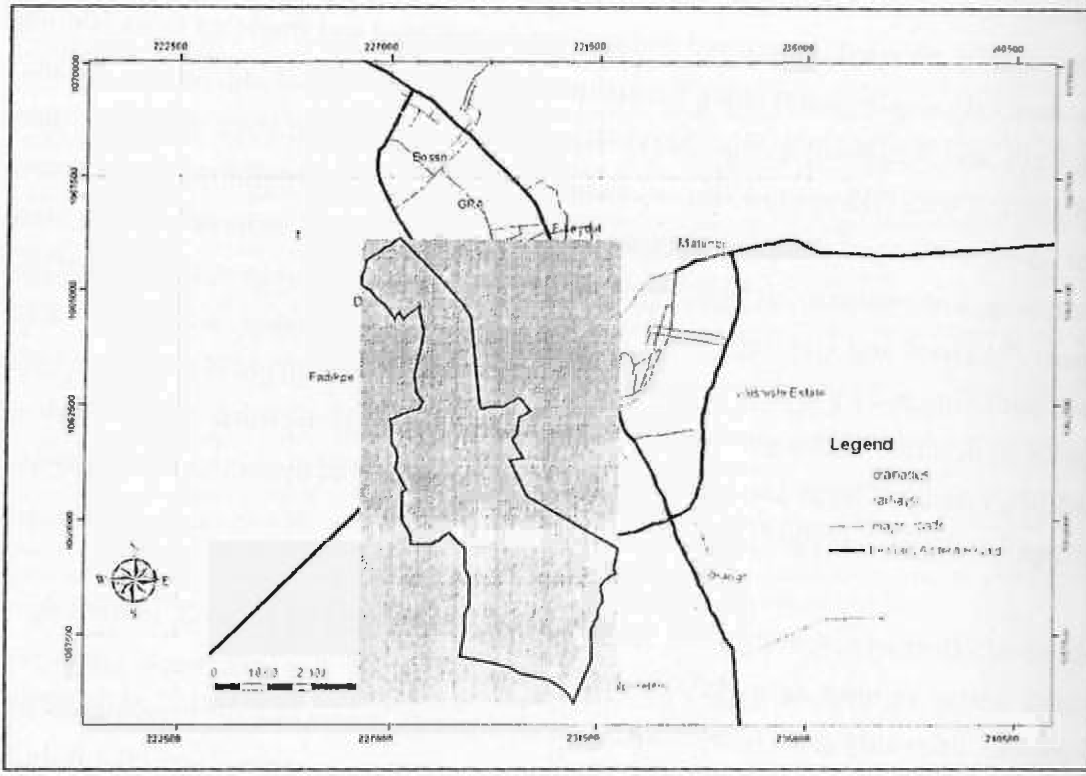


Fig.1. Minna Street Guide Map showing the location of the Study Area (Shaded Area)

Tables 1.0: Projected population of the Sampled Study Area.

Name of Area	1991 population	Projection 1993	Projection 2007
Sauka Kahuta	2,717	3,024	6,399
Barkin sale	3,726	4,147	8,776
Kpakungu	11,298	12,575	26,610
Dutsen kura Gwari	2,059	2,292	4,850
Total	19,800	22,038	46,635

Source: NPC (1991) projected by the Authors using World Bank, 5.5% urban growth rate (1980-1990)

RESEARCH METHODOLOGY

Data Description

Collection of data was done in two phases. This involves primary data collection and secondary data collection. Primary data include Minna Street guide map obtained from Niger state Ministry of Land Survey and Town Planning on scale 1.2500. SPOT HRV image of the study area with spatial resolution of 20m in multispectral, and 10m panchromatic acquired on 15th February 1993, Landsat 7 ETM+ image of the study area acquired on 23th November, 2007 with spatial resolution of 28.5m in seven bands and structured questionnaires on socio-economic characteristics of people along the western byepass which contain enquiries on pull and push factors of migration to the study area were used. Secondary data obtained includes demographic information from National census figure of 1991.

