African Research Review

An International Multi-Disciplinary Journal, Ethiopia
Vol. 4 (3b) July, 2010
ISSN 1994-9057 (Print) ISSN 2070-0083 (Online)

Detection and Mapping of Land Use and Land Cover Classes of a Developing City in Southeastern Region of Nigeria, using Multi-band Digital Remotely-sensed Data *(Pp. 315-330)*

Njoku, John D. - Dept of Environmental Technology, Federal University of Technology, P. M. B. 1526 Owerri, Nigeria
E-mail: dr_jdnjoku@yahoo.com
Mobile Telephone +234 803 401 6638, +234 809 875 1816

Ebe, Toochukwu E. - Dept of Environmental Technology, Federal University of Technology, P. M. B. 1526 Owerri, Nigeria
E-mail: akumzirit2@yahoo.com

Pat-Mbano, Edith C. - Dept of Urban and Regional Planning, Evan Enwerem University, P. M. B. 2000, Owerri, Nigeria
E-mail: eddiepatmbano@yahoo.com

Abstract

Land use and land cover dynamics has been commonplace around Owerri and environs. Landsat TM 86 and ETM+ 2000 were used to detect and map these changes. The imageries were mapped at the scales of 1:250,000 and 1:150,000 using ILWIS Academic 3.0 GIS software. The result showed significant shift in the aggregate land use and land cover class due to natural and anthropogenic forcing agents. Forest vegetation class had the largest coverage on the land use and land cover maps of 1986 and 2000. The bare/eroded surfaces class gave the highest PAVM value of 65.7% followed by water body of 44.9%. This implies that the LU and LC underwent massive

transformation and change in the period of study. These types of LU and LC and the spate of dynamics must be considered in the preparation of development plans for cities in the region.

Introduction

According to Cihlar and Jansen [2001], land cover [LC] and land use [LU] are concepts that define and describe terrestrial environment in natural and anthropogenic contexts. LC is largely of natural origin or is created by LU but, is characterized by the biophysical features of the terrestrial environment. On the other hand, LU refers to the manner in which these biophysical assets are used by people [for details, see Cihlar and Jansen, 2001]. It is the employment of LC and management strategy used on a specific class by human agents for land managers [Baulies and Szejwach, 1997]. LC may be created by LU as defined by infrastructural facilities such as roads, buildings, etc.

The relevance of remote sensing and GIS techniques for periodic LU and LC mapping and change detection has been copiously discussed [see, for example, Adeniyi and Omojola, 1988, Njoku, 1992, Njoku, 2006, Njoku, et al 2006]. These studies emphasized that places characterized by paucity of environmental data, rapid environmental changes and acute ecological problems require regular monitoring for baseline data.

Owerri and environs are characterized by natural and man-made problems and rapid land use and cover changes such as flooding, erosion, induced soil infertility and degradation, deforestation, etc. This study examines the application of multi-temporal remotely-sensed data in the detection of static LU and LU changes between 1986 and 2000. The study provides temporal empirical comparative assessment of TM 86 and ETM+ 2000, while identifying the primary drivers of the intra-class dynamics during the periods in order to predict what types will dominate the area in the future. The study area, Owerri metropolis is a closely-settled built-up area and the administrative capital of Imo State of Nigeria. The pre-1976 Owerri comprised largely pockets of rural settlements of predominantly subsistence farmers. It lies between latitude $5^o25^{'}$N and 5^o $34^{'}$ N and longitude $6^o7^{'}$E and $7^o06^{'}$E covering an area of approximately 5,792.72 km^2. The 1991 population of Owerri was 289, 721 [NPC, 1991], in 1998 the projected population was put at 353, 665 people [Imo State Government, 2000], while in 2006 the population was 401, 873 [NPC 2006]. The area is within the humid tropics and is characterized by high temperature and rainfall regimes with a mean maximum temperature of about 32^0C and a mean minimum of about 21^0C. Recent studies (e.g. Nnaji, 1998, 1999 and FGN, 2003) however reported declining trend in rainfall characterized by large spatial and temporal variations.

