AN ASSESSMENT OF THE IMPACT OF THE GROWTH OF ZARIA ON THE SURROUNDING VEGETATION COVER

BY

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DECLARATION

I declare that the work in the thesis titled "**An assessment of the impact of the growth of Zaria on the surrounding vegetation cover**" has been carried out by me in the Department of Geography, Ahmadu Bello University, Zaria, under the supervision of Professor I.A.Jaiyeoba and Dr. B.A. Sawa.

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

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CERTIFICATION

This thesis titled "AN ASSESSMENT OF THE IMPACT OF THE GROWTH OF ZARIA ON THE SURROUNDING VEGETATION COVER" by Michael, Grace Uhwache meets the regulations governing the award of the degree of Masters of Science of Ahmadu Bello University Zaria, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

To the eternal memory of my Sister Mrs. Hannah-Michael Ambrose Zamani who had a zeal and desire for education. You left in the middle of your course work, May your gentle soul rest in peace, Amen.

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ABSTRACT

Anthropogenic drivers such as urbanization and economic dependence have been a major force shaping various landscapes. Zaria town is no exception of such landscapes. This study is aimed at an assessment of the impact of the growth of Zaria town on the vegetation covers of the surrounding region. The objectives were to map out and analyse the land use and land cover of the area, derive the vegetation cover index (NDVI) from the multi-temporal data set, correlate the city expansion rate with the vegetation cover index, and assess the current status of woody biodiversity in the study area. The study area is within 20km radius around Zaria. The first part of the study employed remote sensing and Geographic Information System techniques to analyze the general land use/land cover of the area using four data sets: Land sat MSS (1973), Land sat TM (1990), Land sat ETM (1999) and NigeriaSat -1 (2009). The results of the land use/land cover analysis showed that the built-up area expanded from 44km^2 in 1973 through 69km^2 in 1990 and 81km^2 in 1999 to 130km^2 in 2009. The cultivated land also showed a general increase trend over time from 409km^2 in 1973 to 433km^2 in 2009. While the forested land showed a decrease, from 89km^2 in 1973 to 63km^2 in 2009. Using the NDVI results, it was found out that 'Dense vegetation' (NDVI classification value of 0.51 to 0.96) decreased from 206 km^2 in 1973 to mere 37 km^2 in 1990. It subsequently increased to 88 km^2 in 1999 then to 134 km^2 in 2009. On the other hand, the 'No vegetation' (NDVI classification value of -0.95 to 0.00) steadily increased from 1,168 km^2 in 1973 to 1,736 km^2 in 2009. The second part of the study involved field survey to determine the physiognomic characteristic of tree species in the study area. Overall, 161 tree stands belonging to 23 species were enumerated over the 25 (50 by 50 m) sample plots covered in the study. The dominant species found among others species are *Khaya senegalensis* (45 trees). This was followed by *Mangifera indica (*26 trees)*, Azadirachta indica,* (17 trees) and *Adansonia digitata,* (14 trees). When the differences in the number of trees amongst the various land uses were subjected to analysis of variance, the results showed highly significant value at greater than 0.05 level. It was also noted from the field survey that, the plantation/ forest area recorded the highest average tree stand of 23.5. This was followed by the fadama/wetlands with an average of 8 tree stand. The built-up area has an average of 7 tree stand and the cultivated lands 5. The scrubland has the least average of 1.6 tree stand. With respect to the other vegetation characteristics, the built-up areas, plantation/forest and the fadama/wetland have comparatively higher mean values for tree height, DBH, biomass and basal area. The result of ANOVA shows that the differences in most of the measured parameters of the woody species amongst the land uses are statistically significant at 0.05 level. It was concluded that the expansion of Zaria town posed a formidable threat to biodiversity in the region and strategies to improve forest conservation in the region are urgently needed.

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ACRONOYMNS AND ABBREVIATIONS

ANOVA – Analysis of Variance

CAD – Computer Aided Device

CBO – Community Based Organisation

CCTA – Colorado Conservation Tillage Association

CEC – Cation Exchange Capacity

DBH – Diameter at Breast Height

EMS – Electromagnetic Spectrum

ERDAS – Earth Resources Digital Analysis system

ETM – Enhanced Thematic Mapper

FAO – Food and Agriculture Organisation

FOS – Federal Office of Statistics

FEPA – Federal Environmental Protection Agency

FRN – Federal Republic of Nigeria

GIS – Geographic Information System

GPS – Global Positioning System

HDI – Human Development Index

ILWIS – Integrated Land and Water Information System

ITD – Inter Tropical Discontinuity

LGA – Local Government Area

LST – Land Surface Temperature

LULC – Land Use Land Cover

MLC – Maximum Likelihood Classifier

MSS – Multispectral Scanner

NCRS – National Centre for Remote Sensing

NDVI – Normalized Difference Vegetation Index

NEEDS - National Economic Empowerment and Development Strategy

NEST – Nigeria Environment Study/Action Team

NIR – Near Infrared

NPC – National Population Commission

$_{pH}$ – Hydrogen point

PZ – Paterson Zachonis

SAP – Structural Adjustment Programme

SD – Standard Deviation

SPSS – Statistical Package for Social Sciences

SWC – Soil and Water Conservation

TC – Tropical Continental

TM – Thematic Mapper

TM – Tropical Maritime

UN – United Nation

UNCED – United Nation Conference on Environment and Development

UNCHS – The United Nations Centre for Human Settlements

UNDP - United Nations Development Programme

UNEP - United Nations Environment Programme

WCED – World Commission on Environment and Development

WSSD – World Summit on Sustainable Development

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

As defined by the Webster dictionary, urbanization refers to the social process whereby cities grow and societies become more urban. Urbanization relates to the shift from a rural to an urban society, and involves an increase in the number of people in urban areas during a particular year (Brennan, 1999). It is the process of altering land uses to create and further develop urban centres. It is the progressive concentration of population in towns and cities. At the regional end, the process proceeds in two ways, namely, through an increase in the number of towns and as a result of the increase in the size of individual towns. Although urbanization is a universal phenomenon, the definition of an urban centre differs from one country to another, and even within the same country, and over time. The 1991 census in Nigeria, for example, defined an urban area as any settlement with 20,000 persons or more (NPC, 1998).

The most obvious effect of urbanisation - an effect which is implicit in its definition is an intensification, as well as diversification, of environmental resource exploitation. There are usually changes in the land cover and landscape pattern brought about by the shift from less intensive to more intensive uses of land. This relates, particularly, to energy, water and agricultural land, as well as basic construction materials, such as sand, clay, stone and wood, all of which are extracted from the environment (Carvalho and Prandini, 1998). Nearly always, however, such diversification of environmental resources exploitation is accompanied by an increase in environmental degradation. By environmental degradation, it is meant the long-term loss in ecosystem function and productivity. Its symptoms include

soil erosion, nutrient depletion, salinity, water scarcity, pollution, disruption of biological cycles, and loss of biodiversity. Urban land degradation obviously is more marked in developing countries, which are characterized by high and largely uncontrolled urbanization rate. This is a global development and environmental issue recognised by the UN Convention to Combat Desertification, the Conventions on Biodiversity and Climatic Change, and the Millennium Goals (UNCED, 1992).

Within the global context, Africa is generally assessed as a rural and the least urbanized continent, with the antecedent high rate of slum development, crime, underdevelopment as well as overpopulation (UNCHS, 2007). However, in most recent time, current trends suggested that Africa's rate of urbanization is two times faster than Latin America and Asia (Tannerfeldt, 1995; UNCHS, 2007). Globally, rapid urbanization is a major public and environmental health challenge for the twenty-first century. In Africa, urbanization appears not to have translated to both proportionate economic growth and better welfare for the citizens or healthy environment (Kjellstrom and Mercado, 2008). For instance, out of the twenty countries identified by the United Nations as possessing the lowest Human Development Index (HDI) in 2005, about 19, representing 95 percent, are in Africa. Conservative estimates indicated that within the next two decades, 87 percent of the population growth in Africa will take place in urban areas, out of which about 55 percent would be living in urban areas (Daramola and Ibem, 2010).

In view of the implications of the increasing urban population for sustainable development in developing countries, the 2002 Johannesburg's World Summit on Sustainable Development (WSSD) called on all governments to address the overwhelming challenge of not only provision of urban basic services, but to take concrete measure at redressing

environmental degradation that has already occurred while conserving remaining resources. While continents like Europe and the Americas have stabilised their population growth and economy to a large extent, and to strive to containing environmental degradation, most countries in Africa, Asia and Latin America have, in the last few decades, not been able to do so (UNHABITAT, 2003).

Thus, while urbanization is the driving force for modernization, economic growth and development, there is yet an increasing concern about the effects of expanding cities, principally on human health, livelihoods and the environment (UNHABITAT, 2003). Rapid urbanization, particularly the growth of large cities, is often associated with problems such as unemployment, poverty, inadequate health facilities, poor sanitation, urban slums and general environmental degradation (UNDP, 2008). All these pose a formidable challenge in many developing countries. The question that arises is whether the current trend in urban growth is sustainable, considering the accompanying urban challenges, especially in the developing countries (UNDP, 2008). The need for quantitative information on the environmental consequences of expansion of cities in Nigeria, provided the basis for this study.

1.2 STATEMENT OF THE RESEARCH PROBLEM

Early accounts of Northern Nigeria, including Zaria area, suggests that there is a high level of agricultural intensification and widespread use of appropriate soil and water conservation (SWC) measures. These include for example, mixed cropping and crop rotations using legumes, a good vegetation cover on plots, minimum tillage, and avoidance of marginal lands in the region (Jaiyeoba, 2010). Such practices led to a dynamic mosaic of

croplands in the gently undulating terrain of the area. There is no doubt however, that in recent times, human activities have profoundly changed the land cover in the Zaria area.

While no comprehensive survey of land degradation in the town and environs has yet been undertaken, fragmentary information tends to suggest that soils and vegetation are degrading, and that a number of environmental problems, within and around the town, have increased in spatial extent and severity (Jaiyeoba, 2010). Prominent among such environmental problems are the discharge of domestic sewage directly into streams of the city, for example, sewage dumping, the deposition of garbage in unsuitable places, excessive soil erosion due to deforestation, etc. in places like Dogarawa, Graceland, Hanwa extension and Samaru. There is every indication that this trend will continue for a long time, if necessary precautions are not taken. The increasing population will add more anthropogenic pressure upon local lands, which, if not managed effectively, can eventually lead to further environmental degradation. In turn, such degradation can affect, and potentially slow down, if not threaten, the pace of economic development in this region.