Sampling Techniques

A set of questionnaire was produced. This was administered to 10% of the total number of household in each of the area along the bye-pass. A systematic sampling technique was adopted for questionnaire administration and this was at every 10th house in all the areas. Questionnaire was administered by oral interview method.

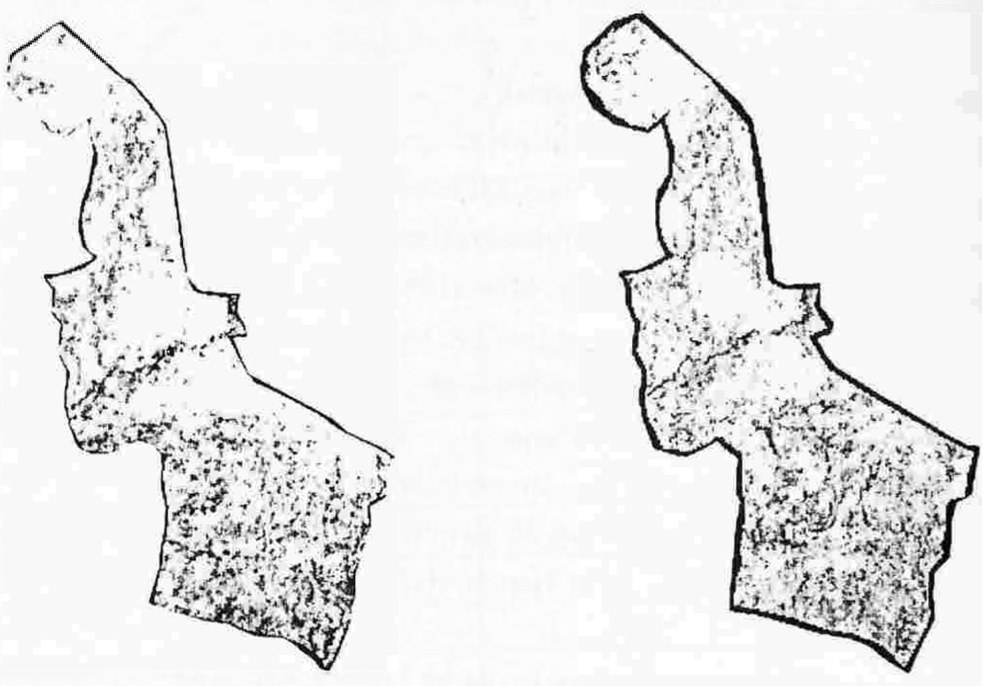
Quantifying and Modeling Urban Sprawl

The intricacies of urban phenomenon such as sprawl could be better understood by analyses of change in land use over time. Measurement of sprawl was carried out by digitizing the western bye-pass from Minna street guide map on scale 1:2500 to generate the boundary of the study area coverage. Minna SPOT HRV image of 1993 and LandSat 7 ETM+ image of 2007 was imported into ERDAS IMAGINE 8.5 image processing software environment where the georeferenced extracted study area from the street guide map was overlaid on the two imageries. The overlay was made possible by georeferencing and co-registering the extracted study area from Minna street guide map to the satellite images by using the of identifiable ground control points (GCP) Collected from the field with the aid of Garmin 76cx hand held GPS receiver to

The satellite imageries were enhanced for easier visual interpretation by applying the linear contrast stretch with saturation. This was used to generate a false colour composite

(FCC, (Fig.2). Training polygons were chosen from the composite images and based on their signatures corresponding to various landuse classes. Supervised image classification was done using minimum likelihood classifier. From the original land use class in the study area, the two imageries were classified into 3 landuse types: *Built-up*, *Vegetation* and *open space*.