The area lies in the rainforest belt of Southeastern Nigeria characterized by low- land tropical rainforest, which has virtually given way to secondary forest re-growths of mostly tree crops and shrubs separated by crops at various stages of growth. In the area, vegetation plays the dual role of humus supply and protection of the soil from the ubiquitous soil erosion. Owerri and environs are within the densely populated region of Southeastern Nigeria. In spite of the increasing population which presses on land availability market gardening is largely practiced. The growth rate of the population growth, its size structure, density, spatial distribution and urbanization characteristics are critical factors of the environment likely to affect LU and LC dynamics. Being the administrative capital of Imo State, associated infrastructure, education opportunities and employment potentials, the city attracts growing migrants from distant and adjourning towns and villages. The emergence of small and medium sized agro-husbandry industries in the peripheral, semi-urban villages have attracted urban sprawl and rapid socio-economic activities. Hence, subsistence agriculture, petty trading, white collar jobs (paid employment), artisanship characterize and significantly influence the contemporary LU and LC patterns. This has exerted great pressure on the ecological resources, even without any eco-conservations efforts. Similarly, soil erosion, flooding, increasing soil infertility resulting in bare surfaces also contributed in shaping these patterns.

Methodology

The study was undertaken with corrected Landsat Thematic Mapper 1986 [TM 86] and Enhanced Thematic Mapper *plus* 2000 [ETM+ 2000] satellite imageries. These were used for LU and LC classification and statistical change analysis of static features captured by the imageries. The 1:100,000 administrative map of Imo State covering the study area was obtained from the Ministry of Lands and Urban Development, Owerri Nigeria. The map was used for the enhancement of LU and LC classification, orientation and geometric registration of the imageries during interpretation.

The satellite imageries were obtained from the National Space Research and Development Agency [NASRDA] Abuja, Nigeria. The TM 86 was obtained from the NASRDA archive while the ETM+ 2000 was obtained from Nigeria

Sat 1. The data were analyzed at the National Centre for Remote Sensing, Jos, Nigeria. The imageries were preprocessed and corrected for system errors, terrain distortions, and were geographically registered before being used for the change analysis using the ILWIS ACADEMIC 3.0 GIS software. The imageries were cloud free and of high quality having being acquired during the dry season 17th and 19th December for the ETM+ 2000 and TM 86 respectively. The Nigeria Sat 1 imagery showed marked influence of meteorological conditions. Erosion sites also slightly affected the classification in the form of non-heterogeneous spectral reflectance. The imagery has ground resolution of 32 meters, swat width of 600 x 450 km, and bands of 1, 2, 3 and 4. The LU and LC patterns represented on the map were used as the starting point of the contemporary LU and LC classification in the present study. This done, the regularity of LU and LC conversion of the different classes were analyzed. Consequently, the LU and LC classes were identified through a combination of their image characteristics, previous LU and LC map patterns and the potential changes that took place in the past. The map was used on the assumption that the trends, regularity and patterns can be identified for the LU and LC conversion process. Image classification was achieved through preparation of a confusion matrix using the ILWIS software. With this a classification scheme for the LU and LC features were developed to be compatible with those already in use in the region and numerically coded and collapsible in nature. The scheme has five levels which cover the LU and LC features in the area as shown on Table 1. Similarly, analysis of the imageries followed an ordered pattern.

The image classification scheme involved the initial step of classification of the different spectral reflections into different classes of objects or terrain features based on the definition template available on the ILWIS 3.0 GIS software. The grouping of features on the imagery was based on the spectral signature responses of the attributes. Virtual analysis of the satellite imageries using the ILWIS software through a clip and subset procedure was undertaken to extract the desired areal extent of the study area from the large data set. In the urban and peripheral, semi-urban areas texture analysis was used in the LU and LC classification enhancement in response to the complex patterns resulting from similar spectral characteristics. This involved the capture and utilization of recurring characteristics to distinguish closely identical LU and LC classes. The on-screen mapping was achieved by delineating areas of relative homogeneity through assigning polygons over those similar areas. The delineation was based on hue, texture and context. It was cross-referenced to the map and socio-economic data as well as other information sources.