Until in recent times, the use of geo-information technologies in the enhancement of sustainable planning and development of urban areas in Nigeria has not been adequately employed. Most fundamental and most often cited land related problems of urbanization are the encroachment of built up areas on neighbouring rural agricultural land, soil erosion and vegetation degradation, and a number of publications exist on these various aspects (Jeje, 1973).

In most of these literatures, especially those on Nigeria, less attention was focused on the use of the relatively new technology - the Geographic Information System (GIS), and its

complimentary technologies. The focus of most existing researches in the country is on the magnitude of these problems from some selected spots of the urban and suburb environments (e.g. Okoye, 1988; Jeje, 2005; Jimoh, 2005 among others). Although the contributions of these studies to literature on land use and planning in Nigeria are noteworthy, their methodological approach of micro scale survey of point-based location from which generalization were made without necessary or adequate interpolation of the point-based (discontinuous) data sets, were severely defective. This no doubt is probably because technologies for interpolation that are now imbedded in the newer paradigm of GIS (as available in software such as ILWIS, ArcGIS, and ArcView among others and third party software like Surfer, CAD) were not known, affordable or unknown, as at the period that such researches were conducted. Kufoniyi (1995) noted, for example, that implementing GIS and the complementary technologies in Nigeria between 1960 and early 1990s was confronted by inadequate knowledge, poor finance, inadequate technical expertise and poor managerial efforts.

Remotely sensed data has become a spectacularly useful tool for mapping natural resources, including vegetation, and land use/ cover changes over geographical areas by overcoming many limitations of traditional surveying techniques to obtain a continuous and extensive inventory of ecosystems (Ridd and Liu 1998; Ward *et al.* 2003; Rogan and Chen 2004; Gillanders *et al*. 2008; Torres-Vera *et al*. 2009). With the use of remote sensing, it is possible to map and monitor the spatial extent of various factors influencing and contributing to environmental degradation in urban areas, such as changes in vegetation cover, impervious surface, land use type, and human activities. Remotely sensed data can also provide the necessary area-based land use/cover parameters to run different urban

change models as well as plausible scenarios used to simulate future response to different planning/management scenarios (Clarke and Gaydos 1998; Veldkamp and Lambin 2001; Lo and Yang 2002; Sohl *et al*. 2007; Tang *et al.* 2007; Yuan 2008). The ability of GIS and other related land based technologies in processing of acquired data from digital surveys, aerial photographs, remote sensing to infer decision making information has led to the increasing use of the method in land administration in many part of the world (Ibiyoye and Eludoyin, 2010). Prior application of the technology in the study of the growth of urban Zaria has predominantly focused upon land use/cover patterns per se (Salleh, 2006; Abbas and Arigbede, 2011). There is therefore a paucity of research analysing the impact of land use/cover, population and city expansion, and vegetation change jointly as key urbanization factors, employing the technology.

The aim of this study is to corroborate the increasing problem of vegetation degradation in the city and environs with the town's expansion. The study hopes to explore the implications of the increasing urban expansion, spurred up by population growth, for environmental sustainability. Needless to state that the attainment of sustainable development will remain a mirage in Nigeria, the Zaria area inclusive, if the current rate of urban population growth and increasing environmental decay are not matched with proportionate economic growth and environmentally friendly development practices. To achieve this objective, quantitative, up-to-date information on rate of urban sprawl and attendant environmental impact is needed to support policy and planning for development.

1.3 RESEARCH QUESTIONS

Crucial questions that the study intends to answer, in a scientifically justifiable way, include:

i. What has been the rate and pattern of expansion of Zaria township in the past four decades vis a vis other land uses?
ii. What proportion of the cropping land has been lost to expansion of the city in the past four decades?
iii. How has the city growth specifically impacted the vegetation cover, particularly the characteristics of the woody biodiversity?
iv. What is the present status of woody biodiversity in the area?

1.4 AIM AND OBJECTIVES OF THE STUDY

The present study aims at assessing the impact of the growth of Zaria town on the vegetation cover within and around the town, using Remote Sensing and GIS techniques.

The specific objectives are to:

i. map out the land use and land cover of the area at four points in time (1973, 1990, 1999 and 2009) using multi-temporal satellite imageries.,
ii. analyse the land use and land cover changes from the multi-temporal land use and land cover data.,
iii. derive the Normalised Difference Vegetation Index (NDVI) from the multi-temporal data set.,
iv. correlate the spatial expansion rate with the vegetation cover index, and
v. assess the current status of woody biodiversity in the study area.

1.5 RESEARCH HYPOTHESES

The research hypotheses arising from the aim and objectives of the study are:

i. There are no significant changes in the rate and pattern of growth of Zaria town in the past four decades.
ii. There are no significant relationships between the rate of growth of Zaria and changes in the vegetation covers of the surrounding areas within the last four decades.

1.6 DELIMITATION AND SCOPE OF THE STUDY

The focus of this study is on the assessment of the extent to which the growth of Zaria has impacted on the vegetation cover in the area. The study entailed the use of Remote Sensing and GIS techniques for the establishment of changing pattern of the urban area, and other land uses. Remote sensing is considered an effective and efficient tool for studies of spatially distributed variables, it offers an economic and flexible means for rapid updating of maps. The time span of this study is between 1973 and 2009 (36 years). Such duration is considered sufficiently long enough to detect whatever impact might have occurred. The NDVI for the area would also be derived. This would be flowed by the actual field assessment of the characteristics of woody tree species in the area. The study area is limited to the Zaria urban area and environs. Some 20km radius around the town has been arbitrarily demarcated for the study, with PZ in Sabon Gari LGA being the centre point. The area encompasses settlements with varying degree of accessibility, while some are relatively accessible by roads along the major roads axis around the town, others are in remote locations accessible only through footpath.

1.7 JUSTIFICATION OF THE STUDY

Landscape disturbance is a common problem caused by changing land covers and landscape patterns of urbanization (Wang and Moskovits, 2001). Such disturbance could lead to low productivity of the ecosystem due to extra travel time, wasted space along borders and the inability to use certain types of facilities. Landscape complexity and heterogeneity are key aspects in assessing ecological processes and biodiversity within regions (Southworth *et al.* 2004). Past research has demonstrated that aspects of landscape pattern or structure influence the occurrence and distribution of species (Forman,1995).

Zaria has become one of the fastest growing and most populous metropolitan areas in north central Nigeria, exhibiting rapid commercial activities, urbanization, and population growth in the past three decades (Bell *et al*. 1999; Bell, 2001). At the same time, the environment is under increasing threat from human-induced and natural disasters. There are already certain problems associated with the destruction of the natural resource base upon which all life depend. Of the various environmental problems faced by the region in the present time, vegetation degradation is perhaps the most fundamental. Despite the importance of understanding the impact of past urbanization on sustainable development generally, there have been few comprehensive analyses of land-use/cover, vegetation/other natural habitats, and socio-economic change across time and space in this centrally located city of northern Nigeria. Thus, this study proposes to fill the gap in knowledge by assessing the effects of urban expansion on the vegetation cover through an integration of science based methods and indigenous knowledge of vegetation degradation assessment and management.

CHAPTER TWO

LITERATURE REVIEW

2.1 URBANIZATION AND ENVIRONMENTAL CHANGES

Urbanization is the outcome of social, economic and political developments. It entails changes in land use and the transformation from rural to metropolitan pattern of organization and governance (Gyabaah, 2003). According to Netzband and Jurgens (2010), cities emerge and evolve from the coalescence and symbiotic interaction of infrastructures, people and economic activities. These interactions are systematic, generally in that they are related to development in the global economy, and are related to the building and transport technologies. But these interactions are also sensitive to local context, in that settlements are individually resilient to constraints in their evolutionary path.

According to Ichimura (2003), over the past half century, a great rural-to-urban population movement has occurred and the process of urbanization is set to continue well into the 21st century. Major demographic evidence has indicated that, already, the Asia-Pacific region is well advanced in the transition from predominantly rural to predominantly urban societies. Although population growth rates have slowed down in many countries for the past decade, 62 percent of the world' population will live in urban areas by the year 2020, while the Asia-Pacific Region will contain about 49 per cent of that urban population and will have contained a level of urbanization of 55 percent. An additional 1.2 billion people will be living in the urban centres of the Asia- Pacific region by 2020 (Ichimura, 2003).

Africa has the lowest level of urbanization and the fastest urban growth. Currently, a little more than one third of Africans are urban dwellers. The proportion, by 2030, will be a little more than half. The urban growth rate for Africa as a whole currently is around 4.4 percent.

East Africa is growing at 5.6 percent per annum and West Africa at 5.1 percent, with individual countries growing at even higher rates. Projections show that the growth rate for Africa as a whole will stay above four percent through 2005 and above three percent until 2020-2025 (Brennan, 1999). The problem of such rapid rates of urban growth is that it makes exceedingly difficult efforts to provide needed services.

Urbanisation can be more broadly understood as a process of social and economic change which has accompanied industrial development. The environmental effects of urbanisation therefore usually include, impacts associated with the public and private activities that occur in urban areas. These activities may also occur in rural areas. However, the impacts in urban areas may be concentrated within a smaller area, or be much greater in absolute terms. Because of economies of scale, the environmental impacts of activities in urban areas may also be easier to manage cost-effectively. A typical example is the case of collection and treatment of sewage.

Urbanisation can affect the built environment, the natural environment, and human populations. Similarly, its environmental impacts may occur at local, regional and global scales. The impacts of urbanisation are highly interrelated. For example, land-use patterns within urban areas can influence transportation options, while the mode of transportation chosen by residents can affect air quality and noise levels.

With respect to the concept of environment, this has been viewed from diverse perspectives, and defined in various ways. The variety of definitions and conceptions of environment is closely linked to the fact that the study of environment is multi-disciplinary, and thus each discipline tended to develop and adopt definition(s) in line with its interest.

