Urban Vegetation Study of Kaduna Metropolis using GIS and Remotely sensed Data

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Abstract

Kaduna metropolis is an example a careful urban planning by the colonialists in 1920's which gradually deteriorated in quality due to poor development control and city management. This study on urban vegetation using Remote Sensing and GIS technique was a follow up on Al-Amin 2005 which used quadrant urban vegetation was studied by the quadrant method. The use of GIS technique has revealed several minute details that were not exposed by the quadrant study of 2005. The analysis shows that only 1.267km2 out of the total study area segmentation of 11.832km2 are covered with a regular pattern vegetation distribution. This only constituted about 10.72% vegetation area while 89.28% Lack vegetation. The study also shows that part of the study area that are without vegetation was (89.28%) equivalent to 10.56km2 is densely populated with high commercial activities and high traffic, while the area classified with vegetation cover (10.72%), equivalent to only 1.267km2 has scarcity population with very low commercial activities and low traffic. This situation is attributed to people's adaptation to a city without vegetation and seems to lack or ignore its consequences.

Keywords: Vegetation, Kaduna, GIS, Segmentation, classification, Satellite

1. Introduction

Today, there is a rebirth of interest in urban environments and in the development of urban ecology. Increasingly people are realizing the city and wildernesses are inextricably connected. We cannot hike in the wilderness while our homes burn from sulfur dioxide, carbon dioxide, carbon monoxide and nitrogen oxide pollution (Jenkins, 1998: Akaike 2008S).

Recent estimates indicate that over 45% of the world's human population now lives in urban areas, with this figure rising to over 60% projected by 2030 (United Nations,1997). Monitoring urban environment change will therefore become increasingly important as the subsequences of ultralisation. The spatio-temporal distribution of vegetation is a fundamental component of the urban/suburban environment (Pickett et al, 2008). Researches have shown that vegetation influences urban environmental conditions and energy fluxes by selective reflection and absorption of solar radiation. The presence of fractional vegetation cover (**FVC**), ***defined as the percentage of vegetation occupying a unit area***, in urban areas may also influence air quality and even human health (Witting R. 2004; Saltonstal 2002).

The main objective of this study is to apply a rare analytical and accurate approach for urban and suburban FVC estimation from satellite remote sensing imagery data and field verification surveys by combining the thematic and mosaic data of transformed models. Four steps are involved in this approach: **Segmentation**-(choosing appropriate study area pixel), **Classification**-(determining vegetation parameters on imagery; especially in the dense vegetation model), **Data extrapolation and presentation**- (a quantitative and precision validation of imagery models), and **Statistical analysis**-(using the nearest neighbour technique for vegetation analysis). The approach is believed to give the true representation of the vegetation data of the Kaduna Urban area.

The city of Kaduna was carefully designed by the colonialists and was deliberately put under strict vegetation management. The aim of that vegetation management according to the colonialists was to

preserve the native vegetation of the ecosystem, and simultaneously the utility of green vegetation to human settlement(Al- Amin 2005). A review of the 1976 Study conducted by Max-Locks in 2008 suggested that the Kaduna Vegetation is undergoing an unprecedented abuse caused by the lack of development control in especially the GRA (Government Reserved Areas) of Malali U/Rimi, Barnawa and the CBD (Central Business District) comprising of Ahmadu Bello way independence way, Ali Akilu road and the adjoining areas.

The focus of this study on Kaduna therefore centres on the above mentioned highly vegetated area. The study will show the benefits of using GIS/remote sensing technique over the quadrant ground method of study. The other benefit is to provide a precise and reliable data on the existing condition of the studied Urban area.

Field survey and visual interpretation from aerial photography are the tools widely used to extract such information (Hamilton et al, 2000; Grove et al 2004). However, these methods are both time-consuming and expensive. Moreover, field survey or aerial photography is usually done once in a few years or longer. Thus, they are difficult to maintain an up-to-date database. Satellite remote sensing imageries, especially with their high spatial resolution like IKONOS (1m for the pan data) and ESRI, have the advantage of frequent revisit, large-scale coverage, and low cost, which can provide multi-temporal data for urban land use mapping, change detecting, and environmental monitoring (Maurer et al 2000; Sagof, 2005).

