LAND USE - LAND COVER CHANGES AND THEIR IMPLICATIONS IN NIGERIA USING GEOSPATIAL TECHNIQUE

BY

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DEPARTMENT OF GEOGRAPHY,
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APRIL, 2015

DECLARATION

I hereby declare that this dissertation has been written by me and that it is a record of my own research work. It has not been presented in any previous application for a higher degree. All borrowed ideas have been duly acknowledged by means of references and quotation marks.

	……	……
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CERTIFICATION

This dissertation entitled **"**Land Use - Land Cover Changes and their Implications in Nigeria using Geospatial technique" by AbubakarKengum meets the regulations governing the award of the degree of M.GIS of Ahmadu Bello University, Zaria and is approved for its contributions to scientific knowledge and literary presentation.

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DEDICATION

This dissertation is dedicated to ALMIGHTY ALLAH who out of the abundance of HIS mercies grants me knowledge, strength and ability to accomplish this task.

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ABSTRACT

The study assessed the land use and land cover changes over Nigeria between 2001 and 2009 and predicted what the scenario will be till the year 2020 when Nigeria is planning to be among the top 20 strong economies of the world. The study used Combined Terra and Aqua MODIS land level 3/level 4 yearly tiled products, MCD12Q1-level 3 yearly land cover type at the scale of 250m. This data was accessed from NASA website and processed using ArcGIS 9.3 software to establish the land use-land cover situations for 2001, 2005 and 2009 and subsequently the changes that have taken place between 2001 and 2009. There was continuing decrease in the waterbodies from 0.53% coverage in 2001 to 0.47% in 2005 which further decreased to 0.40% in 2009. This poses serious implications for agriculture in terms of food security for those using it for irrigation, water availability for different uses and infrastructural development in term of electricity where it is used for power generation. It also has a serious implication for survival and livelihoods on the communities that depend on aquaculture and irrigational farming. The future prediction could spell a serious calamity due to inundation and loss of small lakes and ponds considering the fact that the loss of the ecosystem constitutes severe degradation and increases the vulnerability of people to disaster especially those whose livelihoods are dependent on the wetlands. Furthermore, the research indicates rapid loss of natural resources especially forest and Savanna which have severe implications for livelihoods and vulnerabilities of communities and also for the environment. The General Savanna was being decimated at the rate of 4% while the forest of the study area was being decimated at the rate of about 9% per annum between 2001 and 2009. The loss of forest and grassland is an indication of disturbance and consistent perturbations created by pressure on the existing ecosystems leading to reduction in soil nutrients, decrease resilience and stability and loss of agricultural lands.

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CHAPTER ONE

INTRODUCTION

1.1: BACKGROUND TO THE STUDY

Land is the ultimate resource of the biosphere. Land, to the geographer-environmentalist, is a specific area of the earth surface with physical entity in terms of its topography and spatial nature (Ashaye,1987), and one of the characteristics of space that is widely recognized as significant for planning and management purposes (Anderson, Hardy, Roach, and Witmer,1976). In the ecological perspective, land comprises of at least five interacting components: terrain (soils, bedrock, and landforms), hydrology, climate, flora and fauna, and the relationship that exists among them which tend to vary geographically (Thie,Wilken and Rubec, 1986).

Land use-land cover (LULC) composition and land cover changes are important factors that affect ecosystem conditions and functions. These data are frequently used to generate landscape-based metrics and to assess landscape condition and monitor status and trends over a specified time interval (Jones, Ritters, Wickham, Tankersley, O'Neill, Chaloud, Smith& Neale, 1997). Land cover (LC) refers to the physical cover on the land (the layer of soils and biomass) including natural vegetation, crops and artificial constructions that cover the land surface (Anderson *et al.*, 1976; Campbell, 1996; Verburg, 2000).

Land use (LU) on the other hand refers to the actual use of the land which is the purpose for which man exploits the land cover (Campbell, 1996; Omojola, 1997).The use of satellite-based remote sensor data has been widely applied to provide a cost-effective means to develop LC coverage over large geographic regions such as Nigeria. Land use (LU) can also be defined as the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it. The United Nations Food and Agriculture Organization Water

Development Division explains that "Land use concerns the products and/or benefits obtained from use of the land as well as the land management actions (activities) carried out by humans to produce those products and benefits. Land use describes the use of the land by the people usually with emphasis on the functional role of land in economic activities (Campbell, 1996); and man's activities which are directly related to the land (Anderson, *et al.*, 1976).When man changes the activities on the land to another one it becomes land use change.

Land use-land cover (LULC) has become increasingly important as Nigeria plans to overcome the problems of haphazard, uncontrolled development, deteriorating environmental quality, loss of prime agricultural lands, destruction of important wetlands and loss of fish and wildlife habitat. One of the prime prerequisites for better use of land is information on existing land use - land cover patterns and changes in land use through time. Since land use-land cover change is not an event but a process, it can be understood and forecasted quite well before time. Knowledge of the present distribution and area of such agricultural, recreational and urban lands as well as information on their changing proportions is needed by legislators, planners, and local government official to determine better land use policy, to project transportation and utility demand, to identify future development pressure points and areas, and to implement effective plans for regional and national development. Current land use and land cover data are needed for equalization of tax assessment in many states. Land use-land cover data are also needed by the central government, regional and local agencies for water-resource inventory, flood control, water supply planning and waste-water treatment. Many local agencies need current comprehensive inventories of existing activities on public lands combined with the existing and changing uses of private lands to improve the management of public lands. Local agencies also need land use data to assess the environmental impact resulting from the development of energy

resources, to manage wildlife resources and minimize man- wildlife ecosystem conflicts, to make national summaries of land use patterns and changes for national policy formulation, and to prepare environmental impact statements and assess future impacts on environmental policy.

Remote sensing data has therefore been used in a number of classification schemes at local, regional and continental scales for assessing LULC status, change, transformation and even forecasting (Townshend, Justice, Li, Gurney and McManus, 1991). Many of these attempts were based on (1) similarity of reflected radiation spectra of various land cover types in relation to specific training sites or (2) temporal evolution of reflected radiation and its association to various phenological attributes of vegetation (Loveland, Merchant, Ohlen and Brown, 1991). Both approaches depend on statistical similarities to a predefined set of conditions based on observations or existing maps.

Land cover change refers to complete or partial replacement of one cover type by another. Land use change includes the modification of land cover types such as intensification of agricultural use, without changing its overall classification (Verburg, Chen, Soepboer and Veldkamp, 2000). Land use-Land cover change (LULCC) is a strong indicator of ecosystems disturbances and global change process especially in the tropics. It is probably the most significant regional anthropogenic and natural disturbance to the environment (Roberts, Batista, Pereira, Walker and Nelson, 1998). In essence, land use-land cover changes are products of prevailing interacting natural and anthropogenic processes and trade-offs among ecosystem services. LULCC is central to environmental processes, environmental change and environmental management through its influence on biodiversity, water budget, trace gas emissions, carbon cycling, livelihoods (Verburg *et al.*, 2000), and on a wide range of socio-economic and ecological processes (Desanker, Frost, Justice and Scholes, 1997) which on the aggregate affect global environmental

change and the biosphere. LULCC also plays important role in detecting emerging spatial patterns and the direction of land degradation, land fragmentation, decline of agricultural productivity, rural poverty and depopulation and environmentally-induced migration of people (Verburg *et al*., 2000).

The obtainment and updating of information about the current condition and the continuous dynamic changes of our earth's surface is a task where remote sensing and GIS technologies can best display their advantages. Land use – land cover (LULC) assessment is one of the most important parameters to meaningfully plan for land resources management.

LULC inventories are assuming increasing importance in various resource sectors like agricultural planning, settlements surveys, environmental studies and operational planning based on agro-climatic zones. The knowledge of spatial land cover information is essential for proper management, planning and monitoring of natural resources (Zhu, 1997). Satellite remote sensing imagery is a viable source of gathering quality land cover information at local, regional and global scales (Csaplovics, 1998; Foody, 2002).

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh 1989). Digital change detection has been divided into two major groups. This involves the use of multi-temporal data sets to discriminate areas of land cover change between dates of imaging (Lillesand and Kiefer, 1987). LULCC research of this type is usually 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 is often 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 and Elvidge, 1998). In such research, land cover change is detected as a

change in land cover label between selected image dates. It is based on independent true land cover class classification, which is achieved by supervised classification.

LULCC leads to unsustainable land use and unsustainable land use is driving land degradation. Land degradation is a process in which the value of the biophysical environment is affected by one or more combination of human-induced processes acting upon the land (Conacher and Conacher, 1995). Johnson *et al* (1997) also viewed land degradation as any change or disturbance to the land perceived to be deleterious or undesirable. Land degradation ranks with climate change and loss of biodiversity as a threat to habitat, economy and society. Land degradation in the form of soil erosion, nutrient depletion, water scarcity, salinity and disruption of biological cycles is a fundamental and persistent problem.

Land degradation diminishes productivity, biodiversity and other ecosystem services, and contributes to climate change. It is a global development issue – degradation and poverty are mutually reinforcing – but is politically invisible and largely ignored. The damage can be arrested, even reversed, but this requires concerted, long-term investment across sectors, by all levels of government and by individual land users, research to provide reliable data.

According to Stockings and Murnaghan (2000), there are four main ways of looking at land degradation and its impact on the environment around it: The first being a temporary or permanent decline in the productive capacity of the land which can be seen through a loss of biomass, loss of actual productivity or in potential productivity, or a loss or change in vegetative cover and soil nutrients. Secondly, there is a decline in the lands "usefulness" as a result of loss or reduction in the lands capacity to provide resources for human livelihoods. This can be measured from a base line of past land use. The third is a loss of biodiversity which is a loss of range of species or ecosystem complexity as a decline in the environmental quality. Lastly there

is a shifting ecological risk that causes increased vulnerability of the environment or of the people to destruction or crisis. This is measured through a base line in the form of pre-existing risk of crisis or destruction.

Forest ecosystem services are threatened by increasing human demands. Exploitation of forests has been at the expense of biodiversity and natural regulation of water and climate, and has undermined subsistence support and cultural values for some peoples. These issues are increasingly acknowledged, prompting arrange of technical responses, legislation and non-binding agreements (such as the United Nations Forum on Forests) to conserve forests, and financial mechanisms to support them.

1.2: STATEMENT OF THE RESEARCH PROBLEM

Land cover information constitutes key environmental information for many scientific, resource management and policy purposes, as well as for a range of human activities. Hence it has become a major focus for the International Geosphere-Biosphere Program (IGBP) and the International Human Dimensions Program (IHDP) at global and regional levels. Land cover information is currently scarce for Nigeria as a country.

Nigeria is currently undergoing rapid and wide-range changes in its land due to climate change, the practice of slash-and-burn or shifting cultivation and rapid infrastructural development. The study of these changes necessitates the use of remote sensing because it provides data at synoptic scales and facilitates the discerning of large-scale ecosystem patterns. Although remote sensing technology has been used for mapping in Nigeria at various levels for some time now, there has been no attempt to assess the changes for the country as a whole except on two occasions when the country was merely mapped and the changes not analyzed. In view of the above, a qualitative approach that necessitated the use of historical series of MODIS data to produce land cover maps

of Nigeria, to evaluate the relative changes in land cover from 2001 to 2009 and also to predict the future scenario is highly necessary.

Several studies have been carried out in Nigeria at local or smaller scale such as Land use-land cover change detection in Metropolitan Lagos (Nigeria): 1984-2002 by Adepoju *et al* (2006). In the study, 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 of2002 to improve classification accuracies and provided more accurate maps for land use/cover change and analysis. It 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 have been legally or illegally converted to other land uses within and outside the metropolis.

Ifeoluwa *et al.,* (2011) studied Land use – land cover change detection and associated climatic responses in Akure, Nigeria. They used multi temporal remote sensing data and GIS technique to detect the land use-land cover changes

Fabiyi (2006) also investigated urban land use change analysis of a traditional city of Ibadan using Remote Sensing. The author used the techniques of remote sensing to evaluate land use land cover changes and a projection into 2023 was done using Markov chain model. It was observed that there are considerable dynamic changes in Ibadan metropolis and the major contributor to changes is the vegetal cover, low density and sprawl development.

Zubair (2006) studied change detection in land use and land cover using remote sensing data and GIS in Ilorin and its environs, Kwara State). The author used Landsat satellite images of Kwara State for three Epochs; 1972, 1986 and 2001 for the analysis and was able to identify the land use and land cover changes and the change rate.

Hof and Malami (2006) also studied integrated land use and land cover assessment in grazing reserves in North-West Nigeria using multi-sensor data for the period 1965 to 2002. They were able to map the natural vegetation lands in 1999 from a land cover classification of Landsat ETM+ data. This land cover information was complemented by ground-based quantitative information on plant productivity of grasslands and croplands.

Areola (1977) carried out a study on land types and terrain conditions in Lagos, in which he demonstrated the usefulness of aerial photo interpretation in the identification or mapping of land types. The study used Visual interpretation of infrared black and white photography which was flown at about 1970 over the coastal areas of Lagos between the west of Ikorodu and the Yewa River on the border with Republic of Benin. In the study, the major land types were morphologically determined, while the sub-divisions within each unit were based on differences in vegetation.

Omojola (1997) carried out a land use and land cover inventory and change assessment in a semi-arid region of Nigeria using remote sensing and GIS techniques. The author used aerial photographs for 1962 and 1977 and Landsat MSS and SPOT XS images for 1986 were also used. In the study, the author used the visual (manual) method of remote sensing analysis in the interpretation and was able to derive the land use and land cover attributes of the study area.

To the best of the author's knowledge, no study has been carried out to assess the changes over the whole of Nigeria in recent years. After searching several literatures, it was discovered that Abbas (2009) did an overview of land cover changes in Nigeria, 1975 – 2005 using Landsat data of 1975 and SPOT XS data of 2005. However, the author's work was limited in that he used two dates at such a long period of thirty-five years.

Two other studies were done at different times to map the whole study area without looking at the changes over time. These studies however are full of deficiencies as explained hereafter and they are not recent studies meaning several events have happened after they were done.

The studies are NIRAD (Nigeria Radar) project commissioned in 1976 which was completed in 1978. It was based on imagery acquired through the Side Looking Airborne Radar (SLAR) to produce the first vegetation and land-use maps covering the whole landmass of Nigeria. According to FORMECU (Forestry Management and Coordinating Unit) of 1976, the NIRAD (Nigeria Radar) Project constitutes the first and only nation-wide database on the Nigeria environment as at 1976. The primary thematic purpose of the project was the inventory and mapping of vegetation types in Nigeria as well as the demarcation of forest reserves boundaries (Adeniyi, 1984). A visual image interpretation method was used and the first national land use/land cover information of any appreciable consistency was produced. However, some shortcomings of the study have been identified by Adeniyi (1984) and FORMECU (1996). First, the classification scheme developed in the study is largely related to vegetation (a land cover). Thus the vegetation and land use classes as shown on the 1976/78 produced maps do not discriminate between land use and natural vegetation cover. So it was found that many polygons contain inclusions of other classes to varying degrees.

Secondly, the NIRAD classification scheme did not include human settlements' as a cover category. Hence the interpreters must have treated the interpretation and delineation of settlement boundaries as residual matters. Also, the scheme is besotted with obvious errors associated with the calculated area of the Country and States and consequent variations among land use, land cover categories. Again, the polygon boundary on the 1976/78 vegetation and land use maps appears to have been derived in part from observations (that is, Fieldwork) despite

what the imagery suggested that the boundary classes should be. And lastly, the NIRAD Project may be regarded as suitable for its ad hoc purpose but not suitable for a national land use classification scheme. However, despite the identified shortcomings, the NIRAD Project provided the first national land use/land cover information of any appreciable consistency (Adeniyi, 1984).

The second national database on Nigeria land use and vegetation was provided by the study carried out by Forestry Management and Coordinating Unit (FORMECU) in 1996 and this was part of the national Environmental Management Project (EMP).

The objective of the Project was to assess and evaluate the available data; identify data gaps; develop programs for the production of current and reliable information on vegetation changes and degradation over time; develop and implement a GIS database for Nigeria.

To achieve the objectives the Project involved three broad tasks: (i) the establishment of historic statistical record on the status of vegetation and land use (1976/78) which was used as baseline information: (ii) the establishment of current information on vegetation and land use (1993/95), and (iii) the analysis of trends (extent and intensity of the changes in vegetation and land use)over an 18 years period. These tasks were undertaken using remote sensing data such as Landsat Multispectral (MSS- 1976/78), SPOT Multispectral (1993/1995), Landsat Thematic Mapper (TM-1993), ERS-1 Radar-1994/1995), JERS-1 Radar-1995), and National Oceanic Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR-1978, 1986, 19909, 1995). Some of the major shortcomings of the FORMECU Project include the fact that the scheme was also more of land cover than land use analysis. Second, the little coverage of the land use aspect was limited to agricultural land use. For instance, urban areas were inputted as point data with associated text. Third, the classification scheme was also limited

to the secondary level. Fourth, because of the extent it was more of a generalized study with the intention of correlating the land use in terms of ecological zones in Nigeria. Fifth, the final map products were at a scale of 1:250,000, which were too small for meaningful analysis. Sixth, visual interpretation was utilized. The implication of such is that two individuals may produce different results in addition to being time consuming and expensive. Finally, the impact of human-induced change on water vegetation and soils was on a qualitative basis and so the FORMECU Project recommended for future quantitative land use/land cover change analysis.

As a result of these obvious shortcomings, this study therefore seeks to investigate the recent LULC and changes in Nigeria with a view for effective and efficient management of the land of the country. Thus the need to put in place short and long term disaster preparedness and environmental management strategies which require geospatial data and information gives credence to this study. This is very necessary in view of the fact that in Nigeria, there is the need for articulate disaster mitigation program (Oladipupo, 1990). Lastly, understanding land use-land cover change and land management will help the country balance food production and at the same time preserving her natural resources.

Significant advances have been made in developing techniques and strategies for using geo-spatial data as ancillary information to improve the result of the land-cover classification.

The ever-growing population of the country places increasing demands on ecosystems. According to the Millennium Ecosystems Assessment report, (MEA, 2005), ecosystems degradation tends to harm rural populations directly more than urban population and has its most direct and severe impact on the poor. This is because the poor rural communities depend entirely on resources which are tied to the land for their livelihoods and are therefore highly vulnerable to LULC changes.

Before the 19th Century, land was used for hunting, gathering, herding, and shifting cultivation but rapid and dramatic changes occurred afterwards with cropland expansion driven by population growth and demand for export crops. Population also increased as a result of improved public health provision while railroads and other major transport routes were in place, opening up inaccessible areas. Cropland continues to expand at the expense of savannas, wetlands, woodlands, and forests all leading to Land Cover modification has resulted in significant declines in vegetation density and biodiversity

These issues mentioned above are fundamental problems that should be of concern to geographers, environmentalists, and policy makers. This is even more disturbing as clashes occurred frequently between nomads and farmers as a result of changes in LULC. High rate of land degradation and recent studies have suggested strong linkages between land degradation, livelihood, poverty, human well-being, and vulnerability to other hazards (EEA, 2003; Okali, 2004).

1.3: RESEARCH QUESTIONS

1. What are the past and present patterns of land use-land cover in the study area?
2. What are the extent and rate of change in land use-land cover patterns in the study area?
3. What will be the future scenario of the land use – land cover over Nigeria?
4. What are the implications of the land use – land cover changes over Nigeria?

1.4: STUDY AIM AND OBJECTIVES.

The aim of the study is to assess land use and land cover situation in Nigeria from 2001 to 2009 with a view to knowing the changes that have taken place and predict the future scenario. This aim will be achieved through the following specific objectives. These are to:

i. classify land use and land cover patterns of the study area for 2001, 2005 and 2009 using MODIS satellite imageries.

ii. analyze land use and land cover changes for the area from the multi-date satellite data (magnitude change, percentage change, annual rate of change; and LULC transformation)

iii. predict the LULC change pattern up to 2020.

iv.. examine the implications of this LULCC for natural resources management and disaster management in the study area.

