THE USE OF GEOGRAPHIC INFORMATION SYSTEM IN THE ANALYSIS OF EMERGING URBAN SETTLEMENTS IN THE FEDERAL CAPITAL TERRITORY, NIGERIA

BY

NWAGWU, Chijioke John

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MARCH, 2011

DECLARATION

I hereby declare that this thesis 'The Use of Geographic Information System in The Analysis of Emerging Urban Settlements in the Federal Capital Territory, Nigeria was carried out by me and has not been submitted to any institution at anytime for the award of any degree. Information derived from published and unpublished works of other authors has been duly acknowledged in the text.

NWAGWU, C. John

28-04-2011

Date

CERTIFICATION

This thesis titled: The use of Geographic Information System in the Analysis of Emerging Urban Settlements in the Federal Capital Territory, Nigeria by: NWAGWU, Chijioke John (M.Tech/SSSE/2005/1461) meets the regulations governing the award of the degree of M.Tech. of the Federal University of Technology, Minna and is approved for its contribution to scientific knowledge and literary presentation.

Dr. H.A. Shaba
Supervisor

Signature & Date

Dr. A.S. Abubakar
Head of Department

Signature & Date

Prof. M. Galadima
Dean, School of Science and Science Education

Signature & Date

Prof. (Mrs.) S.N. Zubairu
Dean, Postgraduate School

Signature & Date

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ABSTRACT

Settlements are the aggregation of human habitats; they represent the nucleus of human socio-economic activities. The rate of settlement development over a period of time is one of the major indices of socio-economic development. Monitoring the dynamics of spatiotemporal changes in large urban agglomerations will become increasingly important as the number and proportion of urban settlements continue to increase. Settlement development in the FCT is pervasive and increasingly rapid; this can have adverse effect on the natural environment. This trend of spatial expansion if not sustainably managed could lead to the formation of slums with its attendant social decay. Conventional mapping techniques are time and cost intensive for speedy on-the-spot spatial mapping of most urban centres for policy, planning and research. Satellite remote sensing and geographic information systems offer the most efficient and fast means to map our ever expanding urban landscape. In this research, archived satellite images of the FCT were analyzed using Supervised Maximum Likelihood and Image Segmentation Methods to create a contemporary landuse map of the FCT over a period of nine years (1987-2006). Settlements/Builtup areas showed a continuous expansion from its 1987 spatial extent of 93.6 square kilometers (representing 10 percent of the total landuse) to 122.15 square kilometers in 2006 (representing 15 percent of the total landuse). Areas previously used as farmlands, pristine environments or green areas decreased very significantly from 457.6 square kilometers in 1987 to 393 square kilometers in 2006. Settlements will continuously be in high demand in the FCT owing to its central function as the federal capital, but the natural resources with which to sustain its increasing population remains finite. Thus to effectively carry out the task of managing settlement developments, the FCT Authority should adopt the use of space technologies such as remote sensing and Geographical Information systems in decision making processes, this will give wholesome and qualitative information about current scenarios as it exists to make well informed decision.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Settlement is broadly defined as the aggregation of human habitat, representing the nucleus of human socio-economic activities. The term settlement can also represent a permanent or temporary community in which people live. Settlements range in sizes, from very small number of dwellings (hamlets), to very large cities. At the Vancouver declaration (UNCHS, 1976), human settlement was defined as "the totality of human community with all the social, material, organizational and cultural elements that sustain it". The fabric of human settlements consists of elements and services namely shelter, infrastructure and services which support the cultural elements. Development of urban settlements or urbanization is the physical growth/expansion of urban areas into rural or natural lands as a result of increase in the population of an existing urban area. While the exact definition and population size of urbanized areas varies from country to country, urbanization is attributed to growth and economic development of cities.

Settlement can be urban or rural. An urban settlement is an area with an increased density of human and human-created structures in comparison to the areas surrounding it while rural settlements are large and isolated areas of a country, often with low population density and low human-created structures such as roads, schools, hospitals etc. Urban settlements are created and further developed by the process of urbanization. Measuring the extent of an urbanized area helps in analyzing population densities and urban sprawls (Wikipedia, 2007).

The existing urban settlements of many cities cannot accommodate the inevitable growth of urban population especially due to the impact of rapid socio-economic development. Recent studies have shown that over 45% of the world's human population now lives in urban areas with over 60% projected by 2030 (*United Nations, 1997*). This situation presents problems of almost every kind of urban disorders, and ultimately impacts negatively especially on the environment.

The dividend of socio-economic development is often concentrated and 'enjoyed' by people living in urban settlements. This situation is one of the most evident factors contributing to the high population growth rate of urban settlements. High rates of urbanization and a faster rate of population growth in relation to economic development are major drivers of environmental change, with significant impacts on the natural resources base. Each year, the number of population increases, but the amount of natural resources with which to sustain this population, and improve the quality of lives and eliminate poverty remains finite (UNEP, 2008) thus, increasing the challenges of environmental preservation and sustainable development.

Since the 1960s, a dramatic acceleration in rapid urban growth, combined with surging level of grinding poverty, has heightened concern for the urban situation that has unfolded in Sub-Saharan Africa. Although the majority of the Sub-Saharan population still live in the rural areas, the average annual urban growth rate of 4.8 percent between 1980 and 1993 was more rapid than in any part of the world and is cause for great concern (World Bank, 1995). In the last ten years, urban populations have continued to escalate, and it is likely that half of African's people will soon be living in cities (HABITAT, 1996). While there is no disputing that African cities have undergone rapid growth in the past four decades, there is much debate over the causes and effects of the urban transformation, and the ensuing social and ecological deterioration of the urban landscape. As sub-Saharan cities continue to expand and leave their ecological footprints' (Binns *et.al*, 2003) on their surrounding environment, urban fringes are being rapidly transformed with the intensifying competition for scarce resources, frequently resulting in the progressive degradation of the environment. Solution to the unfolding problems of rapid urbanization is an issue which affects many developing countries.

Spatial development of any geographical area is synonymous with urbanization. In recent years, cities all over the world have experienced rapid growth because of the rapid increase in world population and increased rural-urban migration flows. Specifically, in the larger towns and cities of the developing world, the rate of population increase has been constantly growing and currently, many of them are facing unplanned and uncontrolled settlements development. Urbanization as a process of human agglomeration in multi-functional settlements of relatively substantial size is not a new phenomenon in Nigeria. It can be traced back to the early nineteenth century but the contemporary issue about urbanization in Nigeria is the increasing failure of urban centres to meet the expectations of those who live in them and those who depend on them for their services. Mabogunje (1978).

In Nigeria, Africa's most populous country, there are more cities with over a million people than any other nation on the continent, and as rural areas surrounding these growing cities continue to be integrated into the urban system, government and indeed planners would need an efficient system for mapping and monitoring growth of urban settlements for reasons that are very obvious, since this growth leads to a reduction of vegetative cover, open spaces and forests, development of slums with its attendant health, social and environmental issues, such as waste generation and management, air and water pollution, increased potential for flooding and land degradation.

Conventional mapping techniques (involving field checks, cadastral maps etc) are time and cost intensive for the spatial extent of some urban centre thus, an efficient, cost effective, fast and reliable method of mapping is required to map and monitor the ever expanding urban landscape through the application of Geographic Information Systems (GIS) and Remote Sensing (RS) Effective management of the urban population problem demands good diagnostic tools. Accurate and reliable information is also required to quantify the current situation and to predict future trends: information on patterns of land use is one obvious example, while basic data on population, including its spatial distribution and rates of growth, is another (Adepoju, 2007).

1.2 Problem Statement

Settlement development in the FCT is pervasive and increasingly rapid and this can have adverse effects on the natural environment. This developmental trend if not properly managed could lead to the development of slums and its accompanying social vices, diseases and environmental degradation. Geospatial information derived from remote sensing and GIS application, offers planners and decision makers an opportunity to effectively manage multifaceted development (Brivio et al., 2001). Collation of this essential data over a large urban environment such as the FCT is obviously very time consuming and, in many cases, probably not feasible. A more efficient approach is to use remotely sensed data with field verification to classify land cover types (Ramsey, 2003).

1.3 Aim

The aim of this research work is to analyze the evolving settlements within the Federal Capital Territory (FCT) and their spatial changes between 1987 and 2006 using remote sensing and GIS techniques.

1.4 Research Objectives

The specific objectives are:

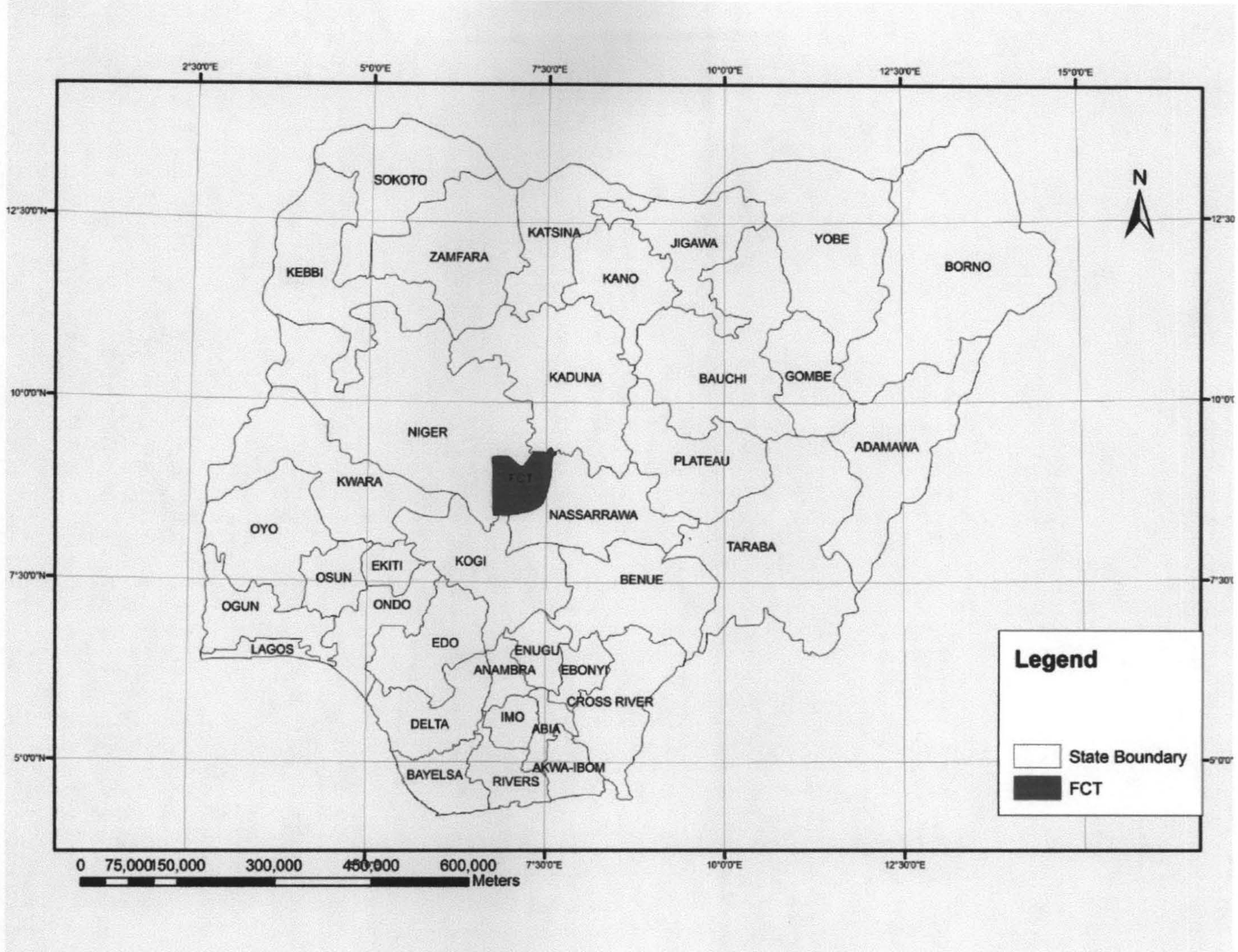
- The production of a contemporary satellite based land use land cover map of the study area
- The identification of settlements in the FCT using image classification techniques
- The statistical analysis of settlement spatial changes in the FCT between the years 1987 to 2006

1.5 Justification

Abuja, the Federal Capital Territory is one of the fastest growing cities in Africa. It has over the years attracted human population from all part of the country and beyond, owing to its status as the capital city of Nigeria. The challenges of catering for the basic needs of the population, places an undue pressure on the landuse landcover of the immediate environment. Recognizing this problem policy/decision-makers need information on where these populations are concentrated and their spatial extent to be able to channel adequate socio-economic interventions to manage development and growth more effectively. Human population migration into Abuja is continuing at an alarming rate causing changes in population densities, administrative services, and the natural environment. Detection and monitoring of settlement growth in Abuja in a timely manner is requisite to accurately assess the impact of human activities on the environment and is one of the most critical information needed for future economic development planning, natural resource allocation, environmental and ecosystem management.

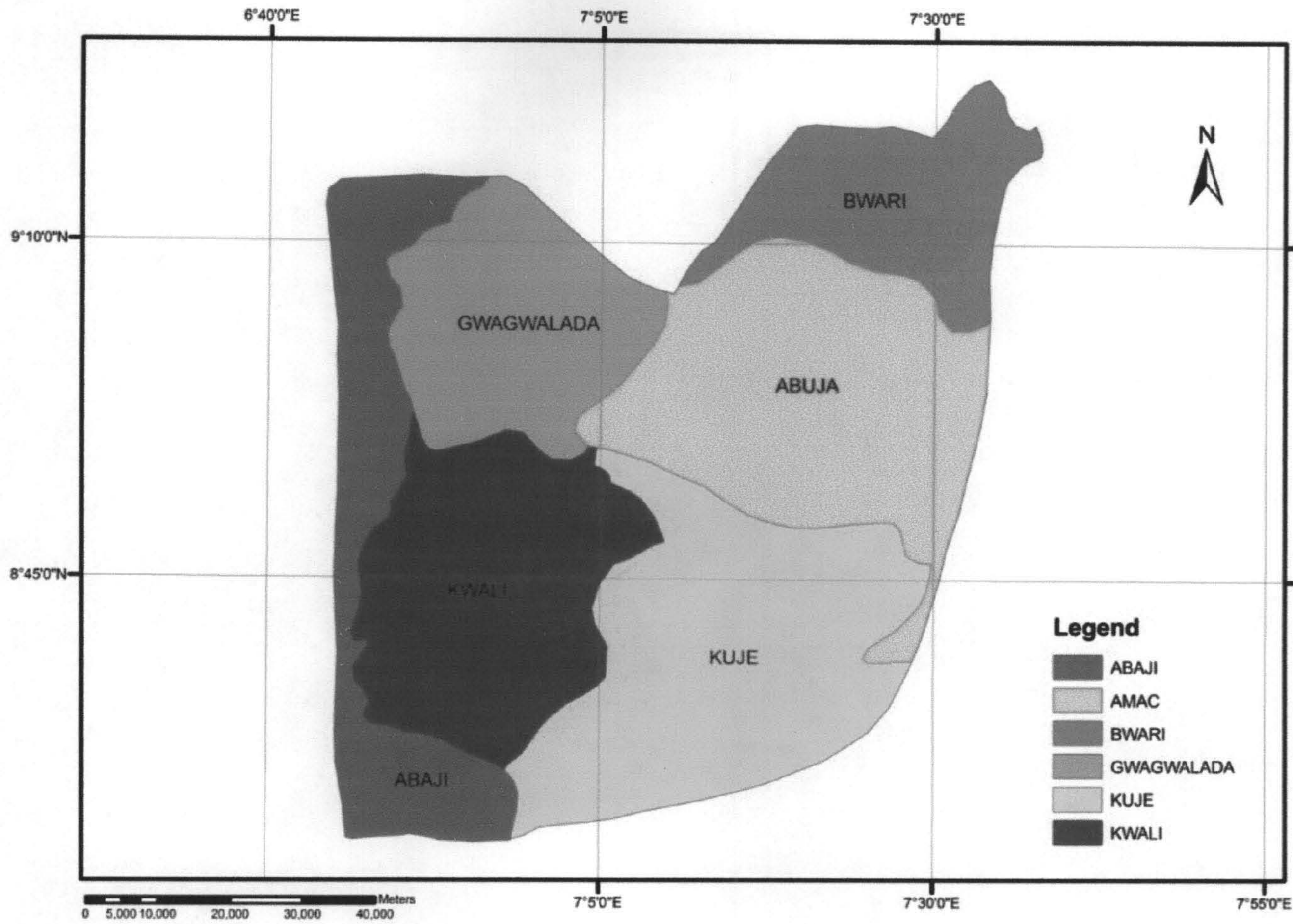
1.6 Study Area

Abuja, the Federal Capital Territory (FCT), lies between latitude 8.25 and 9.20 degrees north of the equator and longitude 6.45 and 7.39 degrees east of the Greenwich Meridian. It is a planned city in the centre of the country, and has been the official capital of Nigeria since 1991. The decision to create a new capital was made in the 1976, and work on it began in the 1980s. The FCT is bordered to the north by Kaduna state, to the east by Nassarawa state, to the south-west by Kogi state and to the west by Niger state. The location of the FCT was chosen so that no single ethnic group would be favored over another, although the Gwaris the original settlers were displaced by the construction of the new capital city. The FCT is divided into six area councils namely; Abuja Municipal, Gwgwalada, Abaji, Kuje, Bwari and Kwali local councils. (Balogun 2001)



Source: Office of the Surveyor General of the Federation (OSGOF)

Fig. 1.1: Location of the Study Area



Source: FCDA, Abuja

Fig. 1.2: The Six Area Councils of the FCT

1.6.1 Weather

The FCT experiences three weather conditions annually. This includes a warm humid rainy season and a blistering dry season. In between the two seasons, there is a brief interlude of harmattan occasioned by the North East Trade Wind, with the main features of dust haze, intensified coldness and dryness. The rainy season begins from April and end in October, when daytime temperatures reach 28-30 degrees and nighttime lows hover around 22-23 degrees. In the dry season, daytime temperatures can soar as high as 40 degrees and nighttime temperatures can dip to 12 degrees, resulting in chilly evenings. Even the chilliest can be followed by daytime temperatures well over 30 degrees. The high altitudes and undulating terrain of the FCT acts as a moderating influence on the weather of the territory. The annual total rainfall is in the range of 1100mm to 1600mm.

1.6.2 Temperature

The FCT records its highest temperatures and greatest diurnal ranges during the dry season months, when the maximum temperature ranges between 30.4°C to 35.1°C. During the rainy season on the other hand, the maximum temperature ranges between 25.8°C and 30.2°C. Also, the diurnal range is much reduced. Two main factors strongly influence temperature patterns in the FCT. These are cloud cover and elevation. The cloud cover is much less during the dry season, hence the high temperatures at this time of the year. As a result of differences in elevation between the north and the south, the latter has higher temperatures throughout the year than the former. Furthermore, the southern and western areas are part of the Niger-Benue, trough which there is a heat trap. These basically account for the relatively high temperatures in this part of the FCT.