The Percentage Absolute Variation of Mapping (PAVM) was calculated to determine the degree of variance and the ability of the imageries to accurately map the features. Comparative and statistical change analysis which involved the measurement and computation of the LU and LC change of 1986 and 2000 was also carried out. This involved determination of the change in areas between individual LU classes in 2000 from their area coverage in 1986 and the conversion of one LU class to another between 1986 and 2000. The values range from 0 to 100%. A zero value implies no change existed between the data sets. The value of 100% means that LU and LC classes identified on one data set was completely transformed on the other set. Figure 1 shows the analysis procedure of change detection.

Results and Discussion

The major LU and LC classes identified in the study are: built-up area, poorly dispersed forest vegetation, cultivation, bare/eroded surfaces and water body. These were easily identified and delineated on TM 86 and ETM+ 2000. There were observed varying degree of spectral signatures on the generated imageries and variations in the settlement class. This was due to marked variations in settlement type such as the densely populated residential, commercial and sparsely populated areas. The variants of forest vegetation was the dormant LU and LC type in 1986 and 2000 and covered a total area of 2,792.72km^2, especially around the out-lying peri-urban areas.

Land areas and features were assigned different spectral signatures to represent changes from one class to the other. The largest inter-class change occurred between the cultivation and the forest vegetation classes. The forest vegetation class has the largest unchanged portion among the classes. The Landsat TM 86 showed different spectral signature for the different classes of LU and LC. The area coverage of the different LU and LC classes is showed on Table 2.

The Landsat ETM+ 2000 showed marked similarities in the spectral signatures in the depiction of the identified LU and LC classes, as presented on Table 3. However, the false color composite, Landsat ETM+ of 12 December 2000 showed a higher resolution of features and attributes. This is traceable to the superior sensor borne by the ETM+ 2000. There were also marked variations of spectral reflectance among the classes and sub-classes as observed on the TM 86. These similarities are due to the high influence of prevailing environmental conditions, since the two imageries were captured during the dry season. Comparative analysis of the two imageries reveal that changes occurred in the intervening period while some LU and LC classes diminished others increased. The LU and LC change map shown in Figure 4 depicts the various inter-class area changes among the five classes.

A visual summary of comparison of the TM 86 and ETM+ 2000 LU and LC change analysis is presented on Table 4. The study revealed that the change from forest vegetation class to other classes were relatively small. The total unchanged forest area was about 1,097.46km^2 and about 23.32% conversion to other classes. The conversion to the built-up class was about 42.79km^2 possibly due to urbanization and land development as a result of population increases in the last two decades. The conversion to the water body class represents about 0.63km^2 of the forest vegetation class. This result could be as a result of misclassification of their spectral signatures. The conversion to the cultivation class showed mainly around the semi-urban outlying areas. These represent the largest conversion of the forest class (about 290.38km^2). This could arise from increased subsistence farming in the outlying areas of Orji, Naze, Irete, Amakohia Uratta and Akwakuma and Egbu/Awaka suburbs. The percentage changes of these conversions are presented on Table 5.

Changes on the built-up class were generally small though conversion to the cultivation class was high. The unchanged segment was about 331.15km^2 and it had about 24.4% conversion to other classes, mainly forest vegetation, water body and cultivation. Conversion to the forest vegetation represents about 15.29km^2. This could be explained by the spectral reflectance of nearby tree canopies especially in the outlying areas, and the regeneration of plant/tree cover over time. Conversion to the water body was about 0.56km^2. This may be attributed to the presence of wetland/flooded areas of the receding rainy season. Conversion to the cultivation class represents 91.04km^2. This largest change may be due to conversion of some existing recreational areas and open spaces to farmlands, especially around Nekede and other suburban locations. This scenario is illustrated on Table 6. The bare/eroded surface class showed a high rate of conversion of about 79.36% on the TM 86 imagery. It was mainly converted to such classes as forest vegetation, built-up and cultivation. Conversion to the forest vegetation class was about 0.02km^2 of the previous eroded surface area. This can be explained by the natural regeneration of plant cover between 1986 and 2000 especially around Aladinma layout of the metropolis. Conversion to the built-up class mainly observed around core Owerri metropolis (e.g. the New Owerri Layout) and the Amakohia Uratta area was about 20.35km^2. This may be as a result of urbanization to meet the demands of the rising population of Owerri and environs. Conversion from bare/eroded surfaces to the cultivation class was minimal and about 1.56km^2. This implied that there is conversion of small proportion of the open spaces and vacant lands into cultivated farmlands [see Table 7].