1.5: THE SCOPE OF THE STUDY

The study covered only land use-land cover status of the study area from 2001 to 2009 with 2001, 2005 and 2009 as the specific dates, land use-land cover changes between the years, causes of the LULCC, implications of the LULC and future scenario in the study area. The study used MODIS satellite data of 2001, 2005 and 2009 only. The study covered the whole of Nigeria.

1.6. JUSTIFICATION FOR THE STUDY

Nigeria's environment is under increasing threat from natural hazards, such as drought, and human activities. There are already certain ominous problems with the environment and visible scars associated with the destruction of the natural resource base (land, water and air) upon which all life depends are being noted. The country's large population (about 140 million in 2006) and its rapid growth rate (about 3 per cent) (FRN, 2007) are contributing to the process of environmental degradation. Land is by far the most important resource necessary for subsistence. Yet much of Nigeria's arable land is being sapped insidiously of its productive potential through overuse and inappropriate technologies. Rapid deforestation, resulting from multiple uses of forest resources for human survival, is a major contributing factor to land degradation. The end

result of deforestation and other agricultural activities, including intensive grazing, over-plowing and over-cultivation, is severe land degradation, usually referred to as desertification, particularly in the northern part of the country.

Apart from the present pockets of erosion sites and permanent inundation of some lands in the study area, reports on cases of land transformation and alteration of the landscape in the study area suggest that land degradation may in the near future be recorded in areas not presently affected (Fasona, 2007). If the experience in the interior Niger delta is anything to learn from then the need to put in place short and long term disaster preparedness and environmental management strategies which require geospatial data and information gives credence to this study. This is very necessary in view of the fact that in the study area, there has been no articulate disaster mitigation program (Oladipo, 1990). A better understanding of the driving forces of land cover change and how they interact is needed to improve land use theory and help the government in meeting up with the vision 2020 environmental plans. This understanding will provide a way to specify the driven forces that most likely result in significant land changes or are relatively unimportant. Human activities have become the dominant force reshaping the surface of the earth where cropland abandonment occurs when the agricultural system is affected by external drivers or because of its own dynamics toward extensification or intensification, which is usually driven by economic conditions or the social environment (Wiken et al., 1981). As a result the study is also needed to plan for the food security and avoid several other factors of environmental hazards.

1.7. DEFINITION OF TECHNICAL TERMS

Land: a specific area of the of the earth surface, a finite resource, a physical entity in terms of its soils, minerals, water and biota.

Land cover: the physical and biological structure that the land supports. It refers to the physical characteristic of earth's surface, captured in the distribution of vegetation, water, desert, ice, and other physical features of the land, including those created solely by human activities such as mine exposures and settlement.

Land-use: is the intended employment of and management strategy placed on land cover type by human agents, or land managers. The use to which land is put that places emphasis upon social, economic and aesthetic functions. It is in itself abstract and manifested in the cover on the land.

Land transformation: the dynamics of process of transition from one land cover type to another which is driven by natural forces and or land use change decisions

Environmental change: changes in the constituents of biophysical life support systems including land, water resources, soil and the atmosphere resulting from natural and anthropogenic alterations.

Ecosystem: a dynamic complex of plants, animal and micro organism communities and the non living environment interacting as a functional unit. Humans are also integral part of an ecosystem.

Ecosystem services: benefits people obtain from ecosystems which include provisioning, regulating, supporting, and cultural services.

Perturbation: strong disturbance in ecosystem equilibrium resulting from breakdown in energy flow systems.

Driving factors: the processes and forces leading to changes in land use-land cover or ecosystem changes

Carrying capacity: the threshold of natural and human population which an ecological area or ecosystem can efficiently support before diminishing return sets in.

Hazards: a potential event that can cause loss of life, or damage to property, social or economic disruption or environmental degradation.

Vulnerability: a multi-scale coupled process of environmental and social complexes of threats to the basis of human existence including habitation, social organization, livelihood, land use, and food security.

Disaster: a serious disruption of the functioning of a community which may exceed the capacity of the community to contain on their own. It may be triggered by nature and or interaction of people and nature.

Land use-land cover change: This is the change to both the land uses and the land cover over time.

Land degradation: Land which due to natural processes or human activity is no longer able to sustain properly an economic function and/or the original natural ecological function

CHAPTER TWO

CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

2.1. CONCEPTUAL FRAMEWORK

2.1.1. Introduction

Spatially-explicit models of the social and environmental causes and consequences of LULCC is made possible by GIS and other computer-based techniques which can define and test relationships between environmental and social variables using a combination of existing data (census data, soil maps, LULC maps), observations on the ground (ecological measurements, household surveys and interviews with land managers) and data from remote sensing. These spatial models of LULCC drivers and their impacts can be used to establish cause and effects in LULCC observed in the past and are also extremely useful tools to land managers and policymakers, offering forecasts of future land use changes and their effects. Models of LULCC dependence on political, economic, environmental and other changes can then be used to explore the impacts of policy decisions and other factors using scenario analysis and other computer modeling techniques, guiding policymakers and land managers toward sustainable land management decisions.

The task of managing natural resources of the earth is daily growing in complexities. This is due partly to increasing uncertainties in the natural-physical systems, as well as increasing interference of man with these systems. The goal of sustainability science is the monitoring and scientific understanding of natural physical systems and processes and their human dimensions. Trans-disciplinary research provides methodological tools for bringing into perspectives human contributions to natural and spatial processes and the impacts of the function of these processes on human activities and well being in both the short and long run time scales.

Natural resources development and management is of tremendous concern to Geography. The utility derivable from resource use and the deleterious effects and consequences of resource

abuse are important for continued existence of man and survival of the natural ecosystems. Degradation process as implication of land use land cover change sets in when the capacity of a natural ecosystem to renew itself is constrained by frequent disturbance and/or perturbations. This issue of land degradation which is the major implication of land use land cover threatens human survival and livelihoods has been and still being examined by Geographers and resources analysts at different spatial and temporal scales using innovative multidisciplinary frameworks and approaches. This chapter therefore reviews some relevant concepts in coupling the environment and natural resource use with ecosystems health and human well being.

2.1.2. Land use - land cover change

Land use and land cover are distinct yet closely linked characteristics of the Earth's surface. The use to which we put land could be grazing, agriculture, urban development, logging, and mining among many others. While land cover categories could be cropland, forest, wetland, pasture, roads, urban areas among others. The term land cover originally referred to the kind and state of vegetation, such as forest or grass cover but it has broadened in subsequent usage to include other things such as human structures, soil type, biodiversity, surface and ground water (MEA, 2005).

Land use affects land cover and changes in land cover affect land use. A change in either however is not necessarily the product of the other. Changes in land cover by land use do not necessarily imply degradation of the land. However, many shifting land use patterns driven by a variety of social causes, result in land cover changes that affects biodiversity, water and radiation budgets, trace gas emissions and other processes that come together to affect climate and biosphere (Saha, 1996).

Land cover can be altered by forces other than anthropogenic. Natural events such as weather, flooding, fire, climate fluctuations, and ecosystem dynamics may also initiate modifications upon land cover. Globally, land cover today is altered principally by direct human use: by agriculture and livestock raising, forest harvesting and management and urban and suburban construction and development. There are also incidental impacts on land cover from other human activities such as forest and lakes damaged by acid rain from fossil fuel combustion and crops near cities damaged by tropospheric ozone resulting from automobile exhaust (MEA, 2005).

Maps and measurements of land cover can be derived directly from remotely sensed data by a variety of analytical procedures, including statistical methods and human interpretation. Maps of land use and land cover (LULC) are produced from remotely sensed data by inferring land use from land cover (e.g., urban = barren, agriculture = herbaceous vegetation). Conventional LULC maps are categorical, dividing land into categories of land use and land cover (thematic mapping; land classification), while recent techniques allow the mapping of LULC or other properties of land as continuous variables or as fractional cover of the land by different LULC categories, such as tree canopy, herbaceous vegetation, and barren (continuous fields mapping). Both types of LULC datasets may be compared between time periods using Geographic Information Systems (GIS) to map and measure LULCC at local, regional, and global scales.

2.1.3. Resource management

Why spatial distributions are structured the way they are is the foundation of geographic science (Abler, *et al.*, 1977). Spatial processes (both natural and human) on Earth are governed by the triscalar matrix of process, structure and stage (Gregory, 1985). This matrix answers the how (process), what (structure) and when (time/stage) questions which characterized all elements on

the earth surface. The field of Geography has indeed gone full cycle with the return of place or location as the key for managing the resources of the earth. According to Berry and Ripple (1994), the need for sustainable management of earth resources has necessitated a paradigm shift from the traditional descriptive approach "*what is where*" to a proactive and prescriptive '*so what*' approach, which takes into consideration not only the location, but also the function and management of such a structure.

Our environment is a complex web of interconnectivities (Gregory, 1985). These interconnectivities provided different challenges which overwhelm a single methodological approach. Hence the systems approach to problems solving using tunas-disciplinary methodologies fits hand in glove to geographic research. Although interdisciplinary approach to researches in geography used to be an exception, the increased dimensions being exhibited by environmental problems – ecosystems degradation and change, climate change, atmospheric pollution, pollution of the ocean and water bodies, etc) have increased the need for understanding the earth as an integrated system.

Development of theories which are mega construct (Abler, *et al.,* 1977) contribute both to scholarly advancement of a discipline and also in solving pressing disparate issues and problems. For resource management as a discipline and risk and vulnerability assessments as a research interest area, a clear theoretical orientation guided by same set of laws and theories is yet to fully evolve (Mitchel, 1989). The reasons for this have been adduced by Mitchel (1989) to include the fact that the discipline is still young and most researches in resource management are normative and empirical focusing on particular problem in specific localities.

Furthermore, there is also the inability to develop or isolate universally operative critical variables that contribute to cause–effect relationships which could make findings comparable. In

few studies where variables were suggested by experience, their measurement possesses a barrier (Mitchel, 1989). Robust laws/theories in resource analysis may actually take some time to emerge. This is because the methods of assessments and analysis of resources are basically trans-disciplinary. Hence, clear theoretical orientations for resource assessments may not come until the relationship of resource management as a field of study with allied disciplines including biogeography, landscape ecology, environmental management and modeling, geology, soil science, etc that equally concentrate on individual biophysical processes of the environment becomes more knitted. Working towards this new trans-disciplinary integration which is the goal of sustainability science is part of the thrust of this study.

2.1.4. Ecological concept

Geography has been a beneficiary of the concourse of various disciplines in the natural, physical and social sciences. Some of the laws, theories and models used in geographic studies actually originated from these allied sciences. Land use and ecosystems are both complex and dynamic and operate at the interface of multiple social and ecological systems. The similarity between land use, social and ecological systems thus allows us to use concepts that have proven to be useful for studying and simulating ecological and social systems in our analysis of land use and cover change (Verburg, *et al* 2000).

The concept of connectivity or spatial autocorrelation which originated from the field of landscape ecology is very relevant here for explanation of spatial behavior and dimensions of the drivers of Land use-land cover change. Connectivity suggests that locations at certain distance are related to each other (Gregory, 1985). It thus portrays the trigger- effect relationship in land use, land transformation and land degradation. Natural ecosystems have large correspondences in structure, function and change with land use systems and the complex social drivers of changes

in land use (Verburg, *et al*, 2000). Thus, by implication, increases land use land cover changes and reinforce occupational shift by local dwellers which leads to opening-up of new lands for survival.

The hierarchy theory is a concept which suggests that higher level processes constrain lower level processes, whereas the higher level processes might emerge from lower level dynamics (Verburg, *et al*, 2000). The hierarchy theory is useful for explanations of the nexus between the proximate drivers and the underlying driving forces of land use and cover change, the productivity of land and the implications of land use land cover change (land degradation). The synergistic interaction between the proximate and underlying factors defines the pathways and trajectories of land use change which may lead to land degradation. A degraded land that is perpetually exposed to the forces of land degradation may find it difficult to return to its original state without artificial restoration.

The concepts of stability and resilience will also be borrowed from the field of ecology and social sciences (Verburg, *et al*, 2000) to explain certain properties and behavior of land use and ecosystems changes. Resilience refers to ability of an ecosystem to absorb or withstand perturbation. In this case, the ability of land to respond to forces of land use change before it becomes degraded. Stability refers to ability of an ecosystem to regain original form after perturbation. Resilience and stability combine to dictate the rate and time at which change in land use will result into permanent change in landscape structure. Both land use changes and ability of ecosystem to withstand perturbations are function of the complex economic, political, social and institutional systems on ground which forms the complex underlying drivers of change. Various sophisticated spatial models and techniques have been developed based on these concepts especially by landscape ecologists to examine the relationship between structure and

function of small and large ecosystems alike. These models and techniques are all based on the principle of spatial relationships, the root of which is predominantly geographic whether implicitly or explicitly (Demers, 2000).

The concept of ecosystem health which is recent in the life sciences is also relevant for explanations of land use and cover change. The concept refers both to the critical linkages between human activity, ecological change and human health, and as well to the health of the ecosystem itself. Although this study did not treat 'human health' as related to diseases and physiological functioning of individuals, it nevertheless delve into the areas of human activity, livelihoods and human vulnerability to hazards which are aggregate components of human well being. The transformation of good lands into degraded lands which is an interest in this study is a measure of the health of an ecosystem.

Humanity depends on the services provided by the ecosystems to survive. A breakdown in the provision of these services could spell disaster for man. Land evaluation is a long established method for assessing land capability. This is a means of estimation of the potential of land for particular kinds of use and the resources it potentially offers. Hence, land use land cover allocation without the necessary precaution and monitoring framework leads to land degradation and resource loss. The location, distribution and extent variables of land resources are very critical to provide a diagnostic link between spatial attributes and other non spatial attributes including variables that may negatively impact the distribution and extent of the resource in question.

2.1.5. The Driving forces of land use-land cover changes

Assessing the driving forces behind LULCC is necessary if past patterns are to be explained and used in forecasting future patterns. Driving forces on LULCC can include almost any factor that

influences human activity, including local culture (food preference, etc.), economics (demand for specific products, financial incentives), environmental conditions (soil quality, terrain, moisture availability), land policy and development programs (agricultural programs, road building, zoning), and feedbacks between these factors, including past human activity on the land (land degradation, irrigation and roads). Investigation of these drivers of LULCC requires a full range of methods from the natural and social sciences, including climatology, soil science, ecology, environmental science, hydrology, geography, information systems, computer science, anthropology, sociology, and policy science.

Although landscapes normally undergo certain transformation processes that include some form of natural degradation, these processes are usually compensated for and counterbalanced by nature's in-built recovery ability. Net degradation occurs whenever the degradation process significantly exceeds nature's restorative capacity. This is the case when degradation process is accelerated by human activities and nature's restorative capacity is often outstripped. The result is degradation disaster which further increases the vulnerability of the people to other forms of hazards. The onset, spread and intensity of land degradation is a function of the complex interplay between the composition of the physical or base elements (soil, terrain, geology, hydrology and geomorphology), ecology, and human activities (land use). The action of natural agents such as rainfall, temperature, etc could trigger a form of degradation on the base elements. Nature induced degradation tends to progress at very slow rate because nature has a way of countervailing negative effects within the natural physical systems.

The most obvious forms of degradation which pose serious threat to people and environment are driven directly or indirectly by the actions of man. Degradation thus sets in at the intersection of

the complex interactions between the physical factors elements, the biological factor elements and the activities of man on the base elements of the biosphere.

The land provides social economic functions that include support to human settlements. It also provides raw materials including water, and it protects and preserve cultural heritage. Socio-economic and socio-cultural forces driving human activities are the greatest forces producing changes (land cover and ecosystems changes) in the environment. An assessment of the state of the environment could be carried out which will indicate the level of impacts (degradation) of these changes. The response of the society to the current situation (policies, regulations to combat impacts and reduce pressure) will dictate the level of the driving force. If intervention strategies and policies are put in place, the tempo of the driving forces and the volume of pressures exerted on the environment is reduced, otherwise, the situation continues until the carrying capacity of the environment is outstretched when disaster sets in.

Land degradation results in loss or deterioration in functions or inability of land to perform these functions. Some of the losses incurred by the land through degradation can be considered irreversible when related to the time needed for the land to renew or regenerate itself. The action of the composite direct and indirect drivers of change causes land degradation which lead to breakdown in the functions and services they provide. This has direct negative impact on human well being by increasing poverty and vulnerability to other hazards. On the other hand, changes in the indirect (underlying) drivers of change such as population, technology, and lifestyle can lead to changes in the direct (proximate) drivers which increase pressure on ecosystems and their services which may lead to ecosystems degradation and thereby affect human well being. The linkages among the human causes, land use and land cover is illustrated in figure 2.1.

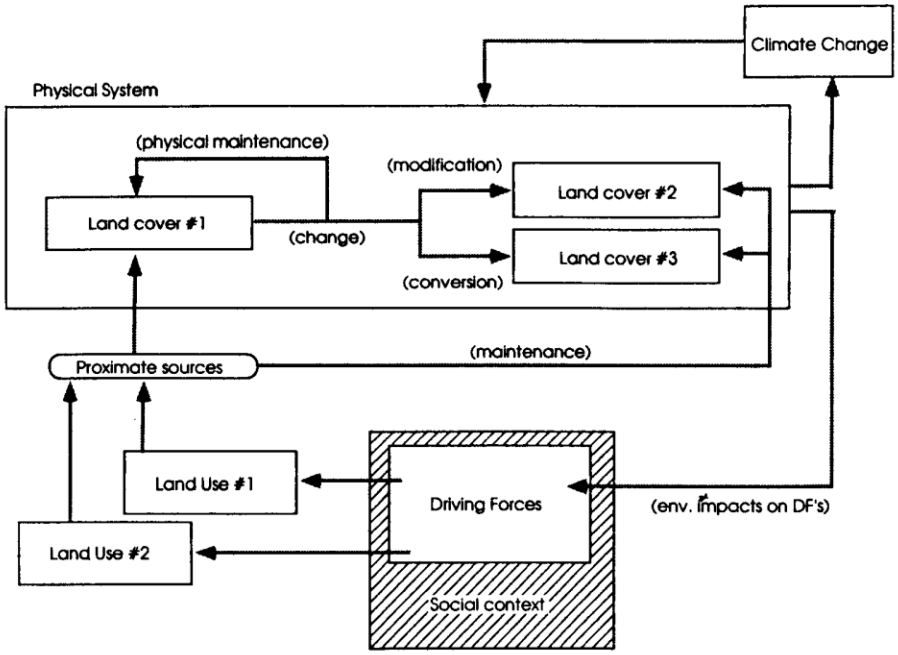


Fig. 2 Linkages among human causes and land use and cover

2.2. Literature review

2.2.1. Background

Humans have been altering land cover since pre-history through the use of fire to flush out game and, since the advent of plant and animal domestication, through the clearance of patches of land for agriculture and livestock. In the past two centuries the impact of human activities on the land has grown enormously, altering entire landscapes, and ultimately impacting the earth's nutrient and hydrological cycles as well as climate. Land-use and land-cover changes are local and place specific, occurring incrementally in ways that often escape our attention. Yet, collectively, they add up to one of the most important facets of global environmental change.

Change in land use and land cover leading to environmental change and natural resource degradation has several dimensions. Different aspects and impacts of environmental change

process have been investigated at different spatial scales by scientists working in different disciplines. However, the meso-scale observation is preferred by geographers and natural resources scientists. A key reason for this is that it bridges the gap between generating too unwieldy data form local spatial scale and too generalized data from macro scale studies. This also explains why geographers and natural resource scientists were the most enthusiastic about the advent of environmental remote sensing.

The scientific research community called for substantive study of land-use and land-cover changes during the 1972 Stockholm Conference on the Human Environment, and again 20 years later at the 1992 United Nations Conference on Environment and Development (UNCED). In the past decade, a major international initiative to study land-use and land-cover change, the LUCC Project, has gained great momentum in its efforts to understand driving forces of land-use change (mainly through comparative case studies), develop diagnostic models of cover change, and produce regionally and globally integrated models (Lambin *et al.*, 1999). The strong interest in land use and land cover results from their direct relationship to many of the planet's fundamental characteristics and processes, including the productivity of the land, the diversity of plant and animal species, and the biochemical and hydrological cycles.

