Land use and land cover change detection with remote sensing and GIS at metropolitan Lagos, Nigeria (1984 - 2002)

by

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“Great names are not always from great house, they are like morning sun which rises from nowhere. But man as an aspirant animal needs to be given all the encouragement and support, if not it will be to the detriment of the society he belongs”

Late Chief Obafemi Awolowo

The political legend of Africa

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ABSTRACT

Lagos is the fastest growing mega-city in the world (UN, 2006), yet it lacks reliable, modern, scientific monitoring techniques to effectively monitor and manage land use/cover changes brought about by urbanization. The capabilities of satellite remote sensing in terms of large spatial coverage, spatial and temporal resolutions adequate for these types of studies, as well as the ability of GIS to handle spatial and non-spatial data, make it the optimal approach for this research. A post-classification approach was adopted with a maximum likelihood classifier algorithm. The Landsat Thematic Mapper (1984) and Landsat ETM (2000) were merged with SPOT-PAN (2002) to improve classification accuracies and provide more accurate maps for land use/cover change and analysis. This also made it possible to overcome the problem of spectral confusion between some urban land use classes. The land cover change map revealed that forest, low density residential and agricultural land uses are most threatened, and most land allocated for these uses has been legally or illegally converted to other land uses within and outside the metropolis. The research explored the underlining socio-economic and political factors which are driving the rapid land use/cover change in metropolitan Lagos, as well as the inter-relationship between population and spatial growth with the aim of using remote sensing and GIS to provide much needed intelligence to achieve sustainable urban and environmental development and planning in the study area.

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CHAPTER ONE: INTRODUCTION

CHAPTER ONE

INTRODUCTION

1.1 LAGOS, NIGERIA: A CITY OF MIGRANT GROWTH

Urbanization is the progressive concentration of population in towns and cities (NPC, 1998). Urbanization is perhaps one of the most important human activities creating enormous impacts on the environment at local, regional and global scales (Turner et al., 1990). According to the United Nations (UN) Centre for Human Settlement, more than half of the world's population will live in urban areas for the first time in human history by 2002 (Torrey, 1998). It is estimated that within the next 25 years nearly two-thirds of the global population (over 5 billion) will come to live in cities (Ramsey, 2003). The world's urban population is growing twice as fast as the total population. This rapid urbanization, especially in the developing world, will continue to be one of the crucial factors that must be taken into account in the human dimensions of global change in the 21st century. For decades cities in the developing countries have been undergoing fundamental, and at times tumultuous, change. Societies are being transformed and economic and political systems are being built and rebuilt under a variety of models and conditions (Ramsey, 2003).

The average global urban population growth between 1950 and 2005 was 2.6%, while Africa's average urban growth was 3.67% for the same period. At the regional level, West African average urban growth was 4.3% and Nigeria 4.4%, while Lagos' average urban growth was 5.8% from 1950 to 2005. 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 constant and currently, many of them are facing unplanned and uncontrolled settlements at the densely populated sites or fringes. Urbanization as a process of human agglomeration in multi-functional settlements of relatively substantial size is not a new phenomenon in Nigeria (Mabogunje, 1978). 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) categorised this failure of Nigerian urban centres under four headings: employment, liveability, manageability and serviceability.

Lagos is one of the fastest growing cities in the world (table 1.1 refers), having grown by more than 10 million people in the last 25 years (UNWUP, 1999). The city has grown from a fishing and agricultural service centre to a mega city with national and international economic, industrial and political functions. These changes in functionality have led to changes of land use/cover in metropolitan Lagos. The rapid rate of change is of great concern to planners and various government agencies, because this growth has profound impact on the available water resources, agricultural land, recreational use, other land uses and limited remaining space (Gluch, 2002). If left unchecked, ecological assets and their services, such as the water storage values of forested hillsides or the landscape value of natural hilltops, are either unrecognised or unwittingly sacrificed (Balmford et al., 2002; Ramsey, 2003).

Country	City	1950	1975	2000	2015
Japan	Tokyo	6 920	19 771	26 444	26 444
India	Bombay	2 901	6 856	18 066	26 138
Nigeria	**Lagos**	**288**	**3 300**	**13 427**	**23 173**
Bangladesh	Dhaka	417	2 172	12 317	21 119
Brazil	Sao Paulo	2 423	10 047	17 755	20 397
USA	New York	12 339	15 880	16 640	17 432
England	London	8 733	8 169	7 640	7 640

Population in thousands

Table 1.1: Major urban population growth & estimates, 1950-2015 (UN, 1999)

Since the amalgamation of Nigeria in 1914, when Lagos became the Federal Capital of Nigeria, its development has been marked by rapid commercial, manufacturing, institutional and urban growth. Either consciously or subconsciously, the ecological and environmental problems in the Lagos metropolitan area were not given the priority required. This has led to environmental degradation, chaotic transportation, poor housing conditions and breakdown of social and infrastructural amenities that are needed to support functional and liveable urban centres in the 21st century.

Lagos is the most populous city in Africa and former capital of Nigeria (a country with a poor infrastructure in its rural areas) and receives large numbers of Nigeria's rural-urban migrants. It is also a focus for migrants from other parts of the world due to its economic importance in sub-Saharan Africa. The high concentration of migrants moving away from actual or perceived poor conditions in rural areas and townships has put unprecedented pressure on the urban resources, infrastructure and environment, straining them almost to breaking point. In addition, levels of poverty, unemployment, overcrowding and the construction of informal settlements have been exacerbated. This has led to a severe crisis in maintenance and to a deterioration in urban services (Baker, 1977) and quality of life, all too common in African cities (Adebayo, 2002). 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 (Baudot, 2001).

1.1.1 Land Use Planning in Lagos

In Lagos, as in many African cities, planners lack such information and often they possess out of date data which is irrelevant for current decision-making. Satellite remote sensing, with its different spatial and spectral resolutions and the ability to provide contemporary land cover data can provide some of this information (Brivio et al., 2001). However, land cover refers to the physical nature of the surface materials present in a given area, whereas land use refers to the specific type and pattern of human development (Anderson et al., 1976; Sabins, 1997, Ramsey, 2003). Collection of this data in a large urban environment is obviously very time consuming and, in many cases, probably unfeasible. A more efficient approach is to use remotely sensed data with field verification to classify land cover types (Anderson et al., 1976; Hixson et al., 1980; Ridd, 1995; Ramsey, 2003).

1.1.2 Monitoring Land Use Change in Urban Centres

Urban centres can be monitored and studied through remote sensing which follows the act of vision (Mather, 1999). By developing a temporal sequence of remote sensing data products, information for monitoring and management can be provided to the decision- and policy-making processes (Star et al., 1997). Sutton, 2001, concludes that without accurate knowledge of locations, activities, land use and land cover changes, and numbers of people on the planet, the human dimensions of global change cannot be understood. Timely and accurate change detection of the Earth's surface features is extremely important for understanding relationships and interactions between human and natural phenomena in order to promote better decision-making (Lu et al., 2003).

Monitoring urban growth and the subsequent land-use change is a fundamental source of information for understanding the patterns of urban land use change, assessing the impacts urban growth will have on the local environment, and the demands it places on the population (Ramsey, 2003). Remote sensing has already demonstrated its great potential as a monitoring tool for many management applications, especially in natural landscapes, in land-use and land cover change detection, mapping city landscapes, and in environmental monitoring (Lunetta and Elvidge, 1998). Its use for land use/land cover change detection in Nigerian urban centres is less obvious. Combined GIS approaches, using additional data sources are also worthy of interest.

Remote sensing has become an accepted tool for mapping, monitoring and modelling of environmental variables and processes in developed countries, while it is rapidly becoming the major tool in developing Asian countries. However, it is not yet popular among African countries, despite the unique access to primary data about the status of land surfaces that remote sensing offers. It also provides data with adequate spatial, spectral and temporal resolutions for most urban and environmental planning and monitoring. There is a clear substantive and methodological rationale for integrating socio-economic data through GIS with satellite imagery (Longley et al., 2001) to derive intelligent information that can back sound governmental policies on land use and land cover related problems.

The primary application of remote sensing data in the examination of urban regions is to provide a synoptic means for extrapolating local, detailed measurements to a regional context (Ramsey, 2003). However, multi-spectral image classification is also very useful for urban studies such as land cover and land use mapping, urban growth mapping and population studies. Besides a broadly accepted deficit in basic data layers such as digital elevation models or land use maps, there is a high demand for such products in studies on urbanization and in land use and land cover change studies. Remote sensing of cities has been limited in the past due to the low spatial resolution of most satellite-based instruments, as well as the lack of demand and use from city officials, planners, and scientists (Townshend, 1981; Harris and Ventura, 1995; Aplin et al., 1999; Ramsey, 2003). This trend is likely to change with the advent of both innovative processing algorithms and inexpensive, higher spatial resolution data (Gong and Howarth, 1990; Aplin et al., 1997; Stefanov, 2002; Ramsey, 2003): among these sensors are the Landsat 7 ETM+, SPOT, Ikonos-1, Quickbird, Advanced Spaceborne Thermal Emission and Reflectance Radiometer (ASTER).

Geographic Information Systems provide a suitable environment in which to integrate remote sensing, other spatially referenced information and socio-economic and population data, to assess the impacts and effects of inter-relationships that exist between various variables: for example, different zonations (Openshaw, 1996), different area-preserving and/or volume-preserving transformations (Martin, 1996), error modelling (Goodchild et al., 1992) and compounding of errors in overlay analyses (Longley et al., 2001). Advances in GIS in storage, manipulation, visualisation and analysis of spatial data make it possible to derive good and better information from processed satellite images and ancillary data. The merging of remote sensing data coverage with other spatial ancillary data types is defined as the process of geospatial "data integration" (Nellis et al., 1990; Lunetta, 1998). This approach provides a powerful tool for this research to explore various inter-relationships between urbanisation and land use/cover change through remote sensing and GIS in the study area.

1.2 THE STUDY AREA

Lagos is located in the S. W. of Nigeria at 6° 27' N and 3° 24'E and has an area of 3853 km². The southern boundary of the state is formed by the 180 km long Atlantic coastline while its northern and eastern boundaries are shared with Ogun State (Balogun et al., 1999). Lagos is bounded in the west by the Republic of Benin. Lagos State is the smallest (spatially) of Nigeria's states, comprising 0.4% of the entire area of the country (Balogun et al., 1999). Lagos state is densely populated, with approximately 13.4 million people (UN 2002) in the State. The rate of population growth exceeded 9 per cent per annum in the 1980s, which resulted in an additional 300,000 persons per annum (Wilbur Smith, 1980; Balogun et al., 1999). The city of Lagos presents a unique dynamic among the world mega cities. In the mid 1960s, Lagos had around 500,000 inhabitants. By the year 2000, this was estimated to be 12 million and the United Nations (2003) estimates a population of 17 million for the year 2015. However, it is not only population movement from outside Lagos that is creating serious problems. According to the Lagos State Environmental Protection Agency, every year three million people move (relocate) inside Lagos from one place to another due to environmental pollution, hazards, construction of new estates or development of new marginal settlements (HUGIN GmbH, 2001). Figure 1.1, 1.2, 1.3, and 1.4 shows the location of the study area from continental to local level.

Figure 1.1: Map of Africa

Figure 1.2: Map of Nigeria

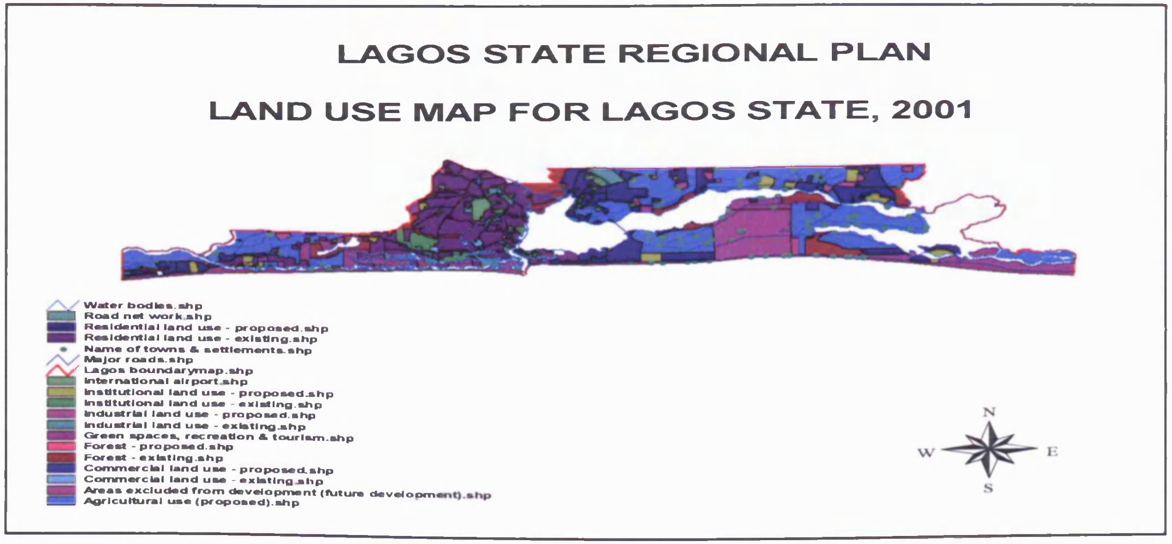

Figure 1.3: Lagos State Map

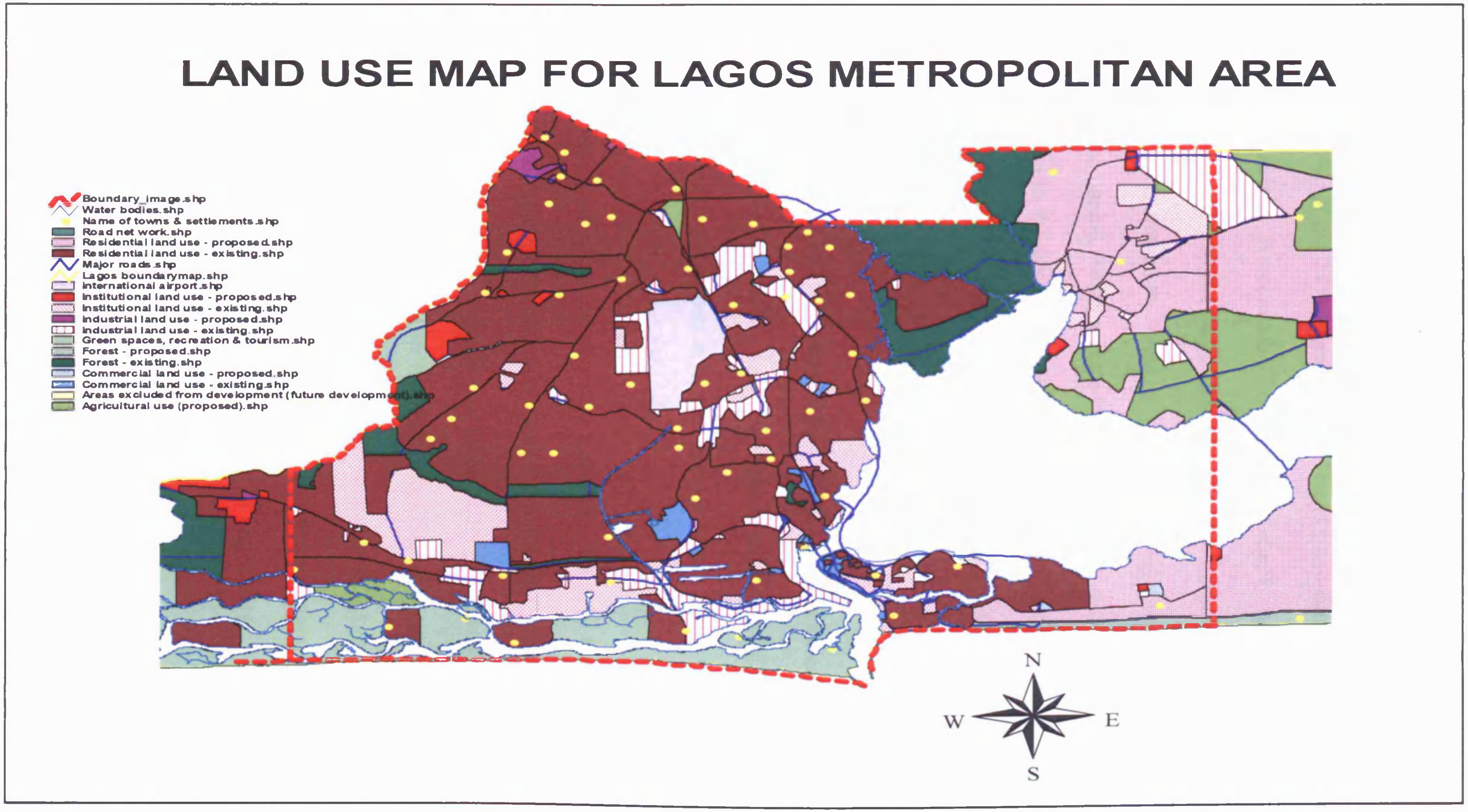

Figure 1.4: The metropolitan Lagos (The Study Area)

Metropolitan Lagos lies on lowland, with about 17,500 hectares of built-up area, of which residential areas occupy the largest proportion of 52%, commercial 5%, industrial 8%, institutional and special use 14%, open spaces 3% and transportation 18% (Oduwaye, 2004). Lagos became a British Protectorate in 1851 and gradually developed into the capital of colonial Nigeria. It remained the capital of Nigeria after independence (October, 1960) until the federal capital was moved to Abuja in 1992. Lagos State was created in 1967 and Ikeja was made the state capital, but has since been incorporated into Lagos City. Badagry is the second largest town in the state and is an old coastal trading port. Epe is a fishing and boat-building town 90 km east of Lagos City (Geomatics, 1998) while Ikorodu is one of the major towns in Lagos State. Lagos city remains the economic capital of Nigeria and the seat of many overseas missions, although these were all scheduled to move to Abuja in 1992. Lagos is connected to the North and East of Nigeria by expressways and an expressway also connects with the Republic of Benin. The city is the southern terminus of the main railway line to the north. The main international airport is located at Ikeja.

The exact population of Lagos city remains uncertain, but it is the largest city in Nigeria. Lagos City grew throughout the twentieth century, but in the period since the 1970s it has expanded dramatically and now extends into Ogun State. Practically all of Nigeria's 250-plus ethnic nationalities are represented in the area called Metropolitan Lagos, although the core population is still Yoruba. Peoples living in the rural part of Lagos State are predominantly Yoruba and Egun. The Egun people living in settlements along the coast and the rural population of Lagos are dominated by the influence of Lagos City.

1.3 AIMS AND RESEARCH QUESTIONS

Given the rate of growth of Lagos metropolis and the associated planning (environmental, social, political and economic) problems, there is a very pressing need:

To map land use/cover change in Lagos and compare these data with official Government land use maps.

To understand the factors for these changes and investigate the inter-relationships between population change and land use/cover.

1.3.1 Research Questions

In addressing the above, the following research questions were identified:

(i) Is the rapid land cover change taking place in Lagos? If yes, what is the spatial pattern of change?

(ii) How accurate is the official Government land use plan?

(iii) What are the socio-economic and political factors driving land use/cover change?

(iv) How is population growth driving land use/cover change?

(v) What are the implications of socio-economic and political factors on sustainable land use/cover change?

1.4 THESIS STRUCTURE

This thesis consists of seven chapters, appendixes and bibliography.

Chapter one is the introduction which contains the growth of Lagos, land use planning in Lagos, monitoring land use change in urban centres, the study area, aims and the research objectives. This chapter also contains the thesis structure.

Chapter two is the literature review. This chapter appraised the global, regional and local trends of urbanisation. It also detailed the monitoring of urban system with Earth Satellite as well as the recent application of remote sensing to urban studies and the review of the techniques of RS/GIS used for urban land use/cover change. Chapter three deals with the data sources and the assessment of the data accuracy or suitability of the available data for urban land use/cover changes in metropolitan Lagos for a scientific research.

However, chapter four establishes the methodologies used to realise the research goals which includes the image processing, classification, change detection and error matrix to access the map products. Chapter five contains the visual analysis of the satellite images, post-classification change detection, the result of image processing and analysis as well analysis of questionnaires and state of land cover and land use in the study area. It also presents the result of questionnaires administered and the Chapter six discusses the summary of land cover and land use change between 1984 and 2002. The relationships between and effects of population growth and urban land use/cover change, was discussed. This chapter also presents the summary of findings. Chapter seven draws the conclusion for this research and presents some recommendations for future research.

CHAPTER TWO: LITRATURE REVIEW

CHAPTER TWO

LITERATURE REVIEW

This chapter begins with the origins of social science that led to the urban studies which gave birth to urban remote sensing. Section 2.2 deals with the global history and trend of urbanization, while its sub sections deal with migration as the major source of urban growth in third world countries and the Nigeria urban centres, the impacts of urbanization in developing countries as well as background information about the Lagos population growth . Section 2.3 deals with urban remote sensing, and includes sub-sections on remote sensing and urban land use/cover change, recent applications of remote sensing to urban land use/cover change and a review of techniques in remote sensing and GIS for urban studies.

2.1 INTRODUCTION

The formative years of the social sciences in the late nineteenth and early twentieth centuries were also the years, in which urban studies first developed, thus providing the context for the geographer's emerging interest in cities (Berry and Horton, 1970). Rapid urban development and dramatic changes of landscape have recently been witnessed in some developing countries as a result of rapid economic development and population growth. The measurement and monitoring of land-use changes in these areas are crucial to government officials and planners who urgently need updated information for planning and management purposes (Yeh and Li, 2001).

A city can be described as a general system with different interconnected subsystems (Laurini 1978, 1979, 1980, 2001) . It can be further explained as a process of economic change, which has accompanied industrial development as well as population increase. Spatially, cities in developing countries continue to expand without proper forward planning for the carrying capacity of the existing housing, infrastructure and services (Adebayo, 2002). The spatial growth which remains inevitable due to the changes in the population and socio-economic activities of urban centres needs to be managed with modern technology with the capabilities to meet the challenges posed by the rapid change and growth pattern of urban centres in this era of globalisation.

Urban growth and land use conversion are major threats to ecosystems. They change natural habitats, disrupt hydrological systems and modify energy flows and nutrient cycles. The environmental effects of urbanization therefore usually include impacts associated with the public and private activities that occur in urban areas. These activities may also be concentrated within a smaller area or be much greater in absolute terms (George, 2002).

2.2 GLOBAL TREND OF URBANIZATION (URBAN GROWTH)

Urban growth is the process of expansion of urban centres spatially brought by the changing economic, social and political activities. The earliest reported and recorded urbanization was ancient Rome, which had an estimated population of 800,000 – 1,200,000 in the third century AD while Elizabethan London numbered about 225,000 people (Hall, 1994). In the nineteenth century, a new kind of city emerged, built on productive power, massed population and industrial technology. This created new problems that led to various social movements, which brought public intervention. That intervention became the root of modern urban planning, which has sought to regulate or direct urbanization in the twentieth century to mitigate the consequences.

Modern urban and regional planning has arisen in response to specific social and economic problems, which in turn were triggered by the Industrial Revolution at the end of the eighteenth century (Hall, 1992). It has been forecast that by the year 2015, more than half of the world's population will be living in urban places (Forbes and Lindfield, 1997). From 1801 to 1911, Britain's urban areas accounted for 94 per cent of the country's population increase (Berry, 1973). Also, one third of the urban growth was due to net migration from rural areas (Lawton, 1972; Berry, 1973). Similarly, in 1990, 77 per cent of the population of North America lived in cities of more than 50,000 people (de Blij and Muller, 1994; Gluch, 2002).

Asia has been the most rapidly urbanizing continent with 589 million people living in urban centres between 1970 and 1990: this represents 56 per cent of the world's urban population increase (Forbes and Lindfield, 1997). Between 1950 and 1975 the urban population of the Third World grew by 400 million (Drakakis-Smith, 2000). Table 2.1 shows the world population distribution by region in 1975, 2000 and 2030. The per cent urban population in Africa and Asia is growing at an alarming rate. Urban growth in Europe (including Russia) throughout the whole of the nineteenth century amounted to some 45 million people, a total exceeded by China alone during the 1980s, though some cities, such as Beijing or Delhi, were considerably more sophisticated than the capitals of the European countries that began to venture overseas in the sixteenth century (Drakakis-Smith, 2000).

Population in Millions

Year	1975		2000		2030		Urban (%)		
Region	Urban	Rural	Urban	Rural	Urban	Rural	1975	2000	2030
Africa	**102**	**304**	**295**	**498**	**787**	**702**	**25**	**37**	**53**
Asia	592	1805	1376	2297	2679	2271	25	37	54
Latin America & Caribbean	198	124	391	498	127	608	61	75	85
Europe	455	221	534	193	540	131	67	73	80
North America	180	64	243	71	335	61	74	77	84
Oceania	15	6	23	8	32	10	72	74	77

Table 2.1: World population distribution by region; 1975, 2000 and 2030.

(Source: United Nations, 2002 (131) Population Reports)

In this new millennium, the challenges of Africa's development are becoming more daunting by the day. The destructive, destabilising and unsettling effects of war, armed conflicts and HIV/AIDS threaten the welfare and well-being of the continent. However, there is a third factor of equally disturbing magnitude: The phenomenon of urbanization and the growth of mega-cities, accompanied by growing poverty, deprivation, hunger, alienation and insecurity. The process of urbanization, once started, continues to gather momentum as more people migrate from rural areas to cities (NPC, 1998). Yet this subject matter has not commanded sufficient attention from political leaders and even development planners, as an urgent development concern (Tibaijuka, 2002). The protection of urban heritage and preservation of rural flora and fauna are desirable (Adejugbe et al., 2004) as the only way to ensure sustainable development and healthy habitats.

2.2.1 Migration to the Cities (Third World Perspective)

In developed countries population movements, rather than natural growth, dictate overall population change in most cities (Drakakis-Smith, 2000). Most of the African major urban centres (metropolis) build on the advantages offered as a political capital established by the colonial masters. One of the major sources of urban population growth in the developing world (Third World) is migration (Todaro, 1994), this is primarily motivated by perceived economic opportunities in the city (Drakakis-Smith, 2000). A strong association between economic and urban population growth has emerged from such theories, although its applicability is limited where examining the trend or nature of urbanization in most African countries, where rural poverty has induced urban migration despite the lack of economic growth in those settlements. Contrary to this, Bangladesh is one of the poor nations and this massive urban shift has not occurred. Also, economic growth in South Korea and Taiwan has rural to urban movement of capital and labour as an important component, while economic growth in Thailand is occurring in a country which is still overwhelmingly rural.

Africa had an urbanization rate of 25 per cent in 1975 (Table 2.1). In the year 2000, this rate was estimated to be 37 per cent, and is expected to reach 53 per cent in 2030. These trends show Africa to be the least urbanised region, while at the same time having the fastest demographic growth rate. Ugokwe (2003) said an analysis of Nigeria's 1991 census showed that 36 per cent of the population lived in 358 urban centres compared to 10.7 per cent in 56 towns and cities in 1953 and 19.3 per cent in 182 urban areas in 1963. So therefore, Africans should focus our attention to urbanization studies because of the associating problems that have already manifested in African urban centres.

2.2.2 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 and Oguntoyinbo, 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 (Daily Trust, 24/04/2004).

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. For instance, the population of Lagos has jumped from 7.7 million in 1990 to 13.4 million in 2000 (Tibaijuka, 2002).

The UN estimates that world urban population will increase by at least 3 billion in the next 50 years (Torrey, 1998). It is projected that by 2015, the population of Lagos will rise to 23.2 million (UN, 1999) when it will be the third largest city in the world, after Tokyo and Bombay. In addition, by 2020, more than 50 per cent of Africa's population will be living in urban areas (Tibaijuka, 2002). 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, 1998). 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 agriculturalisation, industrialisation 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 in short the whole population and socio-economic determinants (Mathew, 1999).

As humankind moves through the twenty-first century, environmental changes are predicted to accelerate, with unknown and potentially devastating consequences (Lunetta, 1999). 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 (Epstein, 1998; Mesev, 2003). In most countries, including the United States, many of the fastest growing urban centres are vulnerable to natural hazards and ecological degradation because of their proximity to coastal and semi-arid environments (WRI, 1996; USCB, 2001; Ramsey, 2003). In Lagos, the nature of migration differs, as there are several million people living outside the territory and working in various part of Lagos. This form of daily or work related movement is causing the authority major transportation problems. This problem is very obvious on every major road leading to Lagos in the rush hour.

2.2.3 Urbanization and its impacts in Developing Countries

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 (Lunetta, 1999). 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 (Lunetta, 1999) as well as looming urbanization problems in worldwide but developing countries in particular.

Urban planners and geographers, as well as social scientists investigating the impact of economic and demographic growth on urbanization (Smutny, 2002) 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 (Donnay, 1999; Weber, 2001; Bahr, 2001; Grey and Luckman, 2003). 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 (Barnsley et al., 2001). This is especially so within developing countries (Baudot, 2001; Grey and Luckman, 2003) and Lagos is no exception.

2.2.4 Lagos' rapid population growth and projection 1950 – 2015

Lagos population growth is dated back to the time of missionary and colonial rules. The rapid population growth started in 1950 and since then there has not been any sign this will halt. The growth rate of Lagos, 1975 – 2000 was 5.6% per annum which was the highest among the 10 most populous urban agglomerations in the world. The estimated 3.7% per annum for 2000 – 2015 also remains the highest compared to other urban agglomerations. The population increase in Lagos was 1,046% between 1950 and 1975 and 306% between 1975 and 2000. The metropolis doubled its population every 10 years (Table 2.2). Though there is a significant reduction in the estimated growth rate per annum for 1975-2000 and 2000-2015 Lagos still remains the highest when compared with other urban centres. The annual population change average at global, continental, regional, national and metropolitan level was compared. Lagos' annual change rate remains the highest throughout the period (1950 – 2015). Lagos' figures are well above the global, continental, regional as well as national average (Table 2.3). This underlines the rapid population growth in metropolitan Lagos see figure 2.1 also.

Urban Agglomeration	**World Ranking (2000)**	**Population in Millions**			**Growth Rate (%)**	
		1975	**2000**	**2015**	**1975-2000**	**2000-2015**
Tokyo	1	19.8	26.4	26.4	1.2	0.0
Mexico City	2	11.2	18.1	19.2	1.9	0.4
Bombay	3	6.9	18.1	26.1	3.9	2.4
Sao Paulo	4	10.0	17.8	20.4	2.3	0.9
New York	5	15.9	16.6	17.4	0.2	0.3
Lagos	**6**	**3.3**	**13.4**	**23.2**	**5.6**	**3.7**
Los Angeles	7	8.9	13.1	14.1	1.5	0.5
Shanghai	8	11.4	12.9	14.6	0.5	0.8
Calcutta	9	7.9	12.9	17.3	2.0	1.9
Buenos	10	9.1	12.6	14.1	1.3	0.7

Table 2.2: Urban agglomeration population and growth rates.

Source: UN (1999)

Area	1950-1955	1960-1965	1970-1975	1980-1985	1990-1995	2000-2005	2010-2015
World	3.02	3.08	2.63	2.67	2.35	2.09	1.91
Africa	4.38	4.83	4.40	4.37	4.15	3.56	3.18
West Africa	5.13	5.36	5.32	5.40	4.94	4.22	3.53
Nigeria	4.65	5.49	5.49	5.50	5.35	4.35	3.39
Lagos	**9.74**	**7.97**	**5.81**	**6.16**	**6.01**	**5.02**	**3.87**

Table 2.3: Average urban population growth at global, continental, regional, national and local level.

Source: UN (2003)

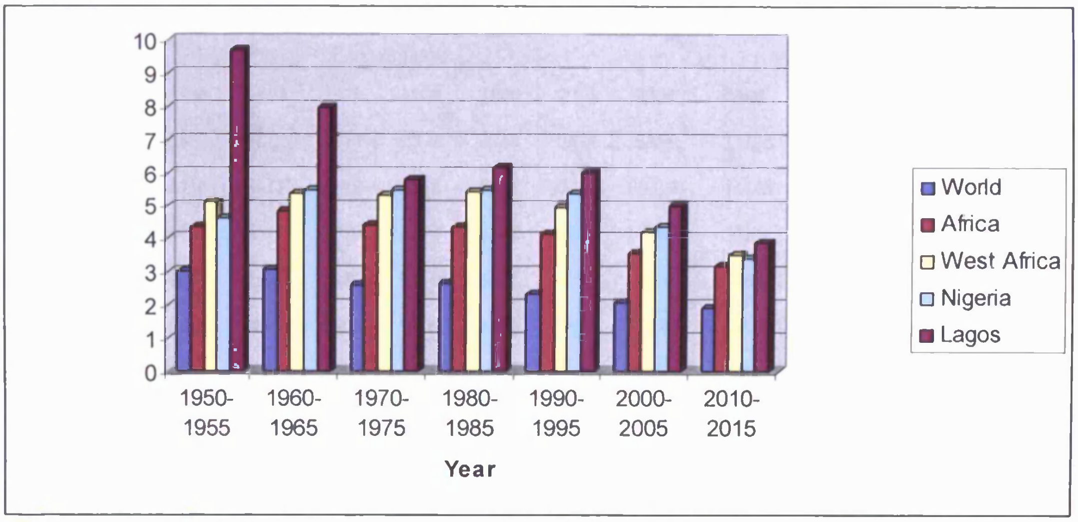

Figure 2.1: Graphical representation of average urban population growth at global, continental, regional, national and local level.

Table 2.4 shows the population estimates (in thousands) of the ten most populous urban centres in Africa in 2005 and their projected populations for the year 2015. The table shows the steady rise in population in the 1950s and 1960s. Lagos doubled her population almost every decade. Population growth became rapid from 1970s to reach a growth rate of over 80% (Table 2.4). The main reason for the increase in population is migration rather than natural population growth. If the trend of population growth is sustained at the current rate Lagos will be the most populous urban agglomeration in Africa and sixth in the world by the year 2010

(UN, 2003). The 2005 population estimates puts Lagos' population on the same level as Cairo, which has the most urban agglomeration population in Africa. Cairo had an urban population of 2.4 million people when Lagos was about 288 thousand people in 1950 (Table 2.4). Most of the urban centres with similar or even higher population figures in 1950 had not reached the 5 million mark in 2000 when Lagos was approaching 10 million people. The African urban population table shows that Lagos' population growth is the highest despite the fact that there are reported higher numbers and rates of urban population growth in the African continent and sub-Sahara region in particular.

City	1950	1960	1970	1980	1990	1995	2000	2005	2010	2015
Lagos	288	762	1414	2572	4764	6434	8665	11135	14037	17036
Cairo	2436	3811	5579	7338	9061	9707	10396	11148	12036	13123
Kinshasa	173	451	1370	2197	3392	4099	4745	5717	7096	8886
Alexandria	1037	1504	1987	2519	3063	3277	3506	3760	4074	4489
Casablanca	625	987	1505	2109	2685	2994	3344	3743	4168	4579
Abidjan	59	180	553	1264	2102	2535	3057	3516	3975	4432
Kano	107	229	346	1189	2095	2337	2596	2884	3242	3689
Ibadan	427	570	740	1290	1782	1965	2160	2375	2649	3001
Cape Town	618	803	1114	1609	2155	2394	2715	3103	3205	3239
Addis Ababa	392	519	729	1175	1791	2157	2491	2899	3429	4136

Table 2.4: African major urban agglomerations; population estimates and projections.

Source: revised 1999 population estimates UN (2003).

Table 2.5 shows the selected major urban centres in Nigeria and compares the growth of Lagos to the national and general pattern of urban growth in the country.

City	1950	1960	1970	1980	1990	2000	2010	2015
Lagos	288	762	1414	2572	4764	8665	14037	17036
Kano	107	229	348	1189	2095	2596	3242	3689
Ibadan	427	570	740	1290	1782	2160	2649	3001
Kaduna	28	99	177	559	961	1194	1498	1711
Benin City	46	83	119	415	738	918	1153	1318
Port Harcourt	58	135	212	451	680	846	1063	1216
Ogbomosho	113	260	381	489	623	829	1117	1301

Table 2.5: Nigerian major urban agglomerations 1950-2015.

The graphical representation (Figure 2.2) shows Lagos' geometric population growth while other urban centres in Nigeria have arithmetic growth rate. The graph shows the arithmetic population growth curve for other urban centres and it is noticeable that the curve shows the same pattern of growth between urban centres before the 1970s. However since then Lagos has experienced exponential population growth with many socio-economic and planning problems accompanying it.

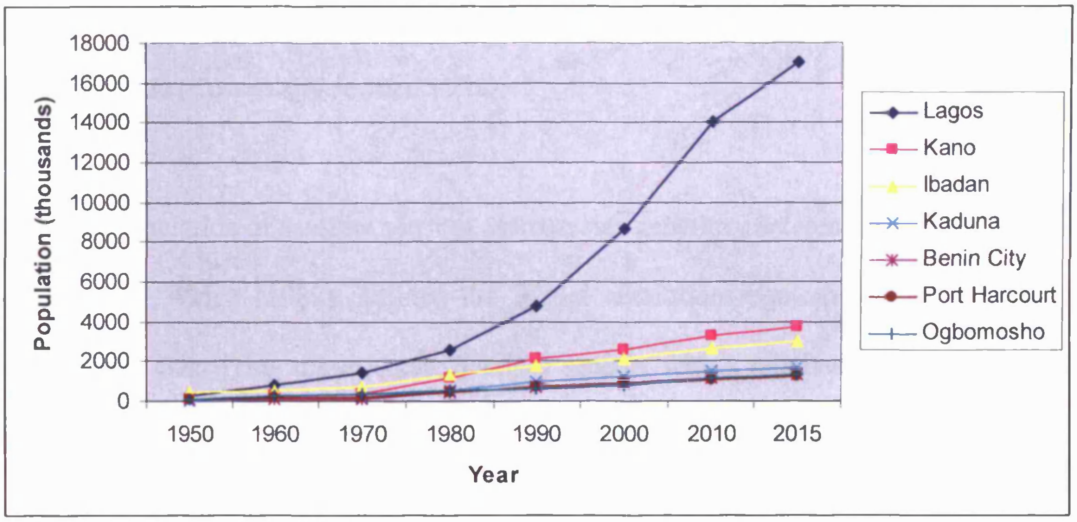

Figure 2.2: Graphical representation of population growth of Lagos and major Nigerian urban centres.

2.3 MONITORING THE URBAN SYSTEM WITH EARTH SATELLITE

Remote sensing provides an opportunity to measure attributes of urban and sub-urban environments and record the data in accurate digital maps and files suitable for analysis within Geographic Information Systems (GIS). This data, together with data available from ground-based observations, can be used to monitor changes in space and time, to develop and validate dynamic models of urban development, and to forecast future land-use patterns and changes in other urban attributes (Cowen and Jensen, 1998). The complex composition of urban landscape materials (water, grass, asphalt, soil, plastic, asbestos, concrete, shingles etc.) poses a big challenge to urban remote sensing feature extraction and classification. The study of residential expansion has a long history that is closely linked to early models of the internal structure of cities, in which an urban area is viewed as a series of concentric rings, sectors, or multiple nuclei (Harris and Ullman, 1945; Cowen and Jensen, 1998). The early models treated the rate of expansion of cities as a struggle between a series of centrifugal and centripetal forces. The past decades have witnessed much research into modelling of this process with empirical data (Cowen and Jensen, 1998).

The new generation of satellite sensing systems has generated interest in the remote sensing of urban areas. Welch (1982) outlined the spatial resolution requirements of remotely sensed imagery for classifying urban areas. Satellite sensors with a relatively fine spatial resolution, such as those carried on the SPOT or Landsat satellites, have considerable potential in urban studies (Weber, 1994). Fine spatial resolution data should be appropriate for the study of urban areas (Foster, 1985) as each pixel is more likely to contain a single land cover type, and the high spatial resolution data will provide additional detail and increase the potential range of any signal and thereby the spectral variability of each land cover class (Weber, 1994).

Welch (1982) stated the spatial resolution that is considered appropriate for urban classification. He believed that finer spatial resolution imagery would be ideal for urban high classification accuracy, but recent advances in spatial resolution of satellite images have not really brought about the much heralded improvement in urban classification accuracy. This is because most of the urban features detectable by the sensors are bigger than the one metre or the metre resolution of the images, hence increasing the pixels that are erroneously classified.

Aplin (2003) concluded that spatial resolution requirements for urban areas will vary considerably according to land use and location and, as such, any urban classification analysis should be considered in the context of its study areas. In addition, there will also be variation in the spatial resolution requirements for different reasons (applications) i.e. why urban areas have been classified in the first place. For instance, urban classification for the purpose of land use or land cover change detection and resource planning and allocation (distribution of social amenities) will require higher spatial resolution than the former. While it may be possible to employ or adapt existing per-pixel classification algorithms to produce maps or land cover for urban areas from very fine spatial resolution images, deriving information on urban land-use is normally much more problematic (Eyton, 1993; Barnsley and Barr, 1996; Barnsley and Barr, 1997). This is because land use is an abstract concept – an amalgam of economic, social and cultural factors – one that is defined in terms of function rather than physical form (Barnsley and Barr, 1997).

In India, unprecedented population growth, coupled with unplanned developmental activities, has led to urbanization lacking in infrastructure facilities (Sudhira and Ramachandra, 2002). Sudhira and Ramachandra (2002) applied standard processes for the analysis of satellite imagery, such as extraction, restoration, classification, and enhancement for the study of urban sprawl growth. Also, the Maximum Likelihood Classifier (MLC) was employed for the image classification. Shan (1999) used multi-temporal land use information of the central city of Shanghai through aerial photos to explore the dynamics of urban spatial structure. The interpretation of aerial photos of 1958, 1984 and 1996 in a GIS revealed the quantitative and structural characteristics of land use change. This was analysed through concentric and sector methods. Based on such analysis, a conceptual model of the spatial structure of Shanghai was developed (Shan, 1999). This revealed the city's shift from the secondary industry to the tertiary/secondary/primary industry development series: urban land use structure has undertaken profound change. While urban sprawl at the fringe and urban renewal in the inner city appear at the same time, the spatial pattern of the city is transforming from a uni-centre to a multi-nuclei one (Shan, 1999). Tachizuka et al. (2002) have experimented in monitoring urban expansion in the Bangkok Metropolitan Region using a linear mixture model. The results seem to have reasonable accuracy.

However, the process known as daysmetric mapping was used by Langford et al. (1990) in generating urban population density models in north Leicestershire, UK, by both eliminating non-urban land cover through image classification and establishing a density relationship between census counts and built land cover (Mesev, 2003). Multi-layer perceptrons were used by Jonathan et al. (2001) for change detection and it was found that a Neural Network-base method is superior to conventional techniques. However, to choose the best algorithms for a specific task, users are advised to consider not only classification accuracy, but also comprehensibility, compactness and robustness in training and classification. King (1989) tried sophisticated statistical procedures and applied them to remote sensing for land cover mapping, but found that the accuracy was very low.

Researchers have tried combining statistical and visual interpretation methods to improve accuracy. Others have tried remote sensing mapping and applied a statistical classification, but have not been successful because it is very difficult to relate the classification to reality. The problem lies with the statistical procedures that generally ignore shape, size, position and association, all of which are fundamental. King (1989) opined that successful mapping depends on knowing what the characteristics of each land cover type are, and using that information to define the appropriate mapping methodology. Different methodologies are required for land cover types with significantly different characteristics.

The integration of remote sensing and socio-economic data has been given a big boost with the daysmetric approach (Langford and Unwin, 1994). Lo (1995) used linear regression models and an allometric growth model for accurate monitoring by calibrating population and housing statistics with spatially aggregated image data. Some other studies demonstrated that urban classification was more accurate using Landsat MSS imagery than Landsat TM imagery (Toll, 1985) or even SPOT HRV imagery (Martin et al. 1988) because although spatial resolution was still more coarse than most urban features, there would now be more pixels erroneously classified, adding to the overall increase in "noise" (Aplin, 2003).

The material composition and non-uniformity of urban areas makes it impractical to advocate a general classification system, because of the diversity within and between urban landscapes that makes them so difficult to classify. However, the variation that makes classification so difficult for cities does not stop with internal features, as they also vary externally (between cities) according to location (Aplin, 2003). The expansive urban landscapes characteristics of North America (Masek et al., 2000) contrast markedly with densely packed European cities

(Forster, 1983), sprawling Asian "mega-cities" (Chen et al., 2000; Ji et al., 2001; Aplin, 2003) and congested African cities.