This multiplicity of definitions, concepts and usage of the term in various disciplines was clearly captured by Porteous (1977) when he stated that:

"the multiplicity of the usage and concept of the term environment have resulted in a variety of adjectival forms which include social environment, molar environment, physical environment home environment, psychological environment, behavioural environment geographical environment" (Porteous, 1977).

For instance, Bain, a sociologist, defined environment as all the external and non-personal conditions and influences that affect the welfare of a people in a given area (Bain, 1973). Hagget, a geographer, on the other hand, defined environment as "the sum total of all conditions that surround man at any point on the earth's surface" (Efobi, 1994), while the Federal Environmental Protection Agency in Nigeria (FEPA) stated that the environment includes water, air, land, plants, animals, and human beings living therein, and the inter-relationships that exist among them (FEPA, 1989). However, a more comprehensive and all embracing definition was offered by Keller who defined the environment as: "total set of circumstances that surrounds an individual or a community, these circumstances are made up of physical conditions such as air, water, and climate and landforms; the social and cultural aspects such as ethics, economics, aesthetics and such circumstances which affects the behaviour of an individual or a community" (Efobi, 1994).

From these definitions, it is clear that environment consist of all the physical, non-physical, external, living and non-living conditions surrounding an organism or groups of organisms that determine the existence, development and survival of organism(s) at a particular time (Daramola & Ibem, 2010). It encompasses constantly interacting sets of physical (natural and man-made) elements and non-physical, living and non-living (e.g. social, cultural,

religious, political, economic) systems which determine the characteristic features, growth and sustainability of both the component elements of the environment and the environment itself (Johnson, 1992; Muoghalu, 2004).

Sustainability in this context relates to the ability of the environment to meet the basic requirements for the sustenance of the living and non- living components of the ecological, economic and socio-cultural systems in a manner that does not limit the possibility of meeting the present and future needs of the various components and aspects of the environment. It can also be viewed as the carrying capacity of the supporting ecosystems (Marcuse, 1998).

Evidences suggested that the prevailing global environmental degradation poses serious threat to sustenance of carrying capacity of the ecosystem (Marcuse, 1998; Peters, 2000); hence environmental sustainability have taken priority position in housing, infrastructure provision, planning, land use and urban development among others (Salama & Alshawaikhat, 2005; Aribigbola, 2008). Although, Marcuse (1998) was of the view that sustainability should not be considered as goal for housing or urban programmes on the account that many of bad housing or urban programmes are sustainable. However, recent development indicated that environmental sustainability is interwoven with urban development and housing programmes (Peters, 2000; Aribigbola, 2008).

According to the Bruntland Report, sustainable development is "the development that meets the present without compromising the ability of future generations to meet their own needs and development" (WCED, 1987). This suggest that the principal goal of sustainable development is meeting present human needs in such as way that will not jeopardize the

potential of posterity to meet their needs . Viewed from a holistic perspective, Wiedenhoeft (1981) and Padisson (2001) noted that sustainable development entails the attainment of equilibrium among three contending sub-systems (economic, social-cultural, and environmental).

Urban areas as centres of arts, culture, education, entertainment, technological innovations, providers of specializes services and "economic engines" (Udeh, 1992; Okeke, 2002; Kadir, 2006; Kjellstrom and Mercado, 2008) are products of urbanization which come with far reaching economic, socio-spatial and health implications (Acho,1998; Marmot, 2006). Adedeji (2005) noted that sustainable development as applied to urban areas is the ability of the urban areas and their regions to continue to function at levels of desired quality of life by communities without limiting the options available to the present and future generations and resulting to adverse impacts within and outside their boundaries. However, Peters (2000) noted that the ecological and sociological "footprint" of cities has spread over ever-wider area and that fewer places on the planet earth are unaffected by this phenomenon. Changes in the ecology of urban environment occasioned by increasing population, overcrowded habitations and uncontrolled exploitation of natural resources may accounted for this wide ecological footprint of urban areas which is not peculiar to developing countries (Stoel, 1999; Hales, 2000). Hales, (2000) however, observed that the pace and scale of growth have outstripped the capacity to maintain acceptable standards of public health, environmental safety and sustainable economic growth in urban areas in less developed nations in Africa, Asia and Latin America.

Generally, environmental problems are mostly due to developmental processes and are of local, regional and global effects. These effects are viewed as consequences of human

activities, and are most often harmful on human beings, livelihoods, animal and plant lives presently or transferred to posterity (Simond, 1994; Acho, 1998; Danish International Development Agency, 2000; Kjellstrom and Mercado, 2008). This has far reaching implications on sustainable development, most especially in the face of declining economic fortunes. Therefore, urban environmental issues will continue to dominant sustainable development agenda in developing nations in particular and the world in general in the next few decades.

Undoubtedly, urbanization is a process that continuously initiates changes in land use. According to Gove *et al* (2001), the impervious surfaces which abound in many urban centres degrade the quality of stream water runoff, collect pollutants either dissolved in runoff or associated with sediment, such as nutrients, heavy metals, sediment, oil and grease, pesticides, fertilizers and fecal coliform bacteria. These pollutants are moved and discharged into water bodies by runoff.

Besides, urban growth in sub-Saharan Africa is mainly taking place in an unplanned manner, creating sprawling low-density development and uneconomic use of environmental resources. Most urban areas in Africa are faced with deteriorating environmental conditions and a weak public sector unable to provide adequate services (Stren and White, 1989; Nordberg and Winblad, 1994 cited in Yankson & Gough, 1999).

Conversions of agricultural land and forest, as well as reclaiming of wetlands, for urban uses and infrastructure, are associated with widespread removal of vegetation to support urban ecosystem. They may also exert additional pressure on nearby areas that may be even more ecologically sensitive. Areas that are ecologically rich often foster higher agricultural

yields, and sustain greater urbanization (Ricketts and Imhoff, 2003). The sprawling urban centres and enormous tracts of agricultural lands that typify the modern age are both a direct and indirect threats to surrounding ecosystems. They are a direct threat through habitat conversion, and an indirect threat through the effects human populations typically have on their environment: habitat fragmentation, resource depletion, waste generation, and freshwater consumption (Ricketts and Imhoff, 2003). The concentration of people around urban centres is impacting not only on the biodiversity of urban and peri-urban area (Romero and Ordenes, 2004) but also in other medium-sized cities (Azocar *et al.,* 2003).

2.2 URBANIZATION CHALLENGES IN NIGERIA

The pre- Independence Nigeria had a very low urban population and an exceeding low level of urban population growth rate. In 1921, according to Onibokun (1989), there are only 10 settlements that could be considered urban, 26 in 1931 and 61 in 1952/54. After Independence, the pace of urbanization quickened, increasing with numbers of towns 183 and a population above 20,000. The period 1970-1995, Nigeria witnessed the most rapid and dramatic growth in its urban population. The factor basically responsible for the explosion was oil boom which created massive rural- urban migration. Other factors include government policy in new states creation, citing of universities in some towns etc (Aniah, 2001).

In the developing countries, like Nigeria, this uncontrolled growth of urban areas, in terms of population and area coverage, have become a very crucial issue that is stressing environmental scientist because of the escalating problems of urban congestion, poor housing, crowded transportation, lack of basic services, ill health, epidemic, low

educational status and high unemployment. As urbanization do not come with its expected economic growth, the complication is increased due to poor urban planning and uncontrolled land use, lack of financial resources and inadequate investment in environmental management, thereby causing more impact on the environment (UNCHS, 1996).

Nigeria's urban population is growing at 3.78 percent per year, as compared to Sub-Saharan Africa's overall rate of 3.67 percent. As the 2005 proportion of urban dwellers (46.2 percent) exceeds that of Sub-Saharan Africa by more than 10 percentage points, Nigeria may face greater challenges in dealing with rapid urbanization than its neighbours (UNPD, 2008). Only 35 percent of Nigeria's land is arable, amounting to fewer hectares per person than Sub-Saharan Africa as a whole (World Bank, 2008d). The World Bank asserts that "agriculture is critical to any sustained improvements in Nigeria's growth performance." For agriculture to be a sustainable and productive source of livelihood, Nigeria must address the problems of land degradation, damage to the environment, and destructive farming methods.

A spectacular impact of urbanization in many parts of Nigeria is the outward expansion of cities and results in changes in land use whereby urban residents buy up prime agricultural land for residential or commercial purposes. The conversion of farmlands and watersheds for residential purposes has negative consequences on food security, water supply as well as the health of the people in the cities and urban areas.

Several studies (Rashid, 1982; NEST, 1991; World Bank, 1992; Anih, 2004; Ijioma & Agaze, 2004; Mba, 2004; Bulama, 2005; Ojeshina, 2005; UN-HABITAT, 2005b) have

identified many of the environmental problems in Nigerian cities as having serious adverse socio-economic and ecological implications. A majority of these problems, it is argued are traceable to a number of factors. These include the colonial antecedent of most Nigerian cities (Ogbazi, 1992; Ikya, 1993), the high rate of urbanization (NEEDS, 2004), the bad psychological orientation of urban residents on the environment as well as poor environmental management practices (Meale, 1991; Agukoronye, 2004). Agbola and Agbola (1997) and Areola (2001) clearly indicated that the spatial structure of Nigerian cities evolved before, during and after the colonial rule in the country made the introduction of modern infrastructural facilities very difficult and expensive especially when dealing with areas having the bulk of ancestral homes of indigenous people. It is also suggested by demographic experts that the high rate of urbanization put at 5.3 percent in Nigeria, which is among the highest in the world, has the tendency of spurring up environmental degradation (Goldstein, 1990).

Closely related to the above is the fact that most urban areas in Nigeria have grown beyond their environmental carrying capacities and existing infrastructure (National Population Commission, NPC, 1998). For instance, the 2006 National population census data (FRN, 2007) revealed that most of the urban areas in Nigeria with small land mass have their capacity to take further population increase already exhausted or extremely limited. With a population figure of more than 140 million and land mass of about 924,000 Km2, current estimates indicated that 10 .percent of the land area accommodated 28 percent of the country's total population (Taylor, 2000). The implication of this is that there is disequilibrium between the population and the environment, and this has adversely affected

the carrying capacity of the urban areas in the country; hence the increasing poor quality of the living conditions and the low liveability index of urban areas in Nigeria.