Land cover is continually moulded and transformed by land-use changes such as, for example, when a forest is converted to pasture or crop land. Land-use change is the *proximate cause* of land-cover change. The underlying driving forces, however, can be traced to a host of economic, technological, institutional, cultural and demographic factors. In fact, humans are increasingly being recognized as a dominant force in global environmental change (Lambin *et al.*,1999). Changes in land use are likely the most ancient of all human-induced environmental impacts, and the first to obtain a magnitude to warrant the title "global." For example, land-cover change,

especially the conversion of forested areas into other uses, has been identified as a contributing factor to climate change, accounting for 33 percent of the increase in atmospheric CO2 since 1850, and a leading factor in the loss of biological diversity. Human uses of land usurp as much as 40 percent of the net primary productivity of the earth, and changes in these may alter ecosystem services locally and globally (Lambin, *et al,*. 1999).

Equally important is the impact of these regional and global changes on society. By altering ecosystem services, changes in land use and cover affect the ability of biological systems to support human needs, and such changes also determine, in part, the vulnerability of places and people to climatic, economic or socio-political perturbations. Take, for example, conversion of forested areas to crop lands, pasture or human settlements.

Deforestation can result in the loss of biodiversity, especially in the tropics; biodiversity loss results in declines in ecosystem integrity, and also genetic losses that may impede future scientific advances in agriculture and pharmaceutics. Deforestation can also impact hydrological processes, leading to localized declines in rainfall, and more rapid runoff of precipitation, causing flooding and soil erosion. And finally, scientists have come to a better understanding of the role that forests play in the carbon cycle, and how forest burning in certain parts of the world is important contributors to greenhouse gases that contribute to climate change. Clearly, all of these changes impact society. This dual role of humanity in both contributing to the causes and experiencing the effects of global change processes emphasizes the need for better understanding of the interaction between humans and the terrestrial environment. This need becomes more imperative as changes in land use become more rapid. Understanding the driving forces behind land-use changes and developing models to simulate these changes are essential to predicting the effects of global environmental change (Veldkamp *et al.*, 2001).

A major reason for researching historical land-use and land-cover change is that by understanding the past, we can better understand future trajectories. Land-use changes such as urbanization tend to radiate out from existing areas of the same class, and many models take advantage of this characteristic to make predictions of future change (Briassoulis 1999). The most significant historical change in land cover has been the expansion of agricultural lands. Today close to a third of the earth's land surface is devoted to pastures or cropland, which amounts to approximately one-half of all lands suitable for agriculture. Since the dawn of plant domestication the progression of cropland was relatively slow. The past century witnessed over half of the worldwide increase in agricultural lands, and in the developing world half the land cover conversion occurred in just the past 50 years (PRB, 2003).

Natural resources are classified into the replaceable and irreplaceable groups. The replaceable group which is important for abundant life on earth consists of the renewable and non renewable subgroups. The renewable natural resources can theoretically last forever and they have been described as the greatest heritage of mankind (Rao, 1990), the real wealth of the nation, and the only sound basis on which to build hope for future prosperity on earth. The renewable resources work as both the sources and sinks for the different types of energy that provide abundant life on the earth. When the normal equilibrium of the source and sink interaction is altered, it results into pollution and degradation which poses serious threat to human well being. The effects of such degradation may sometimes be instantaneous with dramatic consequences, or/and at other times, may go unnoticed even for many years.

The world's vegetation is both a product and an important component of the world's biodiversity. Vegetal cover can be described as the renewable green gold (Odeyemi, 1998) and the base on which the long term sustainability of life on earth anchors. It is the single source of

primary biological production that sustains the human population and animal species. Vegetal cover performs the task of maintaining essential ecological processes, preserving genetic diversity and sustaining development of ecosystems. Biological productivity from plants within the local environment does not only maintain a local ecosystem, but has far reaching regional and global importance. This probably explains why Roberts, *et al* (1998) describe land cover change as the most significant regional anthropogenic disturbance to the environment.

Verburg *et al* (2000) have described land cover change as complete (or partial) replacement of one cover type by another. Land cover change is driven by both natural processes (including climate change) and most importantly by human actions. Human actions that drive land cover change include human land use decisions which are in turn driven by combination of complex underlying drivers (beyond immediate control) and proximate drivers (which could be the result or end product of the underlying drivers). In synthesizing the drivers of land use and land cover change, Lebel and Steffen, (1998); and Geist and Lambin, (2002) agreed that the proximate causes may be natural or human activities or immediate actions at local level while the underlying driving forces are fundamental social process. The proximate (on-site) drivers may include climatic factors (micro climate, oceanic processes and coastal zone influence), land biophysical attributes (soil, geology, and hydrology); and human activities including agriculture, lumbering, as well as dredging and constructions (for oil, transportation, manufacturing, etc), among others.

The underlying drivers include tenure regimes, technological change, international financial assistance and pressure for structural adjustment, demographic and economic changes (urbanization, transport infrastructure and development), globalization of markets and economies, agricultural changes, economic policy and changes (industrialization, changing from

agriculture to petroleum driven economy), social changes (family size, labor, wages, consumption styles and patterns,) political/administrative framework (land use policies, coastal zone management policies), among others, all of which have remote and yet powerful influence on land transportation. The underlying factors may act on or accelerate the proximate drivers of change.

Land use and land cover change are central to environmental processes, environmental change and environmental management through its influence on biodiversity, water budget, radiation budget, trace gas emissions, carbon cycling, livelihoods (Verburg, *et al* 2000), and a wide range of socio-economic and ecological processes (Desanker, *et al* 1997), which on the aggregate affects global environmental change and the biosphere. The implication of unsustainable land use practices on the land cover is land degradation which constrains the ability of the land to perform the processes required for effective functioning of the environment. Land degradation may therefore be viewed as an integral part of land use and land cover change process characterized by entropy. It may be the result of the change process, or its (change process) effect on land use and land cover in space and time which leads to a reduction in resource potential of the land.

Land degradation represents potential threats posed to people and their livelihood, survival and well being as presented by Mitchell, (1989). The processes and combination of factors that lead to land degradation is also the complex suite of proximate and underlying forces that govern land use and land cover change. Land degradation often begins as isolated patches scattered across an area, progresses in discontinuous fashion, and if not addressed on time, expands and combines and before long, the whole area is affected. This progressive slow steady process according to Feddema and Freire, (2001), tends to make actual observation and measurement of these impacts

extremely complicated especially using the traditional methods of resource and degradation inventory.

Another problem with investigation of land degradation is that it can also be clearly contextual, thereby allow different people to report different things (Warren, 2002; Reynolds, *et al*, 2003). For example different stakeholders (natural and biophysical scientists, landscape pattern analysts, development agencies – those who have to distribute funding for mitigation-economists and political scientists, and even the land users) have different viewpoints. However, land degradation hazard becomes a disaster when it either directly or indirectly impacts the habitation, livelihood and survival of some population (Warren, 2002; McBean, 2006).

Global reports on land degradation is very pathetic and more importantly, recent studies have suggested strong link between land degradation, poverty, and vulnerability to disaster (Okali, 2004). Hence the task of monitoring land use and land cover change is very critical not only to the maintenance of ecosystems functions and services but also to human well being. Vegetal land cover removal is a very serious problem around the world. Deforestation rate at global level has been put at 12m.ha/yr (million hectares per year) with 4.1mha/yr for tropical America, 4m.ha/yr for Africa and 1.8m.ha/yr for Asia (Rao, 1990). Correspondingly, the rates of reforestation were put at 0.4m.ha/yr, 0.1m.ha/yr and 0.4m.ha/yr for tropical America, Africa and Asia respectively (Rao, 1990).

The deforested land is vulnerable to other degradation hazards such as erosion, flooding, salinization and soil decay, subsidence, etc. As mentioned earlier, the key drivers of land degradation are mainly the complex underlying drivers which are fully controlled not by nature but by man. There is no doubt that the role of man in the onset and spread of land degradation is well established in the literatures. The land use and land cover change studies of the International

Geosphere – Biosphere Programm (IGBP – LULCC) has also done detailed studies on the complex interactions between among the drivers of change and the influence or impact of ecosystems change n the functioning of the biosphere as a system.

However, much work is still required to disentangle the complex web between land use land cover change caused by people, poverty, land degradation and vulnerability to disasters. The frontier of land use land cover change research is already moving towards this direction and this research work is a contribution to this growing body of knowledge. The rural poor has his livelihood tied almost hundred percent to land resources and thereby highly vulnerable to the short and long term effects and consequences of his activities on the land so there is the urgent need to enlighten him about the consequences of his actions.

Most literatures on the influence of man on the environment emphasized the role of people in accelerating degradation and deemphasized the livelihood needs of the people. But the people will rather survive at the expense of the environment and not the other way round as is portrayed in most literatures. There is, therefore, a need to begin researches that emphasize not the environment, but livelihoods and survival of the people living in the environment. If there is a scientific breakthrough in the area of alternative source of livelihoods for the rural poor and alternative energy areas for urban activities, humanity would have less to worry about the environment, land degradation and other associated hazards.

2.2.2. Resource Assessment

Mitchell (1989) is of the opinion that a resource is a neutral stuff until a use is found for it. The chief variable defining what constitutes a resource is the ability of the people to find a current or future use for a neutral stuff. This depends on the functional capability or level of technology of the people concerned. Most Africans do not even believe timber constitutes a resource of

economic value until the early Europeans began to export timber from Africa to their home countries

Resource appraisal and assessment have therefore not been a straightforward task. Assessment of the productivity of renewable natural resources can be done through the evaluation of the flow of resource stock e.g. the number of logs yielded by a forest stand, the quantity of fish catch from river or sea, etc. However, assessment of the health of the ecosystem which the resource in question belongs is much more difficult. The spatial and temporal scale at which ecosystems health assessment is carried out is very important for comparison and analysis. For example land degradation is clearly contextual.

According to Warren (2002), what constitutes degradation of ecosystems to a group may be perceived differently by some other people, which imply no standardized meaning for land degradation that fits all situations (Reynolds, *et al* 2003). Specifically, the type of land involved (soil types, vegetation, soil fertility, *etc*); land use history, impact on human livelihoods, level of performance of ecosystems functions, a consideration of the views of stakeholders involved, and the spatial and temporal scale of concern required necessary observations before an ecosystem can be labeled as degraded. Warren (2002) is of the opinion that a change in an environmental component that cannot be assessed with present technology or finance, or is inconsequential to a present way of life (including current and future production), does not per se amount to degradation.

Although Reynolds, *et al.*, (2003) is concerned about how to determine the amount of land affected or at risk of degradation, however the method of achieving that largely remain unsolved. The advent of the tools and techniques of Remote Sensing (RS) and Geographic Information System (GIS) and environmental modeling techniques has virtually revolutionalized the task of

inventory and assessment of ecosystems health and degradation. The in-situ field survey method is popular in geography as the traditional method of resource assessment. This method is narrow in spatial and temporal scopes that can be covered. It is also tedious, time consuming and information obtained is already outdated even before the assessment is completed. RS and GIS has made it possible to perform systematic inventory and assessment of land resources and land degradation over space and time so that intervention strategies can be put in place to halt deteriorating ecosystems health and forestall vulnerability to other associated hazards.

RS and GIS have proved invaluable for generating, analyzing and integrating spatial data and information from both the natural and social components of the environment. This twin technologies, though not the exclusive preserve of Geography, has further equipped the geographer-environmentalist and resource analysts with powerful tool for monitoring the environment. It has also imbued the geographer with the skill of an integrator (Mitchell, 1989) and a manager with ability to coordinate the management of natural resources.

Furthermore, the new frontier in land use and cover change research has extended to the use of spatially explicit models to predict future changes in land use-land cover based on some set of user's predefined drivers. This permits the building of future land cover change scenarios that give clue to some present measures (socio-economic and environmental) to be taken to reduce or forestall future negative consequences.

2.2.3. Remote Sensing (RS)

Remote sensing (RS) can be described as an art, science and technology for acquisition of data pertaining to the earth surface using sensors from space platform, processing and analysis of these data and their integration with other existing base spatial data. Curran *et al.*, (1998) described RS as one of the tools we can use to increase our understanding of environment in

space and time. It has been variously defined as the science of deriving information about the earth's land and water areas from images acquired at a distance, which usually relies upon measurement of electromagnetic energy reflected or emitted from the features of interest (Campbell, 1996), and obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area or phenomenon under investigation (Lillesand and Kiefer, 1987).

Janseen and Huurnemann (2001) describes RS as the science of acquiring, processing and interpreting images that record the interaction between electromagnetic energy and matter; and also as the instrumentation, techniques, and methods to observe the earth's surface at a distance and to interpret the images' numerical values obtained in order to acquire meaningful information of particular object on earth. It is a technique of deriving information about objects on the surface of the earth without physically coming into contact with them (NRSA, 1995). Lillesand and Kiefer, (1987) describes Remote Sensing to denote joint effects of employing modern sensors, data processing equipments, information theory and processing methodology, communication theory and devices, space and airborne vehicles, large systems theory and practice for the purpose of carrying out aerial or space surveys of the earth's surface. The orientation of definition-energy, feature, discipline and instrument notwithstanding, the ability of remote sensing to provide data for scientific, technological and sustainable management and monitoring of natural resources offers a concourse.

Remote sensing is an essential tool of land-change science because it facilitates observations across larger extents of Earth's surface than is possible by ground-based observations. This is accomplished by the use of cameras, multi-spectral scanners, RADAR and LiDAR sensors mounted on air- and space-borne platforms, yielding aerial photographs, satellite imagery,

RADAR and LiDAR datasets. Data available from remote sensing vary from the very high-resolution datasets produced irregularly over extents no larger than a single state or province (by aerial photography, imaging, LiDAR, and by high resolution satellite sensors such as IKONOS and Quickbird), to regional datasets produced at regular intervals from satellites (e.g., Nigeriasat-1, Landsat, SPOT), to the lower-resolution (> 250 m) datasets now produced across the entire Earth on a daily basis (e.g., MODIS).

The electromagnetic spectrum (EMS) is the physical basis for remote sensing. The EMS is an abstract idea and diagram of forms of electromagnetic energy for illuminating earth surface features. The source of energy is divided according to their wavelengths. The most widely used part of the spectrum is the visible region because the atmosphere is transparent in this region. The sun is the major source of energy for remote sensing and it emits energy in the manner of a black body whose temperature is about 6000^0K. Every earth based objects with temperature above 0^0K (-273^0C) emit long wave energy. Some active sensors such as photographic cameras, radio detection and ranging devices (RADAR), Laser Radar also generate their energy to illuminate targets or features of interest. The EMS is divided according to energy wavelengths (λ). The EMS can generally be divided into the short waves, the visible, and the long wave and microwave regions. The short wavelength region consists of the cosmic rays, gamma rays (γ), x-rays and ultraviolet (uv) rays. The uv rays is the shortest wavelengths visible to the human eye. The wavelength range for short waves range from $10^{-1}\mu$m (micron) for uv rays to less than $10^{-6}\mu$m for cosmic rays.

The visible portion is a very small spectrum whose limit is often defined by the sensitivity to human visual system. It is a narrow band covering 0.4μm to 0.7μm. It is subdivided into three components blue (0.4 to 0.5μm), green (0.5 - 0.6μm) and red (0.6 - 0.7μm). The long wave

consists of the near, mid, thermal and far infrared portions. The long wave spectrum is a very large segment which extends from about 0.72μm to 15μm and about 40 times as wide as the visible portion. Infrared portion has a wavelength ranges from 0.76μm to 12.5μm. The microwave portion of the EMS has wavelength range from 1mm to 10m and consists of the microwave, radio and television waves. The most widely used part of the spectrum is the visible region because the atmosphere is transparent in this region. Energy propagation for passive remote sensing in the atmosphere is only possible where atmospheric windows are present. When electromagnetic energy is incident on any given surface feature three fundamental energy interaction with the feature are possible; reflection, absorption and transmission.

The proportion of energy reflected, absorbed or transmitted is a function of the material type and condition of the feature. These differences in material types and conditions are very important for natural resources mapping and ecosystems assessment.

2.2.4. Geographic Information System (GIS)

Geographic Information System (GIS) has been variously defined by different schools of thought based on perception and viewpoints, background, professional and expected results/deliverables. Aronoff (1989) defines a GIS as computers based system that is used to store and manipulate geographic information. It is designed for the collection, storage and analysis of objects and phenomena where geographic location is an important characteristic or critical to the analysis. Roger Tomlinson, one of the pioneers of GIS defines it as a configuration of computer hardware and software specially designed for the acquisition, maintenance and use of cartographic data (Campbell, 1996).

Burrough (1986) sees a GIS as a powerful set of tools for collecting, storing and retrieving at will, transforming and displaying spatial data from the real world. Heywood *et al* (1998)

describes GIS by the types of generic questions often asked such as location, pattern, changes and spatial implications and how GIS can provide answers to these questions. Longley *et al.,* (2001) view GIS from viewpoints of different professionals and what they can do with the tool. Geographic information is very critical to GIS. Geographic information is information which can be related to specific locations on the earth (Tomlinson, 1990). It gives information about a place or an area or the location of phenomena and their characteristics on which many human activities depend.

The power of a GIS lies in its ability to bring both spatial and attribute data within a common framework to form a unified database system; and its ability to compare different entities based on their common geographic occurrence through the overlay process. This, together with the ability to manipulate attributes and values of a feature provides GIS with a powerful decision support weapon that can assist in taking decisions about environmental and resource management problems. According to Dangermond (1989), GIS is important today because it offers critically important means for understanding and dealing with some of the most pressing challenges of our environment including tropical deforestation (and ecosystems changes), the future of the global climate, the need for the ecologically sensitive development of global natural resources, acid rain, and rapid urbanization, etc. GIS technology also helps us organize the data about such problems and understand their spatial associations, and provides a powerful means for analyzing and synthesizing information about them which is vital for decision making.

A GIS is basically an integrated system for handling and analyzing geographical data, it arranges data in layers in a manner that is analogous to manual transparent overlays. The data model chosen determines the conventions and procedures used in GIS analysis. This arrangement

permits analysis of different data layers (e.g. soil, geology, vegetation, settlements, road network, etc) layers within a common or unified framework through the overlay process.

GIS is useful in resource assessment, ecosystems degradation analysis and environmental change assessment requirements, such as collecting and systemizing baseline data, estimation of spatio-temporal impacts on the different environmental components, and data management. GIS provides a powerful tool to identify and analyze and model alternatives. GIS has also become indispensable because of its ability to conduct spatial analysis on input data, and generate various output options including information system for land management, data for disaster planning, risk and hazard mapping, linking of environmental databases, and construction of global database for environmental modeling (Rodriguez – Bauchiller, 1995). Land use-land cover change is perhaps the first beneficiary of environmental remote sensing since the launch of Landsat 1 (formerly ERTS -1) in 1972.

Several models have come up as a result of the use of Remote Sensing and GIS in land use-land cover analysis prominent among which are Markov Chain Analysis and Cellular Automata. Markov Chain analysis is a convenient tool for modeling land use change when changes and processes in the landscape are difficult to describe. A Markov process is one in which the future state of a system can be modeled purely on the basis of the immediately preceding state. Markov chain analysis describes land use change from one period to another and uses this as the basis to project future changes. This is achieved by developing a transition probability matrix of land use change from time one to time two, which shows the nature of change while still serving as the basis for projecting to a later time period .The transition probability may be accurate on a per category basis, but there is no knowledge of the spatial distribution of occurrences within each

land use category. Hence, Cellular Automata (CA) model is always used to add spatial character to the model.

Cellular Automata (CA) model uses the output from the Markov Chain Analysis particularly Transition Area file to apply a contiguity filter to "grow out" land use from time two to a later time period. In essence, the CA will develop a spatially explicit weighting more heavily areas that proximate to existing land uses. This will ensure that land use change occurs proximate to existing like land use classes, and not wholly random.

The model also assists in predicting future land use and projecting the magnitude of its implication (land degradation). A serious deficiency of some of these models is that they are not spatially explicit and do not effectively run on a GIS. This is due to limitation on both the current level of GIS and model development. These models in most cases are developed outside the GIS and both the model and GIS thus run independently with data interchange.