Rogan et al. (2003) monitored land-cover change in San Diego County (1990-1996) using multitemporal Landsat TM data. Change vectors of Kauth Thomas features were combined with stable multitemporal Kauth Thomas features and a suite of ancillary variables within a classification tree classifier. A combination of aerial photo interpretation and field measurements yielded training and validation data. Maps of land-cover change were generated for three hierarchical levels of change classification of increasing detail: change vs no-change; four classes representing broad increase and decrease classes; and nine classes distinguishing increases or decreases in tree canopy cover, shrub cover and urban change. This provided information for magnitude and direction of land-cover change. Overall accuracies of the land-cover change maps were between 72 and 92%.

Multispectral image data represents spatially and spectrally sampled quantized measurements of the radiation emanating from a collection of three-dimensional objects on the earth's surface (Barnsley and Barr, 1997b). Consequently, while the detected spectral response associated with each pixel is often related in a reasonably direct way to the physical and chemical properties of the objects present within the corresponding scene (i.e. to land cover), the relationship with land use is, in most instances, both complex and indirect (Barnsley and Barr, 1997b).

Despite this, many categories of land use have a characteristic spatial expression, which may be identified in fine spatial resolution remotely sensed images. For instance, residential districts in many western European towns and cities are often characterised by a complex spatial assemblage of tile-roof and slate-roof buildings, as well as tarmac and concrete roads, interspersed with gardens comprising grass lawns, bare soil and trees. Identification of these features and their spatial pattern is one of the human photo-interpretation techniques developed over time. If this process could be formalised, and the features and patterns measured in digital remotely sensed images, it might be possible to develop an automated or semi-automated system for urban land-use mapping (Barnsley and Barr, 1997).

Yeh and Li, 2001, used entropy to measure and monitor urban sprawl with the integration of remote sensing and GIS. The entropy measurement was based on two location factors - distances from town centres and roads – to capture and reveal spatial patterns. Its application in the Pearl River Delta in China was very successful. Its strength lies in quantitative measurement in identifying the spatial variations and temporal changes of urban growth and sprawl patterns (Yeh and Li, 2001).

2.3.1 Remote Sensing and Urban Land Use/Cover Change

The history of remote sensing is very brief, and dates back about six decades when aerial photography started being used as an effective mapping tool. There were several scientific and governmental efforts on inventories into land use and land cover in the early years of the last century which were based on the mobilisation of huge numbers of participants (Stamp, 1948; Korram et al. 1999), but modern remote sensing started in the 1930s, first from aircraft and later from satellites, and these have been the principal means by which land cover is observed, categorised, recorded and quantified (Khorram et al., 1991; Ediriwickrema and Khorram, 1997; Dobson et al., 1995; Khorram et al., 1999).

Urban land use/cover change detection has two main targets. These are differences between images from two dates (or any other sources of change data) can demonstrate patterns associated with a particular theory of environmental change, or the analysis could lead the investigation to reject that theory in favour of some other that might fit the evidence more closely (Khorram et al., 1999). Change detection is useful in many applications such as land use changes, habitat fragmentation, rate of deforestation, coastal change, urban sprawl and other cumulative changes through spatial and temporal analysis techniques such as GIS (Geographic Information Systems) and remote sensing, along with digital image processing techniques (Ramachandra and Uttam, 2004).

Land cover changes are divided into two major categories. These are conversion between land cover types (between-class changes) or within land cover types (within-class change). The first occurs when there is a complete shift from the initial land use/cover to another type, for example, a change from forest to urban land use/cover. The second type of change occurs when there is a change in the quantity of the component that makes up that particular class type, for instance, transformation of residential land use/cover to commercial.

To effectively map the change of either of the two land use/cover types mentioned above successfully with remote sensing, an appropriate technique(s) must be applied as well as suitable data used for urban land use/cover change detection project.

2.3.2 Recent Application of Remote Sensing to Urban Studies

The characterisation and classification of urban areas has received attention since the early Landsat years with MSS data (Gluch, 2002). Earlier efforts can be traced to the work of Gordon, 1980, Forster, 1980, Jensen and Toll, 1982, Forster, 1983, Ridd et al., 1983 and many more. Technological advancements and improved data qualities (higher spatial, temporal and radiometric resolution) saw many research into the field of urban remote sensing (Lo, 1985; Aplin et al., 1999; Aplin, 2003; Langford, 2003), for instance, spatial and spectral data merging (Welch and Ehlers, 1987; Chavez et al., 1991; Zhang, 2001), sophisticated image processing techniques (Martin, 1989; Fung and Zhang, 1989; Gong and Howarth, 1990; Gong et al., 1992; Mouat et al., 1993; Kwarteng and Chavez, 1998; Li and Yeh, 1998; Mather, 1999; Zhang, 2001; Ji et al., 2001; Gluch, 2002; Langford, 2003), and land cover/use change detection (Weismiller et al., 1977; Toll et al., 1980; Colwell and Weber, 1981; Howarth and Wichware, 1981; Ingram et al., 1981; Hall et al., 1991)

Lillesand et al. (2004) regards the classification process as spectral pattern recognition, though the decision rules may be based on the geometric shapes, sizes and patterns present in the image data. Langford (2003) refined daysmetric mapping, and Lo (2003), zone-based estimation of population with allometric growth model. Batty and Howes (2001) supervised classification for the Buffalo metropolitan region, USA, and Barnes et al. (2001) image processing and classification for urban growth and sprawl detection, mapping and analysis.

Seto and Liu (2003) used ARTMAP and Neural Network Classification to compare with the traditional Bayesian Maximum Likelihood Classification. The ARTMAP achieved higher accuracy with 84 per cent while Bayesian achieved 76 per cent for urban change using either coarse or fine resolution data. Ozkan and SunarbErbek (2003) conclude that Artificial Neural

Network classification with Landsat imagery and synthetic normal and uniformly distributed data, the selection of activation functions plays an essential role in the classification higher accuracy in their study. For the one-hidden layered networks, the tangent hyperbolic activation function is superior to the sigmoid activation function. Furthermore, a network with the tangent hyperbolic function in the hidden layer and the linear function in the output layer was seen as the optimum choice among these networks, while the combination of sigmoid and linear functions also gave good accuracy. For the two-hidden layered networks, though the homogeneous combinations of sigmoid and tangent hyperbolic functions were seen as the optimum choices, the hybrid combinations of sigmoid, tangent hyperbolic, and linear functions were also optimum choice. The sigmoid function is the common function used in the processing of remotely sensed multispectral imagery but the tangent hyperbolic function is also comparable to and can even be superior when using the multi-Layer Perceptron network trained with the scaled conjugate gradient back-propagation learning algorithm.

Thematic assessment of urban growth involves procedures of monitoring and mapping which require robust methods and techniques. Conventional surveying and mapping methods cannot deliver the necessary information in a timely and cost effective mode. Given their technological robustness, remote sensing technologies are increasingly affecting urban land-use change research (Geoghegan et al., 1998; Civco et al., 2000; Yang, 2002). The heterogeneous nature of urban environments, with substantial inter-pixel and intra-pixel changes, are the biggest challenge to the applicability and robustness of these methods and technology (Mickalac, 1993; Kam, 1995; Yang, 2002). Some of these methods are listed below:

- The development of enhanced classification approaches ranging from knowledge-based expert systems (Moller-Jensen, 1990), artificial neural networks (Civco, 1993), fuzzy logic (Ji and Jensen, 1996), to genetic algorithms (Zhou and Civco, 1996).
- The use of pre-classification image transformation and feature extraction techniques, such as median filtering (Sadler et al., 1991) and various measures of image texture (Franklin and Peddle, 1990).
- The incorporation of spatially referenced ancillary data into the classification procedure (Ehlers et al., 1990).
- The application of post-classification spatial processing ranging from modal filtering (Booth and Oldfield, 1989) to contextual reclassification (Gong and Howard, 1992; Barnsley and Barr, 1996)

Lo and Yang (2002) integrated Landsat images and census data in a zone-based cellular approach to analyse the drivers of land-use/land-cover changes in Atlanta, Georgia. It revealed rapid increases in high-density and low-density urban use at the expense of crop and forests during this period of rapid population growth. They also used Landsat MSS, TM, ETM+ images of 1973, 1979, 1987, 1993 and 1999 to study the drivers of rapid population growth of the 13 metro counties of the Atlanta metropolitan area.

Civco et al. (2002), developed an urban growth model that quantifies and categorises urban change. This model uses land cover information as its source data. Hung and Ridd (2002), developed a supervised classifier to estimate ground component percentages from Landsat TM images of urban areas. They applied this technique to a 1990 TM image covering portions of the Salt Lake City area, Utah. The calculated accuracy shows a significant relationship between the estimated and surveyed percentages. Of the six correlation coefficients, two have strong relationships, three have moderate relationships and one has a weak relationship.

2.3.3 Review of Techniques in RS/GIS for Urban Land Use/Cover Change

Historically many efforts have been made to estimate population and delineate urban extent by the use of daytime aerial photography and satellite observations (Clayton and Estes 1980; Foster, 1985; Ali, 1993; Sutton et al., 2001) as well as night-time satellite imagery. There have been limited successes but night-time imagery has been able to provide a profound focus on those areas of the earth where human activity dominates the landscape (Sutton et al., 2001). There has been availability of DMSP OLS data in digital format since 1992. The digital format and dramatic strides in computational capability have allowed for production of substantially improved data products (Sutton et al., 2001). Digital versions of the DMSP OLS imagery have been used to map human settlements globally (Elvidge et al., 1997), map urban extent nationally (Imhoff et al., 1997), and have been strongly correlated to population and energy consumption at nationally aggregated levels (Elvidge et al., 1997). Also, a recently developed dataset that incorporates weighted averages of several gain settings of the satellite (low-gain data) shows great promise for not only estimating city population but actually producing good estimates of the variation of population density within the urban centres (Sutton, 1997; Elvidge et al., 1998; Sutton et al, 2001) as well as determination of various land use and land cover within urban centres.

Regional and municipal planners require up-to-date information to effectively manage land development and plan for change. In urban areas, particularly at the rural-urban fringe, this change is very rapid (Treitz et al., 1992). The changes that occur to the urban core as well as the surrounding metropolitan areas are significant and commonly detectable even with moderate to low spatial resolution satellite data (Anderson et al., 1976; Haack et al., 1987; Stefanov et al., 2001; Ramsey, 2003). Remote sensing and Geographic Information Systems (GIS) technology is appropriate for monitoring and creating such types of information systems at regional, national and international levels. These are useful tools for physical and socio-economic planners to evaluate and monitor the land use change, demographic conditions, growth trends, utilities, services and resources in a multi-disciplinary approach for timely results with cost less than traditional mapping methods. Remote sensing has been recognised as a useful means of supplying up-to-date information on activities within the urban environment, including the rural-urban fringe (Ehlers et al., 1990; Forster, 1985; Jensen and Toll, 1982; Treitz et al., 1992) due to its revisit capabilities to provide data to adequately monitor and detect changes between the revisit times. The change in land use from rural to urban is monitored to estimate population, predict and plan direction of urban sprawl for developers, and monitor adjacent environmentally sensitive areas or hazards (CCRS, 2001). From the mid-1940s, when the management of the United States of America's natural resources began seriously, three major types of data were considered essential as fundamental sources of information: imagery, maps, and descriptive attribute and statistical data (Barker, 1988). The integration of the above three data types into computer based information systems, and advances in the development of models plus research into computer aided spatial information led to the full development of Geographic Information Systems (GIS).

The introduction of satellite imagery provided a great boost to the monitoring and management of environmental resources, for satellite images of a place acquired at different times can be compared to detect changes that have taken place over time. Given its rapid retrieval and global availability, satellite remote sensing is an ideal means for producing measurements from which to monitor various aspects of urban dynamics (Donnay and Barnsley, 1999).

Land use change detection using remote sensing data (satellite and aerial) and analysis using GIS have been applied to both rural and urban areas. Land cover mapping and monitoring provide input data into Geographic Information System (GIS) derived models of infrastructure modifications, utility needs, economic development, and the potential vulnerability of the population to natural hazards and environmental damage (Lindgren, 1985; Martin et al., 1988; Treitz, 1992; Lyon et al., 1998; Balmford et al., 2002; Ramsey, 2003). The method is very efficient for assessing the change or degrading trends of a region. Remote sensing change detection involves the use of multi-date (time series) aerial photos or satellite imageries of the study area, from which land use/cover maps can be generated by visual interpretation or digital image processing. GIS analysis will give the actual area of each land use class, and the area changed, through the overlay operation (Matthew, 1999).

Remote sensing has been accepted as an excellent tool for mapping, monitoring and modelling of environmental variables and processes. With respect to temporal flexibility, remotely sensed data is the only source that can constantly, with relatively consistent accuracy, and allowing for atmospheric conditions, produce data over the same area as frequently as every 16 days from Landsat, and every 26 days from SPOT (Mesev and Longley, 1999). The advantages of remotely sensed data may be summarised in terms of the type of data representation, data accuracy, temporal flexibility, spatial coverage and appropriateness in terms of modelling expediency (Mesev et al., 1999). Especially for developing countries, remote sensing offers unique access to primary data about the status of the land surfaces. Satellite or airborne images give urban planners synoptic views of large areas, which allow them to lay plans for urban expansion effectively (Mah, 2000). Platforms that have been utilized to record remotely sensed images are predominantly aircraft and satellites (Ehlers, 1997).

In addition, remote sensing and GIS can be used separately or in combination for application in urban studies. In the case of a combined application, an efficient, even though more complex approach is the integration of remote sensing data processing, GIS analyses, database manipulation and models into a single analysis system (Michael and Gabriela, 1996; Sudhira and Ramachandra, 2002). GIS techniques must be employed to integrate diverse spatial data sources, extract information, and convey that information to decision makers in an effective fashion (Star et al., 1997).

The integration of GIS and remote sensing with the aid of models and additional database management systems (DBMS) is the technically most advanced and applicable approach today (Sudhira and Ramachandra, 2002). The basic technical need for integrated processing of remotely sensed data and GIS data is that they be spatially referenced. In doing this there are four major data sources that need to be considered: cartographic data, socio-economic data, field data and image data (Ehlers, 1997). By developing a temporal sequence of remote sensing data products, information for monitoring and management can be provided to the decision and policy-making processes. Geographic information systems provide users with tools for effective and efficient storage and manipulation of remotely sensed and other spatial data for scientific, management and policy oriented information (Star et al, 1997).

There are several problems associated with urban remote sensing, ranging from spectral and spatial to temporal as well as algorithm, to adequately extract features and derive information from the complex urban environment with mix-pixel. Urban land is typically composed of features that are smaller than the spatial resolution of the sensors: a complex combination of buildings, roads, grass, trees, soil, water etc. (Lu and Weng, 2004). To comprehend the problems associated with the remote sensing of urban areas, the spatial, spectral and temporal properties of remotely sensed data must be considered with respect to the morphological characteristics of these areas (Jensen, 1981; Weber, 1994). However, recent satellite sensing systems have generated an interest in the remote sensing of urban areas. Satellite sensors with a relatively fine spatial resolution, such as those carried on the SPOT or Landsat satellites (Weber, 1994) have been used in numerous urban studies.

The study of land use and land cover is important for many planning and management activities in urban centres, and it is considered an essential element for modelling and understanding the earth as a system (Lillesand et al., 2004). Currently, researchers have developed land cover maps from local to national to global scales for various environmental purposes. The formulation of governmental policies and programmes by urban and regional planners requires continuous acquisition of data about the earth's surface to meet the challenges of rapid changes on the earth's surface, especially in urban areas as a result of rapid urbanization taking place, mostly in the developing countries. It is known that one of the major factors responsible for the lack of performance of several urban and regional planning agencies is lack of technical know-how and their inability to adequately monitor the growth of cities, towns and villages in a timely, accurate and cost-effective manner. This leads to a poor performance of their basic environmental and natural resource planning role in the social, economic, and cultural domain (Lillesand et al., 2004).

Research has been carried out on the use of remotely sensed data to overcome some of the above urban planning and management failings, though these efforts are mostly focused on settlements in the developed countries. For instance, the DMSP OLS data was used as a feasible method for determining the aerial extent of urban areas as well as population. The result showed that urban areas showed a strong relationship with their corresponding total populations (Sutton, 1998). A relationship between areal extent and city population was discovered by Tobler (1965) and Nordbeck (1969). The identified urban centres population was aggregated on a nation-by-nation basis to estimate the population of the 22,920 urban clusters that exist in the Nighttime satellite image. The sum of these estimates is a total estimate of the global human population, which in this case was 6.3 billion. This is close to the generally accepted contemporaneous (1979) estimates of the global population, which stood at approximately 5.9 billion (Sutton et al., 2001).

As the earth's population increases and national economies continue to move away from agriculture based systems, cities will grow and spread (CCRS, 2001). Hence, the need for scientific methods to adequately monitor the land use/cover change that follows, because of the many effects on sustainable environmental development.

CHAPTER THREE: DATA SOURCES AND THE ASSESSMENT OF MAP ACCURACY

3.1 Data Sources and Methods of Analysis.

3.1.1 Census Data.

3.1.2 Remotely Sensed Data.

3.1.3 Questionnaire.

3.1.4 Field Photographs.

3.1.5 Global Positioning System (GPS) Data.

3.1.6 Secondary Data: Lagos Land Use Map.

3.2 The Accuracy Assessment.

3.2.1 Accuracy Assessment of data used.

3.2.2 Updating the Lagos State Land Use Map.

CHAPTER 3

DATA SOURCES AND THE ASSESSMENT OF MAP ACCURACY

This chapter deals with the data sources and the assessment of data accuracy. Section 3.1 details the data sources for the research. It also covers the research primary data generated from site visits and the Lagos land use map update. Section 3.2 describes the accuracy assessment of the data used.

3.1 DATA SOURCES AND METHODS OF ANALYSIS

The data is a representation, abstraction or model of reality (Gatrell, 1991; Burrough and McDonnell, 1998; Atkinson and Tate, 1999). This research involved a number of different types of data such as remotely sensed satellite images, maps, field surveys, analysis of census and population data. In most environmental sciences there are two main strategies for collecting data: systematic inventory and ad hoc, project-based data collection (Burrough, 1997). An overview of each data set used is now presented. A detailed description of the methods of satellite data acquisition and processing is given in section 3.2. In general, change detection involves the application of multi-temporal datasets to quantitatively analyze the temporal effects of the phenomenon. However, change detection in urban areas has until recently been very difficult with the spatial resolution of image data available and the size of many features of the urban landscape.

Remote sensing data has become the primary data source for detecting land use and land cover since the 1970s (Lu et al., 2003), because of the advantages of repetitive data acquisition, its synoptic view capability and digital format suitable for computer processing. Advances in remote sensing and geographic information science have made the integration of ancillary data with remotely sensed data possible, to achieve the spatial, temporal and spectral requirements for urban classification and analysis. Automated land cover classification accuracy is often enhanced through the use of multidate data sets. In many applications the use of multitemporal data is required to obtain satisfactory cover type discrimination (Lillesand et al., 2004). The extent to which this technique improves classification accuracy is dependent on the cover type involved, timing of dates of imagery, and numbers of images as well as the classification algorithm used.

The Lagos State Government gave approval for the Proposed Land Use Map 2001 to be used for this research and the National Population Commission released a copy of both the 1963 and the 1991 population censuses for the purpose of academic research. In addition, the University of Leicester purchased SPOT 2001 imagery which was also used. This automatically conferred the right to use the data for this project. Other ancillary data used was from primary sources e.g. GIS database, photographs and ground control points (GCPs).

3.1.1 Census Data

The population data used in this research is based on population projections from the United Nations population division, as there has not been a regular and accurate enumeration programme in Nigeria during the 20th century. The 1963 and 1991 population censuses are the only officially published population figures for Lagos in particular, and Nigeria in general. The population for Lagos was both interpolated and extrapolated using population growth rates for Lagos (6.4% per annum) with the 1963 and 1991 census data (Table 3.1). The projected population is supported by the United Nations population projection for Lagos. The major problem encountered with the use of projected population is the continuous change in the boundary of Local Government areas in Lagos State. This problem made it impossible to use local government areas in the analysis section. Also, the population figure relied solely on the United Nation population projection for Lagos as the census data remained unacceptable due to widespread irregularities during the enumeration exercise.

Year	1950	1960	1975	1980	1990	1995	2000	2005	2010	2015
UN	288	762	1890	2572	4764	6434	8665	11135	14037	17036
NPC	288	762	1890	-	5522	-	7401	8593	9944	11471

Source: UN, 2001, NPC, 1998

Table 3.1: Population Growth and Projection in thousands.

3.1.2 Remotely Sensed Data

Considerable effort was put into selecting cloud-free data sets and to get data near the same date and the same season because of seasonal difference effects on the images for classification and change detection. The selected satellite images fall within the same season in Lagos, section 1.2 refers for climatic condition. In fact, these images are cloud free they were acquired between 18th December and 6th February. However, Table 3.2 give detail information about the satellite images used in this research. Table 3.3 shows the LANDSAT (TM and ETM) and SPOT image bands and their corresponding wavelength.

Platform (Sensor)	Path/Row	Date	Spatial Resolution	Temporal Resolution	Radiometric Resolution	Spectral Resolution
Landsat 5 (TM)	191/055	18/12/1984	30 metres	16 days	8 bit	3 visible, 1 NIR, and 2 mid-IR bands
Landsat 7 ETM	191/055	06/02/2000	28.5 metres Pan. 15 metres	16 days	8 bit	3 visible, 3 NIR, and 1 Thermal band
SPOT (HRV2)	067-337	17/01/2002	10 metres (Panchromatic)	14 Days	8 bit	

Table 3.2: Satellite images used.

Sensor Band	Band 1	Band 2	Band 3	Band 4	Band 5	Band 6	Band 7	Band 8
TM	0.45- 0.52	0.52 – 0.60	0.63 – 0.69	0.76 – 0.90	1.55 – 1.75	10.4 – 12.5	2.08 – 2.35	N/A
ETM+	0.45 – 0.52	0.53 – 0.61	0.63 – 0.69	0.78 – 0.90	1.55 – 1.75	10.4 – 12.5	2.09 – 2.35	52 - .90
SPOT	0.12 - 0.90							.

Table 3.3: Landsat and Spot satellite images wavelength and corresponding bands.

Landsat TM, 1984: The image was downloaded from the University of Maryland website (http://glcfapp.umiacs.umd.edu:8080/esdi/index.jsp). Permission was granted to use the data for the purpose of academic research. The image had been processed to level L1G, which includes orthorectification and terrain correction. There are 7 bands in this image. The image was projected to WGS 84 Earth Spheroid, Zone 31.

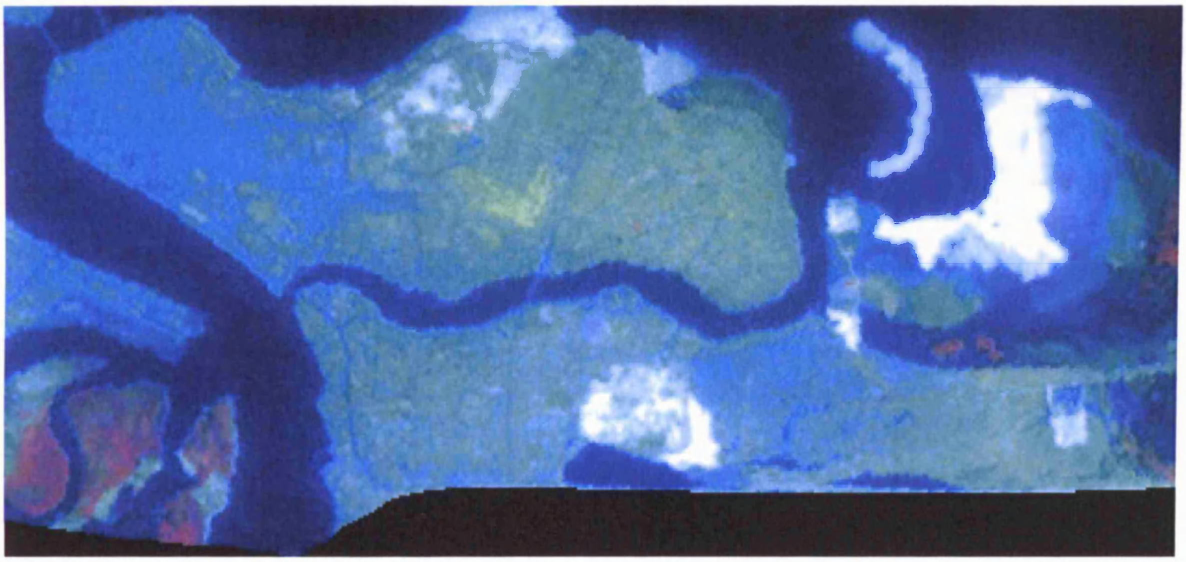

Figure 3.1: Landsat TM, Data Coverage of Lagos Island and Ikoyi acquired on 18/12/1984 (RGB combination).

Landsat 7 ETM+ 2000: This image was downloaded from the University of Maryland website (http://glcfapp.umiacs.umd.edu:8080/esdi/index.jsp). The image was acquired on 06/02/2000. The image is 30 metres by 30 metres for bands 1, 2, 3, 4, 5 and 7, band 6 is 60 metres, and band 8, which is panchromatic, is 15 metres. The image had been pre-processed which includes radiometric correction, geometric correction, bad line replacement and scan gap correction. The sun elevation angle is 51.5 and azimuth angle is 126.8. Table 3.3 refers for detail.

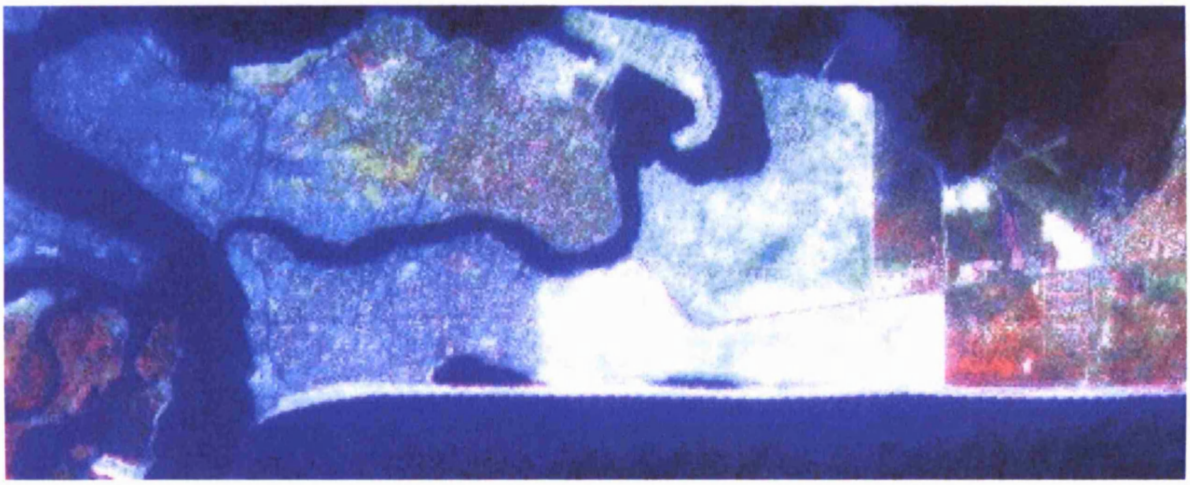

Figure 3.2: Landsat ETM+, Data Coverage of Lagos Island and Ikoyi acquired on 06/02/2000 (RGB combination).

SPOT (Le System pour l'Observation de la Terre): SPOT was designed to provide data for land-use studies, assessment of renewable resources, exploration of geologic resources and cartographic work at scales of 1:50,000 to 1:100,000 (Campbell, 2002). The SPOT image used in this research was acquired on the 17th January, 2002. Data from SPOT 2 HRV 2 MODE P BIL LEVEL 1A was purchased from Infoterra, Leicester, UK. This image is of high quality and high spatial resolution. It is a cloud-free 10 metre black and white (panchromatic) image. This satellite is placed in a sun-synchronous orbit at about 832 km, with a 10:30 am equatorial crossing time. It has 26 days temporal resolution, and this revisit time period increases the chance of getting a cloud free image from the SPOT satellite.

The image had been processed to level 1B, which includes orthorectification and terrain correction, detector radiometric equalization, bulk geometric processing to remove the earth rotation effect and resampling across-track to remove the off-nadir imaging effect and to obtain a 10m pixel size.

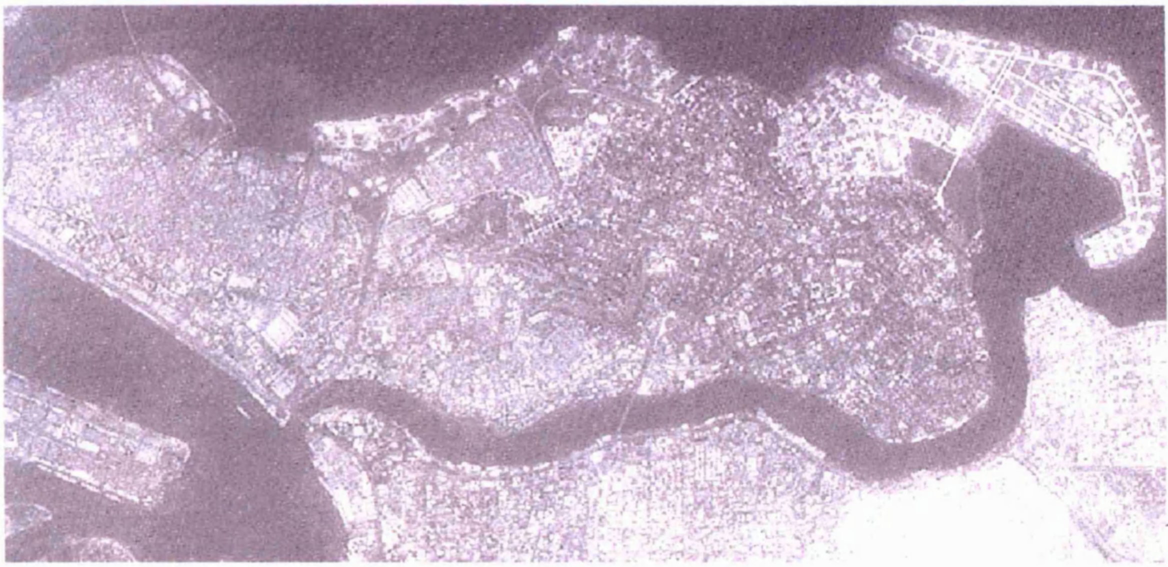

Fig 3.3: SPOT Data Coverage of Lagos Island and Ikoyi acquired on 17/01/2002

(10 metre Panchromatic).

3.1.3 Questionnaire

Semi-structured questionnaire was used to gather information about the study area and the issues regarding land use/cover changes and the factors that are responsible for the rapid land use/cover changes in the study area. Section 4.2.2 refers for detail information about the strategies adopted in the administration, and analysis of the questionnaire. An example of the questionnaire used in this research can be found at appendix I.

3.1.4 Field Photographs

Photographs used in this research were taken during the field survey, which formed part of the primary data collected. The photographs were intended for satellite imagery interpretation, accuracy assessment and photographic evidence of the rapid land cover and land use change in metropolitan Lagos, which is incorporated into a GIS database. In addition, Harmon and Anderson (2003) attached the photographs to the classified land use/cover maps to bring a visual context/appearance of the study area.

3.1.5 Collection of Ground Control Points

The GPS was used to collect data for image geometric correction, as well as the x and y coordinates of locations where samples of different land cover and land use classes were taken for accuracy assessment of image classification. The geometric map correction was necessary after the paper map (land use map) was converted to soft copy by scanning.

During the field survey, 52 GCPs were collected for the purposes of geometric correction but 43 GCPs that have matching distinct features on the map and images such as road junctions, buildings and many other landscape features identifiable clearly on map and the satellite image, were used for the geometric map corrections by image to image registration with the ERDAS Imagine software. This was also used to transform the land use map into the same coordinate system with the satellite images for the spatio-temporal analysis.

3.1.6 Secondary Data: Lagos Land Use Map

The land use map for Lagos State 2001 (MEPP, 2001) was acquired in paper form from the Lagos State Ministry of Environment and Physical Planning. The map was produced from the 1984 land use map of Lagos State by field survey, and recent information about new urban land use and change was used to update the existing land use map (1984). It was scanned to convert it into a digital format for computer processing and then digitized to create the GIS database. It was scanned at 100 dots per inch (dpi) as TIFF in 3 layers (Red, Green, and Blue). Geometric correction of this map was necessary because of distortion to the map and scale before and during the scanning of the map. Additionally, the map needed to be in the same coordinate system as the satellite imagery for analysis in the GIS. The scanned map was imported into ERDAS Imagine and was geo-referenced with the SPOT imagery. Image-to-image rectification was used because of the presence of several common features identifiable in both images that made collection of control points easily obtainable from the images. Bilinear interpolation was used for rectification and the root mean square error is 0.3 pixel. The geo-referenced land use map was imported as a TIFF file into ArcView 9 software (ArcMap), so that shapefiles of line and point features could be digitised and spatially analysed with the remotely sensed data.

As mentioned, the paper version of this map was believed to have lost some of its accuracy through distortion in the map features due to the way the map was folded while it was being transported from Nigeria to the UK. These problems were corrected during geo-rectification. However, the proposed and existing land use types were not properly coloured shaded (coded). There was no distinct representation of the existing and proposed land use types on the map legend. This made it impossible to identify the areas of existing land use and proposed land use. The inability to distinguished existing and proposed land use areas not only cast doubt on the accuracy of the map but also impossible to use. To overcome these problems the land use map was updated on site during fieldwork in February and March 2005. Visual site inspection was carried out by driving through the whole study area to update the map and correct the mistakes on the map legend. However the 1984 features on the map were only identified and updated with the additional assistance of senior town planning officers who have worked in the State for more than 21 years, because of their wealth of experience of the growth, land cover and land use change in metropolitan Lagos.

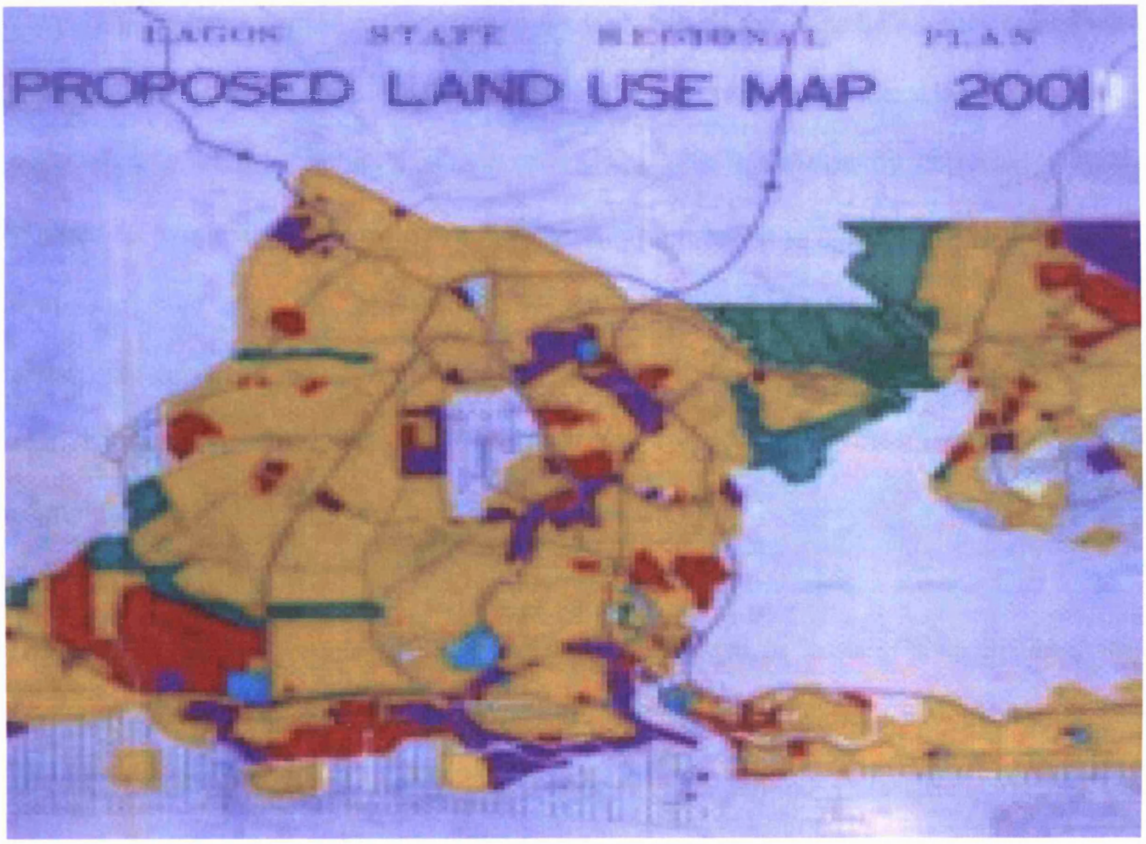

Figure 3.4: The proposed Lagos land use map, 2001.

3.2 THE ACCURACY ASSESSMENT

The classified image is compared with the standard and the level of closeness determines its level of accuracy. However, precision defines "detail", which means the level of detail required by any project that should be in line with the aim of the project, so as to increase classification accuracy by reducing the precision of the classification (Congalton and Green, 1999). But this is also affected by the quality and quantity of data available to the researcher. A delicate balance was reached on the precision of this research considering the limitation imposed by data on the study area. The accuracy achieved with the available data is considered satisfactory for this research.

It is very important to quantify the errors in land cover/land use maps before they can be used, due to legal and other reasons. To eliminate these errors from the source, a land-use map was geo-referenced to the satellite imagery which has been geometrically corrected with the acquired GPS coordinates. This has removed or reduced cartographic errors to the minimal level. One of the major problems with classification accuracy in this research is one posed by mixed pixels due to landscape patterns of Lagos urban centres that are comprised of many small and heterogeneous, indistinct parcels arrange in a complex disorganised pattern for example Agege and Mushin area of Lagos.

The accuracy of land use classification is usually expressed in terms of a confusion matrix. This can be used to assess the general quality of the classification, which is sometimes summarized by an overall precision index (percentage of correctly-classified pixels, Kappa Coefficient, etc.). Hence, error matrix was used to assess the accuracy of the classified images as well as the maps produced. The focus of this aspect is on overall producer's and user's accuracy, because of useful information derivable from them regarding accuracy of satellite based land use and land cover change detection.

An error matrix was considered the most appropriate method to assess the image classification accuracy as well as maps produced from the satellite imagery, so that independently classified images and maps produced can be compared with each other. The map data used for classification accuracy assessment was also assessed, to understand the degree of reliability for the purpose of generating maps with a high level of accuracy from the satellite data. One of the advantages of an error matrix was its ability to generate an overall accuracy as well as producer's and user's accuracy. This allowed the assessment of accuracy of individual land use/cover class. This also made it possible to identify land use classes that are not spectrally separable, which were then merged into a single land use or cover type.

The overall accuracy of the 1984 land cover map is 96.6% and the 2002 land cover map is 98.9%. However, the producer's accuracy shows the degree of identification of cover types in the classified image, while user's accuracy shows the actual percentage of accuracy of the cover types on the ground. This means that for the users of this map, each time a pixel that is classed as forest is visited on the ground (site) 93% of this is actually forest, when the producer of this map said 100% of the place identified on the map as forest was correct. In addition, this affords the researcher the ability to detect the class that has contributed significantly to the reduction in the overall accuracy of the classification and the classes that have similar or confusing spectral signatures with one another.

	(Reference)			**row total**
	1	**2**	**k**	**ni+**
1	**n11**	**n12**	**n1k**	n1+
2	**n21**	**n22**	**n2k**	n2+
k	**nk1**	**nk2**	**nkk**	nk+
column total n+j	n+1	n+2	n+k	**n**

Table 3.4 Error Matrix Calculation Table (source: Congalton and Green, 1999).

Congalton and Green (1999), present the mathematical representation of error matrix and KHAT value. The only data available for reference purposes was the land use map and from my work experience as town planning officer in Lagos State it was obvious that this map was doubtful in terms of its accuracy, though maps are rarely 100% correct (Congalton and Green, 1999), and remote sensing projects/research require trade-offs between the remotely sensed data used and the required level of accuracy acceptable for the research. Since the only available and affordable data as reference was the land use map, ground visits were made to update the land use map and to collect other data for reference purposes. The Lagos land use map was updated during the time of reference data collection (land use/cover types – ground truth). The assistance of planning officers in District Planning Offices was sought to identify and confirm the land use in their district, and any other districts that they have worked in previously. The land use/cover that was in existence before 1984 was determined by the officers with well in excess of 20 years work experience, and was crosschecked while on field survey so that the land use map and the actual land use were cross-referenced. In addition, my knowledge gained as a Town Planning Officer in Lagos was very useful in the identification of areas which were wrongly classified

Number of samples classified into category i in the remotely sensed classification

$$ni+ = \sum_{j=1}^{k} nij \qquad \text{Equation 1}$$

Number of samples classified into category j in the reference data set

$$n+j = \sum_{i=1}^{k} n_{ij} \qquad \text{Equation 2}$$

Overall accuracy between remotely sensed classification and the reference data is computed as follows:

Overall Accuracy $\dfrac{\sum_{i=1}^{k} n_{ii}}{n}$

Producer's accuracy is computed as follows:

Producer's Accuracy $j = \dfrac{n_{jj}}{n_{+j}}$

User's Accuracy is computed as follows:

User's Accuracy's $i = \dfrac{n_{ii}}{n_{i+}}$

Let

$$P_0 = \sum_{i=1}^{k} p_{ii}$$

be the actual agreement, and

$$P_c = \sum p_{i+} p_{+j}$$ p_{i+} and p_{+j} as previously defined above the "chance agreement"

3.2.1 Accuracy Assessment of data used

This section supports the reliability of the data used in this research: the land use map, satellite imagery, population data and primary data collected e.g. reference data. The main focus is on the objectivity and consistency of the data used. Urban land use/cover change detection posed great problems of the reliability of the map generated from satellite images because of spectral confusion of urban land use classes. For any acceptable research findings there must be a high level of confidence in the result, which is what accuracy assessment is all about. But this can only be achieved if the data used is able to achieve a high level of accuracy. In addition, if the information derived from the remotely sensed data is to be used in some decision-making process then it is critical that some measure of its quality be known (Congalton and Green, 1999). However, this section is limited to the assessment of fitness of the data and the researcher's efforts to correct the identified or associated problems in the data used for this research to achieve high accuracy in the project. The overall accuracy of the project is discussed in detail at the analysis chapter, section 5.7 refers.

3.2.2 Updating the Lagos State Land Use Map

The existing land use map for Lagos State was assessed for its accuracy with the reference data collected during the site reconnaissance survey in 2003. There were several areas on the map that did not represent the actual land use/cover type (class) on the ground. The only way to make this map useful was to update it so that reliable information could be derived from it. The methods adopted for the reference data collection were: site visit, walk through, drive through, view from road and bridges and land use and cover identification by Town Planning Officers.

The updated land use map was believed to be very high in its accuracy as most of the areas were visited while some were updated with the assistance of Town Planning field Officers, though maps are rarely 100%. This map was used, in conjunction with ground truth reference data collected, to assess the accuracy of the land use land cover maps produced from satellite images.

The accuracy assessment of the 1984 and 2002 land cover and land use maps gave the researcher useful information about the weaknesses in the classification system used, errors of commission and omission, difficulties in the separation of urban land use types, and comparison of the land use map produced from satellite images and land use map produced from traditional mapping method.

In summary, the level of accuracy of classified images is satisfactory for this research considering the fact that classification of urban land use is very difficult due to the many materials that make up the urban fabric. The reflectance signatures are closely related, therefore the more classes one tries to get, the lower the level of classification accuracy.