For the near future, urbanization will increase and urban growth in developing countries will outpace that in industrialized countries. Martine argues persuasively that concerns for the negative impact of urbanization may be misplaced, "Nevertheless, it is fundamental to recognize that curbing urban growth is not the solution to either environmental or urban problems" (Martine, 1996).

2.3 REMOTE SENSING AND GIS APPLICATION IN URBAN STUDIES IN NIGERIA

Many researchers have stressed the importance of using GIS and Remote Sensing to studying urban sprawl, and the measure of impervious surface is a vital indicator emphasized (Kumar *et al.,* 2008). Impervious surface estimates, vegetation indices and land surface temperature (LST), estimates are indices that have been used by many researchers (Yuan, 2008; Meng *et al.,* 2010).

For any meaningful development to take place in an area there is the need for adequate information on the past and present land use patterns. Sufficient records on land and its uses are generally scanty in Nigeria (Abbas and Arigbede 2011). This may be due to the tedious nature and cost of conducting ground surveys, and the bulky nature of data generated. The use of remote sensing and GIS techniques to capture data and process for safe keeping, management and regular updating, therefore, serves as a reliable alternative to the analogue methodology.

In applying remote sensing and GIS techniques to land use changes in Zaria, Abbas and Arigbede (2011), noted that the built-up areas increased from 2.3 percent in 1985 to 36.4 percent in 2005 while cultivation activities increased from 39.5 percent in 1985 to 44 percent in 1995, and then it decreased to 40 percent in 2005.

In a similar study in Anyigba, Kogi state, Ifatimehin *et al,* (2009) noted that there were tremendous transformations in the various land use in Anyigba town between 1995 and 2006. The built-up area experienced the highest changes from 7.49 percent in 1995 to 29.84 percent in 2006 while vegetation cover suffered the greatest reduction from 31.50 percent in 1995 to 7.16 percent in 2005. A major factor that accounted for the sharp increase in built-up areas is the elevation of the town to a university town, the Kogi State University within the period. As a result of that, both private individuals and government went into development of properties particularly residential, commercial and academic structures.

Also applying the same techniques in Lokoja Ifatimehin and Ufuah (2006) noted that there was a rapid conversion of vegetation cover to other land uses in the town between 1987 and 2005. Their major findings were that, there has been rapid conversion of vegetation cover to other land uses, thus the built-up area has increased in all directions most especially in the southern part of the town and the cultivated land has increased more than any other land uses. In their study, some 3380 hectares of vegetation cover was reported lost between 1987 and 2005, of which 2355 hectares are recoverable and 1025 hectares are not. The rapid loss of the natural vegetation was related to the increasing population of Lokoja while the increase in cultivated land was related to urban poverty.

In another instance, Ishaya, *et al* (2008), noted that Kaduna town recorded a significant increase in the built-up area between 1990 and 2000. Such expansions were mostly at the fringe of the town area and are mainly due to population growth and development in its formal and informal sector of the economy. The expansion of the town has been in all directions, but more especially to the south. Important aspect in the town land use change is the large increase of bare land, from 16 percent in 1990 to 29.4 percent in 2000 while the built up areas has increased from 39.1 percent to 53.8 percent. Some 297.5 hectares of vegetation cover was reported lost annually due to various processes of urban transformation and it is noted that the town has been expanding at the rate of 167.8 hectares annually since 1990. This implies that within the study area, the vegetation covers will be completely lost in few years from now.

Thus, the monitoring of land cover/land use (LCLU) using satellite imagery has been adequate for general extensive synoptic coverage of large areas (Lillesand *et al.,* 2004). As a result, this has reduced the need for expensive and time consuming ground surveys conducted for validation of data. In general, satellite imagery has been able to provide frequent data collection on a regular basis, unlike aerial photography, which provides more geometrically accurate maps, but are limited with respect to extent of coverage and expense.

2.4 URBANIZATION AND BIODIVERSITY LOSS

Biodiversity refers to the variability among living organisms from all sources, including terrestrial, marine and other aquatic ecosystems, the ecological complexes of which they

are part. It includes diversity within species, between species and of ecosystems (UNEP, 2002). It is the variety of life on earth at all levels, from genes to worldwide populations of the same species; from communities of species sharing the same small area of habitat to worldwide ecosystems (IAIA, 2005).

Biodiversity plays an important role in the way ecosystems function and in the many services they provide. Services include nutrient and water cycling, soil formation and retention, resistance against invasive species, pollination of plants, regulation of climate, as well as pest and pollution control by ecosystems. For ecosystem services it matters which species are abundant as well as how many species are present. However, this valuable resource, biodiversity, is declining rapidly due to factors such as land use change, climate change, invasive species, overexploitation, and pollution. Such natural or human-induced factors – referred to as drivers – tend to interact and amplify each other. While changes in biodiversity are more clearly linked to direct drivers such as habitat loss, they are also linked to indirect drivers that are at the root of many changes in ecosystems. The main indirect drivers are changes in human population, economic activity, and technology, as well as socio-political and cultural factors (Netsanet, 2007).

Many drivers affecting biodiversity are stronger today than they were in the past and are also occurring together. Because exposure to one threat often makes a species more susceptible to another, multiple threats may have unexpectedly dramatic impacts on biodiversity. Drivers of extinction range from local to global in scope and from immediate to long-term in their effects. For example, the extinction of species due to habitat loss can be rapid for some species, while it may take hundreds of years for others depending on the geographic distribution of the organism. Species have been disappearing at 50-100 times

the natural rate, and this is predicted to rise dramatically. A study of human population and biodiversity distribution in Africa showed that human population density was highest in areas of high biodiversity (Netsanet, 2007).

One of the major problems arising from urbanization is thus vegetation degradation. It is a decline in the quantity and quality of the grasses, herbs and woody species found in an ecosystem (Douglas, 1994). Conacher and Sala (1998) defined Vegetation degradation as, "the temporary or permanent reduction in the density, structure, species composition or productivity of vegetation cover". Vegetation condition is the key aspect of degradation in grasslands, wood/forest lands and croplands. Thus, over exploitation and management practices may result in vegetation degradation and tend to enhance land degradation risk. Pressure on the natural vegetation has arisen from changing agricultural practice, fire and livestock grazing, and the feed-back with the loss of bio-diversity.

Natural vegetation change is generally progressive in nature in well-endowed dry lands (e.g., areas that are fed regularly by water-borne sediments). In contrast, retrogressive vegetation changes occur once a degeneration of land resources takes place in response either to certain persistent natural phenomena or man-made processes. Natural land degradation develops because the sparse native vegetation and its inherently low productivity are not able to contribute the necessary organic matter that gives life to soil and binds soil particles. With this degeneration in soil quality, productivity falls, leading to reduction of vegetation. However, natural degradation of vegetation is typically gradual and often reversible (Suliman, 1988). In contrast, man-induced destruction is mostly rapid with diminished time or chance to compensate for the loss.

Anthropogenic processes of vegetative degradation are caused both directly by humans and indirectly by their animals. Humans introduce arable farming into rangelands to satisfy the increasing needs for food and other products (LeHouerou, 1992). Vegetation is often set on fire for the purpose of clearing vegetated land rapidly or to eliminate economically useless plants (Parry, 1996). As long as burning was light and the interval between fires ranged from six to seven years, vegetation could regenerate. However, increased frequency of fires has become a major cause of widespread destruction of native vegetation and accompanying land degradation. Moreover, a several-fold increase in erosion and runoff followed when bulldozers were used to remove vegetation instead of manual clearing (Lewis and Berry, 1988). Damage due to fuel-wood extraction is also substantial. However, Dregne and Chou (1993) maintain that overgrazing by livestock stands as the principal factor of vegetation destruction in rangelands. In view of the pivotal place of livestock in the economy of territories susceptible to desertification, wide-scale degradation of rangelands is a matter of serious concern.

In developing countries, about 40% of the energy for cooking is derived from non commercial sources; fuel wood, dung, and crop residues. That percentage increases beyond 80% in small towns and hamlets (Lele *et al.,* 1994). Fuel wood remains the predominant source of energy for cooking. In order to lessen dependence on woody perennials, it is essential to improve the efficiency of cooking with fuel wood and to search for alternative sources of energy. Biogas and solar energy offer attractive alternatives for energy in the tropics (Lele *et al.,* 1994).

2.5 SUMMARY OF REVIEW

It is clear from the foregoing review that there is not necessarily a direct linkage between the rate of urban growth and environmental problems. As noted by Bartone *et al,* 1994, the growth rates of many of the world's megacities have slowed considerably in the past several years. Yet urban environmental problems clearly have worsened in such cities. Overall, the relationships between urbanization and environmental degradation are very complex, involving interactions with the natural and the built environment, as well as various economic, political, and social factors. The regional ecosystem in which a megacity is located, for example, is often a critical determinant of the severity of environmental conditions as well as the complexity of potential intervention strategies (Bartone, *et al* 1994).

CHAPTER THREE

ENVIRONMENT OF THE STUDY AREA

3.1 LOCATION OF THE STUDY AREA

Zaria lies in the Northern part of Kaduna state. It is a historical, ancient and traditional centre of the north with its administrative capital situated at Birnin Zazzau (Zaria City). It remains a strategic political centre of the north with authority vested solely in hands of the Emir of Zazzau (Mortimore, 1970). The study area is some 20km radius around Zaria town. The area is bounded by latitude $10^0$55'00"and $11^0$15'30"N and longitude 7^0 28'E and 7^0 55'E. The total area covered is about 2638.20Km^2 with an altitude of about 613m (fig 3.1). Essentially, Zaria metropolitan area comprises two Local Government Area (LGA), namely, Zaria and Sabon-Gari LGAs. The study area is bounded in the south by Igabi LGA, to the north by Kudan LGA, to the east Soba LGA and to the west Giwa LGA.