The growth of urban sprawl over a period of fourteen (14) years for the whole area was determined by displaying map of Built-up area map for 1993 and 2007 side by side to visualize the spatial change in built-up. A temporal change was obtained by subtracting total area of built-up in 1993 from 2007. Digital image processing through spatial pattern recognition wherein the spectral characteristics of all pixels in the image was analyses and by spatially enhancing the image, urban sprawl pattern recognition was performed by visual interpretation. Spatial statistic regression modeling (Simple Linear Regression) was applied by using causal factors of urban sprawl as the independent with the percentage built-up as the dependent variable and finally multiple variables regression analysis used for showing the relationship between the dependent variable (POBUILT) and the causal factors was used to establish equation for prediction.



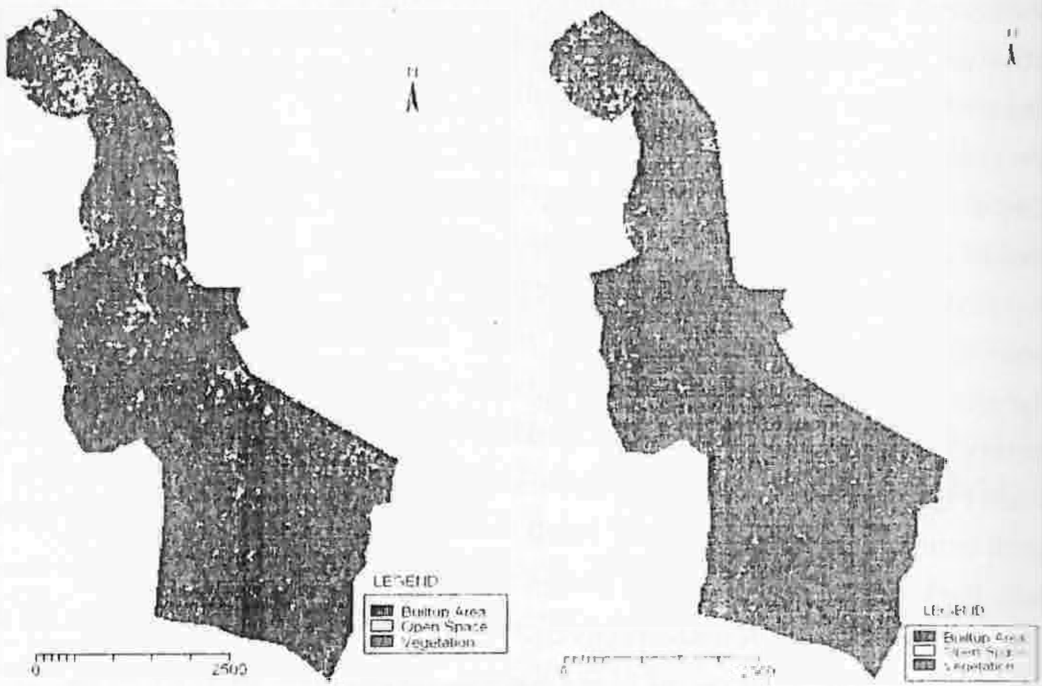
(a) SPOT HRV, 1993 (b) LandSat ETM+, 2007