While remote sensing imagery is introduced into applied areas, many vegetation indexes such as NDVI (**normalized difference vegetation index**), VI (**vegetation index**), SVI (**Soil vegetation index**), which are representative of plant's photosynthetic efficiency, have been widely used for presenting vegetation cover from different data source (Tyrvainen, 2005). However, because of the coarse resolution of the remote sensing imageries like TM, it is impossible to exactly extract vegetation information from such imageries.

High resolution imageries can provide more precise distribution of objects for mixed pixels are much reduced. However, at high resolution imageries, an area that is formerly spectral uniform will be composed of pixels with a higher degree of spectral variation (Zippere et al, 1997). Therefore, the statistical classification procedures based on pixels which have successfully separated spectral classes from coarse or medium resolution imageries based on their spectral properties alone do not work well at classifying high resolution imagery (Sukkof et al, 2008; Zisker et al 2004).

2. Study Area

The study was carried out in Kaduna metropolis consisting of Kaduna north and part of Kaduna South Local Government Area, precisely Ungwan Rimi, Tudun Wada, Kurmin Mashi and Kaduna business district comprising of Ahmadu Bello way, Yakubu Gowon way, Lugard hall, Independence way, and Ahmadu Bello Stadium.

The study area is the capital of Kaduna state which is located between latitude 9^0Nand 12^0N of the equator and longitude 6^0E and 9^0E of the prime meridian. The state shares boundaries with Abuja and Niger at the South-West, Katsina, and Zamfara at the North-West, Kano and Bauchi at the North-East, Plateau and Nasarawa at the South-East. The climate varies from the north to the southern part of the state with an annual mean temperature of between 24^0 C and 29^0C, the length of rainfall varies between 150days to 190days, an annual rainfall of between 1500mm to 2000mm, and relative humidity ranging between 20% and 30% in January, rising to between 60% and 80% in July. Vegetation divides into northern Guinea savannah in the north and southern Guinea savannah in the south of the State.

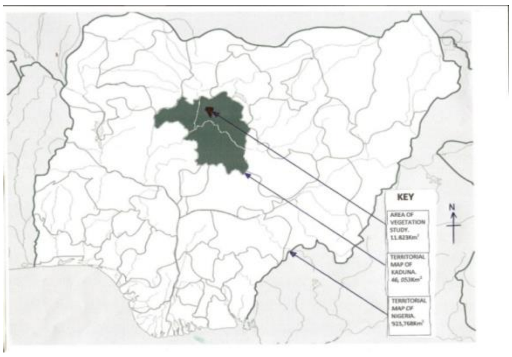

Fig. 2: Study area shown in the map of Kaduna embedded in the map of Nigeria.

3. Materials and Methods

Reconnaissance survey (i.e direct observation) was carried out at the initial stage of this research in other to get acquainted with classified study areas. Data was acquired as satellite imagery from ESRI DigitalGlobe by the National Aeronautics and Space Agency(NASA), U.S Geographic Sytems at (50m resolution) imageries 2013 (Fig. 3 to 16); Google maps (50m resolution) 2013 (Fig.2) and ground assessment of the classified vegetation sites within the study area. ArcGIS explorer desktop software version 2.4.1 was used for this research. As shown above the four steps used in the study area:

3.1 Segmentation:

The imageries were already geo-referenced to two-dimensional mosaic mode; this process involves relating the geometric information of the study area to that of the map (that is relating calculated areas on map to those on the ground). The imageries came in scenes after software-internet query, with the study area being segmented and high-lighted, in order to get a numerical value equivalent to **11.823 Km^2**asthe geometric area of the study area (Fig. 3 in red boundary lines); the outline of the boundaries of the study area was used to view the scenes under high resolution of 50m to get the outline of the classified sites under study.