CHAPTER FOUR: METHODOLOGY

4.1 Primary Data Generated from Field Visit

4.1.1 Interviews and questionnaires

4.2 Image Processing

4.2.1 Image pre-processing

4.2.2 Classification

4.3 An Error Matrix for Assessment of Classification and Map Products

4.3.1 Assessment of Metropolitan Lagos Land Use Map

4.4 Change Detection

4.4.1 Considerations before Change Detection

4.5 Data Integration

CHPTER 4

METHODOLOGY

The chapter focus is on the image processing and interpretation of satellite data to extract information as well as assessment of the result and data used to determine the degree of reliability of the research findings. Methods of primary data collection are also covered in this chapter. The accuracy assessment is carried out to determine the user's and producer's accuracy of the results from this research.

4.1 PRIMARY DATA GENERATED FROM FIELD VISIT

The ground visit (verification) approach was adopted to produce reference data for this research. This was considered the best option because there were no reliable aerial photos with high spatial resolution (detail) and temporal ones that fell within the period under study to perform a good accuracy assessment for the study area. The reference data was collected while on field work in Lagos between January 17 2005 and March 17 2005. The proposed land use map of Lagos State was used as a guide to determine areas appropriate for reference data, in conjunction with the classified satellite images. This activity necessitated special attention to detail because of the level of precision required for urban land use classification accuracy assessment, though not at the expense of overall accuracy. A prime consideration was that mistake(s) on the reference data collection would automatically result in a reduction of the accuracy of the classified images when assessed. This could bias the conclusions about the accuracy of land use/cover maps derived from satellite imagery.

Reference data was collected from 105 sites spread across the study area as well as across different land use/cover types in metropolitan Lagos. Some of the reference points were more concentrated in some areas than others. This is due to the fact that these areas need closer attention than the others, because the literature reviewed and the reconnaissance survey carried out in February 2003 provided an insight into areas where the land use changes or transitions are taking place at a rapid rate.

The complexity of the urban fabric in Lagos did not allow measurement of the reference site, but efforts were made to ensure that all areas where reference data was collected had homogenous land use classes. However, at every location where validation data was collected, GPS x and y coordinates of the location and photographs were taken to ensure that there was no mix-up when the classified image was interpreted and assessed with the reference data. Ground reference data was collected on polygon bases because it is almost impossible to match the pixel on the ground with the actual one on the satellite image due to GPS positional accuracy which was an average of 10 metres. The determination of class was based on the visual examination of dominating land use/cover type.

The Lagos State land use map was used to identify and categorise different land uses in the reference data. This was adopted in order to allow easy integration of the land use map created from satellite images and the existing land use map, to assess the accuracy of the existing land use map of metropolitan Lagos.

Polygon was used as the sample unit for the accuracy assessment of this research because the land use/cover maps generated are in polygon type. This was chosen because of the type of reference data collected in the field. Polygon was drawn to represent the land cover type while in the field and the GPS coordinates were taken to relate this location to the remotely sensed imagery and to land use classes. There are no any land use classes that do not include a mixture of other classes, however small. Residential areas are generally provided with some services such as roads, corner shops, open space etc. These should belong to another class in the land use classification, but I considered them to be part of the residential use as they are part of what makes it a functional class, hence the delineation of polygons that comprise all features that make that land use class.

4.1.1 Interviews and Questionnaires

The survey, part of the qualitative research, served as broad and quantifiable background data in which the case studies were conceptualized. To realise some of the objectives of this research, interviews and questionnaires were considered the best means of unravelling the silent issues behind the rapid land cover/use change in the study area. The reconnaissance survey conducted between February and March 2003 revealed that there were several other factors that are responsible and encouraging land cover/use change besides population growth. The interviews and questionnaire administration were carried out between January 17 and March 15 2006.

The interviews were conducted with planning officers, both in private and public practice, members of the academic community specialising in remote sensing and geographic information science, urbanisation studies, urban sociology and planning, economists, geographers and other related professions and residents were also interviewed. Questionnaire administration cut across the above mentioned group of people but more questionnaires were administered in the field with residents, especially ones dealing with physical transformation process and change of land cover and land use. Appendix I refer for a copy of the questionnaire.

Interviews: The interview was conducted in line with Schein's (1983) 'interactive clinical interview' technique that involves a series of joint explorations between the interviewer and the interviewee. Some lines of enquiry were prepared to serve as guides during the interviews. These were based on literature references and the focus of the research: land use and land cover change and transformation, urbanisation process, socio-economic and political factors and urban remote sensing in third world cities. The interviews were flexible, with questions drafted to obtain specific information from the key respondents while at the same time getting their views of the general change in Lagos and the factors driving rapid land use/cover change. Interviews were conducted with experienced and relatively new city planners and academics and environmentalists, both in public and private practice (see Appendix for some of the respondents).

The interviews also offered opportunities to verify and correct some of the issues concerning urban growth in cities in developing countries raised by other researchers which have been referred to in Chapter 2. In addition, responses during the interviews were triangulated to crosscheck bias among respondents. The interviews were not tape-recorded, but notes were taken during the sessions with the consent of the interviewees. The main reason for interviewees' objection to tape-recorded interviews was the fear of persecution by government if their position became public. In order to get honest opinions the tape-recording idea was dropped. The data and information collected was collated, coded and analysed and potential irregularities, patterns and explanations were flagged and placed into relevant categories that were conceptually linked to the research structure (research questions and objectives).

Narrative inquiry: This is the process of gathering information for the purpose of research through storytelling. The historical background of the land use/cover change of metropolitan

Lagos was inquired from traditional chiefs and elders. This was told orally as most of the information was not written. This was used because it was considered the best way to gain a comprehensive general knowledge of the historical background of the study area as well as change over time. The non-restrictive nature of this method allowed the respondents opportunity to recount and reveal all that they know about the research topic without limitation posed by other means of information and data gathering methods.

During the inquiry session notes were taken of important information, which helped to imporve understanding of the study area and gave a good general perspective of the landscape structure before the present urban landscape takeover. In addition, some areas that had gone through various land use/cover changes were identified.

Questionnaires: Sampling methods were used to select representatives of each category of people and places to be sampled for data collection. Since data cannot be collected from the entire population, suitable sampling methods were considered for different tasks involved in the administration of questionnaires for this research. The stratified-random sampling technique was used because of its combined advantages.

Stratified sampling is a commonly used probability method that is superior to random sampling because it reduces sampling error. A stratum is a subset of the population that shares at least one common characteristic (1997-2005 StatPac Inc.). Stratified sampling method was used to select the parcel of land sampled for ground verification and to check the accuracy of the classification. Samples were taken from all land use classes to ensure a fair representation of the study area. The updated land use map was used for this purpose. To achieve greater precision, strata were chosen with members of the same stratum and spread across the study area having similar characteristics. Some of the reasons behind the choice of this method were: it ensured better coverage of all land cover/use classes identified during reconnaissance survey; it was economical, time conscious and administratively convenient. The people interviewed were selected at random.

Quota sampling was also adopted which is the non-probability equivalent of stratified sampling. Like stratified sampling, the researcher first identifies the strata and their proportions as they are represented in the population. Selected academics were interviewed from three Universities and the College of Technology based in Lagos and outside Lagos. Some of the selected interviewees have researched into urbanization and published books and journals about the urbanization and associated problems in Lagos, as well as in other parts of Nigeria and beyond. Their experience and knowledge was taken into consideration at the selection stage to select a sufficiently large number to be reasonably confident that the stratum represented the population.

4.2 IMAGE PROCESSING

Urban land use classifications pose one of the great challenges to remote sensing because of the numerous features that make up urban areas. As far back as the early 1980s, Welch concluded that only fine resolution satellite imagery could realistically meet the spatial accuracy requirements of urban land use classification. With the development of 3rd generation satellite sensors, with spatial resolutions ranging from 30m to 1m, these requirements for accurate urban land use classification were finally achievable. But even very fine spatial resolution data still does not automatically solve classification problems as most of the urban features are larger than 1m, and this can lead to pixels being erroneously classified (Aplin, 2003).

However, many researchers have tried to develop techniques to overcome the problem of misclassification associated with urban land use and to increase the urban classification accuracy. Another burning issue about urban land use/cover classification in the cities in developing countries is the lack of distinction between cover materials of different land use/cover types. For example, un-tarred roads, childrens' play grounds, open spaces, land fill sites, agricultural land and many more belong to different land use types but have the same cover materials which have the same or very similar spectral reflectance.

This research adopted both quantitative and qualitative statistical analysis techniques as well as GIS techniques (overlay, display, visualisation, photographic evidence etc) because of the nature of the data used, though the two methods are integrated to enrich the analysis of the findings and to acquire an in-depth knowledge of some hidden facts.

Figure 4.1 shows the research methodology flow chart to achieve the research aims and objectives while Figure 4.2 shows detail of activities carried out with remotely sensed data and information extraction from it.

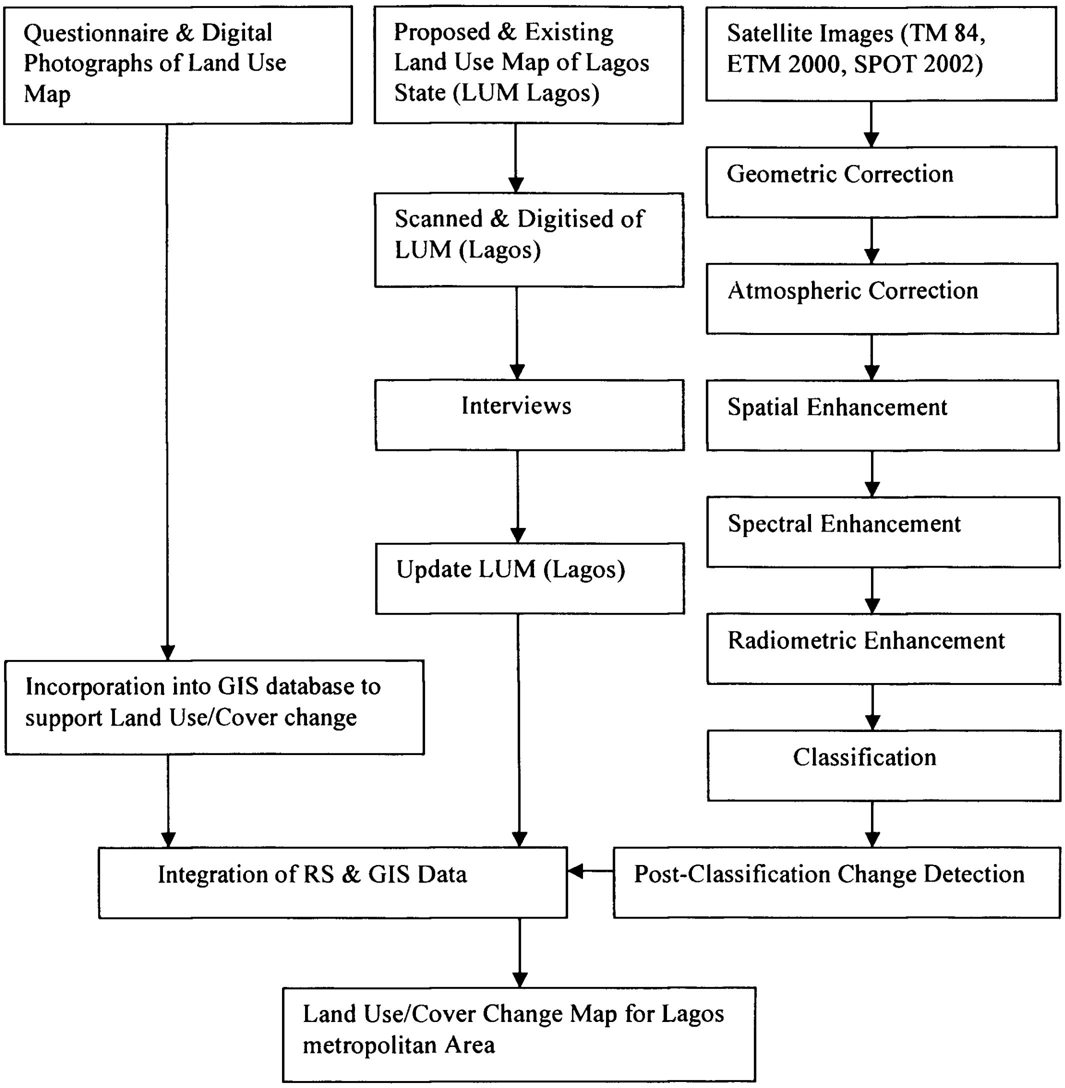

Figure 4. 1: Research methodology flow chart.

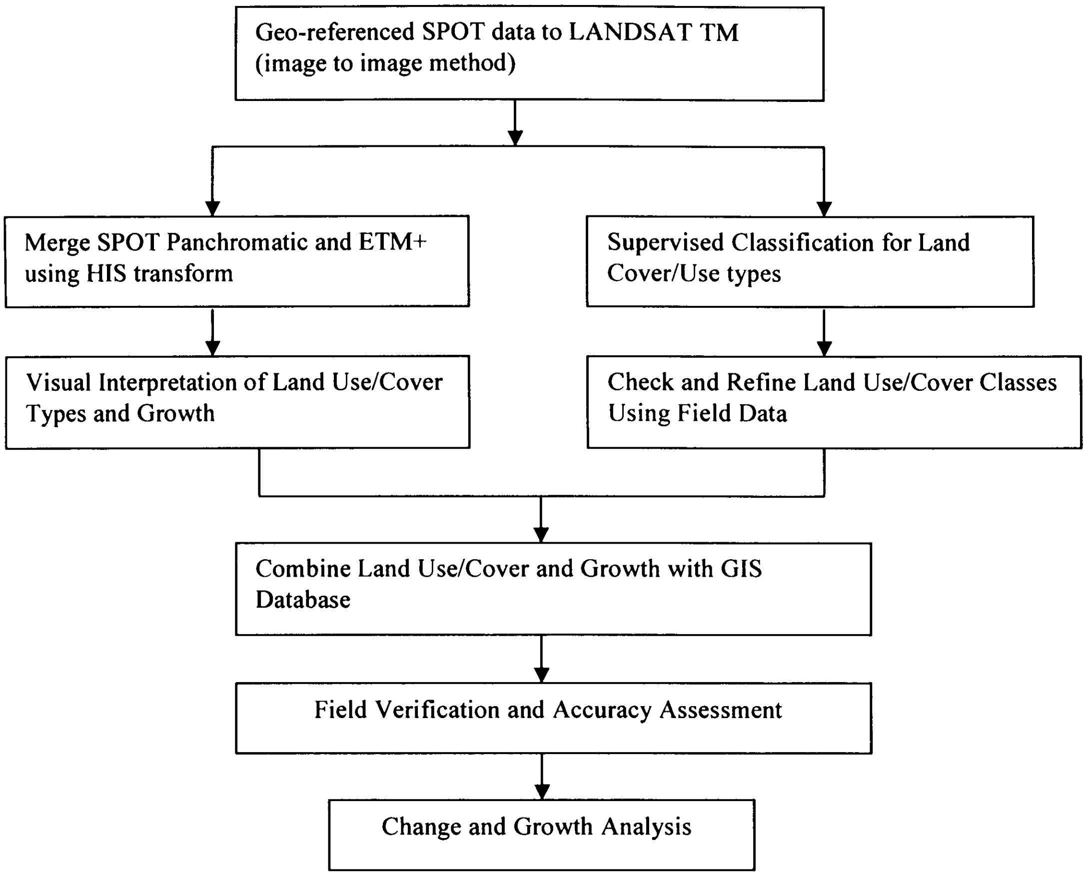

Figure 4.2: Schema of image pre-processing, enhancement and information extraction.

4.2.1 Image pre-processing

The data was unzipped and imported into ERDAS Imagine software version 8.7, which converted the data to Imagine (.img) image format. The importation was on band by band basis. Bands 1 – 5 and 7 were then layer stacked for both Landsat TM 1984 and ETM+. Bands 6 (TM), band 6 (ETM+) and 8 (ETM) were excluded in both images because in Thermal Infrared (TIR) and 15 metres spatial resolution this was considered not as useful for this research as band 8 (ETM). Remotely sensed data in raw form generally contains flaws such as noise, haze effect etc. The removal of flaws present in the data is termed pre-processing (Mather, 1999).

Consideration of various requirements of pre-processing for change detection, multitemporal image registration, radiometric and atmospheric corrections is most important (Lu et al., 2004). The importance of accurate spatial registration of multi-temporal imagery is obvious because largely spurious results of change detection will be produced if there is misregistration (Townshend et al., 1992; Dai and Khorram, 1998; Stow 1999; Verbyla and Boles, 2000; Carvalho et al., 2001; Stow and Chen, 2002; Lu et al., 2004). Also, the results of change detection can be absolutely wrong if actual spectral values are not separated from the atmospheric and scattering effects on the recorded values for satellite images.

Measurement of land use/change over time using multi-temporal image sets requires both corrections for atmospheric variations, and registration of the images in the multitemporal to a common geographical coordinate system. In addition, corrections for changes in sensor calibrations may be needed to ensure that like is compared with like (Mather, 1999). The following correction operations were performed on the data during the pre-processing stage: geometric, radiometric and atmospheric.

Before these corrections were carried out, the images was subset because (i) the study area is only about a quarter of the scenes; (ii) by using subset it saved processing time and reduced storage space; (iii) it was easier to use geometric correction as features were only needed in a small area (iv) it was easier to verify land cover on a smaller area within the image of the study area.

Geometric Correction: This is the transformation of a remotely sensed image so that it has the scale and projection properties of a map (Mather, 1999), and geometric rectification algorithms (Novak, 1992; Jensen, 1996; Jensen et al., 1997) are used to register images to map projections. This is needed because in remote sensing systems, the image of a stationary grid on the Earth is not perfectly reproduced by the sensor. Instead, the geometric characteristics of the scene change as a function of geodetic and intrinsic properties of the imaging system, such as orbit properties, position, satellite attitude, and scan angle.

The imperfections lead to geometric distortions of images, and are the essential motivation behind geometric correction for remotely sensed data. Acceptable image rectification should result in the two images having a root means square error (RMSE) of ≥ 1 pixel (Jensen et al., 1997). The generally accepted 1 pixel size which is $30m^2$ for TM imagery which means that any change in urban land cover/use of ≥ $30m^2$ could be regarded as registration error. Since many urban features are less than this, it became paramount that efforts should be made to achieve RMSE of less than half a pixel size for urban land use/cover application so as to reduce the inherent error that will definitely affect the accuracy of the map products.

RMS error is the distance between the input (source) location of a ground control point (GCP) and the retransformed location for the same GCP. In other words, it is the difference between the desired output coordinate for a GCP and the actual output coordinate for the same point, when the point is transformed with the geometric transformation (ERDAS Imagine, 8.7).

RMS error is calculated with a distance equation:

$$\textbf{RMS error} = \sqrt{(x_r - x_i)^2 + (y_r - y_i)^2}$$

Equation 1

Where:

xi and yi are the input source coordinates

Xr and yr are the retransformed coordinates

RMS error is expressed as a distance in the source coordinate system. If data file coordinates are the source coordinates, then the RMS error is a distance in pixel widths, for example, an

RMS error of 2 means that the reference pixel is 2 pixels away from the retransformed pixel (ERDAS Imagine, 8.7).

Remotely sensed images are not maps (Mather, 1999) hence they are positioned according to pre-established geodetic control, grids, projections and scales (Steigler, 1978; Mather, 1999) and need to be registered to a geographic coordinate. Also, the images in this research were compared scene-to-scene by individual pixels for change detection. The Landsat ETM which has been geo-referenced by the University of Maryland was used for image-to-image geo-rectification of the SPOT image. GCPs are features that can be located with precision and accuracy on accurate maps yet are also easily located on digital images (Campbell, 2002). A total of 24 GCPs were digitized on both images but 6 of the GCPs were check points for the assessment of the transformation. The root means square error was (RMSE) ± 0.437.

The SPOT image was now in the same geometric coordinates and projected onto universal transverse mercator (UTM), Zone 31, WGS 84.

4.2.2 Atmospheric Correction: This was necessary because all the images were acquired at visible and near visible wavelengths which are susceptible to absorption and scattering by dust and water molecules in the atmosphere. Dust can be a problem during the day in Lagos because many roads are not tarred, and this produced dust that interfered with the emitted electromagnetic signals recorded by the sensors. Also, the hamattan (hazy weather condition in sub-Sahara Africa) bears water molecules that leave haze on the image. Clouds in the wet season make remote sensing almost impossible and even when there is cloud free image the water vapour haze effect from the Atlantic Ocean is commonplace

A variety of methods, such as relative calibration, dark object subtraction, and second simulation of the satellite signal in the solar spectrum (6S), have been developed for radiometric and atmospheric normalization or correction (Markham and Barker, 1987; Gilabert et al., 1994; Chavez, 1996; Stefan and Itten, 1997; Vermote et al., 1997; Tokola et al., 1999; Heo and FitzHugh, 2000; Yang and Lo, 2000; Song et al., 2001; Du et al., 2002; McGovern et al., 2002; Lu et al., 2004). The dark pixel subtraction method (Chavez, 1975) was used to remove the effects of atmospheric interference in the true value of the images. This was chosen because dark absent pixels with deep water of the Bight of Benin occur on the same images as Lagos. The value recoded at these pixels was model to zero in bands 5 and 7, which digital numbers (DNs) for clear deep water have little or no atmospheric interference (Foody, 1997). The DN values were then compared with the recoded value for the same pixel in bands 1, 2, 3, 4, 5 and 7. The values recorded by the sensor at the same location (Bight of Benin) that are more than zero in various bands, were taken to be the added values from the atmospheric scattering. The difference was subtracted from the entire bands to eliminate the problem of atmospheric interference. Separation of the two types of surface brightness allowed the focus of the analysis on the actual brightness value on the Earth's surface when the image was acquired.

4.2.3 Image Enhancement and Transformation

This is the process of making an image more interpretable for a particular application (Faust, 1989). The processing of satellite images for enhancement and transformation purposes includes the spatial, spectral and radiometric methods such as contrast enhancement by histogram equalisation, image transformation through principal component analysis (PCA, decorrelation and HIS), and filtering techniques (Low-pass - smoothing, High-pass – sharpening, haze and noise reduction).

These are the operations performed on multiband image sets used to attain the research aims. Arithmetic operations were performed on the multitemporal image set available to generate new images with properties more suitable for the urban land use/cover change detection.

4.2.4 Spatial Enhancement

The resolution merge spatial enhancement technique was used for the improvement of Landsat ETM (28.5 metre) image with the SPOT (10 metre) panchromatic image. The higher spatial resolution yielded better results derivable from the classified image for urban land use/cover studies because many urban features are less than 30m resolution. SPOT image data has proved to be most useful when multispectral and panchromatic information are merged to effectively create enhanced multispectral images of 10m resolution (Lillesand, 1987; Carper et al., 1987; Ehlers, 1988; Ehlers et al., 1990). Welch and Ehlers, 1987, documented in a comparative analysis that this method produces images of superior contrast and spectral discrimination compared to other merging techniques.

A spatial resolution merge was used to integrate imagery of different spatial resolutions (pixel size). The main importance of this technique is that it retains the thematic information of the multiband raster image. The choice of an appropriate resampling technique is determined by the resolutions of the two images to be re-sampled.

The process followed is detailed below:

- Methods: the multiplicative method was used because some of the important urban features, which are generally difficult to identify, are pronounced with this technique. Also, it is based on simple arithmetic integration of the two-raster sets. This image merge algorithm operates on the original image and the result is an increase presence of the intensity component. In addition, this technique is very useful for urban studies and city planning as well as utilities routing etc (ERDAS Imagine, 1997).

- Resampling technique: The choice of this resampling technique is based on the rule of resampling (the rule of resampling suggests using N (square) pixels, where N = resolution ratio, hence, the resolution ratio for Landsat ETM BAND 8 (14.250m²) and Landsat ETM band 1 to 7 (28.500m²) is 2, the square of 2 equals 4). The nearest neighbour resampling technique looks at four surrounding pixels, bilinear looks at eight surrounding pixels while cubic convolution looks at 16 surrounding pixels (ERDAS Imagine, 1997). With this the nearest neighbour resampling technique was the most appropriate and this was used.
- Output image: The resample image combined the spectral information of a coarse-resolution image with the spatial resolution of a finer image. The 10m SPOT (2002) panchromatic data was fused with ETM+ (2000) to produce multispectral 10m image of metropolitan Lagos, Figure 4.3 refers.

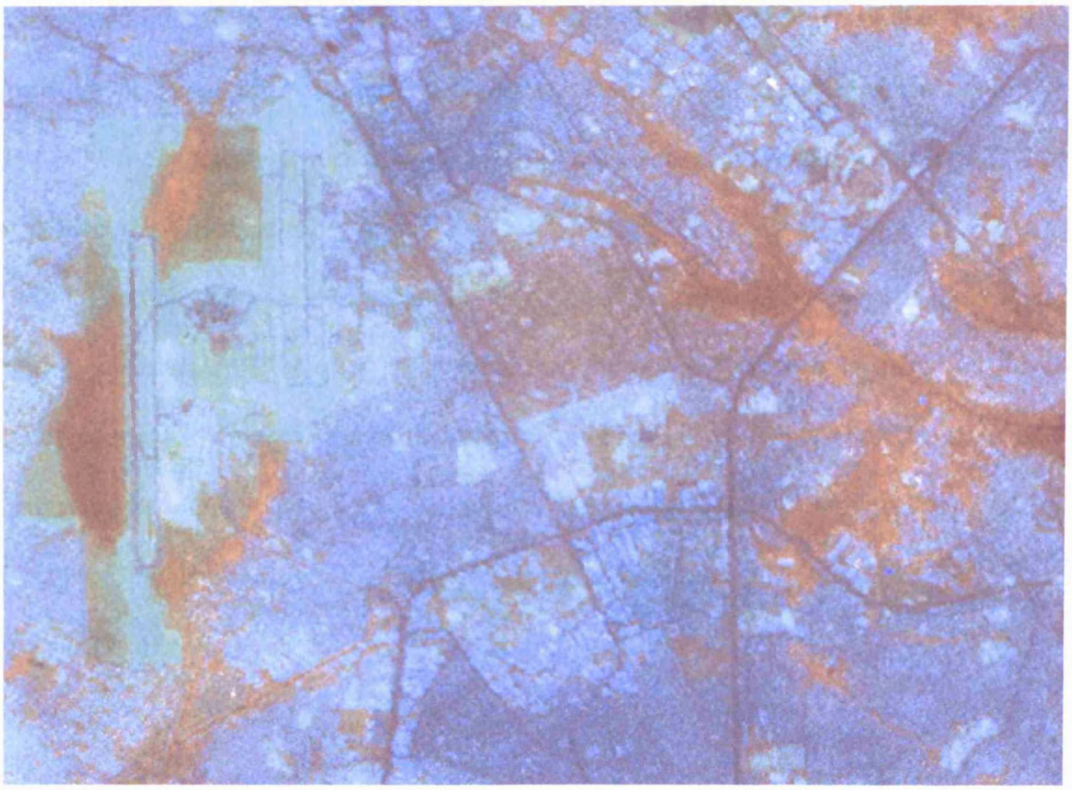

Figure 4.3: Spatial resolution enhancement through resolution merged; Landsat ETM (2000) and SPOT (2002).

4.2.5 Spectral Enhancement (Principal Component Analysis – PCA)

This is a spectral enhancement technique that compresses bands of data that are similar, extracts new bands of data that are more interpretable, applies mathematical transforms and algorithms and displays a wider variety of information in the three available colour guns (R, G, B) (Mather,1999; Campbell, 2002). The presence of correlations among the bands of a multispectral image implies that there is redundancy in the data (Mather, 1999). The bands of PCA data are non-correlated and independent, and are often more interpretable than the source data (Jensen, 1996; Faust, 1989).

Although there are no output bands in a PCA, the first few bands account for a high proportion of the variance in the data - in some cases, almost 100%. Therefore, PCA is useful for compressing data into fewer bands. In other applications, useful information can be gathered from the principal component bands with the least variance. These bands can show subtle details in the image that were obscured by higher contrast in the original image. These bands may also show regular noise in the data (for example, the striping in old MSS data) (Faust, 1989). This method was used because of the need to improve the classification accuracy by taking advantage of PCA as mentioned above. PCA was limited to 3, because the first few bands account for a high proportion of the variation and to display the image in RGB. The output image was 3 PC (PC 1, PC 2, and PC 3), which are the most uncorrelated PCs produced from the 7 bands Landsat images (Figures 4.4 to 4.7 refers).

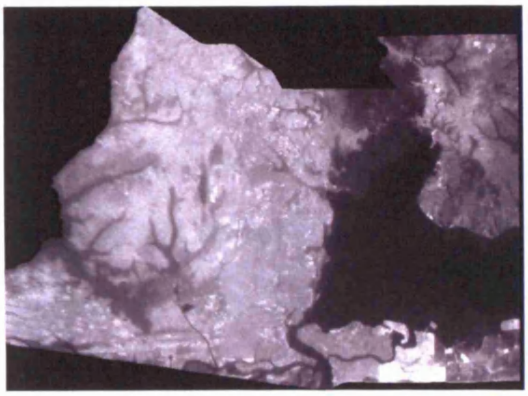

Figure 4.4: PC 1 Image of 2002

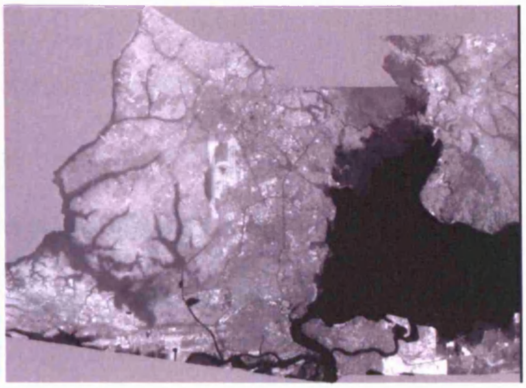

Figure 4.5: PC 2 Image of 2002

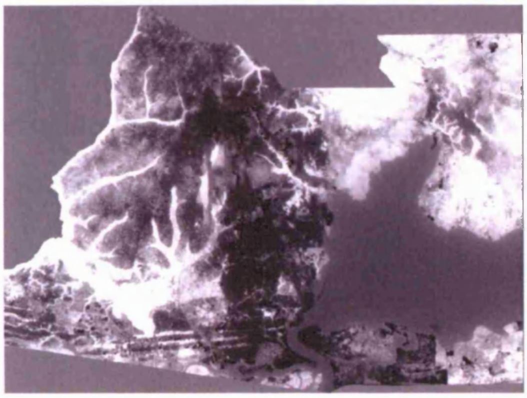

Figure 4.6: PC 3 Image of 2002

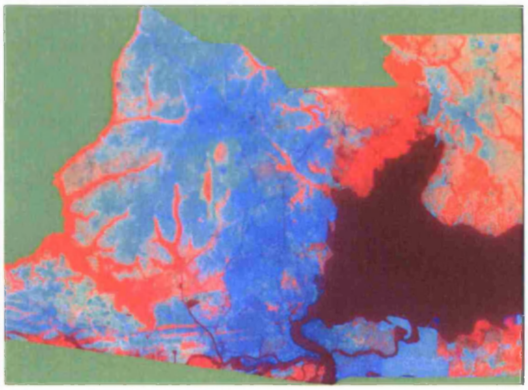

Figure 4.7: PC 1, 2, and 3 Image of 2002 (R,G,B)

4.2.6 Radiometric Enhancement

(i) Haze reduction: this algorithm in ERDAS Imagine (version 8.7) enables the reduction of haze in an input image. The method is based on the tasselled cap transformation which yields a component that correlates with haze. This component is removed and the image is transformed back into RGB space.

(ii) Noise reduction: this dialogue enables reduction of the amount of noise in an input raster layer. This technique preserves the subtle details in an image, such as thin lines, while removing noise along edges and in flat areas.

4.3 CLASSIFICATION

This is the process of assigning pixels to classes (Campbell, 2002). The classification process is considered to be a form of pattern recognition, that is, the identification of the pattern associated with each pixel position in an image in terms of the characteristics of the objects or materials that are present at the corresponding point on the Earth's surface (Mather, 1999).

Image analysis and pattern recognition with image classification is an integral part of remote sensing. Several methods have been developed for image classification over the years by scientists (researchers) but all are based on two forms of digital image classification: (i) classification based on each pixel individually. This is also known as spectral or point classification (Campbell, 2002), per-point or per-pixel classification based on spectral data (Mather, 1999); and (ii) classification based on groups of pixels, these are spatial or neighbourhood classifiers which examine small areas within the image using both spectral and textural information to classify the image (Campbell, 2002). The objective of image classification in this research is to create cluster classes from multispectral images to make sense of spectral information contained in the images. The area coverage of different classes of multitemporal images was compared for changes that have taken place between dates of the images.

The accuracy of the land use/cover map produced from classification is affected by the scale as well as the spatial and spectral characteristics of the image data (Mather, 1999; Lo and Choi, 2004). Effective detection of urban change with remote sensing data is dependent on the classification accuracy. This is an essential part of successful land use/cover change detection. However, there was a need to create accurate informational categories from the processed satellite image with an appropriate algorithm suitable for the data and study area to achieve high classification accuracy. Principal Component Analysis was adopted to reduce the data dimensionality. Thereafter, supervised classification with maximum likelihood classifier was used because it gave a better result than any other algorithms such as neural network, contextual, minimum distance etc. To determine the level of classification accuracy, post-classification accuracy assessment and filtering was performed which provided clear and homogenous information categories.

To achieve high classification accuracy several classification techniques were tried for their effectiveness in classifying land use/cover in metropolitan Lagos. Maximum likelihood classifier achieved the highest classification accuracy. Also, literature review revealed the efficacy of MLC in similar research in similar environments. MLC is a parametric decision rule. The maximum likelihood decision rule is based on the probability that a pixel belongs to a particular class. The basic equation assumes that these probabilities are equal for all classes, and that the input bands have normal distributions. This was adopted as the classification technique most suitable for urban land use/cover classification for the study area.

MLC, as a per-pixel classifier, was able to handle and show the spatial distribution of land uses and land cover types in metropolitan Lagos. The landscape structure and land cover dynamics of metropolitan Lagos makes Maximum Likelihood Classifier (MLC) an appropriate classification method. This is a sophisticated classifier and considered the most appropriate for the study area, though this resulted in what Lu et al., (2004) called "salt and pepper" pattern classification. The ground-truth data agreed with this outcome after the classified image was smoothened. The MLC effectively handled this problem better than other types of classifiers tried for this research. The classification was able to achieve more than 74.5% overall accuracy while other was able to reach 62.9%.

However, the determination of the classification scheme was influenced by two factors: (i) the need to meet the land use classes in the Lagos land use map and classification scheme in Nigeria; and (ii) the land use/cover dynamic of Lagos Metropolis where almost all, if not all, the land cover types are present in virtually all the sub districts.

Three different levels of classification were conducted to meet the international and local classification scheme required by the research into land use/cover change in metropolitan Lagos. The digital image classification was carried out as follows:

Land Cover and Land Use Classification Scheme: Land cover is the classification of satellite images based on the reflected signals according to the earth surface materials. Land use takes into consideration the economic activities taking place in an area and their detectable signal reflectance. Differentiation between land use and land cover is challenging as the two are interchangeably used in remote sensing change detection. In order to achieve a clear differentiation between the two (land use and land cover), three levels of classification were used. The first level of the classification scheme encompasses land cover types; this level was used to classify satellite images into five major land cover types; (i) Urban/Built-Up (ii) Forest (iii) Agriculture (iv) Water Bodies and (v) Bare Soil/ Landfill Sites. The five classes in the classification scheme at level one classification only considered the land cover materials of the study area on a broad scale.

However, levels two and three of the classification scheme have both land cover and land use classes together. Level three was specifically tailored towards the classification scheme used in the production of the Lagos State land use map used as reference data. Also, level three made it possible for critical analysis of land use change from one class to another in the study area to take place. In addition, this allowed the comparison of accuracy of the map produced from the existing maps with the maps produced from satellite data by the users (in the study area) such as town planners, architects, land surveyors, environmentalists.

Preparation of menu categories to be mapped (informational classes): These are the categories or classes of interest to the user of the data. Remotely sensed data does not directly contain information about different land uses but this can be derived from the recorded evidence contained in the brightness of image. This section looked into the trade-off that could be achieved with the local and international standard in matching the spectral classes to the informational classes required by the end-user of the project. The informational classes in this research followed the recommended classification methods for work to be published and student projects (Campbell, 2003). Three levels were recommended and were followed to arrive at the required land use/cover types or map, see Tables 4.1, 4.2, and 4.3 for detail. The USGS land cover/use classes followed three stages because it is very difficult, if not impossible, to infer land use classes from remotely sensed images unless ancillary data such as socio-economic data is used in the interpretation.

CLASSES	COLOUR	
Urban or Built-up	Red	
Agriculture & Forest	Light Brown	
Open Soil/ Beaches	White	
Water	Dark Blue	

Table 4.1: Level I land use/cover types.

CLASS	COLOUR	
Residential	Brown	
Commercial	Orange	
Institutional	Red	
Recreational	Light Green	
Industrial	Purple	
Agricultural	Green	

Table 4.2: Level II land use/cover types.

CLASS	COLOUR	
High Density Residential	Brown	
Medium Density Residential	Light Pink	
Low Density Residential	Ivory	
Open space & Recreational	Light Green	
Commercial Land Use	Light Blue	
Industrial Land Use	Purple	
Water Bodies	Dark Blue	
Farmland/Grassland/Cropland	Light Green	
Beaches, Bare Soil and Landfill Sites	White	
Forest	Dark Green	

Table 4.3: Level III land use/cover types.

Selection of training data

Training data was based on the field data, and a cluster of pixels representing various land-use and land-cover categories was selected as a training set. The training sites (pixels) were selected and spread throughout the study area and analysed. The trade-off usually faced in the development of training data sets is that of having sufficient sample size to ensure the accurate determination of the statistical parameters used by the classifier and to represent the total spectral variability in a scene, without going past a point of diminishing returns (Lillesand et al., 2004). During the refining of the training set redundancy and gaps were identified in the data, so that important spectral classes were not omitted as well as inclusion of redundant spectral classes.

The selection of training data was carefully planned and aimed at true representation of the informational class with the field observations serving as a guide. The training areas were delineated, and the frequency of all spectral bands was examined (means, variance, covariance etc) to ascertain a homogenous training data and to assess the usefulness of the selected training data. Boundary of training data was adjusted where it was discovered that there were bimodal frequency distributions and some were discarded in those areas that were not suitable. Figure 4.8 refers.

Class #	>	Signature Name	Color	Red	Green	Blue	Value	Order	Count	Prob.	P	I	H	A	FS
1	>	Industrial		1.000	0.000	0.000	12	12	3099	1.000	X	X		X	
2		Water Bodies		0.000	0.000	1.000	15	26	37831	1.000	X	X		X	
3		Soil, Land fill site, Beach		1.000	1.000	1.000	6	32	961	1.000	X	X		X	
4		Road Network		1.000	1.000	0.000	17	46	1105	1.000	X	X		X	
5		Forest		0.000	0.392	0.000	13	57	8110	1.000	X	X		X	
6		Low Density Residential		1.000	0.843	0.000	5	62	9371	1.000	X	X		X	
7		High Density Residential		0.647	0.165	0.165	8	68	4666	1.000	X	X		X	
8		Medium Density Residential		1.000	0.753	0.796	3	71	3366	1.000	X	X	X	X	
9		Mixed Uses		1.000	0.647	0.000	4	74	7739	1.000	X	X	X	X	
10		Commercial Use		0.000	1.000	1.000	7	77	4845	1.000	X	X	X	X	

Figure 4.8: Training data for supervised classification.

Modification of Training Fields to Define Homogeneous Training Data

Signature separability was used to assess the signature collected for the informational classes that formed land use classes. Euclidean distance measures were used to calculate the best average with class probabilities option that showed 25.1 best average separability. See figure 4.9 for detail.

Distance Measure: Euclidean Distance

Using Layers: 1 2 3 4 5 6

Taken 6 at a time

Best Average Separability: 25.0967

Combination: 1 2 3 4 5 6

Signature Name		1	2	3	4	5	6	7	8
Water Bodies	1	0	42.5373	52.1801	36.5322	52.7403	16.3695	49.3104	51.7437
Residential	2	42.5373	0	10.0887	6.75448	10.2963	30.1751	16.428	11.4263
Industrial	3	52.1801	10.0887	0	15.7678	2.59883	40.207	17.7989	9.6927
Commercial	4	36.5322	6.75448	15.7678	0	16.5748	25.4664	20.8208	17.8987
Institutional	5	52.7403	10.2963	2.59883	16.5748	0	40.2373	16.3548	7.39213
Forest	6	16.3695	30.1751	40.207	25.4664	40.2373	0	36.0044	38.2429
Agriculture	7	49.3104	16.428	17.7989	20.8208	16.3548	36.0044	0	11.0677
Recreational/Open Space	8	51.7437	11.4263	9.6927	17.8987	7.39213	38.2429	11.0677	0

Figure 4.9: Signature separability for 2002 land use and land cover classes.

Supervised classification was executed after informational classes were prepared as a menu of categories to be mapped, and the selected training data was classified with maximum-likelihood algorithm in ERDAS Imagine. Figure 4.10 shows the classified image while Figure 4.11 shows the statistically filtered image with 3x3 window size.

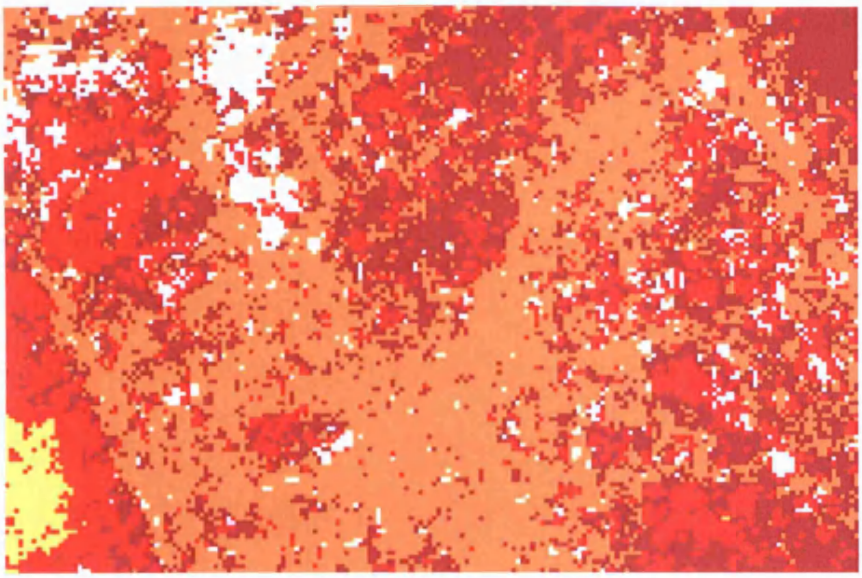

Figure 4.10: Salt and pepper classified image.

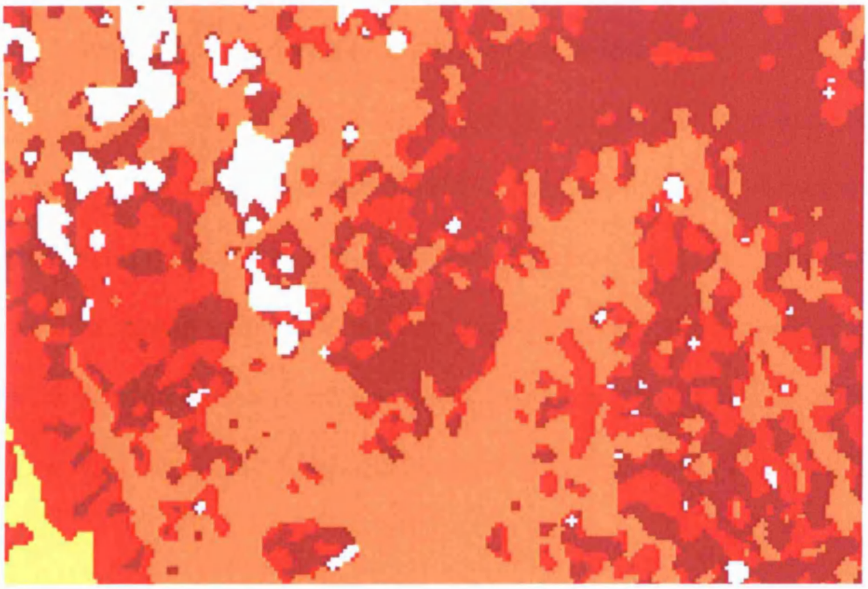

Figure 4.11: Statistically filtered classified image (3X3).

