ASSESSMENT OF LANDUSE/LANDCOVER CHANGES IN KADUNA METROPOLITAN AREA USING REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM TECHNIQUES

BY

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DECLARATION

I declare that the work in the dissertation entitled 'Assessment of Landuse/Landcover Changes in Kaduna Metropolitan area using Remote Sensing and Geographic Information System Techniques' has been performed by me in the Department of Geography, under the supervision of Dr. E.O. Iguisi and Dr. A.L. Bello

The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree or diploma at any university.

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_____	_____	_____
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CERTIFICATION

This dissertation entitled "ASSESSMENT OF LANDUSE/LANDCOVER CHANGES IN KADUNA METROPOLITAN AREA USING REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM TECHNIQUES" by Ndabula Christopher meets the regulation governing the award of the degree of Master of Science of Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

I dedicate this dissertation to my sweet heart and wife Rachel and children Kalyn, Kassang, Nda, Venilat and Ziyong, and my aged mother and bros. Francis and Simon.

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ABSTRACT

This study is aimed at assessing LULC in Kaduna metropolitan area. It is fundamental to this research effort to understand the dynamic relationship between Kaduna urban growth and landuse/landcover change as an index of land degradation.The methodology adopted involved landuse/landcover mapping using field mapping with GPS and GIS technique. The field mapping involved systematic and stratified random sampling techniques. While GIS techniques involve table digitizing of analogue maps and on- screen digitizing, maximum likelihood classification and interpretation of Landsat.TM (1987), Spot.XS (1994) and Landsat.ETM (2001). A hydrographically corrected Digital Elevation Model (DEM) was generated from digitized subset of topomap of 1967 of the study area to aid floodplain analysis, while Normalized Difference Vegetative Index (NDVI) was computed for vegetation analysis.

The Analysis of Variance (ANOVA) using two-factors (x and y) at 0.05 significant level was used to test the hypotheses for the spatial (x) and temporal (y) variations that occur among different landuse/landcover and also among the classes of vegetation cover observed from image interpretation and NDVI analysis respectively. Result showed that there is significant differences between the means extents of the various landuse/landcover classes as well as the vegetation cover categories in

both x and y directions. This signifies that there is both spatial and temporal variations in landuse/landcover and severe deforestation in the 1980's, 1990's and 2000's. This proofs that there is rapid landuse/landcover changes and deforestation in the study area (Kaduna Metropolis and environs).

Results showed that Kaduna experienced rapid growth at an average rate of 1.77Km^2 or 9.84% annually. NDVI analysis and statistical test showed that there is severe deforestation with Non vegetated surfaces increasing at an annual rate of 2.6%, Discontinuous savannah shrubs declining at 1.61%, Dominant savannah shrub declining at 1.38% and forest increasing at 2.42% annually due to agro forest and orchards.

Kaduna metropolitan area is also experiencing rapid landuse/landcover changes with cultivated area experiencing a total of 36.74%, floodplain agricultural area 0.42%, forest area 28.54%, water bodies, 25.74% growth between 1987 and 2001.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

A critical concern of the world today is on the landuse/landcover (LULC) changes especially due to rapid urban growth, because of the strong influence they have on the state of environmental degradation (Lal et al 1989, Townsend, 1992). Monitoring such changes and assessing their impact on the entire ecosystem cannot be overemphasized. This is largely because land surface has considerable control on the earth's energy balance, biogeochemical and hydrological cycles, which in turn influence climate and other systems that shape the earth (Abubakar et al, 2002).

The National Research Council recently identified landuse dynamics as one of the grand challenges for environmental research. Landuse change is often a driver of environmental and climatic changes. Climate change and environmental degradation can in turn affect landuse/landcover in a vicious cycle.

The dynamic nature of urban system foster rapid landcover changes and land degradation which can be tracked most readily using remotely sensed data (Ramsey,2001). Urban environment belongs to the most

dynamic systems on the earth. Understanding the growth and change brought on by urbanisation is critical to planning for the prevention of urban degradation and management of its resources (Yang,2003).

Landuse/landcover are linked to climate and weather in complex ways. Because of the strong links between landcover and climate, changes in landuse and landcover can be important contributors to climate change and variability. Reconstruction of past landcover changes and projections of possible future landcover changes are needed to understand past climate changes and to project possible future climate changes; landcover characteristics are important inputs to climate models. In addition, changes in landuse/landcover especially when coupled with climate variability and change, are likely to affect ecosystems and the many important goods and services that they provide to society (US CCSP, 2003).

Landuse/landcover changes in a human-dominated ecosystem (urban environment) also affect geophysical and social processes leading to land degradation. Therefore, to combat urban land degradation, there is need for the assessment of changes that do take place in

landuse/landcover changes and as they relate to the rate and extents of urbanization.

Determining the effects of landuse/landcover change on the earth system depends on an understanding of past landuse practices, current landuse/landcover patterns and projection of future landuse/landcover as affected by human institutions, population size and distribution, economic development, technological and other factors (US CCSP, 2003).

Monitoring of urban growth and landuse/landcover (LULC) mapping has received a considerable boost from the advent of multi spectral satellite data. Such data has become operationally available since the early 1970s and have paved the way for LULC studies due to their suitable spectral, partial and temporal resolution, thus providing environmental managers with useful tool to study LULC change and their relationship with land degradation processes.

The growth of cities have played major roles in human civilization and also as the focus of a wide variety of demographic, economic, socio-economic infrastructure and activities leading to complex interplay of institutional, technological, demographic and socio-economic factors

causing urban areas to be one of the most dynamic systems on the earth surface and the milieux of environmental drama (Yang, 2003).

Urban areas affect the environment as rural land is converted to urban landuses, resulting in the extraction and depletion of natural resource and the disposal of urban wastes. As cities expand prime fragile agricultural lands, marginal urban fringes are taken over for housing, industries, infrastructure, waste disposal sites, etc. Again, as centres of human activities, cities consume natural resources from both near and distant sources. They generate waste that is disposed of both inside and outside the city. In the process urban areas generate environmental problems over a range of spatial scales, the household, workplace, the neighbourhood, the city, the wider region and the globe (World resources, 1996/97). Lovemore [2002] describe the destruction of natural resources and reduced productivity as environmental degradation. Some other literature sees environmental degradation as particular case of consumption and production externalities. Therefore landcover change is an index of land degradation.

Landcover types and their spatial/temporal distributions are fundamental data required to model ecological processes in urban system.

A systematic understanding of changes in LULC is critical to the understanding of the ecosystem functioning and services and human welfare. Thus, for a sustenable environmental development in the region, there is the need to know the location, type, rate, and magnitude of landuse/landcover changes that are occurring in Kaduna metropolis and environs.

The research paradigm considers cities as ecosystems unto themselves, and investigates the use of existing ecological tools to understand urban system dynamics (Grimin et al, 2000). It is fundamental to this research to understand the dynamic relationships between urban growth and landuse/landcover changes as an index of land degradation and the subsequent effects of these changes on societal decisions. A systematic understanding of changes in landuse/landcover is critical to the understanding of the ecosystem functioning and services and human welfare. A spatially explicit study of landuse and landcover changes would lead to a better understanding of the causes of changes and their consequences on the environment and society. Such understanding will improve environmental management decisions to ensure that ecosystems and changing landscapes are suitably managed (Oyinloye et al, 2003).

1.2 STATEMENT OF RESEARCH PROBLEM

The current understanding of historic landuse/landcover changes (LULCC) in Kaduna metropolis and environs is weak due to the anecdotal or very local nature of past research in this area. Rapid urbanisation and its association with factors of economic growth, population growth, industrialization, urban poverty, political, technological and institutional forces in addition to environmental factors are drivers of LULCC. These factors coupled with the problem associated with the city structure and attendant consumption and production patterns suggest the impact it may have on LULC and by extension, land degradation. While past researches have been carried out on these drivers of LULCC separately in different studies their impact on LULCC and hence environmental degradation has not received similar attention. For instance Ndabula (2000) reported rapid urban growth in Kakuri part of Kaduna metropolis with growth rate varying from 1694337m^2 in 1964, 2839307m^2 in 1977 to 5421642m^2 in 1991. The population of Kaduna metropolis has also shown rapid growth from 10,653 in 1931 to 44,540 in 1952, 149910 in 1963 and 800,000 in 1991 and projected to be well over 1 million by 2000 at its present growth rate of 3.8 (Mamman, 1992). Urban poverty which has become endemic in the past three decades due to rural-urban migration, decline in national

economy and continued breakdown of social infrastructure and unemployment has shown an increasing trend, growing from 17.6% to 37.8% and 58.2% in 1980, 1985 and 1996 respectively (World Bank, 1996). There is a strong relationship between urban poverty and landuse/landcover changes or environmental degradation. The poor are often forced to take actions that may be inimical to the environment, such as clearing forest for farming, fuel wood and homestead construction, indiscriminate solid waste disposal, etc.

The environmental background of Kaduna metropolis and environs shows it to be located in the southern boundary of the sudano-sahelian bio-climatic zone of Northern Nigeria. This ecosystem has been described as climatologically sensitive and the most delicately balanced in the West African bio-climatic zones. It proximity to the southern margin of the sahara desert places it under increasing threats of drought and desertification. For instance Sawa (2002) reported that the occurrence of wet (dry) spells north of latitude 10^0N of northern Nigeria shows spatio-temporal variability with a tendency towards increasing dryness. The study area is underlain by ferruginous tropical soils which experts describe as being fragile. This implies that changes in LULCC can have severe bio-

climatic and hydrological consequences on its environmental resources and hence welfare on the welfare of the teeming urban population.

It is evident from these reports that the influence of both anthropogenic and natural factors or drivers of LULCC are strong in this study area. Therefore monitoring of LULCC in this area is paramount to combating environmental degradation and environmental resource management. Future understanding of LULCC in this area will be greatly improved through new systematic methods and study designs for landuse change research. To understand forces of change that operate at different scales, it will be necessary to conduct studies that explicitly reveal the local and regional variations in landuse and landcover changes. With this the historical and contemporary data needed to develop models that project LULCC for specific intervals into the future will be produced.

1.3 AIM AND OBJECTIVES

The aim is to study the nature of landuse/landcover changes within and around Kaduna metropolis from the 1960's to early 2000's.

The specific objectives pursued to achieve the aim are

i To characterize the nature of landuse/landcover change in the study area in the 1980s and 1990s using satellite datasets.

ii To characterize the nature of landuse/landcover changes from the 2000s to date using satellite data and field mapping using GPS.

iii To identify causes of observed changes.

iv To make suggestions based on the findings.

1.4 RESEARCH HYPOTHESES

i There is no significant difference between the means of extents of the observed landuse/landcover in the 1980s, 1990s and 2000s.

ii There is no significant difference between the means of extents of the observed classes of vegetation cover in the 1980s, 1990s and 2000s.

1.5 SCOPE OF STUDY

This study mainly concerns itself with the character of LULC changes. Therefore, no attempt is made in this study to consider the effects of these changes on both man and the environment or to analyse these changes with land degradation.

CHAPTER 2

LITERATURE REVIEW

2.1 OPERATIONAL DEFINITION OF LANDUSE/LANDCOVER

Landcover/landuse are two different concepts. Landcover emphasizes on land's 'natural properties' and it is the synthetic reflection of various elements in the global surface (Chenghu, 1999).

Landuse emphasizes more on land's 'social properties' and it is the output of activities of man. Thus, landuse is a process of turning natural ecosystem into social ecosystem and the process is a complicated procedure by the synthetic effect from nature, economy and society (Chenghu, 1999).

Landuse/landcover being the new concepts emerging with the remote sensing technology has become a crucial item of basic task in identification and monitoring of urban environment. This is possible with the more thorough development of remote sensing or classification techniques.

Landuse/landcover is continuously changing both under the influence of man and nature resulting in various kinds of impacts on the urban ecosystem (Rajan et al, 1997a). The most important factor in the modification of the landcover and its conversion is the human use component rather than the natural changes (Turner, et al, 1993). Changes in landcover cannot be understood without a better knowledge of the landuse changes that drive them and their links to human causes. The linkages between the human and biophysical causes or drivers to land degradation, land management and landcover are not sufficiently understood (Rajan et al, 1997b).

Remote sensing is a powerful technique for surveying, mapping and monitoring earth resources and changes. This technology combined with GIS which excels in storage, manipulation and analysis of geographic information and socio-economic data provide a wider application (Medis and Wadigamangawa 1996).

Urban land is constantly and rapidly changing due to various human development activities and natural conditions. Therefore, the management of urban environment involves procedures of monitoring and modeling which require reliable information base and robust analytical techniques.

Conventional surveying and mapping methods cannot deliver the necessary information in a timely and cost effective manner. Remote sensing and GIS given their cost effective and technological soundness are increasingly being used to develop useful sources of information and to support decision making in connection with a wide array of urban applications (Cowen and Jessen, 1998, Meser, 1998, Lo and Yang 2002).

The urban environment given its heterogeneous landscape with highly dynamic changes is challenging the applicability and robustness of these methods and technologies. But with recent innovations in data management technologies and theories in the wider areas, RS and GIS have provided scientists with invaluable insights into the study of urban environment (Yang, 2003).

2.2 JUSTIFYING INCREASING INTEREST IN LANDUSE/LANDCOVER CHANGES

Landuse/landcover are linked to climate and weather in complex ways. Because of the strong links between landcover and climate, changes in landuse and landcover can be important contributors to climate change and variability. Reconstruction of past landcover changes and projections of possible future landcover changes are needed to understand

past climate changes and to project possible future climate changes; landcover characteristics are important inputs to climate models. In addition, changes in landuse/landcover especially when coupled with climate variability and change, are likely to affect ecosystems and the many important goods and services that they provide to society (US CCSP, 2003).

Landuse/landcover changes (LULCC) have impact on the entire ecosystem, this is because land surface has a considerable control on the planet's energy balance, biogeochemical and hydrologic cycles which in turn influence the climate and other systems that do shape the earth (Abubakar et al, 2002).