2.2.5: Case Studies

Remote sensing and GIS has been widely applied in resource assessment and environmental change around the world. Application of RS and GIS in tropical deforestation and land cover change has received sustained attention in different parts of the tropical world. Remote sensing has been used for assessment of timber products, to locate potential reserves, to know where reserves were under pressure from other developments, to locate where increasing desertification necessitated shelter belt planning, to rationalize utilization and reforestation, and to realize self sufficiency in food production, and for early detection of land degradation (Parry and Trevett, 1979; Abayomi, 1990).

The indispensability of remote sensing for natural resources and environmental change assessment and management in the developing world are well documented (Fasona, 2007). The

developing countries of the tropics have immense natural resources that can be harnessed to propel development in these countries. Up till now these countries are still in the process of obtaining first generation of digital information of their natural resources and the environment. This explains why remote sensing derived information vital for resource management has not adequately trickled down into the decision making processes.

Space remote sensing provides quantitative data for monitoring the growth and degradation of natural forest, the effects of deforestation on soil, watersheds, underground water recharge, and on various dimensions of the environment (Rao, 1999). On a global scale, the extent and rate of land cover change over most parts of the tropics is now known with some precision (Eyre, 1990). In several studies GIS has been combined with environmental models using remotely sensed data to conduct predictive – prescriptive investigations of ecosystems degradation at local level in different parts of the world.

DeGier and Hussin (1995) generated multi-temporal data from aerial photographs, Landsat MSS and field observations for the Area Production Model (APM) developed by FAO to simulate forest degradation between 1979 and 1993 and future area required for agriculture in the Kali Konto area of Indonesia. In the same vein, soil, land cover, terrain data, rainfall and satellite imageries from IRS –IBLISS-1 were utilized by Saha (1996) to develop a scalogram model to map soil erosion hazard in Doon Valley (Dehradun district, Uttar Pradesh) of India. Pramojanee *et al* (1997) conducted area class mapping of flood hazard and risk in Nakorn Sri Thamarat Province of South Thailand using land use data from Landsat TM imagery, soil classes, elevation and climatic data. The degree of influence of a host of flood causative factors including annual rainfall, size and slope of watershed, gradient of river/stream, drainage density, soil type, land

use, and infrastructure/communication lines that influence drainage and population density were analyzed and rated for degree of flood hazard and risk.

Several studies specifically related to land cover change and its drivers have also been carried out at local level in several parts of the world. The CLUE and CLUE-S models were developed by Verburg *et al*, (2000) to analyze relations between land use and its proximate driving factors as well as the dynamic simulation of near future land use changes in the Sibuyan Island of the Philippines and the Klang – Langat watershed of Peninsular Malaysia. By coupling the Universal Soil Loss Equation (USLE) with GIS, both Shrestha, *et al* (1996) and Sah et al, (1996) assessed soil erosion and watershed degradation respectively in the Uthai Thani province of Thailand and Trijuga watershed of Nepal. While Shrestha, *et al* (1996) utilized land use and elevation derivates as inputs into the USLE models.

Sah *et al* (1996) utilized base maps, satellite images, soil sample data and socio-economic data. The European Environmental Agency (2003) also carried out a study that was aimed at identifying probable problem areas for soil degradation hot spots and developing policy relevant indicators for land degradation in Europe. The study which utilized both the Driving Forces Pressure State Impact and Responses (DPSIR) and multifunction and multi-impact (MF-MI) framework reported that land cover and land use management are the most important factors that influence soil erosion and land degradation in Europe.

Mama *et al* (2002) coupled regression and Markov transitional models with remote sensing and socio-economic data to improve understanding of the inter-annual dynamics of biomass loss and land use transitions of thereby develop empirical models for environmental change in the central region of Benin Republic.

Although the use of data from satellite remote sensing for environmental change assessments in Nigeria dated back to the late 1970s, the integration of remote sensing data with GIS data for environmental change and impact studies is recent. Coupling of environmental models with GIS and remote sensing for ecosystems change assessment in Nigeria is still at infancy. Although the production of 1:50,000 topographic maps of Nigeria started in 1946 (Balogun, 2003), the extensive large area photographic campaigns of the 1960s by the Canadian and British governments under the Commonwealth Africa Aid Program gave impetus to the 1:50,000 mapping. The photographic campaign appears to be the most comprehensive national resource survey in Nigeria. The sets of 1:50,000 maps produced from the campaign still provide the most comprehensive topographic data in Nigeria at that scale to date.

The beginning of the use of satellite data for land resources mapping in the country began with the Nigeria Radar (NIRAD) project in 1978 when 1:250,000 vegetation maps were produced using data from Side Looking Airborn Radar (SLAR) flown by Motorola Aerial Remote Sensing Inc. (MARS) and Hunting Technical Services Limited (Abayomi, 1990). The NIRAD project discovered about 15,000km^2 of coastal freshwater swamp forests (Abayomi, 1990) which need to be conserved and improved by enrichment planting to prevent appreciable deforestation. An update of the mapping was carried out between 1994 and 1996 by the then Forestry Resources Management Evaluation and Coordination Unit (FORMECU) of the Federal Ministry of Agriculture with assistance from the World Bank. Landsat TM data was used and the mapping was done at 1:250,000.

Apart from general land use and vegetation mapping and assessment, some works on land use and land cover change and their socio-economic implications have also been carried out. There are also reports on degradation elements especially soil erosion, flooding and deforestation.

Some of these reports also emanated from the land use and land cover change studies. For example, from a change analysis of multi-date archival remote sensing data, soil lateralization was discovered to be a result of overgrazing and burning of savannah vegetation in north-west Nigeria (Omojola, 1997). This increases soil vulnerability to erosion and reduces crop yield. Results from analysis of multi-date Landsat TM and SPOT XS data by Jande and Nsofor (2002) showed that about 50,000 ha of vegetation was destroyed in the Makurdi area of central Nigeria between 1976 and 1993. Forest loss in the Afaka forest reserve in northwest Nigeria was also assessed by Nwadialor and Nsofor (2002) using multi-date archived imageries.

CHAPTER THREE

THE STUDY AREA AND RESEARCH METHODOLOGY

3.1. INTRODUCTION

This chapter discusses the study area where such issues as location, climatic types, topography, vegetation, natural resources and the extreme points of the study area are discussed under the study area. The chapter also presents the types and sources of data used for the study and the overall procedure used in achieving the objectives of the study.

3.2. THE STUDY AREA

3.2.1: Location

Nigeria is located in West Africa, bordering the Gulf of Guinea, between Benin and Cameroon with Geographic coordinates of 10 00^0 N, 8 00^0 E. It has a total area of 923,768 km^2 with land of 910,768 km^2 and water area of 13,000 km^2. The country is bordered by Benin, Cameroon, Chad, and Niger (Figures 3.1 and 3.2).

3.2.2: Climate types

The Tropical rain forest climate or Equatorial monsoon designated by the Koppen climate classification as "Af" is found in the southern part of the country. This climate is influenced by the monsoons originating from the South Atlantic Ocean, which is brought into the country by the (maritime tropical) mT airmass, a warm moist sea to land seasonal wind. Its warmth and high humidity gives it a strong tendency to ascend and produce copious rainfall, which is a result of the condensation of water vapour in the rapidly rising air.

The Tropical rainforest climate has a very small temperature range. Then temperature ranges are almost constant throughout the year, for example, Warri town in the southern part of Nigeria, records a maximum of 28 °C for its hottest month while its lowest temperature is 26 °C in its coldest month. The temperature difference of Warri town is not more than 2 °C.

The southern part of Nigeria experiences heavy and abundant rainfall. These storms are usually convectional in nature due to the regions proximity, to the equatorial belt. The annual rainfall received in this region is very high, usually above the 2,000 mm rainfall totals giving for tropical rainforest climates worldwide. Over 4,000 mm of rainfall is received in the coastal region of Nigeria around the Niger delta area. Bonny town found in the coastal region of the Niger delta area in southern Nigeria receives well over 4,000 mm of rainfall annually. The rest of the southeast receives between 2,000 and 3,000 mm of rain per year.

The southern region of Nigeria experiences a double rainfall maxima characterized by two high rainfall peaks, with a short dry season and a longer dry season falling between and after each peaks. The rainy season begins around March and last to the end of July with a peak in June. This rainy season is followed by a short dry break in August known as the August break which is a short dry season lasting for a week in August. This break is broken by the Short rainy season starting around early September and lasting to Mid October with a peak period at the end of September. The ending of the short rainy season in October is followed by Long Dry Season. This period starts from late October and lasts till early March with peak dry conditions between early December and late February.

The Tropical savanna climate or Tropical wet and dry climate, is extensive in area and covers most of Western Nigeria to central Nigeria beginning from the Tropical rainforest climate boundary in southern Nigeria to the central part of Nigeria, where it exerts enormous influence on the region.

This climate, the tropical savanna climate exhibits a well marked rainy season and a dry season with a single peak known as the summer maximum due to its distance from the equator.

Temperatures are above 18 °C throughout the year. Abuja, Nigeria's capital city found in central Nigeria, has a temperature range of 18.45 °C to 36.9 °C, and an annual rainfall of about 1,500 mm with a single rainfall maxima in September.

The single Dry season experienced in this climate, the tropical savanna climate in central Nigeria beginning from December to march, is hot and dry with the Harmattan wind, a continental tropical (cT) airmass laden with dust from the Sahara Desert prevailing throughout this period.

With the Intertropical Convergence Zone (ITCZ) swinging northward over West Africa from the Southern Hemisphere in April, heavy showers coming from pre-monsoonal convective clouds mainly in the form of squall lines also known as the north easterlies formed mainly as a result of the interactions of the two dominant air masses in Nigeria known as the Maritime tropical(south westerlies) and the Continental tropical(north easterlies), begins in central Nigeria while the Monsoons from the south atlantic ocean arrives in central Nigeria in July bringing with it high humidity, heavy cloud cover and heavy rainfall which can be daily occurrence lasting till September when the monsoons gradually begin retreating southward to the southern part of Nigeria. Rainfall totals in central Nigeria varies from 1,100 mm in the lowlands of the river Niger Benue trough to over 2,000 mm along the south western escarpment of the Jos Plateau.

The Sahel Climate or Tropical dry climate, is the predominant climate type in the northern part of Nigeria. Annual rainfall totals are lower compared to the southern and central part of Nigeria. Rainy season in the northern part of Nigeria lasts for only three to four months (June–September). The rest of the year is hot and dry with temperatures climbing as high as 40 °C.

Alpine climate or highland climate or mountain climate, are found on highlands regions in Nigeria. Highlands with the alpine climate in Nigeria are well over 1,520 metres above sea level. Due to their location in the tropics, this elevation is high enough to reach the temperate climate line in the tropics thereby giving the highlands, mountains and the plateau regions standing above this height, a cool mountain climate.

3.2.3: Seasons

Nigeria, like the rest of West Africa and other tropical lands, has only two seasons. These are the Dry season and the Rainy season. The dry season is accompanied by a dust laden air mass from the Sahara Desert, locally known as harmattan, or by its main name, The Tropical Continental (CT) air mass, while the rainy season is heavily influenced by an air mass originating from the south atlantic ocean, locally known as the south west wind, or by its main name, The Tropical Maritime (MT) air mass. These two major wind systems in Nigeria are known as the trade winds.

3.2.4: Trade winds

3.2.4.1: Tropical maritime airmass

The Tropical Maritime Airmass (mT) is responsible for Nigeria's rainy season. This wind (the Tropical Maritime Airmass) invades the country from February in the southern part of Nigeria while it takes longer for the wind to fully cover the whole of the country, reaching the northern part of Nigeria in June. Its invasion is as a result of the northward retreat, of the tropical continental airmass (cT) known as the harmattan. The northward retreat of the tropical continental airmass (cT) is caused by the sun's northward shift from the tropic of Capricorn in the southern hemisphere to the tropic of cancer in the northern hemisphere. This shift begins

from February and ends in June, when the sun is fully overhead, at the tropic of cancer in the northern hemisphere.

During this northward migration of the sun as a result of the earth tilting along its axis, the sun crosses the equator (around March), moving over West Africa at this time on its journey to the northern hemisphere. West Africa comes directly under the sun at this time. The sun is overhead throughout west Africa and over Nigeria during this period of the sun's northward migration to the tropic of cancer in the northern hemisphere.

The whole of West Africa is heated intensely as result of the increased insolation received from the sun being overhead over West Africa. Temperatures can climb as high as 35 °C over West Africa during this time. Temperatures in the northern part of Nigeria can go as high as 48 °C in cities like Maiduguri.

The high temperatures coupled with an increase in insolation causes a region of low pressure to develop over West Africa and Nigeria (between March and May). The Tropical continental airmass (cT) from the Sahara Desert in the northern part of West Africa is weakened due to the overheating of the land surface in West Africa and Nigeria at this time. The Tropical continental airmass (cT) begins to retreat northwards to the Sahara Desert due to massive heating of the land which transfers heat in the form of convection into the Tropical continental airmass (cT) which constitutes the main layer of air above the land. This transfer of heat in the Tropical continental airmass (cT) in turn, causes the wind to expand and become lighter as this is the normal behaviour for winds moving above intensely heated grounds. The Tropical continental airmass (cT) loses its strength as a major airmass in the region of west Africa and over Nigeria at this time (around February in the southern part of Nigeria to June in northern Nigeria) and begins to

retreat coupled with the rising of air in form of convection within this airmass (Tropical continental airmass (cT)), further weakening the dominance of the wind over west Africa and Nigeria. The Tropical continental airmass (cT) finally retreats from most part of Nigeria, and the West African atmosphere around April to May, leaving an empty atmosphere over Nigeria. The sun's rays enter into the atmosphere of Nigeria more intense than it does during the presence of the Tropical continental airmass, which contained dust (in form of haze) that reduced the intensity of the sun. The overheating of the West Africa land mass and Nigeria in particular creates a low pressure region over West Africa and Nigeria. This low pressure zone attracts the Tropical Maritime Airmass (mT) from the South Atlantic Ocean since areas of low pressures experiences inward blowing winds because winds are moving air blowing outwards from regions of high pressure to regions of low pressure.

The Tropical Maritime Airmass is a warm humid and unstable trade wind due to its warmth. Convectional currents are easily set up within the airmass whenever there is little instability in the airmass as a result of a slight to a very high orographic uplift in mountainous regions like the Obudu Plateau or the heating of the land which can trigger the formation of cumulonimbus cloud leading to thunderstorms within the airmass.

During the dominance of the Tropical Maritime Airmass (mT) in the rainy season of Nigeria, mornings are bright and sunny, the sun's heating of the land in the mornings and afternoons sets up convectional currents, these currents rise vertically and cumulonimbus clouds are formed, by afternoons to evenings, torrential downpour follows.

The Easterly wave or the African easterly waves is another major contributor of rainfall during the summer monsoons months of May to September in Nigeria.

The nature of this wave changes at about the 15 degrees line. The wave that passes south of this line carry moisture and create convection that leads to rain clouds (Park, 2004). Nigeria's northern end is south of the 15 degrees line at about 14 degrees (Park, 2004). Nigeria's location in the wetter part of the easterly waves south of the 15 degree line creates wetter climatic conditions for Nigeria especially during the monsoons.

3.2.4.2: Tropical continental airmass

The Tropical Continental Airmass (cT) locally known as the harmattan, is a wind originating from North Africa which crosses the Sahara Desert into west Africa to Nigeria. This airmass dominates Nigeria's climate during the dry season from December to March. The Tropical continental airmass is dusty and creates a haze within the atmosphere of West Africa and Nigeria when it predominates. The haze is as a result of the dust within the airmass limiting visibility and blocking much of the sun's rays from reaching the earth.

3.2.4.3: Effects of the tropical continental airmass

The airmass has no ability of forming rain due to low humidity within the airmass, since it crosses the Sahara Desert; it picks up dust instead of water thereby creating little chances for rainfall.

The airmass makes life difficult as a result of low visibility which hampers transportation. The dust haze creates an almost desert conditions in the country during the dominance of the Tropical

continental airmass (the harmattan). But it’s coming brings some relief to farmers since the low humidity present in the air quickens the drying of their crops.

3.2.5: Temperature

Nigeria's location in the tropics has given her a tropical hot climate. Temperatures in Nigeria vary according to the seasons of the year as with other lands found in the tropics. Nigeria's seasons are determined by rainfall with rainy season and dry season being the major seasons in Nigeria.

The rainy season of Nigeria brings in cooler weather to the country as a result of an increased cloud cover that acts as a blockage to the intense sunshine of the tropics by blocking much of the sun’s rays in the rainy season; this in turn cools the land, and the winds above the ground remains cool thereby making for cooler temperatures during the rainy season. But afternoons in the rainy season can be hot and humid, a feature of tropical climates.

The dry season of Nigeria is a period of little cloud cover in the southern part of Nigeria to virtually no cloud cover in the northern part of Nigeria. The sun shines through the atmosphere with little obstructions from the clear skies making the dry season in Nigeria a period of warm weather conditions. In the middle of the dry season around December, a dusty wind from the Sahara Desert called the harmattan enters Nigeria from the northeastern part of the country blocking sun rays partially from shining and also creating haze in the atmosphere, this activities of the wind lowers temperatures considerably saving inhabitants for some time, from the scorching heat that would have occurred as a result of clearer skies during the dry season. But

with the withdrawal of this wind around March to April following the onset of the rainy season, temperatures can go as high as 44 °C in some parts of Nigeria (Areola, 1977).

On the highlands in central Nigeria with 1,200 metres or more above sea level, namely the Jos Plateau, the temperature ranges between 21°C to 25°C which are cool all year round (Areola, 1977).

Along the Nigeria-Cameroon border, in the eastern part of Nigeria with highlands of an average height of more than 1,524 m to some standing above 2,000 metres above sea level, the climate on these highlands is temperate all year round. The major highlands in this region are the Obudu Plateau above 1,584 m, Mambilla Plateau above 1,524 m and Mt. Chappal Waddi above 2,000 m (Areola, 1977).

3.2.6: Topography

Nigeria's most expansive topographical region is that of the valleys of the Niger and Benue River (which merge into each other and form a "y" shaped confluence at Lokoja). Plains rise to the north of the valleys. To the southwest of the Niger there is "rugged" highland, and to the southeast of the Benue hills and mountains are found all the way to the border with Cameroon. Coastal plains are found in both the southwest and the southeast.

3.2.6.1: Niger Delta

The Niger Delta is located in the southern part of Nigeria. It is one of the world's largest arcuate fan-shaped river deltas. The riverine area of the Niger Delta is a coastal belt of swamps bordering the Atlantic Ocean. The swamps are vegetated tidal flats formed by a reticulate pattern

of interconnected meandering creeks and distributaries of the River Niger. The vegetation of the Niger Delta consists mainly of forest swamps. The forests are of two types, nearest the sea is a belt of saline/brackish Mangrove swamp separated from the sea by sand beach ridges within the mangrove swamp. Numerous sandy islands occur with fresh water vegetation. Fresh water swamps gradually supersede the mangrove on the landward side. About 70% of Nigeria's crude oil and gas production is from the area. The riverine area is home to a large population of people living mainly in small villages scattered along the banks of rivers and creeks. Rainfall in the coastal belt of the Niger Delta is heavy due to the closeness of the Delta region to the equator. Annual rainfall totals vary from 2400 to over 4000 millimeters.

Niger Delta cities and their annual rainfall totals in millimeters:

- Warri — 2,730mm
- Forcados (coastal town in the Niger Delta) — 4,870mm
- Port Harcourt — 2,400mm
- Calabar (coastal city) — 3,070mm (rainiest city with over one million people in Nigeria)
- Bonny (south of Port Harcourt) — 4,200mm

3.2.7: Vegetation

Nigeria is covered by three types of vegetation: forests (where there is significant tree cover), savannahs (insignificant tree cover, with grasses and flowers located between trees), and

montane land. (The latter is the least common, and is mainly found in the mountains near the Cameroon border.) Both the forest zone and the savannah zone are divided into three parts.

Some of the forest zone's most southerly portion, especially around the Niger River and Cross River deltas, is mangrove swamp. North of this is fresh water swamp, containing different vegetation from the salt water mangrove swamps, and north of that is rain forest (Encarta, 2009).