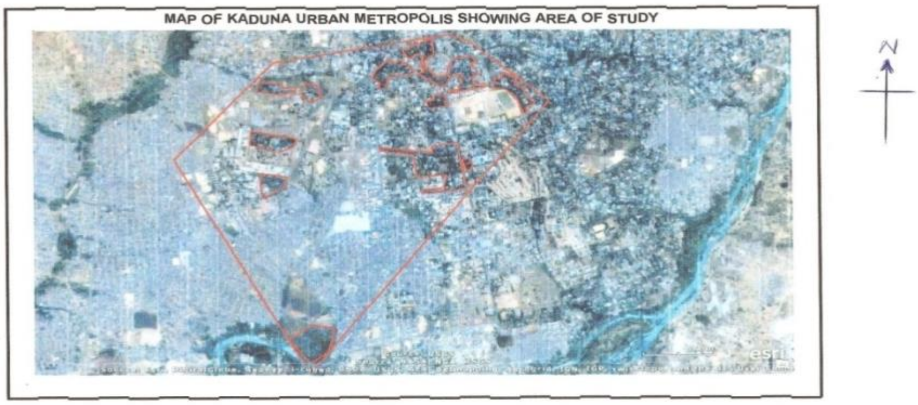

Fig 3: Satellite imagery of the study area showing segmented area of study.

Segmented (11.823Km^2) and classified areas (total=1.267Km^2) are shown in red boundary lines on the satellite imagery.

3.2 Classification:

The process of classification is getting the various study sites (subsets) through characteristic imagery reflectance of vegetations as fractional vegetative cover of an identified site at high resolution. This procedure leads to the identification and classification of **10** fractional vegetative cover sites, with geometrical areas and distances between the nearest fractional vegetative cover site as shown on the satellite imageries in **figures 4 to 10**(see appendix 1)and corresponding numeric values shown in **table 1**.

3.3 Observation and Interpretation:

Onscreen visual interpretation was done; the process of digitization was automatically done together with the interpretation using ArcGIS View 2.4.1. First, there was a creation of mosaic map which indicated the areas of concern, then extrapolation of data from the mosaic imagery. Imageries were carefully examined, after which three basic categories were classified. These categories include; vegetation area (trees and grassland), built infrastructures (settlements and roads) and rivers.

An interpretation key was used to help in the identification of the area of study as sub-superimposed on the map of Kaduna and superimposed on the map of Nigeria (Fig. 2).The area of vegetation concentration is the point of interest, and could be seen on the satellite imagery in two-dimensional mode (2D) with regular pattern as dark-green colour with characteristic texture reflectance signifying trees, while light-green colour with characteristic texture reflectance signifies grassland. The dark-green characteristic texture of the trees is associated with the chlorophyll content of fresh vegetation and no signs of cultivation.

The settlements were identified and also interpreted as mostly regular shaped and usually linked by road networks. They are also identified by their whitish, bluish, greenish and brownish colour, which is the reflectance of the roof top materials.

The roads were identified and interpreted as another category with linear features usually linking settlements. Light reflectance interpreted for unsurfaced roads, and dark reflectance for surfaced roads. The last to be identified and interpreted were the rivers, which were identified and interpreted as linear features, associated with several tributaries and are aligned by light-blue reflectance indicating vegetation along the banks.

3.4 Nearest Neighbour Statistical Technique:

The basic statistic employed is called the Nearest Neighbour Statistic (R_n) defined as the ratio of the mean distance (D_0) in the area under investigation to some expected mean distance (D_e) usually under a random distribution. (see details in the appendix 2)

3.5 Accuracy Assessment

Satellite images (pixels) were compared with ground survey (true verification) which revealed striking similarities. Random pixels were checked and the percentage of accurate imagery gave a fairly good estimate of accuracy of whole images.