Evaluate classification performance: Classified images were evaluated for their level of accuracy. Overall, user's and producer's accuracy were assessed (section 5.8 refers for detail). This allowed the researcher to determine the degree of correctness of the classification.

4.4 AN ERROR MATRIX FOR ASSESSMENT OF CLASSIFICATION AND MAP PRODUCTS

This method was considered the best to assess the reference data used for classification because it is used to calculate the overall, producer's and user's accuracy for the data used. It was also used to calculate the accuracy of individual land use/cover classes. Section 5.8.1 shows details of how error matrix was used. For example institutional land use class had 35.5% producer's accuracy and 33% user's accuracy. This land use class reference data was redefined to yield greater accuracy of 89%. Without the adoption of error matrix to assess the accuracy of data used it would be impossible to detect the class that has contributed greatly to the reduction in the overall accuracy of the classification.

4.4.1 Assessment of Metropolitan Lagos Land Use Map

The existing land use map for metropolitan Lagos was assessed for its accuracy with the reference data collected during the site survey. There were some areas on the map that did not represent the actual land use/cover type (class) on the ground. The only way to overcome this problem was to update the map so that reliable information could be derived from it. The methods adopted for the reference data collection were: site visit, walk through, drive through, view from roads and bridges and land use and cover identification by Town Planning Officers.

The updated land use map when assessed with reference data has a tremendously high accuracy as most of the areas were visited, while some were updated with the assistance of Town Planning Field Officers. This map was used in conjunction with ground verification reference data collected, to assess the classification accuracy of the land use land cover maps produced from satellite images.

4.5 CHANGE DETECTION

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh 1989; Lu et al., 2003). Digital change detection has been divided into two major groups This involves the use of multitemporal data sets to discriminate areas of land cover change between dates of imaging (Lillesand et al., 2004). This research is focused on the changes between-class (conversion between land cover types) and within-class (changes within a land cover type).

Post-classification change detection approach was employed due to its ability to bypass the problems and difficulties associated with analysis of images acquired at different times of the year and sensors (Yuan et al., 1998). In this research, land cover change is detected as a change in land cover label between two image dates. It is based on two independent true land cover class classifications, and was achieved by supervised classification.

Land use patterns change over time in response to economic, social, and environmental forces (Campbell, 2002). The importance of urban land use/cover change detection is its ability to reveal the areas that require the greatest attention of planners and administrators for communities to achieve development in a harmonious and orderly manner that guarantees a functional, sustainable and aesthetically pleasing environment.

4.5.1 Considerations before Change Detection

Meaningful change detection operation with images is performed when the conditions below have been satisfied. The objective of change detection is to get reliable information from the images to take an informed and reliable decision on the subject matter.

- **Precise image registration:** Multi-temporal images meant for change detection must be accurately registered to one another. The image to image registration method was used to register Landsat ETM+ 2001 to Landsat TM 1984 with the root mean square error of 0.37. This is considered a very good image registration result for urban land use/cover change detection that required image registration of less than half a pixel size. In addition, precise radiometric and atmospheric calibration or normalisation is very important, section 4.2.1.2 refers.

- **Phenological consideration:** Images acquired on the same date were not available for the study area but all the images used in this research were collected within the same season to remove seasonal change effects on the images which can affect the result of change detection. Landsat TM and ETM were acquired in December while SPOT was acquired in January which is about a two week interval. This time interval has little or no significant change or influence on the vegetation of the study area.

- **Selection of same spatial and spectral resolution**: Efforts were made to satisfy this requirement, but same spatial image could not be achieved, as SPOT 10m panchromatic image was used to enhanced the spatial quality of the image for the extraction of urban features in the ETM+ image. However, the spectral resolution was achieved as the two images were reduced to 3 PCA (principal component analysis) images. These are the 3 most uncorrelated bands created from each image which are good for image classification to achieve high accuracy because of distinctiveness and variation among classes.

4.6 DATA INTEGRATION

The main purpose of data integration is to allow data from different sources to be referenced in the same spatial domain so that this data can be effectively overlaid with other data for further analysis. Since data from different sources makes use of different map projections, there is need for their conversion into a standard and common map projection. However, this task was performed with utmost attention to overcome data been inaccurately geo-referenced, which can result in spatial inconsistency among different data sources even though the same map projection is utilized.

Data integration in this research started from the pre-processing stage where all satellite images and map (LUM) were geo-referenced to a common coordinate system (Zone 31 North, WGS 84). This established the data integration at the later stage, where products of image processing, the land use/cover (LULC) map, was overlaid on the Lagos land use map for spatial analysis and change visualisation.

CHAPTER FIVE: RESULTS

CHAPTER 5

RESULTS

This chapter describes land cover and land use change between 1984 and 2002 derived from post-classification comparison and change detection. It also covers the validation of Lagos State land use map, the results of a questionnaire administered on the drivers of change (socio-economic, cultural and political factors) that encourage rapid urbanisation and land cover and land use change in metropolitan Lagos. In addition, classified images were used to mapped and detect the land use classes that have changed over time, the direction of change, validation and accuracy of change. Land use/cover class at significant risk of total elimination is revealed (the analysis in this chapter is based on RS-GIS spatial analytical methods). The accuracy of the classified images was thoroughly assessed to determine the degree of accuracy and validity of the information derived from satellite images.

5.1 INTRODUCTION

Land-use/cover type or patterns and temporal change over time in the study area were mapped with post-classification change detection methods. The 1984 image (TM) and merged ETM+ (2000) and SPOT (2002) were classified at three levels independently. The first level was land cover type, the second level was land use type and the third level was the land use classes (the classification scheme was tailored to correspond with a land use map of the study area). The classified images were used to calculate areas occupied by individual classes which were analysed for changes within and between classes.

Two images (1984 and 2002 images) were separately classified and a post-classification change detection method was used for land use and land cover change detection. A change matrix was produced that revealed the spatial distribution of land use/cover changes in the study area. This then helped to improve understanding of identified factors that serves as drivers of change such as geographical, economic, social, political and environmental and their contribution to the land use/cover change in metropolitan Lagos. This is very important because it gives an insight into the trends and evolving trends in the landscape structure of Lagos which have resulted from the rapid changes that have taken place. This argument is an integral part of this study because for a community to develop in a harmonious and orderly manner, planners and environmental managers, as well as administrators, need information about where changes are taking place for urgent attention.

5.2 VALIDATION OF LAGOS STATE LAND USE MAP

The KHAT values below are used as a measure of how well remotely sensed classification agrees or are accurate with the referenced data. Landis and Koch (1977) grouped KHAT values as: 0.80 (i.e., 80%) represents strong agreement; 0.40 and 0.80 (i.e., 40–80%) represent moderate agreement; and a value below 0.40 (i.e., 40%) represents poor agreement (Congalton and Green, 1999). The conditional Kappa values in Table 4.9 shows that agriculture, bare soil, water bodies, industrial and residential land cover types have strong agreement while recreational, institutional, commercial and forest have moderate agreement.

$$\hat{k} = \frac{ObservedAccuracy - ChanceAgreement}{1 - ChanceAgreement}$$

- Shows the extent to which the correct values of an error matrix are due to "true" vs. "chance" agreement.
- Ideal case: c.a. → 0, o.a. → 1, K-hat → 1

$$\hat{k} = \frac{n\sum_{i=1}^{k} n_{ii} - \sum_{i=1}^{k} n_{i+}n_{+i}}{n^2 - \sum_{i=1}^{k} n_{i+}n_{+i}}$$; n_{ii}, n_{i+}, and n_{+i} as previously defined above.

where:

k: # of rows, columns in error matrix

n: total # of observations in error matrix

n_{ii} : major diagonal element for class I

n_{i+} : total # of observations in row i (right margin)

n_{+i} : total # of observations in column i (bottom margin)

The existing land use map for Lagos State was assessed for its accuracy with the reference data collected during site reconnaissance survey in 2003. There were several areas on the map that did not represent the actual land use/cover type (class) on the ground. And the only way to make this map useful is to update it so that reliable information can be derived from it. The methods adopted for the reference data collection were: through site visit, walk through, drive through, view from road and bridges and land use and cover identification by Town Planning Officers. These data was used to develop the reference data for the accuracy assessment error matrix table below (table 5.1).

The overall accuracy of the Lagos land use map was 65%. This was updated to achieve very high accuracy to serve as reference data for the assessment of remotely sensed data based land use/cover classifications. However, the updated land use map was 98% which is believed to be very high accuracy as most of the areas were visited while some were updated with the assistance of Town Planning field Officers. Though, maps are rarely 100%. This map was later used in conjunction with ground truth reference data collected to validate and assess the accuracy of the land use land cover maps produced from satellite images.

Reference Data

Existing Map	Residential	Commercial	Industrial	Institutional	Recreational	Agriculture	Forest	Water	Row Total	Producer's Accuracy	User's Accuracy
Residential	47	1	0	2	0	9	0	3	63	64	75
Commercial	2	12	6	0	1	1	0	0	22	63	55
Industrial	0	4	16	2	0	2	3	0	27	53	59
Institutional	0	1	5	14	0	0	0	0	20	70	70
Recreational	6	0	0	0	11	2	1	0	20	84	55
Agriculture	6	0	0	0	0	8	1		15	36	53
Forest	7	0	3	2	1	0	11	0	24	69	45
Water	5	0	0	0	0	0	0	24	29	89	83
Column Total	73	19	30	20	13	22	16	27	220		

Table 5.1: Accuracy Assessment of Lagos Land Use Map

Overall Accuracy = 65%

5.3 LAND USE/COVER CHANGE DETECTION

Digital change detection methods have been broadly divided into either spectral change identification methods or post-classification methods (Nelson, 1983; Pilon et al., 1988; Singh, 1989; Lunetta and Elvidge, 1998). The post-classification method was considered the most suitable for this study because of differing data sensors and spatial resolution of the images used. Change detection is the process used to identify differences in the state of an object or phenomenon by observing it at different times (Singh, 1989; Lu et al., 2004). Timely and accurate change detection of the Earth's surface features is extremely important for understanding relationships and interactions between human and natural phenomena in order to promote better decision making (Lu et al., 2004). The change between 1984 and 2002 detected from classification comparison of satellite images helped understanding of the relationships, interaction and influence of human activities on the land cover as it affects the land use of Lagos.

Post-classification comparison and change detection was analysed after the rectified images were separately classified from two periods of time (1984 and 2002). The land use and cover was labelled according to the land use classification scheme of reference data used (land use map of Lagos).

5.3.1 LAND COVER CHANGE BETWEEN 1984 AND 2002

The land area coverage of individual land use and land cover classes was calculated from the classified images. The supervised classification method was used to derive both 1984 and 2002 classified land use/cover maps.

The post-classification comparison of land use/cover classes gives the change that took place between 1984 and 2002 in hectares. Table 5.2 below shows detail of temporal change between land cover types. The urban/built-up area has increased by 35.5%, and bare soil has nearly doubled with 96% increase from the initial area coverage in 1984. There is an increase of 1.6% in water bodies which may be due to sensor difference or canalisation projects in the study area. There is 57.8% decrease in the forest and agriculture land cover. The spatial growth or expansion in other land cover types has taken place directly on the agricultural land and forests, as this is the only land cover type with a decrease in area coverage for the period under study. Figure 5.4 gives a graphical representation of the land cover change in Lagos between 1984 and 2002.

Land Cover Type	1984 Area (Ha)	1984 %	2002 Area (Ha)	2002 %	Change Area	% Change
Urban/Built-Up	47728	35	64656	47	+16928	35.5
Bare Soil	1265	1	2483	2	+1218	96.3
Water Bodies	55602	40	56465	41	+863	1.6
Forest & Agric	32865	24	13856	10	-19009	-57.8
Total	137460	100	137460	100		

Table 5.2 1984 and 2002 land cover change derived from post-classification comparison.

Figures 5.1 and 5.2 are the classified images at level 1, and show the land cover types of the study area together with the land cover change detection, achieved by the comparison of land area (hectares) in each class at different dates (1984 and 2002). There are four classes in the 1984 image, land cover classification while there are five in the 2002 land cover classification. The reason for this is to overcome the problem of confusion between bare soil and new urban development which have close spectral reflectance but the urban/built and new urban were merged as one land cover class for statistical analysis see table 5.2 for detail.

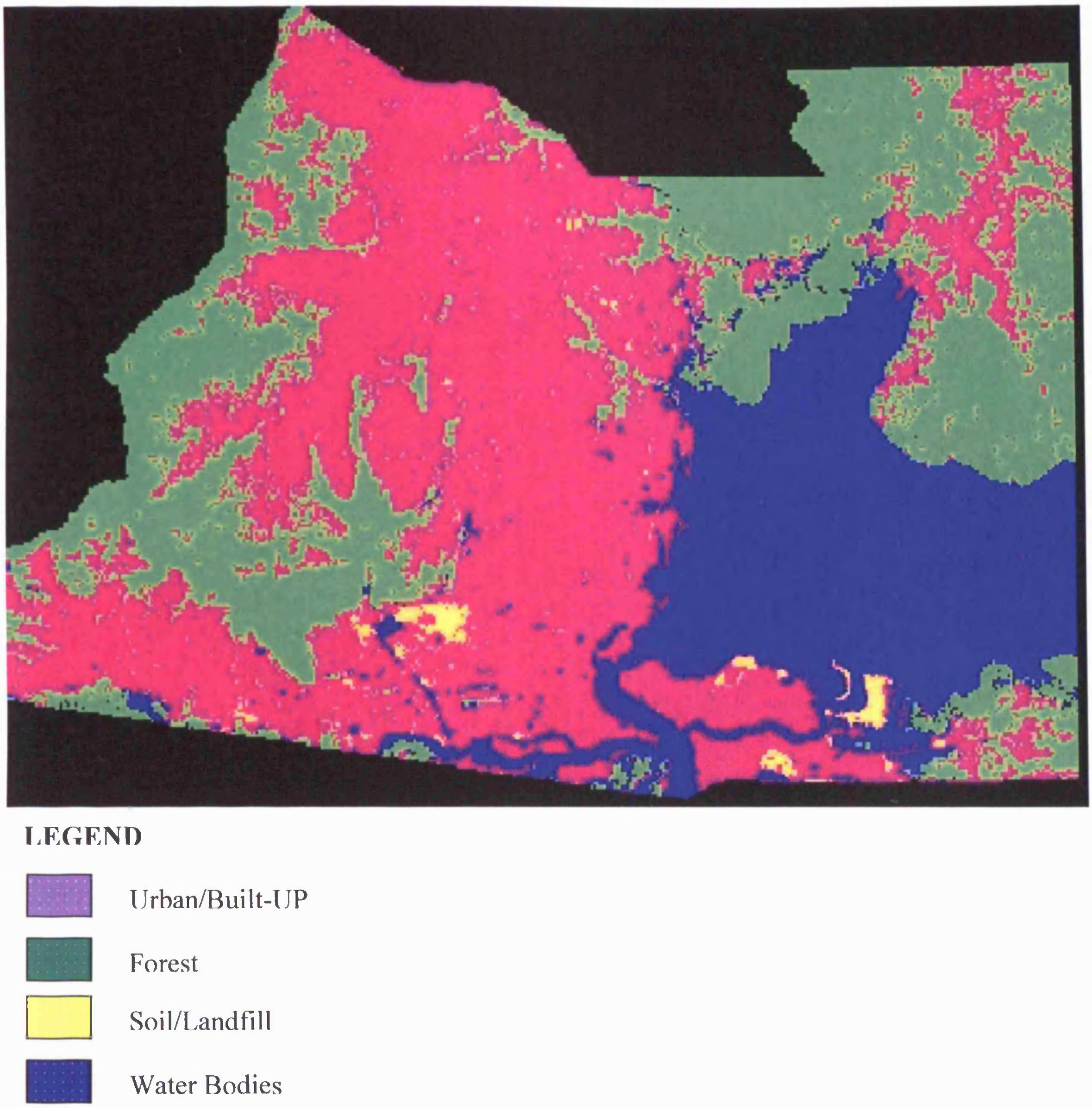

Figure 5.1: 1984 level I classified image (land cover).

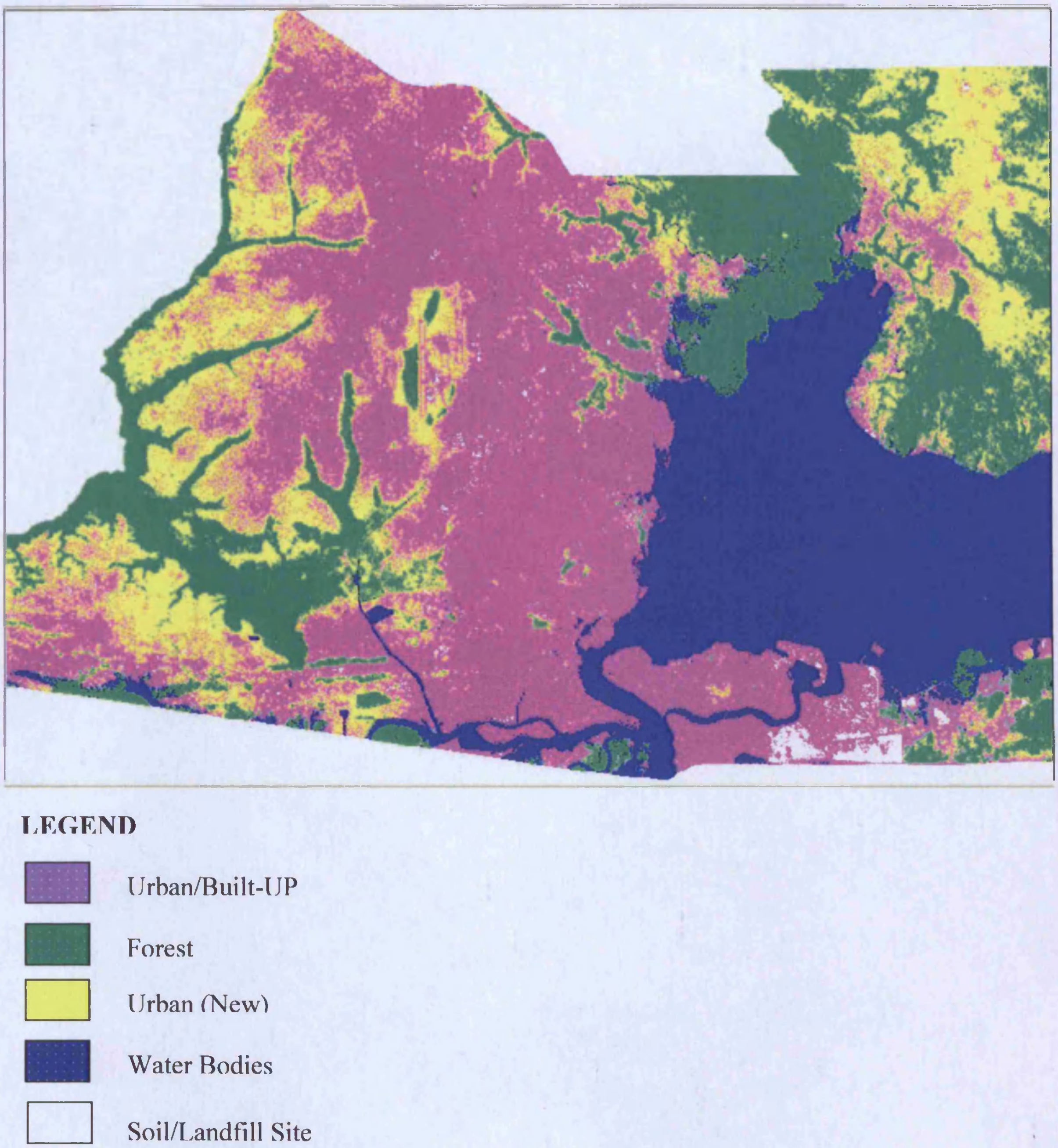

Figure 5.2: 2002 level I classified image (land cover).

Figure 5.3 highlights the areas that have changed between 1984 and 2002. The transformation or change from one class to another is used to understand the dynamics of land use and cover taking place, and the future trends that are likely to follow based on the current situation for it. Each class was compared and the percentage change was calculated to determine the rate of change between different classes.

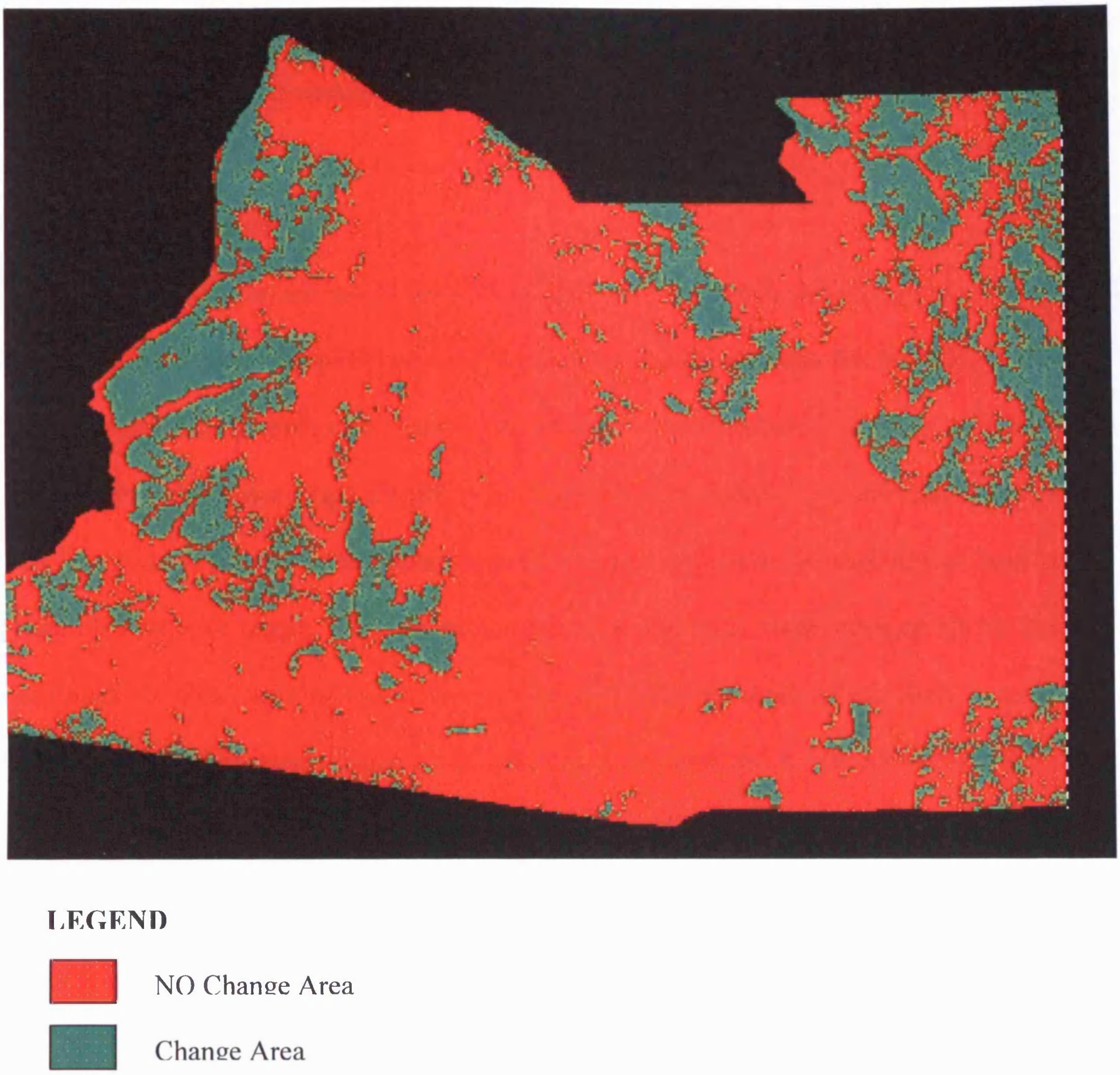

Figure 5.3: Highlight of change area from level I classification between 1984 and 2002

5.3.2 SUMMARY OF LAND COVER CHANGE BETWEEN 1984 AND 2002

The post-classification comparison of land cover classes gives the change that took place between 1984 and 2002 in hectares (Table 5.2). The land cover classes show detail of spatio-temporal changes between land cover types at level 1 classification, as the classification scheme at this level is based on the land cover change.

Urban expansion due to rapid population increase and transformation of the economic functions of Lagos from the initial agrarian settlement to the one that plays economic, institutional, political as well as social functions at the national, regional and global level underline the land cover change that has taken place in Lagos.

5.3.2.1 Urban/Built-Up

These land cover types accounted for 35% of land cover in metropolitan Lagos in 1984. By 2002, this land cover type occupied 47% which is a 36% increase for the period under study. Most of the growth took place at the urban periphery where forest and agricultural land cover is the major target for urban growth such as residential, commercial, industrial etc. The lack of effective governmental policy to protect forest and agricultural land has made this an easy target. This has now reached an alarming stage because all the land allocated for these uses in the land use map of Lagos has been encroached or totally developed for other uses, mainly urban land use. The rapid and unprecedented growth of 36% in urban areas within two decades has not happened in other cities like Lagos.

5.3.2.2 Bare Ground

This land cover type is the smallest, but what is happening within this class cannot be ignored or underestimated, because this land cover type has doubled its size within the last two decades. The shocking fact about this class is that most of the areas that were bare soil in 1984 have become urban/built-up, but still this class has increased from 1% in1984 to 2% in 2002. Field data collected and residents' responses on the questionnaire reveal the main reason behind this 100% increase to be aggressive land reclamation as well as land fill activities by the state government and land owners (indigene) of metropolitan Lagos. Most of the affected areas were swampy forest and water bodies as illustrated by the case of the Banana Highland and Oniru Family estates, both located at the south eastern part of the study area. This development has changed and is still shaping the landscape structure of metropolitan Lagos.

5.3.2.3 Water Bodies

There was a 4% increase recorded in this land cover class. This can be attributed either to the differing ability of sensors in detecting water, or human activities such as canalisation. There has been some governmental effort at channelling of canals, rivers and creeks in Lagos for effective management of run-off water and water transportation, but there was not enough data or information about major projects between the periods under study to corroborate this. The only acceptable logical thinking or belief is that the ability of the sensors for the data used (TM and ETM+) in this research have varying abilities to detect water.

5.3.2.4 Forest and Agriculture

These land cover types accounted for 24% of metropolitan Lagos in 1984 but this has since been reduced by 58% as they are an easy target for urban expansion. Most of the urban/built land cover changes (growth) have taken place either on the farmland or forest cover. Other land cover types such as bare soil have also contributed in no small way to the decrease in this land cover class, because most of the areas for land reclamation and land fill were swampy forest.

To summarise, an increase of 36% in urban/built-up cover within two decades is a testimony to the changing socio-economic activities in the study area. Bare soil nearly doubles its size from the initial area coverage in 1984. There is an increase of 1% in water bodies which may be due to sensor differences or canalisation projects in the study area. The 58% decrease in the forest and agriculture land cover shows that the spatial growth or expansion in other land cover types has directly taken place on the agricultural land and forest, as indicated by this being the only land cover type with a decrease in area coverage for the period under study.

5.3.3 LAND USE CHANGE 1984-2002

The level 3 classification scheme has eleven classes, from land cover to different land use types. Table 5.3 shows the land cover/use post-classification comparison derived from independently classified images of 1984 and 2002. The change is calculated in percentage and area (hectares) within each land use class.

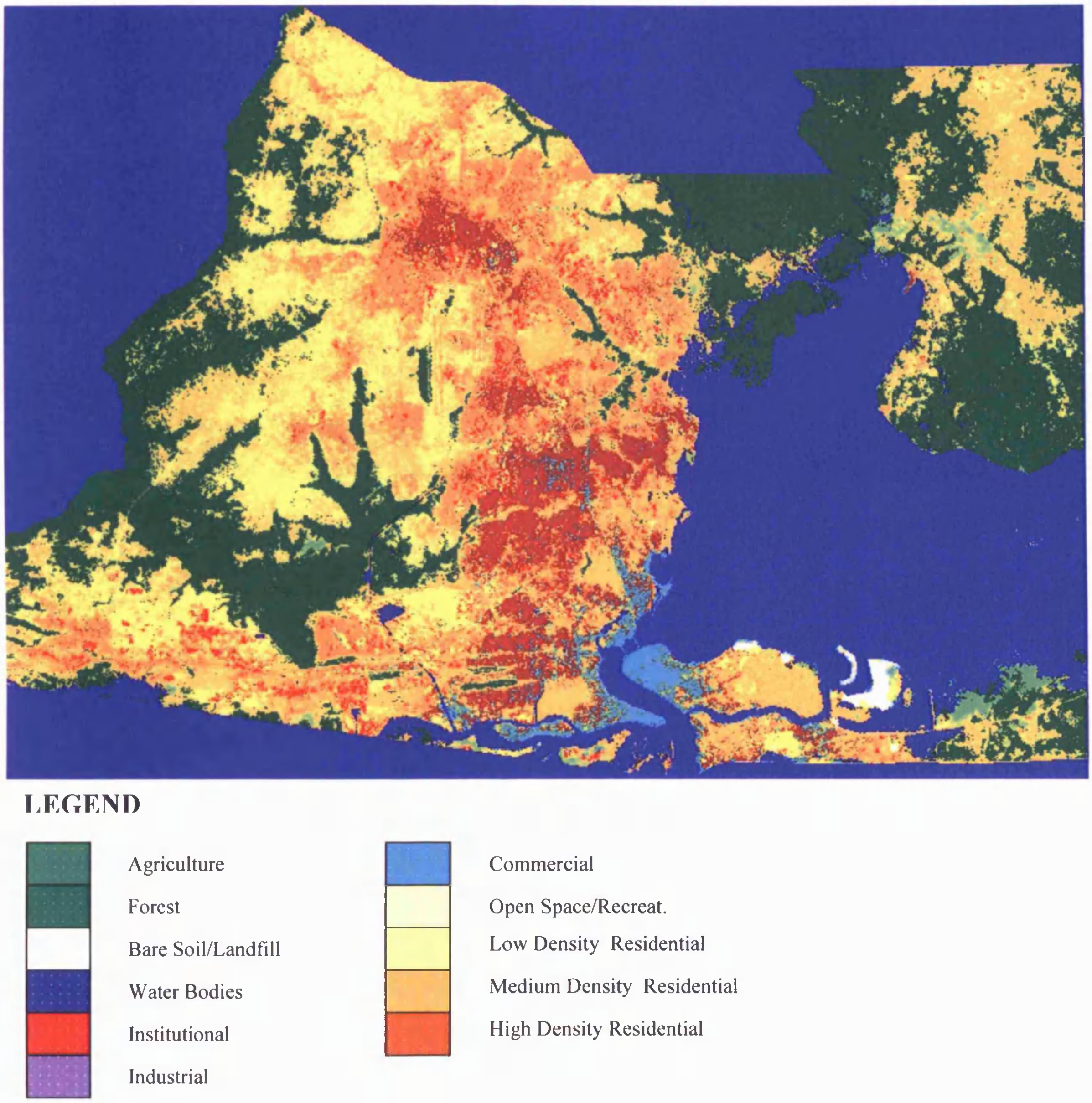

Figure 5.4: 1984 land use/cover map from level III classification

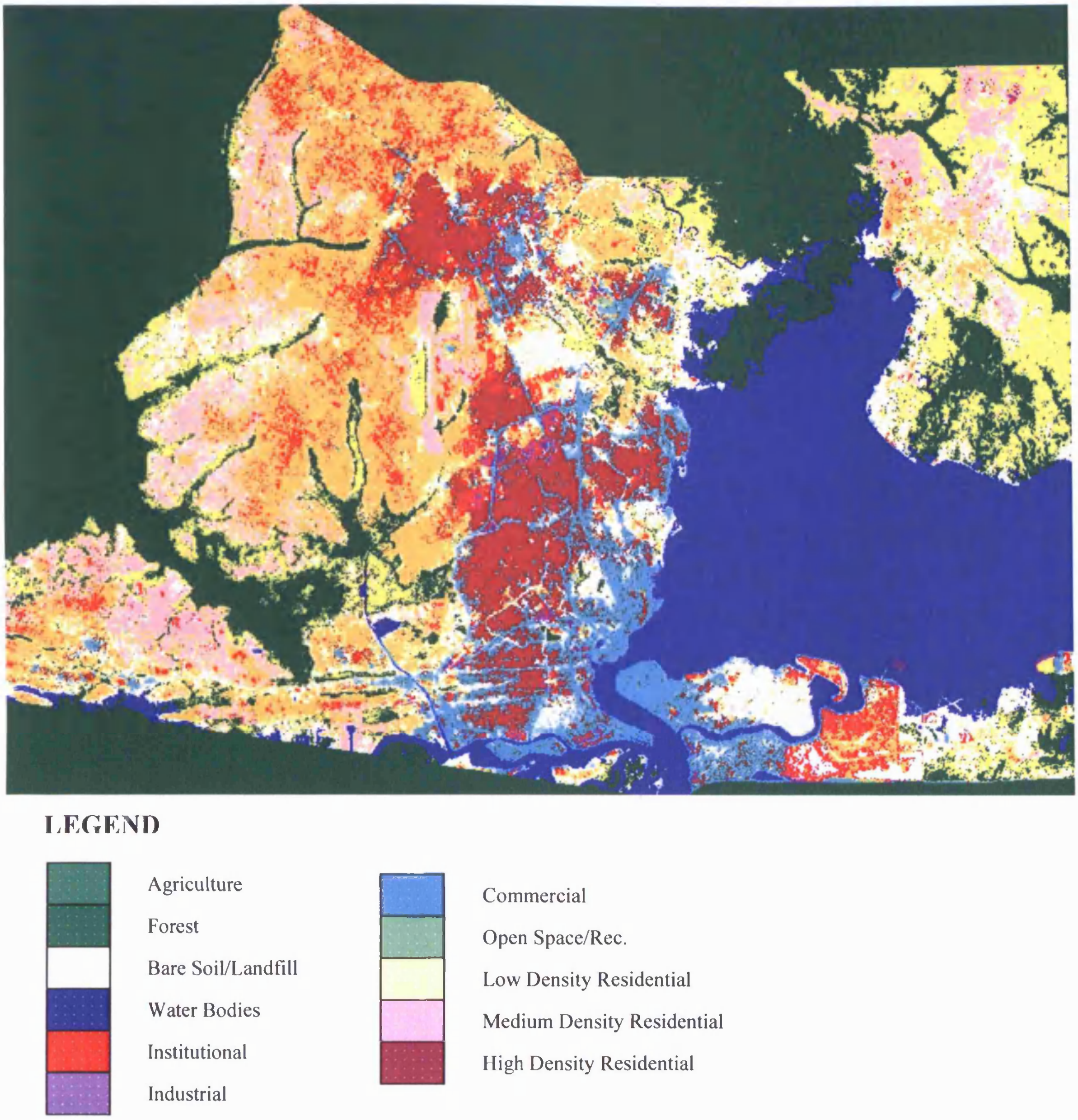

Figure 5.5: 2002 land use/cover map from level III classification

In 1984 residential land use accounted for 31% of the study area, while in 2002 residential areas accounted for 48%. The rate of residential land use growth, which is faster than any other land use/cover types, does not do justice to the residential land use conversion in the study area as this is primarily a result of the dominant growth in residential land use at the outskirts of the metropolis. The change in commercial land use area is clearly visibly from Figures 5.4 and 5.5. Most of the growth associated with commercial land use is due to transformation between land use classes. The residential land use class is the most affected by this trend of land use and cover change within metropolitan Lagos. The affected area was calculated using a GIS masking operation to determine the rate of conversion of residential land use to commercial, is shown in Table 5.3.

Land Cover Type	1984 Area	1984 %	2002 Area	2002 %	Change Area	% Change
Forest	25628	18.6	19265	14.0	-6363	-24.8
Bare Soil/ Landfill	274	0.2	459	0.3	185	67.5
Water Bodies	56860	41	56676	41	-184	-0.3
Agriculture	1591	1.6	826	0.6	-765	-48.1
Institutional	1365	1.0	3816	2.8	2451	179.6
Industrial	2342	1.7	1581	1.6	-761	-32.5
Commercial	1477	1.1	5517	4.0	4040	273.5
Open Space/ Recreational	10425	7.6	8570	6.2	-1855	-17.8
Low Density Residential	21306	15.5	13317	9.7	-7989	-37.5
Med. Density Residential	10361	7.5	18958	13.8	8597	83
High Density Residential	5831	4.2	8475	6.0	2644	45.3
Total	137460	100	137460	100		

Table 5.3: 1984 and 2002 land use change derived from post-classification comparison of level III classification

5.3.3.1 Forest

In 1984, forest land cover was 25628 hectares. This had been reduced to 19265 hectares by the year 2002. There are five different types of forest across Lagos but none of them have been spared the effects of urban growth. In the 1984 image, forest accounted for 18.4% but in the 2002 image forest accounted for 14%. Between 1984 and 2002 there was a 25% decrease in the forest cover which means that almost one quarter of the forest existing in 1984 has now been converted to other uses (urban). The rate at which forest land cover has been converted to other land cover types is alarming. If nothing is done about the rate of forest clearing, which is proceeding on a massive scale at present, there are many environmental problems that may result. Such as flooding, urban heat highland may occur and total destruction of ecosystem.

5.3.3.2 Bare Soil/Landfill Site

This is one of the rapidly changing land use classes in the study area. There has been more than 100% change in the land area occupied by bare soil/landfill. It has grown from 274 hectares in 1984 to 459 hectares in 2002. This is as a result of aggressive land reclamation programmes embarked upon by the state government as well as land owners (indigenous/aborigine Lagosians).

5.3.3.3 Industrial Land Use

More than 60% of industries in Nigeria are located in Lagos. There was a 33% decrease in industrial land use between 1984 and 2002. This is attributed to the problems faced by many industries due to the isolation of Nigeria by the international community because of military dictatorship in the country from 1983 – 1999. This had a terrible effect on the nation's industrial growth, as many of the manufacturing industries collapsed due to inability to import raw materials or export the finished goods as well as lack of international financial aid and investment in this sector because of several sanctions imposed on Nigeria. The effects of this led to the change in many industrial estates and land use such as Ogba, Ikorodu, Ikeja, Orile Iganmu, Osodi industrial estates, which have some of the industrial buildings converted to places of worship, shops and residential apartments

5.3.3.4 Institutional Land Use

Lagos served as the federal capital for many decades (1914 – 1991). This is the main reason there are many institutional uses such as governmental agencies, tertiary institutions (universities, polytechnics, colleges of education), specialist hospitals, foreign embassies and many more in the metropolis. Despite the movement of the federal capital to Abuja in 1991, Lagos still hosts all the institutional functions named above. The identified new underlying factor for the increase of 179% in institutional land use (Table 6.2) is the conversion of industrial buildings to places of worship which is prevalent in areas mentioned above.

5.3.3.5 Commercial Land Use

This land use class recorded the highest change during the period covered by this research. There was an increase from 1% in 1984 to 4% in 2002. Most of the changes took place in high-class residential neighbourhoods and major roads and traffic corridors. Areas designated "Residential Neighbourhoods" have since been turned into banks, offices, shops and many more without any regard for the environmental hazards, transportation and security problems to nearby residents. In Lagos, if an old building is being renovated or entirely redeveloped, a check on the new tenant will often reveal it to be either a bank or a fast food company. Allen Avenue, Opebi Road, Obafemi Awolowo Way, Adeniyi Jones Street, Aromire Street and Isaac John Street (Ikeja GRA), all in Ikeja, were residential areas, but today these streets have little or no sign to show that they were once residential neighbourhoods. Banks, eateries and other light commercial activities are now competing for dominance there (Njoku J., 2006).

The same situation is mirrored throughout the metropolis. For example, Ajao Estate, Airport Road, Adeniran Ogunsanya and Bode Thomas streets in Surulere, all of which were previously residential areas. The entire Victoria Island and South West Ikoyi, which were designed as residential neighbourhoods for the upper income class, have become high streets with the attendant over-stretching of the available infrastructure. In these areas, competing signposts for banks and eateries adorn the landscape. The siting of these banks, private hospitals and clinics, multinational corporations and eateries appears not to have taken into consideration the narrow roads in most of the locations. The majority of these banks and fast food outlets have few or no parking spaces for the vehicles of their many customers, who have no other option than to park in unauthorized and oftentimes dangerous spots. This situation has led to chaotic traffic conditions, noise pollution and inadequate infrastructure facilities in areas meant for residential land use.

5.3.3.6 Open Space/Recreational Land Use

Corruption and lack of respect for planning laws and regulations by the successive governments in Lagos has sacrificed the advice and position of town planning officers and other related professionals regarding open space and recreational (children's play grounds) land use. Much of this land use that was the hallmark of residential neighbourhoods has been converted by military fiats during the period of military maladministration of the nation which led to environmental abuse. There was a 18% reduction in open space and recreational land use as a result of arbitrary conversion to residential land use for the military and their cronies.

5.3.3.7 Low Density Residential Land Use

There was a decrease of about 38% in low density residential estates, despite the fact that there are new low density residential estates around the metropolis. Victoria Island and Ikoyi south, which were high-class (GRA) low density neighbourhoods, have fallen to the high rents that banks and other commercial outlets are prepared to pay for these areas. Other areas such as Ikeja GRA, Omole Estate and FESTAC Town and many more are currently going through conversion of use on a massive scale sometimes without government approval. The State government policy was change to allow the conversion of building use with main focus on revenue generation since 1999 this has created more problems than imagined by the government.

Interviews with government officials revealed that this practice was stopped, not because of the public outcry about it, but because the State Government realised that the money spent on the upgrade of infrastructural facilities such as roads and drainage reconstruction far outweighed the revenue generated. There are still several other environmental problems that the change brought with it, hence the immediate halt to the policy that allowed unethical land use conversion in the affected areas.

To summarise, the third level of image classification gives insight and impetus to the spatial variation and transformation of land use classes in metropolitan Lagos. In 1984 images, residential land use accounted for 64% of the total area, which had declined to 56% in 2002. The percentage change or decline is significantly traceable to the growth in per cent change in commercial land use, which was 14% in 1984 and now 26% in 2002, though there are also recorded growths in other land use classes which are far less than the scenario in the commercial/residential class. There are many former low residential areas which are now totally commercial. This trend, if left unchecked or challenged, means that in 25 years time the Lagos metropolitan area would be 45% commercial land use with many if not all the existing low density residential areas been converted to commercial land use. Other land use classes such as recreation, agriculture and residential, which are vulnerable, would have been taken over by commercial land use that can pay its way through economic strength. The same situation can be said to be the fate of new residential areas around or along the very active and aggressive part of Lagos considered favourable to business executives. This has led to many socio, economic and environmental problems such as congestion, housing shortage (quantity and quality) and environmental degradation.

5.4 SPATIAL ANALYSIS OF DIRECTION OF LAND USE CHANGE IN LAGOS

The visual analysis of the satellite images used in this research provided insight into the landscape structure of the study area. This helped with understanding the spatial distribution and arrangement of different land use/cover types as shown by textural difference throughout the study area. Though visual analysis does not reveal quantitative or statistical data facts, it provided a good knowledge of the general pattern of land use and land cover distribution in metropolitan Lagos. This played a crucial role in understanding the direction of growth and salient issues that have led to land use/cover conversion and differential rates. Data of various types such as the Lagos land use map, satellite images, photographs and questionnaire were combined for spatial analysis of the change that took place in the study area. Photographs were also included to provide pictorial information about the actual state of the study area.

From the survey conducted one of the major factors driving land use change in Lagos, Ikoyi, Victoria and Lekki axis is the geographic constraint imposed on these areas by the ocean, lagoons and rivers. This has traditionally made it very difficult for growth and expansion to follow its natural course and dictated the extent and direction development has followed over the years. It is only recently that technology has been deployed to overcome this in some areas such as Banana Highland, Maroko, which was land-filled to overcome the natural constraints imposed by water bodies. Visual comparison of Figures 5.6 and 5.7 shows the difference in the landscape structure of the same area, highlighted with a circle. The difference is due to desperate efforts by government and private developers to overcome natural constraints and, as pressure mounts from urban growth, to transform every parcel of land into a useful piece for urban development. Another notable thing from Figures 5.6 and 5.7 is the constraint imposed on the free growth of metropolitan Lagos by the political boundary in the northern part of image. Although the city has already grown outside the boundary, this has had an impact on the direction and rate of growth around this area as state policies were directed at changing the direction of growth by establishing new areas for development.