The savannah zone's three categories are divided into mm' Guinea forest-savanna mosaic, made up of plains of tall grass which are interrupted by trees, the most common across the country; Sudan savannah, similar but with shorter grasses and shorter trees; and Sahel savannah patches of grass and sand, found in the northeast (Encarta, 2009).

3.2.8: Natural resources and land use

Nigeria's natural resources include but are not limited to petroleum, tin, columbite, iron ore, coal, lead, zinc, natural gas, hydropower and arable land.

3.2.9: Extreme points

This is a list of the extreme points of the study area, the points that are farther north, south, east or west than any other location.

- Northernmost point - unnamed location on the border with Niger immediately northwest of the town of Chadawa, Sokoto State.
- Easternmost point - unnamed location on the border with Cameroon immediately east of the village of Munyego, Borno State.
- Southernmost point - unnamed headland south of the town of Egeregere, Bayelsa State.

- Westernmost point - unnamed location on the border with Benin Republic immediately east of the Beninoise town of Jabata, Oyo State.

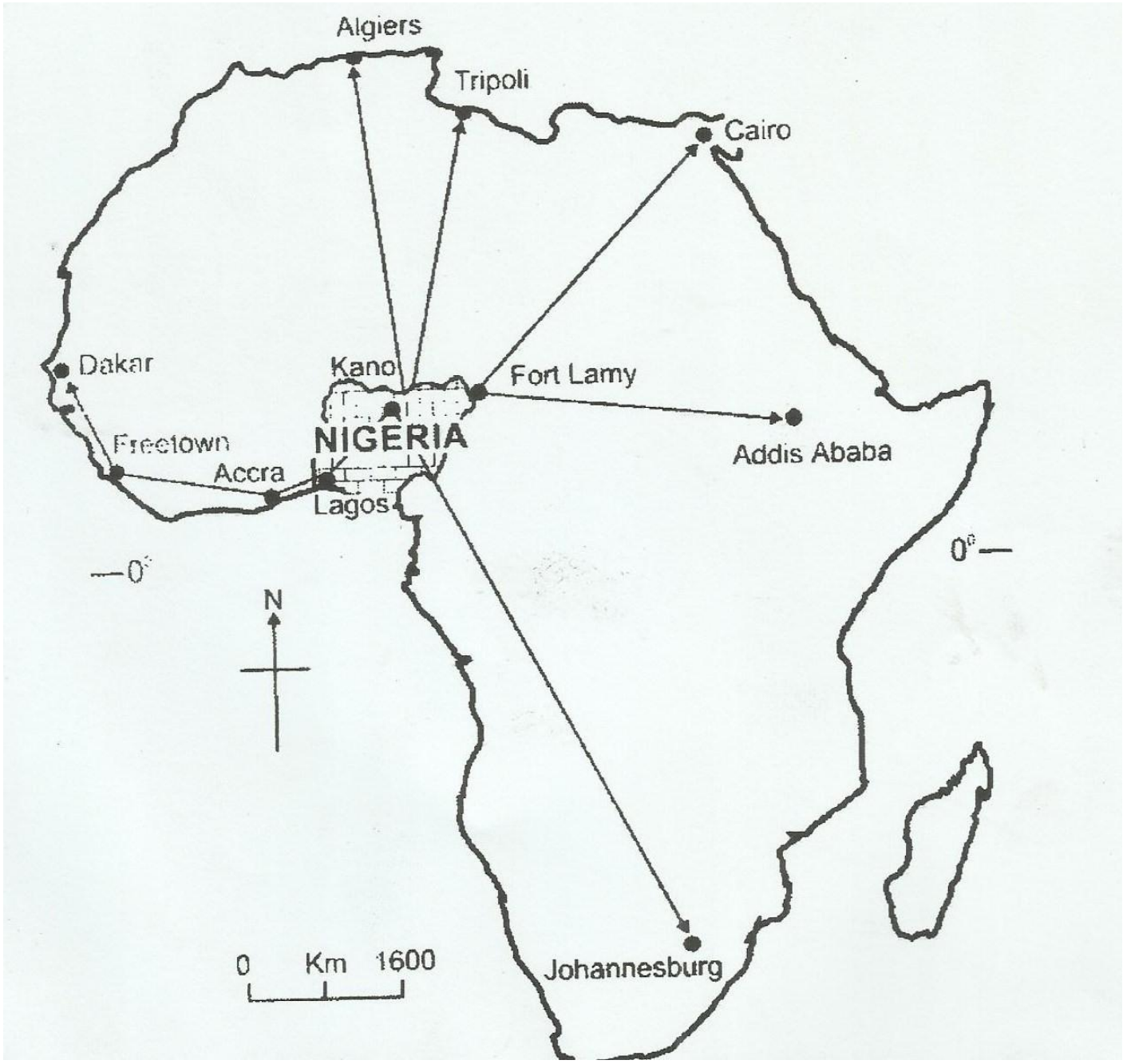


Figure 3.1: Map of Africa showing the study area

Source: Areola, 1977

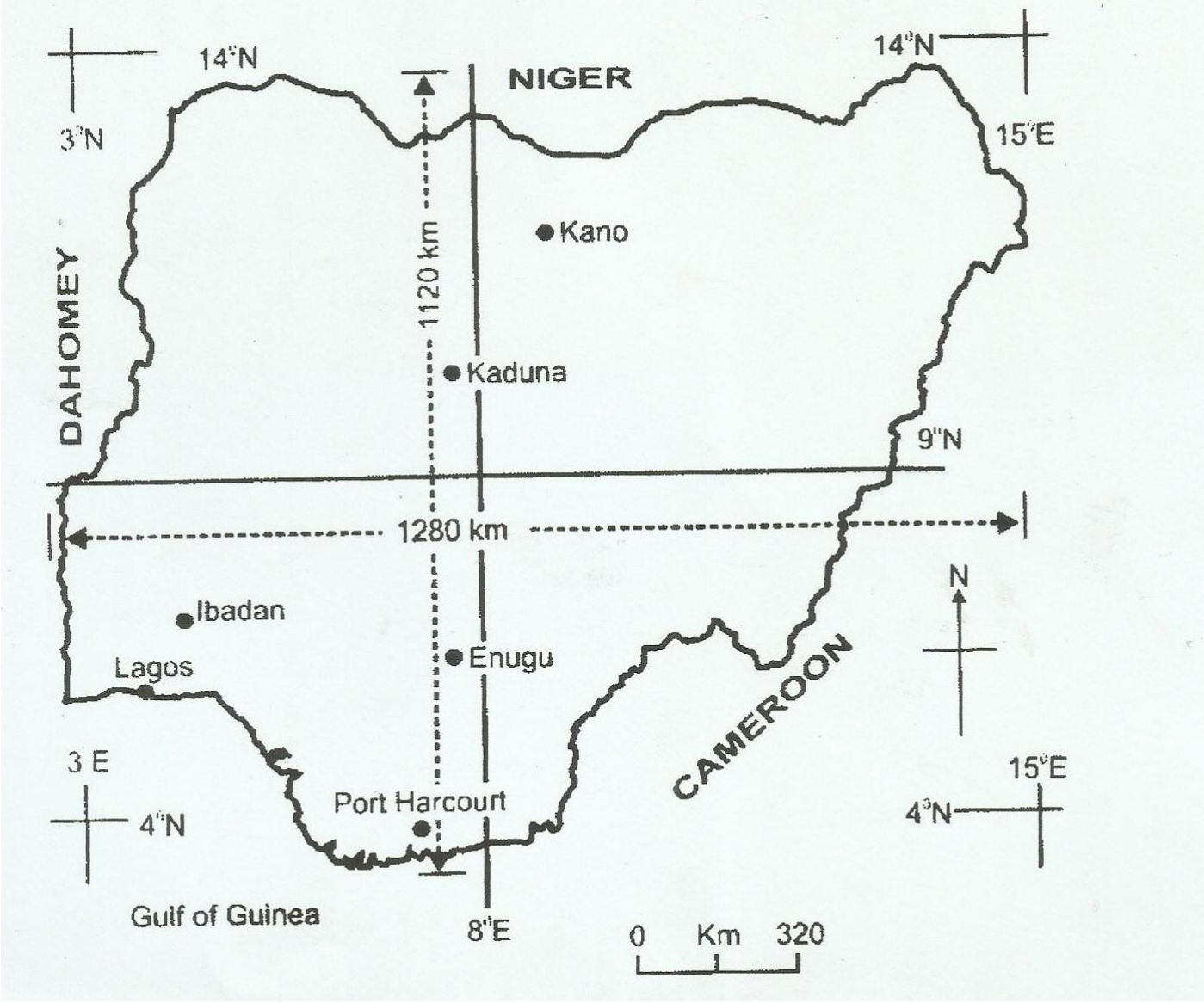


Figure 3.2: The study area

Source: Areola, 1977

3.3: RESEARCH METHODOLOGY

3.3.1: Types and Sources of data

The type and source of the geospatial data sets used are Combined Terra and Aqua MODIS land level 3/level 4 yearly tiled products, MCD12Q1-level 3 yearly land cover type with spatial resolution of 250m. This data was accessed from NASA website (www.ladsweb.nascom.nasa.gov/data). The imagery sets were processed using ArcGIS 9.3 software.

3.3.2 Methodology for Image Interpretation

Aronoff (1989) identified measurement, classification and estimation as the three types of analyses that can be carried out on remote sensing data. The last two relates to the objectives of this study. Extraction of information from remote sensor data can be done using digital analysis, manual/visual analysis, and lately, the hybrid system.

3.3.2.1 Digital Process

The analysis used digital classification already embedded in the imagery set. The primary classes of land use- land cover embedded in the imageries are Forest, General savanna, Wetland, Farmland, Barren while the secondary (subtype) land use-land cover classifications are Fresh water, evergreen neddleleaf forest, evergreen broadleaf forest, deciduous broadleaf forest, mixed forest, closed shrublands, open shrublands, woody savannas, savannas, grasslands, wetland, croplands, urban and built up, croplands mosaics, snow/ice, and barren or sparsely vegetated.

3.3.3 Field Checks and Accuracy Assessments

Validating accuracy of classification is vital towards placing a premium on generated data (Jensen, 1986). Validating accuracy of land use classes interpreted from remote sensing imageries requires a validated superior resolution dataset of the same area. In a place such as the study area where such superior data is not available, fieldwork is the best alternative.

Reconnaissance field work was carried out which provided an opportunity to establish contacts and familiarization with the communities and indigenous population. The main field check was conducted in company of six local field assistants. The field check was conducted with a handheld Garmin S76 Global Positioning Systems (GPS), digital camera and field note. A total of 185 field checkpoints were established by GPS. Observations of land use land cover characteristics and human imprints were made and recorded. According to Jensen (1986), the ideal number of check points required to be tested in the land use classification map is determined from the binomial probability given in equation 3.1:

$N = 4(p)(q\sim)/e^2$ ………………………………………………… 3.1

Where: N = is the number of points required,

p = is the expected percent accuracy

q~ = the difference between 100 and p

e = is the maximum allowable error

For an expected 90% accuracy and allowable error of 5%, the minimum number of points required is 144. This shows that the number of checkpoint (185) established on the field is far higher than the ideal number of checkpoints required. The checkpoints (stored as GPS waypoints) were downloaded using the Easy GPS program. The coordinates (together with descriptions) were imported into Arc GIS and added to the GIS database as an event theme which was converted into a data layer. This theme of field coordinates was then used as a base for assessing accuracy of the interpreted imageries as described by Jensen (1986).

The use of handheld GPS as opposed to the traditional method of pixel selection made the field verification exercise very fast (Olorunfemi, 2001). Field observations recorded about group of pixels around the GPS checkpoints points were matched with what has been interpreted.

Qualitative assessment was made by visual evaluation of remote sensing derived land use/land cover data with data from fieldwork. For quantitative assessment of the tribute accuracy of the map, the GPS checkpoints were analyzed for error matrix using the omission and commission errors computation method used by Jensen (1986). Omission and commission errors were calculated for the different land use land cover classes, accuracy for each class was estimated and the overall accuracy for the map was also determined using equation 3.2.

$P = p\sim - (1.645 \sqrt{(p\sim)(q\sim)/n + 50/n)}$ …. ……. 3.2

Where: P = map accuracy in percent

p~ = value c/n (number of correct points over total number of points) in percent

q~ = 100- p~. While n = sample size

3.3.4 Land use-Land cover Change Analysis

Land use and land cover change analysis from remote sensing imageries is a principal means for, and component of, environmental information and resource monitoring. Several works (Jensen, 1986; Omojola, 1997; Roberts, *et al*, 1998) have discussed the means, methodologies and techniques for change detection studies. Change detection for land use and land cover may be carried out using pre-classification or post classification approach. The pre-classification change detection involves matching pixel for pixel to process multi-date imageries of the same area so as to generate changes. In this case, the digital number (DN) of cells in image of time t^0 is digitally matched and co-related with the DN value for the image of time t^1 using change detection algorithm. The result represents the change area. This is very original because it uses the raw or

native DN values of the image which reflects the spectral reflectance of surface features. In this case, subtle changes may easily be captured.

However, where different environmental conditions prevail at the time of acquisition of the different images, differences in reflectance which is reflected in DN values may not correspond to changes in surface feature or classes. This may not be recognized by the change algorithm and hence unrealistic results may be generated.

The second methodological approach is the post classification change detection. This involves digital classification of the multi-temporal image of the same area. The classified image data are thereafter overlaid. Change is generated based on the classes rather than on differences in DN values. Much as this is straightforward, any miss classification error is automatically transmitted into the change generated. So the accuracy of change generated is a function of the accuracy of classified imageries. Therefore, for this study, land use land cover layer for 2001 was overlaid with land use land cover data generated for 2005 and 2009 in the GIS environment. Change analysis was then performed by intersecting the different multi-temporal land use and land cover layers (2001, 2005 and 2009). Change maps were generated and the resulting tables also produced.

3.3.5. Magnitude change, percentage change (trend) and annual change rate

The comparison of the land use land cover statistics assisted in identifying the percentage change, trend and rate of change between 2001 and 2009.

In achieving this, the first task was to develop a table showing the magnitude of change (area) and the percentage change for each static year (2001, 2005 and 2009) measured against each land use land cover type.

The magnitude change for each LULC class was calculated by subtracting the area coverage of the second year from that of the initial year as shown in equation 3.3.

Magnitude = Magnitude of the new year - Magnitude of the previous year……3.3

Percentage change (trend) for each LULC type was then calculated by dividing magnitude change by base year area coverage and multiplied by 100 as shown in equation 3.4.

$$\text{Trend (percentage change)} = \frac{\text{magnitude of change}}{\text{Base year}} * 100 \quad \ldots\ldots\ldots\ldots 3.4$$

In obtaining the annual rate of change for each LULC type, the trend (percentage change) was divided by 100 and multiplied by the number of study year 2001 – 2005 (4 years), 2005 – 2009 (4 years) and 2001 – 2009 (8 years) as the case may be is as shown in equation 3.5.

$$\text{Annual rate of change} = \frac{\text{Trend (percentage change)}}{\text{No of study years}} * 100 \quad \ldots\ldots\ldots\ldots 3.5$$

3.3.6: Future Projection

Markov Chain Analysis is a convenient tool for modeling land use change when changes and processes in the landscape are difficult to describe. A Markov process is one in which the future state of a system can be modeled purely on the basis of the immediately preceding state. Markov chain analysis describes land use change from one period to another and uses this as the basis to project future changes (Zubair, 2006). This is used to predict the land use - land cover situation in each LULC type for the year 2020 based on the 2001-2009 scenarios.

Projection for 2020 = 2001-2009 annual rate of change * 11 (2020 – 2009) + 2009 magnitude (area coverage)……..3.6

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. INTRODUCTION

This chapter presents the status of land use-land cover as they were in 2001, 2005 and 2009. It also shows the maps of the LULC. The LULC classification accuracy is also presented alongside LULC changes, LULC transformation and LULC prediction for the future. The result is discussed immediately as it is presented.

4.2. LAND USE-LAND COVER STATISTICS FOR 2001, 2005 AND 2009

The static LULC statistics for the study area in 2001, 2005 and 2009 is presented in table 4.1 and figures 4.1 and 4.2. It shows both the primary and the secondary classes' area coverage in hectares and their percentages.

INSERT Table 4.1: LULC Statistics for 2001, 2005 and 2009

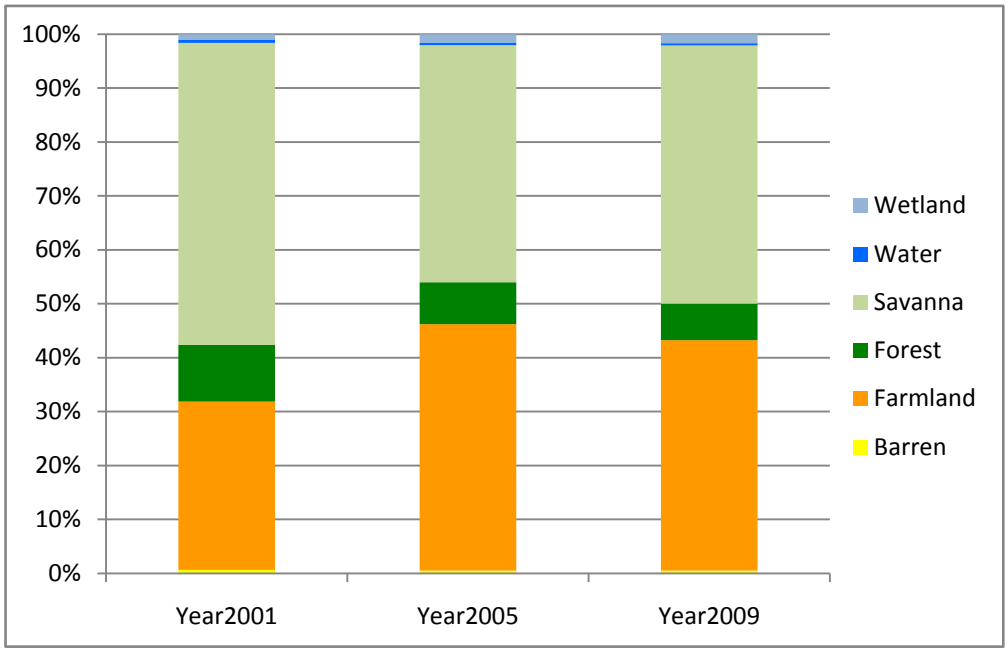


Figure 4.1: Primary Land Use – Land Cover for 2001, 2005 and 2009

4.2.1. Static Land Use-Land Cover for 2001, 2005 and 2009

There were five (5) primary LULC categories and 17 secondary LULC categories in all the three dates (2001, 2005 and 2009) as shown in table 4.1, figures 4.1.

The waterbodies had 0.53% coverage in 2001, decreased to 0.47% in 2005 and further decreased to 0.40% in 2009. The decrease could be associated with land reclamation of the waterbodies, siltation and natural shrinkage in the volume of lakes and rivers. The effects are ecosystems and habitat loss, loss of livelihood, economic losses, increased poverty and settlement dislocation.

The total forest cover had 10.51% in 2001, decreased to 7.72% in 2005 and further decreased to 6.78% in 2009. This shows that the forest resources have been on the degradation due to effects of climate change, farming, logging activities, woods for domestic uses construction and other anthropogenic factors. The effects might not be immediate but if not curtailed it could be devastating especially if carbon is not sunk through the forest.

The total savanna cover was 56% in 2001, decreased to 44% in 2005 as a result of agricultural activities and increased to 47.91% in 2009 due to high gain from forest cover. The loss in savanna could affect agriculture especially if it is lost to barren lands.

The wetland area was 1.07% in 2001, increased to 1.54% in 2005 and further increased to 1.65% in 2009. The steady increase was due to gain from the forest ecosystem as a result of increase in rainfall and human imprint that allowed the water to persist on the forest cover that gradually turned part of the forest cover into wetland.

The farmland of the study area was 31.24% in 2001, increased drastically to 45.72% in 2005 as a result of the need for food security and encouragement by the government for the people to embrace agriculture; and decreased to 42.71% in 2009 probably because of flooding and low return from agriculture.