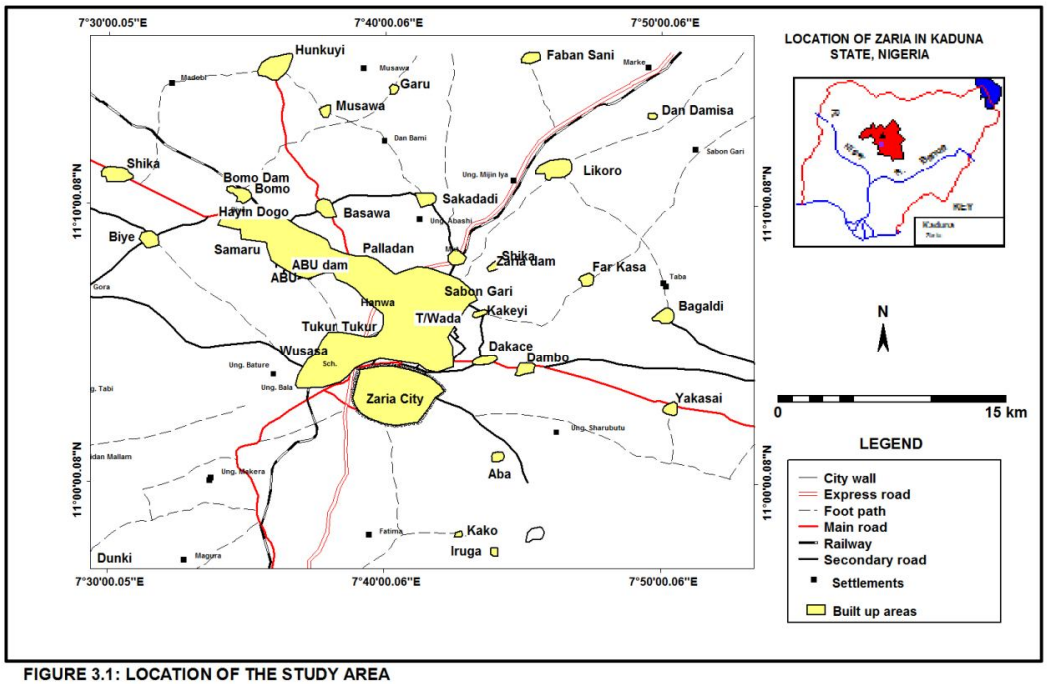


FIGURE 3.1: LOCATION OF THE STUDY AREA

Source : Modified from Zaria Topographic Map, Sheet 102, and Igabi 124, 1: 100,000

3.2 CLIMATE

3.2.1 Rainfall

Laying some 670km away from the Gulf of Guinea coast, the Zaria region experiences a tropical continental climate with a distinct wet and dry season (Kowal & Knabe, 1972). The movement of the Inter Tropical Discontinuity (ITD) and associated Tropical Continental (Tc) and Tropical Maritime (Tm) air masses control the wet and dry seasons. The tropical continental air mass originates from the Sahara Desert and the tropical maritime air mass across the Atlantic Ocean.

The rainfall regime is single maximum with a long-term average of about 1100 mm per year (Adejuwon *et al*; 1989). Of great importance is the fact that rainfall in the area is seasonal in character. About ninety percent of the rains fall between April and October, the months with the heaviest rains being July and August. Monthly total can vary widely, and so the annual total.

Rainfall intensity is an important consideration as well, as intensities greater than 25mm/hr are potentially erosive. Annual intensity as high as 70mm/hr over a 30min period have been recorded. The highest intensity of rainfall is associated with convectional lightning and thunderstorms at the beginning and end of the wet season (Peters *et* al, 1988). These storms occasionally produce hail. During the wet season, the rainfall is more prolonged but less intensive, and therefore less erosive**.**

3.2.2 Temperature

Temperature is always high. Every month has an average temperature close to 27^0C, usually with no perceptible seasonal variation. The annual temperature range (fluctuation

between the average temperature of the coolest and warmest months) is minuscule, typically only 2^0 or 3^0 and only rarely over 7^0 or 8^0. Daily temperature variations are somewhat greater, although still not impressive. On a typical afternoon, the temperature will rise to the high $30s^0$C and dropping to the middle or low $20s^0$C in the coolest period just before dawn.

The relative humidity is very low during the dry season and changes greatly in august when mostly mean humidity goes up to over 55%. Temperature is generally high throughout the year with the mean daily maximum temperature of about 37ºC and shows a major peak in April then it drops rapidly to its lowest value in October. The dry season is practically rainless and it begins in early November and lasts till April, when wet season takes off. The year in Zaria can be divided into the following season summarized in table 3.1 below:

Table 3.1: The Characteristics Seasons of Zaria

S/N	Season and Character	Period of Occurrence (onset and ceasation)
1	Dry Season ("winter" season characterized by the cool hazy harmattan winds).	November to February
2	Hot Season	March to April
3	Season of Thunder storms and squalls	May to June
4	Wet Season (very warm)	July to October

Source: Mortimore (1970).

3.3 GEOLOGY

The Zaria area is a dissected portion of the Zaria-Kano plains, an extensive peneplain developed on crystalline metamorphic rocks of the Nigerian Basement complex (Wright and McCurry, 1970). Russ (1951), described the Basement complex as composing of older

high grade metamorphosized gneiss interspersed by belts of younger metasediment of mainly quartzite and schist oriented in the north – south direction (fig 3.2) In the south-eastern corner, younger granites and bathyliths are evident. Deep chemical weathering and fluvial erosion, influenced by the bioclimatic nature of the environment, have produced the characteristic high undulating plains with subdued interfluves (Mortimore, 1970). According to Ike (1988), the older granite outcropping of Zaria is exposures of a syntectonic to late tectonic granite batholiths which intruded a crystalline gneissic basement during the Pan-African Oregeny. In some places, the interfluves are capped by high grade lateritic ironstone especially in the Northwest. Egbeifo (1978), in his work on Kubanni Basin in general listed the different basement rocks found in the area viz:

(i) Coarse perphyritic – biotite granite which is distinctly foliated and aligned.

(ii) Medium – coarse grained biotite granite gneiss.

(iii) Aplite granite, pegmatites and quartz veins intrude most of the bodies; and

(iv)Weathered basement. This is about 14% of the basin's total area and formed a storage aquifer.

The surface of the older granite basement is overlain by a deposit of older laterite, young laterite, older alluvium and younger alluvium; the last two being quaternary deposits. The thickness of this zone varies from place to place, especially along stream valleys. There are frequently older granites exposed on the surface. They exist either in the form of domed hills (inselbergs), or as low outcrops (whaleback), (Wright and McCurry, 1970). The economical benefits that could be obtained from this basement complex includes: Gold, Amethyst, Laterite, Building materials, Ornamental stones, Ceramic materials and Water.

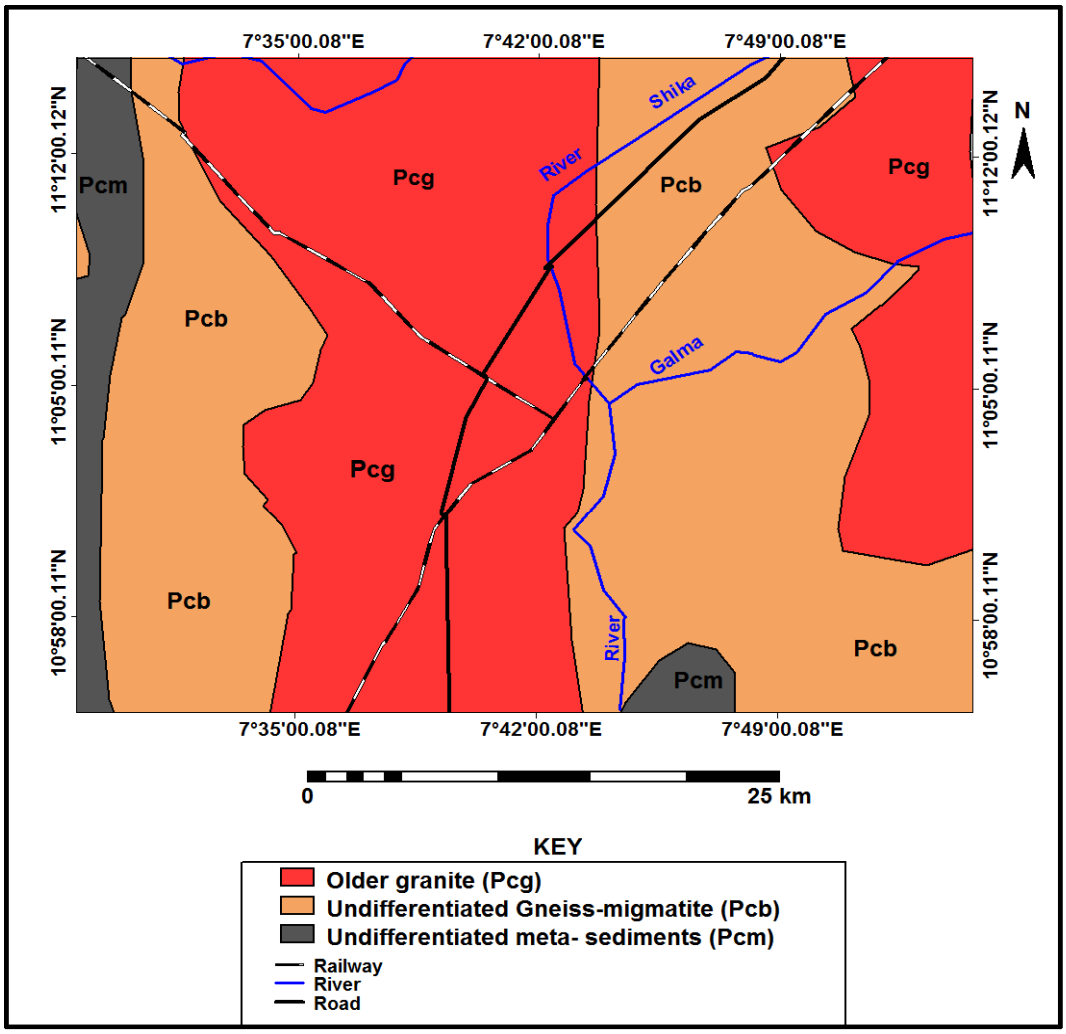


FIG. 3.2: THE GEOLOGY OF THE STUDY AREA

Source: Adapted and Modified from Geological map of Nigeria, 1984

3.4 LANDFORMS

The plains on which Zaria is situated are part of the vast, gently undulating plains scenery which extends almost unbroken from Sokoto to Lake Chad and beyond, and from south of Kaduna to the Tigueddi scarp near Agades (Thorp, 1970). There are variations in both the composition and surface form within Zaria.