Table1.1: Mean Monthly temperature in FCT (^{o}C)

Jan.	Feb.	Mar.	Apr.	May.	Jun	Jul	Aug	Sep.	Oct.	Nov.	Dec.
33.8	35.1	31.1	30.2	28.5	26.6	23.6	28.0	25.8	30.4	32.5	32.7

Source: FCT- Agricultural Development Programme (ADP)

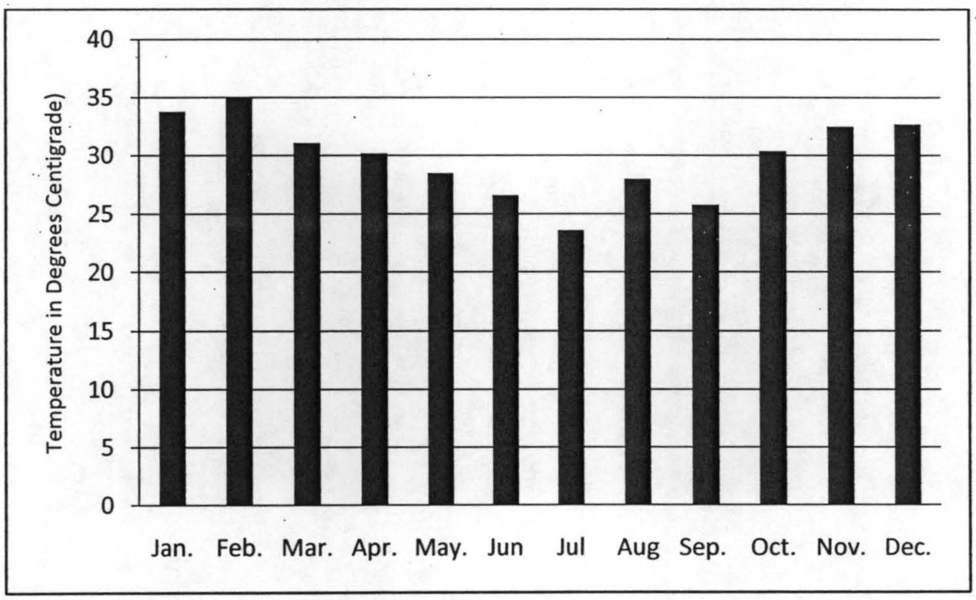


Fig. 1.3: Bar Chart of Mean Monthly temperature in FCT (^{o}C)

1.6.3 Hydrology

The FCT is well drained, having the following major rivers Gurara, Usuma, Mangol, Yewu, Bobo, Afara-Bokwoi, Wuye, Wupa, Itsu, Iku, Tapa, Jabi and Wosika. It has six main drainage basins; these are Usuma river basin, which is the largest. It drains the northern two-thirds of the FCT; Iku and Itsu River basins, both to the northwest of gwagwalada; Mangol River basin west of Kwali, and Robo and Afara-bokwoi River basins south of kwali. The two biggest rivers are Usuma and Gurara, which both constitute major elements of the physical landscape. The former is already being managed to the advantage of the city and some of the satellite towns through the construction of the lower Usuma Dam. Gwagwalada and Kubwa Waterworks. River Gurara is the biggest of all the rivers and it carries enormous quantities of water that is still largely emptied into river Niger. The river has a course which is characterized by two distinct sections. The upper course consists of the pre-Cambrian basement complex rocks, while the lower course flows through sedimentary rocks, which are characterized by relatively small surface run-offs. Thus the river is a great potential resource for development purposes. This is because topographic setting suggests a water resource management system in which a major dam or series of small dams or barges can be constructed across the river.

1.6.4 Population and Human Activities

The estimated population of the FCT is 1.5 million (NPC, 2006), yet on a daily basis people from all corners of the country relocate in large numbers to the FCT. The present largest indigenous group in the FCT is the Gbagyi, living in the rural areas. Being centrally located, Abuja is blessed with a mix of agricultural produce such as tubers and root crops of the south and grains of the north. The FCT has proven deposits of a wide range of mineral resources including marble, tin, mica, clay, wolfromite, tantalite and talc. The indigenous people of the FCT are mostly farmers, who engage in crop production as a means of livelihood. Crop production remains the most pronounced economic activity of the indigenes of the FCT while residents from other parts of the country are more into social services and other business oriented activities. (Chup *et. al,* 2000)

1.6.5 Vegetation

The areas now designated the FCT falls within the Guinea Savannah vegetation Zone of Nigeria. Patches of rain forest, constituting about 7.4 per cent of the total mass of vegetation, however, occur in the Gwagwa plains, especially in the gullied terrain to the south and rugged southeastern parts of the territory. The dominant vegetation of the territory is classified into three savannah types, as follows:

1.6.5.1 Park or Grassy Savannah:

This covers the largest area within the FCT, having about 53% percent of the total areal coverage. Park Savanna is different from the woodland. It has a ticker and taller growth of grasses and has better marked horizontal separation between foliage of the shrub layer and that of the tree layer. The tree species that are found within it are somewhat similar to those of the woodlands. However, there are a number of species within the former that can be regarded as dominant only in that environment. Four of such species are *Daniella oliver*, *Albizia zygia*, shea butter tree *Butyrosperum paradoxium*, and African locust bean *Parkia clappertoniana*. The shea butter tree is the most widespread of them all within this environment. The last three species bear fruits that are commonly used in preparing food items by the Gwari, and other indigenous people of the FCT. They also utilize *Daniella oliver* for making household furniture.

1.6.5.2 Savannah Woodland:

This vegetation type occurs most extensively in the more rugged and less accessible parts of the FCT. Woodlands are found in a large area east and south of Kwali along the Sukuku range hills that fringe the Robo plains. Other areas where they are found include the upper basins of the Robo and Afara-Bokwoi, the Agwai-Karu hills to the south-east and parts of Iku plains to the north. There are quite a number of other patches of the vegetation in the north-west of Iku-Gurara plains, in the Gurara Valley as well as the sedimentary rock belt in the South-west.

The woodland are the most luxuriant of the three types of savanna species, which are virtually absent from the forests. With respect to structure, the woodlands are much simpler vegetation than the forest. It has an upper tree stratum with foliage crowns that spread and touch, to provide a light continuous canopy. Below this light canopy, trunks of the typical savanna trees are more prominent than anything else. Examples of the more common species here are Afzelia Africana, Shea butter tree *Butryospermum paradoxium* and African copaiha balsom tree *Daniellia Oliver*. The dominant grass elements include species of Andropogon and *Brachiavia deflexa*.

1.6.5.3 Shrub Savannah:

This vegetation type occurs extensively on low interfluves and ridges, in a number of localities. These include Iku-Gurara Plains, the middle Gurara Valey region, Usuma Valley between Cibiri and Gwarko, and between Gwagwalada and Tunga-Aguma. Other areas are on the undulating terrain between the Robo and Afara-Bokwoi, from Bugako in the south, to Sukuku in the north, and around the range of hills to the north of the Gwagwa Plains.

The vegetation is made up of the same species as the Park Savanna. Consequently, the characteristic trees, shrubs and grasses are exactly the same. There are two main features that strongly differentiate Park Savanna from Shrub Savanna. The Shrubs provide the foliage layer in the latter, whereas they do not in the former. Also grassy elements in the shrubs Savanna are definitely more in number than those in the Park Savanna. Trees appear as emergents with foliage crowns scattered at considerable distances from one another. Examples of the species that are locally dominant in the shrub layer are *Anona senegalensis*, *Terminalia macropters* and *Detarium microcarpum*. Some of the grasses that are locally dominant are *Andropogon gayanus*, *Andropogon pseudapricus* and *Loudetia arundinacea*. The tree elements that emerge above the general shrub layer include *Butyrospermum Paradoxium*, *Daniellia oliver* and *Parkia clappertoniana*. (Adakayi 2000a)

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Urbanization and its impacts in Developing Countries

The formative years of the social sciences in the late nineteenth and early twentieth century were also the years, in which urban studies first developed, thus providing the context for the geographer's emerging interest in cities. Rapid urban development and dramatic changes of landscape have been witnessed in some developing countries as a result of rapid economic development and population growth. The measurement and monitoring of settlement spatial and temporal changes in these areas are crucial to government officials and planners who urgently need updated information for planning and management purposes.

Many scientific advances have occurred over the latter part of the twentieth century that have dramatically advanced our understanding of ecosystem processes, but we are poorly positioned to predict with an acceptable degree of certainty what awaits humanity in the coming decades (Ali, 2010). Rapid urbanization and industrialization have caused not only social problems but also environmental problems in most of the African and Asian mega-cities (Tachizuka et al., 2002). The challenges are daunting: changing climate, sea level rise, changing hydrologic regimes, vegetation redistributions and potential agricultural failures on a massive scale (Ali, 2010) as well as looming urbanization problems for decision makers worldwide but more severe for developing countries in particular.

Urban planners and geographers, as well as social scientists investigating the impact of economic and demographic growth on urbanization (Boarnet et al, 2005) should employ all available techniques to study and understand the spatio-temporal changes both within and outside the urban areas. This will unravel the future trend of urban land forms, land use and land cover. Regular and up-to-date information on the extent of urban areas is primarily required for regional-scale planning purposes, such as mapping urban growth. Effective planning policy and appropriate resource management can only be accomplished through informed decisions, but even basic information on urban extent is often outdated, inaccurate, or simply does not exist, this is especially so within developing countries. (Luckman, 2003)

2.2 Urban Centres in Nigeria

Nigeria has many large urban centres, most of which are poorly planned or not planned at all due to their growth through organic development. Factories, markets, shops, industries and houses exist side by side, and there is often no zoning scheme (Sada et al, 1978). This leads to the current scenario in all urban areas in the country: inadequate infrastructural facilities and social amenities. Inadequate roads, poor drainage systems, poor sanitation, inadequate water supply, shortage of housing and poor quality of housing condition as well as a total lack of recreational facilities exist in most Nigerian cities.

The most notable feature of urbanization in Nigeria from the 1991 census is the great increase in the number of urban centres all over the country, and the increase in the share of urban population in various regions of the country. The 1952/3 population census identified 329 urban centres nationwide, while the 1991 census identified 1,650 urban centres in Nigeria. Also, while 10.65 per cent of the people lived in urban centres of 20,000 people or more in 1952/53, this proportion had increased to 35.7 per cent by 1991 (NPC, 1998).