4. Result and Discussion

4.1 Extrapolations

Data obtained from the mosaic satellite imagery were extrapolated using the standard ArcGIS geometric software tools, they are presented in table 1 below.

Table 1.List of classified sites showing spatial geometrical information.

	Classification Of Area	Classification Code	Size Of Classified Area(Km^2)	Nearest Neighbour Distance(Km)
1	Scanty vegetation around Ali Akilu rd and Dendo rd	A	0.100	0.640(MEAN)
2	Disperes vegetation around Lugard hall, GT-Bank and U/Rimi	B	0.238	0.591(MEAN)
3	Vegetation behind Murtala square	C	0.105	0.359
4	Vegetation along Independence way, DITV station and sokoto rd	D	0.032	0.503
5	Scanty vegetation around Govt. College rd, Kurmin Mashi	E	0.046	0.445
6	Vegetation inside Kad poly Staff qtrs. Kurmin mashi	F	0.060	0.445
7	Vegetation inside Governor's lodge (Kashim Ibrahim house),T/wada	G	0.113	0.541
8	Vegetation around Kad poly, T/wada campus	H	0.077	0.541
9	An area of dispersed vegetation at Kanta rd, Independence way and Y/Gowon way	I	0.316	0.367
10	vegetation by Kaduna river- around oando flling station opp Ahmadu Bello Stadium	J	0.180	3.004
		Total		**7.436**

NB: The nearest neighbor distance as stated on the extrapolated table, signifies the nearest distance between two or three identified fractional vegetative cover (FVC) of a classified site.

5. Discussion and Conclusions.

The nearest neighbour statistical technique states that when the statistical value of the nearest neighbour index **(R_n)** is greater than "**one**", then the ***vegetation distribution is regular or perfectly dispersed.*** Here, the calculated values of $\mathbf{R_n}$ is $\boldsymbol{R_n=1.37}$ (see appendix 3). This implies that the vegetation pattern within a classified (subset) area of study is regular or perfectly dispersed. Conversely, taking account of the total study area, it is seen that there are only very scanty vegetations or absolutely no vegetation in the rest of the total study area segmented.

Analysis shows that only 1.267Km^2 out of the total study area segmented 11.823Km^2 are covered with a regular pattern vegetation distribution, representing about 10.72% vegetation area while 89.28% lacks vegetation.

The total area segmented for study is full of commercial activities being the centre of Kaduna metropolis. Not less than 300, 000 people out of the total of about 6-million people in Kaduna state (2006 census) either reside or do business within the segmented study area of 11.823Km^2. Since the study area accommodates regular population distribution, it means that only about 10.72% of about half a million people within the study area enjoy the benefits of vegetation, against 89.28% devoid of vegetation.

Physical ground survey (truth verification) of the study area shows that about 50% of the trees in the classified vegetation sites are *MangiferaIndica* (Mango), about *20% are Guenengusspp, 10% Agzoraspp, 8% Dorantaspp, 5% Causerinaspp,* and others constituting about 7% (including*Moringaspp, Flambolaspp, EculcalyillsCameldulenees and AzadirachaIndica*); signifying an almost complete obliteration of indigenous tree speeches of native Kaduna. This is in line with the quadrant study carried out by Al-Amin(2005) on native vegetation displacement in Kaduna metropolis.

Physical ground survey observes that the vegetations are deliberately planted over the years which gives it the regular distribution pattern in nature. It implies that non-native vegetation dominates the classified vegetation area of the metropolis.

Amazingly, observation shows that the area without vegetation (89.28%) equivalent to 10.556Km^2 is densely populated with high commercial activities and high traffic. While the area of classified vegetation cover of 10.72%, equivalent to only 1.267Km^2 has scanty population with very low commercial activities and extremely low traffic. This situation is due to the peoples adaptation to a city without vegetation and seems to lack or ignore its consequences.