There is a strong relationship (direct or indirect) between LULCC and land degradation processes. LULCC in a human dominated ecosystem also affect geophysical and social processes leading to land degradation (Lal, et al 1989, Towsend, 1992). There is a well-established tendency for water run-off to increase with land degradation (Symeonakis and Drake, 2004; UNEP, 1990; Rubio and Bochet, 1998). Overgrazing, for example leads to trampling and compaction of the soil which reduces the infiltration and

thus increases the amount 0f rainfall water that is generated as run-off. Deforestation also leads to increased overland flow since it removes the vegetation cover which probably affects rates of run-off more than any other single factor. There is a strong relationship between LULCC and land degradation processes. In other words LULCC is an index of land degradation. To combat land degradation there is therefore the need the for assessment of changes that do take place in LULC from time to time (Abubakar, et al, 2002). The dynamic nature of urban ecosystem foster rapid LULCC and land degradation. The use of remotely sensed data to monitor the status of the dynamic change of LULC has become the most rapid, effectual and credible method to study urban environmental degradation (Chengu, 1999)

A systematic understanding of changes in LULC is critical to the understanding of the ecosystem functioning and services and human welfare (Ramsey,2001).

Landcover types and their spatial/temporal distributions are fundamental data required to model ecological processes (Ramsey et al 2001). Also, LULCC is significant in modeling climatic, hydrologic processes since landcover characteristics are there important inputs. Recent studies

indicate that human activities are a significant component of ecosystem processes that need to be incorporated into existing ecological models.

LULC data is critical to effective environmental planning, management thus, sustenable development.

Determining the effects of landuse/landcover change on the earth system depends on an understanding of past landuse practices, current landuse/landcover patterns and projection of future landuse/landcover as affected by human institutions, population size and distribution, economic development, technological and other factors (US CCSP, 2003).
History of landcover changes and infrastructure changes due to urban expansion is one of the essential data to assess and predict the urban risk and environment in future.

2.3 REVIEW OF CONVENTIONAL LANDUSE/LANDCOVER REMOTE SENSING CLASSIFICATION METHODS

Landuse/landcover being new concepts developing with remote sensing technology have become crucial items of basic task in identification and monitoring of urban environment. This is possible with

the more thorough development of remote sensing or classification techniques .The use of remotely sensed data to monitor the status of the dynamic changes of landuse/landcover of the urban areas has become one of the most rapid, credible and effectual methods of studying urban environmental degradation (Chenghu and Jiancheng, 1999).

The manner, degree, structure, area distribution and benefits of landuse are not only affected by natural condition but also restricted by diversified natural, economic and technologic condition. Among all factors the social production form is determinant landuse that is the most direct and leading factor to the landcover change.

In carrying out research and application of the landuse/landcover Remote Sense investigation, the uniform classification system which is called Remote Sensing landuse/landcover classification system.

Conventional landuse/landcover classification methods include traditional classification, neural networks based classification and symbolic knowledge based reasoning classification methods.

2.4 TRADITIONAL LANDUSE/LANDCOVER REMOTE SENSING CLASSIFICATION METHODS

The traditional methods can be classified into rationalization, hierarchical, decision tree, and statistical classification methods. The rationalization, hierarchical, and decision tree classification methods require that the one who wants to do the classification should master the geo-regularity in the Remote Sensing imager to a sufficient degree or the outcome is difficult to reflect the true geo-distribution. Therefore, the limitation to these traditional methods is the difficulties to hold the criterion of classification and the qualitative component in the methods is primary.

Mathematical and statistical analysis models include the following methods.

- Iterative Self Organizing Data (ISO DATA) clustering
- Minimum distance method
- Maximum likelihood
- K-means
- Red Green Blue (RGB) clustering, etc

All these are based on parametric or non parametric statistical distribution model. They do the basic analytical processing of the Remote sensing image by mathematical computing and statistical analysis.

2.5 NEURAL NETWORKS BASED LANDUSE/LANDCOVER CLASSIFICATION METHOD

Compared to the traditional classification methods, artificial neural networks based classification method simulates the human vision and neural processing system to get the cognition to the Remote Sensing image.

Neural network classifiers are non-parametric and therefore may be more robust when distribution are strongly non-gaussian. During training, the network is capable of forming arbitrary decision boundaries in the feature space. The Artificial Neural Network (ANN) method generally can get higher accuracy of the outcome and it has been widely used in landcover/landuse classification. ANN's superiority is shown in the complicated land type such as the urban environment.

Since the publication of Rumenhart and Mccleland (1986) there has been a renaissance of interest in using neural network for

landuse/landcover classification. Honald (1989), McCleland (1989), Hepner (1990), Yoshida (1994), etc used ANN method in the landcover classification by using landsat image and all showed improved accuracy. Bruzzpure (1997) classified the complicated landcover using ANN method and 9% improvement in accuracy comparing to maximum likelihood classifier was achieved.

2.6 SYMBOLIC KNOWLEDGE REASONING BASED LANDCOVER/LANDUSE CLASSIFICATION METHOD

A symbolic knowledge based system is a larger and complex set of program functioning as an expert system that simulates the higher order interpretation, initiates or simulates the logic of human perception. It is called machine or computer vision.

By building the spectral knowledge base, Wherton (1987) improved the accuracy of landcover classification. Kartikeyan (1995) built the framework of Remote Sensing landcover expert classification system.

2.7 REMOTE SENSING INTELLIGENT GEO-INTERPRETATION MODEL (RSIGIM)

RSIGIM is a hierarchical processing and analysing model for research into how to simulate the synthetic geo-experts interpretation and decision process to the RS image by computer system from low level to high level. RSIGIM passes through several courses including information transfers, statistical basic processing and analyzing units, physiological vision cognition, psychological logic cognition, knowledge discovery decision and analysis. The process is just like the intelligent interpretation process of an expert to picture from relieving, observation, judgment, association to memory.

The framework of RSIGIM has several target such as:-

- To describe, recognize and classify geo-objects phenomenon, hidden in RS image
- To extract the imagery mechanism and intrinsic feature including classifying types, size, structure, relationship and other geo-properties of geo-objects in RS image.
- To discover and represent the geo-knowledge from huge accumulated image base. Furthermore, to predict and carry out

decision to the geo-phenomenon by integrating certain geo-analytical model.

2.8 REVIEW OF EMPIRICAL CASE STUDIES IN MONITORING URBAN EXPANSION AND LANDUSE/LANDCOVER CHANGES

Rapid urban growth started being a focus among researchers, mainly in the early 80s, especially in the developing countries where it was alarming. So much so that a milestone is achieved at the United Nations Center for Environment and Development (UNCED) Earth Summit in Rio de Janeiro, Brazil in 1992, when it was agreed to focus attention on the deterioration of urban environment. Hence, the birth of the United Center for Human Settlement (UNCHS) (Bartone, 1994).

In the 80s' most researches were concerned with urban growth or landuse without necessarily linking such studies with landcover changes. In Nigeria, for example, Ikhuoria (1983,1984) applied RS and GIS techniques to study urban landuse inventory and mapping from semi-controlled photo mosaic of Benin City in Nigeria.

He adopted Adeniyi's classification scheme for Lagos since they have similar spatial characteristics. Since the classification scheme was highly

detailed, class separation problems were minimized by carrying out extensive reconnaissance surveys and field verification during the photo interpretation stage. Stereospairs of 1979 panchromatic air photos of Benin City were used. The photographic prints were not corrected for tilt and relief displacement distortions. Supporting data included topographic and town plan maps and also terrestrial photographic reconnaissance of the urban area using a canon TS camera to supplement the air photos. Photographic elements such as size, tone/colour, pattern, texture, shape, association, etc were used to obtain a standard manual or visual photo interpretation of landuse types using a pocket mirror stereoscope, mainly during preliminary examination of an overlapping pair before it was mosaiced. A Mosaic of approximately 400 sets of 23x23cm, 1:6000 prints were made. The entire mosaic for Benin City at 1:6000 measured about 230x180cm. Interpreted landuse patterns were delineated on an acetate overlays on the photo mosaic. Information on the overlays was checked by ground observation using a stratified random sampling procedure.

Also, Olorunfemi (1983) monitored expansion of housing landuse in Ilorin using aerial photographic approach.

There are similarities in the studies of Ikhuoria, Adeniyi and Olorunfemi, especially because the remotely sensed data was only

panchromatic aerial photographs. Interpretation techniques were chiefly analogue photo interpretation using photographic elements such as size, tone/color, pattern, texture, shape and association using pocket mirror stereoscopes. Stereos pairs were first produced and finally interpreted patterns were delineated on acetate overlays on the photo mosaic to produce maps.

Extensive reconnaissance surveys for field verification during photo-interpretation were done to obtain some degree of accuracy. Also photographic prints were not corrected for geometric distortions.

It can be deduced that these studies were tedious and slow with large errors. They lack synoptic and temporal advantages of satellite data and because in these studies multi date remotely sensed data were lacking, hence monitoring changes in growth and landuse changes could not be their focus. Also the data handling was poor since the flexibility of manipulating various themes as in GIS techniques were not achieved.

Olorunfemi (1987) in another study identified and measured areal extents of settlements in the Oyo – Ogbomosho – Illorin areas from Land sat MSS scene of 1972 on 1:50000 and 1:100000 topographic maps of

Nigeria which were useful in providing information on settlement naming and identification. The methodology involved initial display of the false colour composite (FCC) of the whole scene (bands 4, 5 and 7) and the examination of the histogram of the image brightness values which suggested a need for image enhancement. Therefore, a total of 95 sample pixels were selected for Illorin, Ogbomosho and Oyo as training areas. The spectral signatures of these areas were stored so that it will be possible to classify the whole scene based on the spectral responses observed in the training areas (i.e supervised training).

The application of landsat MSS data was a landmark in the series of urban growth studies in Nigeria. GIS techniques of image interpretation such as False Colour Composite [FCC] enlargement and supervised classification schemes proved the robustness, versatility and flexibility of satellite data over aerial photographs. The extensive field surveys were reduced to sample pixels used during training and classification. Extraction of information layers was done by on-line digitization and no longer by tracing on transparencies. Visualization and interpretation were enhanced by spatial enhancement of image and not by mirror stereoscope and photographic elements i.e. spectral seperability was based on spectral signatures determined by statistical values inherent in the image.

Ndabula (2000) used multi temporal air photos to monitor urban Kakuri in Kaduna metropolis. The techniques involved analogue photo interpretation of uncontrolled photo mosaic of the delineated built up areas. This information layer was then digitized into the vector layer and geo-referenced for each of the temporal series and then overlay of the three temporal series of 1970's, 80's and 90's with vector layers were rasterised into maps showing Kakuri urban growth.

This study had improved the use of multi date air photos of three decades and conversion of analogue layers of uncontrolled photomosaic's into vector layers by using manual digitizer and GIS to manipulate various themes to produce overlay maps of urban growth being monitored over a period of three decades. Also information from different sources could be harmonized during map composition on overlay by geo-referencing data from these different sources to a common base topo-map of the study area.

Maktar and Sunar (2001) analyse urban growth of Instabul, Turkey using multi temporal satellite data. Azaz (2001) in similar study monitored urban growth in Alexandria, Egypt using satellite images.

These later studies have tremendous improvement over previous studies. They combined information layer extracted from ancillary data sources such as topo-map, administrative map which were used as base maps with layers of information from three multi temporal satellite data sets.

However, there is still limitations in this study as delineation of built up boundaries was based on image classification alone. Higher accuracy may be achieved using Vegetation Soil Water [VSW] Index or Normalised Difference Vegetation Index [NDVI] as proposed by Yamagata et'al (1997) which Shigenobu et'al (2003) applied to delineate new urban areas in Bangkok metropolitan region in Thailand.

By the late 80s and early 90s most studies have gone beyond just monitoring urban growth to examining impacts of these growth on landuse/landcover changes.

For instance, Shukla et al in (1989) used topo map of 1974, Landsat FCC bands 4, 5, 7 of 1975, Landsat TM FCC bands 2, 3, 4 of 1986 and IRS-IA LISS – 2 FCC bands 2, 3, 4 of 1989. To study urban sprawl in Kampur Metropolis in India. The topo map of 1974/75 was used as threshold base map, from which the relevant ground truth information was

extracted for interpretation of Landsat MSS FCC of December 1975, since there was correspondence of the two data sets. The usual interpretation of Landsat MSS FCC was carried out with a view to identifying the different mappable categories of urban landuse/landcover following the usual elements of interpretation. Using this as a data base, the information on landuse/landcover categories extracted by the visual interpretation of Landsat TM FCC of March 1986 and IRS – IA FCC of January 1989 were transferred on the base map. A series of visits (ground truthing) were also made to the city area for verification and collection of ground truth. The information on the urban landuse pattern was interpreted and urban landuse/landcover maps were prepared for the different dates. The spatial extent of the city growth was thereafter computed and growth pattern analysed for town planning purpose. Part of the result is illustrated in Table 2.1.