The barren land which comprises of built up and a sparsely vegetated area was 0.64% in 2001, decreased to 0.54% in 2005 and slightly increased to 0.55% in 2009. The decrease was as a result of loss of the barren cover type especially sparsely vegetated areas to other land covers. The increased barren land could lead to resettlement, loss of agricultural lands, loss of livelihoods, soil impaction, increased poverty and human vulnerability.

The pictorial representation of the discussion above is shown in figures 4.3 to 4.5.

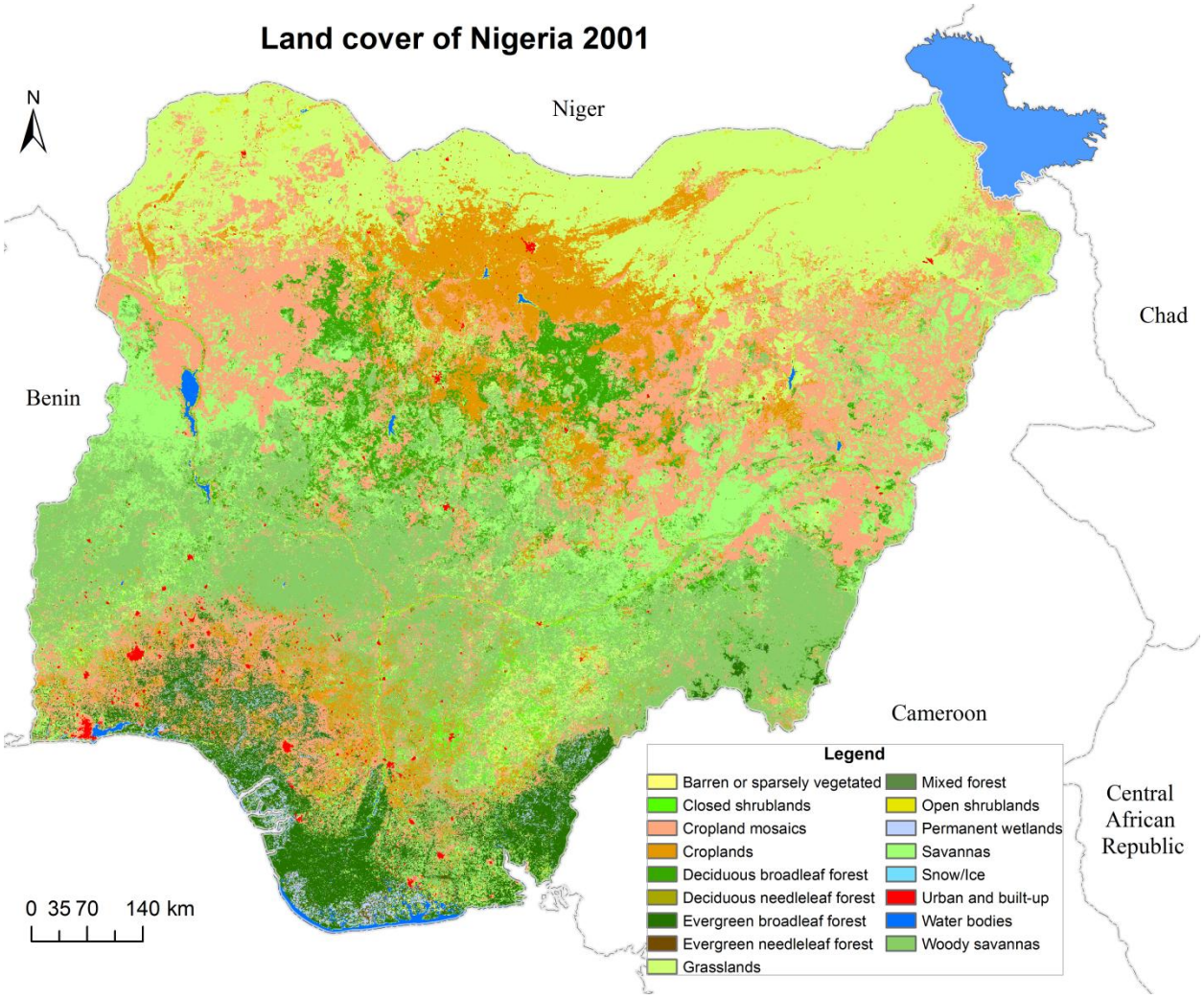


Figure 4.3: Land use-land cover map for 2001

Source: GIS Analysis

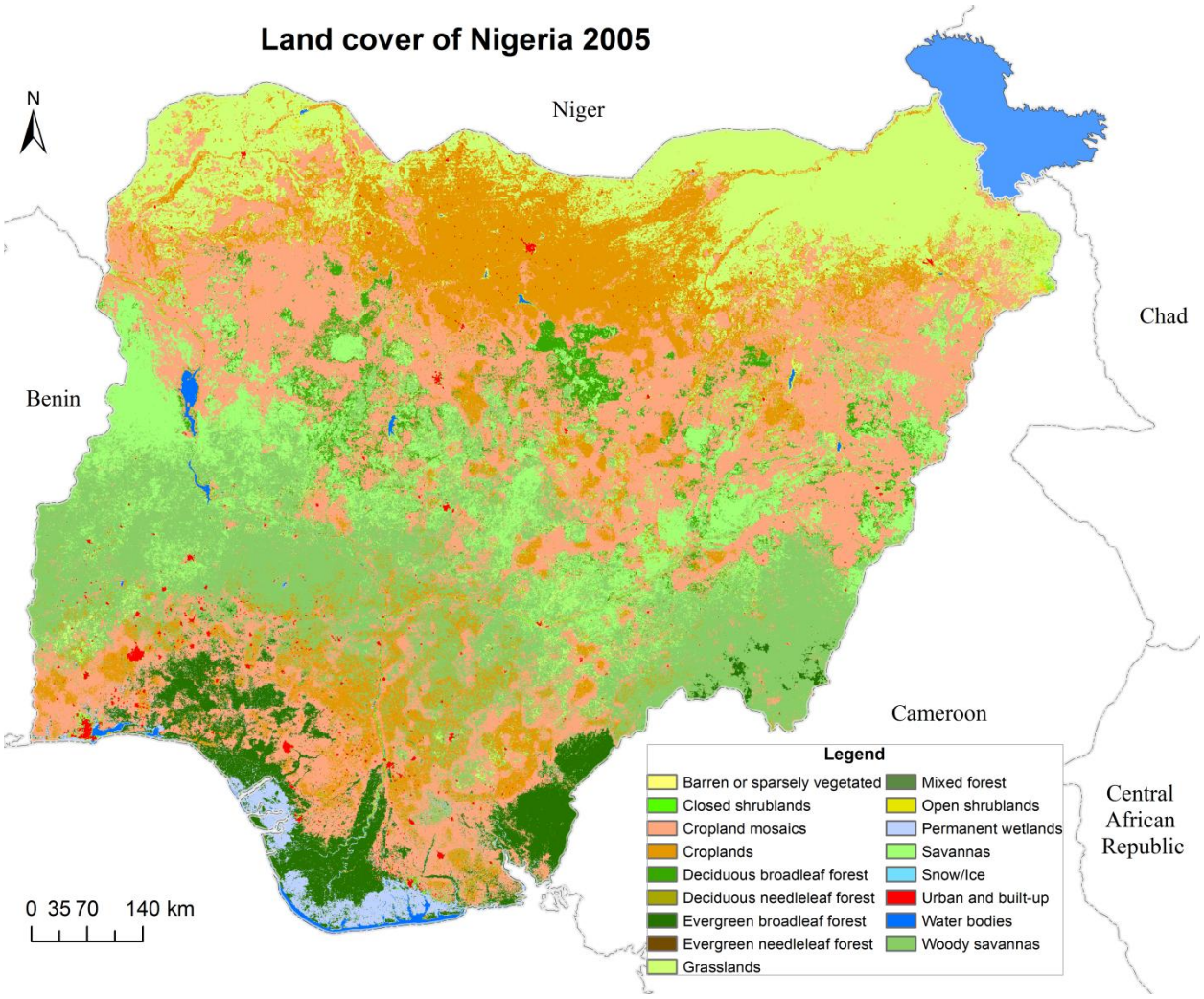


Figure 4.4: Land Use-Land Cover map for 2005

Source: GIS Analysis

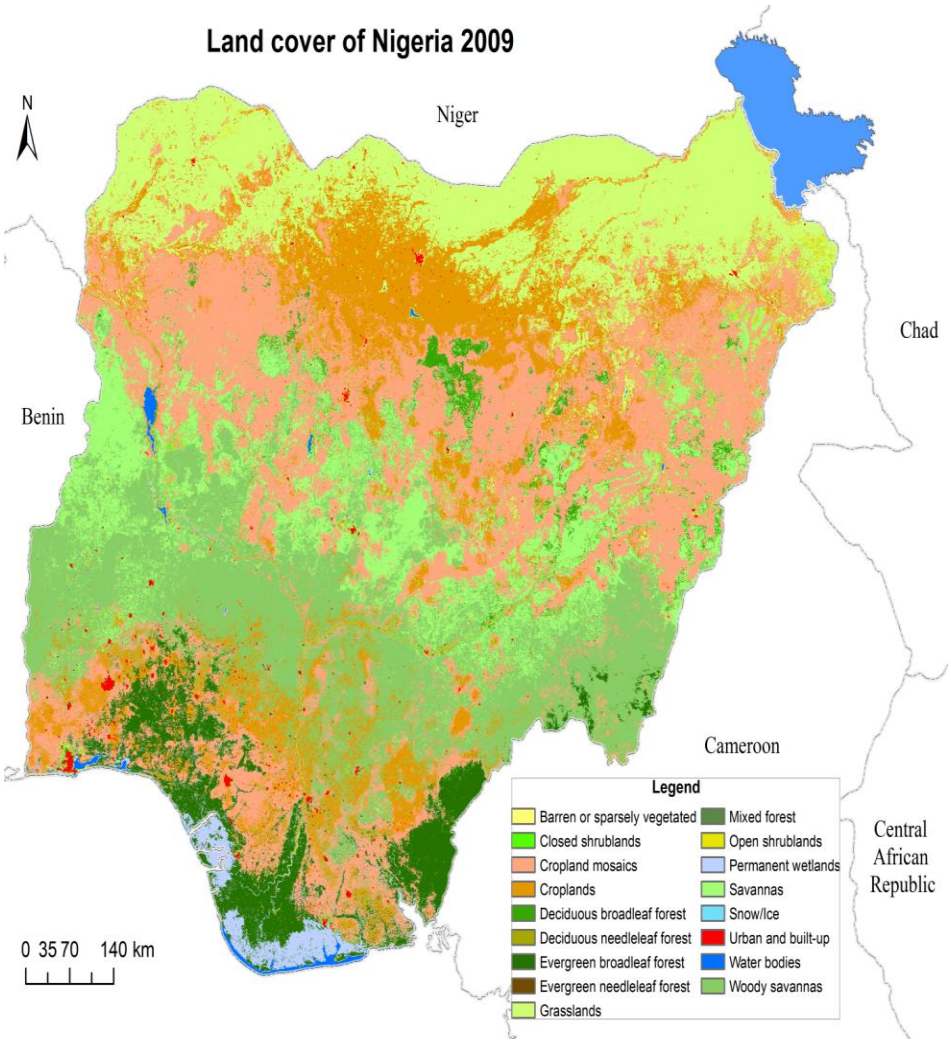


Figure 4.5: Land Use-Land Cover map for 2009

Source: GIS Analysis

4.3: LAND USE – LAND COVER CHANGES FROM 2001 TO 2009

The changes in the land use- land cover classes over the three dates are presented by showing the magnitude of change and percentage change of the land use- land cover classes over the years. The annual rate of change of each land use- land cover over the period is also presented.

4.4. MAGNITUDE, TREND (PERCENTAGE CHANGE) AND ANNUAL RATE OF CHANGE (2001-2009)

The change magnitude, percentage (trend) and annual rate of change from 2001 to 2009 is presented in table 4.2. The primary LULC changes between 2001 and 2009 are also pictorially shown in Figures 4.6 to 4.11.

INSERT Table 4.2: The change (magnitude, trend and annual rate) 2001 - 2009

4.4.1: Magnitude Change (2001, 2005 and 2009)

From table 4.2, the magnitude change in the area of waterbodies between 2001 and 2005 was -55661ha, the magnitude change between 2005 and 2009 was -70644ha and between 2001 and 2009 it was -126305ha. This shows that the water body has been on the decrease between the years.

The magnitude change in the forest cover was -2462865ha meaning a decrease in the magnitude between 2001 and 2005, it decreased again (-848932ha) between 2005 and 2009 while it was also a decrease (-3311797ha) between 2001 and 2009.

The magnitude change in the savanna primary class between 2001 and 2005 was -10877699ha which means a decrease in the magnitude, it was 3543392ha between 2005 and 2009 which

means there was an increase in the magnitude of the savanna while the overall magnitude change between 2001 and 2009 was a reduction in coverage (-7334307ha).

Between 2001 and 2005, the wetland increased in magnitude by 428888ha, it also increased between 2005 and 2009 by 97948ha while between 2001 and 2009 it increased by 526836ha.

The magnitude change in farmland coverage between 2001 and 2009 was an increase in size of 10396134ha, it also increased by 13127237ha between 2001 and 2005 while there was a decrease (-2731103ha) between 2005 and 2009.

For barren lands, the magnitude change between 2001 and 2005 was a decrease (-87452ha), it increased by 7427ha between 2005 and 2009 but also decreased (-80025ha) between 2001 and 2009.

4.4.2: Trend between the years (2001, 2005 and 2009)

From table 4.3, the trend follows the pattern of the magnitude change with waterbodies having -11.48, -16.46 and -26.05 between 2001 and 2005, 2005 and 2009 and from 2001 to 2009 respectively. It was a decreasing trend between the years. The same decreasing trend continued for forest resource at -26.05, -12.14 and -35.03 for 2001-2005, 2005-2009 and 2001-2009 respectively.

The trend for savanna cover was -21.42 between 2001 and 2005, 8.88 between 2005 and 2009; and -14.44 between 2001 and 2009. It was a decreasing trend.

The Wetland trend between 2001 and 2005 was 44.14; it was 6.99 between 2005 and 2009 and 54.23 from 2001 to 2009. It was an increasing trend.

The trend between 2001 and 2005 for farmland LULC was 46.34 while the trend was a decreasing one (-6.59) between 2005 and 2009 but it increased in trend (36.70) between 2001 and 2009.

For the barren cover, it was a decreasing trend. The 2001-2005 trend was -15.09; the trend was 1.51 between 2005 and 2009 while it was -13.80 between 2001 and 2009.

4.4.3: Annual change (2001, 2005 and 2009)

From table 4.3, it can be observed that some LULC classes continued to decline in their annual rate area coverage since 2001 to 2009. These LULC classes are waterbodies (-2.87, -4.11, -6.51) and forest (-6.51, -3.04, -8.76). Some LULC classes had fluctuating area coverage based on their annual rate of change; such LULC classes include grassland (-5.36, 2.22, -3.61), wetlands fluctuated but it increased all through (11.04, 1.75, 13.56), farmlands (11.58, -1.65, 9.17) and barren lands (-3.77, 0.38, -3.45).

4.5: LAND USE-LAND COVER TRANSFORMATION

The transformation of land use-land covers from one particular type to another was generated from the GIS analysis to know which particular class has lost or gained from the other. This is achieved by developing a transition probability matrix of land use change from time one to time two, which shows the nature of change.

4.5.1: Contingency matrix of change

Tables 4.3, 4.4 and 4.5 show the contingency matrices of LULC changes of 2001-2005, 2005-2009 and 2001-2009. The diagonal figures on the tables represent the static land cover while other figures represent the matrices of change from one land cover class to another.

INSERT TABLE 4.3 HERE

INSERT TABLE 4.4 HERE

INSERT TABLE 4.5 HERE

The record (row) totals indicate the areal extent of each LULC class in initial period (t^1) and the field (column) totals represent the area of each LULC class in present period (t^2). In other words, reading down each row of the table indicates the transition (loss) of the row header class into other LULC classes in year t^2; and reading down each column indicates the transition (gain) from each LULC class to the column header class in year t^2. In simple term, the column represents gains from other LULC classes to the column header, while the row represents loss of row headers to other LULC classes. The frequency of land transformation from the contingency matrices (tables 4.3 to 4.5) shows that the study area experienced rapid LULC transformations within the period under investigation.

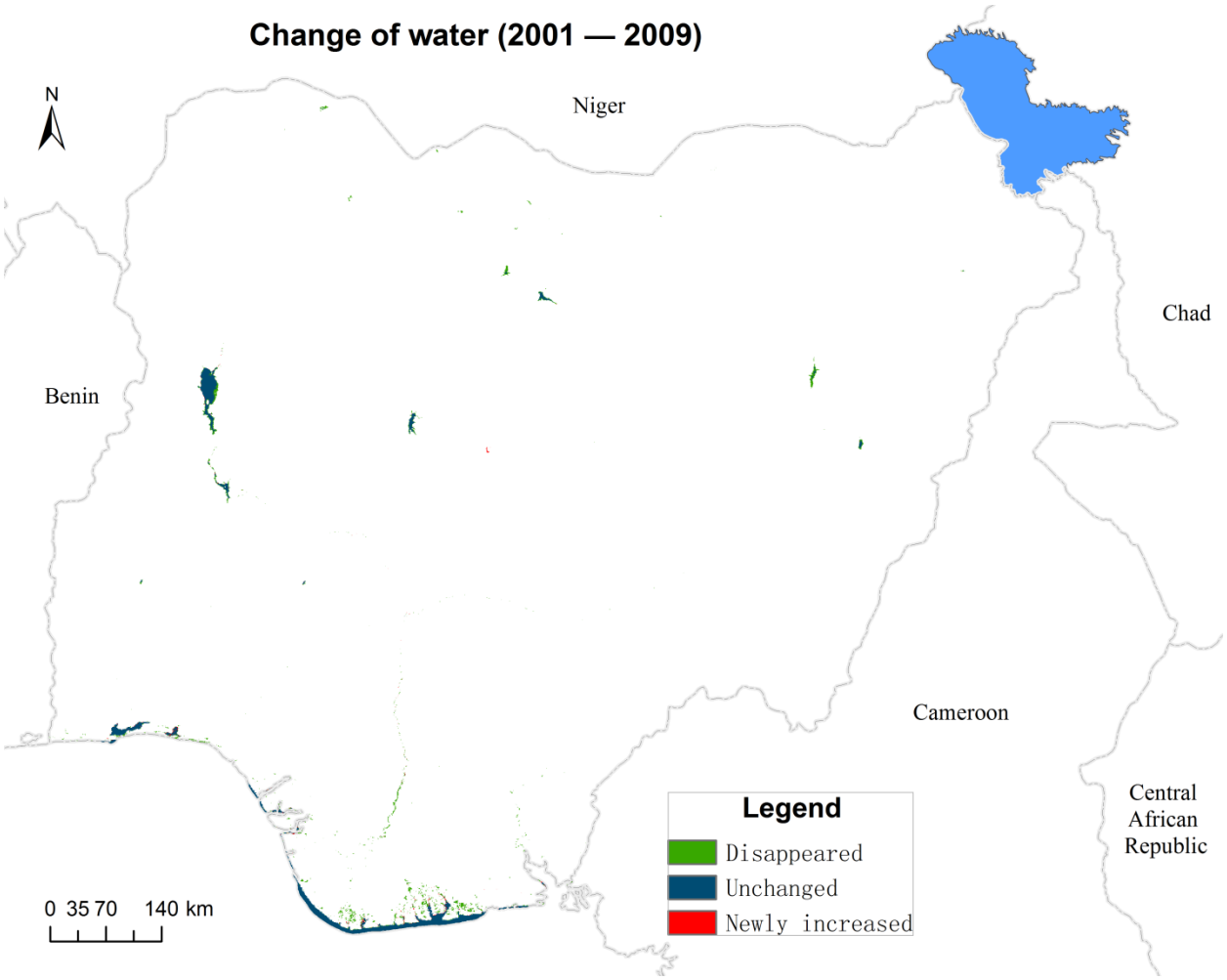


Figure 4.6: Change in water LULC (2001-2009)