This study on low vegetation cover shows that the Kaduna metropolitan environment is hazardous in nature since there are only few vegetations to absorb the enormous carbon dioxide and other air pollutants emitted to give out oxygen for human and animal respiration.

The consequences of the above are poor air quality in the metropolis. Intense heat is experienced during the day due to high rate of evaporation in the absence of vegetation and significant area covered with tar and concrete pavements. High noise pollution of more than 70db is experienced in many the parts of the metropolis. Within the study area of 11.823Km^2, there is no amusement park or any landscape for aesthetic value. The metropolis lacks the presence of a typical ecosystem, with its inherent biodiversity. More so, the absence of vegetation as wind-breaker result in the parking-off of roofings and buildings during windstorms. Due to lack of vegetation, high electrical energy is required to power electrical appliances such as fridge and air-condition to supplement natural cooling.

In conclusion, the ESRI satellite images by the ArcGIS software and the application of the Nearest Neghbour analytical technique provides a simple, physically based assessment of vegetation abundance and distribution in the Kaduna metro area. If the method proves equally effective in other urban areas it could provide an efficient means for systematic, quantitative analyses of a major determinant of urban environmental conditions.

Quantitative validation of imageries of satellite-derived vegetation estimates with high spatial resolution vegetation measurements from aerial photography shows agreement from greater than 1 to 2.15 for regular or perfectly dispersed vegetation fractions across the full range of vegetation distribution and abundance for the Kaduna metropolitan area.

The role of urban vegetation distribution in the modulation of mass and energy flux through the urban system, as well as its impact on human health and environmental conditions, warrants further investigation into vegetation monitoring and its applications to urban systems. Comparative analyses of the role of vegetation distribution on urban environmental conditions could result in significant improvements in health, energy efficiency and quality of life for vast numbers of people in rapidly expanding conurbations. In addition, an improved understanding of the mass and energy fluxes through urban centers would improve our understanding of the dynamics of the larger scale metro-agro-plexes within which many urban centers exist. Because of the disproportionately large impact of urban areas on their surrounding environments, such an investigation would presumably yield a relatively large return in the form of improved understanding of one of the major anthropogenic drivers of global change.

The future of our cities depends on our ability to conserve and use our resources wisely. As reviewed in this paper, vegetation in cities can play an important role in the aesthetics and design of cities; biological conservation; reduction in the use of fossil fuels; and reduction in some forms of pollutants.

Those who have designed and planned cities have seen that, beyond its roles in the physical, biological and conservation realms, vegetation has an important societal function. Vegetation is essential to achieving the quality of life that creates a great city and that makes it possible for people to live a reasonable life within an urban environment. As long as people agree that cities are important to civilization and that it is essential that we improve the conditions of urban residents, especially the

urban poor, people must understand that vegetation is an integral part of the city environment.

References

Al-Amin, M. A (2005): Native Vegetation Replacement with Exotic Spicies in Kaduna Metropolis, in Sati S. A. ed: Geographical study of Kaduna Region.

Akaike, H. (2008). "On the Likelihood of a time series model".The Statistician 27:217- 235.

Grove, J. M., W.R. Burch and S.T.A. Picket (2005). Social Mosaics and Urban Forestry, Baltimore, Maryland. Community and Forestry: Continuity andComplexity,Ohio.

Hamilton, S.D., Dettmmann, P.D and Curtis, A.L. (2000).Landholder perceptions of remnant vegetation on Private land in the box-ironbark region of northern Victoria. research Report 1/00. National Research and Development Program on rehabilitation, Management and Conservation of Remnant Vegetation. Canberra: Environment Australia.

Jenkins, J.C. (2005). What does non-forest land contribute to the global C balance? USDA Forest Service North Central Research Station General Technical Report NC.

Maurer, Ute, Tim Peschel, and Solveig Schmitz (2000)."The flora of Selected Urban Land-use Types in Berlin and Potsdam with Regard to Nature Conservation in Cities." Landscape and Urban Planning 46 (4): 209 – 215.