TABLE 2.1 URBAN GROWTH IN KAMPUR, INDIA

S/NO	YEAR	DATE BASE	URBAN SYSTEM (Km^2)	URBAN GROWTH (Km^2)	% OF URBAN GROWTH NEW BASE	% GROWTH PER ANNUM
1	1974/4/75	Topo map	115.28	-	-	-
2	1975	Landsat MSS	114.22	-	-	-
3	1986	Landsat TM	170.59	55.31	47.97	4.3
4	1989	IR S-IA	211.40	40.80	23.92	7.9
5	1986-89	-	-	40.81	23.92	7.9

Source: Shigenobu (2003)

Ruklanti Silva (1996) applied RS and GIS technologies in monitoring landuse changes in the administrative districts of Ampara and Moneragala in eastern and Uva provinces of Srilanka. Amongst other data sources he used were IRS LISS –II with spatial resolution of 40m in pixel size, landuse maps of Ampara and Moneragala, topographic map of paramana. Geometric corrections were applied to geo-reference raw image using the landuse map. Based on the histogram, linear stretch enhancement technique with 2,3,4 bands combination was used in his analysis to improve contrast. Landuse map of the study area was digitized using Pc arc/info. Then vector data was converted to raster format and used with PCI to geo-reference the image. He used supervised classification in his analysis. First, he selected the training areas based on spectral signatures

and spectral seperabilities among classes. These training samples were used in the maximum likelihood classification. Therefore, landuse classification was performed by visual interpretation of the enhanced initial data. The usually interpreted landuse boundaries have to be spline before overlaying it with existing landuse layer. The general outline of his methodology is shown in fig. 2.1

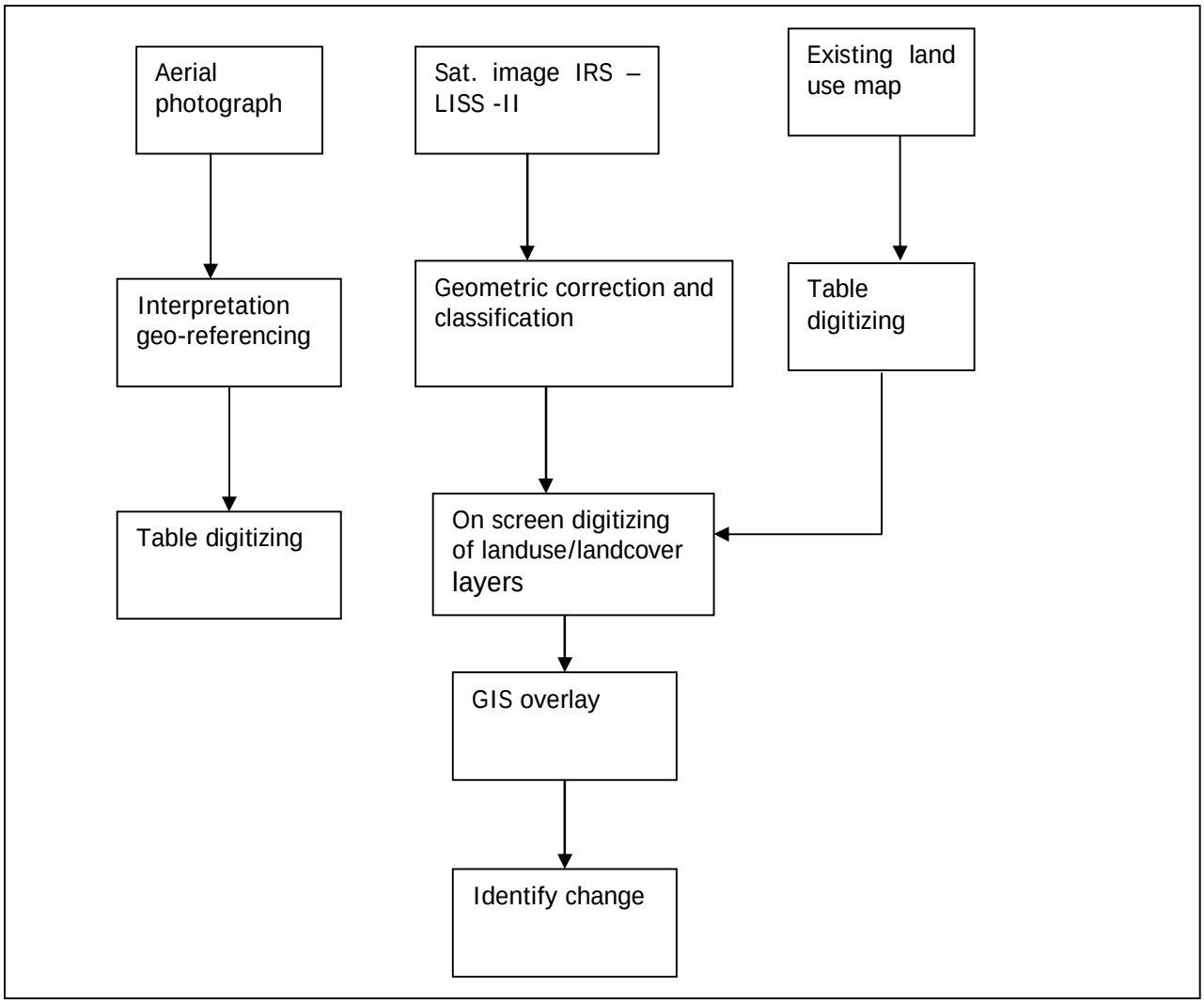


Fig. 2.1 Outline of General Methodology
Source: Ruklanti (1996)

The study of Ruklanti in 1996 showed improvement over that of Shukla et'al in 1989, such that information layers were extracted from different sources such as air photos, landuse maps as ancillary data and use with satellite data of multi- date. This encompassed air photo. Interpretation, map digitization using manual table digitizers and screen digitization for satellite images. These were composed as overlays into landuse/landcover map. Also, extraction of layers in Shukla's study was based on visual interpretation of FCC of landsat TM, but in Ruklantis supervised classification in the maximum likelihood classifier was used.

Medis and Wadigamangawa (1996) in their study used landuse map of 1981, topo-map of 1983, landsat TM of 1992 and aerial photographs of 1994 for mapping landuse/landcover changes in Nil Wala basin. The methodology adopted involved geometric corrections prior to image classification. The image was georeferenced using 1:50,000 topo-map of the study area. Considering the most useful combination of spectral bands for landuse/landcover mapping, a normalized Difference Vegetation Index i.e. B4- B3/B4+B3 was computed for vegetation analysis.

The selection of training areas was based on spectral signature and spectral seperability among classes. Training statistics of each class were

generated. Finally, a classified image was generated by supervised classification based on maximum likelihood classifier. The landuse boundaries of the classified image were then converted to vector in order to compose 1992 data of landcover.

The results indicated that the landuse patterns of the study area have changed. Although detailed information can be provided by aerial photographs, the study revealed the great potential of multi spectral satellite data for broad level mapping and monitoring changes in landuse/landcover over a period of time. Socio-economic development as well as topographic factors were attributed as reasons for these changes.

This study when compared with that of Ruklanti showed an improvement in image interpretation by the use of NDVI computation in addition to supervised classification. This guarantees more accuracy especially in vegetation analysis and even built up delineation.

Takuro et'al [2002] studied on the changing characteristics of landuse as commons in Roviana, western province, Solomon Islands using high resolution satellite data and aerial photographs. Their methodology involved the collection of GCPs and other ground truth data using Trimble GPS. Also socio-economic, behavioural, demographic and other data were collected. Data used were IKONOS pancromatic and multi spectral images acquired in July 2002,digital aerial photos acquired in October 1991 and pancromatic aerial photos acquired in May 1969 and October 1947 which were used for analysis of change in landuse in Dekurana between 1991 and 2002 and Dora island in 1947,1969 and 2002. The IKONOS pancromatic image was corrected based on GCPs after the differential correction. Multi spectral IKONOS image and aerial photos were registered with this geo-refernced pancromatic image. A supervised maximum likelihood classification was performed for the whole image of IKONOS multi spectral data. At this stage gardens and tree plantation could not be distinguised properly from grasslands or bare soils. Hence these two classes were classified manually, making AOI (Areas of Interest) files on pancromatic image. These AOI files were then combined to the computed image to produce the classification map. Aerial photo interpretation involved creating a mosaic image in 1991 by combining five photo scenes.

This was interpreted mannually by creating AOI files for each land class, taking same category in the IKONOS image analysis.

Results for Dekurana showed that natural and degraded forest and coconut and useful plant groves, deceased from 1017.1ha to 870.7ha. The increase of grassland and bare soil reflected the increase of anthropogenic disturbances on forest.

This study had the advantage of using high resolution satellite images and aerial photographs which were supported with field data collected using high accuracy Trimble GPS. These high resolution data minimizes extensive ground truthing, though it was limited with comparability between the supervised classification computed from four band high resolution image and the manual classification of aerial photos.

Abubakar et'al (2002) in their study on assessment of environmental degradation using satellite remote sensing technologies, examine landuse/landcover changes in Talata Mafara area of Zamfara state in Nigeria. They used Landsat MSS,1986 and Spot XS,1995. Radiometric correction was done using destripping procedure, while geometric corrections was Image – to – map registration technique. Maximum

Likelihood unsupervised classification method was used for clustering and identification of various actual ground location of clusters into landuse/landcover. The DOT grid method was used to calculate total area by each landuse/landcover class. Their results showed that changes among six landuse/landcover classes between 1986 and 1995. For instance, Agricutural land increased from 117.00km^2 to 158.50km^2, while Grass/Shrub/Thicket Landcover decreased from 20.13km^2 to 12.50km^2. There was a drastic increase in Bare surfaces from 5.38km^2 to 27.13km^2. Settlement showed a slight decrease from 1.25 km^2 to 1.13km^2 rather than the expected growth. Uncultivated vegetated wetland also showed a decrease from 14.63 to 8.25km^2 and Water bodies increased from 3.88 km^2 to 5.00km^2.

Symeonakis et al (2003) in their study on landuse/landcover change and land degradation study in Spain and Greece using RS and GIS succeeded in mapping the various types of LULC in Alicante province in South East Spain and the Aegeon Island of Lesbos, Greece. They achieved these using the landsat data and the fuzzy classification and convolution modules of Erdas Imagine 8.5 software. The images were rectified using DEM and projected to the right geographical projection using 54 Ground control points with a total Root Mean Square Error (RMSE) of 25.24m. In

order to further assist the fuzzy classifier in distinguishing between the different classes, one additional layer of information was stacked to the 4 MSS bands of the 1978 image and the 6 ETM bands of the 2000 image namely, the Normalised Difference Vegetation Index, thus forming a 5-layered and a 7-layered image respectively. The four principal components of these multi layered images were then extracted, the last 3 of which were then used for the delineation of the sampling areas that would serve as training for the classifier. Five (5) fuzzy layers per pixel were used and the resulting classified images were assessed using 100 random points and the aerial photographs as ground truth. The result of the classification for 1978 shows that the vast majority of the catchment area was covered by various types of orchards, with an approximate area of 12392ha of the entire catchment. The second LULC type in terms of area covered was matorral 7541ha, thirdly is bare land 7363ha, fourthly forest, 1039 ha, fifthly urban 889ha and lastly horticultural 879ha. For the year 2000 matorral had increased to 940ha, orchard decreased to 895ha, bare land decreased to 650 ha, horticulture increased to 2527ha, urban increased to 1937 and forest decreased to 817ha. These results are shown in Tables 2.2A and 2.2B.

TABLE 2.2A: Spain (Xal A^3 Catchment Area, Alicante Province)

Landuse/landcover class	Extent in (ha) 1978	Extent (ha) 2000
Built up (urban)	889	1937
Orchards	12392	8955
Matorral	7541	9480
Bare land	7363	6508
Forest	1039	817
Horticulture	879	2527

Source: Symeonakis (2003).

TABLE 2.2B: Greece (Island of Lesbos)

Landuse/landcover class	Extent in (%) 1975	Extent (%) 1999
Urban/bare	1	4
Olive groves	30	21
Matorral & pine forest	20	31
Sparse macquis	14	14
Dense macquis	8	-
Decidom forest	5	-
Oaks	-	1

Source: Symeonakis (2003).

The mapping of LULC classes over the island of Lesbos in Greece was carried out using the Landsat MSS and TM images of 1975 and 1999 respectively. The methodology applied the maximum likelihood (ML) classification which was then tested with randomly distributed ground truth data acquired with the use of GPS. The result of the ML classification for 1975 showed that the greatest part of the island was covered by olive groves, covering approximately 30% of the entire island. Matorral and pine forest both covered about 20% of the island area, followed by sparse maguis 14%, dense maguis 8%, decidous forest 5%, bare and urban 1%.

In 1999 olive groves declined to 34133 ha, or 21%, matorral covered 30576 ha or 19%, sparse maguis 22530 ha or 14%, pine forest increased overwhelmingly to 20168 ha or 12%, bare land increased to 5213 ha or 3%, oaks 1795 ha or 1% and urban area increase to 1399 ha or 1%. Some of the changes that appear to have taken place between 1975 and 1999 are directly related to degradation processes namely:-

- An important decrease in forested areas, due to the large number of fires that took place on the island in the 1980s and 1990s
- An increase of bare areas from 1890 ha in 1975 to 5213 ha in 1999.
- A 4% loss of olive groves and their conversion to pasture due to their location in inaccessible mountainous areas

- The increase in urban land 23% is partly due to tourism.

Yu Cheng-Ming et al (2003) adopted RS and GIS to analyse the trend of Urbanization in the suburbs of a large city Kaohsiung in South Taiwan. This study recognized that the use of a number of investigators that have used social and economic data or the landuse map in order to analyse trend of urbanization are not efficient. This necessitated their taking a different approach evaluating the trend of urbanization by using RS and GIS method which helped them understand landuse more broadly and simultaneously. Main data sources are Landsat MSS, 1972, Landsat MSS, 1981, Landsat TM, 1990 and Landsat TM 2000 for change detection analysis. They used air navigation charts and GIS data to assist in knowledge based classification. They made landcover maps to compare changes in urban areas from 1972 – 2000. They also computed NDVI index to understand changes in plants areas. Finally, they used these outcomes to determine the trend of urbanization in Kaohsiung. The categories of landuse/landcover identified included water, bareland, rice field, residential, forest and grass.

Shigenobu et al [2003] monitored long-term urban expansion by the use of RS images from different sensors for Bangkok Metropolitan Region in Thailand. They used landsat TM of 1993, landsat ETM of 2002. Other

ancillary data included topographic maps, landuse maps used for analysis and result validation. In their methodology they geo referenced images to common base maps. In total, 75 GCPs were selected on both images and used for geometric corrections. Images were re-sampled to 30m resolution using nearest neighbour interpolation with root mean square error (RSME) of 0.73. Then, the original numbers of landsat images were converted to radiance, in order to apply Linear Mixture Model of different dates.