Source: GIS Analysis

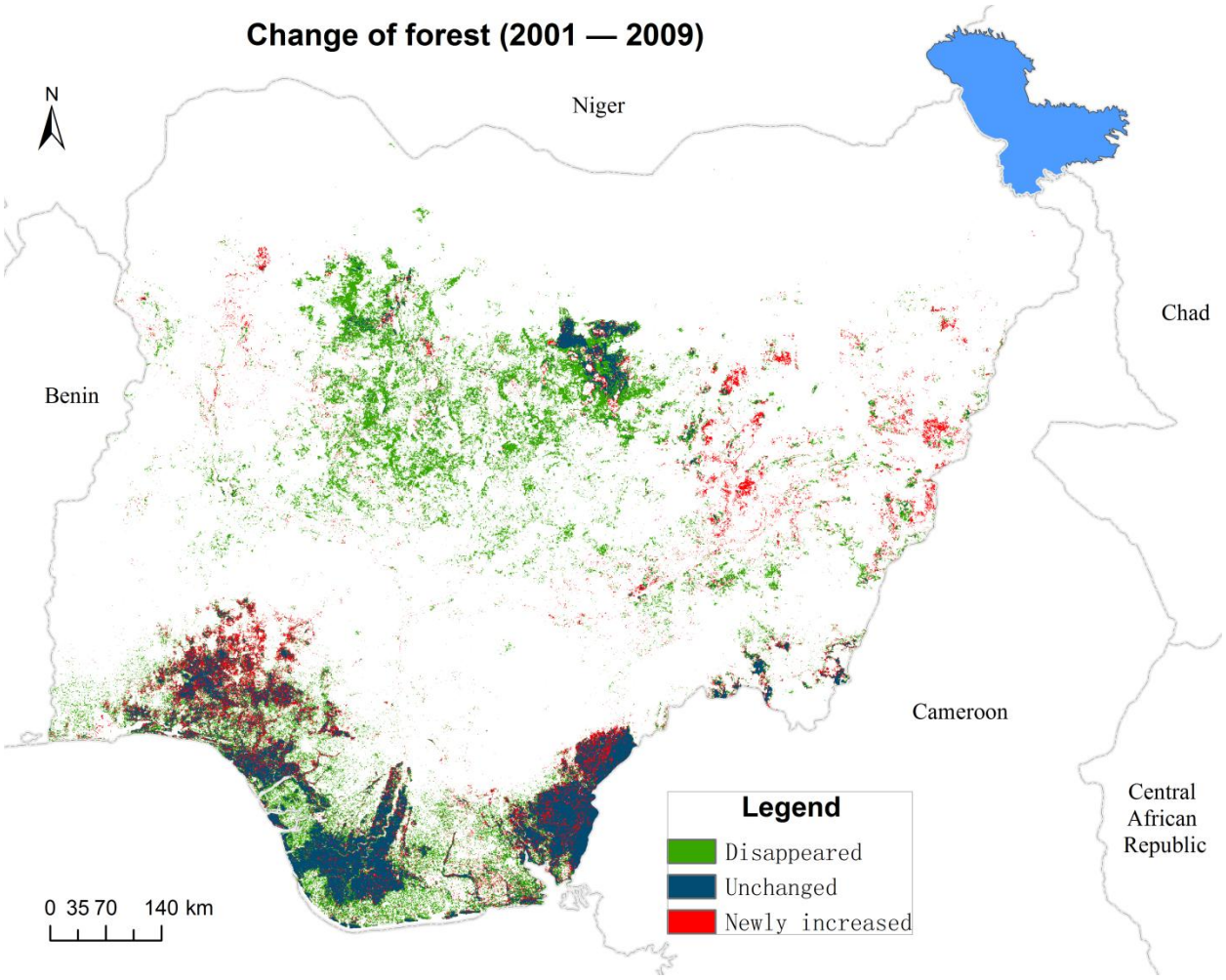


Figure 4.7: Change in forest LULC (2001-2009)

Source: GIS Analysis

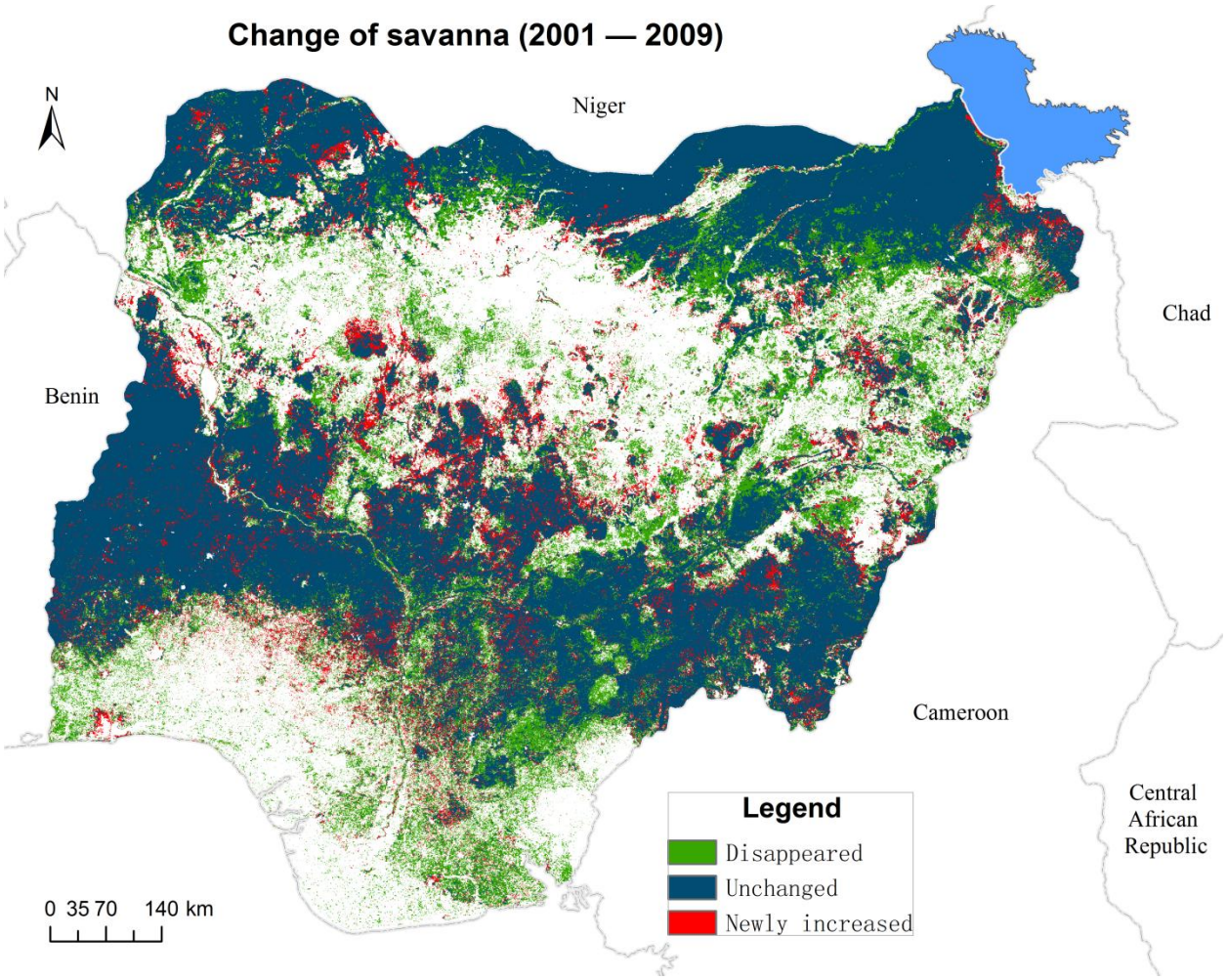


Figure 4.8: Change in savanna LULC (2001-2009)

Source: GIS Analysis

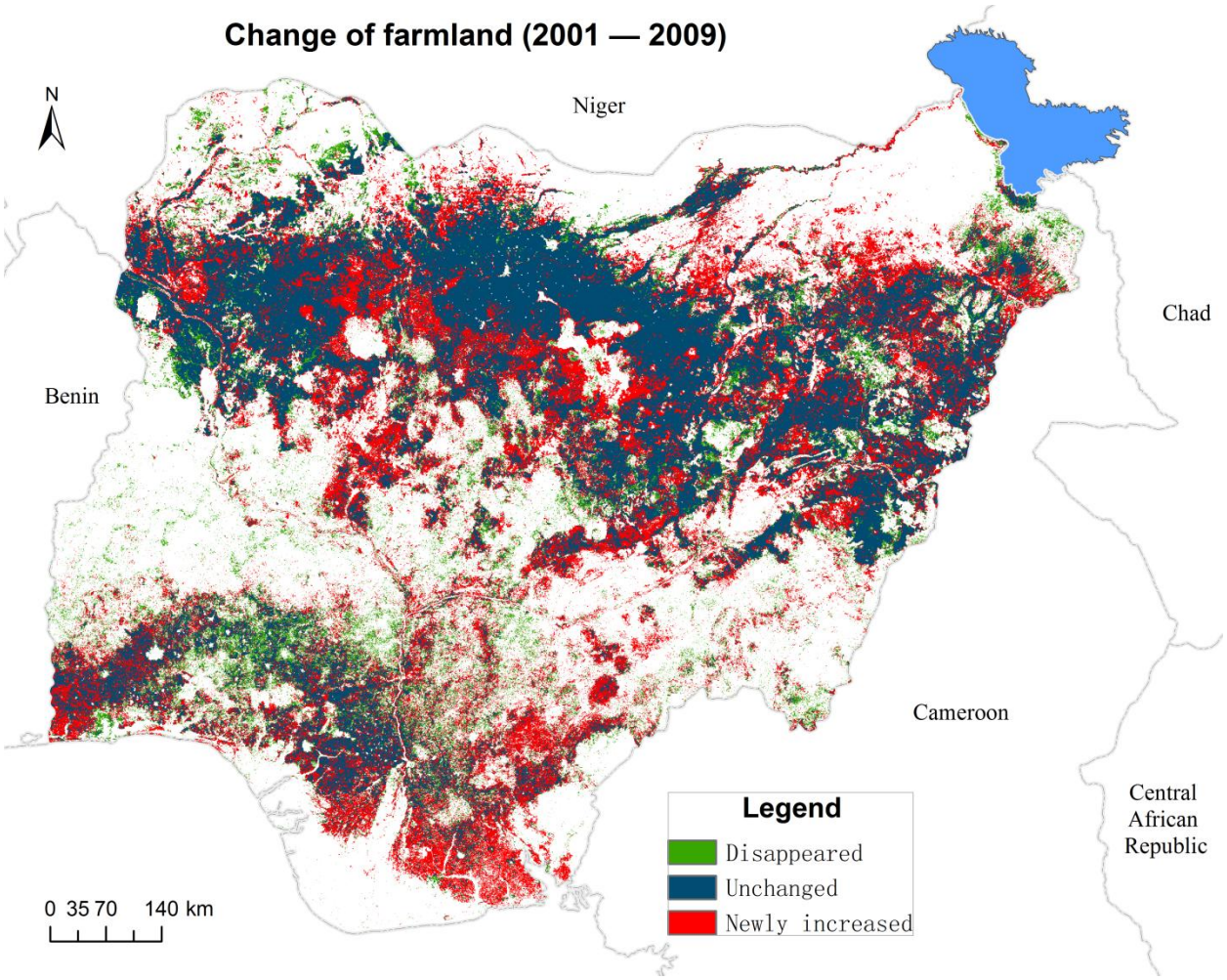


Figure 4.9: Change in farmland LULC (2001-2009)

Source: GIS Analysis

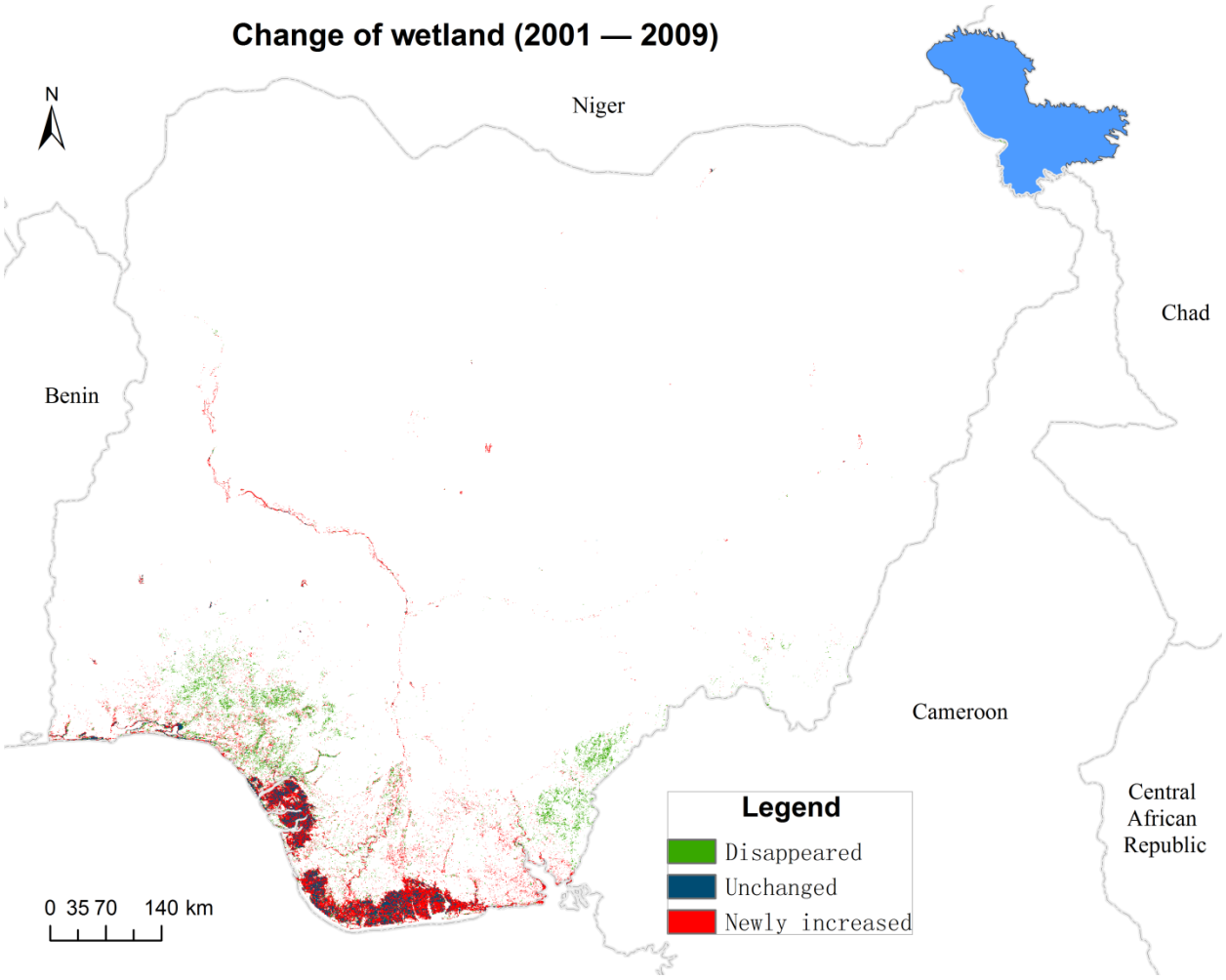


Figure 4.10: Change in wetland LULC (2001-2009)

Source: GIS Analysis

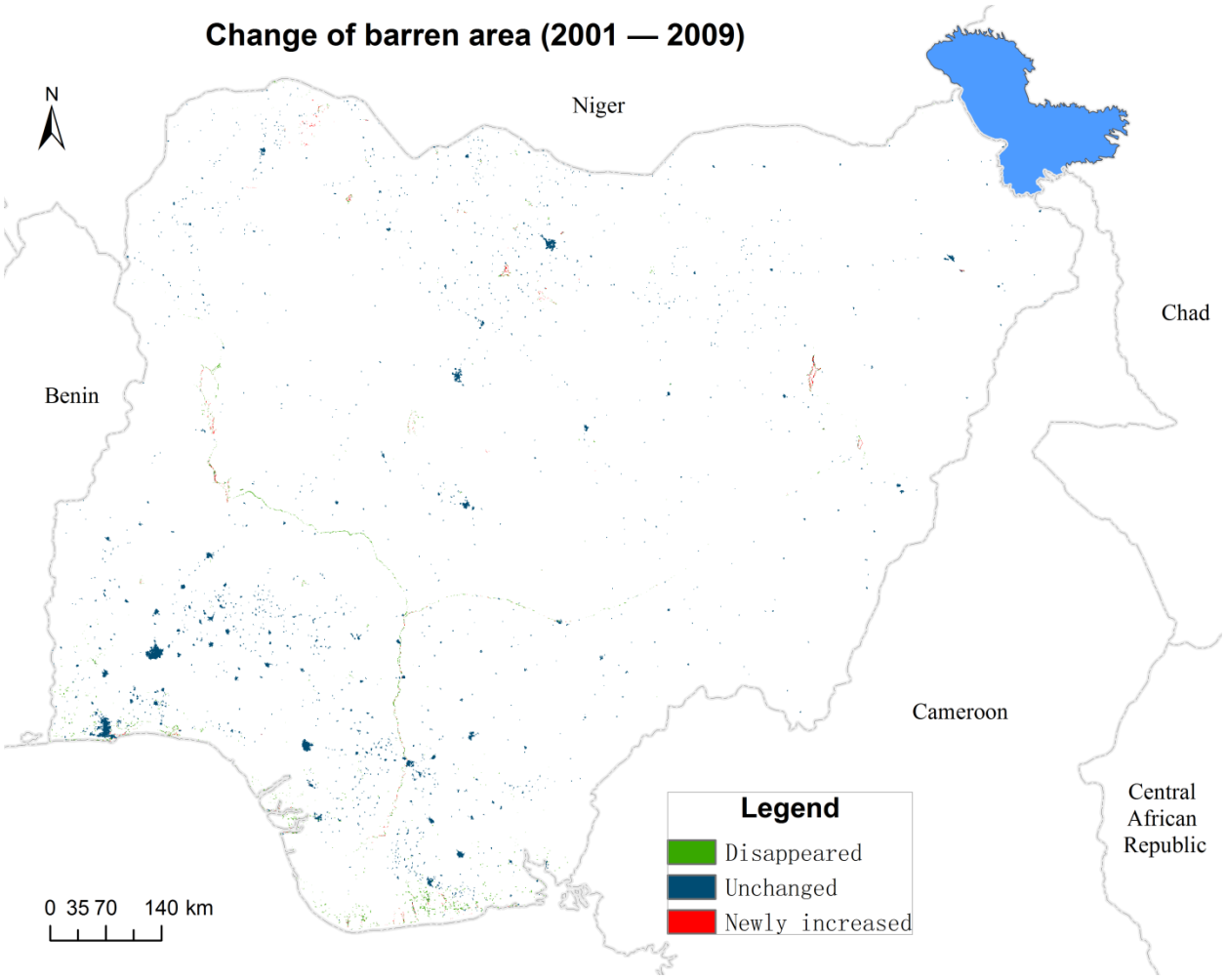


Figure 4.11: Change in barren LULC (2001-2009)

Source: GIS Analysis

4.6: CLASSIFICATION ACCURACY FOR THE LAND USE-LAND COVER

Confusion matrix from the 180 checkpoints collated on the field to validate the accuracy of the LULC data for 2009 was generated. Indices for errors of omission and commission were calculated using the omission and commission error method used by Jensen (1986).

Anderson, *et al*., (1976) were of the opinion that the overall accuracy of LULC maps for natural resource management should be around 85% and it must be approximately equal for most categories. The overall accuracy evaluates the relationship between the Remote Sensing derived map and the assumed true map in total area in each land use category. However, it does not provide for compensating errors that occur in the various categories (Jensen, 1986) Specific errors of omission and commission on each land use classes are required to compliment the overall estimated map accuracy. Table 4.6 summarizes the confusion matrix statistics.