Sagoff, Mark.(2005). "Do Non-native Species Threaten the Natural Environment?"

Journal of Agricultural and Environmental Ethics 18:215-236.

Saltonstall, Kristin (2002). "Cryptic Invasion by a Non-native Genotype of Phragmitesaustralis into

North America." Proceedings of the National Academy of Sciences, USA 99 (4): 2445-2449.

Sukopp, Herbert, and Angelika Wurzel (2003). "the effect of climate on the vegetation of central European cities." Urban Habitat 1 (1): 66-86 (on-line Journal *http://www.urbanhabitat.org/vo1n01/climatechange-pdf.pdf;*) accessed 21 July 2010.

Tyrvainen, Liisa, StphanPauleit, Klaus Seeland, and Sjerp de vries(2005). "Benefits and Uses of Urban Forest and Trees."Pp. 81-144 in urban Forest and Trees, eds. Cecil C. Konijnendijk, kjellNilson, Thomas B. Randrup, and jasper Schiperijn. Berlin: Springer.

United Nations (1997): Worl Population Explotion and Related consequences. Geneva.

Wittig, Rudiger (2004). "The Origin and Development of the Urban Flora of Central Europe." Urban Ecosystem 7:323-339.

Zerbe, Stefan, Ute Maurer, Solveig Schmitz, and Herbert Sukopp(2003). "Biodiversity in Berlin and its

Potentials for Nature Conservation." Landscape and Urban Planning 62:139-148.

Ziska, Lewis H., James A. Bunce, and Ernie W. Goins(2004). "Characterization of an Urban-rural CO_2/temperature Gradient and Associated Changes in Intial plant productivity During Secondary Succession."Oecologia 139: 454-458

Appendix 1:

Fig. 4: Satellite imagery classifying area of study around Kanta road, Independence way and Gowon way. The classified area (0.316Km^2) is shown in green coloured boundary lines demarcating classified area of study.

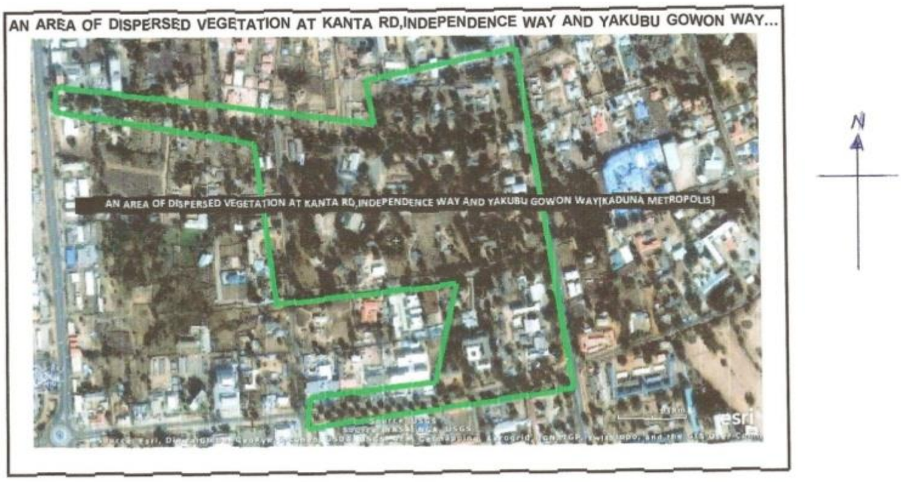

Fig. 5: Satellite imagery showing a classified area of study around Lagard hall, GT-bank and U/Rimi. The classified area (0.238Km^2) is shown in green coloured boundary lines demarcating classified area of study.