Fig 2: Enhanced False Colour Composite Image of the Study Area

RESULTSAND DISCUSSION

Image Analysis and Interpretation

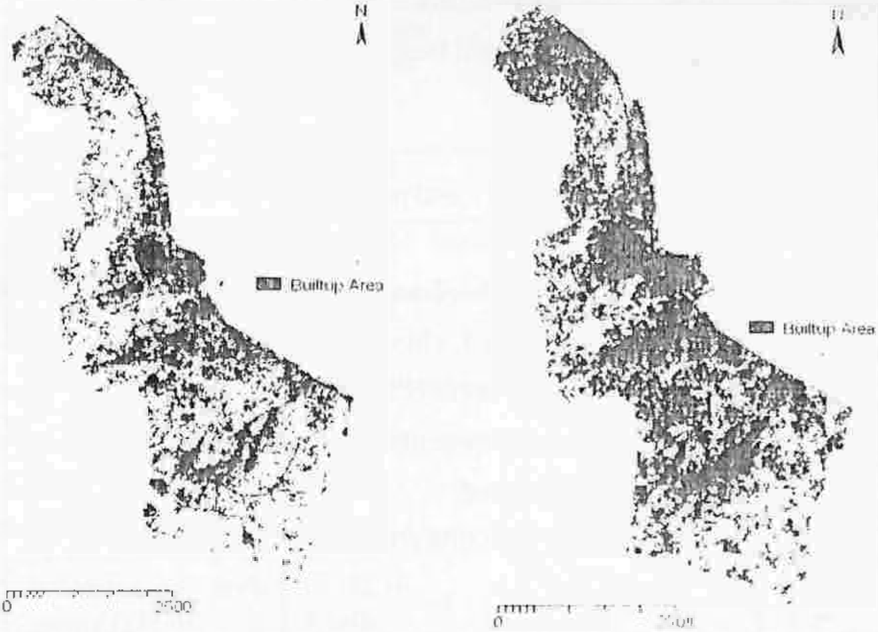
The basic image processing technology such as image extraction, enhancement and classification were applied in this study. The combination of Spot HRV band 1; Green, 0.5-0.59 micrometer, band 2; Red, 0.61-0.68 micrometre and band 3; Near infrared, 0.76-0.89 micrometer and also the combination of Landsat 7 ETM+ band 4; Near infrared (NIR) 0.76 0.90 micrometer, band 3; Red, 0.63 0.69 micrometer and band 2; Green, 0.52 0.62 micrometer were used to enhance and create a false colour composite of the image. The training polygons chosen from the composite were used to create signatures and based on these signatures, corresponding to the original land use classification in the study area; supervised image classification was done using *maximum likelihood classifier* (a strong classifier with high susceptibility to training site used to evaluate the likelihood that each pixel belongs to one of these classes). In this case, spatial classes of homogeneous representative samples of information class referred to as training area were selected and assigned three landuse classes namely: Built- up, vegetation and open space. The numerical information in all spectral bands for the pixel comprising the areas are used to "train" the computer to recognize spectrally similar area for each class using special program or algorithm to determine the numerical "signature" for each training class. The classified Spot HRV and Landsat ETM image are shown in Fig.3 respectively. From the classified image, the area under built-up(see fig.4) for each zone was computed and the result shows that 2007 area coverage for Sauka Kahuta, Barkin Sale, Kpakungu and Dutsen Kura Gwari are 242.62 acres, 232.4 acres, 215.14 acres and 124.84 acres respectively, which summed up to 815.01 acres for the study area. The 2007 built-up for Sauka Kahuta, Barkin Sale, Kpakungu and Dutsen Kuran Gwari are 138.56 acres, 135.70 acres, 127.98 acres and 111.54 acres respectively, which also summed up to 513.78 acres. The built-up for 1993 is 322.38 acres and this indicate that the percentage spatial expansion in built-up in 1993 is 41%, while the percentage spatial expansion in built-up in 2007 is 65% of the total area of the study area coverage. This connotes that the percentage change in built-up from 1993 to 2007 is 59% compare to the percentage change in population growth from 1993 2007 which is 111.61%. Analysis shows little increase in per capital land consumption over the decade and this tells that though there is sprawling growth, the growth is not excessive. Through digital image processing, pattern recognition was carried out by spatially enhancing the images and two patterns of urban sprawl were recognized by visual interpretation considering pattern as element of interpretation. These patterns are: Low density sprawl pattern and Ribbon sprawl. Low density sprawl pattern are found to the far west of the study area particularly in Sauka Kahuta, Barkin Sale and Kpakungu. It occurs as relatively consumptive use of land that lack facilities/utilities. Ribbon sprawl pattern is seen as development that follows the part close to edges of the western bye-pass where land is developed haphazardly and lack proper accessibility.