The overall accuracy is given by: *(n/N)*100*……*4.1*

Where n=producer's number of correct points, and N=total number of checkpoints.

Table 4.6: Statistics for Confusion Matrix

Variables	Percentage
Average	11.10
Average commission error (Confusion)	9.07
Average user accuracy	88.90

Average producer accuracy	90.98
Overall Map accuracy	87.35
Tested overall accuracy	84.62

Source: Generated from GIS confusion matrix

From table 4.6, the overall map accuracy is 87.35% with the average omission and commission errors being 11.10% and 9.07% respectively. The average user accuracy and average producer accuracy were 88.90% and 90.98% respectively. The implication of this statistics is that the overall map accuracy of 87.35% was adequate for the research considering the fact that Anderson et *al* (1976) stipulated 85% as required accuracy minimum for a research of this nature.

4.7: LAND USE - LAND COVER PROJECTION

The LULC projection for the future was done using Markov chain model incorporated in the Arc GIS software. The change between 2001 and 2009 was used as the basis for the prediction. The result generated is shown in table 4.7 and also represented in Figures 4.12 (a-f).

INSERT Table 4.7: LULC prediction (2010-2020)

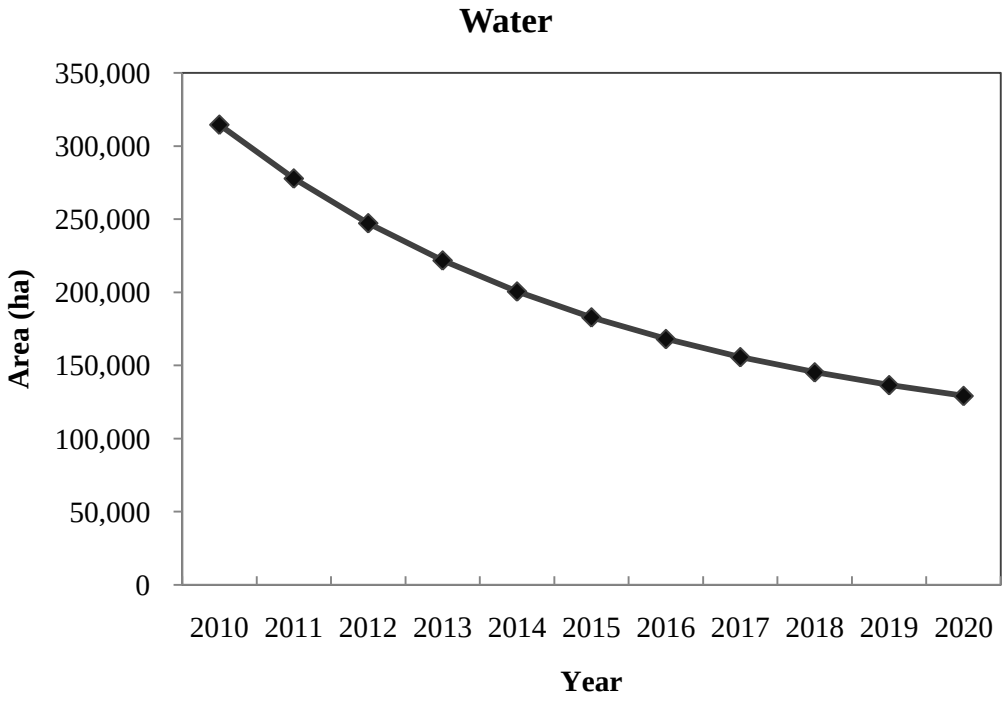


Figure 4.12a: Waterbodies LULC prediction (2010-2020)

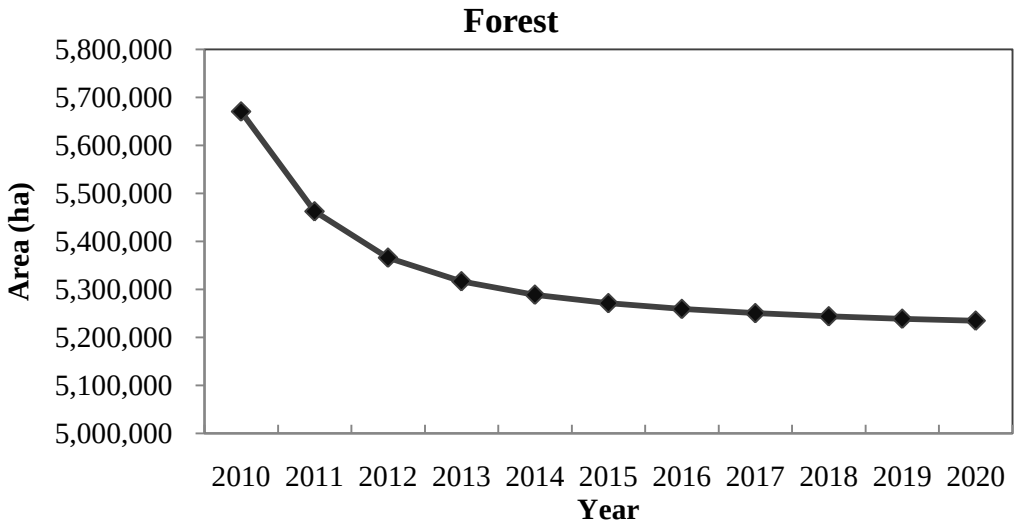


Figure 4.12b: Forest LULC prediction (2010-2020)

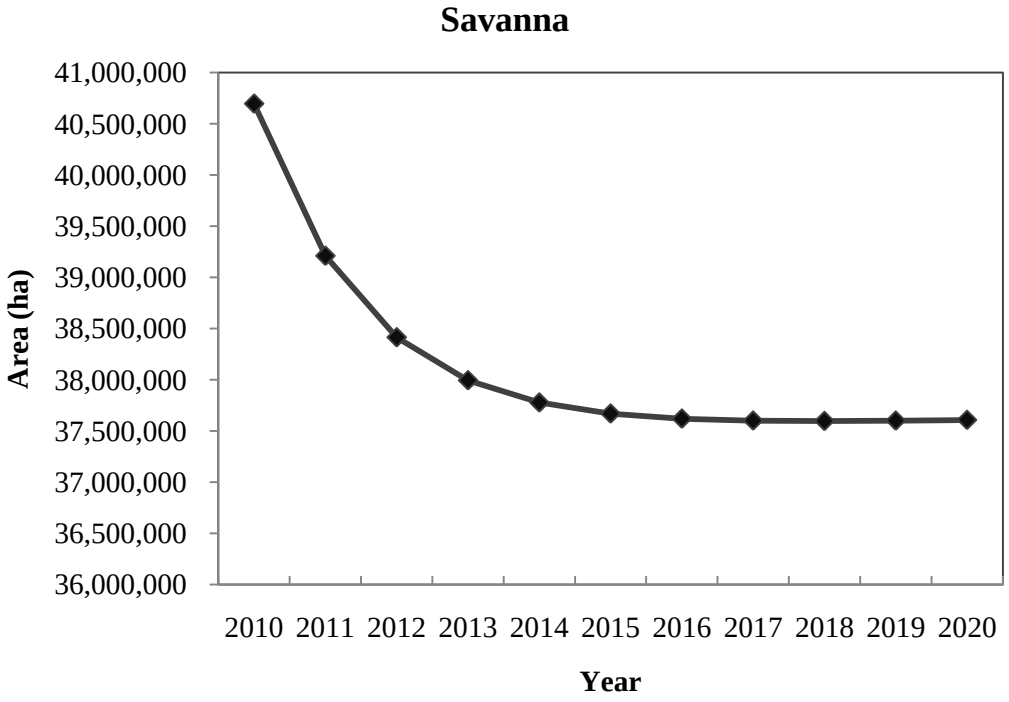


Figure 4.12c: Savanna LULC prediction (2010-2020)

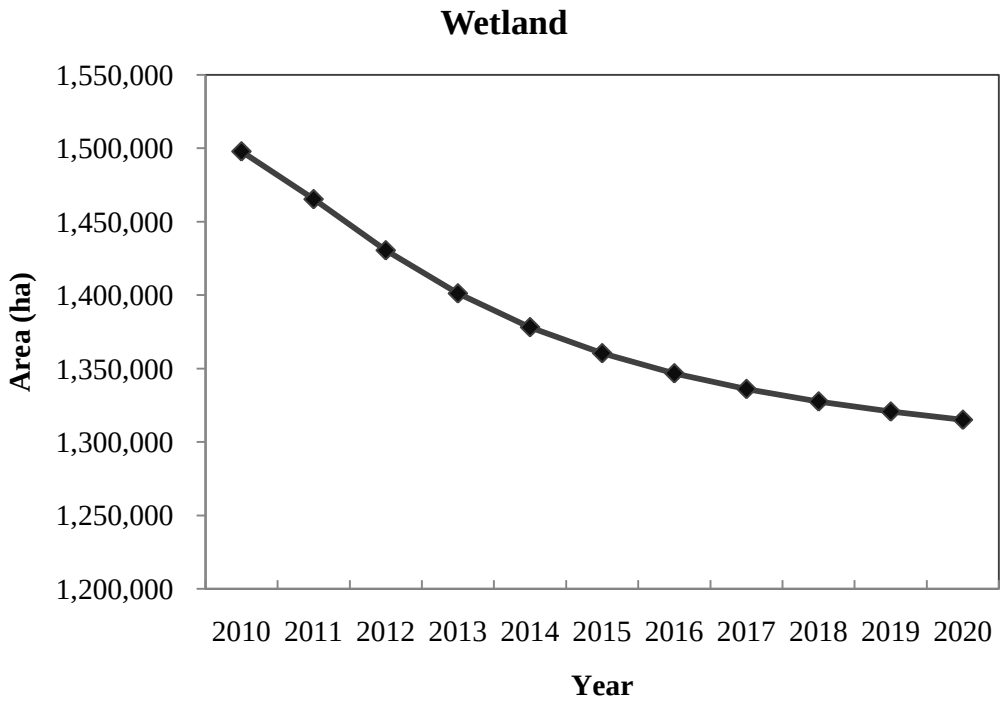


Figure 4.12d: Wetland LULC prediction (2010-2020)

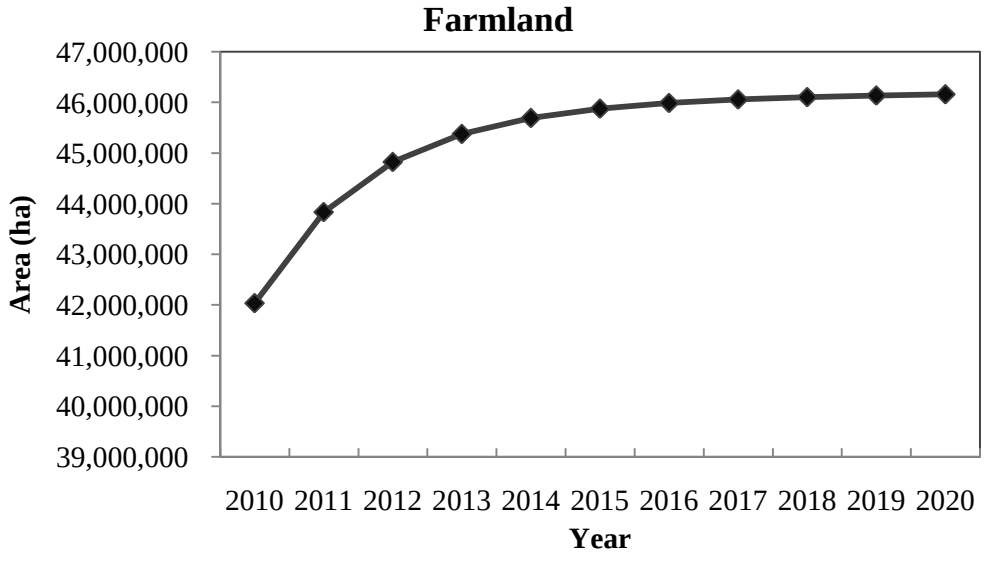


Figure 4.12e: Farmland LULC prediction (2010-2020)

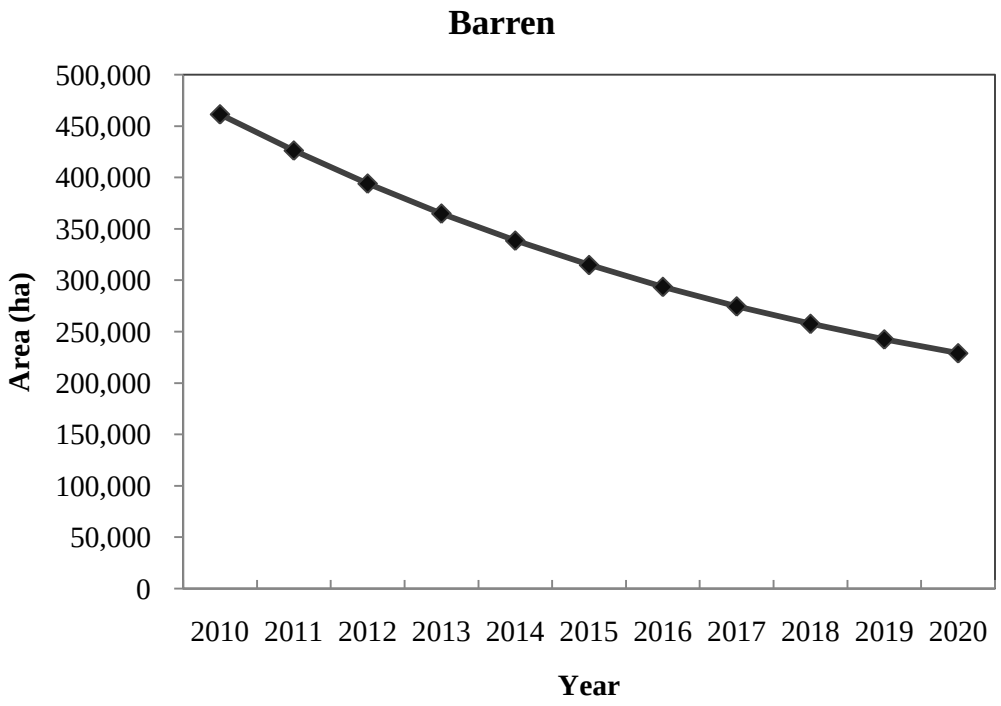


Figure 4.12f: Barren LULC prediction (2010-2020)

From table 4.7 and figures 4.12 (a – f), it can be observed that using the 2001-2009 change scenario as the basis in Markov chain analysis model, all the primary LULC types would decrease in area coverage from 2010 to 2020 except the farmland that would increase in area coverage. This sends a very alarming danger to the planners and environmentalists that a lot of work needs to be done fast to stem the impending implications for the study area and its inhabitants.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1: SUMMARY

The study was to examine the LULC over Nigeria between 2001 and 2009, the Land use-land cover changes that have taken place within the periods and the implications the land use-land cover changes had on the study area. The study used Combined Terra and Aqua MODIS land level 3/level 4 yearly tiled products, MCD12Q1-level 3 yearly land cover type at the scale of 250m. This data was accessed from NASA and processed using ArcGIS 9.3 software to establish the land use-land cover situations for 2001, 2005 and 2009 and subsequently the changes that have taken place between 2001 and 2009. The impact of the changes was also looked at especially in the field during the ground truthing. The future pattern of the LULC of the study area was also examined up till 2020.

5.2. KEY FINDINGS

Findings in the study area have shown a significant spatio-temporal variation in the rate of gain and loss amongst the different land use-land cover categories. But of utmost relevance is the near complete loss of the study area's ecological biodiversity.

- There was continuing decrease in the waterbodies from 0.53% coverage in 2001 to 0.47% in 2005 which further decreased to 0.40% in 2009. This poses serious implications for agriculture in terms of food security, water availability for different uses and infrastructural development in term of electricity. It also has a serious implication for survival and livelihoods on the communities that depend on aquaculture and irrigational farming.

- The results obtained from the research indicate rapid loss of natural resources especially forest and savanna which have severe implications for livelihoods and vulnerabilities of

communities and also for the environment. Savanna was being decimated at the rate of 4% while the forest of the study area was being decimated at the rate of about 9% per annum between 2001 and 2009.

- The loss of forest and grassland is an indication of disturbance and consistent perturbations created by pressure on the existing ecosystems leading to reduction in soil nutrients, decrease resilience and stability and loss of agricultural lands.

- The steady decline in wetland from 2010 to 2020 in the future prediction could spell a serious calamity due to inundation and loss of small lakes and ponds considering the fact that the loss of the ecosystem constitutes severe degradation and increases the vulnerability of people to disaster especially those whose livelihoods are dependent on the wetlands.

- It was discovered during the ground truthing that the major drivers of LULC changes as evidenced on the field were human and human accelerated factors such as logging, farming, lumbering and climate change effects.

5.3: CONTRIBUTION TO KNOWLEDGE

Having gone through several literatures, it could be said that:

- This research is the first in the study area to combine Remote Sensing and GIS techniques to investigate LULC changes, LULC transformation and even future prediction of the LULC scenario up till the year 2020.

- By using the trans-disciplinary approach, the research has contributed to the strengthening of the relationship between the field of resource management and its allied disciplines including Geography, Remote Sensing, Environmental management and GIS.

- The research generated critical environmental information and data layers that can be developed into an environmental databank and information systems for natural resource management, disaster management, risk assessment, and management of critical areas, land degradation hotspots and disaster-vulnerable zones in the study area

5.4: CONCLUSION

The research has highlighted the LULC patterns from 2001 to 2009 using MODIS satellite images to produce maps and the statistics of the study area. The changes in LULC for the study area over the period 2001 and 2009 has also been examined and therefore a prediction of the scenario of the study area from 2010 t0 2020 has also been done. The study has also brought out the nexus between LULC, LULC change, environmental perturbation, natural resource loss and the impacts of the changes on the people of the study area thereby making them to be vulnerable. It has also shown the efficiency and effectiveness of trans-disciplinary approach to examining environmental problems with the use of strongholds of Remote Sensing and GIS. It has also demonstrated the link between various LULCs in such a way that what happened to one LULC

type invariably was happening to another or sets of LULC types and that the impact in an area could spin off in several other areas. For example, the loss of fishing pond or lake leads to forced shift in occupation and sources of livelihood and opening of new lands for other livelihood sources including farming and logging. In addition, the movement of people from a degraded LULC also leads to establishment of settlements together with the transfer of human activities to another LULC probably still fertile or yet to be degraded. From the above therefore, this means that a holistic approach to the investigation of LULC and LULCC that incorporates all the basic connectives is better and this can only be achieved through investigations that utilize trans-disciplinary approach to researches which is key to sustainable science.

Lastly, this study has shown that one key reason while policies, legislations, conventions, frameworks etc on the environment and natural resource monitoring has not yielded positive results in Nigeria is because the government agencies as enforcers lack the needed data and tools required to appraise and monitor the situation on the field. Hence, standards are set without indices to monitor activities on the ground. This is a key issue which needs to be addressed before sustainable environment and natural resource management can be a reality in Nigeria.

5.5: RECOMMENDATIONS

Based on the strength of the findings of this study, the following recommendations to entrenching sustainable environment, natural resources and disaster management in the study area are proposed:

- There is the need for ecosystems restoration for areas that have suffered terrible degradation.

- The population presently knows that things are no longer the same as they used to be. But much more than this, they must be made to be aware and fully understand the current state of change in the environment through information.

- The local communities are presently implementing the only adjustment mechanism they know which is to move away from degraded LULC. But local ingenuity, indigenous technology and know-how, and local community-centered efforts should be made and supported to restore the environment.

- The tacit, informal and experienced based old "natural" community instinct needs to be rekindled to safeguard forest loss and maintain green countryside. Information, education and incentives should also be provided to stimulate the interests of the local communities in reforestation and sustainable farming activities.

- There is urgent need for the governments through appropriate MDAs to embark on data gathering on critical environmental variables through in-situ and field measurements. Remote sensing and GIS with the view to developing an integrated comprehensive databank and information systems for environmental monitoring and natural resource management. A synergy of efforts by all relevant MDAs is recommended to eliminate waste of resources, time and man-hour.

- Legislations compelling environmental protection, restoration and remediation need to be enforced.

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