3.5 RELIEF AND GEOMORPHOLOGY

In general, over much of Zaria area, relative relief (the height range between interfluves crests and the valley bottom) is less than 20m. Similarly, the average slope (average inclination of the landscape from the horizontal) really exceeds 6 degree (a slope value which is still quite satisfactory for a wide range of land use) and is very rarely more than 10 degree. Average slope is predominantly 3 degree. Taking the relative relief and the average slope together, we can characterize the terrain as gently rolling to undulating, studded with residual hills of various shapes and sizes.

The plain area is stunted by a large number of mostly small residual hills, either as isolated features or grouped together, including:

(i) **low ridges** on quartz and pegmatite veins, rising less than 10m above the surrounding terrain

(ii) **low whalebacks** on migmatite, granite-gneiss and granite; the inhabitants of the area use these as drying, grinding and pounding surfaces and often build their granaries on them, safe from the fierce.

(iii) **Inselbergs -** more commonly occurs, perhaps, on granites and migmatites. Occurring often as impressive, steep-sided domes, they are also found as elongated and assymetrical features. They may be relatively free of boulders, but more commonly carry boulders of various sizes on their tops and on fairly gentle side slopes.



PLATE I: A Boulder

(v) **Broken rocky hills -** these rise abruptly (many as much as 200m) from the gently-sloping plains surrounding them which also differ by carrying weathered and transported regolith of various depths.

The valleys are shallow but wide, stretching several tens of kilometres into the headwater areas with gentle sloping valley sides; imperceptibly grading into flat moist to marshy alluviated bottomlands or floodplains, called "fadamas" in Hausa. Although stream valley incisions and dissections of the high plains are evident in several areas, especially in the Zaria region, they are due more to anthropogenic influences and climatic factors than regional geologic instability (Abdulraheem, 2011). Figure 3.3 below shows the relief of the study area.

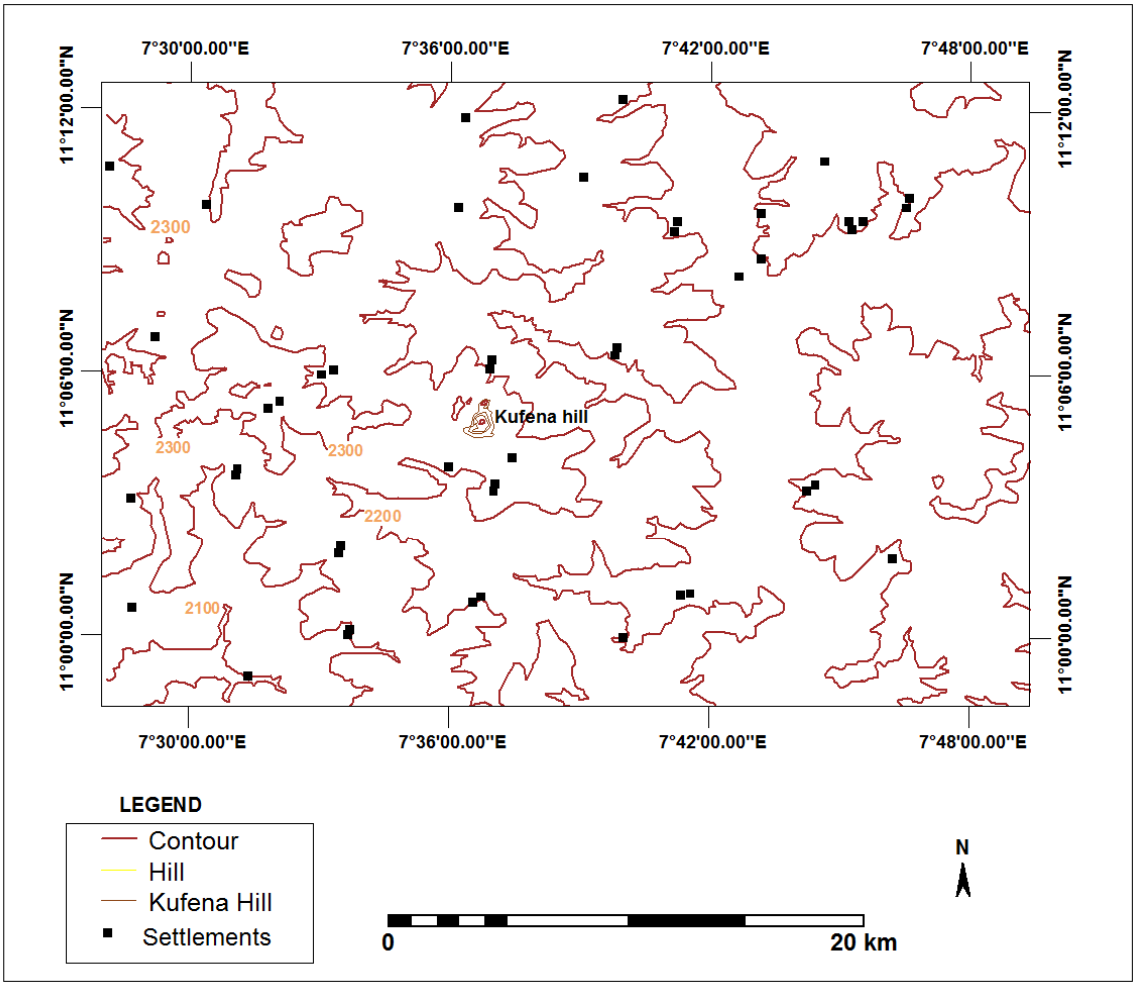


FIGURE 3.3 : THE RELIEF OF THE STUDY AREA

Source : Adapted and Modified from Zaria Topographic Map, Sheet 102 , 1: 100,000

3.6 DRAINAGE

The drainage system of Zaria area focuses on the River Galma, a major tributary to River Kaduna (fig 3.4). It flows north-ward while Kubanni River flows eastward. The confluence of Galma and Kubanni is about 1.2km at the North-Eastern direction. Galma and Kubanni rivers carry water throughout the year (Thorp, 1970). Stream flow in the area strongly reflects the climatic environment and, in particular, the seasonal and torrential nature of the rainfall. Thus, three main types of stream flow pattern have been recognized in the area:

i. Perennial flows: low dry season discharges; flash floods superimposed on high rainy season discharges. This flow pattern occurs on the largest stream;

ii. Seasonal flow: zero dry season flow; flash floods superimposed on rainy season flow which may be high or low depending on catchment area;

iii. Flash flow only that is, there is flowing water in the stream channel only during rainy season and for a short while after runoff producing storm.

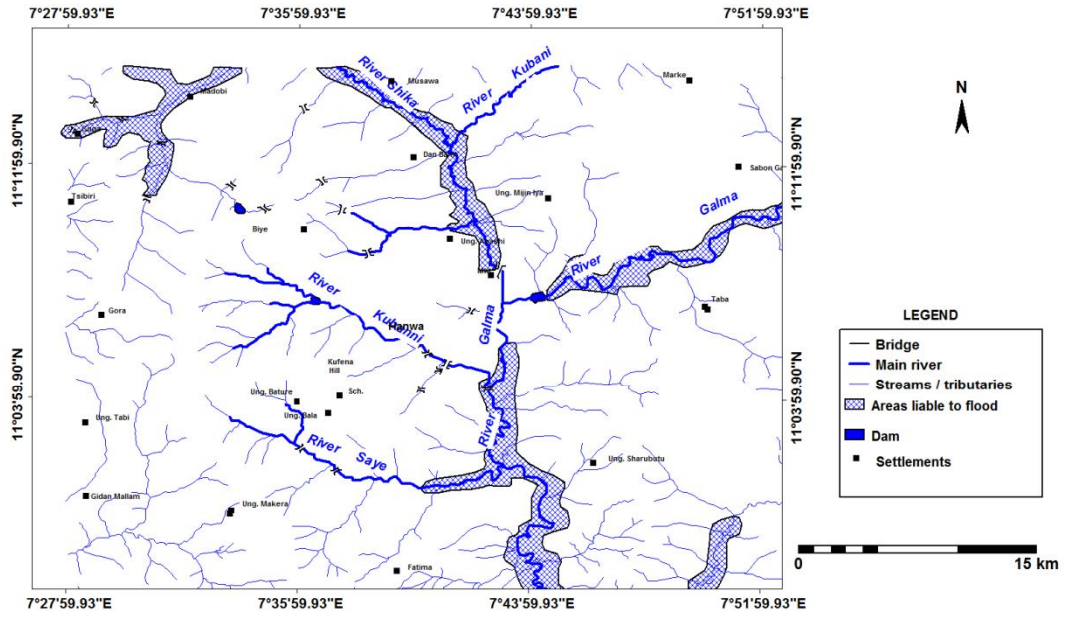


FIGURE 3.4: THE DRAINAGE PATTERN OF THE STUDY AREA

Source : Modified from Zaria Topographic Map Sheet 102 and Igabi Sheet 124, 1: 100,000

3.7 SOILS

Soils in Zaria area represent an interface between intensive chemical weathering of rocks and an active surface and subsurface denudational system fueled by intensive rainfall and rapid runoff. The soils' parent materials are derived from crystalline metamorphic rocks of the Basement Complex and Quaternary deposits. Two groups of parent rocks are involved, namely: granitic rocks (granites, gneisses and quartzite) and schists. Based on the CCTA

soils classification scheme, most soils in Zaria area belongs to the leached ferruginous tropical soils (Tomlinson, 1963). Such soils are developed on the deeply weathered metamorphic rocks of the Basement Complex (D'Hoore, 1963). A few occupying valley bottom positions are hydromorphic (Hausa, fadama) (FAO: Gleysols), while those around the base of inselbergs and other residual hills are lithosols**.**

3.7.1 Fadama soils

These occupy the floodplains of the major rivers. The surface horizons are dark grey and faintly mottled, becoming well mottled lower down the profile where the colour is dark grey brown to grey brown and were soft iron concretions are many. The parent materials of these soils are characterized by a great heterogeneity, as reflected by the stratification of the profiles. Some variations in soil texture are therefore to be expected. The soils have well developed sub angular blocky to prismatic structure in the surface horizons, but usually massive and permanently moist at lower horizons. During the dry period, the surface layer often shows weak polygonal cracking. The soils have poor to very poor drainage, but where the stream has incised into the valley the soil tend to be better drained. The reaction is mostly slightly acid and the clay mineralogy mostly kaolinite, but often with small amount of 2:1 lattice clays (Lews, 1962).