Urbanization in Nigeria between the 1953 and 1991 censuses shows that the rate of urban growth was much greater than the population growth rate of the country. Within this period the country's population increased from 32 million to 89 million, almost a threefold increase, while the population of urban centres of 20,000 people or more increased from 3 million to 32 million, a tenfold increase (NPC,1998). However, Mabogunje (1987) argued that instead of the Nigerian government broadening the access of individuals to the enjoyment of various national resources, the position had become one of restriction through concentration of facilities and opportunities in a very limited number of cities, giving rise to sharp differentials in urban and rural incomes and to growing social and territorial inequalities.

The study of Nigeria's environment in 2002 by the US Agency for International Development (USAID) identified three major threats to the country's natural spaces: the unsustainable use of renewable natural resources, unplanned urban development and petroleum industry operations. The Agency recommended that to plan for effective activities and to manage the environment in a more sustainable manner, the Nigerian Government needed to address these threats and their underlying causes, these been increasing poverty, population growth and migration, and political and institutional constraints (USAID, 2002).

According to the United Nations' population report (2002), Africa now has more than 37 per cent of its population already living in cities, but it also has the world's highest rates of urbanization (in excess of 5% per annum) in many cities and towns, with their populations doubling every twelve – fifteen years.

The UN estimates that world urban population will increase by at least 3 billion in the next 50 years and by 2020, more than 50 per cent of Africa's population will be living in urban areas (UN, 2007). Yet despite this growing global trend towards an urban society, how urban and suburban areas function as ecological systems is poorly understood (Grove, 1996). The lack of basic knowledge of the urbanization process and its ecological impacts has made us unable to assess, much less to manage and restore the urban ecosystems in both urban cores and suburban fringes. In recent years, the rapidly sprawling cities on the earth's surface have been described as ecology's last frontier (McDonald, 2002). Against this enormous surge in urban population growth, we need more than good intentions to deal with the challenges posed by urbanization and its associated problems. Land has been going through tremendous transformations due to sprawl resulting from intensive agricultural activities, industrialization and urbanization. The changes in land use affect the ecosystems in terms of land cover, land quality and capability, weather and climate, the quantity of land that can be sustained and the whole population and socio-economic determinants (Adepoju, 2007).

As humankind moves through the twenty-first century, environmental changes are predicted to accelerate, with unknown and potentially devastating consequences (Ali, 2010). Any environmentally compatible urban planning must begin with a comprehensive look at the use of land. Planners therefore need detailed information about the extent and spatial distribution of various urban land uses, housing characteristics, population growth patterns, urban sprawl, the existing condition of infrastructure and utilities (Saxena, 2001).

The ever-increasing growth in the size and density of cities, especially the "mega-cities" of much of the developing world, has major repercussions not only on the quality of human life but also on the environment and atmosphere (Mesev et al, 2008). In most countries, including the United States, many of the fastest growing urban centres are vulnerable to natural hazards and ecological degradation. (Ramsey, 2003).

Landscape ecology incorporates the study of biological, physical and societal causes and consequences of spatial and temporal changes and variation in the landscape (Turner, 1989). According to Khorran et al, (1994), some changes may affect entire areas uniformly and instantaneously, while others may take the form of slow advances or retreat of boundaries between classes, and still other changes may have very complex spatial textures. In the spatial context, they proposed four types of changes whereby land cover category either:

i. Becomes a different category;

ii. Expand, shrink or alter in shape;

iii. Shift position;

iv. Fragment or coalesce.

Change detection, according to Singh (1989), is the process of identifying differences in the state of an object or phenomenon by observing it at different times. Macleod and Congalton (1999) list four aspects of change detection which are important when monitoring natural resources:

i. detecting the changes that have occurred;

ii. identifying the nature of the change;

iii. measuring the area extent of the change; and

iv. assessing the spatial pattern of change.

Natural landscapes worldwide are being destroyed or converted to other uses especially for the purposes of human settlement development with far reaching consequences for the environment. The first step towards ensuring sustainable human settlement development is to develop methodologies for the generation of basic information required for effective environmental monitoring and management (Jennings, 1995). This information can then be used for detailed resource inventory and for decision making purposes (Scott et al, 2002), thus using established remote sensing detection methodologies to monitor these changes can serve as an evaluation of environmental management practices (Brothers and Fish, 1978).

2.3 Remote Sensing and Geographic Information System (GIS)

Since the launch of the first civilian earth observation satellite in the early 1970s there has been a systematic repetitive collection of digital imagery covering most of the globe. One of the most powerful applications of remote sensing has become the identification and analysis of features on the earth surface that have changed overtime.

Due to the raster format of digital imagery, change analysis procedures are easily implemented. This characteristic also gives a great prospect of automated image interpretation and analysis, a majority of authors and researchers are developing a variety of image change detection methods with varying degrees of accuracies. These methods often involve change extraction and change classification, image ratios and principal component analysis. Mahavir (1996) adapted a model of the 'Continuously Built-up Area' concept which allowed for the identification of settlements at different levels of satellite image generalization. This model achieved a high level of accuracy in its prediction of the changing pattern of settlements but is primarily focused on settlement formation and its spatial pattern.

Ackermann et al (2004) characterized settlement shapes on the Senegalese littoral to examine their evolution over an eleven years period (1988 – 1999). The transformation of settlement shapes over this period was analyzed by the creation of an index of change which yielded an examination of the relationship between settlement shape and their particular site of establishment. Esch et al. (2005), adopted a robust object-oriented analysis, relying on accurate image segmentation to identify built-up areas in different spatial scales. Yang et al (2002), conducted landuse landcover classification using unsupervised image clustering classification algorithm. Asep Karsidi (2004) used a supervised maximum Likelihood classification of PCA and NDVI transformed images to classify and identify landuse land cover categories. Yun (1997) adopted an axis-oriented linking method and some logical image segmentation to identify new settlement development in an urban area of Shanghai, China with an accuracy of 86%.

Remote sensing technology has evolved into an integral research tool for the natural sciences, offering the best option for settlement mapping and monitoring processes, availing planners and decision makers of various advantages hitherto not easily derived from conventional mapping techniques for informed decisions. RS/GIS is an appropriate tools and techniques for large area spatial data acquisition, identifying and mapping settlements, it has the ability to generate vast amount of data with continuous temporal and spatial coverage thus providing a successful means for monitoring urban growth and changes for the study and understanding the emerging settlements in the FCT. Its synoptic capability, allows for mapping of large areas of dispersed landscapes at a very cheap rate and in a timely manner. Remote sensing makes it possible now to gather information concerning urban landscapes and its adjacent areas in their entireties which are reliable basis for urban planning.

Geographic Information system (GIS) is an information system specifically designed to acquire, manipulate, store, analyze and output geospatial datasets. It combines the conventional database management system with a geospatial data processing capability which makes it uniquely appropriate for the mapping community. GIS allows us to view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, reports, and charts. A GIS helps us to answer questions and solve problems by looking at spatial data in a way that is quickly understood and easily shared. This technology can be integrated into any information system framework.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Data Sources

3.1.1. Primary Data

This research work used both primary and secondary data sources, for the various analysis carried out on settlements within the FCT. Satellite data constituted the base data, from which the contemporary landuse landcover map was derived. The selection of appropriate image dates is an integral component of the success of any project involving multi-date analysis, thus data acquired on or close to about the same season and time (Anniversary dates) was selected for this research work. This is to minimize discrepancies in reflectance caused by seasonal earth surface changes and satellite sun angle differences (Coppin & Bauer, 1996).

Table 3.1: Satellite Data

Platform	Sensor mode	Spatial resolution	Source	Path/Row	Acquisition date
Landsat	Multi spectral	30m	GLCF	189/54	Dec. 21st 1987
Landsat	Multi spectral	30m	GLCF	189/54	Dec. 27th 2001
Landsat	Multi spectral	30m	GLCF	189/54	Dec. 9th 2006

Source: Global Land Cover Facility (GLCF)

The first and second images were downloaded from the Global Land Cover Facility (GLCF) hosted by University of Maryland through the ESDI interface.

3.1.2 Secondary Data

Other ancillary vector data used in the study included: the FCT administrative boundary, roads, lakes, rivers and settlements digital maps obtained from the National Space Research and Development Agency (NASRDA) Abuja.

3.2. Image Preprocessing

Preprocessing of satellite images prior to image classification is essential. Preprocessing involved image registration and geometric correction. The goal of satellite image preprocessing is to achieve as much as possible the status of normalization such that all images appear as if they were acquired from the same sensor. All satellite images used in the research were geometrically corrected and referenced to the same coordinate system. The project area falls within the Northern Hemisphere of zone 32 projection. The Clarke 1880 Spheroid and Minna datum were used to define the common geo-reference system for all the images and other vector files used for the research. This is to ensure that all maps and imageries fit perfectly when overlaid. The nearest neighbour resampling method was used to avoid altering the original pixel values of the image data. The images were resampled to 28.5m spatial resolution. The resultant root mean square error (RMSE) was about 0.5 pixels.

3.3 Image Subset

As part of the preprocessing tasks, the vector map of the FCT was used to "cut out" the same area from the three satellite data sets. This process of data reduction is known as image subsetting. It is used to eliminate extraneous data in the satellite image file, and also speeds up processing by making the amount of data to process smaller.