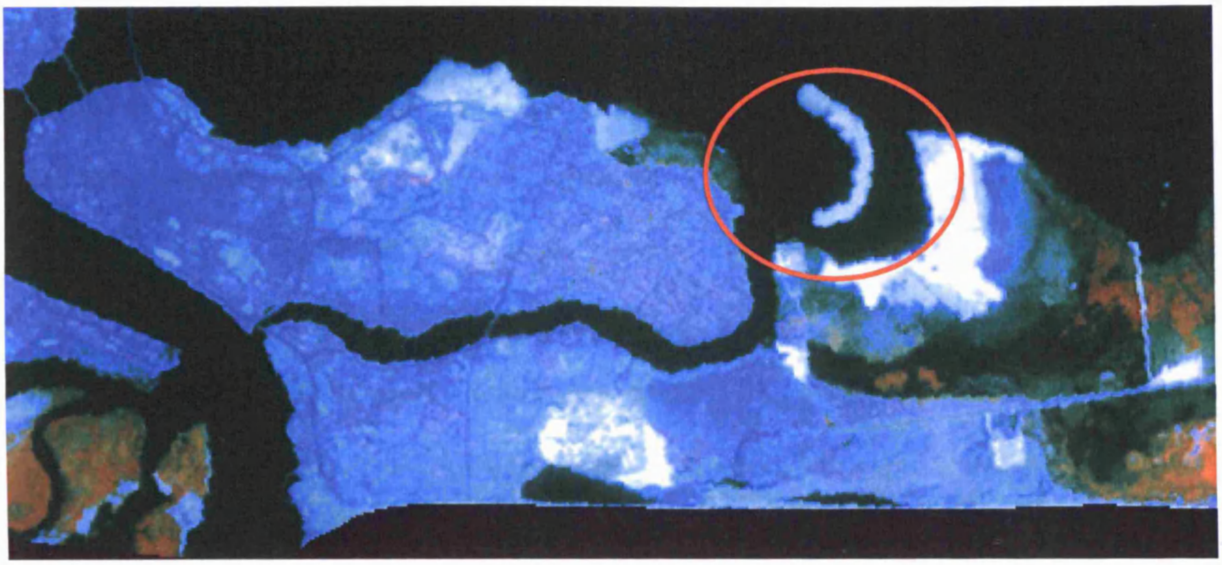

Figure 5.6: 1984 image of Lagos Islands with the original landscape structure of Banana Highland and Lekki areas highlighted with circle

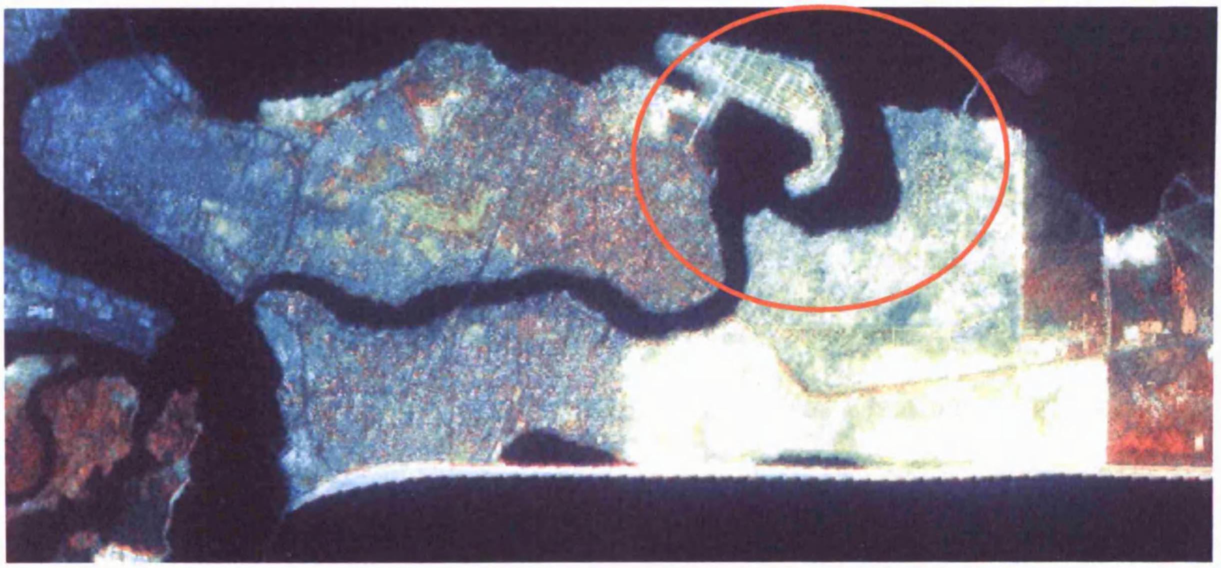

Figure 5.7: 2000 image of Lagos Islands with highlighted area of notable landscape structural change of Banana Highland and Lekki (red circle).

The GIS provided the opportunity to overlay multitemporal and ancillary data to explore various factors that may be responsible for the nature, direction, trend and rate of change taking place in the study area. Also, this allows the exploration of land use classes and their effects on the adjoining land use/cover type. Comparisons of the 1984 and 2002 land use produced from satellite images reveals very distinct features such as commercial uses along all the major roads in the metropolitan Lagos.

The nature of land use change in Lagos is revealed by the result of the level III classification and supported by the photographs taken in the field, which provided detailed information about different land use classes. The two classified images were overlaid in order to reveal areas where changes have occurred and the nature of transformation and land use class that are succeeding one another. Notable among these areas are major traffic corridors where residential buildings have been transformed into commercial use. Also, forest and agricultural land at the city outskirts has been developed, mainly for residential land use purposes.

Figures 5.7 and 5.8 land use/cover maps show rapid land use changes within the last two decades. Within metropolitan Lagos, commercial land use is the major class that is putting pressure and competition on other classes. Residential land use is the weakest of as it does not have the economic ability to compete with commercial land use, institutional or industrial. This is obvious in Ikoyi, Victoria and Lekki areas. Most of the residential uses at or along major transportation routes have been converted to commercial. This land use change at Ikoyi and Victoria Island is the result of the growth of commercial activities at Lagos Island. The inability of Lagos Island to expand due to spatial restrictions and limitation by lagoons surrounding the area led to pressure being placed on the adjoining residential areas such as Ebute Meta, Ikoyi and Victoria Island.

At the beginning of the last decade Ikoyi and Victoria Island were mainly low density residential areas, but financial considerations by landlords and the ineffectiveness of government policies led to massive conversion of land from residential to commercial uses. Though government should have halted the trend, corruption of government officials and a lack of coherent policy have failed to stop the conversion of residential buildings to offices, shops and banking halls. Within a few years, the trend took hold while government officials watched helplessly because people involved in this activity are the so-called powerful and elite in Lagos society. Where there was strong opposition to illegal conversion of building by some of the Town Planning Officers, corrupt ones helped the developers to get away without punishment or sanction on the affected developer and building. This has infuriated some other landlords who found that previously desirable properties were now undesirable due to the associated problems that come with the evolving new land use type. Noise and air pollution from power generation plant, traffic congestion and environmental degradation forced these landlords to convert their building use and relocate to another place.

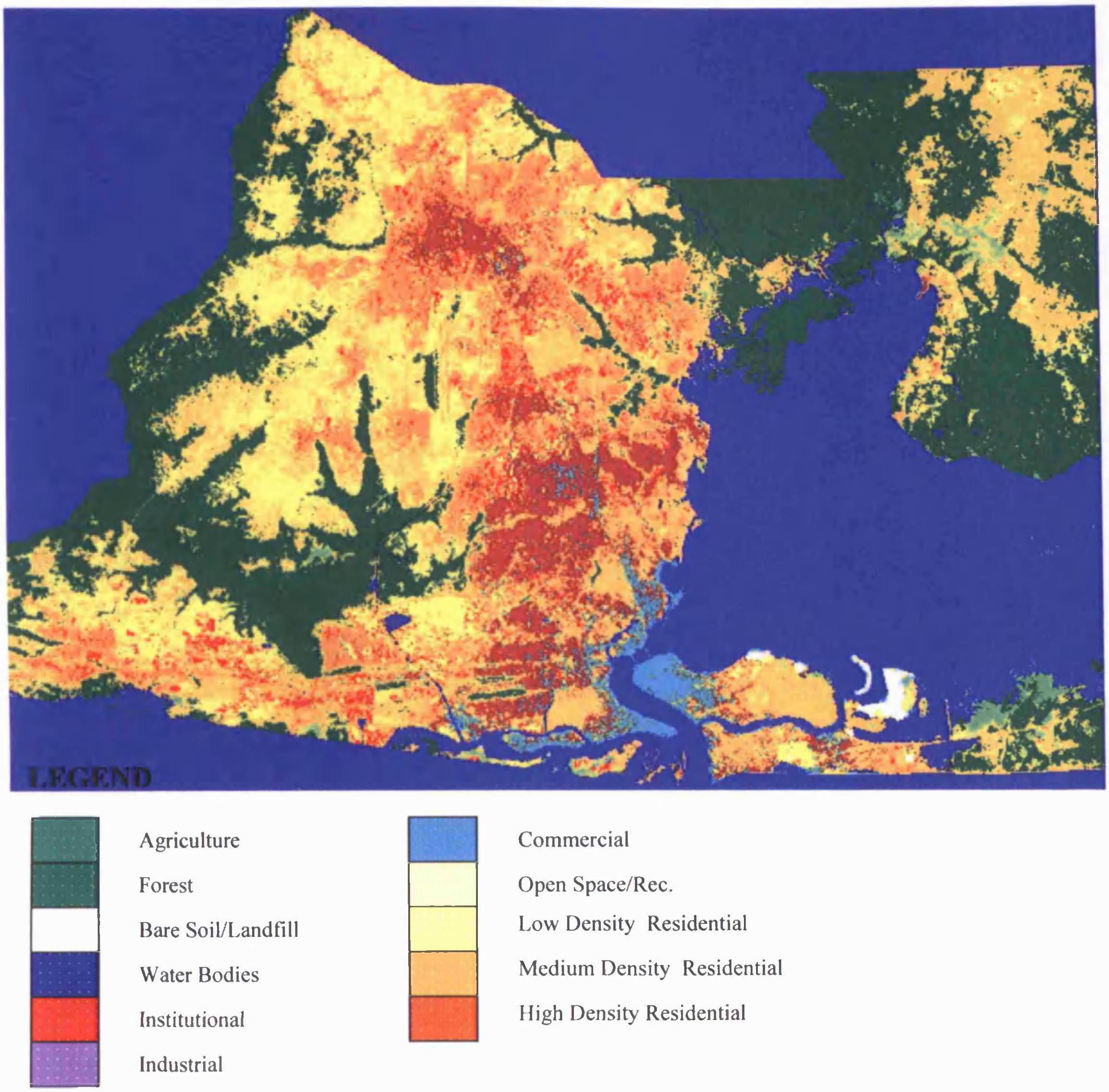

Figure 5.8: 1984 land use/cover map from level III classification

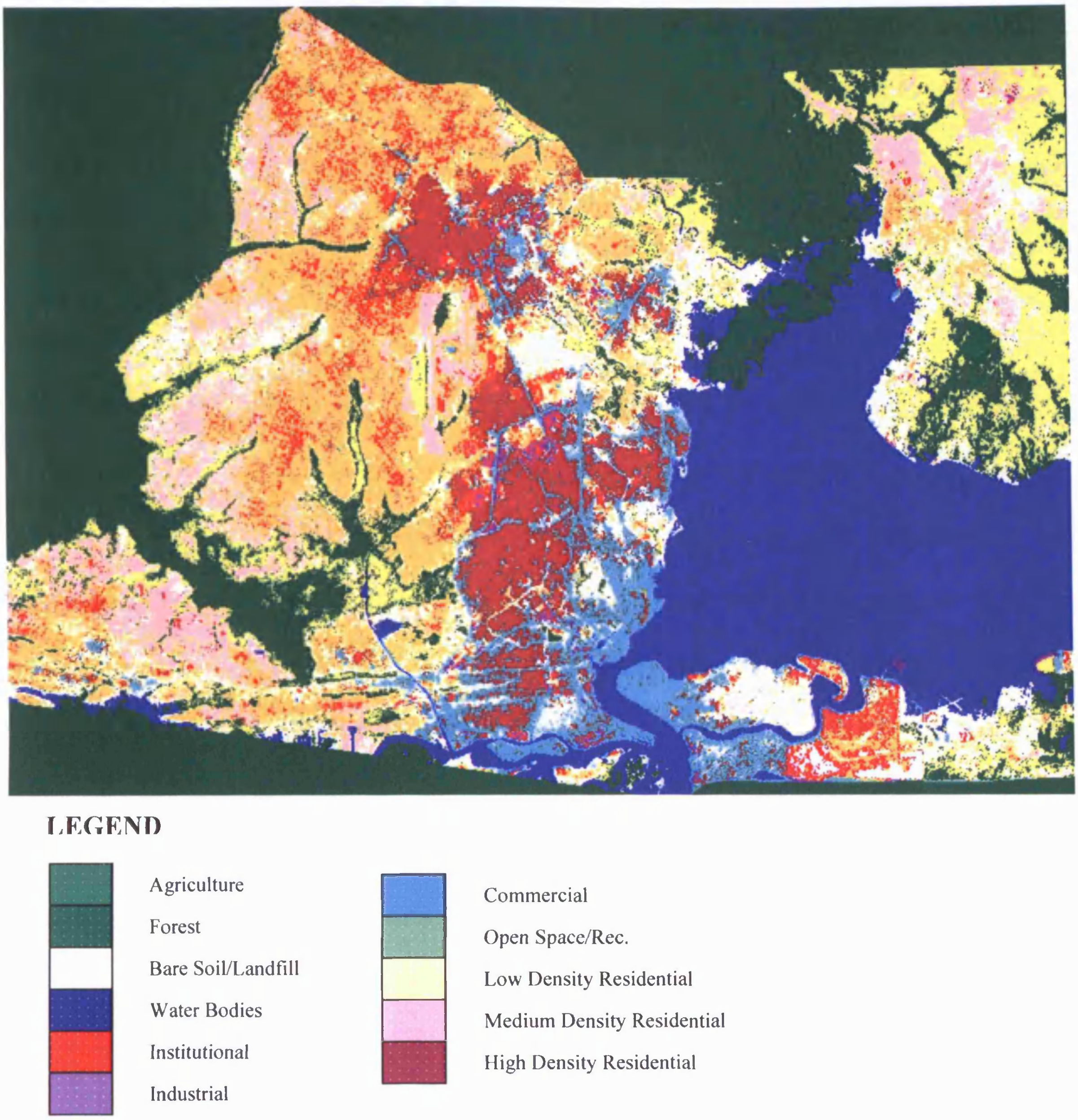

Figure 5.9: 2002 land use/cover map from level III classification

In 1984 residential land use accounted for 31% of the study area, while in 2002 residential areas accounted for 48%. The rate of residential land use growth, which is faster than any other land use/cover types, does not do justice to the residential land use conversion in the study area as this is primarily a result of the dominant growth in residential land use at the outskirts of the metropolis. The change in commercial land use area is clearly visibly from Figures 5.8 and 5.9. Most of the growth associated with commercial land use is due to transformation between land use classes. The residential land use class is the most affected by this trend of land use and cover change within metropolitan Lagos. The affected area was calculated using a GIS masking operation to determine the rate of conversion of residential land use to commercial, is shown in Table 5.3.

5.5 PHOTO-INTERPRETATION OF LAND USE/COVER TYPES AND CHANGE

With the absence of reliable aerial photographs of Lagos it is very difficult to perform any quantitative validation of the land cover/use change in Lagos through photo interpretation. However, photographs of land use and land cover types were used to give more information about the man-made direct impact on the landscape structure as well as land use/cver conversion and the threat posed by rapid urbanisation that is driving the rapid land use/cover conversion or change. Figures 5.10 and 5.11 show the nature of land cover and land use types in Lagos Island. They represent the commercial land use, institutional section of Lagos Island and the car park. These form the Lagos Central Business District known as Lagos Island. This area is classified as commercial land use because it serves a complementary function with the CBD.

Figure 5.10: Institutional land use at Lagos Island (GPS lat/long: 0543146/0713198:)

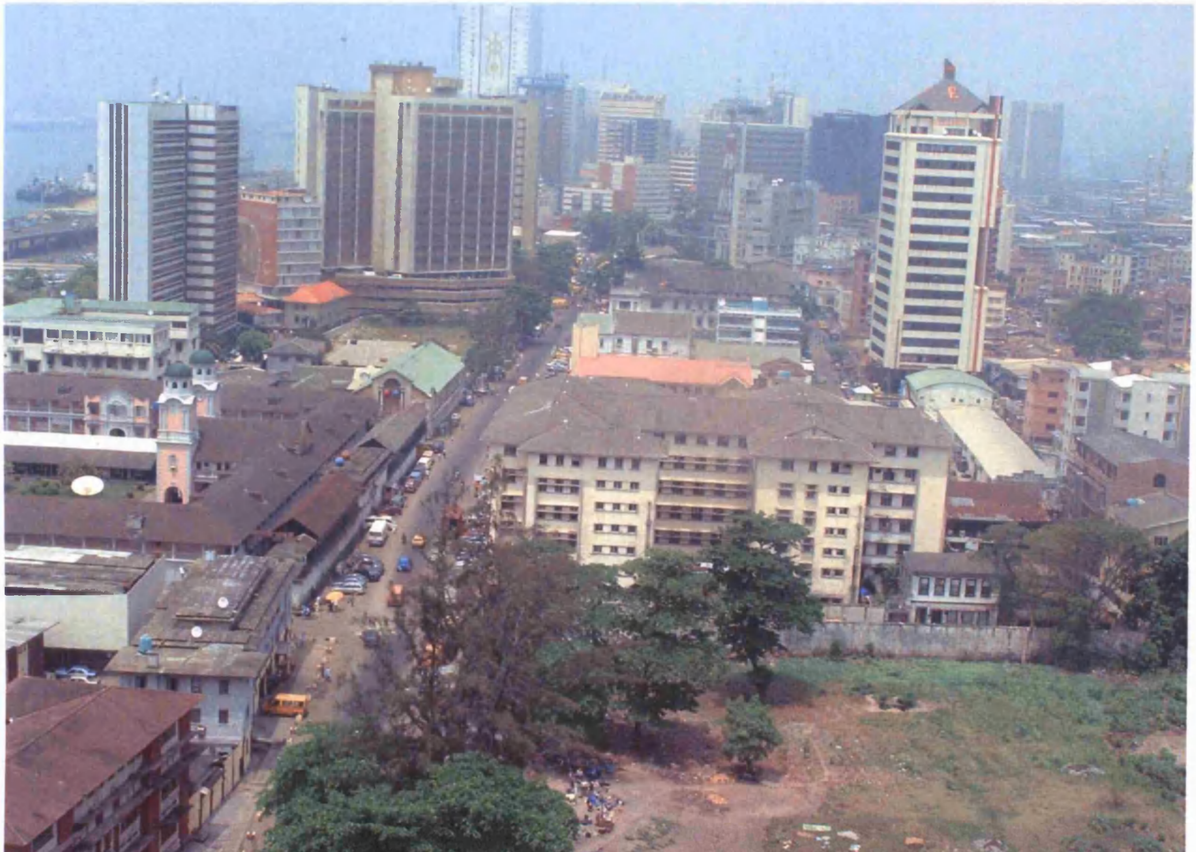

Figure 5.11: Lagos Island Business District (GPS lat/long: 0543739/0713024)

Figure 5.12 shows a low density residential estate that is built on a sand-fill site which the state government started in the mid 1990s. The whole area was water-logged and swampy in 1984 before it was landfilled for residential land use. In the 1984 satellite image this area was sandbank while most of the estate is landfill. Figure 5.1 shows the original condition of this estate while Figure 5.11 shows the present state of the area.

Figure 5.12: Osborn estate, new residential development on reclaimed/landfill site
(GPS lat/long: 0546501/0714651)

Figure 5.13 is one of many landfill sites around metropolitan Lagos. The area was part of the Lagos Lagoon before being sand-filled to pave the way for urban development. The massive scale of landfill of lagoons and creeks destroys the habitat of aquatic animals and plants. The idea of landfill has taken firm root in Lagos and the rate at which this is proceeding, if not checked, will potentially lead to grave hazards such as flooding, ocean surge and ecological destruction which is one of the problems confronting adjourning neighbourhood of Orile-Iganmu in metropolitan Lagos see figure 5.13.

Figure 5.13: Landfill site at Banana Highland Ikoyi, Lagos. (GPS lat/long: 0549648/0713644

Figure 5.14: Flooding at Orile-Iganmu in metropolitan Lagos as a result of land cover change (Photo by Sun news publishing Nigeria limited).

Continuous clearing of plantations and forest is occurring (Figure 5.15) due to the pressures of rapid population growth of metropolitan Lagos. More than 50% of the lands under these land use classes (agriculture and forest) have been converted within the last 18 years. The land use types that bear most of the brunt of this are agriculture and forest with about 58% reduction between 1984 and 2002. They are the easiest targets because there is less return on investment as a result of agricultural practice in the country (subsistence farming). In fact, the majority of Nigerian farmers live below the poverty line, hence farmers see the idea of selling their land as a means to immediate cash to meet urgent needs such as school fees for children, health costs and food for their families. They believe that urban land use type that takes over can provide blue collar jobs for farmers and their families. All these factors combined led to the rapid land use/cover change in the study area.

Figure 5.15: Palm Oil Plantation: conversion of agriculture land use to urban residential development (Adebowale Gardens residential estate. GPS: lat/long: 0571053/0715227)

Figure 5.16: Land fragmentation for subsistence agricultural practice around metropolitan Lagos (GPS: lat/long: 0522333/0715749).

5.6 VALIDATION AND ACCURACY OF LAND USE/COVER CHANGE

Accuracy assessment for Levels I, II& III

Accuracy assessment for Level I: Tables 5.4 shows error matrix and kappa values for 1984 land cover classification. The table shows the accuracy level of individual land cover classes as regards the producer's and user's accuracy. Overall accuracy of the land cover map produced from the 1984 satellite image is 96.6%.

Referenced Data

Classified Data	Water Bodies	Forest	Urban/Built	Bare Soil	Row Total	Producer's Accuracy	User's Accuracy	Kappa Value
Water Bodies	8	0	1	0	9	88.89	88.9	0.87
Forest	0	10	1	0	11	100	90.9	0.89
Urban/Built	1	0	60	0	61	96.77	98.4	0.94
Bare Soil	0	0	0	8	8	100	100	1.0
Column Total	9	10	62	8	89			

Table 5.4: 1984 Level I error matrix for land cover types.

Overall Accuracy = 96.63%

Overall Kappa Statistics = 0.93

Table 5.5 shows detail of accuracy of each land cover class as well as the overall accuracy of the 2002 land cover classification of 98.9%. This is higher than 1984 land use classification, which might be a result of sensors' ability to detect or make distinction between classes, or because of the higher spatial resolution of the data used. Also, the overall kappa value shows strong agreement with the reference data used for the accuracy assessment.

Referenced Data

Classified Data	Water Bodies	Forest	Urban/Built	Bare Soil	Row Total	Producer's Accuracy	User's Accuracy	Kappa Value
Water Bodies	6	0	0	0	6	80	100	1.0
Forest	0	4	0	0	4	100	100	1.0
Urban/Built	0	0	74	1	75	100	98.7	0.9
Bare Soil	0	0	0	4	4	100	100	1.0
Column Total	6	4	74	5	89			

Table 5.5: 2002 Level I error matrix for land cover types.

Overall Accuracy = 98.9%

Overall Kappa Statistics = 0.96

Accuracy Assessment for Land Cover and Land Use Level II

Tables 5.6 show the accuracy of classification of land cover and land use of 1984 and 2002 images with high kappa value for 1984 and 2002 respectively.

Reference Data

Classified Data	Agriculture	Bare Soil	Water Bodies	Open Space/ Recreational	Institutional	Commercial	Forest	Industrial	Residential	Row Total	User's Accuracy	Producer's Accuracy	Kappa Value
Agriculture	8	0	0	1	0	0	0	0	2	11	73	100	0.70
Bare Soil & Landfill	0	5	0	0	0	0	1	0	0	6	83	71	0.82
Water Bodies	0	0	5	0	0	0	0	0	0	5	100	100	1.0
Open Space/ Recreational	0	0	0	2	0	0	0	0	0	2	100	67	1.0
Institutional	0	0	0	0	6	0	0	0	2	8	75	67	0.72
Commercial	0	2	0	0	1	18	0	1	0	22	82	100	0.77
Forest	0	0	0	0	0	0	5	0	0	5	100	83	1.0
Industrial	0	0	0		0	0	0	4	0	4	100	80	1.0
Residential	0	0	0	0	2	0	0	0	27	29	93	87	0.90
Column Total	8	7	5	3	9	18	6	5	31	92			

Table 5.6: Error matrix for 1984 level II land use/cover types.

Overall Accuracy = 86.96%

Kappa (K) statistics = 0.84

Reference Data

Classified Data	Agriculture	Bare Soil	Water Bodies	Open Space/ Recreational	Institutional	Commercial	Forest	Industrial	Residential	Row Total	Producer's Accuracy	User's Accuracy	Kappa Value
Agriculture	8	0	0	1	0	0	0	0	2	11	100	73	0.70
Bare Soil & Landfill	0	5	0	0	0	0	1	0	0	6	71	83	0.82
Water Bodies	0	0	5	0	0	0	0	0	0	5	100	100	1.0
Open Space/ Recreational	0	0	0	2	0	0	0	0	0	2	67	100	1.0
Institutional	0	0	0	0	6	0	0	0	2	8	67	75	0.72
Commercial	0	2	0	0	1	18	0	1	0	22	100	82	0.77
Forest	0	0	0	0	0	0	5	0	0	5	83	100	1.0
Industrial	0	0	0		0	0	0	4	0	4	80	100	1.0
Residential	0	0	0	0	2	0	0	0	27	29	87	93	0.90
Column Total	8	7	5	3	9	18	6	5	31	92			

Table 5.7: Error Matrix for 2002 level II Land Use/Cover Types.

Overall Accuracy = 86.96%

Kappa (K) statistics = 0.84

Supervised classification training signature contingency matrix level II: Signature collected for training sample that was used for the classification at level II was assessed for the suitability of the sample to represent and its level of distinction from other land use classes. Table 5.8 are the contingency matrix table showing the overall accuracy of the representative signatures used for the classification. Table 5.9 show the accuracy value of individual land use and cover types.

Reference Data

Classified Data	Water Bodies	Forest	Agric	Bare Soil	Industrial	Commercial	Recreational	Institutional	Residential	Row Total	Class Training Signature Accuracy
Water Bodies	798	0	0	0	0	0	0	0	0	798	100
Forest	0	637	0	0	0	0	0	0	0	64	100
Agric	0	0	100	0	0	0	0	0	1	637	99
Bare Soil	0	0	0	64	0	0	0	0	0	101	100
Industrial	0	0	0	0	64	0	0	0	0	118	97
Commercial	0	0	0	0	0	111	0	0	7	71	97
Recreational	0	0	0	0	0	0	63	0	8	70	98
Institutional	0	0	0	0	2	0	0	68	0	64	100
Residential	0	0	1	0	0	3	1	0	103	108	87
Column Total	798	637	101	64	66	114	64	68	119	2031	

Table 5.8: Contingency Matrix for 1984 level II Land Use/Cover Types. **Overall Accuracy = 98.86%**

Reference Data

Classified Data	Water Bodies	Forest	Agric	Bare Soil	Industrial	Commercial	Recreational	Institutional	Residential	Row Total	Class Training Signature Accuracy
Water Bodies	6921	13	0	0	0	0	0	0	0	6934	**97.25**
Forest	171	7725	0	0	0	0	0	0	0	7896	**99.83**
Agric	0	0	260	1	1	0	7	2	4	275	**84.42**
Bare Soil	0	0	1	672	13	0	0	2	0	688	**92.95**
Industrial	0	0	5	50	259	0	0	1	0	315	**94.87**
Commercial	25	0	0	0	0	813	0	2	179	1019	**95.99**
Recreational	0	0	42	0	0	0	487	4	266	799	**84.99**
Institutional	0	0	0	0	0	26	11	288	132	457	**84.21**
Residential	0	0	0	0	0	8	68	43	2009	2128	**77.57**
Column Total	7117	7738	308	723	273	847	573	342	2590	20511	

Table 5.9: Contingency Matrix for 2002 level II Land Use/Cover Types. **Overall Accuracy = 94.75%**

SUPERVISED CLASSIFICATION TRAINING SIGNATURE CONTINGENCY MATRIX LEVEL III: There is a significant reduction in both the overall accuracy from the contingency matrix table and individual class accuracy. This is because at the level III, it is more difficult to separate some of the land cover/use signature types.

Reference Data

Classified Data	Water Bodies	Forest	Agric	Bare Soil	Industrial	Commercial	Recreational/ Open Space	Institutional	Low Density	Medium Density	High Density	Row Total	Class Training Signature Accuracy
Water Bodies	2359	0	0	0	0	0	0	0	0	0	0	2359	97.1
Forest	69	1361	0	0	0	0	0	0	2	0	0	1432	99.9
Agric	0	0	163	0	0	0	0	0	3	0	0	166	98.8
Bare Soil	0	0	0	487	1	0	0	0	0	0	0	488	94.9
Industrial	0	0	0	26	67	15	0	0	0	0	0	108	93.1
Commercial	0	0	0	0	3	420	0	0	0	0	56	479	81.1
Recreational/Open Space	0	0	1	0	0	0	37	0	12	3	0	53	84.1
Institutional	0	0	0	0	0	1	0	59	0	5	0	65	98.3
Low Density	1	1	1	0	0	1	1	0	209	14	1	229	91.6
Medium Density	0	0	0	0	0	2	6	1	2	112	2	125	83.6
High Density	0	0	0	0	1	79	0	0	0	0	399	479	87.1
Column Total	2429	1362	165	513	72	518	44	60	228	134	458	5983	

Table 5.10: Contingency Matrix for 1984 level III Land Use/Cover Types.

Overall Accuracy = 94.82%

Reference Data

Classified Data	Water Bodies	Forest	Agric	Bare Soil	Industrial	Commercial	Recreational	Institutional	Low Density	Medium Density	High Density	Class Training Signature Accuracy	Row Total
Water Bodies	6912	13	0	0	0	0	0	0	1	0	0	97.1	6926
Forest	165	7725	0	0	0	0	0	0	3	0	0	99.8	7893
Agric	0	0	260	1	1	0	7	2	0	1	0	84.4	272
Bare Soil	0	0	0	669	13	0	0	2	0	6	0	92.5	690
Industrial	0	0	5	50	259	0	0	1	0	0	0	94.8	315
Commercial	25	0	0	0	0	707	0	1	35	0	102	83.5	870
Recreational	0	0	42	0	0	0	461	4	36	135	0	80.5	678
Institutional	0	0	0	0	0	2	11	287	41	165	105	83.9	611
Low Density	15	0	0	0	0	38	59	9	1840	12	32	92.5	2005
Medium Density	0	0	1	3	0	0	35	22	16	1282	0	80.1	1359
High Density	0	0	0	0	0	100	0	14	18	0	1147	82.8	1279
Column Total	7117	7738	308	723	273	847	573	342	1990	1601	1386		22898

Table 5.11: Contingency Matrix for 2002 level III Land Use/Cover Types.

Overall Accuracy = 92.79%

5.7 ANALYSIS OF QUESTIONNAIRES

The questionnaire administered shows the factors that are responsible for the rapid land use/cover change in metropolitan Lagos as well as the reliability of the information derived from it. The assessment of reliability of the information from the questionnaire is based on the professional experience of the respondents, age and length of stay in the neighbourhood. The age of respondents is considered to be very important to the quality of data and information derivable from the survey. About 75 per cent of people interviewed are more than 30 years old. This is believed to be a reliable source of information about the land use/cover changes and transformation in the study area that is dated back to over two decades.

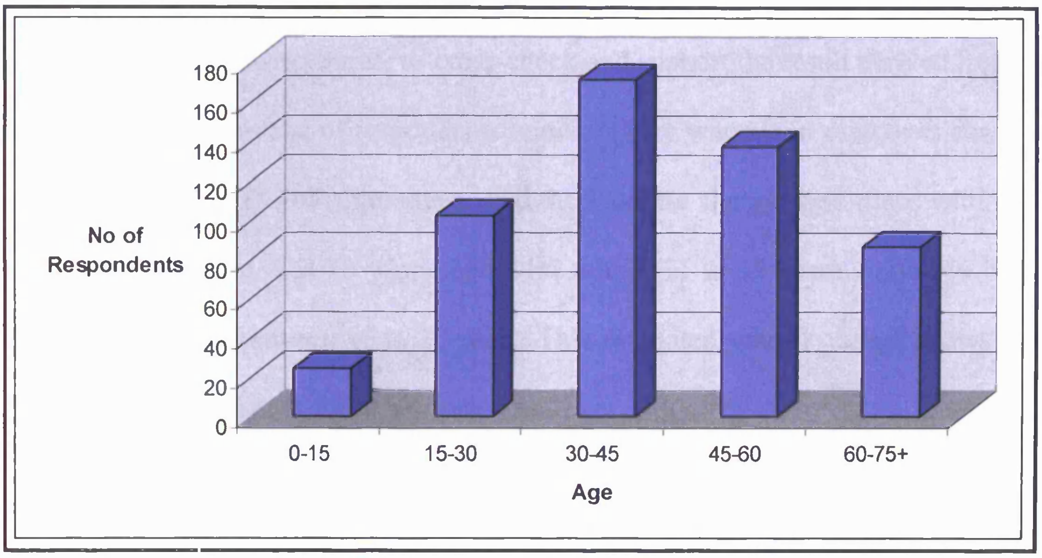

Figure 5.17: Shows the age distribution of respondents.

Figure 5.18 shows the length of residency of the respondents in the area. The length of time lived in an area is believed to provide reliable information about the past and present land use/cover of the area. The rate and trend of changes is best determined by those who actually witnessed the changes, 66% lived in the area between 16 and 20 years and above while 15% has been living in their respective neighbourhood. This indicates reliable information from the respondents.

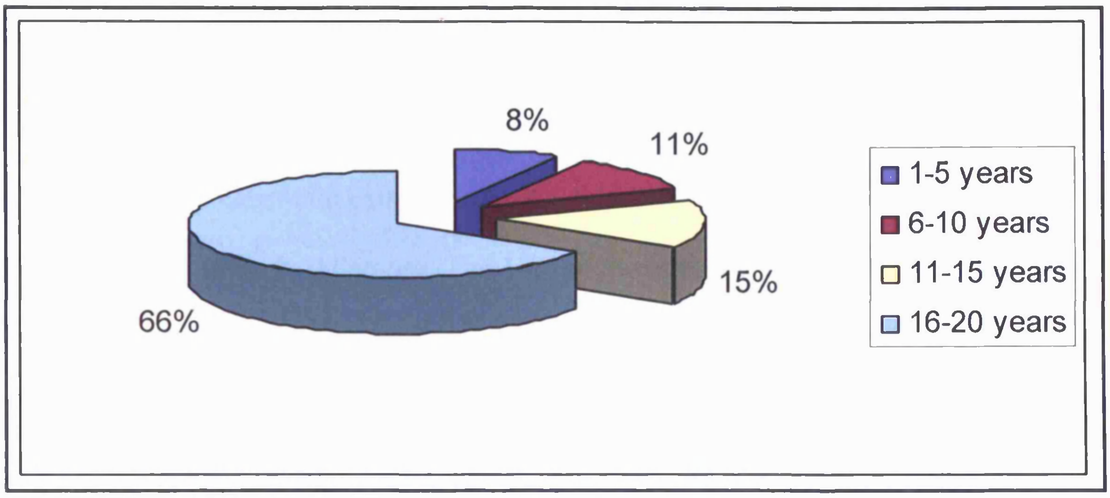

Figure 5.18: How long the respondents have lived in the area.

Figure 5.19 gives information about the transformation of major land use/cover types from one use to another in the study area, to cross-check and support the result derived from the satellite imagery. The percentage of respondents and the years when land use/cover change happened in their area. The 38% of respondents said the land use change took place within the last five years, 29% between 6 to 10 years, and 24% within 11 to 15 years while 9% land use/cover change took place between 16 to 20 years. This estimated year of change shows an increasing land use/cover change in the study area.

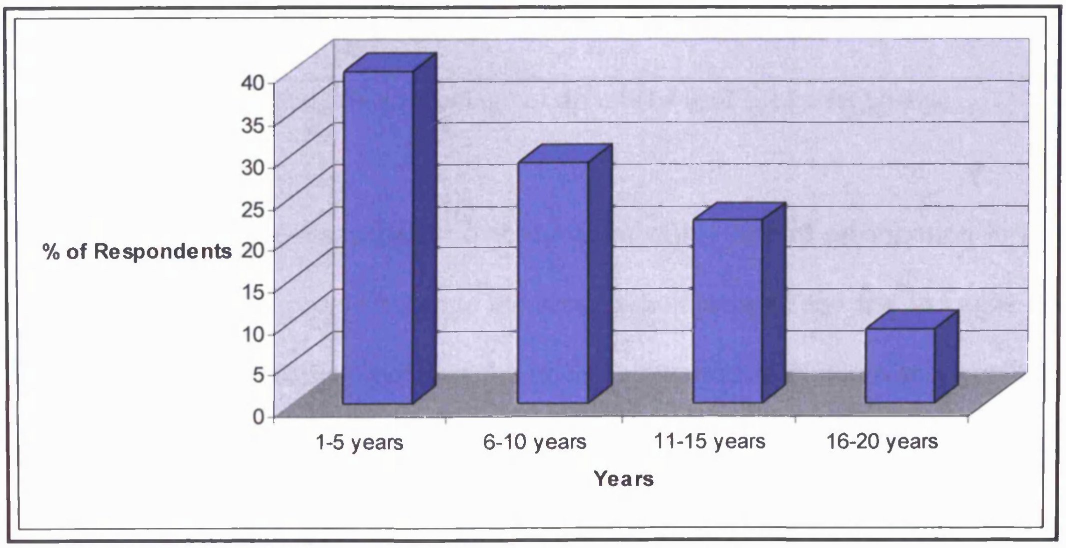

Figure 5.19: Shows the percentage of respondents and the years when land use/cover change happened in their area.

Table 5.12 shows that profit maximisation for economic gain is the major consideration for building use change by landlord in metropolitan Lagos. More than 70% of the respondents believed that the economic gain is the major factors considered by the building owners before the conversion of the building use. The 13% of the landlord was encouraged by the change in government policy that allowed the conversion of building use with the payment of money to the State government due to the revenue generation target set for the ministry of physical planning. However, social and environmental problems forced the 11% and 5% to change their building use because of social and environmental problems such as noise pollution, traffic congestion, crime and many more social vices.

Drivers of Change	Number of Respondents	Percentage (%)
Economic	351	71
Social	55	11
Political	64	13
Environmental	25	5
Total	495	100

Table 5.12: Table showing the percentage of drivers of land use/cover change.

Figure 5.20 shows the respondents' determination of the rate of urbanisation in Lagos. The majority (87%) of the people poll rate the urbanisation as rapid and fast in Lagos. More than 68% of the respondents believed that the rate of urbanisation in Lagos metropolitan areas is very rapid, while about 19% believe that the rate is fast, and 7% and 6% believe that the rate is moderate and slow respectively.

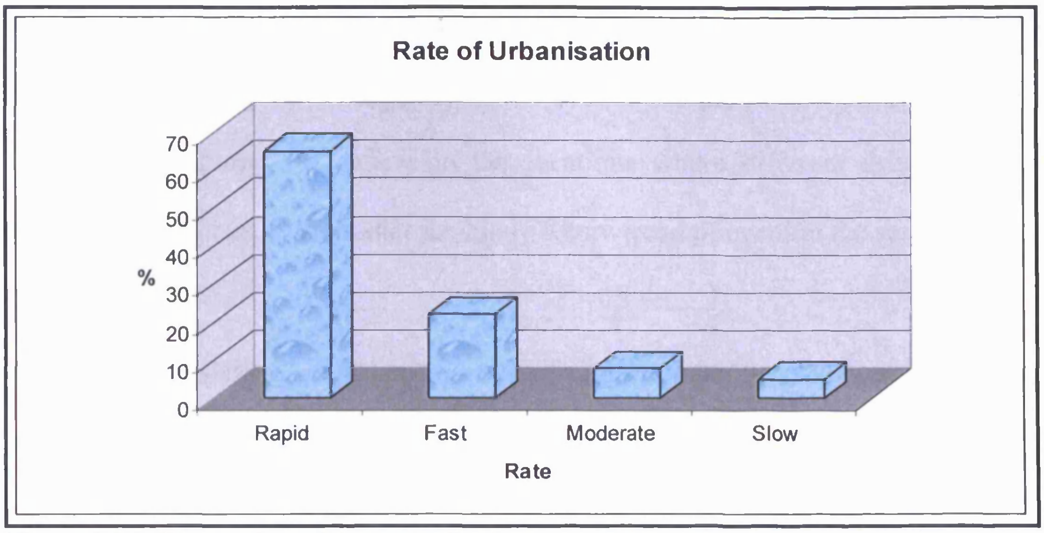

Figure 5.20: Perception of the rate of urban growth in metropolitan Lagos from questionnaire data.

5.8 DRIVERS OF CHANGE AND THEIR LOCATION

The spatial analysis of drivers of change is based on the point pattern analysis whereby the points represent the respondents of the administered questionnaires. The entire body of points were interpolated and mapped in relation to the views of the respondents on the identified drivers of change. These factors (driver of change) were mapped to reveal the spatial pattern, identified trend in the data, explored relationships and coverage of each factor.

The assumption that makes interpolation a viable option is that spatially distributed objects are spatially correlated that is, things that are close together tend to have similar characteristics. Using this analogy, it is easy to see that the values of points close to sampled points are more likely to be similar than those that are farther apart, this is the basis of interpolation. The point interpolation is to create an elevation surface from a set of sample measurements. In the following graphic, each symbol in the point layer represents a location where the elevation has been measured. By interpolating, the values between these input points were predicted.

Inverse distance weighted Interpolation, Kriging and Spline method was used to predict values for cells in a raster from a limited number of sample data points acquired during field survey. These data was used to determine the locations where different drivers of change have dominating effect so as to predict the likely future trend of event in the study area.

Interpolation is defined as the method of predicting unknown values using known values of neighbouring locations. Interpolation is utilized most often with point based elevation, the image below illustrates a continuous surface that has been created by interpolating sample data points. Spatial distribution of respondents was mapped with distance weighted average (figure 5:20), this shows a very good spread of the respondents throughout the study area. Hence, the information derived from the survey is true representation of the land use/cover change and its drivers.