3.7.2 Weakly developed soils

These occur principally near the base of inselbergs and crests of ridges, but may also be found close to rock outcrops in any topographical position. They are characterized by poor horizon development and are mainly less than 50 cm deep. Colour range from pale brown

to light yellowish brown in the surface layer to yellowish red at the lower layer. Some prominent mottles, often associated with weathering rock fragments, may occur at depth. Structure are mostly moderate sub angular blocky throughout, while texture range from sandy loam in the top layer to sandy clay loam at the lower layer. The soils contain many angular quartz and feldspar grains, and a few stones. There is usually an irregular boundary to the underlying granitic rocks and occasional pockets of soil may extend to a depth of up to 1 m. The soils are moderately acid, with pH of less than 6.0. The level of all exchangeable cations and CEC are low and so also organic matter content (Lews, 1962).

Structure is mostly strongly developed medium sub angular blocky. The clay fraction has been found to be predominantly Kaolinite (Lews, 1962), the soils are moderately acid, with pH (in H_2O) between 5.3 and 6.5. An exception to this pattern includes the localized slightly calcareous soils. Soil organic carbon content is highly variable, but generally low, often less than 1.5 percent at the surface and 0.5 percent at the subsoil. Total nitrogen and available phosphorous are low, less than 0.10 percent and 15 ppm, respectively, and show strong correlation with organic matter content. The cation exchange capacity are low to very low, often less than 15me/100g, and so the exchangeable cations (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, Al^{3+}) (Kowal and Knabe, 1972; Jaiyeoba and Ologe, 1990).

3.8 VEGETATION

Given the climate of the area, the original vegetation must have been a thick woodland or dry forest. Evidence of such vegetation still exists in the forestry reserves close to the study area. As in many parts of Nigeria, the long period of occupation of the region has led to profound modification of much of the vegetation cover.

The main plant or physiographic communities now found in the area include

(i) tree savanna\cultivation parkland,

(ii) shrub savanna,

(iii) woodland and savanna woodland,

(iv) fadama grassland,

(v) inselberg vegetation, and

(vi) afforested vegetation. The communities are largely an expression of climatic and edaphic factors, which have been modified by man's activities.





PLATE II: Scattered cultivation

The Savanna parkland/shrub savanna/savanna woodland differs little except for the relative proportion of woody and herbaceous components. The communities have evolved from the system of bush fallowing practice in the area, and forming distinctive pattern around settlements.

In the immediate vicinity of settlement, and over otherwise intensively farmed areas, is man-made parkland or tree savanna. The community is a peculiar non-natural vegetation type, which is the mark of many settlements in northern Nigeria. It consists of remarkably uniform immature trees of economic value that are scattered throughout a mosaic of

cultivated fields and short-term fallows covered with mostly annual grasses. Such grasses may include *Rhynchelytrum repens, Panicum kerstingii, Setaria pallide-fusca, Aristida sp.* and *Hackelochloa granularia* The trees are largely indigenous and represent either the few surviving species of once-dense tree savannah woodland, which formally covered the whole area, or trees deliberately planted by man. Prominent among such trees are *Ceiba pentandra*, *Tamarindus indica, Adansonia digitata* and *Mangifera indica*. Others are *Vitex doniana, Vitaleria paradoxa, Borassus aethiopum, Afzelia africana, Acacia albida, Khaya senegalenesis, Parkia bigloboza, Daniella oliveri, Ficus sycomorus, Pterocarpus erinaceus* (Abdulraheem, 2011).

A little further out from settlement areas, the parkland or parkland savanna extends into shrub savanna. Here, the intervals between successive crops are long enough to allow trees and shrubs that have been suppressed during the period of cultivation to commence regrowth. The ensuing community thus consists typically of shrubby coppice and sucker regeneration from stumps and rootstocks that have not yet been eliminated by cultivation. *Pennisetum polystachyon* and *P. pedicellatum* grasses are common in the early stages of newly fallowed land, but typically perennial *Andropogoneae* soon follows these.

On the outer perimeter of the shrub savanna, especially were villages are widely spaced or absent, the shrub land zones merges with the remaining tree savanna or savanna woodland vegetation (Appendix G shows some common shrubs found in the area). The vegetation here includes such remnants of the climatic climax as have survived modification imposed by recurrent annual fires, fuel wood collection, and light to moderate bush fallowing.



Jatropha curcas



A combination of different shrubs



Acacia ataxacantha



Isoberlinia doka craib

PLATE III: Some common shrubs

Bottomland sites, consisting of basal slopes, floodplains or fadama, marshy oxbow lakes, shallow backwaters and river banks of matured rivers, support characteristic grassy vegetation.

Remnants of a dry forest often fringe the base of inselbergs where runoff from the exposed rock above creates soil conditions favorable to continuing vegetative growth during the dry season, and weathered granite rocks continually supply mineral nutrients to the soil.

Dominant tree species of such communities include *Albizia lebbeck,* and *Milletia thonningii*, and climbers such as *Acacia ataxacantha.*



PLATE IV: Fadama

Planted vegetation communities are rear but nevertheless abound, especially within built-up areas. They often serve as avenue and compound planting on watershed sites, and combine both indigenous and exotic species, such as *Daniella oliveri, Khaya senegalensis, Mangifera indica,* and *Dalbergia sisso*.



PLATE V: *Mangifera indica* plantation



PLATE VI: *Khaya senegalensis* plantation

3.9 LAND USE AND ECONOMY

Land use practices in the area include cultivation for food production, animal grazing or pastoral farming for dairy products, establishment of settlements and industrial expansion. Agriculture is by far the single most important activity in the area. Rain fed agriculture takes place during the rainy seasons on the upland fields supporting such crops as millet, guinea corn, maize, groundnut, cotton, soybeans and yam while irrigated agriculture on the other hand takes place on the low land field (fadama), and support labour intensive higher valued crop such as sugarcane, onions, tomatoes, pepper, spinach and garden vegetables at the dry season.

Animal rearing is another major activity in the study area. Many factors contributed towards making Zaria attractive to pastoral Fulani. These include the location between wet season pastures to the north and sparsely populated bush area to the south, supply of animal feed and water near settlement (Abdulraheem, 2011).

Agriculture is the earliest economic activity in Zaria. Physical planning problems, constraints and the slow rate of economic growth has increased the amount of land devoted to agriculture instead of the planned use. In Zaria 80% of the people engage in agriculture while the remaining 20% are engaged in other economic activities such as commerce, manufacturing, transportation etc. Those that engage in farming, about 28% of them obtain the land as an inheritance or a gift, 44% rent it from a landlord, 7% go as far as converting a plot of land to a farmland and 21% lease the land from public or semi- public institution. The development of agriculture has been encouraged by the availability of land under many different jurisdictions. Commercial activities, manufacturing industries and infrastructural

facilities have contributed to the economic activities and which has brought about positive impact in the area.

3.10 POPULATION AND SETTLEMENT

Zaria comprise of six (6) Traditional districts, Birni Da Kewaye (Zaria town and its environs), Dutsen Abba, Gyallesu, Tudun Wada, Tukur Tukur, and Wuchiri. They all lie within the farmlands of the monotonous plains which make up most of the area occupied by the Hausa speaking farmers and craftsmen of Zaria (Urquhart, 1970). Urban Zaria is rated as the second largest city in Kaduna State. Zaria is a cosmopolitan city with tribal nationalities from all parts of Nigeria and other West African countries co-existing harmoniously in the midst of the warm receptive traditional values and norms of the people of Zazzau. The main Ethinic groups are Hausa and Fulani and they are predominantly muslims.

The pattern of human settlement is tied to the historical, political and socioeconomic forces the area has been subjected to from the precolonial to post colonial period. Prior to the advent of the British occupation, the basic unit of human settlement was the extended family compound. This pattern of settlement dominated the Hausawa cultural groups to the north (i.e. Giwa, Igabi, Zaria, Sabon Gari, Kudan, Makarfi and parts of lkara LGAs). The impact of the historical and cultural developments on settlement pattern and the nature of the rural economy (agrarian), created the dominance of the urban centre (Mortimore, 1970**).**

In recent times, the rate of population has been astronomical due to high birth rate and immigration. The population of Zaria, as put together by the population and housing census of 2006, is 1, 364,942 people. But for the purpose of this study, the major local government

that concerns it are Zaria and Sabon-gari local government areas with a population of 196,090 and 142,247 respectively (NPC, 2006). Islam and Christianity are the dominant religions practiced here.

CHAPTER FOUR

MATERIALS AND METHODS

4.1 DATA REQUIRED AND SOURCES

Table 4.1 summarizes the data required for the study and their sources. The reconnaissance survey, the purposive interview, and the field survey yielded the primary data for the study, while the topographic map and satellite imageries, and literatures, both from internet and libraries, yielded the secondary data.

Table 4.1: The Data Required for the Study and Sources

S/N	Data Required	Sources
1.	Satellite imageries of Zaria area for 1973, 1990, 1999 and 2009 for processing of land use and land cover change	National Centre for Remote Sensing, Jos.
2.	Normalised Difference Vegetation Index (NDVI)	Satellite imaging processing and ground truthing
3.	Diversity and characteristics of woody species.	Detailed Field survey
4.	Baseline condition of study area	Review of related literatures and corroborated with field information.

Table 4.2 summarizes the characteristics of imageries acquired, because the imagery of 1973 (MSS) and that of 2009 (NigeriaSat-1) were of different spatial resolutions, they had to be resampled to that of 1999 (ETM) before further analysis were done on them. Another major drawback of the imagery used relate to the fact that they differ in their acquisition dates.