When comparing satellite images that catch same objects from different sensors, characteristics of sensors such as spectral and spatial resolution must be considered because some objects are observed in different ways by different sensors. In this sense, direct comparison of spectral signatures may not give correct information on landcover changes. Therefore, they used USW (vegetation – soil – water) indices which were proposed by Yamagata et al (1997) were used as landcover category – mixing ratio in each pixel for single data image and then compared between 1993 and 2002 imaged to detect landcover change.

The VSW index evaluates the composition of three basic elements: vegetation, soil and water in each pixel. The VSW indices was used in order to detect six main landcover categories: built-up, dry bare soil, dry dense vegetation, irrigated dense vegetation, wet soil and water. In order

to detect the new urban area between 1993 and 2002 in the study area, change pixels were first delineated using the VSW indices and secondly based on the samples of these, landcover categories were selected and statistics of VSW indices were investigated. Landcover categories were thus, determined for each pixel in both 1993 and 2002 images. Finally new urban areas were detected and land conversion types were estimated. Results showed the expansion of Bangkok metropolitan region. Total new urban area was 38.4 x 10^3 ha and was found to be converted almost equally from dry bare soil 10.3 x 10^3 (23.6%), dry dense vegetation 10.3 x 10^3 ha (26.8%), irrigated dense vegetation 9.02 x 10^3 (23.5%) wet soil (25.2%) and water 0.369 x 10^3 ha, (0.961%).

Shiro et al (2003) investigated long-term landcover changes of Bangkok metropolitan region using RS data from different sensors. They devised a new method which does not compare the spectral signatures directly but compare the landcover category mixing ratio in each pixel derived from different sensors. They used VSW (vegetation-soil-water) indices which were proposed by Yamagata, et al (1997) as landcover category mixing ratio in each pixel for single data image and then compared 1993 with 2003 images to detect the landcover change. The

VSW index evaluate the composition of the three basic elements: vegetation, soil and water in each pixel.

Oluborede et al (2004) carried out a study on Development of Administrative Map and Mapping/Monitoring of Urban growth of some cities in Osun State using Nigeria Sat-1 data of 2003, Landsat TM, 1991 and Spot-XS; 1986 with auxiliary data such as topo maps and administrative maps to monitor urban growth in Ilesha, Ife and Osogbo in Osun State, Nigeria. Their methodology included scaling and conversion to UTM of latitude and longitude values of the boundaries of topo maps of these cities. Linear stretching was performed to enhance image quality. The images were resampled using Nearest Neighbourhood Method using Multi-Scope software. Geo-referencing was done by selection of a minimum of six GCPs identifiable both on topo maps and images. Coordinates of these points were converted from geographical to UTM. Area boundaries were extracted from the administrative maps used as base map by digitization. Cartographic visualization, symbolization of topo features and annotation of local government areas were carried out using Arc view 3.2 software. Boundaries extraction from images was also through screen digitization. Overlays of urban growth of these 3 cities were obtained by composition of digital layers. Results showed that Ilesa,

had a horizontal spatial growth of 141.33% between 1968 and 1986 and 36.84% between 1986 and 2003. Ile-Ife had a spatial growth of 398.85% between 1966 and 1986 and 8.72% between 1986 and 2003. Osogbo recorded a spatial growth of 422.22% between 1966 and 1986 and 11.49% between 1986 and 2003.

TABLE 2.3: RESULTS AND ANALYSIS OF URBAN GROWTH IN SOME CITIES OF OSUN STATE

S/N	Name of Town	Date/yr	Growth in the km^2	Increase in km^2	Duration	% growth	% Gr. P.A
1	Ilesa	1968 1986 20036	14.38 34.70 47.48	- 20.32 12.78	- 18 17	- 141.33 36.84	 5.01
2	Ile-Ife	1960 1996 2003	13.06 65.15 59.48	- 52.10 5.68	- 20 17	- 398.85 -8.72	 9.72
3	Osogbo	1966 1986 2003	10.92 57.00 63.55	- 46.09 6.55	- 20 17	- 422.22 11.49	 10.90

Source: Oluborede (2004).

Extensive studies have been carried out in China by Li Yingcheng et'al (2003) on landuse change and urban growing monitoring in China. In a recent study, the group completed several RS monitoring projects, such as landuse change and urban growing monitoring of Hena province (1991-1997), Zhenzhou city and Luoyang city (1997-1998), Xian city and Wuhan city (1998-1999), Beijing (1998-1999). They used spot panchromatic and Landsat TM. In order to utilize the high resolution character of spot data and the multi-spectrum character of Landsat TM data. They used

resolution merging technology to merge the spot1996 with Landsat TM 1997, spot, 1998 with Landsat 1999. The K-L analysis and interpretation with eyes were used to extract the change information

Nigam (2004) applied RS and GIS for landuse/landcover mapping and change detection in the rural urban fringe area of Enchede City in the Netherlands. His study evaluates the effectiveness of High Resolution Satellite data and computer aided GIS techniques in assessing the landuse change dynamics within Enschede city, from 1993 to 1998. The methodology adopted involved the visual interpretation of landuse on acetate overlays according to the landuse classification. Satellite images were used for the year 1993 and 1996 at scale 1:25,000. A minimum delineation unit of 5mm x 5mm was used for mapping. Data was then digitized using ILWIS, thereby creating a digital database for further analysis. Subsequently, landuse maps were crossed with each other to identify and quantify the landuse changes types. Finally, hot links and user interface were developed so that the information can be provided to the user with a well-documented procedure using Arc view environment.

Gupta and Srivastava (2004) in their study monitored changes in landuse/landcover in Allahabad district in India, using multi-sensor satellite data. Data used included LISS – III digital data of December 2000 of IRS-1D Satellite along with IRS-1B LISS-II digital data of December 1994. The survey of India (SOI) topographical map 63-G at the scale 1:250,000 and other collateral data such as modified master plan 2001 of Allahbad district. The overall methodology adopted for the preparation of landuse/landcover map and change analysis is shown with the help of a flow chart. Digital image processing techniques was used for preparation of landuse/landcover maps from the multi-data, multi-sensor satellite data. The Anderson's multi level classification system has been adopted (Anderson et al, 1976). ERDAS IMAGINE 8.7 image processing software and its GIS analysis capabilities (vector module) have been used for the preparation of multi-data landuse/landcover maps and to monitor the change pattern. The SOI topo-map 63-G was first scanned at 400 dpi resolution and then registered using ERDAS IMAGE Software. For registration, 9-well distributed Ground Control Points (GCPs) at the intersection of latitude-longitude lines have been selected. The second order polynomial transformation with nearest neighbourhood resampling technique was adopted and a registration error of 0.42 pixels was obtained. Process of image to image registration is then adopted for the

registration of satellite imagery and modified master plan of Allahabad distribution on already registered SOI topo-map. The registration error (r.m.s) obtained was 0.49 pixels for IRS-1D LISS-III data and 0.62 pixel for modified master plan. After this, LISS-II imagery is registered over LISS-III imagery by using 16 GCPs with registration error as 0.38 pixel.

Oyinloye et al (2004) applied Nigeria Sat-1 data for landuse/landcover mapping of Ilesa and environs within Osun state in Nigeria. Their methodology included image enhancement through global contrast stretching, selection and extraction of sub scene covering the study area. Contrast enhancement of FCC of the sub scene and geo-referencing of the sub scene for improved metrical qualities using GCPs from GPS. NDVI computation was used for vegetation analysis. The supervised digital image classification of thematic features was used for mapping of landuse/landcover classes. Their results showed that between 1991 and 2003, built-up has increased from 79.17 to 139.76km2, while the Agro forestry/secondary re-growth vegetation class decreased drastically from 1452.70 to 297.40km2. Furthermore, Annual crop/Shrub/Fallow lands increased from 726.00 to 1014.84km2. Bare surfaces however, decreased from 499.78 to 297.40km2 within the same period.

From the LULC studies reviewed, it shows that the traditional LULCC classification method is the most widely used, with very few others applying the neural networks method. Limitations of these traditional methods of classification is that without integration with geo-knowledge it is difficult to truly reflect some special geo-distribution and especially the defect of being difficult to gain the parameter of the parametric model is existing when processing or analysing the implicated spatial information.

Despite its strong non-linear mapping ability to processing and analysing the Remote Sensing information with complicated spatial distribution, most ANN methods are also just a computing behaviour like general computing models. Therefore ANN method without being supported by geo-knowledge e.g. aerial photos also cannot truly reflect the distribution character of some special type of phenomenon in RS image.

The use of traditional or Neural Networks LULC classification methods is limited with the reliance on ancillary data and geo-knowledge or field survey to achieve reliable degree of accuracy. Some of these ancillary data may not be readily available or may be some source of error. Therefore, there is need to apply more accurate methods such as the

Symbolic Knowledge Reasoning Based and Remote Sensing Intelligent Geo-Interpretation Model which is not commonly been used. These LULC classification methods reduce the task of field reconnaisance.

With rapid development of RS technology, especially deeper studies in RS Geo-analysis models, RS landuse/landcover classification has become the most credible, rapid and effective measure to monitor the condition and changing of landuse/landcover in the global surface (Zhou et al, 1999). Based on this, Chung (1999) suggested the use Fuzzy Supervised Classification of remotely sensed. This is to overcome the limitations of the conventionally computer assisted supervised classification which are based on the assumptions that the training sites must be relatively homogenous. However, this assumption is not often valid in the areas with highly complex land surface. Fuzzy classification will improve accuracy interms of pixel mixing ratio of complex land surface. Zhou et al (1999) have developed Remote Sensing Intellegent Geo-Interpretation Model [RSIGIM] which is a hierarchical model with 3 levels of models and methods such as Mathematical and Statistical Classification (MSC), Neural Computation Classification (NCC) and Symbolic Logic Reasoning Classification (SLRC). RSIGIM allows Geo-decision to structurally and parametrically fused. It

also allows integrated spatial data and spatial geo-analysis model with geo-knowledge model.

There is need to rely on the use of High Resolution satellite data and multispectral aerial photographs over the low resolution satellite data that have been widely used in most studies. These can be well supported by ancillary data such as field survey especially, using high accuracy GPS which will encourage the integration of GPS, GIS and RS data. Also, the use of satellite data from different sensors in any particular study should be improved to using data from the same sensor.

CHAPTER 3

THE STUDY AREA

3.1 LOCATION

The study area is Kaduna metropolis and environs. It is encompassed between latitudes $10^0$23' and $10^0$43'N and longitude $7^0$17' and $7^0$37'E. It is the capital of Kaduna State, Nigeria. The metropolis cuts across four local government areas including Kaduna North, Kaduna South, Chikun and Igabi. See Figures 3.1 and 3.2.

3.2 CLIMATE

The climate of Kaduna metropolis is tropical continental type characterised by seasonal variations. The area is influenced by the tropical wet and dry climate (AW by Koppen's classification) with seasonal alternation of moist maritime air mass (tropical maritime/SW trade wind), and dry continental air mass (North easterly trade wind/hamattan). The hamattan is pronounced between November and March and is cold, dry and dusty.

The variation in the on-set of rainfall is attributable to the fluctuation of the boundary between these two air masses. Rainy season normally starts from April increasing gradually to its peak in August and then decline

by September and October (Gimba, 1999). During the rainy season humidity is constantly more than 60% at mid-day approaching 100% at night. Insolation is constantly high throughout the period, although most of it is lost through reflection and absorption by thick cloud covers (Ati, 1998). Clouds are mostly commulus nimbus. Monthly average rain fall is about 361mm, usually recorded between April and September.

3.3 SOILS

The interplay of geological, geomorphological and Bio-climatic factors result in the area underlain with ferruginous tropical soils containing about 30-40% clay at reasonable depth due to intensive leaching. The soil profile is less than 3m, with hard-pan which may be encountered within the profile. These soils are characteristically waterlogged when it rains and dries out with cracks during the dry season (Kofa, 1983). Some areas have permanently water logged soils called 'Fadama'. Experts note that these ferruginous tropical soils are fragile with nutrient holding capacity not good to support intensive agriculture for long periods without application of fertilizers or manure. In recent times, soil degradation has taken the forms of erosion due to loss of vegetal cover, compaction from trampling by grazed animals, acidification/alkalinisation from synthetic fertilizers.

3.4 VEGETATION

The vegetation is basically Northern Guinea Savanna. Composed of Savanna wood lands (trees), shrubs patch land or extensive grass land. The trees lay long taproots, develop thick barks, and shed their leaves to survive long dry season or drought. Grasses have developed durable roots, which remain under the ground after the tops have been burnt by fire

during the dry season. After the dry season the grasses sprawl again with the onset of rain. In the wet season however, vegetation becomes green with fresh leaves and tall grasses. Exotic vegetation can be observed in the G.R.A areas while agro forest is observed in the Afaka area and orchards mostly alone River Kaduna. The riparian vegetation (along stream valleys) is usually dense and made up of savannah woodlands. Ornamental vegetation now common around residential and administrative corridors. Botanical gardens have increase the greening of the metropolis. Despite these, there appears to be a general trend of decline in the natural vegetation.

3.5 GEOLOGY

Kaduna metropolis is situated on the high plains of Hausaland which consist mainly of the Precambrian rocks of the basement complex (Barbour, et al 1982, Buchaman; 1955), mainly of older granites, schist and quartzite in different composition. The weathered profile is rich in red clay which are mined for construction purposes, while granite is also commonly quarried. Though no large scale mining of solid minerals is known to be existing in Kaduna urban environment. The rock is known to be stable and withstand all kinds of civil engineering construction such as dams, roads, buildings, etc.

3.6 LANDFORM

Kaduna metropolis and its surrounding area are characterised by extensive gentle slopes, undulating plains with vast rolling lowland plains generally below 610m above sea level. Slope is generally less than 4^0**,** except for the few dispersed protruding resistant granitic rocks (Inselbergs) which are the result of erosion of Precambrian rocks by agents of denudation. Lateritic mesas, plains and broad stream valleys are also common features. These valleys are broad and often streamless. while the streams have extensive flood plains (Young, 1976) and marshy lands.