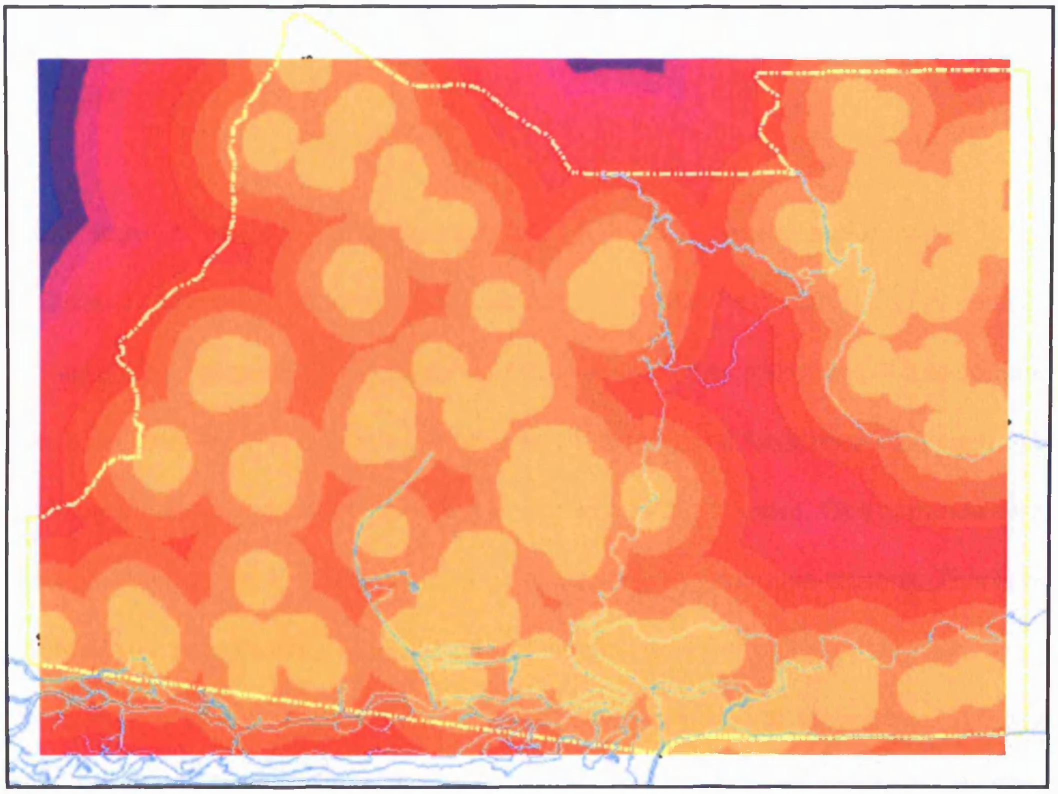

Figure: 5.21: Interpolation of the point data showing the spatial coverage of respondents

However, this study has found that five major factors are responsible for the land use/cover conversion in metropolitan Lagos. These are: economic, population growth, political, social and environmental. From the survey conducted, 96% of people interviewed identified these factors as being the driving forces behind land use conversion in Lagos. The need to provide shelter for the ever-expanding population has made residential land use the biggest threat to other uses, especially agricultural, recreational and open space. In contrast, residential land use is under pressure in the inner city and high class residential estates where commercial land use is taking over. Solademi Fatai (2005) identified two patterns of land use change in the study area. In the city, commercial uses are the biggest threat, while residential expansion is the case around the city periphery and surrounding settlements like Ikorodu, Ajah, and Egbe. Economic reasons are said to be the most potent of them all because people want to maximise profit from investment in real estate and the land use class that can pay most is being favoured to occupy available property. Some even sell their homes outright because they can make an instant profit on it.

Major areas of land use/cover conversions that have witnessed rapid change in the last two decades. The field survey showed two major types of land use conversion or change going on in Lagos. The first one is the conversion of residential areas (Ikoyi and VI) to commercial land use. More than 80% of residential houses in Victoria Island have been converted to other uses such as offices, clinics, schools, eateries, hotels and many more. One common feature about the new building use is that it is all motivated purely by economic reasons. This is being done without any consideration for the public interest or environmental impact, or indeed the transportation problems that accompany such development. The second type is the conversion of building use along major roads to commercial, places of worship and schools. This has also brought with it the aforementioned problems. The maps below show the spatial locations where the drivers of change have more impact than another. See figure 5. 21 – 5.24.

Social Factor: This is one of the major factors affecting land use change in Lagos metropolitan area. The low density residential area such as Ikeja GRA, Ikoyi, Lekki-Ajah axis are considered a place meant for the super rich in the society. Hence, for the social value that is attributed to this area many people will stop at nothing to ensure that a piece of land is acquired to build master-piece so as to show that they belong to the exclusive club of affluence in the society. This often led to the conversion of vital component of functional neighbourhood such as children playing ground and open space to residential land use. Figure 5.22 shows Ikoyi, Lekki-Ajah, Ikeja GRA and other low density residential areas as where the land use change are taken place based on social value attributed to those area.

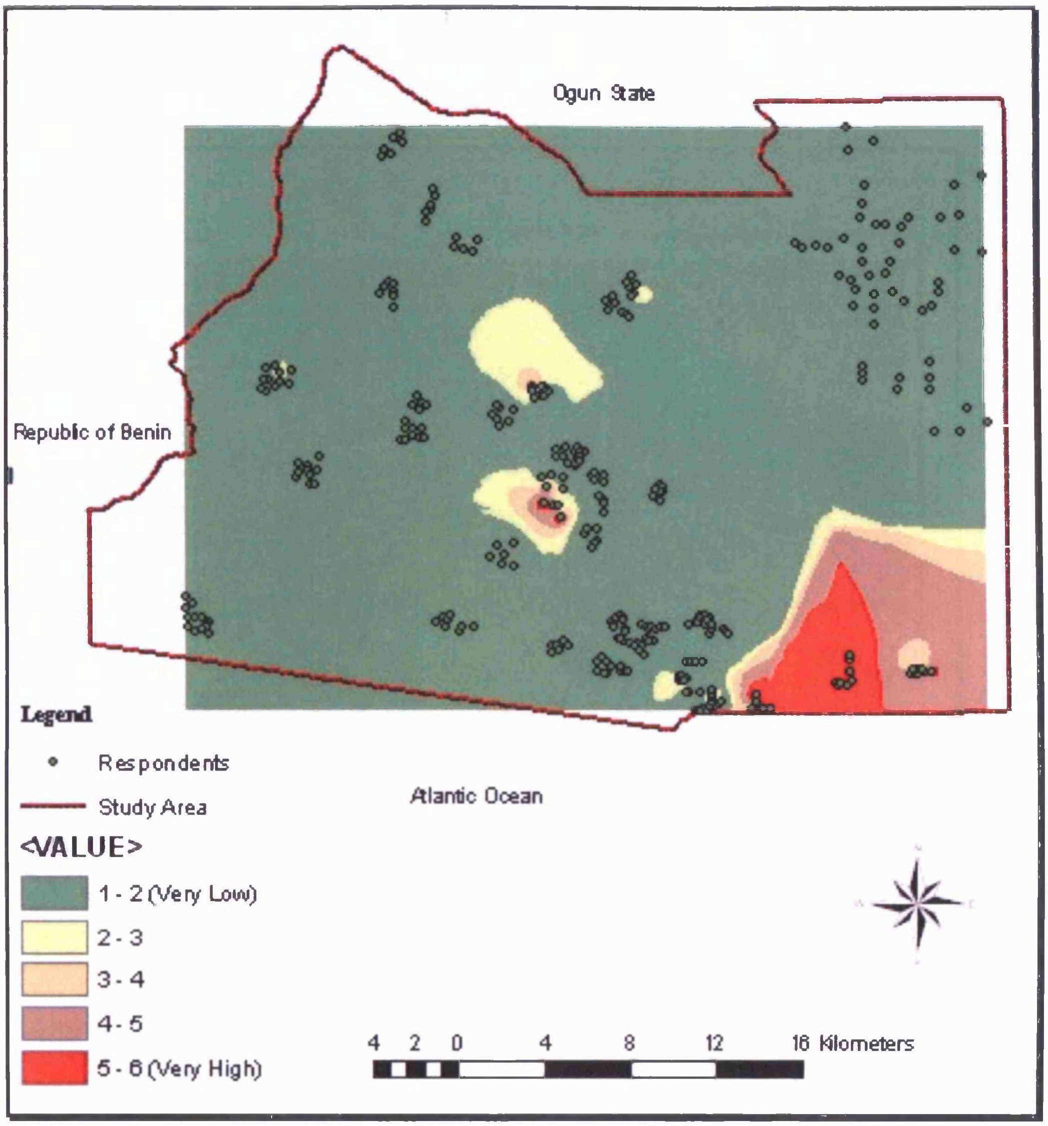

Figure 5.22: Map showing area where Social Factor is driving land use change.

Political Factor: This factor has greater impact on the land use/cover change in metropolitan Lagos because of the location of many institutions both federal and state in the study area. The establishment of schools, hospitals, local government secretariat and many more by the government usually relied on the constitutional power of government to revoke land for the use of the public functions. Though, compensation is paid but the scale area coverage of the required land often present change in the land use of the place where it happened. Figure 5.23

shows the areas where political factor is the major cause of the land use/cover change due to the establishment of general hospital, university or secretariat etc.

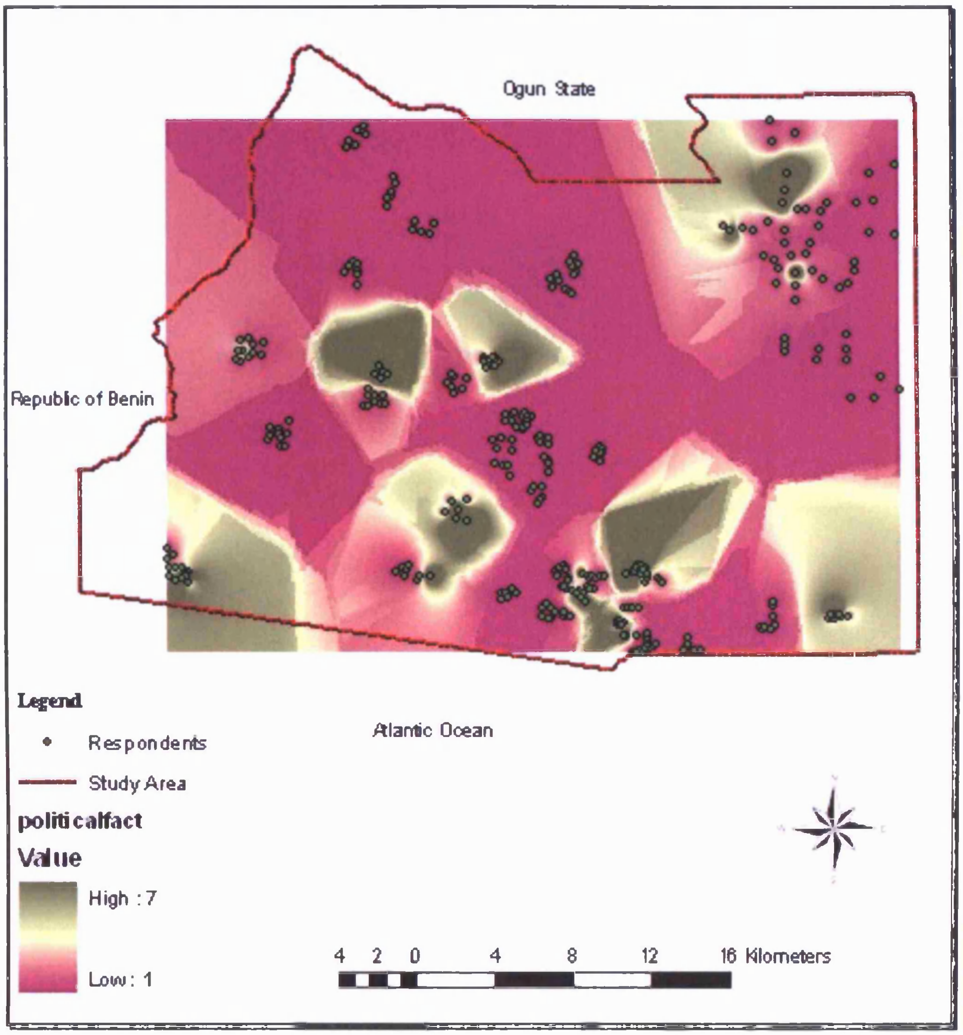

Figure 5.23: Map showing area where Political Factor is driving land use change.

Economic Factor: This is the most potent of all drivers of land use/cover change in the study area. The commercial function that Lagos serves to Nigeria and West African sub region makes nearly every business ventures compete for space either for offices, industrial estate, shopping complex and several others at Lagos. There is general spread of the economic factor as the driver of land use and cover change throughout the study area. The areas where this factor has low impact are the institutional land use.

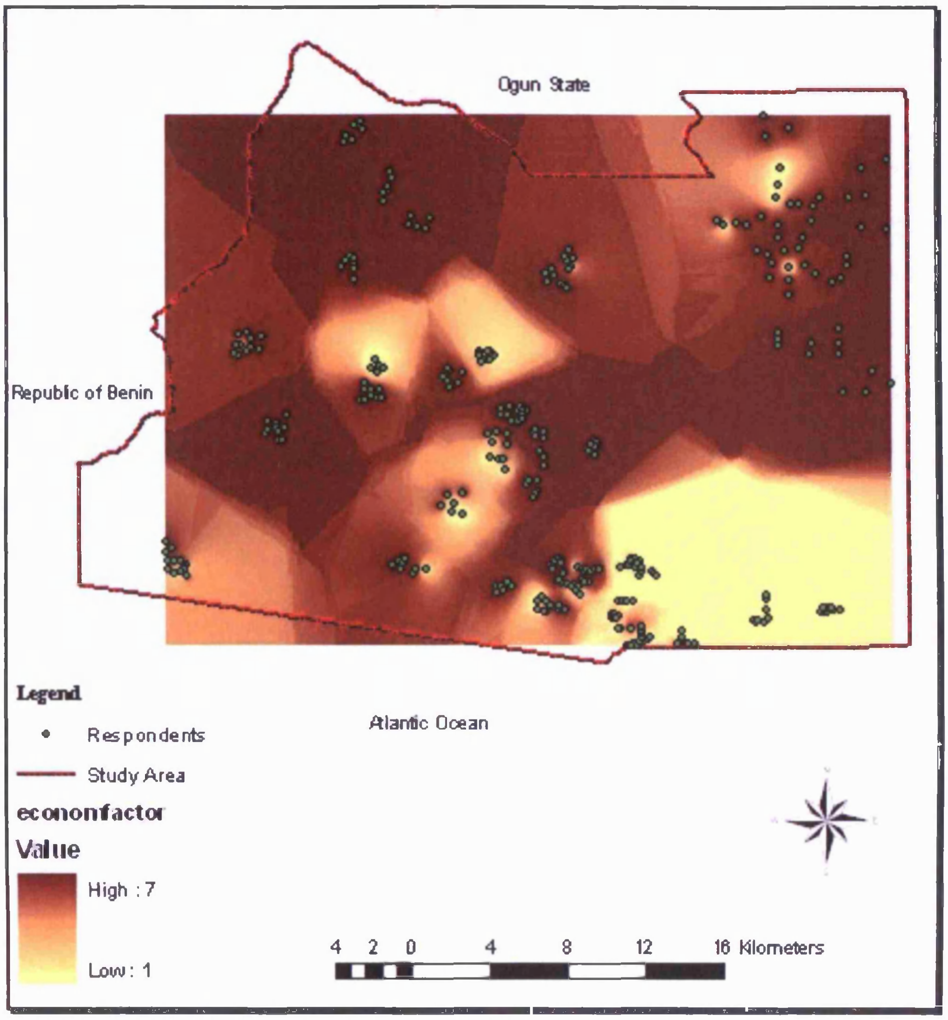

Figure 5.24: Map showing area where Economic Factor as driver of land use change.

Environmental Factor: This is a factor that is peculiar to only one part of the study area as the map below shows (figure: 5.25). Many landlords at Victoria Island and Ikoyi converted their building use to commercial or institutional because of the environmental problems that followed the conversions process started by economic consideration for the change of use by other landlords. The serenity, aesthetically pleasing environment that characterised this area was replace by noise and waste pollution, transportation chaos and many more. The environmental degradation at Victoria Island forced the reluctant landlords to sell their homes to banks, eateries, etc and relocated to other areas.

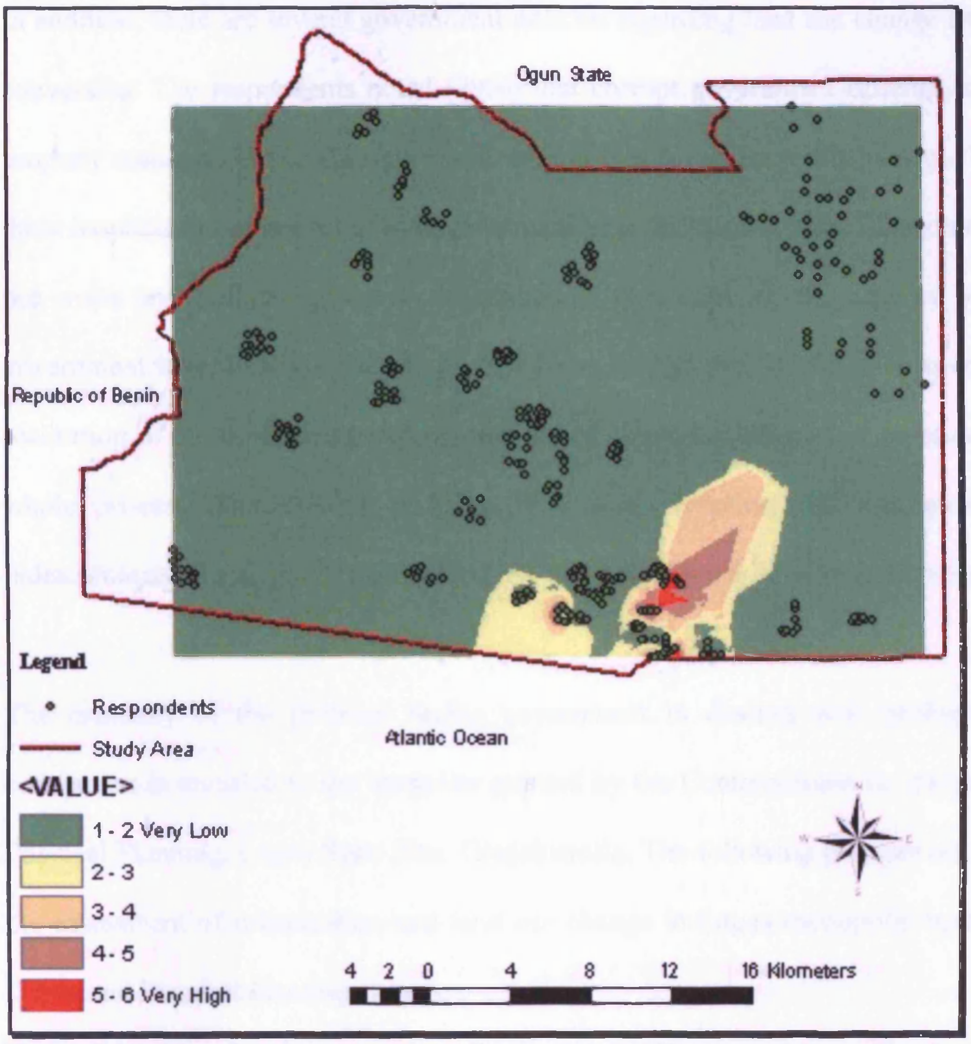

Figure 5.25: Map showing area where Environmental Factor as driver of land uses change.

The rate of land use/cover conversion, transformation and change varies from one place to another but there is a regular pattern throughout the study area. The land use class with greatest conversion in the inner city is residential to commercial. This scenario is found throughout the study area. In fact, there are districts where almost the entire residential land use has been converted to commercial. More than 80% of residential houses have been converted to commercial land use at Victoria Island while all major road corridors are being converted to commercial land use (e.g. Ikorodu road, Obafemi Awolowo Road, Agege motor road and many more) throughout the metropolis.

In addition, there are several government policies regarding land use change and building use conversion. The respondents noted (79%) that corrupt government officials, developers and property managers explore loopholes in the policies to advance self-interest. They often use these loopholes to their own advantage by justifying the need to make amendments to the land use maps and building plans to accommodate new uses. In the case of Victoria Island, government had already agreed to the land use change from residential to commercial, but realisation of the enormous problems mentioned above has forced the government to halt the whole process. The existing policies, if honestly implemented, can guard against the indiscriminate illegal conversion of land use and building use in metropolitan Lagos.

The enormity of the problem facing government in dealing with problem of land use conversion is revealed in the interview granted by the Commissioner in charge of Urban and Physical Planning, Lagos State Hon. Gbajabiamila. The following pointers are extracted from the assessment of urbanization and land use change in Lagos metropolis by the Ministry of Urban and Physical Planning, Lagos:

The interview conducted with commissioner for Physical Planning revealed the followings:

* There is a substantial increase in new residential areas, especially at the fringe areas of Ikorodu, Ojo and Ipaja.

* Existing villages and smaller sub-urban settlements clustering around the metropolis and those lying within or outside government acquisitions have expanded very rapidly.

* The inner core areas of the city have also undergone restructuring, with very sizeable in-filling of new developments that are mostly substandard and blighted.

* The old, exclusive, highbrow residential districts of Ikoyi and Victoria Island annex have been subjected to most vicious change of use, increase in densities and heights of residential buildings.

* The Commissioner decried what he called 'serious short-comings' in the past and present planning process, particularly in the non adherence to the provisions of the regional plan. "The negative consequences of this rapid growth of metropolitan Lagos are reflected in the inability of essential social and economic infrastructure and services such as, water, drainages, good roads, electricity and solid waste management to cope with the demands of the expanded city. This state of affairs and its consequences are sad realities that the people of Lagos State have had to live with", he lamented.

In conclusion, the Commissioner identified the consequences of Urbanization and Physical Planning to include:

*Shortage of housing and high incidence of urban slums.

*Scarce, inadequate and deplorable conditions of urban infrastructure necessary to sustain a good standard of living

* Traffic congestion and transportation crisis that have resulted in high cost of travel to work

* Very high densities of urban population that has led to congestion, pollution of the environment and destruction of renewable and non-renewable resources that should have been conserved for the present and future generations

* Inadequate formal employment centres and large informal sector.

The above extract from the Commissioners' assessment of the state of urbanization and numerous problems facing the metropolitan Lagos underlines the failure of the planning authority to manage the metropolis effectively as a result of organizational failure, poor policy implementation and lack of technologically equipped personnel. However, this research finding confirmed the impression of the Government about the urbanization and land use/cover change in and around the metropolitan Lagos.

CHAPTER SIX: SUMMARY OF FINDINGS AND DISCUSSION

CHAPTER SIX

SUMMARY OF FINDINGS AND DISCUSSION

This chapter discusses the result and evidence of rapid land cover and land use change in Lagos and explores the interrelationships between socio-economic, population and land use and cover change. The discussion relate the summary of findings (result) to the literature which is based on the land use/cover change detection between 1984 and 2002 with the aim of explaining causes and factors responsible for the land use change. In order to put this research work into context and to better understand the dynamics of land use/cover change through time in Lagos, this chapter first explored a number of standard change detection techniques, work of other researcher and location where similar work or result were found. In addition, the image processing techniques and post-classification change detection, socio-economic survey integrated to provide information about the drivers of land use/cover change the merits of this approach were also discussed.

6.1 MAPPING LAND USE/COVER CHANGE IN LAGOS WITH REMOTE SENSING, GIS AND QUALITATIVE SOCIO-ECONOMIC SURVEY.

The timely and accurate change detection of the Earth's surface features is extremely important for understanding relationships and interactions between human and natural phenomena in order to promote better decision-making (Lu et al., 2003). Urban centres have been monitored and studied through satellite remote sensing with the development of temporal sequences of remotely sensed data (Lu et al., 2003; Paul Alplin, 2003). The integration of remote sensing and socio-economic data has been given a big boost with the daysmetric approach (Langford and Unwin, 1994). Lo (1995), linear regression models and an allometric growth model for accurate monitoring by calibrating population and housing statistics with spatially aggregated image data.

Researchers have tried combining statistical and visual interpretation methods to improve classification accuracy. Others have tried land cover mapping and applied a statistical classification (Munroe and Müller, 2007). King (1989) opined that successful mapping depends on knowing what the characteristics of each land cover type are, and using that information to define the appropriate mapping methodology. Different methodologies are required for land cover types with significantly different characteristics. The variation that makes classification so difficult for cities does not stop with internal features, as they also vary externally (between cities) according to location (Aplin, 2003). The expansive urban landscapes characteristics of North America (Masek et al., 2000) contrast markedly with densely packed European cities (Forster, 1983), sprawling Asian "mega-cities" (Chen et al., 2000; Ji et al., 2001; Aplin, 2003) and congested African cities. Remote sensing has been recognised as a useful means of supplying up-to-date information on activities within the urban environment, including the rural-urban fringe (Ehlers et al., 1990; Forster, 1985; Jensen and Toll, 1982; Treitz et al., 1992) due to its revisit capabilities to provide data to adequately monitor and detect changes between the revisit times. The change in land use from rural to urban is monitored to estimate population, predict and plan direction of urban sprawl for developers, and monitor adjacent environmentally sensitive areas or hazards (CCRS, 2001).

Deriving information on urban land-use is normally much more problematic (Eyton, 1993; Barnsley and Barr, 1996; Barnsley and Barr, 1997). This is because land use is an abstract concept – an amalgam of economic, social and cultural factors – one that is defined in terms of function rather than physical form (Barnsley and Barr, 1997). In order to achieve the research aims with the research questions remote sensing and GIS techniques, and socio-economic survey were conducted to explain the origin and causes of the observed land use/cover change in the study area. The measurement and monitoring of land-use changes in these areas are crucial to government officials and planners who urgently need updated information for planning and management purposes (Yeh and Li, 2001).

The manifestation of various social, economic, and environmental problems as a result of rapid land use/cover change in Lagos as well as the urgent need to meet the millennium urban development goals have made it imperative for Lagos land use/cover studies. Lagos been one of the fastest growing cities in the world, the concern of Planners and various governmental agencies were confirmed with this research findings. The factors responsible for the rapid changes in land use/cover were uncovered through the socio economic data integrated with remote sensing data. The rapid rate of change have impacted negatively on the water resources, agricultural land, recreational land use and many other socio-economic problems unearthed by this research.

The study of land use/cover changes in Lagos in the last two decades has revealed the trend, pattern and nature of the change. Three main causes of the rise in urban population were identified: population growth by natural increase, rural-to-urban migration and increase in the size of metropolitan Lagos (reclassification of urban areas). The situation in Lagos is not dissimilar to other cities found in developing countries except for the massive scale at which the change is taken place. This ever increasing population makes management, planning and control of metropolitan Lagos more difficult. The spatial and temporal changes and the effects in metropolitan Lagos are documented for the last two decades. This is not limited to the proportion of land cover/use that is agricultural, urban, water bodies, and so on, but also the demographic and structural changes over time. This work has uncovered unprecedented rates of land cover change due to urbanisation between 1984 and 2002.

The ever-increasing growth in the size and density of cities, especially the "mega-cities" has major repercussions not only on the quality of human life but also on the environment and atmosphere (Epstein, 1998; Mesev, 2003). In most countries, including the United States, many of the fastest growing urban centres are vulnerable to natural hazards and ecological degradation because of their proximity to coastal and semi-arid environments (WRI, 1996; USCB, 2001; Ramsey, 2003). In India, unprecedented population growth, coupled with unplanned developmental activities, has led to urbanization lacking in infrastructure facilities (Sudhira and Ramachandra, 2002). 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 (Lunetta, 1999) as well as looming urbanization problems worldwide but developing countries in particular.

The study of land use and land cover is important for many planning and management activities in urban centres, and it is considered an essential element for modelling and understanding the earth as a system (Lillesand et al., 2004). Currently, researchers have developed land cover maps from local, national to global scales for various environmental purposes. The formulation of governmental policies and programmes by urban and regional planners requires continuous acquisition of data about the earth's surface to meet the challenges of rapid changes on the earth's surface, especially in urban areas as a result of rapid urbanization taking place, mostly in the developing countries which remains information black-hole at the local and regional scale of land use/cover change. It is known that one of the major factors responsible for the lack of performance of several urban and regional planning agencies is lack of technical know-how and their inability to adequately monitor the growth of cities, towns and villages in a timely, accurate and cost-effective manner. This leads to a poor performance of their basic environmental and natural resource planning role in the social, economic, and cultural domain (Lillesand et al., 2004).

Many studies have been carried out about the land use/cover change at global, regional and local level. But most of these research works have concentrate on developed countries of Europe and America with Asia continent playing a catch-up. The few researches carried out in Africa have several areas still untouched most especially land use/cover at regional and local level. The study of such region is very paramount to the effective monitoring and management of earth resources globally due to the daunting challenges mentioned above as well as the implication these area posed to the socio-economic and political stability of the region and world at large.

Sudhira and Ramachandra (2002) applied standard processes for the analysis of satellite imagery, such as extraction, restoration, classification, and enhancement for the study of urban sprawl growth. Also, the Maximum Likelihood Classifier (MLC) was employed for the image classification. Shan (1999) used multi-temporal land use information of the central city of Shanghai through aerial photos to explore the dynamics of urban spatial structure. The interpretation of aerial photos of 1958, 1984 and 1996 in a GIS revealed the quantitative and structural characteristics of land use change. This was analysed through concentric and sector methods. Based on such analysis, a conceptual model of the spatial structure of Shanghai was developed (Shan, 1999). However, multi-layer perceptrons were used by Jonathan et al. (2001)

for change detection and it was found that a Neural Network-base method is superior to conventional techniques. However, to choose the best algorithms for a specific task, users are advised to consider not only classification accuracy, but also comprehensibility, compactness and robustness in training and classification. King (1989) tried sophisticated statistical procedures and applied them to remote sensing for land cover mapping, but found that the accuracy was very low.

Lo and Yang (2002) integrated Landsat images and census data in a zone-based cellular approach to analyse the drivers of land-use/land-cover changes in Atlanta, Georgia. It revealed rapid increases in high-density and low-density urban use at the expense of crop and forests during this period of rapid population growth. They also used Landsat MSS, TM, ETM+ images of 1973, 1979, 1987, 1993 and 1999 to study the drivers of rapid population growth of the 13 metro counties of the Atlanta metropolitan area. Batty and Howes (2001) used supervised classification for the Buffalo metropolitan region, USA, and Barnes et al. (2001) used image processing and classification for urban growth and sprawl detection, mapping and analysis. But this research used a robust method by integrating socio-economic survey, remote sensing and GIS to derive reliable information for monitoring and management of urban land use/cover. In addition, remote sensing and GIS can be used separately or in combination for application in urban studies. In the case of a combined application, an efficient, even though more complex approach is the integration of remote sensing data processing, GIS analyses, database manipulation and models into a single analysis system (Michael and Gabriela, 1996; Sudhira and Ramachandra, 2002). GIS techniques were employed to integrate diverse data sources both spatial and non-spatial (socio-economic survey) data, to map and extract information which are convey through visualisation and presented to decision makers in an effective fashion. This research used socio-economic data gathered and mapped the drivers of change with GIS which revealed the spatial pattern, trend and coverage or extent to which identified drivers of change have impact on the land use/cover change in the study area.

Land use/cover change (LUCC) results from the complex interaction between social, ecological and geophysical processes. Land users make decisions about their environment that are governed and influenced by political and institutional constraints at local, regional, national and international levels. Socio-economic survey and statistical analysis of LUCC phenomena is one powerful tool due to its ability to test theoretical assumptions, rank relative factors, and yield result that answered research questions. This study used remote sensing, GIS techniques and qualitative socio-economic survey to generate information that accesses the effects of rapid land use/cover in Lagos as well as the drivers of change and their spatial area of influence.

6.2 SUMMARY OF FINDINGS

These findings were derived from satellite based land use/cover change detection and socio-economic survey conducted. Remote sensing, GIS and Socio-economic survey conducted with field observation about the land use/cover change detection in Lagos revealed these findings. The rapid population and urban growth in metropolitan Lagos has manifested in various ways: the land use/cover transformation, land use change, loss of agricultural land, urban sprawl and changed in landscape structure of the metropolis. Land occupied by water has been dredged for waterways, while swampy areas have been sand filled for building purposes all these were as a result of social, economic, political, population and environmental factors.

6.2.1 Land Use Transformation

Wei (2004), studied urban land use transformation in China with statistical analysis to revealed the transformation and found that urban reforms, urban land use adjustment, as well as population growth and economic development were the factors driving the rapid land use transformation. The urban growth dynamics of metropolitan Lagos reveal that most of the multi-nuclei centres developed along the major transportation interchanges (flyovers). The original land use of such areas was residential, but the traffic interchanges where passengers change buses/rail created pedestrian traffic build up, that encouraged small businesses which in turn attracted other commercial land uses. The lack of government intervention and lack of initial provision for this land use (commercial, institutional, industrial etc) allowed the competition, succession and survival pattern to develop as a method of evolution of land use/cover change in Lagos.

This organic development was and still is not properly studied, managed and planned for in Lagos. This pattern is now being replicated in planned areas throughout Lagos such as Ikeja GRA, Victoria Island and Ikoyi. The current master plan for Lagos made excessive provision for residential land use without adequate and holistic forward planning for other land uses. The lack of proper consideration for the existing situation in Victoria Island, Ikoyi and Lekki axis will lead to vicious circle of land use change. The historical background of land use/cover transformation in Lagos shows that very soon these residential estates will be converted to other land uses that are not adequately planned for (for example commercial and institutional land uses). This research have combined the GIS, RS and Socio-economic survey to identified the areas of potential land use transformation with the mapping of spatial coverage and influence of various drivers of land use/cover change in the study area.

6.2.2 Land Use/Cover Conversion

Land is a fundamental factor of production, and through much of the course of human history, it has been tightly coupled to economic growth (Richards 1990). As a result, control over land and its use is often an object of intense human interactions (Turner et al. 1993). The possible forces driving land-use and land-cover changes were grouped into six categories: population; level of affluence; technology; political economy; political structure; and attitudes and values (Turner and Meyer 1991; Stern et al. 1992; Turner et al. 1993). Population growth, economic, social, political and environmental reasons were identified as the main drivers of land use conversion in Lagos. The low density residential areas like Victoria Island and Ikoyi are the prime choice for location of businesses by foreign partners who only find these parts of Lagos habitable and safe for business due to the amenities and social infrastructural services provided for these high income earners' residential estates.

More than 76 per cent of people interviewed believed that economic consideration is the major reason why house owners change their building use for the sole aim of profit maximization. This is underlined by the fact that the majority of building conversion was from residential to commercial uses. Uses such as banks, eateries, shops were able to pay higher rents, thereby giving landlords economic strength to pay the high charges or fines imposed by the State government which is meant to discourage these activities.

6.2.3 Loss of Forest and Agricultural Land

Agricultural land can be broadly defined as land used primarily for production of food and fibre which include the following categories: cropland and pasture, orchards, groves and vineyards, nurseries and ornamental horticultural areas, and confined feeding operations Lillesand et al., 2004 while forest is define as the trees and other plants in a large densely wooded area. Jakubauskas M.E. (2001) studied and analysed the potential effects of climate change on land use, land cover, and land management practices on agricultural land use at western Great Plains of Arkansas, Texas, USA. He warned that, effects of changes on the long-term sustainability of agriculture could be substantial, with direct and immediate social, economic, and policy consequences.

Valuable and fertile agricultural land has been lost to urban development for ever, the evergreen rainforest and agricultural fields that adorn Lagos have been replaced with impervious urban land cover materials such as roads, residential estates, shopping complexes, industrial estates, airport, seaport and many more. Much of the agricultural heritage of Lagos (fishing, farming and hand crafts) has been abandoned for industrial and tertiary economic activities. Flora and fauna bear the resultant effects of land use/cover change that was brought about by changes in economic activity and the resultant urban growth.

Lagos' urban expansion has had a tremendous negative impact on both plants and animals, especially aquatic ones. Urban growth has been achieved at the expense of plants, animals and the environment. The period under study recorded an estimated 57.8% decrease in forest and agricultural land use/cover. The replacement of agricultural land and forestry with urban land use is certainly contributing to the urban heat-highland which in turn contributes to the global warming, though, this need researched to ascertain the level of its contribution. The magnitude of the impact of Lagos growth on the environment can only be appreciated with a trip to the Lekki conservation area where the original habitats of the aforementioned are still intact or have minimal urban interference.

6.2.4 Uncontrolled Urban Sprawl

In India, unprecedented population growth, economy, need to leave at a close proximity to urban resources and basic amenities coupled with unplanned developmental activities have led to urban sprawl (Sudhira H.S. and Ramachandra T.V., 2002). The settlement that lacks infrastructure facilities dispersed development along highways, or surrounding the city and in rural countryside is often referred as sprawl (Theobald, 2001). The organic development of many towns and villages that make up the modern metropolitan Lagos has been identified as the origin of the urban sprawl across the metropolis. Though, there were urban clearance attempts in some part of Lagos in the 1920s and 1930s, but these schemes took place in a few selected areas such as Surulere and Lagos Island. The inability of government to carry out this exercise successfully all over Lagos laid the foundation for the widespread urban sprawl seen today throughout metropolitan Lagos. This is aggravated with the unprecedented level of urbanisation in Lagos.

The indiscriminate land use/cover change without planning permission and regard for planning laws have contributed immensely to the sprawl development in Lagos. There are several shanty towns and villages around and within Lagos (Maroko, Ajegunle, Oworonsoki and many more). Some of these shanties have become part of the metropolitan Lagos and still nothing is done about it despite the fact that these areas are the hob of social vices such as crime, prostitution, health and environmental hazards in the metropolis.

6.2.5 Natural Landscape Structure

Recent developments in landscape ecology have emphasized the important relationship between spatial patterns and many ecological processes. Quantitative methods in landscape ecology link spatial patterns and ecological processes at broad spatial and temporal scales.

Remote sensing and GIS was used as an important tool in ecosystem temporal change analysis, landscape fragmentation analysis, and a probability model developed to assess the relationship between ecosystem change and anthropogenic variables by Yanning GUAN, Steven M. de JONG and Johan de MEIJERE (2000). The changing characteristics of landscape structure in the Lake Kusumigaura Basin, Japan from 1979 to 1996 were investigated using time-series high-quality GIS datasets to calculate landscape indices to characterize the landscape structure (Matsushita et al. 2005). The study found that human-modified landscapes, such as artificial fields and golf courses, increased rapidly during the study period, while forests and croplands decreased rapidly in the same period. The landscapes in the Lake Kusumigaura Basin became more fragmented and heterogeneous. The research concluded that the fragmentation trend is most likely to continue due to the increasing population in recent years which is the main driving factor.

The location of Lagos on a coastal strip of the Atlantic Ocean has both positive and negative effects on its spatial growth as well as landscape structure like other coastal cities such Johannesburg, London, Tokyo, New York and many more. The Lagos landscape structure is made up of lagoons, sandbanks, islands, creeks and mainland Lagos. These have multiplier effects on the spatial distribution of land cover types which also affect the land use distribution of the metropolis. Modern metropolitan Lagos is built on the merits of its uniqueness which induced the anthropogenic landscape structural changes. The creeks and lagoons were exploited to provide water transportation (seaport) access to the islands, the hinterland and the rest of the world. The current landscape structure of Lagos shows human-modified landscape through the aggressive government policy of land reclamation. The sand filled Banana highland (figure 5.5 and 5.6 refers) and over 96% increase in bare soil between 1984 and 2002 shows the rate at which land reclamation policy has modified the landscape structure of metropolitan Lagos as a result of pressure from population growth and land use change.

6.2.6 Biophysical and Hydrological Change

The extract from field interview showed that the replacement of forest and agricultural fields with impervious urban materials has led to problems such as flooding and ocean surges, which affects the occupants of the Lagos Island, Victoria Island, Ikoyi and parts of mainland Lagos. Flooding and ocean surges are two of the major problems experienced in the coastal region of Lagos and are the most threatening environmental problems in this pat of Lagos. The research findings shows that these have been aggravated by landfill that has taken place on a massive scale as identified in the land cover change map. Also, lagoons and creeks that naturally absorb the excess run-off water and rises in ocean level are either reduced in width or totally in-filled and built on. All these combined has resulted in distortion or destruction of eco-systems.

6.2.7 Poor Implementation of Master Plan

The execution of the Lagos master and land use plan was poorly implemented. Though, the metropolis started with organic development but various government interventions have not been properly executed. This has been identified by 85% of people interviewed as the reason for the difference in the plan and development on the ground. Both environmental professionals in public and private sectors identified this factor as the root cause of rapid land use change taking place in the metropolis. The poor implementation of the structural plan provided for Lagos metropolis was a result of high level of corruption, ill-equipped personnel, lack of use of technological capabilities to manage the metropolis on the part of government professionals vested with the implementation of the plans, monitoring and management. For example, most of the areas in the Ikorodu axis of metropolitan Lagos that are now residential was planned for other uses such as agriculture, industrial and institutional land use.

6.2.8 Errors in Land Use Map

The use of remote sensing accuracy assessment in which the Lagos land use map was accessed with the reference data collected found the map to be 65% accurate. Also, GIS overlay and visualisation methods have brought to the fore the errors that are present in the Lagos land use map. The classified satellite images were overlaid on the land use map this revealed the use of land allocated for certain use been developed for other use.

However, after the error and uncertainty in the map was assessed and the overall accuracy of the map found to be 65%, this map was updated (see section 3.1.6). The updated land use map was then used to access the accuracy of the land use map produced from satellite imagery. The level of map accuracy is very important to the study, management and control of land use and land cover because of its direct and indirect impact on policy formulation and implementation. Policies relating to land use and cover management and control are mostly based on information derived from maps and other auxiliary data sources available. In the case of the Lagos land use map, 65% overall accuracy level is not adequate for a sound policy to manage or control a complex mega city like Lagos. Land use map that have high overall accuracy should provide reliable information to adequately manage rapidly growing urban agglomeration. But lack of sufficient accuracy in the land use map has played a prominent role in the failure of the planning department to achieve a desirable result

6.3 LAGOS POPULATION GROWTH AND LAND USECOVER CHANGE

Lagos population growth is dated back to the time of missionary and colonial rules. The rapid population growth started in 1950 and since then there has rapid population growth. Lagos is one of the fastest growing urban agglomerations in the world, with a population of 288,000 in 1950, 3.3 millions in 1975, 13.4 millions in 2000 and an estimated 23.2 millions by 2015 (UN, 1999). The growth rate of Lagos, 1975 – 2000 was 5.6% per annum which was the highest among the 10 most populous urban agglomerations in the world. The estimated 3.7% per annum for 2000 – 2015 also remains the highest compared to other urban agglomerations (Table 6.1).

The population increase in Lagos was 1,046% between 1950 and 1975 and 306% between 1975 and 2000. The metropolis doubled its population every 10 years (Table 6.3). Though there is a significant reduction in the estimated growth rate per annum for 1975-2000 and 2000-2015 Lagos still remains the highest when compared with other urban centres. The annual population change average at global, continental, regional, national and metropolitan level was compared. Lagos' annual change rate remains the highest throughout the period (1950 – 2015). Lagos' figures are well above the global, continental, regional as well as national average (Table 6.2). This underlines the rapid population growth in metropolitan Lagos.

Urban Agglomeration	World Ranking (2000)	Population in Millions			Growth Rate (%)	
		1975	2000	2015	1975-2000	2000-2015
Tokyo	1	19.8	26.4	26.4	1.2	0.0
Mexico City	2	11.2	18.1	19.2	1.9	0.4
Bombay	3	6.9	18.1	26.1	3.9	2.4
Sao Paulo	4	10.0	17.8	20.4	2.3	0.9
New York	5	15.9	16.6	17.4	0.2	0.3
Lagos	6	3.3	13.4	23.2	5.6	3.7
Los Angeles	7	8.9	13.1	14.1	1.5	0.5
Shanghai	8	11.4	12.9	14.6	0.5	0.8
Calcutta	9	7.9	12.9	17.3	2.0	1.9
Buenos	10	9.1	12.6	14.1	1.3	0.7

Table 6.1: Urban agglomeration population and growth rates

Source: UN (1999)

Area	1950-1955	1960-1965	1970-1975	1980-1985	1990-1995	2000-2005	2010-2015
World	3.02	3.08	2.63	2.67	2.35	2.09	1.91
Africa	4.38	4.83	4.40	4.37	4.15	3.56	3.18
West Africa	5.13	5.36	5.32	5.40	4.94	4.22	3.53
Nigeria	4.65	5.49	5.49	5.50	5.35	4.35	3.39
Lagos	9.74	7.97	5.81	6.16	6.01	5.02	3.87

Table 6.2: Average urban population growth at global, continental, regional, national and local level

Source: UN (2003)

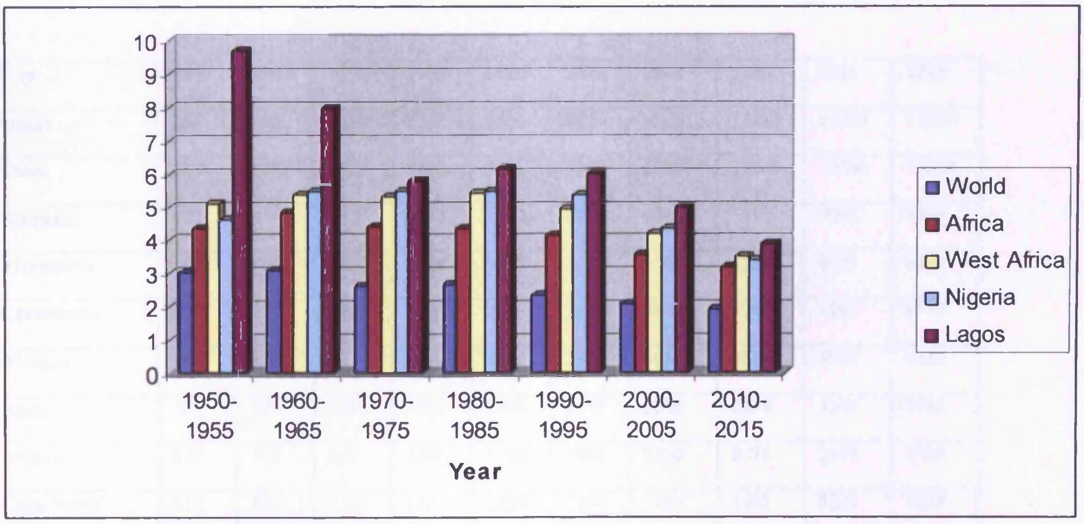

Figure 6.1: Graphical representation of average urban population growth at global, continental, regional, national and local level

Table 6.3 shows the population estimates (in thousands) of the ten most populous urban centres in Africa in 2005 and their projected populations for the year 2015. The table shows the steady rise in population in the 1950s and 1960s. Lagos doubled her population almost every decade. Population growth became rapid from 1970s to reach a growth rate of over 80% (Table 6.3). The main reason for the increase in population is migration rather than natural population growth. If the trend of population growth is sustained at the current rate Lagos will be the most populous urban agglomeration in Africa and sixth in the world by the year 2010 (UN, 2003). The 2005 population estimates puts Lagos' population on the same level as Cairo, which has the most urban agglomeration population in Africa. Cairo had an urban population of 2.4 million people when Lagos was about 288 thousand people in 1950 (Table 6.3). Most of the urban centres with similar or even higher population figures in 1950 had not reached the 5 million mark in 2000 when Lagos was approaching 10 million people. The African urban population table shows that Lagos' population growth is the highest despite the fact that there are reported higher numbers and rates of urban population growth in the African continent and sub-Sahara region in particular.