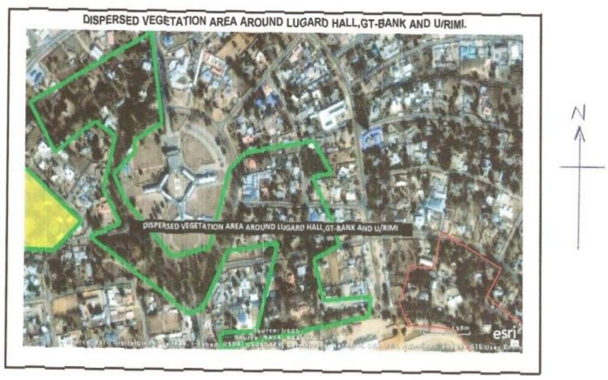

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Fig. 6: Satellite imagery showing a classified area of study around Ali Akilu road and Dendo road.

The classified area ($0.100Km^2$) is shown in green coloured boundary lines demarcating classified area of study.

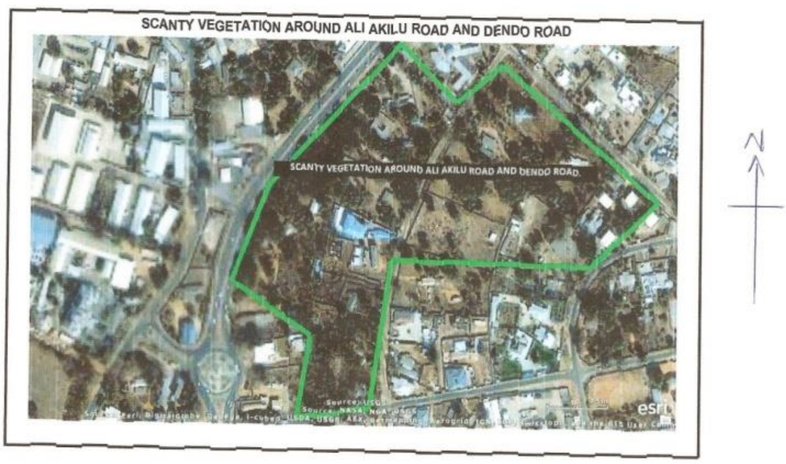
Other Classified areas are:

Classified area of study around Govt. college road, Kurmin Mashi. The classified area($0.046Km^2$) is shown in red coloured boundary lines demarcating classified area of study.

Classified area of study around Asa pyramid hotel off independence way.

The classified area is shown in green coloured boundary lines demarcating classified area of study.

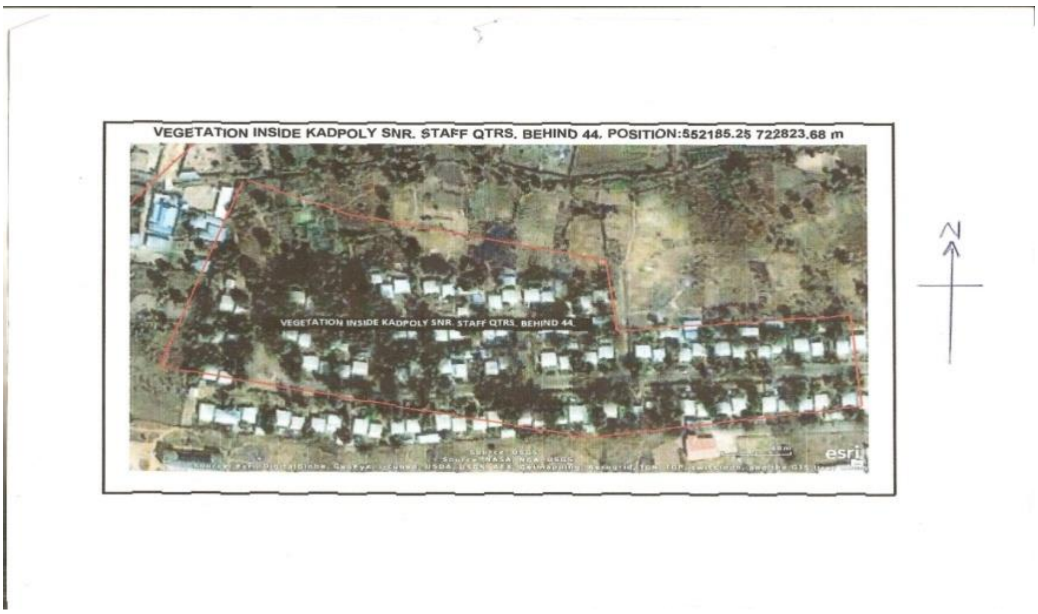
Classified area of study behind Murtala Mohammed Square.