(a)SPOTHRV, 1993

(b) LandSat 7ETM+, 2007

Fig 3: Landuse Map of the Study Area



(a) Built-up Area in 1993 (b) Built-up Area in 2007

Fig 4: The Extend of Urban Sprawl in the Study Area

Analysis of Field Data (Questionnaire)

The result of analysis of questionnaire revealed that about 56% of inhabitant of the study area relocated from Minna CBD and other neighborhoods because of easy access to cheap land and the remaining 44% that migrated from the villages did that in search for white collar jobs and other facilities that are lacking in the villages.

Research findings indicates that 77% of residents of the study area are not aware of development control and this signifies that there is very low level of awareness of urban planning law and development control standards. Most of the inhabitants do not have building plan for their houses and few that have never seek for building approval and their reasons been the delay in its approval process.

Urban Sprawl Modeling

From the adopted Spatial Regression Modeling after Wu (1998) and Yeh et al. (2001), the following variables considered as the causal factors of sprawl in the study area were used to model the sprawl effect. This includes:

(a). Population of the areas (*POP07*).

(b). Population density of Area' A' (*PoDA*), and population density of Area B' (*PoDB*).

Other key factors that brought about haphazard development in the study area as revealed from field analysis were also used. This are:

(c) Low price of land in the study area (*LOPLAND*)

(d) Low level of awareness of development control (*LOAW*).

(e) Unavailability of building plan and

(f) Drift from villages in search for white collar jobs *(COLARJOB)*.

The percentage built-up (*POBUILT*) is the proportion of the built-up to the total area of the zones. The population density 'A' (*PoDA*) is the proportion of the population in every zone (area) to the built-up area of the zone. The population density 'B' (*PoDB*) is the proportion of the population every zone to the total area of that zone. The casual factors/parameters of urbanization such as population,'A' and 'B' population density and other key casual factors of sprawl as revealed from questionnaire analysis were analyzed by simple regression analysis with percentage built-up (POBUILT) as dependent variable.

The result of regression as shown in table 2.0 reveals the independent variables that play significant role in sprawl development in the study area.

Table 2: Correlation Coefficient among Causal Factors and Percentage Built-up by Linear Regression Analysis

Dependent Variable(y)	**Independent Variable (x)**	**Regression Equation**	**Coefficient of Determination(r^2)**	**Coefficient of Correlation (r)**
POBUILT	*POP* (2007)	y=76.49 – 0.0009x	0.0961	0.3100
POBUILT	Pop.Density A(*PoDA*)	y=71.72 0.0629 x	0.1035	0.3217
POBUILT	Pop. Density B (*PoDB*)	y=69.58 – 0.0628x	0.0340	0.1844
POBUILT	% of migrant because of access to cheap land (*LOPLAND*)	y=105.66 – 0.5840x	0.6437	0.8030
POBUILT	% of low level of awareness of dev't control (*LOAW*)	y=152.16 – 1.160x	0.6250	0.7906
POBUILT	% of people who migrated in search of jobs(*COLARJOB*)	y=111.09 – 1.142x	0.6040	0.7770

Source: Authors Field Analysis, 2007

Coefficient of determination (r^2) is the proportion of the total variation in 'y' explain by the regression y by 'x' and ranges from 0to 1. The correlation coefficient 'r' ranges from -1 to+1 and indicates the direction of the relationship. The higher the value of (r), the more it explains the variation in dependent variable (*POBUILT*) as influenced by the independent variables. The high correlation coefficient from the analysis therefore, revealed that low price of land, low level of awareness of development control and migration in search for white collar jobs played significant roles in the increasing urban sprawl phenomena in the study area. Summary of the regression analysis is shown in the appendix