City	1950	1960	1970	1980	1990	1995	2000	2005	2010	2015
Lagos	288	762	1414	2572	4764	6434	8665	11135	14037	17036
Cairo	2436	3811	5579	7338	9061	9707	10396	11148	12036	13123
Kinshasa	173	451	1370	2197	3392	4099	4745	5717	7096	8886
Alexandria	1037	1504	1987	2519	3063	3277	3506	3760	4074	4489
Casablanca	625	987	1505	2109	2685	2994	3344	3743	4168	4579
Abidjan	59	180	553	1264	2102	2535	3057	3516	3975	4432
Kano	107	229	346	1189	2095	2337	2596	2884	3242	3689
Ibadan	427	570	740	1290	1782	1965	2160	2375	2649	3001
Cape Town	618	803	1114	1609	2155	2394	2715	3103	3205	3239
Addis Ababa	392	519	729	1175	1791	2157	2491	2899	3429	4136

Table 6.3: African major urban agglomerations; population estimates and projections

Source: revised 1999 population estimates UN (2003).

In addition, Lagos' population growth is compared with major cities in Nigeria. Figure 6.2 shows the selected major urban centres in Nigeria and compares the growth of Lagos to the other cities nationwide and general pattern of urban growth in the country. The graphical representation shows Lagos' geometric population growth and the arithmetic growth of other urban centres in Nigeria. The graph shows the arithmetic population growth curve for other urban centres and it is noticeable that the curve shows the same pattern of growth between urban centres before the 1970s. However since then Lagos has experienced exponential population growth.

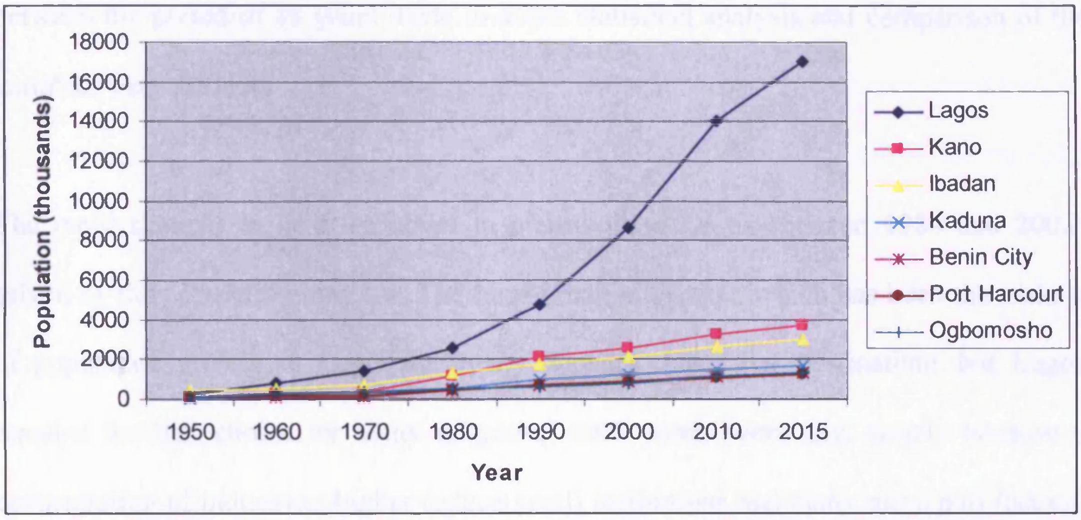

Figure 6.2: Graphical representation of population growth of Lagos and major Nigerian urban centres.

6.3.1 RELATIONSHIP BETWEEN POPULATION GROWTH AND LAND USE/COVER CHANGE IN LAGOS.

There are many factors which contribute to the land use/land cover change in metropolitan Lagos. These are: economic, political, geographical, landscape, corruption etc., but the rapid population growth in Lagos is the main factor responsible for the rapid spatial growth and the associated pressure on different land use types leading to conversion and change of land use and land cover in the metropolis. There is positive correlation between the land use/cover change and population change during the period under study.

There is a positive correlation between the land cover change and population growth of Lagos during the period under study. The land use/cover change from predominantly forest and agriculture to urban land use/cover from 1984 to 2002 recorded growth of about 35.5% while the population growth was 236.9%. Though the percentage changes between the two variables are not the same, there is a strong positive correlation between them. The lack of data (satellite images) free of cloud with adequate spatial resolution to study urban land use/cover change in-between the period of 18 years made in-depth statistical analysis and comparison of the two variables very difficult.

The rapid changes in land use/cover in metropolitan Lagos between 1984 and 2002 were driven by the population increase. The rural-urban migration, which has been the main source of population growth in Lagos for many decades, has other destinations but Lagos still remains the first choice for many migrating rural youth every day, simply because of the concentration of industries, higher (educational) institutions and many more pull factors. This non-stop population influx has had a devastating negative effect, not only on infrastructural facilities, but also on the environment. In the early 1980s, open spaces and vegetation cover were visible all over the Lagos metropolitan landscape but population growth of over 236% between the periods has put enormous pressure on the available but limited land resources to accommodate the ever growing population of the metropolis. This has led to almost total extinction of this vital land use class that gives or improves urban environmental living conditions as well as eco-system stabilization. The role plants play in the eco-system cannot be over-looked if the millennium environmental sustainability development goal is to be achieved.

Additionally, lack of reliable population data makes planning and implementation of land use policies difficult. This is one of the major problems that made implementation of land use plans by successive governments, to accommodate the population increase in an orderly and planned manner, a failure. The demand for shelter and other services by the increasing population led to unprecedented urban growth (spatial). The need to accommodate the influx of people to Lagos encouraged the growth of shanty towns and villages which later deteriorated to slums that are found in all parts of modern metropolitan Lagos.

The period of rapid population growth (Figure 5.4) and increase in economic activities in the early 1990s marked the period of urban to rural movement. There was mass movement of people from the inner city to the peripheries for affordable housing, because economic activities within the city had increased rent beyond the reach of many residents, resulting in land use and land cover change in metropolitan Lagos and its environs.

6.3.2 EFFECTS OF RAPID POPULATION GROWTH AND LAND USE/COVER CHANGE ON METROPOLITAN LAGOS.

Lunetta, 1999, predicted accelerated environmental changes with unknown and potentially devastating consequences through the twenty-first century. The manifestations are aggravated by the rapid changes in the land use/cover and 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) to serve as intelligence that provide reliable information for effective planning and management of the very obvious environmental change and challenges of twenty first century. On this backdrop the effects of rapid population growth and land use/cover change in Lagos as revealed by this research were discussed.

6.3.2.1 Environmental impact: The environmental effects of land use and land cover change in Lagos are numerous, ranging from pollution to destruction of flora and fauna. The rapid land use/cover change and population growth has brought about environmental degradation and pollution such as noise, water, oil spillage, waste and many more. The rate at which waste is generated in metropolitan Lagos due to ever increasing population without reliable information for effective planning has made it very difficult for the waste management agencies to cope with collection and disposal. This has a big impact on environmental conditions in the study area because the rate of waste generation is a lot higher than its collection, leading to both biodegradable and non-biodegradable waste littering much of Lagos. Also, the designated landfill sites cannot cope with the rate of the waste being generated due to the ever increasing population of Lagos which creates bad odours in many parts of Lagos. This poses a great danger to the healthy living of people in Lagos. Most of the water in the lagoons and creeks is polluted with industrial effluent and direct disposal of solid and toxic waste into them. The situation is so bad in some areas that the whole lagoon water has turned into a deep sewer that collects untreated industrial effluent which is finally discharged into the Atlantic Ocean, at great risk to the marine flora and fauna. In addition, perennial flooding and noise pollution is one of the major problems facing Lagos due to land use change and rapid population growth, even the high-class residential estates and government residential reserved areas are not exempted from these problems.

6.3.2.2 Social: The ever expanding population has led to overcrowding, high crime rate, and congestion throughout metropolitan Lagos. The development of shanties and unregistered houses has inevitably made it impossible to manage crime and other vices in the metropolis. The realisation of this failure made the Governor of Lagos State to seek the protection of lives and properties by the ethnic militia (Oodua People's Congress) to complement the police (BBC World Service, Saturday, 23 June, 2001), who themselves are inadequate both in numeric strength and quality of personnel. The failure of other agencies or organs of government to provide for decent living in Lagos is evident in the Economic Intelligent Unit survey (2005) which rates Lagos as the 5^{th} worst place to live in the world (http://news.bbc.co.uk/2/hi/business/4306936.stm). Most of the elite residents of Lagos, government officials and the diplomatic community have resorted to private arrangements for security, to protect their lives and properties. Social infrastructural amenities such as parks and gardens, children's play grounds and open spaces, where provided, are not adequate or overuse due to the number of people using these social amenities. Also, these land use classes have been the easiest targets for land use change/conversion because most land under these uses is public land and this has made it possible for corrupt government officials to convert its use for personal gain.

6.3.2.3 Economic Impact: The population agglomeration of Lagos made it the first choice for industrialists and business executives. Both local and international organisations consider Lagos the best place to establish industry or locate business because it provides ready markets as well as a good supply of labour, both skilled and unskilled. The seaports, airports, rail and road connectivity to other parts of Nigeria and West Africa provide good transportation links to the whole world which is a vital part of a successful business venture. More than 40% of industries and over 45% of businesses in Nigeria are located in Lagos. This puts pressure on land use/cover leading to the unprecedented changes in land use and cover. The financial strength and influence on land use/cover of these businesses is evident in the complete change of use in Lagos Island, Victoria Island, Ikeja and many more residential areas that are now commercial land use.

In addition, there is a positive correlation between the land use/cover change and population growth of Lagos during the period under study. The land use/cover change from 1984 to 2002 recorded growth of about 35.5% while the population growth was 236.9%. Though, the percentage change between the two variables are much more than one another but it is obvious that rapid population growth is a major factor responsible for the over one-third of land use change in Lagos within two decades. The lack of data (satellite images) free of cloud with adequate spatial resolution to study urban land use/cover change in-between the period of 18 years made in-depth statistical analysis and correlation of the two variables impossible.

The rapid changes in land use/cover in metropolitan Lagos between 1984 and 2002 are hereby concluded to be mainly driven by the population increase. The rural-urban migration, which has been the main source of population growth in Lagos for many decades, has other destinations but Lagos still remains the first choice for many migrating rural youth every day, simply because of the concentration of industries, higher (educational) institutions and many more pull factors. This non-stop population influx has had a devastating negative effect, not only on infrastructural facilities, but also on the environment. In the early 1980s, open spaces and vegetation cover were visible all over the Lagos metropolitan landscape but significant population growth between the periods has put enormous pressure on the available but limited land resources to accommodate the ever growing population of the metropolis. This has led to almost total extinction of this vital land use class that gives or improves urban environmental living conditions as well as eco-system stabilization. The role plants play in the eco-system cannot be over-looked if the millennium environmental sustainability development goal is to be achieved.

Population growth modelled and statistics has shown that future prediction of people in Lagos will reach 17036 millions in 2015 (UN, 2003). Therefore, it can be concluded that equally rapid land cover and land use change will follow the same trend of population growth into the future.

CHAPTER SEVEN

7.1 Conclusions and Recommendations

7.2 Recommendations for future research

CHAPTER SEVEN

CONCLUSIONS AND RECOMMENDATIONS

7.1 RESEARCH QUESTION REVISITED:

(i) Is the rapid land cover change taking place in Lagos? If yes, what is the spatial pattern of change?

(ii) How accurate is the official Government land use plan?

(iii) What are the socio-economic and political factors driving land use/cover change?

(iv) How is population growth driving land use/cover change?

(v) What are the implications of socio-economic and political factors on sustainable land use/cover change?

(vi) How can the drivers of change observed be mapped and explained?

The research objectives of this study are to map land use/cover change in Lagos and compare these data with official Government land use maps. Secondly, to understand the factors for these changes and investigate the inter-relationships between population change and land use/cover. These are to advance our knowledge and understand of land use and land cover change at both regional and local levels in a place not known or considered as a hotspot in previous studies. Lepers et al. (2005) concluded in their study that operational monitoring of land cover should be extended to regions that are not known as hotspots but where rapid changes are taking place which may catch the scientific community by surprise. This research has found unprecedented rapid land use and land cover change throughout metropolitan Lagos. The Lagos Island axis has experienced nearly total change of land use in the last two decades. Also, the accuracy of the official Government land use plan is 65% through remote sensing techniques. This is considered not good as government policies and decisions are based on the information derived from this map.

The inter-relationship between population growth and land use/cover change was examined. The rate of spatial growth and pattern of changes in the Lagos metropolitan area were also examined to assist in decision-making regarding physical planning and sustainable development of the metropolis. The study revealed that rapid population growth in the study area has been, and continues to be, the main driving force for the rapid land cover change. The changing socio-economic activities in the metropolis are identified as pivotal to the land use conversion, especially in high-class residential areas. Between 1984 and 2002 political factors also had significant impacts on the land use/cover change in the study area, because the period marked an era of political instability in which military juntas had no regard to planning laws and orderly development of metropolitan Lagos.

The research applied remote sensing and geographic information sciences techniques to study land use/cover changes in the study area, while the field survey focused on the reasons and factors that are responsible for the rapid land use/cover change through the interview of main actors such as Town Planners, Land Officers and Academia. Satellite remote sensing allowed a retrospective, synoptic viewing of metropolitan Lagos and provided the potential for a geographically and temporally detailed assessment of the metropolitan development (Yang and Lo, 2002) and the immediate and future resultant land use and land cover changes. Also, the effects and inter-relationships between population growth, socio-economic, political and land use/cover changes were examined.

The following conclusions can be drawn from the study: the overall accuracy of the existing land use map is 65%, population growth is 5.6 per cent in metropolitan Lagos, land use conversion is noticeably higher in the low density residential areas, and corruption and executive lawlessness are the main socio-political problems that encourage land use/cover conversion.

The results have been able to establish the importance and capabilities of remote sensing and GIS to map urban land use changes, even in difficult African cities such as Lagos with high spectral confusion. The spectral and temporal resolution of satellite data and improved classification techniques gave it an economic advantage over the traditional mapping techniques still in use in many African urban centres. Urban land use and land cover classification through satellite remote sensing was an extremely difficult task for metropolitan Lagos, but the merged SPOT and Landsat data with improved spectral and spatial resolution achieved higher classification accuracy for reliable land use/cover maps that were able to answer the research questions.

(i) Is the rapid land cover change taking place in Lagos? If yes, what is the spatial pattern of change?

This research has been able to establish the unprecedented rapid land use and land cover change in metropolitan Lagos as well as the location and types of changes that have taken place in the study area. There are two types of change: (a) conversion of land use types, notably the conversion from residential land use to commercial land use. Also, the area (location) where this type of change has taken place has been identified, Victoria Island, Ikoyi, Ikeja GRA, Agege, Festac town etc. (b) land cover changes such as the change from forest land cover type and water bodies to urban land use/cover type. The identification of the nature and location of the urban land use and land cover changes that have occurred in the city over the past two decades and the examination of the socio-economic and political factors responsible for the changes have answered some of the research questions.

(ii) How accurate is the official Government land use map?

The overall accuracy of the Lagos land use map is 65%. This is not a good land use map where reliable information can be derived for sound government decision and policies on environmental planning, management and control. Hence, the resultant achievement is the chaotic metropolitan areas like Lagos.

(iii) What are the socio-economic and political factors driving land use/cover change?

From the questionnaire administered, the research established the change in economic activities of the study area from agriculture and fishing to industrial, commercial and institutional activities. Also, the prominent political role played by Lagos as the former federal capital before its relocation to Abuja in 1992 has been significant. These factors combined to play a major role in the land use/cover transformation and changes in the study area because they exert pressure on the limited land resources available for development by different competing land uses

(iv) How is population growth driving land use/cover change?

Population growth was identified as the major factor driving the rapid land use/cover change in metropolitan Lagos. The annual population growth of 5.6 per cent in Lagos is the highest in Africa and ranks among the highest in the world (see Sections 6.4 and 6.5 for detail). This has put huge pressure on the land use/cover, leading to changes in land cover as well as change and conversion of land use. Section 5.6 details the effects of the population growth on land use/cover of the study area. Forest and agricultural land uses have lost 58 per cent of their land cover to urban growth within the last two decades.

(v) What are the implications of socio-economic and political factors on sustainable land use/cover change?

The research revealed that there is not much effort towards sustainable land use/cover development due to lack of political will. The conversion of building use prominent among this change is the conversion from residential to commercial which has been carried out without adequate consideration for the effects on the environment and its planning implications. The visible result is environmental chaos which will cost a significant amount of money to remedy.

(vi) How can the changes observed be mapped and explained? The factors that serves as the drivers of land use/cover change in metropolitan Lagos was mapped based on the point data collected through the questionnaire administered. This revealed the spatial coverage of each factors and the extent and level of impact each factor played on the changes in the study area.

7.2 RECOMMENDATIONS FOR FUTURE RESEARCH

The land use/cover conversion in the study area originated from the evolution of the metropolis from organic development. Most land use/cover evolved through competition, succession and survival patterns and not through any formal or professional planning processes. The establishment of city planning was based on an attempt to correct problems that have followed the exponential growth of Lagos and since then the planning department has been struggling to take a decisive lead in the direction, monitoring and management of its growth. Hence the development has always been ahead of planning, leaving the planners to trail behind with measures or policies that are corrective in nature. These have contributed little or nothing in terms of control and management of land use/cover change of metropolitan Lagos. The following are hereby recommended as immediate measures needed to tackle the problems identified in this research:

(i) The establishment of a dynamic urban research department would be a major step forward towards the understanding of the dynamics of urban growth and land use/cover change. This department should be established to provide the intelligence that is needed to combat the problem of land use conversion as this is firmly rooted in poor planning and execution of land use plans, where they exist. The main responsibility of this department should be to fund and carry out cutting-edge research on urban growth, monitoring and management, and to advise the government on policy issues regarding land use/cover change needed to achieve sustainable environmental development.

(ii) The existing land use map of metropolitan Lagos should be updated with the use of satellite remote sensing data and techniques as it has been proven a better approach by this study. This will give planners a reliable land use/cover map with higher accuracy and lead to success in policy implementation. The government should employ the capabilities of satellite remote sensing and geographic information technology for intelligence mapping that will provide reliable and adequate spatial data as well as information useful for improved planning and effective monitoring and management of land use/cover in Lagos.

(iii) The use of remote sensing and GIS for land use management, monitoring, planning and development processes would curb corrupt activities of some planners and other government officials. It would also provide adequate spatial information on the existing land use/cover of the metropolis as well as future growth patterns for better planning.

In conclusion, this research has been able to establish facts about metropolitan Lagos as a hotspot for land use/cover changes at a local level and in a place that has not been given adequate research attention in many other studies. This may be due to the fear of research communities about the volatile nature of the study area in terms of safety of lives and properties and the lack of off-the-shelf data to study this area. The study revealed the loss of forest and agricultural land and the problem of land use conversion with its associated problems that is leading Lagos towards total urban chaos. It also highlighted the threat posed by the land use and land cover changes to the sustainable environmental development.

This research has demonstrated the importance of remote sensing, digital image processing and GIS techniques in producing accurate land use/cover maps as well as change matrix (statistics) of metropolitan Lagos for the last two decades. Hence, it is hoped that this research will bridge the gap in the information and knowledge of areas with rapid population growth and land use/cover change.

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APPENDIX I

QUESTIONNAIRE FOR PLANNING OFFICIALS OF LAGOS MINISTRY OF PHYSICAL PLANNING.

1. What is your name? ……………………………………………………………..

2. What is your position? …………………………………………………………..

3. How long have you been working here? ………………………………………

4. How do you rate the rate of urbanisation in this district?

Very High ☐

High ☐

Relatively high ☐

Low ☐

5. Do you observed any land use/cover changes in your district?

Yes ☐

No ☐

6. What rate is your observation if yes in question 5?

Very High ☐

High ☐

Relatively high ☐

Low ☐

7. Give these land use/cover type marks according to your observed rate of change (mark out of 10 according to your observed changes)

Residential ☐

Commercial ☐

Industrial ☐

Recreational ☐

Institutional ☐

Open Space/Green belt ☐

Agricultural ☐

8. Which of this land use type is most threatened?

Residential ☐

Commercial ☐

Industrial ☐

Recreational ☐

Institutional ☐

Open Space/Green belt/Forest ☐

Agricultural ☐

9. What are the factors responsible for the land use/cover changes in your district?

....

....

10. What are the government measures to halt the changes in land use/cover?...

....

....

11. Professional view on the urbanisation in Lagos regarding physical planning: problems, prospects and solutions.

....

....

....

....

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QUESTIONNAIRE FOR RESIDENTS

1. Name……………………………………………………………………………..

2. Address/Location……………………………………………………………………

3. Sex: Male ☐ Female ☐

4. Age (years)

(i) 0 – 15 ☐

(ii) 15 – 30 ☐

(iii) 30 – 45 ☐

(iv) 45 – 60 ☐

(v) 60 – 75 + ☐

5. What is your Occupation? ……………………………………………………………..

6. How long have you leaved here (year)?

(vi) 0 – 15 ☐

(vii) 15 – 30 ☐

(viii) 30 – 45 ☐

(ix) 45 – 60 ☐

60 – 75 + ☐

7. What Land Use(s) used to be here?

Residential

Commercial ☐

Industrial ☐

Recreational ☐

Institutional ☐

Open Space/Green belt/Forest ☐

Agricultural ☐

8. When does development start here?

1 – 5 years ☐

5 – 10 years ☐

10– 15 years ☐

15 – 20years ☐

20 years above ☐

9. How will you rate the rate of urbanisation in this area?

Rapid ☐

Fast ☐

Moderate ☐

Slow ☐

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CHECKLIST: THINGS TO DO AT SAMPLING POINT

Identify features that can be clearly relate to or see on the images such as road junction, land use/cover type, river, land mark etc:

1. GPS: Collection of ground control point to verify the accuracy of geo-rectification of images. Also, to be used to geo-correct the Lagos Land Use and Road Network Map.

2. Land use/cover type: Check the land use/cover type with the classified images and Lagos land use map.

3. Questionnaire: Administer the questionnaire and interview local people about the land cover type of that particular place in 1984. And find out when the present land use type started. As well as,

4. Photographs: Photographic evidence of the present land use/cover type, areas selected for control points.

APPENDIX II

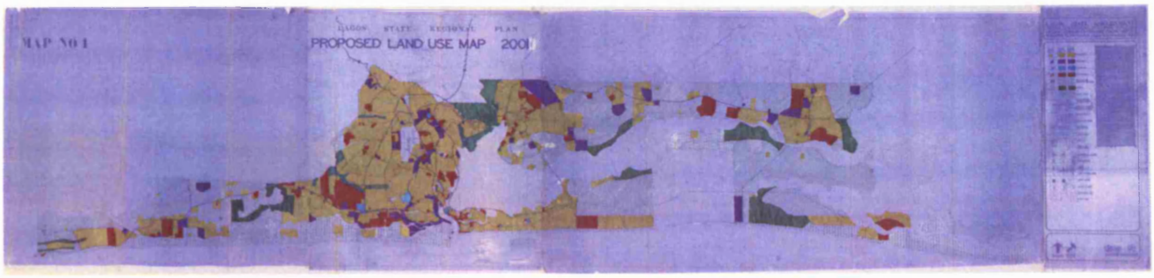
Location and GPS coordinates of selected reference points

Location Point	GPS Coordinates X	Y	Land Use/Cover Type
1.Osborne Estate 1 Ikoyi	0546501	0714651	Residential – Low
2. Osborne Estate 2 Ikoyi	0546807	0714922	Residential – Low (Water Boundary, Lagoon)
3. Osborne Estate 3 Ikoyi	0547370	0714601	Residential – Low: New Buildings
4. Park View Estate 1 Ikoyi	0548264	0714380	Residential – Low Density
5. Park View Estate 2 Ikoyi	0548892	0714643	Residential – Low Density
6. Banana Highland, 1 Ikoyi	0549648	0713644	Sand filled site
7. Banana Highland, 2 Ikoyi	0549496	0713621	Road – Concrete Bricks
8. Banana Highland, 3 Ikoyi	0551006	0714332	Road – Concrete slab
9. Atlantic Ocean 1	0544046	0706660	Water
10. Atlantic Ocean 2	0544556	0707250	Water
11. Oniru Estate 1	0550518	0710965	Sandfill (Sand Cover)
12. Oniru Estate 2	0549760	0710263	Sandfill?
13. Oniru Estate 3	0549872	0710249	Sand filled (Sand Cover)
14. Lekki (Adebowale Gardens)	0571053	0715227	Cleared Land 4 Residential Estate
15. Lekki 2	0571072	0715269	Forest
16. Lekki 3	0592102	0715437	Forest
17. Lekki 4	0558678	0712303	Lekki Conservation Foundation
18. Lekki 5 (Chevron Estate)	0558672	0713876	Sand filled
19. Ikeja Industrial 1 Estate (Guiness Junction	0537079	0731108	Industrial Land Use
20. Ikeja Industrial 2	0537623	0731835	Industrial
21. Mile 2 Bridge	0534924	0714140	Road
22. LAS University	0522356	0714388	Car Park (Institutional)
23. LAS University	0522150	0714808	Open Space – Grass Cover
24. Igando-Iba Road	0523119	0721019	Road – Tarmac Surface
25. Igando-Iba Road	0522333	0715749	Farmland/Vegetables
26. National Stadium	0540278	0718296	Recreational
27. Victoria Island	0545321	0710757	Adeola-Odeku Road
28. Victoria Island	0545212	0710750	Adeola-Odeku Road

29. Unilag	0544468	0720474	Lagoon Front (Recreational)
30. Bar Beach	0546879	0709888	Soil – Beach (Atlantic Ocean)
31. Bar Beach 2	0546876	0709961	Road – Akin Odesola Rd.
32. Ikeja	0537702	0729048	Commercial Computer Village
33. Ikeja Awolowo House	0537693	0729220	Commercial
34. Bonny Cantonment	0545121	0711572	Road
35. Lagos Polo Club	0546514	0712513	Recreational

APPENDIX III

Lagos land use regional plan



APPENDIX IV

Digitised Lagos regional land use plan

APPENDIX V

Summary Report for 1984 Land Use Classification

Zone layer name: d:/new folder/new folder/1984metropolis_level2_classified.img
Zone number 2
Zone name: Recreational
Class layer name: d:/new folder/new folder/1984metropolis_level2_classified.img

Class	Class Name	Count	%	Hectares
2	Recreational	198249	100.00	16102.775
	Total	198249	100.00	16102.775

Zonal Statistics:

Majority:	2	Mean:	2.0000
Median:	2	Minimum:	2
Maximum:	2	Range:	1
Diversity:	1	Std. Deviation:	0.0000
Majority Count:	198249	Majority %:	100.0000

Zone layer name: d:/new folder/new folder/1984metropolis_level2_classified.img
Zone number 5
Zone name: Commercial
Class layer name: d:/new folder/new folder/1984metropolis_level2_classified.img

Class	Class Name	Count	%	Hectares
5	Commercial	25290	100.00	2054.180
	Total	25290	100.00	2054.180

Zonal Statistics:

Majority:	5	Mean:	5.0000
Median:	5	Minimum:	5
Maximum:	5	Range:	1
Diversity:	1	Std. Deviation:	0.0000
Majority Count:	25290	Majority %:	100.0000

Zone layer name: d:/new folder/new folder/1984metropolis_level2_classified.img
Zone number 9

Zone name: Exposed Soil
Class layer name: d:/new folder/new folder/1984metropolis_level2_classified.img

Class	Class Name	Count	%	Hectares
9	Exposed Soil	10153	100.00	824.677
	Total	10153	100.00	824.677

Zonal Statistics:

Majority:	9	Mean:	9.0000
Median:	9	Minimum:	9
Maximum:	9	Range:	1
Diversity:	1	Std. Deviation:	0.0000
Majority Count:	10153	Majority %:	100.0000

Zone layer name: d:/new folder/new folder/1984metropolis_level2_classified.img
Zone number 13
Zone name: Agricultural and Forest
Class layer name: d:/new folder/new folder/1984metropolis_level2_classified.img

Class	Class Name	Count	%	Hectares
13	Agricultural and Forest	610774	100.00	49610.118
	Total	610774	100.00	49610.118

Zonal Statistics:

Majority:	13	Mean:	13.0000
Median:	13	Minimum:	13
Maximum:	13	Range:	1
Diversity:	1	Std. Deviation:	0.0000
Majority Count:	610774	Majority %:	100.0000

Zone layer name: d:/new folder/new folder/1984metropolis_level2_classified.img
Zone number 14
Zone name: Residential
Class layer name: d:/new folder/new folder/1984metropolis_level2_classified.img

Class	Class Name	Count	%	Hectares
14	Residential	394067	100.00	32008.092
	Total	394067	100.00	32008.092

Zonal Statistics:

Majority:	14	Mean:	14.0000
Median:	14	Minimum:	14
Maximum:	14	Range:	1
Diversity:	1	Std. Deviation:	0.0000
Majority Count:	394067	Majority %:	100.0000

Zone layer name: d:/new folder/new folder/1984metropolis_level2_classified.img
Zone number 16
Zone name: Institutional
Class layer name: d:/new folder/new folder/1984metropolis_level2_classified.img

Class	Class Name	Count	%	Hectares
16	Institutional	137727	100.00	11186.876
	Total	137727	100.00	11186.876

Zonal Statistics:

Majority:	16	Mean:	16.0000
Median:	16	Minimum:	16
Maximum:	16	Range:	1
Diversity:	1	Std. Deviation:	0.0000
Majority Count:	137727	Majority %:	100.0000

Zone layer name: d:/new folder/new folder/1984metropolis_level2_classified.img
Zone number 22
Zone name: Industrial
Class layer name: d:/new folder/new folder/1984metropolis_level2_classified.img

Class	Class Name	Count	%	Hectares
22	Industrial	40067	100.00	3254.442
	Total	40067	100.00	3254.442

Zonal Statistics:

Majority:	22	Mean:	22.0000
Median:	22	Minimum:	22
Maximum:	22	Range:	1
Diversity:	1	Std. Deviation:	0.0000
Majority Count:	40067	Majority %:	100.0000

Zone layer name: d:/new folder/new folder/1984metropolis_level2_classified.img

Zone number 32
Zone name: Transportation
Class layer name: d:/new folder/new folder/1984metropolis_level2_classified.img

Class	Class Name	Count	%	Hectares
32	Transportation	58936	100.00	4787.077
	Total	58936	100.00	4787.077

Zonal Statistics:

Majority:	32	Mean:	32.0000
Median:	32	Minimum:	32
Maximum:	32	Range:	1
Diversity:	1	Std. Deviation:	0.0000
Majority Count:	58936	Majority %:	100.0000

Zone layer name: d:/new folder/new folder/1984metropolis_level2_classified.img
Zone number 33
Zone name: Water Bodies
Class layer name: d:/new folder/new folder/1984metropolis_level2_classified.img

Class	Class Name	Count	%	Hectares
33	Water Bodies	508457	100.00	41299.420
	Total	508457	100.00	41299.420

Zonal Statistics:

Majority:	33	Mean:	33.0000
Median:	33	Minimum:	33
Maximum:	33	Range:	1
Diversity:	1	Std. Deviation:	0.0000
Majority Count:	508457	Majority %:	100.0000

AREA	RESPONDENT	SEX	AGE	ECONOMICFA	SOCIALFACT	POLITICALF	ENVIRONMEN	RATE_OF_UR	ID
Ikorodu	Resident	Male	35	7	1	1	1	7	1
Ikorodu	Resident	Male	40	7	1	1	1	7	2
Ikorodu	Resident	Male	23	7	1	1	1	5	3
Ikorodu	Resident	Male	18	7	1	1	1	5	4
Ikorodu	Resident	Male	42	7	1	1	1	5	5
Ikorodu	Resident	Male	67	7	1	1	1	5	6
Ikorodu	Resident	Male	23	7	1	1	1	5	7
Ikorodu	Resident	Male	15	7	1	1	1	5	8
Ikorodu	Resident	Male	17	7	1	1	1	5	9
Ikorodu	Resident	Female	33	7	1	1	1	5	10
Ikorodu	Resident	Female	38	7	1	1	1	5	11
Ikorodu	Resident	Female	27	7	1	1	1	7	12
Ikorodu	Resident	Female	25	7	1	1	1	7	13
Ikorodu	Resident	Male	71	7	1	1	1	7	14
Ikorodu	Resident	Female	65	7	1	1	1	7	15
Ikorodu	Resident	Female	43	1	1	7	1	5	16
Ikorodu	Resident	Male	15	1	1	7	1	5	17
Ikorodu	Resident	Male	65	1	1	7	1	5	18
Ikorodu	Resident	Male	29	1	1	7	1	7	19
Ikorodu	Resident	Male	31	1	1	7	1	7	20
Ikorodu	Resident	Male	19	7	1	1	1	7	21
Ikorodu	Resident	Male	32	7	1	1	1	5	22
Ikorodu	Resident	Female	47	7	1	1	1	5	23
Ikorodu	Resident	Male	37	7	1	1	1	5	24
Ikorodu	Resident	Male	21	7	1	1	1	7	25
Ikorodu	Resident	Male	19	7	1	1	1	7	26
Ikorodu	Resident	Female	14	7	1	1	1	7	27
Ikorodu	Resident	Male	28	7	1	1	1	7	28
Ikorodu	Resident	Male	44	7	1	1	1	7	29
Ikorodu	Professio	Male	44	7	1	1	1	1	30
Ikorodu	Professio	Male	37	7	1	1	1	7	31
Ikorodu	Professio	Male	32	7	1	1	1	1	32
Ikorodu	Professio	Male	56	7	1	1	1	7	33
Ikorodu	Professio	Female	52	7	1	1	1	7	34
Ikorodu	Professio	Male	49	7	1	1	1	5	35
Ikorodu	Professio	Female	34	7	1	1	1	5	36
Ikorodu	Professio	Male	61	7	1	1	1	5	37
Ikorodu	Resident	Male	33	7	1	1	1	5	38
Ikorodu	Resident	Male	25	7	1	1	1	5	39
Ikorodu	Resident	Male	43	7	1	1	1	5	40
Ikorodu	Resident	Male	18	7	1	1	1	3	41
Ikorodu	Resident	Male	22	7	1	1	1	3	42
Ikorodu	Resident	Male	41	7	1	1	1	7	43
Ikorodu	Resident	Female	56	7	1	1	1	7	44
Ikorodu	Resident	Female	44	7	1	1	1	7	45
Ikorodu	Resident	Female	37	7	1	1	1	7	46
Ikorodu	Resident	Female	56	7	1	1	1	7	47

Ikorodu	Resident	Male	64	7	1	1	1	7	48
Ikorodu	Professio	Male	40	7	1	1	1	5	49
Ikorodu	Professio	Male	22	7	1	1	1	5	50
Ikorodu	Professio	Male	51	7	1	1	1	5	51
Lagos Island	Professio	Male	35	7	1	1	1	5	52
Lagos Island	Resident	Male	28	7	1	1	1	5	53
Lagos Island	Resident	Male	43	7	1	1	1	7	54
Lagos Island	Resident	Male	46	7	1	1	1	7	55
Lagos Island	Resident	Male	79	7	1	1	1	7	56
Lagos Island	Resident	Male	81	7	1	1	1	7	57
Lagos Island	Resident	Male	66	7	1	1	1	7	58
Lagos Island	Resident	Male	54	7	1	1	1	7	59
Lagos Island	Resident	Male	37	7	1	1	1	7	60
Lagos Island	Resident	Male	45	7	1	1	1	5	61
Lagos Island	Resident	Male	29	7	1	1	1	5	62
Lagos Island	Resident	Male	14	7	1	1	1	5	63
Lagos Island	Resident	Male	25	7	1	1	1	5	64
Lagos Island	Resident	Male	47	7	1	1	1	5	65
Lagos Island	Resident	Male	44	7	1	1	1	5	66
Lagos Island	Resident	Female	21	7	1	1	1	5	67
Lagos Island	Professio	Female	33	1	1	7	1	7	68
Lagos Island	Professio	Male	29	1	1	7	1	7	69
Lagos Island	Professio	Male	61	1	1	7	1	7	70
Lagos Island	Professio	Female	28	1	1	7	1	7	71
Lagos Island	Professio	Female	58	7	1	1	1	7	72
Lagos Island	Professio	Female	45	7	1	1	1	7	73
Lagos Island	Professio	Male	21	7	1	1	1	7	74
Lagos Island	Professio	Male	69	7	1	1	1	7	75
Lagos Island	Professio	Male	41	7	1	1	1	7	76
Lagos Island	Professio	Female	49	7	1	1	1	7	77
Lagos Island	Resident	Male	56	7	1	1	1	7	78
Lagos Island	Resident	Male	39	7	1	1	1	7	79
Ikoyi	Resident	Male	70	7	1	1	1	7	80
Ikoyi	Resident	Male	32	7	1	1	1	7	81
Ikoyi	Resident	Male	36	1	1	7	1	7	82
Ikoyi	Resident	Male	75	1	1	7	1	5	83
Ikoyi	Resident	Male	36	1	1	7	1	5	84
Ikoyi	Resident	Male	16	1	1	7	1	5	85
Ikoyi	Resident	Male	65	1	1	7	1	5	86
Ikoyi	Resident	Female	34	1	1	7	1	7	87
Ikoyi	Resident	Female	37	1	1	7	1	7	88
Ikoyi	Resident	Female	29	1	1	7	1	7	89
Ikoyi	Resident	Male	26	1	1	7	1	7	90
Ikoyi	Professio	Male	31	1	1	1	7	7	91
Ikoyi	Resident	Male	25	1	1	1	7	7	92
Ikoyi	Professio	Male	33	1	1	1	7	7	93
Ikoyi	Professio	Female	83	1	1	1	7	7	94
Ikoyi	Professio	Female	21	1	1	1	7	7	95

Ikoyi	Professio	Female	36	1	1	1	7	7	96
Lagos Island	Professio	Female	74	1	1	1	7	7	97
Lagos Island	Professio	Female	33	1	1	1	7	7	98
Lagos Island	Resident	Male	27	1	1	1	7	7	99
Lagos Island	Resident	Male	56	1	1	1	7	7	100
Victoria Island	Resident	Male	43	1	1	1	7	7	101
Victoria Island	Resident	Male	23	1	1	1	7	7	102
Victoria Island	Resident	Male	67	1	1	1	7	7	103
Victoria Island	Resident	Male	55	1	1	1	7	7	104
Victoria Island	Resident	Male	49	1	1	1	7	7	105
Victoria Island	Resident	Male	20	1	1	1	7	7	106
Victoria Island	Resident	Male	19	1	1	1	7	5	107
Victoria Island	Resident	Female	31	1	1	1	7	5	108
Victoria Island	Resident	Female	40	1	1	1	7	5	109
Victoria Island	Resident	Female	80	7	1	1	1	5	110
Victoria Island	Professio	Female	41	7	1	1	1	5	111
Victoria Island	Professio	Female	36	7	1	1	1	5	112
Victoria Island	Professio	Female	31	1	7	1	1	5	113
Victoria Island	Professio	Male	70	1	7	1	1	7	114
Victoria Island	Professio	Male	42	7	1	1	1	7	115
Victoria Island	Professio	Male	56	7	1	1	1	7	116
Victoria Island	Professio	Male	62	7	1	1	1	7	117
Victoria Island	Professio	Male	29	7	1	1	1	7	118
Victoria Island	Professio	Female	23	1	1	7	1	7	119
Victoria Island	Professio	Male	17	1	1	7	1	7	120
Victoria Island	Professio	Male	24	1	1	7	1	7	121
Victoria Island	Professio	Male	32	1	1	7	1	7	122
Victoria Island	Professio	Male	40	1	1	7	1	7	123
Victoria Island	Professio	Female	37	7	1	1	1	7	124
Victoria Island	Professio	Female	42	7	1	1	1	7	125
Victoria Island	Professio	Male	33	1	7	1	1	7	126
Victoria Island	Professio	Male	39	1	7	1	1	7	127
Lekki	Professio	Male	45	7	1	1	1	7	128
Lekki	Professio	Male	39	7	1	1	1	7	129
Lekki	Resident	Male	32	1	7	1	1	7	130
Lekki	Resident	Male	13	1	7	1	1	5	131
Lekki	Resident	Male	44	1	7	1	1	5	132
Lekki	Resident	Female	72	1	7	1	1	5	133
Lekki	Resident	Female	66	1	7	1	1	5	134
Ajah	Resident	Female	45	1	7	1	1	5	135
Ajah	Resident	Male	34	1	7	1	1	5	136
Ajah	Resident	Male	69	1	7	1	1	5	137
Ajah	Resident	Male	55	1	7	1	1	5	138
Ajah	Resident	Male	59	1	7	1	1	5	139
Ajah	Resident	Male	35	1	7	1	1	5	140
Ajah	Resident	Male	61	1	7	1	1	7	141
Ajah	Resident	Male	31	1	7	1	1	7	142
Ajah	Resident	Female	42	1	7	1	1	7	143