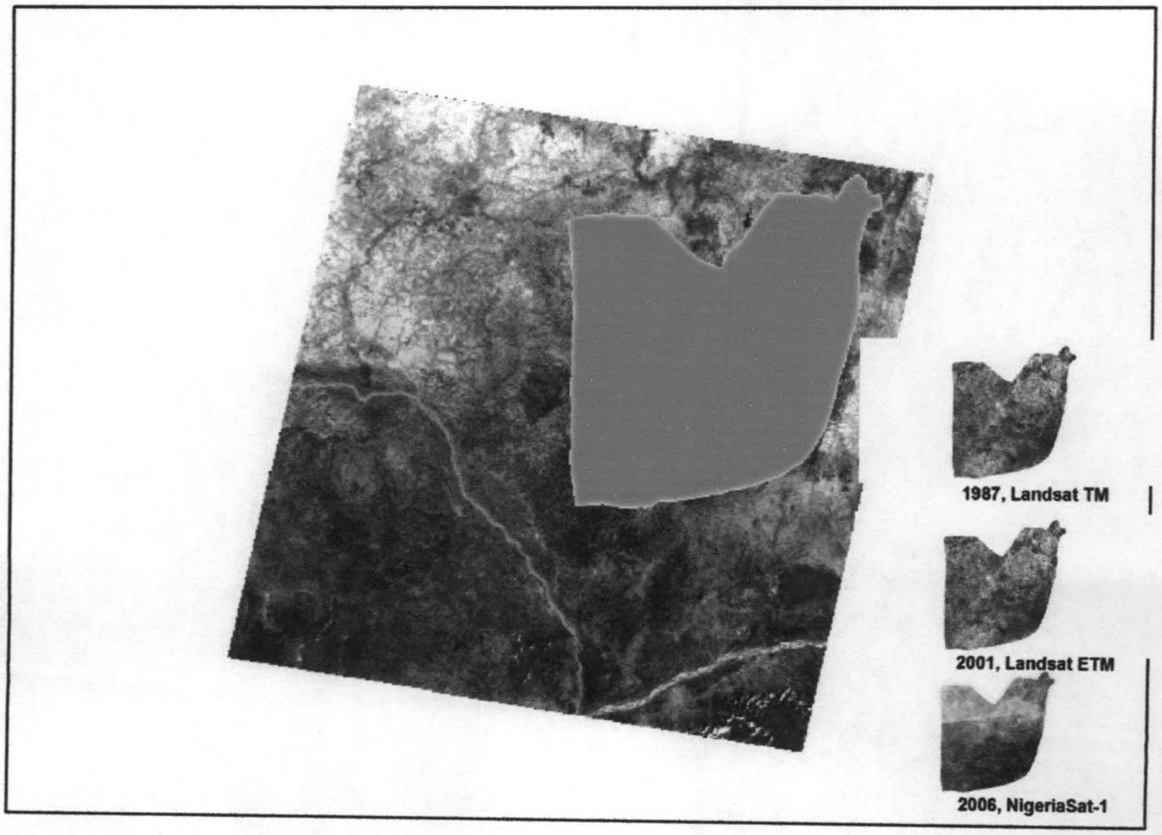


Fig. 3.1: FCT Subset for 1987, 2001 and 2006

3.4 Image Classification

The use of satellite imageries in contemporary mapping processes offers the unique challenge of delineating the heterogeneous spatial features which are captured, and extracting them into various thematic classes. Feature extraction into distinct classes or themes of land use and land cover categories, from remotely sensed satellite imageries is normally carried out using various image classification techniques. In satellite remote sensing there are basically two types of classification – unsupervised and supervised classification.

3.4.1 Unsupervised image classification

This is an image classification method that groups pixels according to their reflectance values or digital number (DN), this variation in reflectance is a sure method of delineation of features into various land cover types automatically without human intervention (ERDAS, 1999). This process was carried out for the three sets of data (1987TM, 2001 ETM and 2006 NigeriaSat-1). Unsupervised image classification for this project was achieved in ERDAS Imagine using the ISODATA algorithm, which utilizes a minimum spectral distance formula to form clusters of similar spectral signature sets. The number of clusters/classes selected determines the level of the ability of the algorithm to separate clusters spectrally. For the purpose of this research, 20 clusters were selected.

3.4.2 Supervised Image Classification

This is another method of image classification in which the analyst defines small areas called training sites, on the image which are representative of each desired land cover category. The delineation of training areas is most effective when an image analyst has local knowledge of the geography of a region. The image analyst then trains the software to recognize spectral values or signatures associated with the training sites. After the signatures for each land cover category have been defined, the software then uses those signatures to classify the remaining pixels (ERDAS, 1999). Most research works in current remote sensing processes involving image classification adopts various techniques to derive high levels of accuracies using a combination of classification techniques. The maximum likelihood classification scheme was adopted by the researcher, because it gave the best accuracy (Richards 1995). Accuracy of spatial data has been defined by the United States Geological Survey as: "The closeness of results of observations, computations, or estimates to the true values or the values accepted as being true" (USGS, 1990). Accuracy assessment or validation is an important step in the processing of remote sensing data. It determines the information value of the resulting data to a user.

3.5 Classification Scheme

Often times the selection of feature classes is influenced by the research application and the classes are usually expected to be precisely defined such that they can be radiometrically differentiated on the image. This is not always an easy task as the classes may be so close radiometrically and thus become very complicated to differentiate (Imran et al 2009). In this research, the land use classification scheme adopted is based on the aggregate landcover types present in the study area, and this was applied to all the satellite dates used in the research work. They are namely:

- Settlement/Built-up Areas
- Vegetation
- Rock-outcrop
- Bare Surfaces
- Water Bodies

3.5.1 Settlement/Built-up Areas

In the course of interpretation, the first difficulty encountered was the definition of spatial attributes for digitizing. Settlement/built-up areas comprise asphalt, concrete and cemented surfaces, compacted clay surfaces metal, glass and plastic surfaces and all areas of continuous development that are covered by bricks and mortar, such as buildings and transportation features.

3.5.2 Vegetation

These includes all green leafy vegetations such as grasslands, plantations, farms, forest reserves brushes and shrubs etc

3.5.3 Water Bodies

This includes all forms of water features such as streams, rivers, lakes, and swamps.

3.5.4 Rocky Outcrops/Bare Surfaces

These includes exposed rock surfaces as a result of both natural processes such as weathering, erosion activities and man induced processes such as excavation for construction activities, farming etc.

CHAPTER FOUR

4.0 RESULTS

This chapter presents the analysis and discussion of results based on the objectives of the study. Satellite image for 1987, 2001 and 2006 were processed and analysed to produce the contemporary landuse maps for the years 1987, 2001 and 2006 respectively using image classification (Supervised Maximum Likelihood and Image Segmentation Methods). Statistical analysis of the respective landuse maps are discussed and presented.

4.1 Classified Image of FCT (1987)

Figure 4.1 below shows the 1987 classified image of the study area. The bright red indicates the extent of settlements, while the green shows the extents of vegetated areas; white/grey shows the extent of bare surface/rock outcrops and blue shows the extents of water bodies (rivers, surface waters)

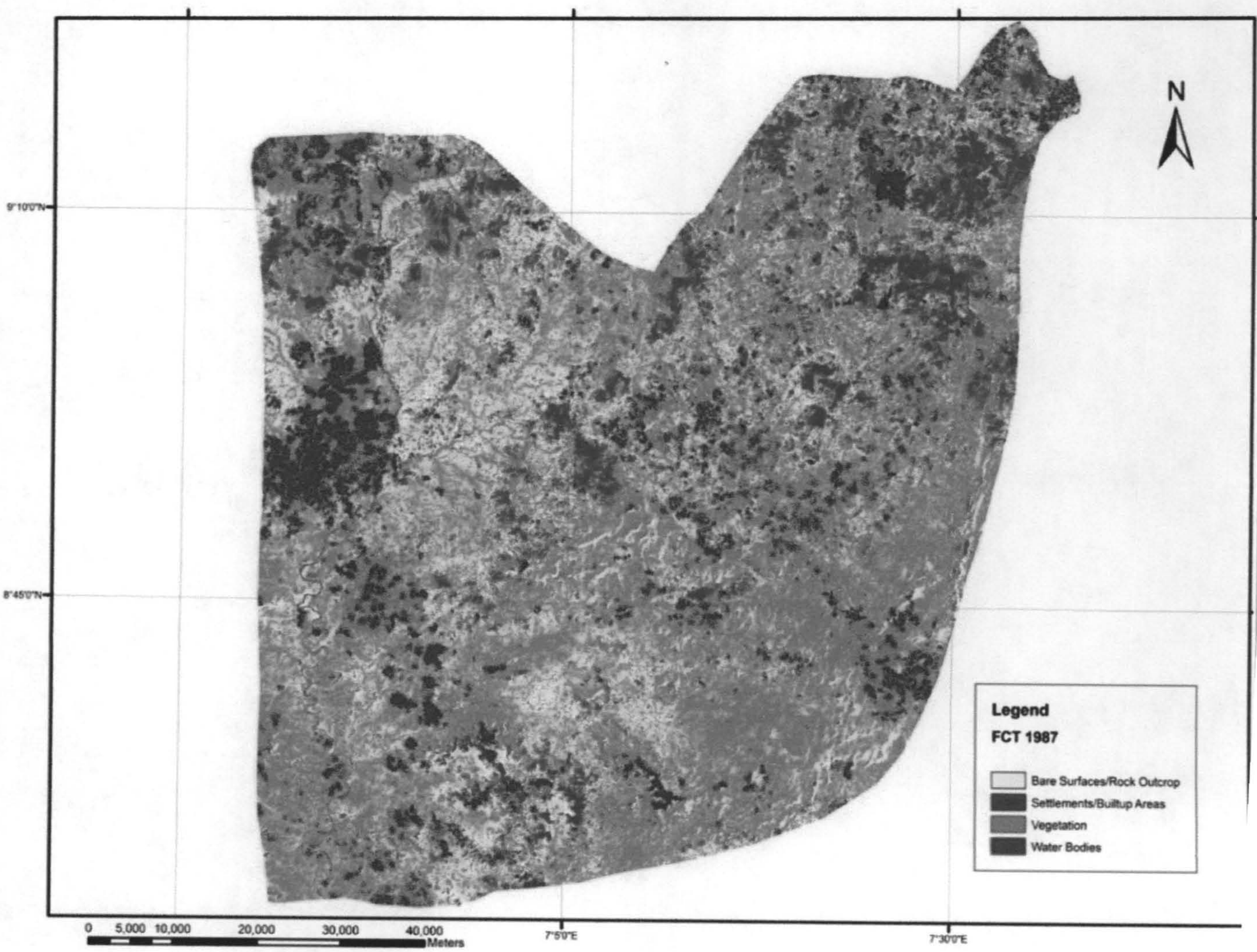


Fig. 4.1 Classified Image of FCT (1987)

4.2 Landuse Classes of FCT (1987)

Table 4.1 below shows extracted statistical spatial extent of the various landuse classes from the classified image of 1987.