In assessing the cumulative effect of causal factors by considering more variables, more factors were further regressed using Multiple Regression Analysis Model. However, since *LOPLAND* contributed more to the variation in (*POBUILT*) of the model and population is a driving factor of sprawl proliferation. *LOPLAND* and POP07 was considered for multiple regression modeling and the probable relationship is:

$POBUILT (y) = 113.48 + 0.00055 (POP07)\ 0.7925(LOPLAND)$ -----------------
Eqn. (1)

Where the Correlation Coefficient (r) = 0.8998, the unadjusted and adjusted coefficient of multiple determination r^2 and r^{-2} are 0.8097 and 0.4291. This reveals that the amount of variation in y (POBUILT) as accounted for by population (POP07) x_1 and (POPLAND) x_2 is 42.91%.

Forecasting the Scenario of Urban Sprawl

Based on the urban population growth rate of 5.5%, the urban growth rate of the study area was calculated thus:

$$\text{Urban growth rate } Ur = n\sqrt{\frac{b_2}{b_1}} - 1$$

Where $b_2 =$ Built-up for 2007

$b_1 =$ Built-up for 1993

$n =$ Number of years between the dates

Therefore;

$$Ur = 14\sqrt{\frac{513.78}{322.38}} - 1$$

$$Ur = 10.79\%$$

Forecasting built-up for year 2021, the total area of the study area was projected by using the simple formula.

$$a_2 = a_1 (Ur + 1)^n$$

Where: a_2 = Area Coverage of the study area at a future date.

a_1 = Area Coverage of the study area at the present date.

a_1 2007 = 815.01 acres.

a_2 2021 = 815.01 (10.79% + 1)^{14}

a_2 2021 = 815.01 (4.20)

a_2 2021 = 3423.04 acres

The population and total area projected for year 2021 was substituted in *equation* (1) thus:

$$POBUILT = 113.48 + 0.00055\ (POP2021)\ \ 0.7925\ (LOPLAND)$$ ---------------- Eqn. (2)

Percentage of those who relocated to Sauka Kahuta, Barkin Sale, Kpakungu and Dutsen Kura Gwari because of low price of land *(LOPLAND)* are 66, 71, 93 and 44 respectively and therefore, the average of *(LOPLAND)* for the four areas that make-up the study area = 66 + 71 + 93 + 44/4 = 68

Projected population for year 2021 = 98,682

Substituting 98,682 and 68 in equation 2, we have.

$POBUILT\ (2021) = 113.48 + 0.00055\ (98,682)\ \ 0.7925\ (68)$

Percentage built-up area for year 2021 ($POBUILT2021$) = 113.59%

Let' x' be built-up area for 2021:

$$POBUILT2021 = \frac{x}{Area2021} X100$$

$$(x) = \frac{113.59 X 3423.04}{100}$$

(x) = 3,888.23 acres

Using the new relationship in equation 2, it was found that the percentage built-up for 2021 is 113.59% and built up is 3,888.23 acres which exceed the total area in acres of the study area projected for 2021. This indicates that with high relocation of people to the study area in recent times, the pressure on land would continue to increase as ever and the agricultural fields, open spaces and water bodies would be prime targets for sprawl development.

Recommendations

Based on the results of the research findings, the following recommendations were made:

1. Public enlightenment campaign is very crucial to any veritable development as far as adherence to development control standards are concern. Niger State Urban Development Board (NUDB) should be charged with that responsibility and this can only be achieved where the board organize lectures in languages the inhabitants will understand better, to educate them on the need for development to conform to master, area and local plan, production and approval of building plan and also to make them understand the menace of poor physical planning.
2. The Board should make provision for sufficient vehicles which town planners and allied professional would use to move around all areas in Minna town to ease monitoring of physical development so as to ensure adherence to plan.
3. NUDB should produce layout for land in the study area yet to be developed and ensure that developers' actions strictly conform to layout plans so that accessibility will be improved.
4. Government should provide infrastructures such as roads, layout pipes for efficient water supply and electricity in form of site and service scheme to encourage and ease development in the study area, so that future development will align with available utilities and facilities.