The conversion in the water body class showed high bias and was about 84.37%. The estimated unchanged segment was about 1.49km^2. The estimated conversion to the built up class may be due to bias in the classification following the influence of the spectral reflectance of proximate features on the built-up class [such as vacant lands] around the outlying rural areas around the old Nekede road/Otamiri river. This represents about 3.35km^2. The conversion to the forest vegetation represents about 3.19km of the water body surface area. Bias here may have been introduced by possible interference of overlying tree/plant cover over the water bodies. This made classification difficult. The conversion to the cultivation class was about 1.5km^2 a value higher than the unchanged area segment of the water body class. The percentage changes of these are presented on Table 8. LU and LC changes in cultivation class were about 66.36% of the total surface area involving the built-up, water body and forest vegetation class. Unchanged area segment of the cultivation class was about 295.89km^2. This may be attributed to land development and encroachment which characterize New Owerri and Aladinma layouts. Thus, about 150.79km2 of the entire area of the cultivation class is affected. Change to the forest vegetation class was about 444.32km^2. This may be as a result of natural regeneration of the plant/tree cover particularly the wooded shrubslands present at locations such as Naze. Also, fallowed farmlands and other cultivatable arable lands may have presented this scenario. The changes are shown on Table 9.

The comparison of the differences between the areas covered by the classes in the data sets is presented on Table 10 and Figure 10. The difference show the absolute mean value of changes in the LU and LC classes based on the ability of TM 86 and ETM+ 2000 to detect and map the features. Simple percentages were used to show the differences and to represent the relative amount of the LU and LC classes as a percentage of the total area. The strength of their differences is shown using the Percentage Absolute Variations of Mapping [PAVM] values expressed as:

$$PAVM = \frac{A_1 - A_2}{A_1 + A_2} \times \frac{100}{1}$$

Where A_1 = Landsat TM 86 map percentage of the LU and LC classes within the study area.

A_2 = the absolute differences in values between A_1 and A_2

The values show that there was an overall change of about 26.9% between the data sets. The forest vegetation showed the lowest (4.31%), while the eroded/bare surfaces showed the highest change of 65.74%. This portrays the ability of the two imageries to accurately map identical features. Detailed PAVM results of the imageries are shown on Table 10.

Conclusions

The results of the study revealed significant shift between the two periods. The imageries proved very useful and effective in the accurate mapping of ground features. The bare/eroded surfaces class gave the highest PAVM value of 65.7% followed by water body 44.9. This implies that the LU and LC underwent massive transformation and change in the referred period. This may be as a result of massive land/physical development due to rising spate of urbanization around Owerri and environs. Apart from these, irregular and scattered LU and LC patterns characterizes the study area, thereby making lack of spatial specialization a hindrance to integrated land management and development with consequent environmental problems such as soil erosion, loss of biodiversity, soil infertility and loss of environmental aesthetics.

Given the above results of the study, it is imperative to monitor and inventory the key drivers of LU and LC change. It is also relevant to apply GIS and RS techniques to acquire land based data.