The classified area (0.105Km^2) is shown in green coloured boundary lines demarcating classified area of study.

Fig. 10: Satellite imagery showing a classified area of study inside KadpolySnr. Staff Qtrs, behind 44 Army hospital.

The classified area (0.060Km^2) is shown in red coloured boundary lines demarcating classified area of study.



Appendix 2:

In a purely random distribution of points, the expected mean distance D_e between each pair of points and its Nearest Neighbour is

$D_e = 1/2\sqrt{P}$**……………………………..Equation (1)**

The statistic R_n is given by

$R_n = D_0/D_e$**………………………………Equation (2)**

Thus R_n reduces to

$R_n = 2D_0\sqrt{P}$**………………………………Equation (3)**

And **P** is given as

$P = N/A$**……………………………………Equation (4)**

Where:

R_n…..Is called the Nearest Neighbour Index of the classified sites

D_0…..is the Observed Mean-First Nearest Neighbour classified site

D_e……is the Expected Mean-First Nearest Neighbour classified site

P……is the Density of Points-which is the density of classified sites in the study area.

N….. Number of Points-which is the Number of classified sites (subsets) in the study area with regards to Fractional vegetative Cover.

A…..is the Area under Study- which is the segmented portion of Kaduna metropolis under study.

And D_0 is calculated as

$D_0 = \sum D/N$**………………………………..Equation (5)**

D……is the Total Sum of the Distances between classified sites called the Nearest Neighbour Distances.

The general rule for applying the method is based on the fact that the Nearest Neighbour Statistic has a value that ranges between **0** and **2.15.** $0 \angle R_n \angle 2.15$**………………………Equation (5)**

The bases for operation on which the theoretical rules stand are base on the following:

$R_n \leq 1$……Implies vegetation distribution is RANDOMLY SCATTERED.

$R_n = 0$……….vegetation distribution is CLUSTERED.

$R_n = 2.15$ OR $R_n \nearrow 1$…..vegetation distribution is REGULAR or PERFECTLY DISPERSED.

R_n in this case is called the **Nearest Neighbour Index** and is used simply to describe point patterns without carrying out any test of significance.

The total area of study is denoted as **$A=11.823Km^2$**

Total area of classified vegetation cover=**$1.267Km^2$**

Total distance between classified vegetations sites is denoted as

D=7.436Km

Number of classified vegetation sites is denoted as **N=10.**

Using Equation….(3): $R_n=2D_0\sqrt{P}$

From Equation….(5): $D_0=\sum D/N$

Hence, **D=7.436/10=0.744Km**

By Equation….(4), **P**=Density of vegetation on classified study sites=**N/** Hence, **$10/11.823=0.846Km^{-2}$**

Therefore**:** $R_n=2\ (0.744)\ \sqrt{0.846}=2\times0.744\times0.91$ $R_n=1.37$

R_n is the Nearest Neighbour index, whose value determines the distribution pattern of vegetation within the study area in Kaduna metropolis.

By percentage observation:

Since the total area of study **A=11.823Km^2**

And the total area of classified vegetation**=1.267Km^2**

Then, the total area without vegetation**=11.823Km^2 −1.267Km^2 =10.556Km^2**

Hence, the percentage **area of classified vegetation =1.267×100% / 11.823 = 10.72%**

And, the percentage **area without vegetation =10.556×100% /11.823 = 89.28% OR 100% − 10.72% = 89.28%**