Table 4.1: Landuse Classes of FCT (1987)

Landuse Classes (1987)	Area (Km2)	%
Bare Surfaces/Rock Outcrop	296.0657	32.79
Settlements/Builtup Areas	93.633	10.37
Vegetation	457.6121	50.68
Water Bodies	55.7079	6.17

4.3 Pie Chart of Landuse Classes of FCT (1987)

Figure 4.2 below shows the pie chart of extracted statistical spatial extent of the various landuse classes from the classified image of 1987.

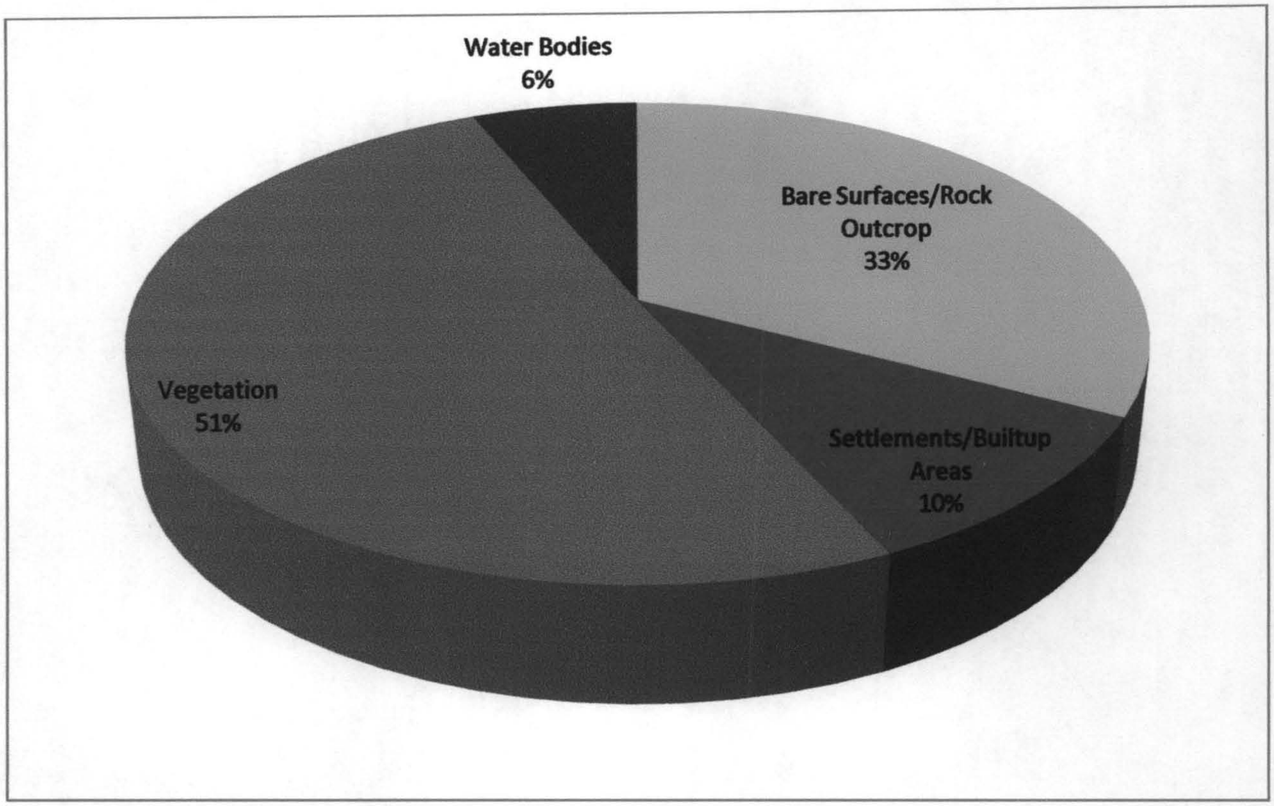


Fig. 4.2 Pie Chart of Landuse Classes of FCT (1987)

4.4 Classified Image of FCT (2001)

Figure 4.3 below shows the 2001classified image of the study area. The bright red indicates the extent of settlements, while the green shows the extents of vegetated areas; white/grey shows the extent of bare surface/rock outcrops and blue shows the extents of water bodies (rivers, surface waters)

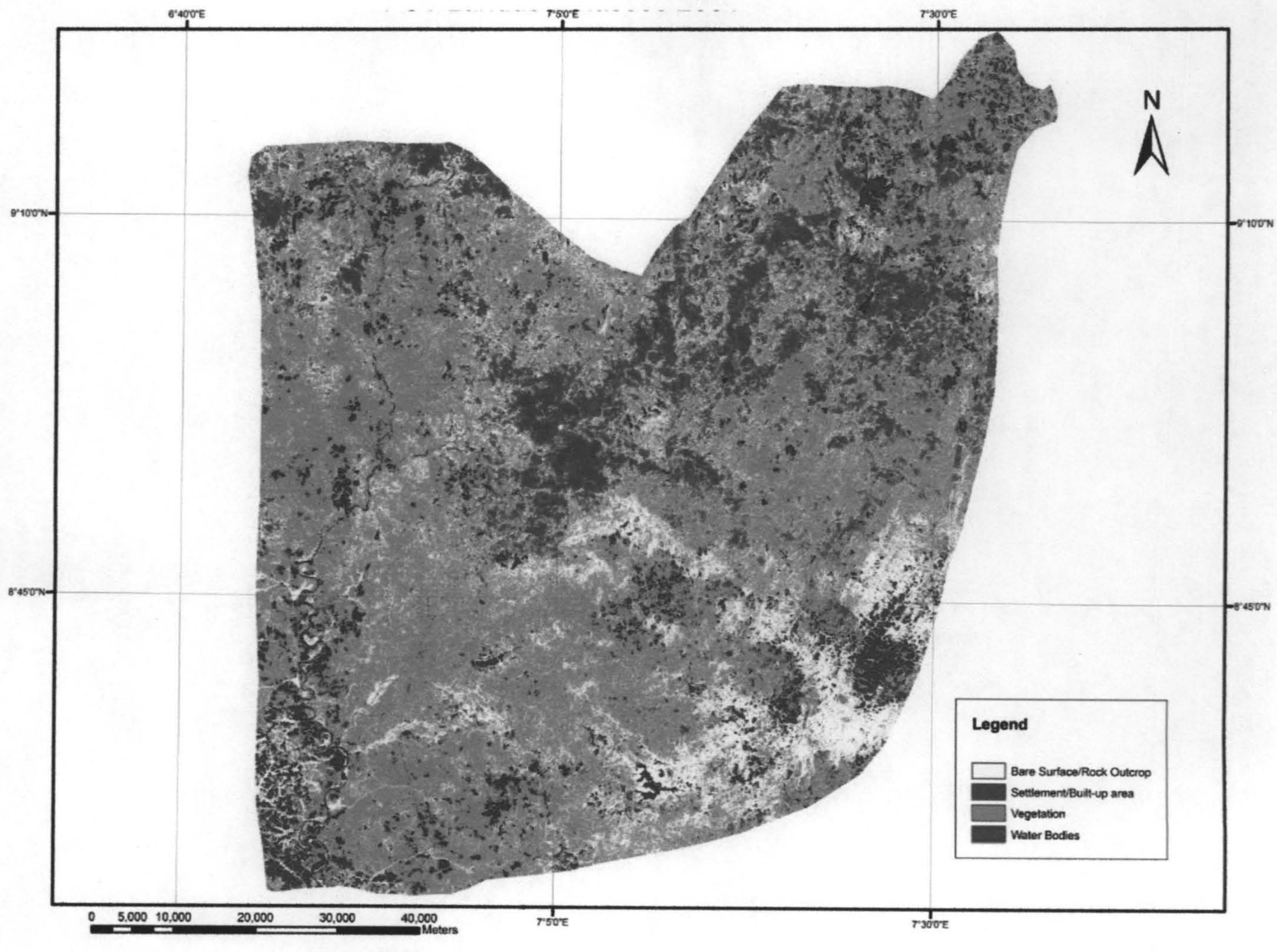


Fig. 4.3: Classified Image of FCT (2001)

4.5 Landuse Classes of FCT (2001)

Table 4.2 below shows extracted statistical spatial extent of the various landuse classes from the classified image of 2001.

Table 4.2: Landuse Class 2001

Landuse Classes 2001	Area (Km2)	%
Bare Surfaces/Rock Outcrop	279.2552	30.92
Settlements/Builtup Areas	122.4623	13.56
Vegetation	445.8816	49.38
Water Bodies	55.4196	6.14

World Bank (1995). *World Development Report, 1995*, http://wdronline.worldbank.org/worldbank/a/c.html/world_development_report_1998_99/back_matter/WB.0-1952-1118-9.back. (accessed Nov. 2009).

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4.6 Pie Chart of Landuse Classes of FCT (2001)

Figure 4.4 below shows the pie chart of extracted statistical spatial extent of the various landuse classes from the classified image of 2001.