Table 1: Land Use and Land Cover Classification Scheme [*Adapted from* Njoku, 1992]

	Class	Numeric code	Feature Name [Subclass]
1	Built-up	11	Villages
		12	Urban Areas
		121	Mixed Traditional Areas
		122	Mixed Modern Areas
		123	Commercial Areas
		124	Industrial Areas
		125	Open Spaces/Recreational Areas
		126	Institutional Areas
		127	Transportation
		128	Vacant Lands
2	Cultivation	21	Actively Cultivated Lands
		22	Uncultivated Farm Lands
		23	Rainfed Agricultural Lands
		24	Orchard/Fruit Trees
		25	Orchard/Fadama
		26	Tree Nursery
3	Vegetation /Forest	31	Grassland/Shrub
		32	Shrub/Grassland
		33	Wooded Shrub land
		34	Forest cover
4	Water Body	41	River / Streams
		42	Lakes / Ponds
5	Bare / Eroded Surface	51	Rocky / Lateritic Surfaces
		52	Sandy Surfaces
		53	Quarry / Erosion Sites

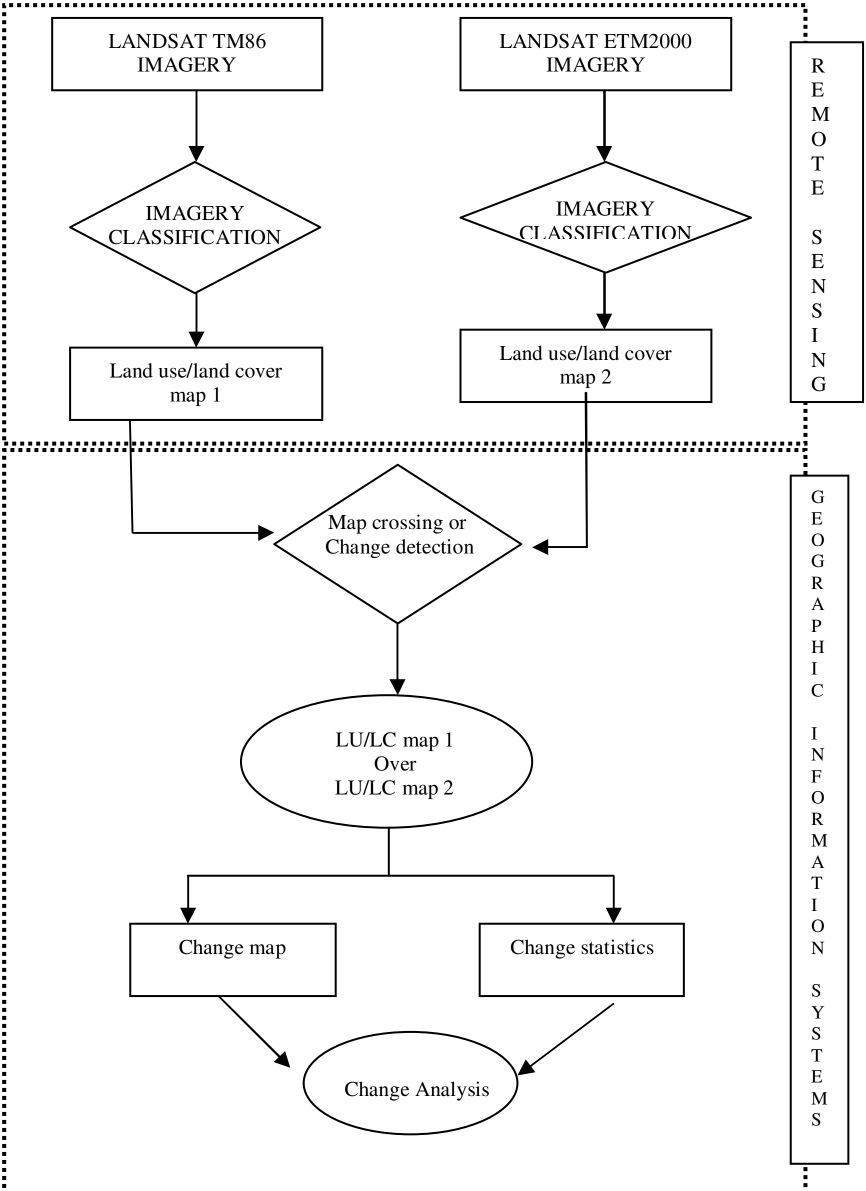
LANDSAT TM86 IMAGERY
LANDSAT ETM2000 IMAGERY
IMAGERY CLASSIFICATION
IMAGERY CLASSIFICATION
Land use/land cover map 1
Land use/land cover map 2
REMOTE SENSING
Map crossing or Change detection
LU/LC map 1 Over LU/LC map 2
Change map
Change statistics
Change Analysis
GEOGRAPHIC INFORMATION SYSTEMS