3.7 HYDROLOGY

Kaduna metropolis and environs is drained by River Kaduna which has it source at Kwal on the north central Jos Plateau and is among the larger tributaries of river Niger. River Kaduna is the major source of domestic and industrial water for the metropolis. The Kangimi Dam is the source of potable water supply by Kaduna state water board for the metropolis. There are other artificial earth dams around the metropolis majorly for agricultural purposes.

Since the rivers are located in a seasonal climatic belt of wet and dry condition they have characteristic fluctuation in volumes with rivers having full volumes during the rainy season with peaks causing occasional flooding over their banks. This decreases during the dry season.

The weathered regolith is generally shallow except along river valleys, hence causing the area not to be very rich in underground water. Most of the shallow wells which most urban dwellers rely on for daily domestic consumption often dry up during the dry seasons when water table level falls low.

3.8 THE POLITICAL DEVELOPMENT OF KADUNA METROPOLIS

The historical-political development of Kaduna metropolis is antecedent to the present demographic and socio–economic structure of the town. Kaduna town grew up as an important military garrison. The establishment of a base for the West Africa Frontier Force (WAFF) in 1912 in Kaduna was an important landmark that led to in–migration into Kaduna town. This marked the beginning of the Urbanization Process. The development of the town as an administration and political headquarter of the defunct Northern region from Zungeru and the movement of Lord

Lugard to Kaduna Town in 1912 accentuated the development processes. Before this time, Kaduna town had served as a trading station and labour camp with a few scattered Gbagi small farmsteads.

The choice of Kaduna town was informed by its physical terrain, especially its vast undulating plains, its centrality within the Northern protectorate, the availability of adequate water supply and pleasant climate (Dodo, 2001). Kaduna town has no strong tradition of indigenous political authority because of the heterogeneous nature of its dwellers. This made Kaduna to have less political complication and was significant to the British Colonial administration.

A law was enacted in 1956 making Kaduna the Capital territory of Northern Nigeria, from thence Kaduna ceased to be part of Zaria Province and was then governed and administered as a separate L.G.A. At inception both Kaduna town and the Urban district of the European reservation area (GRA) covered an area of about 120km^2 with the passing of the township ordnance law of 1917, Kaduna was considered as one of the 18 second class townships in Nigeria.

3.9 POPULATION

As cities grow either as a result of in-migration or natural increase or a combination of both very distinct forms of living and working structures emerge (Arowolo, 1987). The population of Kaduna metropolis comprises the following major ethnic groups: Atyab (Kataf), Hausa, Bajju (Kaje), Fulani, Gbagyi (Gwari), Kadara, Ikulu, Kagooro, Jaba, Moroa, Ninzam, Kaninkom, Kuturmi etc. Other non-indigenous ethnic groups comprise nearly all ethnic nationalities of Nigeria because of its cosmopolitan nature.

The population of Kaduna metropolis has shown steady and rapid increase as follows: 10,653 in 1931, 44,540 in 1952, 149, 910 in 1963 and 800,000 in 1991. It was projected as at 2000 that the population of Kaduna metropolis alone would have been well over one (1) million at the present growth rate of 3.8% (Mamman, 1992).

Until the coming of the British, the local population of Kaduna metropolis was widely scattered and sparse. The establishment of a base for the West Africa Frontier Force (WAFF) in Kaduna was an important landmark that led to immigration into Kaduna town and the subsequent growth of adjourning towns. This growing migration stimulated a spate of individual migration into the city by relations and friends of these workers. The agglomeration of textile industries, reagent company, DIC, NNPC, etc

provide employment for the metropolis. The concentration of government employment opportunities and infrastructure also affected most of the people migrating in from other parts of the country. The changing economic and commerce status of the town also attracted investor and other professionals. There was also the deliberate policy by the state government to attract more people into Kaduna town in the attempt to secure enough labour to clear the surrounding bush and thereby force it from tsetse fly and dangerous reptiles (Mamman, 1992).

Kaduna town has long been known as a social melting pot because of the level of social integration due to the assemblage of people from different ethnic groups in Nigeria and Africa. Part of the internal dynamics in Kaduna town is the high level of rural urban migration becoming the second highest with positive net migration after Lagos (NPC. 1998).

However, the state of religious crisis in the metropolis is gradually causing a reversal in flow of population in the last two decades with increasing number of people now opting for the FCT.

Among other undesirable consequences of population growth in the metropolis is overcrowding causing extreme squalor (filth) in most of the slums. Kaduna metropolis has one of the highest urban growth in Nigeria

as it is said to be growing at about 10% per annum (NPC, 1998). Although the religion crisis of 2000 caused some internal residential mobility and exodus of people, mainly Igbo traders from the East.

3.10 HUMAN ACTIVITIES

The socio-economic activities of Kaduna metropolis is related to its geographical location, environmental setting, histo-political and demography factors. This comprises Agriculture, Mining, and Industrialization/manufacturing.

3.10.1 AGRICULTURE

The physical location of Kaduna town as earlier seen in the physical setting implies that the state has a lot of agricultural potentials. Its location on a monotonous lowland makes mechanized farming around Kaduna metropolis increase e.g. Wushishi farms, Niyya farms, Quarro, Albarka, Cloudy River, Sambawa farms etc eventhough the ferruginous soils are not particularly rich, they are fragile thereby requiring the application of chemical fertilizers and organic fertilizer to increase their fertility.

Livestock grazing is common in and around Kaduna metropolis. Also, there is the rearing of environmental unfriendly animals like pigs in most of the slums settlement. There is substantial flood plain agriculture along the river Kaduna. The vast land surrounding the metropolis is under intensive cultivation.

3.10.2 MINNING

The commonest mining activities is soil mining for construction purposes. The ferruginous soils are rich in clay and iron which makes them good for construction. Most of the soil mined is used for moulding mud blocks which is used by the poor for building houses. This is also used by modern burnt bricks factories. These soils are also excavated in huge quantities for road construction. It is common to see large pits as imprints of these activities.

Quarry activities is common due to the availability of granitic rocks. This is dominant in the southern axis of the metropolis around Kujama area where quarrying has been done on large scales for a long period.

Sand mining activities along the River Kaduna is gradually attaining larger scale with increasing demand for sand for concrete constructions.

The scale of this sand mining may likely have serious geomorphological implications on the River Kaduna channel morphology.

3.10.3 INDUSTRIALIZATION/MANUFACTURING

Kaduna metropolis is noted among the cities in Nigeria for the highest concentration of industries, second to Kano in the entire Northern states. It is estimated that Kaduna has over 60 medium and large scale industries involved in different manufacturing and processing. The state has a dozen textile industries and this led to its being nick-named 'Manchester' of Nigeria (S.A.E Joint Venture, 1995). These industries include the multi-Purpose Kaduna Refinery and Petrochemical Company (KRPC), International Brewery and Beverages industries (IBBI), Peugeot Automobile of Nigeria (PAN), Nigeria Brewery Plc, Defence Industrial Corporation (DIC) and Flour Mills. Others include chemical fertilizer, plastic, ceramics, aluminum, furniture, foam industries etc. These have given impetus to many service oriented industries e.g. Banking, Insurance, Medical, entertainment (Hotels, stadium), advertisement, airports. The growing number of motor parks and 'rest' and eating joints is also significant. Mechanic workshops are scattered throughout the metropolis among other cottage industries.

The location of industries in Kaduna is heavily lopsided in favour of two local governments in the state; namely Kaduna north and Kaduna south Local government areas which constitute Kaduna urban. At least 65% of industrial establishment in the state are located in the metropolis (FOS, 1997). Most of these industries are made up of manufacturing 22.8%, private professional services 21%, trade 14% (ibid) etc the processes of these industries are associated with various forms of pollutions.

3.10.4 COMMERCE

The location of Kaduna town as a junction town by road and rail transport systems facilitated commercial activities. The metropolis is dotted with pockets of commercial centers with the nerve as the famous central market. Another notable market is the Sani Abacha International trade fair complex. The famous 'PANTEKA' market is known for spare parts transactions with its environment littered with scrabs. Kaduna town has over 80% of all commercial activities and government patronage in the state. The products of these industries have stimulated commercial activities of the state making it one of the major players in commerce in Nigeria.

3.10.5 INFRASTRUCTURE

There seems to be a widespread of infrastructure. The metropolis has a good network of roads/streets with all parts of the metropolis very accessible. However, the quality of these roads/streets remain poor especially in the slum areas of Rigasa, Barnawa, Television, Nasarawa, Tudun-Wada, Sabo, Romi, Ung Gwari, Kurmin Mashi etc. In the G.R.A area the quality of roads or streets are very good. The metropolis is well accessed in the west by the western-by-pass, and in the heart of the metropolis but the Ahmadu Bello way. Presently the eastern by-pass is under construction. While the government is making efforts to repair or construct good roads in the metropolis, so many appear to be fast degrading.

Another public utility is the pipe bore water network which appears to extend to almost every part of the metropolis except for the outskirts. However, the water supply is inadequate, a situation which results in the sitting of shallow wells, deep wells (Boreholes) especially in the overcrowded slums areas. Some residents have to rely on direct water supply for River Kaduna especially for domestic and irrigational purposes.

CHAPTER 4

METHODOLOGY

4.1 TYPES OF DATA COLLECTED

Data collected in this study include:

i. landuse/landcover change of Kaduna metropolis and its surrounding areas from 1970s to date.

ii. Rate of growth of Kaduna metropolis from 1960 to date.

iii. Distribution and extents of gullies, soil mining, sand mining and quarrying fields and solid waste dumps within Kaduna metropolis

iv. Extent of flood plain, and encroachment of urban area into River Kaduna flood plain.

4.2 SOURCES OF DATA COLLECTION

Primary source of data included field survey. While secondary sources included satellite images, vegetation and landuse map (Kaduna sheet 32 by FORMECU 1993/95), street Guide of Kaduna by KEPA 1997, Topo-map of Kaduna (1967). Details of types and sources of data are shown in table 4.1.

TABLE 4.1: TYPES AND SOURCES OF DATA USED FOR THE STUDY

S/N	Type of Data	Source of data	Reso-lution	Scale	Sheet No	Date
1	Extent of landuse/landc over and urban growth	SPOT XS, LANDSAT TM LANDSAT ETM, TOPO/MAP OF Kaduna, Nig. Veg. & landuse map	20m 28.5m 15m - -	 1:50,000 1:250,000	- - - KD S.E 132, N.E 144. KD N.E 32,	1978 1995 2001 1967 1993/95
2	Extents and distribution of gullies, soil mining and quarry fields, solid waste dumps.	GPS				2005
3	Extent of flood plain and build-up encroachment into it.	Digital Elevation Model (DEM) generated from topomap of Kaduna				1967

4.3 TECHNIQUES OF DATA COLLECTION

The techniques used in data collection can be broadly classified into two:-

i. Field surveys using GPS and

ii. GIS techniques.

4.3.1 FIELD SURVEY

The following field equipment and materials were used for field surveys, Garmin 12 GPS, Dry cell batteries, street guide of Kaduna map of Ao size, vegetation and landuse map, sheet 32 of 1993/95, plain papers, pencils, and two field assistants with motor-cycles.

4.3.1.1 PLANNING AND DESIGN OF FIELD SURVEYS

Field survey was designed to be in three phases. The first phase covered the urban built-up areas of the metropolis. The second covered the areas outside of the metropolis, while the third phase centred on degraded features in the built-up area which have been selected as samples for detailed measurement of extents. The street guide of Kaduna map of 1:250,000 scales was used to ensure thorough field survey.

In order to avoid unnecessary repetition of surveying the same feature more than once or revisiting the same place for different features,

a field notebook designed with rows and columns in the format of GPS tracks and waypoints was used to survey different features simultaneously. Each row representing names of categorized land degradation features and column representing x, y and z coordinate values of the various features. Field hours were restricted to day time since the GPS uses solar energy.

4.3.1.2 FIELD SAMPLING TECHNIQUES

While all x and y coordinates values were used to represent spatial distribution of all refuse dumps, a 10% systematic random sampling was used (i.e every tenth) refuse dumps was mapped as polygon by picking coordinates round it in a clock-wise direction for areal extent estimation. For all active gullies, soil mining and quarries fields, polygon mapping of x and y coordinates in a clock-wise direction were used to enable areal extents computation.

4.3.1.3 FIELD MAPPING

The GPS was initialized or set-up to UTM, Minna datum 32 and to true bearing. GPS was allowed to capture at least four satellites with expected position error (EPE) not greater than 5 to give 3D accurate reading.

Considering the sizes, number and scale of features mapping varied from point representation to polygon representation for example, features such as refuse dumps, quarries, soil mining fields and gullies were represented as polygons. While all refuse dumps where represented as points to show their spatial distribution.

GPS x and y coordinates of polygonal features were taken in a clock-wise direction. This is for easy plotting of features in ARC INFO environment. GPS coordinate values of x and y were read and recorded for each identified features.

4.3.2 GIS TECHNIQUES OF DATA COLLECTION

Analogue maps such as street guide of Kaduna of 1997 and Kaduna topo-map of 1967 were inputted into GIS using table digitization techniques. Vector layers of 1997 transport network and 1967 urban area were extracted. Images were imported into ERDAS-IMAGINE environment and ARC VIEW 3.0a interchangeably for further GIS operations and edited in ARC INFO. All coordinates (x,y) from GPS field mapping were entered into Excel sheet, transferred to Notepad and then to arc info for plotting into maps.

IMAGE-PRE-PROCESSING TECHNIQUES: Image pre-processing techniques included image enhancement, Geo-referencing, sub setting, generation of false colour composites (FCC) and other composites bands.

IMAGE-ENHANCEMENT: The linear contrast stretch was used in the ERDAS IMAGINE modeling functions to increase visual discrimination amongst objects in scenes of all images for better visual perception and interpretation. All images filtered to reduce stripping effect.