Ajah	Resident	Female	50	1	7	1	1	7	144
Ajah	Resident	Male	60	1	7	1	1	7	145
Ajah	Resident	Male	44	1	7	1	1	7	146
Ajah	Resident	Male	15	1	7	1	1	7	147
Ajah	Resident	Male	40	1	7	1	1	7	148
Ajah	Resident	Male	57	1	1	7	1	7	149
Ajah	Resident	Male	51	1	1	7	1	7	150
Yaba	Resident	Female	78	1	1	7	1	7	151
Yaba	Resident	Male	52	7	1	1	1	7	152
Yaba	Resident	Male	36	7	1	1	1	7	153
Yaba	Resident	Female	89	7	1	1	1	7	154
Yaba	Resident	Female	57	7	1	1	1	7	155
Yaba	Resident	Female	33	7	1	1	1	7	156
YABATECH	Professio	Male	37	7	1	1	1	7	157
YABATECH	Professio	Male	41	7	1	1	1	7	158
YABATECH	Professio	Male	47	7	1	1	1	7	159
YABATECH	Professio	Female	56	7	1	1	1	7	160
YABATECH	Professio	Male	47	7	1	1	1	7	161
Ikorodu Road	Professio	Male	65	7	1	1	1	3	162
Ikorodu Road	Professio	Male	69	7	1	1	1	3	163
Ikorodu Road	Professio	Male	32	7	1	1	1	3	164
Ikorodu Road	Professio	Male	36	7	1	1	1	3	165
Ikorodu Road	Professio	Male	58	7	1	1	1	3	166
Mushin	Professio	Male	63	7	1	1	1	3	167
Mushin	Professio	Male	45	7	1	1	1	3	168
Mushin	Professio	Male	53	7	1	1	1	3	169
Mushin	Professio	Female	67	7	1	1	1	3	170
Mushin	Professio	Male	75	7	1	1	1	3	171
UNILAG	Professio	Female	63	7	1	1	1	7	172
UNILAG	Professio	Male	44	7	1	1	1	7	173
UNILAG	Professio	Male	69	7	1	1	1	7	174
UNILAG	Professio	Male	57	7	1	1	1	7	175
UNILAG	Professio	Male	42	7	1	1	1	7	176
UNILAG	Professio	Male	35	7	1	1	1	7	177
UNILAG	Professio	Male	60	7	1	1	1	7	178
Shomolu	Professio	Male	34	7	1	1	1	5	179
Shomolu	Professio	Male	31	7	1	1	1	5	180
Shomolu	Resident	Male	87	7	1	1	1	5	181
Shomolu	Resident	Male	54	7	1	1	1	5	182
Mushin	Resident	Male	46	7	1	1	1	5	183
Mushin	Resident	Male	61	7	1	1	1	5	184
Mushin	Resident	Male	43	7	1	1	1	5	185
Mushin	Resident	Male	71	7	1	1	1	5	186
Mushin	Resident	Female	36	7	1	1	1	5	187
Surulere	Resident	Female	47	1	7	1	1	5	188
Surulere	Resident	Male	14	1	7	1	1	5	189
Surulere	Resident	Male	78	1	7	1	1	5	190
Surulere	Resident	Male	46	1	7	1	1	5	191

Ikorodu Road	Resident	Male	57	7	1	1	1	7	192
Ikorodu Road	Resident	Male	39	7	1	1	1	7	193
Ikorodu Road	Resident	Male	45	7	1	1	1	7	194
Ikorodu Road	Resident	Male	43	7	1	1	1	7	195
Oshodi	Resident	Male	56	7	1	1	1	7	196
Oshodi	Resident	Male	59	1	1	7	1	7	197
Oshodi	Resident	Female	70	1	1	7	1	7	198
Oshodi	Resident	Female	68	1	1	7	1	7	199
Oshodi	Resident	Female	46	1	1	7	1	7	200
Oshodi	Resident	Male	60	7	1	1	1	1	201
Oshodi	Resident	Male	58	1	7	1	1	7	202
Oshodi	Resident	Male	47	1	7	1	1	7	203
Oshodi	Resident	Male	49	1	7	1	1	1	204
Oshodi	Resident	Male	50	7	1	1	1	1	205
Ojota	Resident	Female	55	7	1	1	1	7	206
Ojota	Resident	Male	52	7	1	1	1	7	207
Ojota	Resident	Male	46	7	1	1	1	7	208
Ojota	Resident	Male	49	7	1	1	1	7	209
Ogudu	Resident	Male	52	7	1	1	1	7	210
Ogudu	Resident	Male	55	7	1	1	1	7	211
Ogudu	Resident	Male	58	7	1	1	1	7	212
Ketu	Resident	Male	48	7	1	1	1	7	213
Ketu	Resident	Male	49	7	1	1	1	7	214
Ketu	Resident	Male	61	7	1	1	1	7	215
Ketu	Resident	Male	66	7	1	1	1	7	216
Ketu	Resident	Male	58	7	1	1	1	7	217
Ketu	Resident	Male	49	1	7	1	1	7	218
Isolo	Resident	Male	32	7	1	1	1	1	219
Isolo	Resident	Male	37	7	1	1	1	1	220
Isolo	Resident	Male	56	7	1	1	1	1	221
Isolo	Resident	Male	78	7	1	1	1	7	222
Isolo	Resident	Male	67	7	1	1	1	7	223
Isolo	Resident	Female	54	7	1	1	1	7	224
Isolo	Resident	Female	44	7	1	1	1	7	225
Ojo	Professio	Male	48	7	1	1	1	7	226
Ojo	Professio	Female	57	7	1	1	1	7	227
Ojo	Professio	Female	62	7	1	1	1	1	228
Ojo	Resident	Male	34	7	1	1	1	1	229
Ojo	Resident	Male	31	7	1	1	1	1	230
Ojo	Resident	Male	46	7	1	1	1	1	231
Ojo	Resident	Male	67	1	1	7	1	1	232
Ojo	Resident	Male	81	1	1	7	1	7	233
Ojo	Resident	Male	38	1	1	7	1	7	234
Ojo	Resident	Female	59	1	1	7	1	7	235
Ojo	Resident	Female	51	1	1	7	1	7	236
Ojo	Resident	Female	47	7	1	1	1	7	237
Ojo	Resident	Female	56	7	1	1	1	7	238
Ojo	Resident	Female	43	7	1	1	1	7	239

Mile 2	Resident	Female	48	7	1	1	1	7	240
Mile 2	Resident	Female	67	7	1	1	1	7	241
Mile 2	Resident	Female	59	7	1	1	1	7	242
Mile 2	Resident	Male	60	7	1	1	1	7	243
Mile 2	Resident	Male	56	7	1	1	1	7	244
Mile 2	Resident	Male	48	7	1	1	1	5	245
Mile 2	Professio	Male	49	7	1	1	1	5	246
Mile 2	Professio	Male	71	7	1	1	1	7	247
Amuwo	Professio	Male	55	1	1	7	1	7	248
Amuwo	Professio	Male	58	1	1	7	1	7	249
Amuwo	Professio	Male	54	1	1	7	1	7	250
Amuwo	Professio	Female	53	1	1	7	1	7	251
Amuwo	Professio	Female	58	7	1	1	1	7	252
Amuwo	Professio	Female	48	7	1	1	1	7	253
Egbe	Professio	Male	46	7	1	1	1	7	254
Egbe	Professio	Male	52	7	1	1	1	7	255
Egbe	Professio	Male	49	7	1	1	1	7	256
Egbe	Resident	Male	48	7	1	1	1	7	257
Egbe	Resident	Male	75	7	1	1	1	7	258
Egbe	Resident	Male	60	7	1	1	1	7	259
Egbe	Resident	Male	46	7	1	1	1	7	260
Egbe	Resident	Male	53	7	1	1	1	7	261
Egbe	Resident	Male	58	7	1	1	1	7	262
Igando	Resident	Male	47	7	1	1	1	7	263
Igando	Resident	Male	54	1	1	7	1	7	264
Igando	Resident	Male	47	1	1	7	1	7	265
Igando	Resident	Male	49	1	1	7	1	7	266
Igando	Resident	Male	38	1	1	7	1	7	267
Ikotun	Resident	Male	72	1	1	7	1	7	268
Ikotun	Resident	Male	49	1	1	7	1	7	269
Ikotun	Resident	Male	56	7	7	1	1	7	270
Ikotun	Resident	Male	58	7	1	1	1	7	271
Ikotun	Resident	Male	55	7	1	1	1	7	272
Ikotun	Resident	Male	51	7	1	1	1	7	273
Ikotun	Resident	Male	60	7	1	1	1	7	274
Ikotun	Resident	Male	47	7	1	1	1	7	275
Ikotun	Resident	Male	53	7	1	1	1	7	276
Ikotun	Resident	Male	46	7	1	1	1	7	277
Ikotun	Resident	Female	57	7	1	1	1	7	278
Akowanjo	Resident	Male	60	7	1	1	1	7	279
Akowanjo	Resident	Male	64	7	1	1	1	7	280
Akowanjo	Resident	Female	50	7	1	1	1	7	281
Akowanjo	Resident	Female	67	7	1	1	1	7	282
Akowanjo	Resident	Female	46	7	1	1	1	7	283
Akowanjo	Resident	Male	49	7	1	1	1	7	284
Akowanjo	Resident	Female	54	7	1	1	1	7	285
Agege	Resident	Male	39	7	1	1	1	7	286
Agege	Professio	Female	34	7	1	1	1	7	287

Agege	Professio	Male	56	7	1	1	1	7	288
Agege	Professio	Male	21	7	1	1	1	7	289
Agege	Professio	Male	25	7	1	1	1	7	290
Ijaye	Professio	Male	41	7	1	1	1	7	291
Ijaye	Professio	Male	37	7	1	1	1	7	292
Ijaye	Professio	Male	30	7	1	1	1	7	293
Ijaye	Professio	Male	41	7	1	1	1	7	294
Ijaye	Professio	Male	58	7	1	1	1	7	295
Ijaye	Professio	Male	54	7	1	1	1	7	296
Ijaye	Professio	Male	26	7	1	1	1	7	297
Agege	Professio	Male	19	7	1	1	1	5	298
Agege	Professio	Male	15	7	1	1	1	5	299
Agege	Resident	Male	31	7	1	1	1	5	300
Agege	Resident	Male	27	7	1	1	1	5	301
Agege	Resident	Male	43	7	1	1	1	5	302
Agege	Resident	Male	56	7	1	1	1	5	303
Isheri	Resident	Male	15	7	1	1	1	5	304
Isheri	Resident	Male	19	7	1	1	1	5	305
Isheri	Resident	Male	49	7	1	1	1	5	306
Isheri	Resident	Male	38	7	1	1	1	5	307
Isheri	Resident	Male	20	7	1	1	1	5	308
Isheri	Resident	Male	72	7	1	1	1	7	309
Isheri	Professio	Male	18	7	1	1	1	7	310
Isheri	Professio	Male	21	7	1	1	1	7	311
Isheri	Professio	Male	47	7	1	1	1	7	312
Isheri	Professio	Male	29	7	1	1	1	7	313
Apapa	Professio	Male	21	7	1	1	1	7	314
Apapa	Professio	Female	39	7	1	1	1	7	315
Apapa	Professio	Male	45	7	1	1	1	7	316
Apapa	Professio	Female	18	7	1	1	1	7	317
Apapa	Professio	Male	14	7	1	1	1	7	318
Apapa	Professio	Male	24	7	1	1	1	7	319
Apapa	Professio	Male	19	7	1	1	1	7	320
Apapa	Professio	Male	32	7	1	1	1	7	321
Apapa	Resident	Male	45	1	1	1	7	7	322
Apapa	Resident	Male	69	1	1	1	7	7	323
Apapa	Resident	Male	30	1	1	1	7	7	324
Apapa	Resident	Male	45	1	1	1	7	7	325
Apapa	Resident	Male	66	7	1	1	1	7	326
Apapa	Resident	Male	16	7	1	1	1	7	327
Apapa	Resident	Male	13	7	1	1	1	7	328
Apapa	Resident	Male	69	7	1	1	1	7	329
Apapa	Resident	Male	21	7	1	1	1	7	330
Apapa	Resident	Male	67	7	1	1	1	7	331
Abule Egba	Resident	Male	29	7	1	1	1	7	332
Abule Egba	Resident	Male	72	7	1	1	1	7	333
Abule Egba	Resident	Male	67	7	1	1	1	7	334
Abule Egba	Resident	Male	91	7	1	1	1	7	335

Suberu Oje	Resident	Male	88	7	1	1	1	3	336
Suberu Oje	Resident	Male	74	7	1	1	1	3	337
Suberu Oje	Resident	Male	89	7	1	1	1	3	338
Suberu Oje	Resident	Female	78	7	1	1	1	3	339
Suberu Oje	Resident	Female	69	7	1	1	1	7	340
Suberu Oje	Resident	Female	21	7	1	1	1	7	341
Suberu Oje	Resident	Female	44	7	1	1	1	7	342
Alagbado	Resident	Female	20	7	1	1	1	7	343
Alagbado	Resident	Female	31	7	1	1	1	7	344
Alagbado	Resident	Female	49	7	1	1	1	7	345
Alagbado	Resident	Female	34	7	1	1	1	7	346
Alagbado	Resident	Female	37	7	1	1	1	7	347
Alagbado	Resident	Male	21	7	1	1	1	3	348
Olodi-Apapa	Resident	Female	46	1	1	7	1	3	349
Olodi-Apapa	Resident	Female	82	1	1	7	1	3	350
Olodi-Apapa	Resident	Female	24	1	1	7	1	3	351
Olodi-Apapa	Resident	Male	31	1	1	7	1	3	352
Olodi-Apapa	Resident	Male	38	1	1	7	1	3	353
Olodi-Apapa	Resident	Male	29	1	1	7	1	7	354
Olodi-Apapa	Resident	Male	23	1	1	7	1	7	355
FESTAC Town	Resident	Male	44	1	1	7	1	7	356
FESTAC Town	Resident	Male	59	1	1	7	1	7	357
FESTAC Town	Resident	Male	67	7	1	1	1	7	358
FESTAC Town	Resident	Male	28	7	1	1	1	7	359
FESTAC Town	Professio	Female	41	7	1	1	1	7	360
FESTAC Town	Professio	Female	49	7	1	1	1	7	361
FESTAC Town	Professio	Female	36	7	1	1	1	7	362
FESTAC Town	Professio	Female	70	7	1	1	1	7	363
FESTAC Town	Professio	Male	40	7	1	1	1	7	364
FESTAC Town	Professio	Male	39	7	1	1	1	7	365
Victoria Island	Professio	Male	29	7	1	1	1	7	366
Victoria Island	Professio	Male	14	1	1	1	7	7	367
Victoria Island	Professio	Male	32	1	1	1	7	7	368
Victoria Island	Professio	Male	52	7	1	1	1	7	369
Victoria Island	Professio	Male	28	7	1	1	1	7	370
Victoria Island	Professio	Male	55	7	1	1	1	7	371
Ibafon	Professio	Male	39	7	1	1	1	7	372
Ibafon	Resident	Male	33	7	1	1	1	7	373
Ibafon	Resident	Male	59	7	1	1	1	7	374
Ibafon	Resident	Male	47	7	1	1	1	7	375
Ibafon	Resident	Male	72	7	1	1	1	7	376
Satellite Town	Resident	Male	74	7	1	1	1	5	377
Satellite Town	Resident	Male	15	7	1	1	1	5	378
Satellite Town	Resident	Male	17	7	1	1	1	5	379
Satellite Town	Resident	Male	19	7	1	1	1	5	380
Satellite Town	Resident	Male	21	7	1	1	1	5	381
Satellite Town	Resident	Male	29	7	1	1	1	5	382
Satellite Town	Resident	Male	26	7	1	1	1	5	383

Amuwo-Odofin	Resident	Male	41	7	1	1	1	5	384
Amuwo-Odofin	Resident	Male	39	7	1	1	1	7	385
Amuwo-Odofin	Resident	Male	44	7	1	1	1	7	386
Amuwo-Odofin	Resident	Male	71	7	1	1	1	7	387
Amuwo-Odofin	Resident	Male	48	7	1	1	1	7	388
Amuwo-Odofin	Resident	Male	36	7	1	1	1	7	389
Amuwo-Odofin	Resident	Male	45	7	1	1	1	7	390
Amuwo-Odofin	Resident	Male	25	7	1	1	1	7	391
Amuwo-Odofin	Resident	Male	29	7	1	1	1	7	392
Amuwo-Odofin	Resident	Male	26	7	1	1	1	7	393
Amuwo-Odofin	Resident	Male	24	7	1	1	1	7	394
Amuwo-Odofin	Resident	Male	34	7	1	1	1	7	395
Trade Fair Complex	Resident	Male	15	7	1	1	1	5	396
Trade Fair Complex	Resident	Male	27	7	1	1	1	5	397
Trade Fair Complex	Resident	Female	42	7	1	1	1	5	398
Trade Fair Complex	Resident	Female	37	7	1	1	1	5	399
Trade Fair Complex	Resident	Female	54	7	1	1	1	5	400
Trade Fair Complex	Resident	Female	38	7	1	1	1	5	401
Trade Fair Complex	Resident	Female	45	7	1	1	1	5	402
Trade Fair Complex	Resident	Male	67	7	1	1	1	5	403
Trade Fair Complex	Professio	Male	48	7	1	1	1	5	404
Trade Fair Complex	Professio	Male	36	7	1	1	1	1	405
Trade Fair Complex	Professio	Male	41	7	1	1	1	1	406
Trade Fair Complex	Professio	Male	45	7	1	1	1	1	407
Ikotun	Professio	Male	57	7	1	1	1	1	408
Ikotun	Professio	Female	70	7	1	1	1	1	409
Ikotun	Professio	Female	19	7	1	1	1	1	410
Ikotun	Professio	Male	68	7	1	1	1	1	411
Ikotun	Resident	Male	32	7	1	1	1	1	412
Ikotun	Resident	Male	45	7	1	1	1	1	413
Ikotun	Resident	Male	46	7	1	1	1	1	414
Ikotun	Resident	Male	31	7	1	1	1	1	415
Ikotun	Resident	Male	44	7	1	1	1	7	416
Ikotun	Resident	Male	23	7	1	1	1	7	417
Ikotun	Resident	Male	14	7	1	1	1	7	418
International Airpo	Professio	Male	43	7	1	1	1	5	419
International Airpo	Professio	Male	35	7	1	1	1	5	420
International Airpo	Professio	Male	77	7	1	1	1	5	421
International Airpo	Professio	Male	39	7	1	1	1	5	422
International Airpo	Professio	Male	36	7	1	1	1	5	423
International Airpo	Professio	Male	30	7	1	1	1	5	424
International Airpo	Professio	Male	19	7	1	1	1	5	425
International Airpo	Professio	Male	24	7	1	1	1	5	426
International Airpo	Professio	Male	39	7	1	1	1	5	427
Ilupeju	Resident	Male	47	7	1	1	1	7	428
Ilupeju	Resident	Male	32	7	1	1	1	7	429
Ilupeju	Resident	Female	67	7	1	1	1	7	430
Ilupeju	Resident	Male	80	7	1	1	1	7	431

Ilupeju	Resident	Male	47	1	1	1	1	7	432
Ikeja General Hospi	Resident	Female	32	1	7	1	1	5	433
Ikeja General Hospi	Resident	Female	24	1	7	1	1	5	434
Ikeja General Hospi	Resident	Female	56	1	7	1	1	5	435
Ikeja General Hospi	Resident	Male	38	1	7	1	1	5	436
Ikeja General Hospi	Resident	Male	22	1	1	7	1	5	437
Ikeja General Hospi	Professio	Male	71	1	1	7	1	5	438
Ikeja General Hospi	Professio	Male	69	1	1	7	1	5	439
Ikeja General Hospi	Professio	Male	25	1	1	7	1	5	440
Ikorodu	Professio	Male	34	1	1	7	1	7	441
Ikorodu	Professio	Male	21	1	1	7	1	7	442
Ikorodu	Professio	Male	40	1	1	7	1	7	443
Ikorodu	Professio	Male	37	1	1	7	1	7	444
Ikorodu	Professio	Male	18	7	1	1	1	7	445
Ikorodu	Resident	Male	21	7	1	1	1	1	446
Ikorodu	Resident	Male	21	7	1	1	1	1	447
Ikorodu	Resident	Male	23	7	1	1	1	1	448
Ikorodu	Resident	Male	42	7	1	1	1	1	449
Ikorodu	Resident	Male	66	7	1	1	1	1	450
Ikorodu	Resident	Male	41	7	1	1	1	7	451
Ikorodu	Resident	Male	48	7	1	1	1	3	452
Ikorodu	Resident	Male	63	7	1	1	1	3	453
Ikorodu	Resident	Male	31	7	1	1	1	3	454
Ikorodu	Resident	Male	36	7	1	1	1	3	455
Ikorodu	Resident	Male	27	7	1	1	1	3	456
Ikorodu	Resident	Male	15	7	1	1	1	7	457
Okokomaiko	Resident	Male	19	7	1	1	1	3	458
Okokomaiko	Resident	Male	29	7	1	1	1	3	459
Okokomaiko	Resident	Male	25	7	1	1	1	3	460
Okokomaiko	Resident	Male	18	1	1	7	1	3	461
Okokomaiko	Resident	Male	31	1	1	7	1	3	462
Okokomaiko	Resident	Male	49	7	1	1	1	3	463
Okokomaiko	Resident	Male	17	7	1	1	1	3	464
Oluti	Resident	Male	34	7	1	1	1	5	465
Oluti	Resident	Male	46	7	1	1	1	5	466
Oluti	Resident	Male	14	7	1	1	1	5	467
Oluti	Resident	Male	66	7	1	1	1	5	468
Oluti	Resident	Male	23	7	1	1	1	7	469
Oluti	Resident	Male	76	7	1	1	1	7	470
Oluti	Resident	Male	66	7	1	1	1	7	471
Oluti	Resident	Male	51	7	1	1	1	7	472
Oluti	Resident	Male	58	7	1	1	1	5	473
Lekki	Resident	Male	71	1	7	1	1	7	474
Lekki	Resident	Male	44	1	7	1	1	7	475
Lekki	Resident	Male	22	1	7	1	1	7	476
Lekki	Resident	Male	73	1	7	1	1	7	477
Lekki	Resident	Male	15	1	7	1	1	7	478
Lekki	Resident	Male	29	1	7	1	1	7	479

Ajah	Resident	Male	54	1	7	1	1	7	480
Ajah	Resident	Male	73	1	7	1	1	7	481
Ajah	Resident	Male	72	1	7	1	1	7	482
Ajah	Resident	Male	49	1	7	1	1	7	483
Ajah	Resident	Male	31	1	7	1	1	5	484
Ajah	Resident	Male	67	1	7	1	1	5	485
Ajah	Resident	Male	45	1	7	1	1	7	486
Ajah	Resident	Female	65	1	7	1	1	7	487
Ajah	Resident	Male	32	1	7	1	1	7	488
Lekki	Resident	Female	15	1	7	1	1	7	489
Lekki	Resident	Male	79	1	7	1	1	7	490
Lekki	Resident	Male	21	1	7	1	1	7	491
Lekki	Resident	Male	34	1	7	1	1	7	492
Lekki	Resident	Male	56	1	7	1	1	7	493
Lekki	Resident	Male	27	1	7	1	1	7	494
Lekki	Resident	Male	35	1	7	1	1	7	495

LAND USE/LAND COVER CHANGE DETECTION IN METROPOLITAN LAGOS (NIGERIA): 1984-2002

ABSTRACT

This paper examines the land use/land cover changes that have taken place in Lagos over the last two decades due to rapid urbanisation. Lagos is one of the fastest growing mega-cities in the world, yet it lacks reliable modern, scientific monitoring techniques to effectively monitor and manage land use changes brought about by urbanization. The capabilities of remote sensing in terms of large spatial coverage, spatial and temporal resolutions adequate for these types of studies, as well as the ability of GIS to handle spatial and non-spatial data, make it the optimal approach for this. A post-classification approach was adopted with a maximum likelihood classifier algorithm. The Landsat TM (1984) and Landsat ETM (2000) were merged with SPOT-PAN (2002) to improve classification accuracies and provide more accurate maps for land use/cover change and analysis. This also made it possible to overcome the problem of spectral confusion between some urban land use classes. The land cover change map revealed that forest, low density residential and agricultural land uses are most threatened: most land allocated for these uses has been legally or illegally converted to other land uses within and outside the metropolis.

Key words: Land Use/Cover; Change Detection; Lagos; Urbanisation; Remote Sensing; GIS.

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INTRODUCTION

Lagos is located in Nigeria at latitude 6 27' N and longitude 3 24'E. This falls just above the equator on the continent of Africa. Metropolitan Lagos has an area of 137,460 hectares. Lagos was the former capital of Nigeria with an estimated population of 14.5million people (UN, 2003). Rapid population growth brought many environmental, social and economic problems which led to the relocation of the Federal Capital of Nigeria in 1991from Lagos to Abuja. Despite various governments efforts at decentralisation of activities thought to serve as pull factors for the rapid population growth resulting from the influx of migrants from the rural hinterland Lagos still accounted for over 40% of commercial, industrial and institutional activities in Nigeria. The impact of concentration of the above activities in a naturally confined and landlocked area, coupled with rapid urbanisation, has put enormous pressure on the land cover and land use in the metropolis and its environs.

Although there are a lot of efforts at Federal and State Government level to manage and control the situation, Lagos, as one of the fastest growing urban agglomerations in the world, has proved very difficult to manage with traditional (orthodox) planning techniques. The failure is visible all over the metropolis, as the whole city now resembles a damaged spider's web, which can only be disentangled by sophisticated modern technology. The adoption of technology (RS and GIS) can provide the much needed and missing intelligence which is very important to modern urban management and control. The strategic location of Lagos in Nigeria and the role of attracting direct foreign investment to the nation and the African continent make it pertinent for the Government and private sector to re-examine the state of Lagos and the challenges facing her at the international level in order to attract investment for the economic development of the country. Hence the need to use the cutting edge capabilities of remote sensing and GIS to study the trend and rate of spatial growth and the structural landscape changes.

Urban classifications pose one of the great challenges to remote sensing because of the numerous features that make up the urban centre. Welch (1982) concluded that only finer resolution satellite imagery could meet the spatial requirements of urban classification accuracy, feature identification and extraction. With the development of third generation satellite sensors, with spatial resolution ranging from 30m to 1m, Welch's (1982) prediction for accurate urban classification was finally met. But this still does not automatically remove the classification problems facing researchers in the field of urban remote sensing studies. As most urban features are larger than 1 metre, this leads to more pixels being erroneously classified (Aplin, 2003).

DATA

Data is a representation, abstraction or model of reality (Gatrell, 1991; Burrough and McDonnell, 1998; Atkinson and Tate, 1999). In most environmental sciences there are two main strategies for collecting data: systematic inventory and ad hoc, project-based data collection (Burrough, 1997). Satellite remote sensing falls under systematic surveys. Remote sensing data are primary sources, extensively used for change detection in recent decades (Lu D., et al., 2003). Because of the advantages of repetitive data acquisition, its synoptic view and digital format suitable for computer processing, remotely sensed data, such as Thematic Mapper (TM), Satellite Probatoire d'Observation de la Terre (SPOT), Radar and Advanced Very High Resolution Radiometer (AVHRR), have become the major data sources for different change detection applications during the past decades. In general, change detection involves the application of multi-temporal datasets to quantitatively analyze the temporal effects of the phenomena.

Satellite images from Landsat TM (1984), ETM+ (2000) and SPOT (2002) panchromatic were used in this study. Careful consideration was given to the images used (spatial, temporal, spectral and radiometric suitability). Table 1 shows detail information about the satellite images used. Lagos State Land Use Map (2001) and photographs taken while on field study were also used for ease of interpretation of the satellite images and their analysis. Additionally, population data from the United

Nations population division was used to show the growth rate of metropolitan Lagos both at national and international level.

Platform (Sensor)	Path/Row	Date	Scene ID #
Landsat 5 TM	191/055	18/12/1984	P191R55_5T841218
Landsat 7 ETM+	191/055	06/02/2000	0750003230013
SPOT (HRV2)	067-337	17/01/2002	2067-33702-1-1710:25:502 p067-337/0

Table 1: Satellite Dataset used; Identified by Path/Row, Date and Scene ID for the Study Area

METHODOLOGY

Principal Component Analysis (PCA): PCA is a feature space transformation designed to remove spectral redundancy (Schowengerdt, 1997; Ozkan and Erbek, 2005). It allows redundant data to be compacted into fewer bands - that is, the dimensionality of the data is reduced. The bands of PCA data are non-correlated and independent, which makes it more interpretable than the source data (Jensen, 1996; Faust, 1989; ERDAS Imagine, 1997). The purpose of PCA is to define the number of dimensions that are present in a data set, and to fix the coefficients which specify the positions of that set of axes that point in the direction of greatest variability in the data (Ozkan and Erbek, 2005). This method was used because of its ability to improve the classification accuracy by taking advantage of the strength of PCA mentioned above. The first few bands account for a high proportion of the variation in the data. PCA was limited to 3 bands to display the image in RGB.

Classification: The objective of image classification is to create cluster classes from multispectral satellite imagery. Image classification is essential in making sense of the many colours present within an image. Supervised classification technique with maximum likelihood classifier was used. The fact that landscape structure and land cover dynamics are very complex in most African urban centres makes Maximum Likelihood Classifier (MLC) an appropriate classification method. This is a sophisticated classifier and is considered the most appropriate for the study area. MLC, as a per-pixel classifier, was able to handle and show the spatial distribution of land uses and land cover types in metropolitan Lagos, though, this can result in what Lu et al., 2004 called "Salt and Pepper" pattern classification. The classification accuracy of 96.6% for level 1 classification and 87% and 83.7% accuracy for levels 2 and 3 respectively underline the strength of MLC to handle remotely sensed data from metropolitan Lagos, where land use classes have little or no spectral distinction because of organic development due to lack of planning and zoning laws at the initial stage of growth. The MLC effectively handled this problem better than other types of classifiers tried for this research. One of the reasons for the performance of MLC could be attributed to the fact that it is a per-pixel classifier.

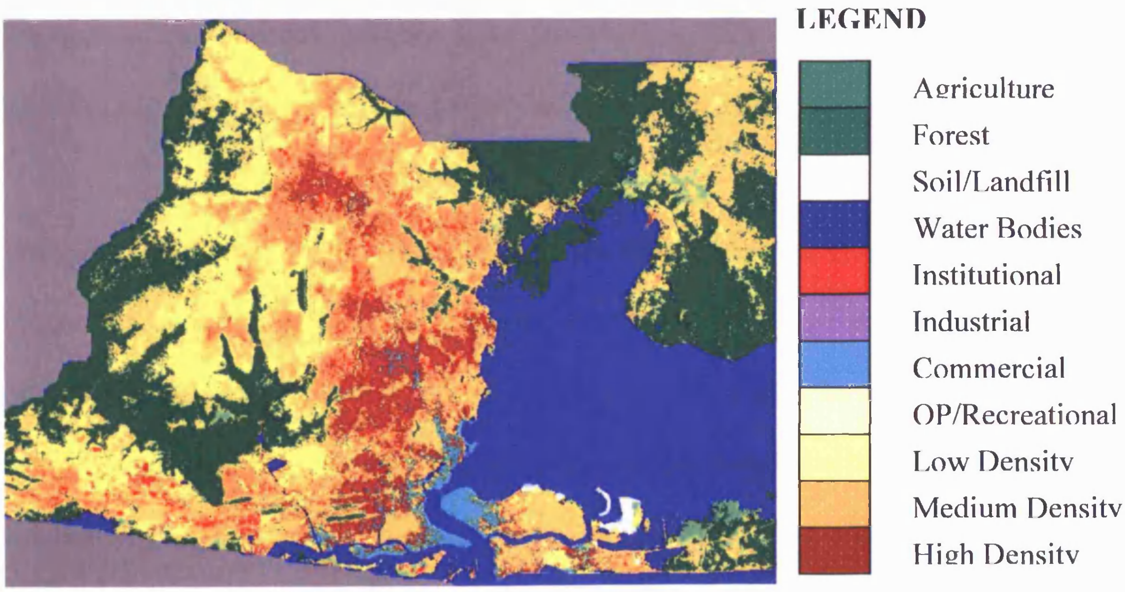


Figure 1: 1984 Land Use/Cover Level III Map

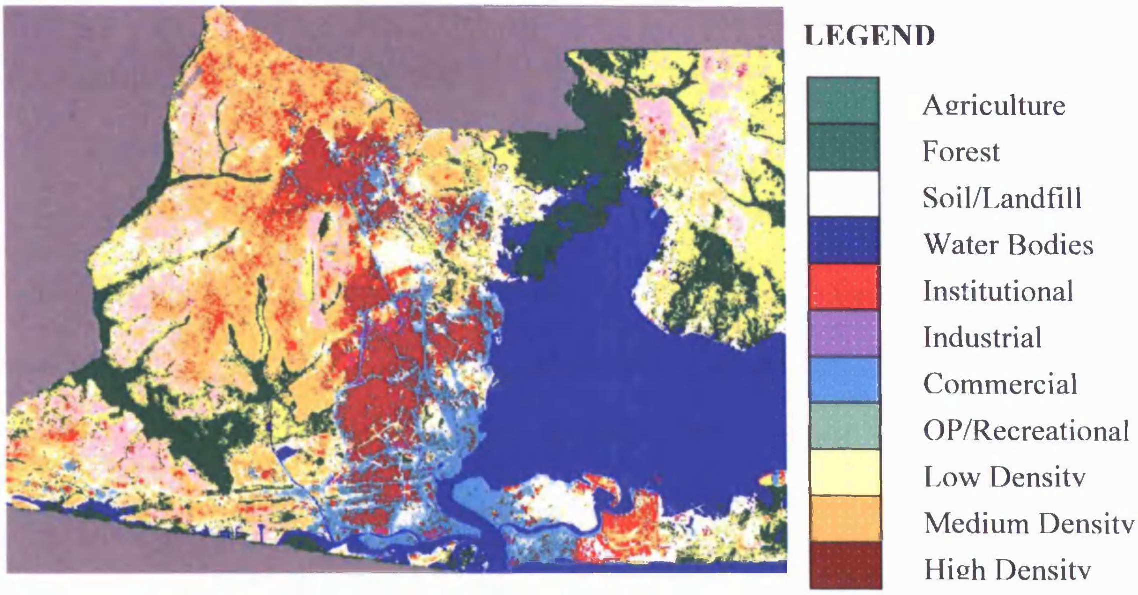


Figure 2: 2002 Land Use/Cover Level III Map

Change Detection: Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh 1989; Lu D. et al., 2003). Digital change detection has been divided into two major groups. This involves the use of multitemporal data sets to discriminate areas of land cover change between dates of imaging (Lillesand T.M. et al., 2004). This research is focused on the changes between-class (conversion from one land cover class to another) and within-class (changes from one land use to another).

Post-Classification change detection approach was employed due to its ability to bypass the problems and difficulties associated with analysis of images acquired at different times of the year and sensors (Yuan D. et al., 1998). In this research, land cover change is detected as a change in land cover label between two image dates. It is based on two independent true land cover class classifications, and was achieved by supervised classification.

CLASSIFICATION ACCURACY ASSESSMENT

Campbell J.B. (2002) defines accuracy as "correctness", which measures the agreement between a standard assumed to be correct and a classified image of known quality. Accuracy is considered an important step in evaluation of different image processing routines in image classification (Foody, 2002; Lu and Weng, 2005). For any acceptable research findings, there must be a high level of confidence in the result, which is what accuracy assessment is all about. Error matrix is used to assess the accuracy of the classified images. Congalton and Green, 1999, present the mathematical representation of error matrix and KHAT as follows:

The KHAT values below are a measure of how well remotely sensed classification agrees with the reference data. Landis and Koch (1977) grouped KHAT

$$\hat{k} = \frac{ObservedAccuracy - ChanceAgreement}{1 - ChanceAgreement}$$

- Shows the extent to which the correct values of an error matrix are due to "true" vs. "chance" agreement.
- Ideal case: c.a. → 0, o.a. → 1, K-hat → 1

$$\hat{k} = \frac{n\sum_{i=1}^{k} n_{ii} - \sum_{i=1}^{k} n_{i+}n_{+i}}{n^2 - \sum_{i=1}^{k} n_{i+}n_{+i}}$$; n_{ii} , n_{i+} , and n_{+i} as previously defined above.

k: # of rows, columns in error matrix n: total # of observations in error matrix

n_{ii} : major diagonal element for class I n_{i+} : total # of observations in row i (right margin)

n_{+i} : total # of observations in column i (bottom margin)

The overall accuracy of the classification is 96.6% for level 1 (land cover) and 86.6% for level 2 (land cover/use). Detail of producer's and user's accuracy for level 1 classification is in Table 2.

The Kappa values are such that 0.80 (i.e., 80%) represents strong agreement, 0.40 and 0.80 (i.e., 40–80%) represents moderate agreement and a value below 0.40 (i.e., 40%) represents poor agreement (Congalton and Ross, 1999). The conditional Kappa values in Table 3 show that water bodies, forest, urban/built-up areas and bare soil land cover have strong agreement with the classification.

Referenced Data

Classified Data	Water Bodies	Forest	Urban/Built	Bear Soil	Row Total	Producer's Accuracy	User's Accuracy
Water Bodies	8	0	1	0	9	88.89	88.89
Forest	0	10	1	0	11	100	90.91
Urban/Built	1	0	60	0	61	96.77	98.36
Bare Soil	0	0	0	8	8	100	100
Column Total	9	10	62	8	89		

Table 2: 1984 Level I Error Matrix for Land Cover Types.

Overall Accuracy = 96.63%

Class Name	Kappa
Water Bodies	0.87
Forest	0.89
Urban/Built Up	0.94
Bare Soil	1.0

Table 3: K-hat value for each category

Overall Kappa Statistics = 0.93

RESULTS AND DISCUSSION

The post classification comparison of land use/cover classes gives the change that took place between 1984 and 2002 in hectares. Table 4 below shows detail of temporal change between land cover types. The urban/built-up area has increased by 35.5%, and bare soil has nearly doubled with 96.3% increase from the initial area coverage in 1984. There is an increase of 1.6% in water bodies which may be due to sensor difference or canalisation projects in the study area. There is 57.8% decrease in the forest and agriculture land cover. The spatial growth or expansion in other land cover types has directly taken place on the agricultural land and forests as this is the only land cover type with a decrease in area coverage for the period under study.

Figure 3 gives a graphical representation of the land cover change in Lagos between 1984 and 2002.

Land Cover Type	1984 Area (Ha)	1984 %	2002 Area (Ha)	2002 %	Change Area	% Change
Urban/Built-Up	47728	35	64656	47	+16928	35.5
Bare Soil	1265	1	2483	2	+1218	96.3
Water Bodies	55602	40	56465	41	+863	1.6
Forest & Agric	32865	24	13856	10	-19009	-57.8
Total	137460	100	137460	100		

Table 4: 1984 and 2002 Land Cover Change derived from Post-Classification Comparison.

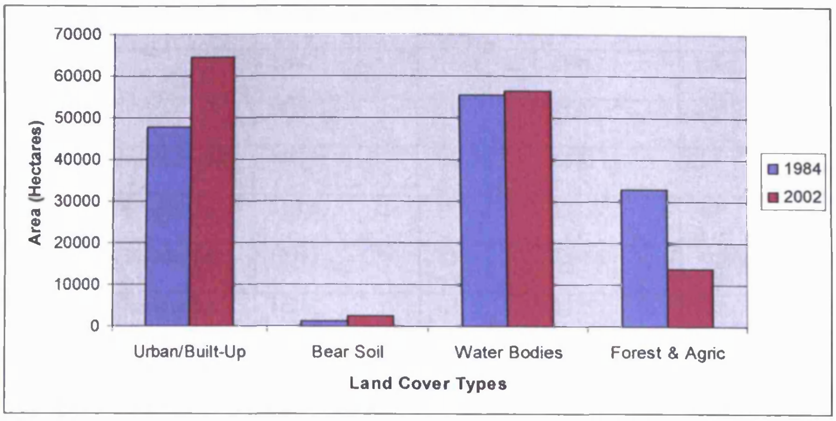


Figure 3: Chart showing Land Cover change between 1984 and 2002

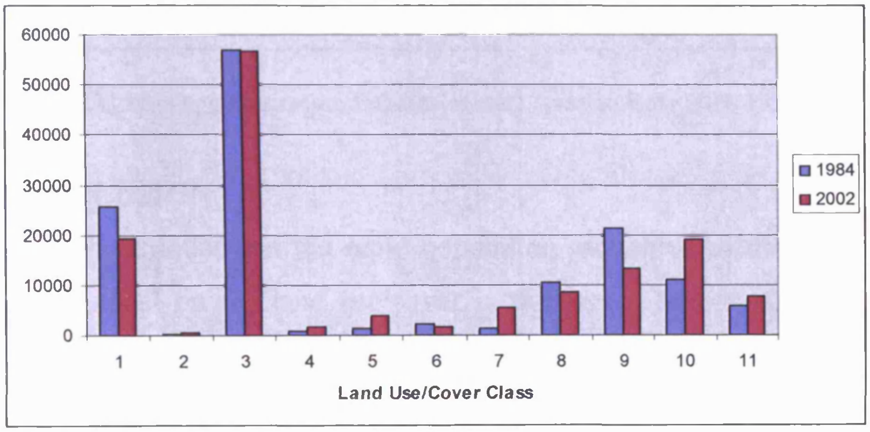
Figure 4 shows the land cover/use post-classification comparison derived from independently classified images of 1984 and 2002. The change is calculated in percentage and area (hectares) within each land use class. Forest land cover has decreased by 24.8% and agricultural land use has also decreased by almost half (48.1%).

The 32.5% decrease in industrial land use can be attributed to the economic recession during the period under study which led to the conversion of this use to places of worship (churches). This is one of the reasons for the 179.6% increase in institutional land use. However, the highest increase is in commercial land use, with 273.5%. Most of the change in commercial use is the result of conversion from residential to commercial, notably in the low density areas such as Victoria Island, Ikoyi and along major roads in the metropolis.

Land Cover Type	1984 Area	1984 %	2002 Area	2002 %	Change Area	% Change
Forest	25628	18.6	19265	14.0	-6363	-24.8
Bare Soil/ Landfill	274	0.2	459	0.3	185	67.5
Water Bodies	56860	41	56676	41	-184	-0.3
Agriculture	1591	1.6	826	0.6	-765	-48.1

Institutional	1365	1.0	3816	2.8	2451	179.6
Industrial	2342	1.7	1581	1.6	-761	-32.5
Commercial	1477	1.1	5517	4.0	4040	273.5
Open Space/ Recreational	10425	7.6	8570	6.2	-1855	-17.8
Low Density Residential	21306	15.5	13317	9.7	-7989	-37.5
Med. Density Residential	10361	7.5	18958	13.8	8597	83
High Density Residential	5831	4.2	8475	6.0	2644	45.3
Total	137460	100	137460	100		

Table 5: 1984 and 2002 Land Cover/Use Change derived from Post-Classification Comparison



LEGEND

1 Forest
2 Bare Soil
3 Water Bodies
4 Agriculture
5 Institutional
6 Industrial
7 Commercial
8 Open Space
9 Low Density
10 Medium D.
11 High Density

Figure 4: Land Use/Land Cover change between 1984 and 2002.

Population Growth: Lagos is one of the fastest growing urban agglomerations in the world, with a population of 3.3 million people in 1975, 13.4 million in 2000 and an estimated 23.2 million by 2015 (UN, 1999). The average annual growth rate of Lagos from 1975 – 2000 was 5.6% which was the highest among the 10 most populous urban agglomerations, and the 3.7% for 2000 – 2015 also remains the highest compared to other urban agglomerations. Table 6 refers. There is a significant reduction in the estimated growth rate between 1975-2000 and 2000-2015 but Lagos still remains the highest when compared with other urban centres. Rapid population growth is one of the major factors responsible for the spatial growth and the associated pressure on different land use types leading to conversion of one land use class to another.

Urban Agglomeration	World Ranking (2000)	Population in Millions			Growth Rate (%)	
		1975	2000	2015	1975-2000	2000-2015
Tokyo	1	19.8	26.4	26.4	1.2	0.0
Mexico City	2	11.2	18.1	19.2	1.9	0.4
Bombay	3	6.9	18.1	26.1	3.9	2.4
Sao Paulo	4	10.0	17.8	20.4	2.3	0.9
New York	5	15.9	16.6	17.4	0.2	0.3
Lagos	6	3.3	13.4	23.2	5.6	3.7
Los Angeles	7	8.9	13.1	14.1	1.5	0.5
Shanghai	8	11.4	12.9	14.6	0.5	0.8
Calcutta	9	7.9	12.9	17.3	2.0	1.9
Buenos	10	9.1	12.6	14.1	1.3	0.7

Table 6: Urban Agglomeration Population and Growth Rate (UN, 1999)

CONCLUSION

It is not in doubt that the rapid population growth of metropolitan Lagos has had a great impact on the land use/cover in the area. The reduction in some of the land cover/uses underlines the dangerous trend that the pressure poised by population growth and the changing functionality of Lagos and her importance in the world economic globalisation will have on land use and land cover. For effective management and control of the land use/cover there is an urgent need for both state and federal governments to strengthen and train planners and related professionals with modern techniques such as GIS and RS to monitor and manage Lagos with good intelligence provided for effective policy formulation. Otherwise, the much desired safe, healthy, functional and aesthetically pleasing urban environment will become more unobtainable by the day.

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