Table 2: LU and LC Classes in 1986

LANDSAT TM 86 [19th December 1986]	Area in km^2
Bare/Eroded surface	21.96
Cultivation	891.94
Forest Vegetation	1, 431.25
Built-up	438.04
Water Body	9.53
Total	2, 792.72

Table 3: LU and LC Classes in 2000

LANDSAT ETM+ [of 12th December 2000]	Area in km^2
Bare/Eroded surface	4.54
Cultivation	680.40
Forest vegetation	1,560.00
Built-up	543.88
Water Body	3.62
Total	2,792.72

Table 4: Summary of the LU and LC change analysis between the periods 1986 and 2000

LU / LC Classes	TM 86 [Classified]	ETM+ 2000 [Classified]	Area in Km^2
Vegetation Δ Forest Vegetation	Forest Vegetation	Forest Vegetation	1097.46
Vegetation Δ Built-up	Forest Vegetation	Built-up	42.79
Vegetation Δ Water body	Forest Vegetation	Water Body	0.63
Vegetation Δ Cultivation	Forest Vegetation	Cultivation	290.38
Built-up Δ Forest Vegetation	Built-up	Forest Vegetation	15.29
Built-up Δ Built-up	Built-up	Built-up	331.15
Built-up Δ Water Body	Built-up	Water Body	0.56
Built-up Δ Cultivation	Built-up	Cultivation	91.04
Eroded Surface Δ Forest Vegetation	Bare/Eroded Surface	Forest Vegetation	0.02
Eroded Surface Δ Built-up	Bare Eroded Surface	Built-up	20.35
Eroded Δ Cultivation	Bare Eroded Surface	Cultivation	1.58
Water Body Δ Forest Vegetation	Water Body	Forest Vegetation	3.19
Water Body Δ Built-up	Water Body	Built-up	3.35
Water Body Δ Water Body	Water Body	Water Body	1.49
Water Body Δ Cultivation	Water Body	Cultivation	1.50
Cultivation Δ Forest Vegetation	Cultivation	Forest Vegetation	444.32
Cultivation Δ Built-up	Cultivation	Built-up	150.78
Cultivation Δ Water body	Cultivation	Water Body	0.95
Cultivation Δ Cultivation	Cultivation	Cultivation	295.89
Δ = changed to		Total Area	2792.72

Table 5: Summary of the change analysis of the forest vegetation

Classes	Landsat TM 86 [Classified]	Landsat ETM+ 2000 [Classified]	Area in km^2
Vegetation Δ Forest Vegetation	Forest Vegetation	Forest Vegetation	1097.50
Vegetation Δ Built-up	Forest Vegetation	Built-up	42.79
Vegetation Δ Water Body	Forest Vegetation	Water Body	0.63
Vegetation Δ Cultivation	Forest Vegetation	Cultivation	290.38
Δ = Changed to		Total	1431.30

Table 6: Summary of the changes on the built up class

LU and LC Classes	TM 86 [Classified]	ETM+ 2000 [Classified]	Area in km2
Built up Δ Forest Vegetation	Built up	Forest Vegetation	15.29
Built up Δ Built up	Built up	Built up	331.15
Built up Δ Water body	Built up	Water body	0.56
Built up Δ Cultivation	Built up	Cultivation	91.04
Δ = Changed to		Total	438.04

Table 7: Summary of the changes on the bare/eroded surface class

LU and LC Class	TM 86 [Classified]	ETM+ 2000 [Classified]	Area in km2
Bare/eroded Δ surface Δ Forest vegetation	Bare/eroded surface	Forest vegetation	0.02
Bare/eroded surface Δ Built up	Bare/eroded surface	Built up	20.35
Bare/eroded surface Δ Cultivation	Bare/eroded surface	Cultivation	1.56
Δ = Changed to		Total area	21.95