GEO REFERENCING: Images were geo referenced using ground control points (GCP's) obtained from GPS, using image- to- GPS techniques. A total of ten (10) GCP's were collected using GPS on the field. These points were distributed to ensure images are balanced on all the four axes and centralized at the center. The choice of images- to- GPS technique is based on the fact that most of the data used was collected in the field using GPS and this reduced error during map composition and allowed points to fit in. The coordinates of these reference points were converted from geographic to UTM, in order to aid measurement later. The same projection was used for the vector layer extracted from the street guide map of Kaduna (KEPA, 1997) by using image to map technique. It was the same for the vector layer extracted from vegetation and landuse map (FORMECU,1993/95). The result of geo referencing is shown in table 4.2.

Table 4.2: Results of Point Geo-referencing of images and maps

Image/map	No. of tie points	Accuracy of geo reference (sigma) in pixel/size/mm
SPOT XS	10	0.0280
Landsat. TM	10	0.190
Landsat. ETM	10	0.068
Street guide map	10	0.345
Veg. And landuse map	10	0.200

SUBSETTING: Coordinates of the study area were picked from the vegetation and landuse map sheet 32 of Kaduna and registered to create a box which defined the subset made up of the study area using Arc view 3.0a software.

Another subset of the study area comprising of only the built-up boundaries was also created to aid large scale representation of maps for detail interpretation of degradation in the built-up area.

GENERATION OF FALSE COLOUR COMPOSITES (FCC): The false colour composites of images were processed from Landsat images by selecting bands 4.3.2 which conform to near infra Red (NIR), Red (R) and

Green (G) planes respectively. Further linear stretching was performed on the FCC of the sub-scenes to enhance image quality.

IMAGE INTERPRETATION: Supervised classification in the maximum likely hood classifier was used. The vector layer from Nigeria vegetation and landuse map (FORMECU, 1993/95) was imposed on images and used to update boundaries of similarly identified landuses in all the three (3) temporal sets of images used. To further aid classification of vegetation cover change, a Normalized Difference Vegetation Index (NDVI) computation was done. All classification results were delineated as polygons using on-screen digitization with the aid of ERDAS imagine software. Results of digitization were edited using Arc Info software. Interpretation of classes was done after the classification of FORMECU 1993/95 in Nigeria vegetation and landuse map. Layers were topologies and saved as themes or converges, for use in maps composition.

GENERATION OF HYDROLOGICALLY CORRECTED DIGITAL ELEVATION MODEL (DEM)

Using the boundaries of subset of Kaduna urban area, a topo-map of 1967 was used to digitize contours as source of spot heights or Z-

values. This was used to generate the DEM using Arc Info. The DEM was used to delineate the boundaries of the flood plains of river Kaduna which was digitized as a layer and saved as a coverage for map analysis.

NORMALIZED DIFFERENCE VEGETATIVE INDEX (NDVI)

The NDVI computation was performed to help in assessing the type and extent of vegetation cover in Kaduna metropolis and environs or to help explain deforestation. NDVI is computed as the ratio of the measured intensities in the red (R) and near infrared (NIR) spectral bands using the formula:

NDVI = (NIR - red)/(NIR + red).

NVDI values were scaled. This scaling converts a number between -1 and 1 into a pixel value that is appropriate on a gray tore display. NVDI out put comes in panchromatic tone with gray representing pixel value of greater than 0 and 1 for vegetative surfaces and 0 or less than 0 for non vegetative surfaces. This was however converted from continuous format to thematic format for display in color tones for easy interpretation. Erdas Imagine Version 8.3.1 was used

4.4 DATA ANALYSIS TECHNIQUES

All the data collected from field surveys and inputted into GIS and those generated from images and DEM in GIS were collectively analysed by map composition. All the various coverages were manipulated in their digital formats severally by overlay or super imposition to produce different thematic maps.

Areal extents for all polygon features and number for all point features were automatically computed or generated using Arc Info software and area and perimeter calculated thus:-

(1) To calculate total refuse dumps area (TRF_A) and perimeter (TRF_P)

$$TRF_A = \frac{(\Sigma rfa_{i \ldots n})}{n} N$$

Where

TRF_A = Total refuse dump area

rfa = area of sample dump

n = total no of samples

N = Total no of refuse dumps in Kaduna metropolis

$$TRF_P = \frac{(\Sigma rfp_{i-n})}{n} N$$

(2) To calculate total soil mining field area (TSM_A) and perimeter (TSM_P)

$$TSM_A = \Sigma SM_{ai \ldots n}$$

Where

TSM_A = Total soil mining field area

SM_{an} = area for a sample soil mining field

$TSM_P = \Sigma SM_{pi-n}$

Where:

TSM_P = Total soil mining field perimeter

SM_P = perimeter of sample soil mining field

(3) To calculate total gullies Area (TG_A) and perimeter (TG_p)

$$TG_A = \frac{(\Sigma g_{ai-n})N_1}{n_1} + \frac{(\Sigma G_{ai-n})N_2}{n_2}$$

Where:

TG_A = Total gullied Area

G_A = area for larger sample gullies

g_a = are for smaller sample gullies

n_1 = no of samples of smaller gullies

n_2 = no of samples of larger gullies

N_1 = Total no of smaller gullies in Kaduna metropolis

N_2 = Total no of larger gullies in Kaduna metropolis

$TG_P = (\underline{\Sigma g_{pi-n}})N_1 \ (\underline{\Sigma G_{pi-n}})N_2$

n_1 n_2

Where:

TG_P = Total gullies perimeter

g_p = perimeter of sample of smaller gullies

G_p = perimeter of sample of larger gullies

n_1 = no of samples of smaller gullies

n_2 = no of samples of larger gullies

N_1 = Total no of smaller gullies in Kaduna metropolis

N_2 = Total no of larger gullies in Kaduna metropolis

(4) To calculate total Quarry area (TQ_A) and perimeter (TQ_P)

$$TQ_A = \left(\frac{\Sigma Q_{ai-n}}{n_1}\right)N_1 + \left(\frac{\Sigma q_{ai-n}}{n_2}\right)N_2$$

Where:

TQ_A = Total Quarries area in Kaduna metropolis

Q_a = area of larger sample of Quarry

q_a = area of smaller sample of Quarry

n_1 = no of sample larger Quarries

n_2 = no of sample of smaller Quarries

N_1 = Total no of larger Quarries

N_2 = Total no of smaller Quarries

$$TQ_P = \left(\frac{\Sigma Q_{pi-n}}{n_1}\right)N_1 + \left(\frac{\Sigma q_{pi-n}}{n_2}\right)N_2$$

n_1 n_2

Where,

TQ_P = Total Quarries perimeter in Kaduna metropolis

$_{Qp}$ = perimeter of larger sample of Quarry

q_p = perimeter of smaller sample of Quarry

n_1 = no of sample larger Quarries

n_2 = no of sample of smaller Quarries

N_1 = Total no of larger Quarries

N_2 = Total no of smaller Quarries

To calculate total land degraded area (T_A) and perimeter (T_P) in Kaduna metropolis

$T_A = TSM_A = TG_A + T\ Q_A$

$T_P = TSM_P + TG_P\ TQ_P$

STATISTICAL ANALYSIS

Analysis of Variance (ANOVA) using two-factors (x and y) is used to test the hypotheses.

ANALYSIS OF NDVI STATISTICS

The NDVI statistics was used to analyse deforestation in Kaduna metropolis and environs

. Using the total number of pixels distribution in each vegetation category and respective sensor's spatial resolution to calculate areal changes in the various categories of vegetation as scaled from NDVI computation as follows:

Area per pixel = (sensor's resolution)m^2

e.g

Landsat.ETM = $(14.25)^2 = 203.06m^2$

" spot. XS = $(20)^2 = 400m^2$

" Landsat TM = $(28.5)^2 = 812.25m^2$

Therefore to calculate Area covered by a vegetation class;

Area = nPix * aPix

Where;

nPix = Number of pixel distribution for a particular Veg. class.

aPix = Area per pixel for a given sensor's resolution.

This is used to calculate total area for each class of vegetation from NDVI for the respective decade (1980s, 1990s and 2000s) using area per pixel for Landsat.TM, $812.25m^2$, spot.XS, $400m^2$ and Landsat.ETM, $203.06m^2$ respectively.

CHAPTER FIVE

PRESENTATION AND DISCUSSION OF RESULTS

5.1 RATE OF URBANISATION

Kaduna metropolis has recorded unprecedented growth since the 1960's to date. The entire built-up area of Kaduna metropolis was estimated to be 21.10km^2 in the 1960's. By the 1980's it has grown to 126.13km^2 and to 158.40km^2 in the 1990's. This growth continued in the 2000's such that as at 2002, built –up was estimated at 172.47km^2. Kaduna metropolis has a total spatial growth of 151.37 km^2 or 717.39% between 1967 and 2001, signifying an average annual growth rate of 9.84% or 1.77km^2. However, this growth has varied from time to time. For instance, between 1967 and 1987 (20 years duration) a total of growth of 497.77% representing 24.59% per annum was experienced. This growth rate declined between 1987 and 1994 (7 years duration) which recorded a total of 25.59% representing 3.66% per annum for that period. This growth further declined to 8.88% total growth or 1.27% per annum between 1994 and 2001. This is summarized in Table 5.1.

TABLE 5.1: RATE OF URBAN GROWTH OF KADUNA METROPOLIS

S/n	Date/year	Growth in Area km^2	Increase in km^2	Duration	% Growth for Duration	% Growth Rate P.A	Growth P.A in km^2
1	1967	21.10	-	-	-	-	-
2	1987	126.13	105.03	20	497.77	24.55	4.98
3	1994	158.40	32.27	7	25.59	3.66	0.25
4	2001	172.47	14.07	7	8.88	1.27	0.08
		Total	151.37	17.39	29.52	5.32	
					Average	9.84	1.77km^2

Figure 5.1 shows the composite of built-up area

Growth rate of 9.84 in Kaduna metropolis show similarities with results of Oluborede et al (2004) for Nigerian cities such as Ilesha with annual growth rate of 5.01%, Ile-Ife with annual growth rate of 9.72% and Osogbo 10.90%. Growth rates in these Nigerian cities including Kaduna is very high. However, the highest growth rates correspond with 1960s to 80's in all these cities. This can be attributed to the period of highest economic growth, rural-urban migration when most of these cities became administrative headquarters. From the 90's to date growth rates have declined following economic recession, changes in government policies such as creation of L.G.A which drastically reduced rural-urban migration. Also, civil crisis that are becoming common in urban areas such

as the religious crisis in Kaduna in 1987 and in 2000, and the Modakeke communal classes in Ile-Ife have all contributed to the decline in growth.

This growth in Kaduna metropolis when compared to those international cities e.g Bangkok Metropolitan Region in Asia as shown by Shigenobu et al (2003) which increased from 38.4 to 24.3 x 10^3 ha or 53.03% between 1993 – 2003 signifying an annual growth rate of 5.8%.

Las Vegas the fastest growing major United States' city in the last decade is growing at only about 6% per annum (Andrian, 2003).
Results of Shukla et al (1989) showed that urban sprawl in Kampur city India is at the rate of 7.9% per annum.

This 9.84% annual growth rate of Kaduna and those of other Nigerian cities confirm World Bank (1997) report that Africa has the highest urban growth rate of all regions of the world.

It can be seen from these values that the growth rate of Kaduna metropolis has varied over time. Whereas in the 60's and 70's growth rate was relatively high, but became much higher in the 80's. The decade of the 80's corresponds with the period of rapid industrialization in Kaduna.

When it was assessed to have the second largest concentration of industries in Nigeria after Lagos. The metropolis was made the state capital in 1967. This led to an increase in administrative institutions in the city with a large number of civil servants adding to those of industrial workers. Generally, there was massive rural-urban migration as there were more job opportunities and better infrastructures which attracted the rural population and other people from other parts of Nigeria which led to rapid population growth. These in addition to other factors as trade and commerce, military garrison and political role which the metropolis has played have spurred this rapid horizontal growth of Kaduna metropolis.

The rate of urbanisation in the 1990's to 2000's though high is not as high as that of the 80's. This could be attributed to government policies of the Babangida administration that spread development to the grassroots or rural areas through local government councils. Other programs such as DFFRI, MAMSER, etc created job opportunities and infrastructure at the local government areas thereby, reducing rural-urban migration. Also the period coincided with the economic recession that bedeviled the entire country with so many industries folding-up, accompanied by massive retrenchments, lack of job opportunities, poor state of urban infrastructure which displaced so many urban dwellers into the rural areas. The

movement of the seat of government to Abuja generally could have affected Kaduna as a neighbouring town. A considerable number of people and businesses moved to Abuja. This period also suffered serious religious crisis which diverted some development projects from Kaduna to adjourning towns.

5.2 MAJOR LANDUSE/LANDCOVER CHANGES

From the classification adopted six major landuse/landcover classes were identified and mapped in the study area as shown in Figure 5.2a, b, and c. Landuse changes were observed to vary among classes and decades. For instance, built-up area changed from 126.13km2 to 158.96km2 to 172.47km^2 in 1987, 1994 and 2001 respectively. Representing 46.34km^2 or 36.74% growth between 1987 and 2001. Cultivated area, increased from 949.77km^2 to 968.78km^2 in the 1987 and 1994 respectively and declined slightly to 953.80km^2 in 2001 showing a total growth of 4.03km^2 or 0.42%. Increase in cultivated land can be inferred from the increase in urban population. A large proportion of the urban population are engaged in farming activities to support their livelihood. During this period some form of mechanized farming such as

the Wushishi farms, Niyya farms, etc had also taken over large portions of land for cultivation.