Conclusion

Remote sensing/GIS and spatial statistic has been proved to be a very efficient tools in monitoring and analysis of multifaceted dynamics of our urban environment as it is evident in the study area that in year to come. Spatial development will occur in an unprecedented manner and our ecosystem will be prime target of its negative consequences. Therefore future scope of this work should venture into generating the imageries of further sprawl from satellite images finer spatial and spectral resolution under different scenario and subject them to unsupervised classification to understand any threat to natural resource and ecosystems.

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Appendix I: Summary of Simple Regression Analysis of POBUILT and POP07

Simple regression equation is $y = a \pm bx$, where $a = \bar{y} - b\bar{x}$, $b = \frac{\sum xiyi}{\sum xi^2}$, $\bar{y} = 66$, $\bar{x} = 11659$,

$\sum xi^2 = 305874171$, $\sum yi^2 = 710$, $\sum xiyi = -275909$, $\sum\left(y - \overset{n}{y}\right)^2 = 641.80$. Thus

$b = \frac{-275909}{305874171}$, $b = -0.0009$ and, $a = 66 - (-0.0009)11{,}659$, $a = 76.49$. The simple regression

equation is $y = 76.49 - 0.0009x$, $r^2 = 1 - \frac{\sum\left(y - \overset{n}{y}\right)^2}{\sum\left(y - \bar{y}\right)^2}$, $r^2 = \frac{641.80}{710}$, $r^2 = 0.0961$, $r = \sqrt{r^2}$,

$r = \sqrt{0.0961}$, $r = 0.3100$

Appendix II: Summary of Multiple Regression Analysis of POBUILT, POP07 and POPLAND

Multiple regression equation is $y = \pm a \pm b_1 x_1 \pm b_2 x_2$, where $a = \bar{y} - b_1\bar{x}_1 - b_2\bar{x}_2$, $\bar{x}_1 = 11659$ and

$\bar{x}_2 = 68$

$$b_1 = \frac{\left(\sum x_{1i} y\right)\left(\sum x_{2i}^2\right) - \left(\sum x_{2i} y\right)\left(\sum x_{1i} x_{2i}\right)}{\left(\sum x_{1i}^2\right)\left(\sum x_{2i}^2\right) - \left(\sum x_{1i} x_{2i}\right)^2}, \quad b_2 = \frac{\left(\sum x_{2i} y\right)\left(\sum x_{1i}^2\right) - \left(\sum x_{1i} y\right)\left(\sum x_{1i} x_{2i}\right)}{\left(\sum x_{1i}^2\right)\left(\sum x_{2i}^2\right) - \left(\sum x_{1i} x_{2i}\right)^2}$$

$$b_1 = \frac{(-275909)(1367) - (-777)(559489)}{(305874171)(1367) - (559489)^2}, \quad b_1 = 0.00055$$

$$b_1 = \frac{(-777)(305874171) - (-275909)(559489)}{(305874171)(1367) - (559489)^2}, \quad b_1 = -0.7925$$

Thus, $a = 66 - 0.00055(11659) + 0.7925(68)$, $a = 113.48$

Multiple regression equation is $y = 113.48 + 0.00055x_1 - 0.7925x_2$

$\sum\left(y - \overset{n}{y}\right)^2 = 135.12$, $\sum\left(y - \bar{y}\right)^2 = 710$, $r^2 = \frac{135.12}{710}$, $r^2 = 0.8097$, $r = \sqrt{0.8097}$, $r = 0.8998$

The adjusted Coefficient of multiple determination $r^{-2} = 1 - (1 - r^2)\left[\frac{n - 1}{n - k}\right]$,

$r^{-2} = 1 - (1 - 0.8097)\left[\frac{4 - 1}{4 - 3}\right]$, $r^{-2} = 0.4291$