Table 8: Summary of the changes on the Water body class

LU / LC Class	TM 86 [Classified]	ETM+ 2000 [Classified]	Area in km^2
Water Δ body Forest Vegetation	Water body	Forest vegetation	3.19
Water body Δ Built-up	Water body	Built-up	3.35
Water body Δ Water body	Water body	Water body	1.49
Δ = changed to		Total	8.03

Table 9: Summary of the change statistics on the Cultivation

LU / LC Classes	TM 86 [Classified]	ETM+ 2000 [Classified]	Area in km^2
Cultivation Δ Forest Vegetation	Cultivation	Forest vegetation	444.32
Cultivation Δ Built-up area	Cultivation	Built-up	150.78
Cultivation Δ Water body	Cultivation	Water body	0.95
Cultivation Δ Cultivation	Cultivation	Cultivation	295.89
Δ = changed to		Total	891.94

Table 10: PAVM of the LU and LC Classes.

LU / LC Classes [TM 86]	Area in km^2	% intra class	LU / LC Classes [ETM+ 2000]	Area in km^2	% intra class	PAVM
Bare/ Eroded surfaces	21.96	0.8	Bare/Eroded surfaces	4.54	0.2	65.7
Cultivation	891.94	31.9	Cultivation	680.4	24.4	13.5
Forest Vegetation	1431.25	51.2	Forest vegetation	1560.28	55.9	4.3
Built-up	438.04	15.7	Built-up	543.88	19.5	10.8
Water body	9.53	0.3	Water body	3.62	0.1	44.9

References

Adeniyi, P O and Omojola, A., 1988, "SPOT HRV MSS and Landsat TM data for Land use and Land cover Mapping in the closely settled area of Sokoto, Nigeria", in Some Applications of Remote Sensing in North-West Nigeria. A Post Project Workshop on Resource Mapping of Sokoto - Rima Basin, held at the University of Lagos, 1 – 3 November, page 131 – 147.

Baulies, X and G. Szejwach, [eds.] [1997]: Survey of needs, gaps and priorities on data for Land use/ land cover change research. *Report presented at the LUCC data requirement workshop,* 11 – 14 November, Barcelona

Cihlar J and L J M Jansen [2001]: From land cover to land use: A methodology for efficient Land use Mapping over large areas, *Professional Geographer* 53 [2], pp 275 – 289, Association of American Geographers.

Federal Government of Nigeria, 2003, "First National Communication on Climate Change (Final Draft)", Federal Ministry of Environment, Abuja.

Imo State Government, [2000]: Imo State of Nigeria Populations Projections by Local Government Areas, Imo State Planning and Economic Development Commission, Owerri

National Population Commission [1991]: *1991 Population Census*, Federal Republic of Nigeria, Abuja

National Population Commission [2006]: *2006 Population Census,* Federal Republic of Nigeria, Abuja

Njoku, J. D. 1992, "A Multi – band Assessment of SPOT Imaging System for Land and Land Cover Mapping of Northwestern Nigeria". Unpublished MSc Thesis**.** Dept of Geography and, Planning, University of Lagos, Akoka , Lagos.

Njoku, J. D. 2006, "Analysis of the effect of Global Warming on Forests of SE Nigeria using Remotely- sensed data". Unpublished PhD Dissertation**.** Dept of Geography and Environmental Management, Imo State University, Owerri.

Njoku, J D, Okoli, C G, Uzoije, A P and Iwuji, M C. 2006, "Assessment of Multi-band Capabilities in the Detection of Built-up areas in Northwestern Nigeria". Journal of Applied Sciences Asian Network for Scientific Information, 6 [10] 2177-2184.

Nnaji, A. O. 1998, "Climate Forcing, Precipitation Variability and Rainfall Forecasting Models for Northern Nigeria". Proceedings of the 94th Annual Conference of Association of American Geographers. Boston Massachusetts. March 26th- 29th

Nnaji, A. O. 1999, "Climate Variation in the Sub – Saharan Region of West Africa: A Study of Rainfall Variability in Northern Nigeria," unpublished PhD Dissertation, Department of Geography, University of Florida, Gainesville.182pp.