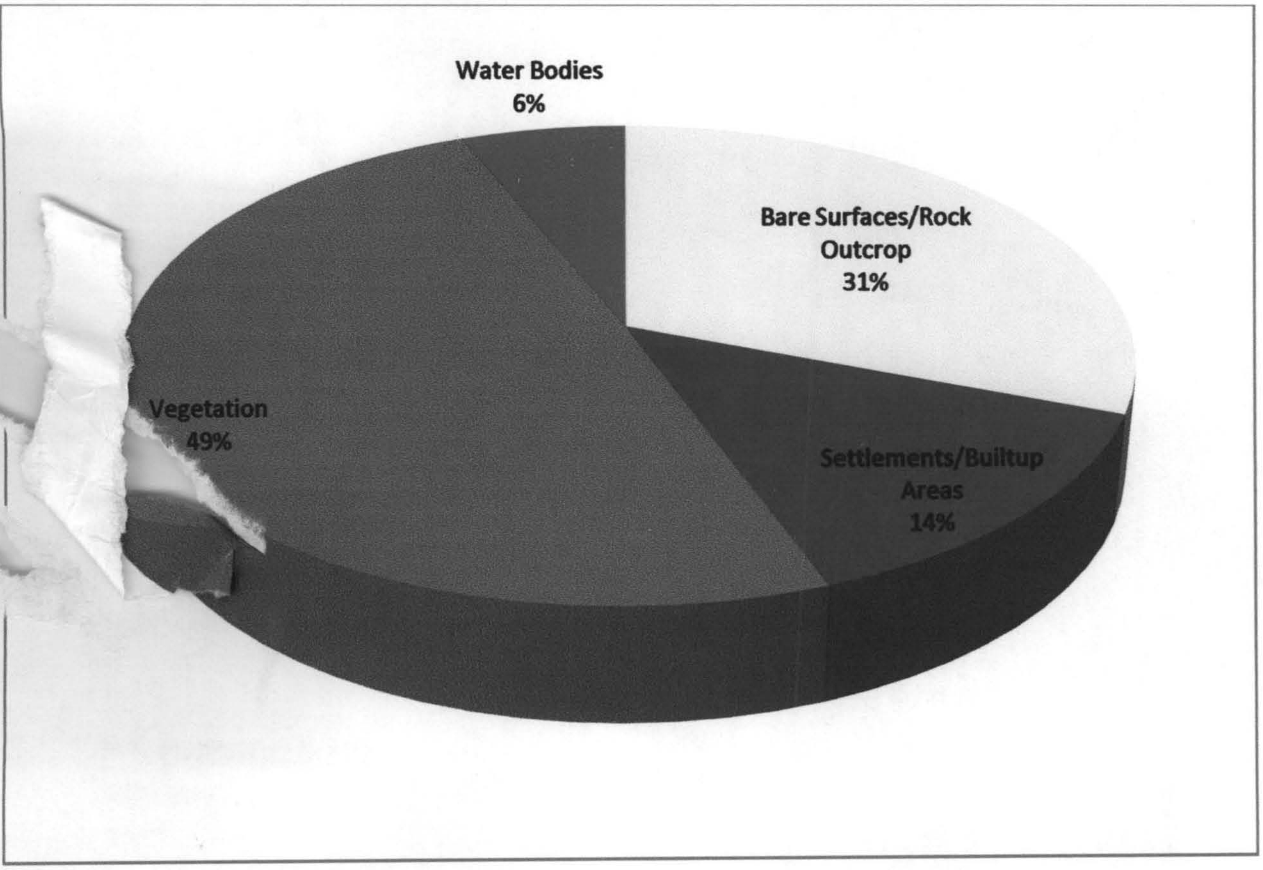

Fig. 4.4 Pie Chart of Landuse Classes FCT (2001)

4.7 Classified Image of FCT (2006)

Figure 4.5 below shows the 2006 classified image of the study area. The bright red indicates the extent of settlements, while the green shows the extents of vegetated areas; white/grey shows the extent of bare surface/rock outcrops and blue shows the extents of water bodies (rivers, surface waters)

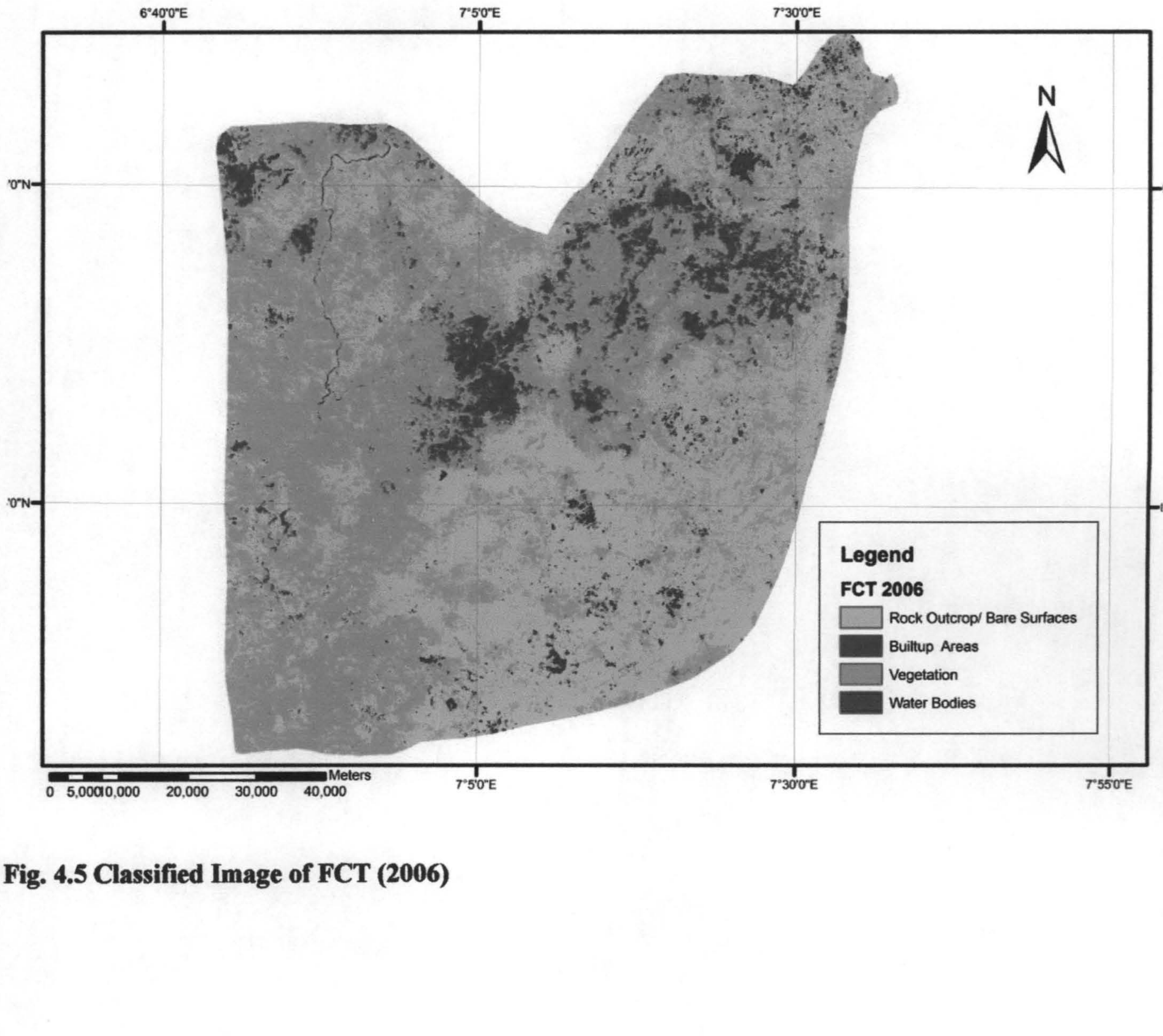

Fig. 4.5 Classified Image of FCT (2006)

4.8 Landuse Classes of FCT (2006)

Table 4.3 below shows extracted statistical spatial extent of the various landuse classes from the classified image of 2006.

Table 4.3: Landuse Class (2006)

Landuse Classes 2006	Area (Km2)	%
Bare Surfaces/Rock Outcrop	287.1248	35.23
Settlements/Builtup Areas	122.1483	14.99
Vegetation	392.9275	48.21
Water Bodies	12.7886	1.57

4.9 Pie Chart of Landuse Classes of FCT (2006)

Figure 4.6 below shows the pie chart of extracted statistical spatial extent of the various landuse classes from the classified image of 2006.

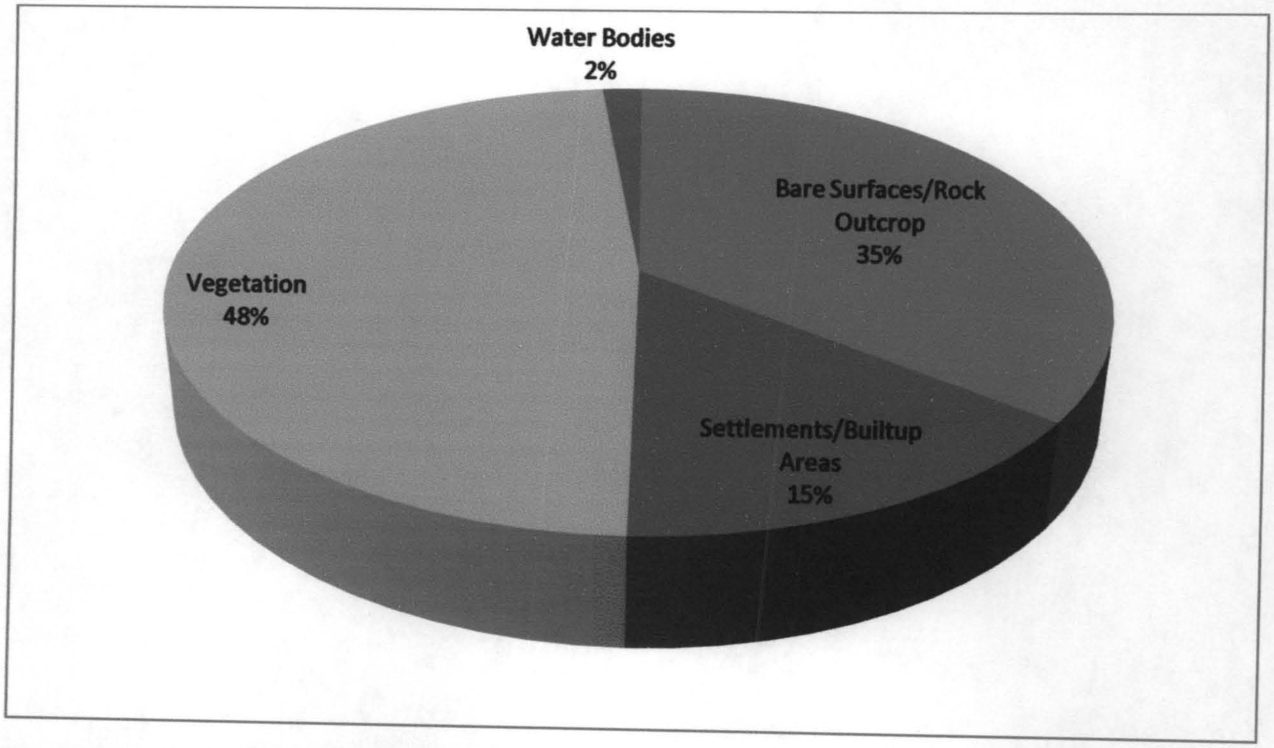

Fig. 4.6 Pie Chart of Landuse Classes FCT (2006)

4.10 Landuse trend analysis 1987-2006

Table 4.4 below shows the landuse trend analysis indicating changes in the various landuse classes from 1987 to 2006.