Areas traditionally used for Flood plain agriculture have shown tremendous changes from 25.32km^2 to 32.30km^2 in the 1987 and 1994 representing a total growth of 5.96 km^2 or 23.54% for the duration. Market gardening activities along the flood plains increased with increased demands for fresh foods and vegetables which was lucrative and was able to attract more farmers into irrigation and rain fed agriculture on the flood plains. However, by 2001 flood plains agriculture area has slightly declined to 31.28km^2 as large parts of the flood plain within the urban segment of river Kaduna have been taken over by built-up areas (25.40km^2). Landuse for Forestry has declined drastically from 221.31km^2 in the 1987 to 164.34km^2 in the 1994 and 2001 respectively which means a total growth of -56.97 km^2 (decline) or 25.74%. This is largely due to its conversion to cultivation. Besides, deforestation occurred as a result of the search for fuel wood in the forests by a large portion of the urban dwellers, especially in the face of insufficient electricity supply. Most of the natural savanna wood land has been cleared. What seems to be left of the forests is the forest reserve of Afaka.

Water bodies (dams or lakes) have increased from 12.28 km^2 to 13.03km^2 between 1987 and 2001, a growth of 0.65km^2 or 5.25% this growth is as a result of the construction of earth dams under the policy of Kaduna state government to encourage irrigation farming in the state. The major water body is the Kangimi Reservoir which is source of portable water supply for Kaduna metropolis. The summary of these results is shown in Table 5.2 and can be visually appreciated in Figure 5.3

TABLE 5.2: RESULTS AND ANALYSIS OF LANDUSE/LANDCOVER CHANGE IN KADUNA METROPOLIS AND ENVIRONS FROM (1987 – 2001)

Landuse/ Landcover	Extents In 1987 In (km^2)	Extent in 1994 in (km^2)	Extents in 2001 (km^2)	Change in Area Extent between 1987-2001	% Change in Area Extents BETWEEN 1987-2001
Build-up area	126.13	158.96	172.47	46.34	36.74
Cultivated area	949.77	968.78	953.80	4.03	0.42
Flood plain agric area	25.32	32.30	31.28	5.96	28.54
Forestry area	221.31	164.34	164.34	-56.97	25.74
Water bodies	12.38	13.03	13.03	0.65	5.25
Broad river	10.05	10.05	10.05	0	0

The results in landuse/landcover changes in Kaduna show similarities in pattern with other places. For instance the results of landuse/landcover change of Oyinloye et al (2004) in some areas of Osun state of Nigeria showed that between 1991 – 2003 bare surface increased from 139.76km^2 to 499.78km^2, secondary forest increased from 1040.00km^2 to 1452.70km^2, annual crops/shrubs/fallow land

decreased from 1014.84km^2 to 726.00km^2 and built up areas increased from 79.174km^2 to 139.76 km^2.

In Roviana, western province of Solomon Islands a study by Takuro et al (2002) showed increase in bare soil from 780.7ha to 1017.1ha between 1991 and 2002 in Dekurana.

In the studies of Abubakar et al (2002) landuse/landcover changes in Talata Mafara showed increase in cultivated land from 117.00km^2 to 158.20km^2, grass/shrub/thicket decreased from 20.13 km^2 to 12.50km^2 while bare surface increased from 5.38 km^2 to 27.13 km^2 between 1986 and 1995.

In all these studies there is a similar trend of increasing bare surface and decline in most forest cover which can be inferred to mean that on a global scale there is increasing deforestation and bare surface. Also, built-up area in most of these studies is increasing and this appears to have corresponding landuse/landcover changes. This agrees with the fact that rapid urbanization with its attendant population growth, urban poverty, economic growth have serious impact on LULC change and hence land degradation. Other anthropogenic activities such as bush burning,

overgrazing, intensification of land tenure activities and deforestation for fuel wood also account for LULCC than natural factors such as desertification, climate change and drought.

Similarly, in a study by Symeonakis et al (2000) in the Xal A[3] catchment area of Alicante province in Spain, observations showed that between 1978 and 2000 built up area increased from 889ha to 1937ha, orchards decreased from 12392ha to 8955ha, matorral increased from 7541ha to 9480ha bare land decreased from 7363ha to 6508ha, forest decreased from 1039ha to 817ha and horticulture increased from 879ha to 2527ha. While in Island of Lesbos in Greece urban/bare increase from 1% to 4%, olive groves decreased from 30% to 29%, Matorral and pine forest increased from 20% to 31%, sparse macquis remain at 14%. Dense macquis increased from 8% to 21%. decidous forest decreased from 5% to 0% and oaks forest from 22% to 1%.

In the Alicante case study, 12% of the bare land was successfully converted and rehabilitated to matorral (2237ha), agricultural land (994ha) horticulture (1648ha) and forest (161ha). The 21% decrease in forest was

attributed to forest fires that occurred in the area as reported by (Belda, 1997) while build-up area increased by 113%.

5.3 DEFORESTATION IN KADUNA METROPOLIS AND ENVIRONS

The NDVI shows major classes of vegetation cover as follows:

i. Non vegetated (built-up/water/bare/harvested farm plots).

ii. Discontinuous savanna shrubs/scattered trees/grasses.

iii. Dominant savanna shrubs/minor trees/dense grasses.

iv. Forest (Agro forest/orchards/riparian/dominant savanna wood land. This can be seen in figures 5.4a, b, and c for 1987, 1994 and 2001 respectively. The extent of these changes is illustrated in figure 5.5

The NDVI statistics as shown in Appendices 6 to 8 were used to compute extents of landcover for the 4 various classes of vegetation. The results showed that there has been a trend in depletion of vegetation especially as non vegetated surfaces (built-up)/water/bare and harvested farms surfaces have increased from approximately 314km^2 in 1987 to 364km^2 in 1994 to 432 km^2 in 2001, a growth of 118 km^2 (37.58%) or 2.6% per annum.

Harvested plots are considered as bare surfaces since at the time of capture of these images (Nov and Dec) crops have been harvested leaving mostly bare surfaces.

In the lightest vegetation class of discontinuous savanna shrubs/scattered trees/grasses there has been a decline from 439km^2 in 1987 to 388 km^2 in 1994 and to 340km^2 in the 2001, a growth of -99 km^2 (22.55%) or 1.60% per annum decline. In the Dominant savanna shrubs/minor trees/ dense grasses it remained fairly the same in the 1987 and 1994 been 430km^2 and 431 km^2 respectively, but was drastically reduced to 347 km^2 in the 2001 representing a total growth of -83km^2 (19.30%) or 1.38% per annum.

The increase in bare surfaces and subsequent decrease in both the dominant savanna/shrubs/densed grasses/minor trees and discontinuous shrub/grasses/scattered trees can likely be attributed to colonization of adjacent vegetation by urban expansion, and farm lands as a consequent of the increase in urban population and poverty, hence pressure on land for food crops which results into intensification of agricultural activities in and around Kaduna metropolis. Besides, the shrubs are the most harnessed for fuel wood which has also increased due to inadequate electricity to these esteemed urban population who are predominantly poor and rely majorly on fuel wood derived from available natural (vegetation) resources.

In the densest vegetation class of agro forest reserve/riparian/dominant trees/woodlands and orchards, there has been a general increase between the 1987 and 2001 from 174.00 km^2 to 233.00km^2, a growth of 59 km^2 (33.91%) or 2.42% per annum. The increase is likely to be as a result of increased Agro forest and Orchards. The Riparian vegetation (along river valleys), especially along other stream channels other than River Kaduna are not much affected since most of the flood plain agriculture is concentrated along River Kaduna. There appear to be losses in the Agro forest reserve as it is being harnessed for

commercial purposes as the state's source of revenue, but there is an increase in orchards especially along River Kaduna. This is summarized in Table 5.3.

TABLE 5.3: RESULTS AND ANALYSIS OF DEFORESTATION IN KADUNA METROPOLIS ENVIRONS FROM (1987 – 2001)

VEG CLASS	LANDCOVER AREA IN KM^2,1987 (nPix* 14.25m^2)	LANDCOVER AREA KM^2 1994 (nPix * 20m^2)	LANDCOVER AREA IN KM^2, 2001 (nPix* 28.5m^2)	GROWTH CHANGE KM^2 1987-2001	% GROWTH CHANGE 1987 – 2001	% GROWTH P.A
Built-up/bare/water/harvested farms	314	364	432	+118	37.58	2.68
Discontinuous savannah shrubs/grasses	439	388	340	-99	22.55	1.61
Dominant savannah shrubs/ minor trees/ dense grasses	430	431	347	-83	19.30	1.38
Agro forest/orchards/riparian/ dominant savannah wood land	174	169	233	+59	33.91	2.02

Monitoring landcover characteristics especially as recorded by satellites images between October and December from 1987 – 2001 has shown that non vegetated surfaces have increased by about 37.58% representing a rate of 2.68% per annum between 1987 and 2001. While discontinuous savannah shrubs/scattered trees/grasses and Dominant savannah shrubs/minor trees/dense grasses vegetation classes are most depleted as they decrease by about 22.55% and 19.10% or 1.61% and 1.38% per annum respectively. However, there was an increase in agroforest/orchards/riparian/dominant savanna wood land by about 33.91% at 2.42% per annum.

In other words, as at 1987 only about 23.23% of the entire study area was non-vegetated but by 2001 the total non-vegetated surfaces in the study area have increased to 31.95% as observed during October - December when bush-burning is still minimal. Therefore, there is a likelihood of this figure been exceeded between January and April when bush burning must have claimed most of the grassland.

Other factors that may be linked to deforestation in Kaduna metropolis and surrounding areas include bush burning, clearance for cultivation and over grazing. Another possible reason is declining land

productivity due to soil nutrients depletion thereby, diminishing its capacity to support natural growth of vegetation. Yet another reason is the expansion of urban infrastructure such as roads (especially the eastern By-pass under construction) and institution such as Nigeria Defence Academy permanent site which has been under severe construction in the past one decade.

Deforestation in Kaduna metropolis shows similarities with other studies. Most other studies such as that of Abubakar et al (2002) who studied landuse/landcover change in Talata Mafara and that of Oyinloye et al (2003) who studied landuse/landcover in Ilesha showed that bare surfaces are generally increasing while the shrubs are declining since they are easily cleared for farming or fuel wood. Agro forest showed an increase in all of these studies because of deliberate tree planting to combat desertification worldwide and conservation of residual forest such as national parks or forest reserves.

5.4 BUILT-UP ENCHROAMENT INTO RIVER KADUNA FLOOD PLAIN

A hydrologically corrected Digital Elevation Model was generated with floodplain delineated as shown in figure 5.6 The total flood plain area of the built-up segment of River Kaduna was estimated to be 48.55km^2.

However, built-up has been encroaching or degrading this flood plain with an increasing trend. The extent of built-up area encroachment on flood plain in the 60's was estimated to be 2.00km^2 or about 4.08% of the floodplain area. By the 80's this has increased to 19.22km^2 or 39.57% and 22.74km^2 or 48.90% in the 90's, and In the2000's by about 25.39km^2 or 52.30% of flood plain area. This is shown in Figure 5.7and summarized in Table 5.4

This trend of encroachment into flood plain is the combined effect of vertical and horizontal urban growth. Most urban infrastructure in Kaduna are concentrated in the central area. This attracted both horizontal and vertical growth in Kabala Constain, GRA, Malali, Ungwar Rimi, Kawo extension axes. This area coincided with areas of well defined property right, high land value which also attracted development.

TABLE 5.4: RESULTS AND ANALYSIS OF BUILT-UP ENCROACHMENT ON FLOOD PLAIN FROM 1960'S TO 2000'S.

Year	Total flood plain area in Km^2	Extent of build-up encroachment in km^2	Extent of unencroached flood plain in km^2	% of encroached flood plain
1960s	48.55	2.00	46.55	4.08
1980s	48.55	19.22	29.33	39.57
1990s	48.55	22.74	25.81	48.90
2000s	48.55	25.39	23.16	52.20

Flood plain encroachment is not just peculiar to Kaduna metropolis alone, but studies show that these trends are also common even in other countries. For instance a study by Nicholas MP (2003) described St. Louis as the epicenter of flood plain encroachment in the United States. He observed that more than any other place, the greater St. Louis metropolitan area is allowing its flood plain to turn into development. It has over $2.2billion in new development on land that was under water in 1993. Construction has taken over 18,000 acres.

5.5 PROLIFERATION OF REFUSE DUMPS

No fewer than 393 major refuse dumps were found distributed over the entire metropolis. The sizes or area extents of refuse dumps showed that the average area covered by a refuse dump is 342m^2 with a perimeter of 203m. This implies that the over 393 dumps are distributed over an entire area of 134406m^2**.** From field observations, refuse dumps in commercial areas are fewer since refuse collection is centralized but are characteristically larger in sizes. In contrast refuse dumps in residential areas are more numerous over short distances and smaller than those in commercial areas.

What is worrisome about these refuse dumps is their spatial patterns. For instance, refuse dumps are more distributed or located along major roads with the Western by-pass being the worst littered with refuse dumps. There are no fewer than 50 refuse dumps on the western by-pass majorly concentrated along Gonin-gora, Television and Tudun wada by-pass axis. The Railway line is another major targetted sites for refuse dump with no fewer than 40 dumps majorly distributed along Television, Sabo, Trikania – Kakuri, Kasuwa, Abaka- unguwar shanu - Unguwar kanawa rail lines. Another major target site are streams/gullies with no fewer than 35 refuse dumps directly on stream/gully channels. Most of these streams have been blocked by these dumps resulting in local

flooding during heavy rain storms with run-off or river flow overtaking some roads. Other refuse dumps are commonly found in association with quarry pits, uncompleted buildings and swamps.

Solid waste generation is high with increasing population and changing consumption pattern accompanying improvement in standards of living with high income levels. The use of packaged and canned foods such as pure water in polythene and plastic containers is one of the leading source of solid waste generated in urban area presently. Increasing number of industries most often generate large solid waste from by-products of production processes, packages of raw materials and final products. In commercial areas where food items come in packages such as baskets, papers, leaves, etc and where industrial products are removed from packages end up in generating large quantities of solid waste. All these and many other factors are responsible for the increased proliferation of refuse dumps.