Table 4.4: Trend of Landuse Changes 1987-2006

	1987		**2001**		**2006**	
Landuse Classes	Area (Km^2)	%	Area (Km^2)	%	Area (Km^2)	%
Bare Surfaces/Rock Outcrop	296.0657	32.79	279.255	30.92	287.12	35.23
Settlements/Builtup Areas	93.633	10.37	122.462	13.56	122.15	14.99
Vegetation	457.6121	50.68	445.882	49.38	392.93	48.21
Water Bodies	55.7079	6.17	55.4196	6.14	12.789	1.57
Total	903.0187	100	903.0187	100		100

4.11 Landuse trend analysis graph 1987-2006

Figure 4.7 below shows the graph of observed changes of the various landuse classes 1987 to 2006.

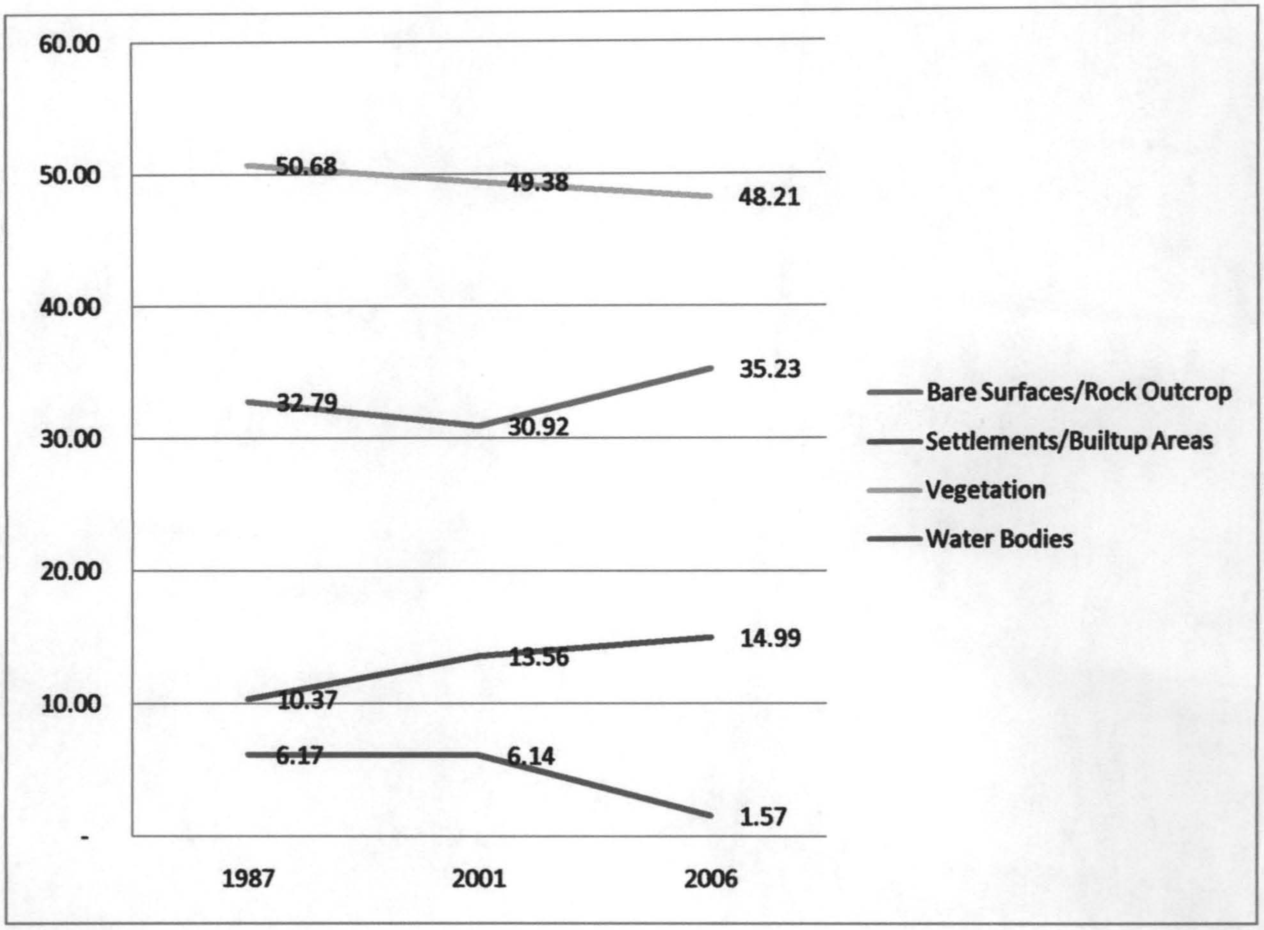

Fig. 4.7 Trend of Landuse changes 1987- 2006

CHAPTER FIVE

5.0 DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Discussion

The use of satellite imageries to monitor spatio-temporal changes in large urban/suburban settlements of the FCT is an invaluable tool which gives a synoptic perspective of the proportion of increase in spatial extent of settlements as the number and proportion of urban residents continue to increase.

5.1.1 Classified Image of the FCT (1987)

The Landsat image of the FCT (1987) forms the base year for the research, the image classification model leveraged the reflectance values of the aggregate features identified by the researcher during the field work to determine the various landuse coverage as shown in Table 4.1.

5.1.2 Classified image of the FCT (2001)

The classified image of the FCT in 2001 shows remarkable differences in the various landuse types adopted in the research. This period is reflective of the rapid rate of the development of the

FCT. Settlement/builtup areas increased from 93.633 Km2 representing 10.37% of the total land area to 122.462 km2 which represents 13.56% of the total land area. This shows an increase of 3.19%, this is attributed to the development of settlements. Also vegetal cover decreased from 457.6km2 (50%) of the total land use in 1987 to 445.88 (49.38%) in 2001. This is an indication of some of the consequences of settlement development i.e. it leads to the loss of farmlands and other vegetative covers. Rock-outcrop/bare surfaces also experienced spatial changes from 296 Km2 (32%) in 1987 to 279.255 (30.92%) in 2001. Water bodies remained fairly constant for both years 55.70km2 (6.17%) in 1987 to 55.419 (6.14%) in 2001.

5.1.3 Classified image of the FCT (2006)

The classified image of the FCT in 2006 shows a remarkable difference in the percentage of the aggregate spatial features adopted in the research. Water bodies which remained fairly constant in the previous comparison (1987-2001), reducing to 1.57% of the total landuse, this has very serious implications for domestic, agricultural and industrial water uses in the FCT. This is as a result of the increase in the spatial extent of bare surfaces and settlements/built-up areas which increased from 30.92 % to 35.23% for bare surfaces and 13.56% to 14.99% for settlements/built-up areas. This is indicative of the ever increasing need for dwellings especially in the satellite towns- Lugbe, Kuje, Gwagwalada, Kubwa, Deidei, Kwali etc, and other infrastructural developments such as roads, hospitals, banks etc.

5.2 Conclusions

Earth observation techniques provide useful information to city planners working in data poor environments. Information that can be derived from satellite imagery includes large-scale changes of the city and directions of growth of the urban areas. Furthermore, a limited number of city sections can be identified using the spectral information and supervised classification algorithms. However, the spatial resolution and spectral information is not sufficient to identify socio-economic properties of city quarters. Monitoring socio-economic changes within urban/suburban quarters requires sensor systems with high spatial resolution and sufficient spectral bands. Government will need to incorporate cutting edge technologies for accurate settlement mapping and monitoring into its future development strategies. Considering the pressure placed on social infrastructures by the growing population of the FCT, the need to study this development will be a major challenge in the foreseeable future.

Urbanization is associated with various ecological social and economic changes in both urban areas and the surrounding natural environment. In order to keep up with the effects and impacts of this development, effective urban and regional planning requires accurate and up-to-date information on the urban dynamics.

The use of remote sensing and GIS technologies will play a significant role in advancing the understanding and management of the phenomenon of urban settlement development in the FCT.

5.3 Recommendations

This research work presents a contemporary landuse dynamics of the FCT over a period of 9 years (1987 -2006), thereby showcasing the appropriateness of Space technology for mapping, monitoring and managing of settlements development in the FCT. Settlements will continuously be in high demand in the FCT owing to its central function as the federal capital. Thus to effectively carry out the task of managing developments the FCT Authority should

- Invest in the acquisition of relevant technologies such as Remote Sensing, Geographic Information Systems (GIS) for quick on the spot assessment of various spatial features especially settlements.
- Invest on human capital development to take advantage of the opportunities offered by cutting edge technologies in the satellite image processing and interpretation
- Acquire at regular intervals relevant high and medium resolution satellite imageries covering the FCT for effective monitoring and coordination of all developments in the FCT
- Adopt the use of space technologies such as remote sensing and Geographical Information systems for decision making processes, this will give wholesome and qualitative information about current scenarios as it exists to make well informed decision.

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