Another interesting feature of the distribution of dumps was that in most residential areas refuse materials are taken out to road or streets ends from the homes. The spatial pattern of these refuse dumps distribution is shown in Figure 5.8. This makes it easier for refuse management especially for transfer to landfill sites, although there is no such management presently in Kaduna metropolis.

Most of the four major soil mining fields have being proposed as landfills but unfortunately none is in use even though there are evidences of industrial solid waste dump along the routes to these landfills with only few reaching the landfill as destination.

Another interesting solid waste dump is the Panteka scrab dump which was estimated to cover an area of about 92867m^2 or perimeter of 1815m. These scrabs have taken a considerable parcel of land and remain a major feature of land degradation.

The areas with clustered refuse dumps corresponds with the high density residential areas where population size and growth are very high. These areas are also where most of the urban poor resides. These are people whose environmental attitude/behavior are indifferent to public

health and who can not spare their scarce finances on maintaining their environment unlike the rich. These are often areas of social discrimination by government waste management activities and policy implementation. The consumption patterns of these urban poor recently has changed to the consumption of packaged foods and drinks such as pure water in polythene bags, thereby increasing the non biodegradable waste. It was observed too, that there are large numbers of refuse dumps in commercial and industrial areas where it is believed that large quantities of solid waste from either raw material of finished products are generated.

5.6 EXTENT OF LAND DEGRADATION

Major categories of land degradation include soil mining, quarries, and gullies.

Tree major soil mining fields were identified, mapped and estimated as shown in Figure 5.9 and summarized in Table 5.6:

TABLE 5.6 GEOMETRIC CHARACTERISTICS OF SOIL MINING FIELD IN KADUNA METROPOLIS AND ENVIRONS

Name of soil mining field	Areas (m^2)	Perimeter (m)
Rafin Guza	697706	4016
KM6, Abuja road	65355	1254
Mando	83287	1646
Tudun wada	303328	2210

A fifth soil mining site predominately for local mud blocks molding is located at Television with an area of 7414m^2 or 392m in perimeter. Though other soil mining activities for local purposes are common in most of the high density, poor residential areas, these are not large enough for mapping.

Therefore, the total mapped soil mining area (TSM_A) = 1157089m^2 and total soil mining perimeter (TSM_P) = 9519M.

It was observed that some areas in these soil mining fields can become deep such that ponds are always associated with them. Soil is mined majorly for road construction and buildings. Presently the

construction of the eastern by-pass is resulting in heavy mass of soil being mined.

Extent of gulling was estimated from the nine main active gullies identified and mapped in the metropolis and showed the following characteristics (Table 5.7):

TABLE 5.7: GEOMETRIC CHARACTERISTICS OF GULLIES IN KADUNA METROPOLIS AND ENVIRONS

Name/Location of Gully	**Area(m^2)**	**Perimeter (m)**
Rigasa	14089	3657
Kurumi gwari kakuri	10364	1623
Tudun wada/Nupawa	4796	827
Kunai street Nasarawa	4550	791
Television/Poly Quarters	4230	785
Television/Command Secondary School	3274	327
Unguwar Romi	3549	330
Off kigo road	3660	332
Kurmin Mashi	3012	308

The area and perimeter of the last four gullies (Television/Command Secondary School, Unguwar Romi, Off Kigo Road and Kurmin Mashi) computed from the averages of the Tudun wada/Nupawa, kunai and television/poly quarters which were used as samples for this categories of medium sized gullies. Therefore, the average area = 4207m^2 or a perimeter of 649m. Therefore, total gullies degraded area TG_A = 53920m^2 and total gully perimeter TG_P = 9823m.

It was generally observed that as gullies head into built-up areas, they begin to show high degree of dissection which appear to conform with major sources of artificial drainages (open drains) which drain domestic waste waters and run-off. This may imply that these open drains with high flow of domestic water and run-off exacerbate the rate of gullying. Besides, all of these active gullies except one (off Kigo road) are located in high density residential areas.

Also it was observed that these gullies have their deepest points towards the active head i.e they become deeper as they approach the built-up areas. Their depths vary from gully mouth to head in an average of less than 1m to 5m respectively. They are generally narrower with average widths of 10m along their lengths.

These gullies are threatening urban development especially residences, roads/streets, bridges/culvert, electric poles etc. The Rigasa gully is the largest identified and is posing threats to a lot of homes along its drainage area. Others of major concern are the Kurmin Gwari, Kakuri and Kunai street Nasarawa which have displaced and are still displacing buildings. Two active gully heads are already raring their heads into the western by-pass along television and Kurmin Mashi. Most streets have been cut off especially in Rigasa and off Kigo road. It was observed that effort have been made to stabilize the gullies in such ways as concretization, dumping of refuse dumps etc but most of these approaches have failed.

Extent of degradation from quarrying was estimated from seven (7) main quarries that were identified in the metropolis as shown in Table 5.8

Malali	quarry	=	larger size
Unguwar Rimi	“	=	medium
Gari	“	=	medium
Tudun wada	“	=	medium
Tudun Nupawa	“	=	medium
Narayi (1) and (2)	quarries	=	larger sizes

From this sampling the average area of the three (3) larger quarries was calculated to be 4425m^2 or 1286m perimeter while for the four medium sizes they are 7187m^2 in area or 566m in perimeter. Therefore the total quarry degraded area TQ_A is 161510m^2 or total TQ_P of 6122m. Some of these quarries are also commonly associated with ponds due to their depths. Urbanisation has been responsible for severe quarrying activities in Kaduna metropolis to meet up construction needs of buildings, roads, culverts bridges etc. though most large scale quarrying for road construction occurs far away from the metropolis in Kujama area, etc.

From all these we can estimate total land degradation in Kaduna metropolis as the sum total of $TSM_A + TG_A + TQ_A$ = 1372501m^2 or

and $TSM_P + TG_P + TQ_P$ = 25464 m perimeter.

Sand mining is predominant along River Kaduna especially at the Rafinguza segment. Massive quantities of sand are known to be evacuated from that area. Though sand mining occurs along other stream in the metropolis but in lesser scale. It is certain that this severe sand mining along River Kaduna has some implication on its morphology. The need for sand for construction purposes is responsible for this trend.

5.7 TESTING THE RESEARCH HYPOTHESES

Statistical analysis was carried out to Test the three (3) Research or Null Hypotheses stated in 1.4 of chapter one.

Test for Hypothesis (1): Statement H_0= There is no significant difference between means of extents of the observed landuse/landcover the 1980s, 1990s and 2000s.

To achieve this, Analysis of Variance (ANOVA) using two-factor at 0.05 confidence level was used since we are concern with variations between classes of landuse/landcover (Rows) and the various years 1980s, 1990s and 2000s (columns)

Summary of results:

F=1116.096854

Fc=3.325834529

Confidence level=0.05

For details refer to Appendix 3

Interpretation: $F>F_c$, therefore, reject H_0 there by accepting alternative hypothesis which means that there is significant difference between the means of extents of the various landuse in 1990's and 2000's this means changes in one landuse has affected the other thereby landuse/landcover in the 1980's, shows significant changes 90,s and 2000's.

Test for Hypothesis (2): Statement of Null (Research) Hypothesis H_0: There is no significant difference between the extents of observed classes of vegetation cover from 1980's to 2000's.

This was tested using Analysis of Variance (ANOVA) using two-factor to compare the spatial differences (extents) between classes of vegetation cover in the different temporal intervals as observed in NDVI analysis.

Summary of results:

F=9.1499513

F_c=4.757062664

Confidence level=0.05

For details refer to Appendix 4

Interpretation: $F>F_c$ therefore, rejects Null (Research) Hypothesis H_0 and adopted alternative hypothesis which means there is significant difference between the means of extents of the observed classes of vegetation cover from 80's, 90,s and 2000's. This implies, there is severe deforestation in all classes of vegetation cover under the study period.

CHAPTER 6

SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 SUMMARY OF FINDINGS

Results from this study has revealed that there is rapid urbanization in Kaduna metropolis and rapid landuse/cover changes in Kaduna urban and environs. Kaduna has been urbanizing at an average rate of 1.77km^2 or 9.84% per annum. This rate of growth has also resulted in changes in other landuse/cover between 1980's and 2000's as follows: Cultivated area has changed from 949.77Km^2 to 953.80Km^2. Flood plain agriculture has grown from 25.32 Km^2 to 31.28 Km^2. Forested area has declined from 221.31 Km^2 to 164.34 Km^2, while water bodies increased from 11.24 Km^2 to 13.03 Km^2.

Encroachment of built up on the river Kaduna flood plain of the metropolis has progressed from 1.98 Km^2 or 4.08% in 1960's to 25.39 Km^2 or 52.30% in 2000's.

Deforestation based on NDVI analysis showed that non-vegetated surfaces comprising bare/built-up/water bodies/harvested farms plots have grown from313.53 Km^2 to 432.23 Km^2 signifying 37.5% increase or 2.68% annual

growth rate between 1987 and 2001. Similarly, discontinuous savannah shrubs/grasses with scattered trees has declined from 438.93 Km^2 to 339.47 Km^2, representing 22.5% total growth or 1.61% annual growth between the same period. Dominant shrubs/Dense grasses with minor tree component has declined from 429.24Km^2 to 346.73Km^2, a total growth of 19.30% or 1.38% annual growth during the same period and Agro forest/Orchards/Riparian/Dominant savannah trees/wood land has increased from 174.10 Km2 to 232.65 Km^2 which means 33.91% increase between the period or 2.42% annual growth rate.

The Analysis of Variance (ANOVA) using two-factors at 0.05 significant level was used to test for the spatial and temporal variations that occur among different landuse/landcover and classes of vegetation cover observed from image interpretation and NDVI analysis respectively. Result showed that there is significant differences between the means extents of landuse/landcover and classes of vegetation cover in 1980's, 1990's and 2000's. This proofs that there is rapid landuse/landcover changes and deforestation in the study area (Kaduna Metropolis and environs).

Total land degraded by gulling, Quarrying and soil mining was

estimated to be about 1372501m^2 or perimeter of 2546m.

6.2 CONCLUSION

It can be concluded that the causes of these changes in landuse/landcover in kaduna metropolis include rapid urbanization, population growth, urban poverty, economic growth, industrialization, institutional forces, etc. Other factors such as drought, bush burning, etc. also contribute to these changes. The possible implications of these landuse/landcover changes include land degradation processes such as soil erosion, gullying due to increase overland flow or runoff as a result of removal of vegetation cover, surface compaction, deforestation, desertification etc. These might eventually have effect on climate/weather, hydrology, ecosystem functioning and societal welfare since agriculture may become unprofitable due to lose in soil fertility.

6.3 RECOMMENDATIONS

Firstly, since it has been established in this study that Kaduna metropolis is rapidly growing at an average rate of 1.77Km^2 or 9.84% and that this rapid growth results in landuse/cover changes and land degradation, it is recommended that Kaduna State Government should endeavour to equip planners and decision makers (such as KEPA,

KASSUPDA, KSLS, KAPWA, KSDPC etc) with adequate spatial data to ensure broad based decisions. This can be achieved by investing in the acquisition and management of geo-information technology.

Secondly, approaches to urban environmental management especially of pollution and land degradation in the past have been centered on technical and legislative controls and dominantly government affairs. The progress and success of this has been very slow and in most cases failed. Therefore, as a new approach, attention should be geared towards environmental behaviour, public participation and consultation in addition to technical legislative and government participation. The government, private sector and public must all be stakeholders and work in partnership. The government provides the policy, legislation, enlightenment, enforcement and incentives, where possible to the private environmental entrepreneurs and public. The private sector should invest in environmental project facilities while the public bears responsibility of paying for services of private entrepreneur and maintaining project facilities of provided by government. This will work well particularly for solid waste disposal \management and other Infrastructural degradation and pollution controls.

Thirdly, a landuse/landcover Remote Sensing monitoring project that will last at least 10 years to provide data that will aid government and other environmental stakeholders to scientifically manage land resources and the urban environment for suitable development should be initiated by the Kaduna State Government. Historical and contemporary data would be needed to develop models that project landuse/landcover for specific interval into the future.

Also, concerted efforts should be made to stabilize most of the active gullies in the metropolis especially those that pose threats to urban development. Special emphasis should be given to the Rigasa, Kurmin Gwari and Kunai Street in Nasarawa gullies, where some few houses may be resettled to allow for proper control on these gullies. Good artificial drainages especially in highly dense residential areas should be constructed to effectively control run-off and domestic waste waters as ways of reducing gulling processes.

Furthermore, since current law does not prohibit construction within delineated flood plain area, regulatory criteria that will limit encroachment on flood plain is necessary. To this end, a Floodplain Action Group should be established to regulate development activities on the

flood plain. The goal is to ensure effective flood plain encroachment compensation to offset or mitigate the adverse effects of encroachment. Developers should be issued with Environmental Resource Permit when they provide reasonable assurance that surface water management system will not cause adverse water quality to receiving waters and adjacent land or cause flooding to on- site or off-site property or cause adverse impact to existing surface water storage and conveyance capabilities, or cause adverse secondary impacts to water resources or cause unacceptable cumulative impact upon wet land and surface waters. Indeed, further development on the flood plain should be stopped by government acquiring the land for environmentally friendly development such as green parks, recreational sites, etc. in the same vein soil mining and quarry activities should be restricted to the outskirts of the metropolis where degraded fields can be reclaimed for landfills and other uses.

6.4 SUGGESTIONS FOR FURTHER STUDIES

Finally, this study which assesses landuse/landcover change may be considered to have provided a basis for understanding environmental degradation processes thus, environmental management. Thus, the results are very basic and there is the need for further studies. Specifically, the

following suggestions are relevant;

1. Modelling of the effect of landuse changes on the runoff generation and sediment yield of different sub-basins in Kaduna Metropolitan area
2. Predicting storm runoff from different landuse/landcover classes in Kaduna Metropolitan area using GIS based distributed model.
3. Assessment of impact of urban poverty or environmental degradation in Kaduna metropolis and environs.

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