Table: 4.2 Satellite Data Used for Digital Image Processing

Date of acquisition	Type of satellite image	Spatial resolution (m)
7th December 1973	Landsat Multi Spectral Scanner (MSS)	28
27th November 1990	Landsat Thematic mapper (TM)	30
19th October 1999	Landsat Enhanced Thematic Mapper (ETM)	30
10th September 2009	NIGERIASAT-1	32

The instruments/equipment used for the image processing includes:

- GPS (Global Positioning System) for determining Latitude and Longitude of each sample point
- 1:100,000 Topographic map of Zaria sheet 102 and Igabi sheet 124 second edition produced by Federal surveys, Nigeria in 1965. For mapping out the study area and obtaining the geographical coordinates
- Satellite imageries;

Appropriate software includes:

- The Integrated Land and Water Information System (ILWIS) 3.3 academic software, Microsoft office Word, Microsoft office Excel and Statistical Package for Social Sciences (SPSS)

The equipment for the detailed field survey on the other hand includes:

- Measuring tapes for sample plot length transect and girth of trees
- Abney level for measuring tree height
- Field notebook/data sheet for taking records in the field

4.2 RESEARCH DESIGN AND METHODOLOGY

This research is designed to collect and analyze information on the land use/land cover, as well as the characteristics of woody species in the study area. Figure 2 summarizes the methodological approach to the study.

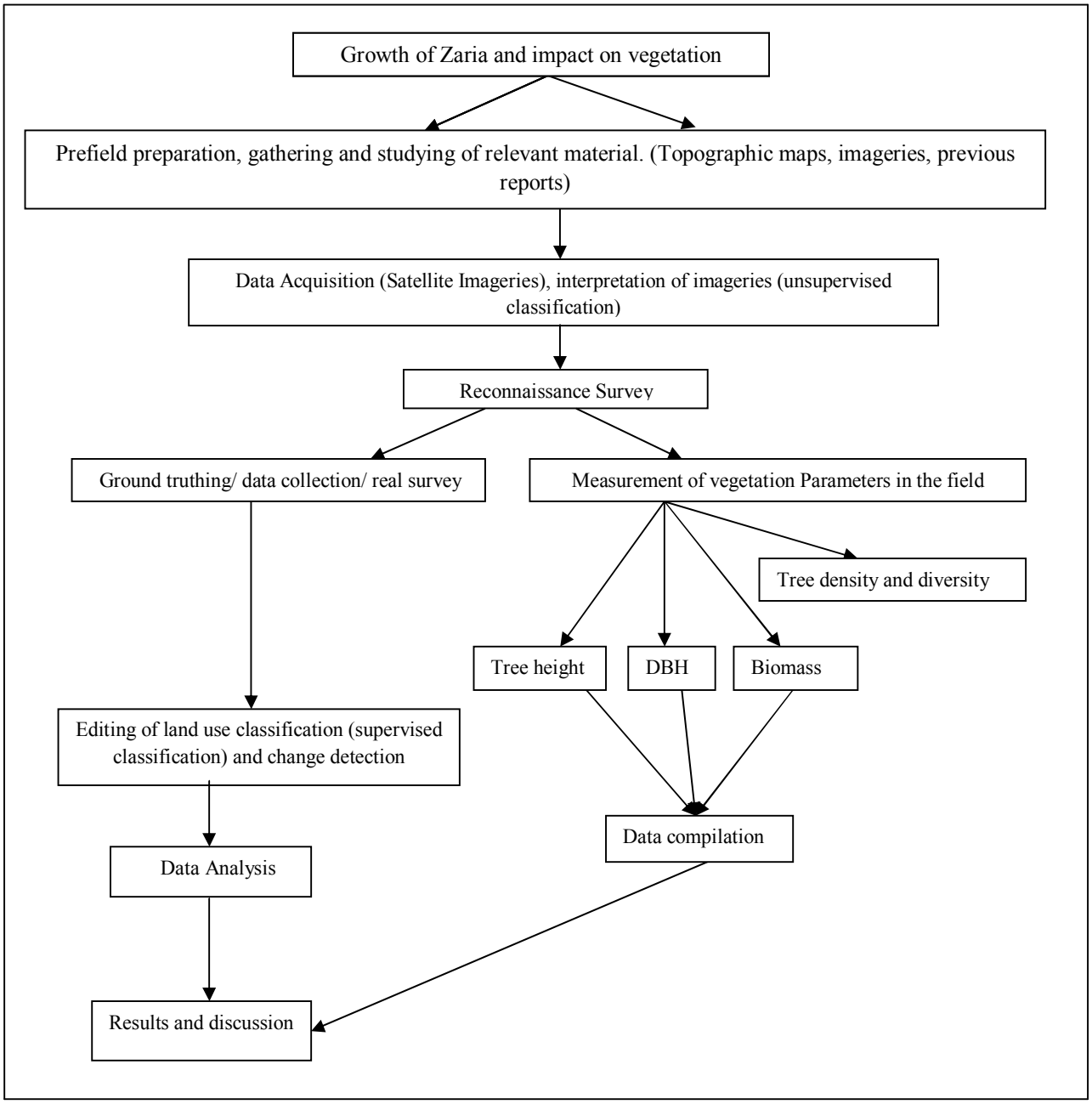


Fig 4.1 Summary of the approach methodology employed in the study

4.2.1 Reconnaissance survey

The reconnaissance survey of the study area was carried out from 23rd to 28th of January, 2012. The objectives of the survey were to:

i) consult relevant community leaders in the study area, with a view to intimating them of the objectives of the study and to seek for their permission and cooperation,

ii) have a general overview of the environment,

iii) acquire available relevant information/data

4.2.2 Land Use/ Land Cover Analysis

4.2.2.1 Analysis of satellite images for land use/ land cover

The procedure followed in the image processing and land use land cover (LULC) analysis is that of first sub- setting the coordinates of the area demarcated for the study on the topographical sheets (Zaria sheet 102 and Igabi sheet 124 of scale 1: 100,000) on the imageries. The image sampling, classification, crossing and change detection were then carried out using the Integrated Land and Water Information System (ILWIS) 3.3 academic software along with other instruments. Figure 4.2 summarises the procedure that was followed in the satellite imagery processing and analysis.

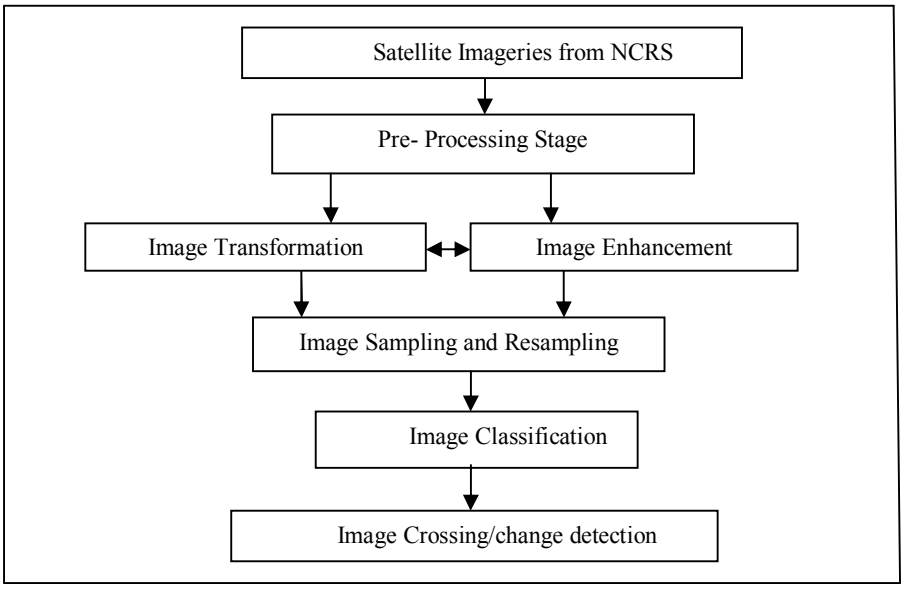


Figure 4.2: Flow Chart of method of Analysis of Satellite Image

4.2.2.2 Pre-processing stage

The pre-processing stage usually involves image rectification and image sub-setting. This is with a view to correcting whatever distortion that might have occurred during acquisition from satellite (Paul, 1992; Ogunleye, 2010). The images that were used for this work, however, were not pre-processed by the researcher as the agency that provided the images (that is NCRS) had already done that.

4.2.2.3 Image sampling and resampling

This process aids in sampling and identifying each land use stated using the spectral signature of each of the land use/ land cover. In that regard it aid the sub-division of the image into separated regions represented by image objects which contain information about their spectral characteristic, shape and position there by enabling the pixels of the images in identification of their spectral properties. For the resampling, as indicated earlier, the

images are in different spatial resolution (table 4.2). There was therefore, the need to resample for easy classification and crossing to obtain the change detection.

4.2.2.4 Image classification

Before any useful thematic information can be extracted from remote sensing data, a land use land cover (LULC) classification scheme has to be developed to obtain the class of interest to the analyst (Congalton, 1991). Mather (1999) considered classification to be the process of recognition of the pattern associated with each pixel position in an image in terms of the characteristics of the objects. Classification involves three main issues: creating samples, image sampling and generalizing the sampled features (Jeb, 2008b).

For the purpose of this study, supervised classification, based on seven classes (Table 4.3), was employed. The supervised classification technique entails "training" of the image data into various themes or classes, based on their land use/land cover scheme drawn out. With this technique, samples of the different features on the image are given sample pixels depicting a given land use/land cover type. The Maximum Likelihood Classifer assumes that a pixel has certain probability of belonging to a particular class. These probabilities are equal for all classes and the input data in each band follows the Gaussian (normal) distribution function (Lillesand *et al,* 2004).

Table 4.3: Classification Schemes Adopted in the Study

S/N	Land use/ land cover type	Interpretation
1.	Built-up areas	This includes all developed lands such as: Residential, Administrative, Educational, Industrial and commercial land uses
2.	Bare surfaces	All bare surfaces such as: sites of building under construction, dilapidated buildings, and farm sites left to fallow.
3.	Water bodies	All water surfaces such as: Rivers, Streams, Ponds and Dams
4.	Scattered cultivation	All agricultural land uses such as farming
5.	Forest/Plantation	All lands protected by law from exploitation, it could be natural or man-made, that is, land used mainly for wood production, other forest products, recreation, protection, including natural forest, plantation, afforestation, woodlots, other.
6.	Scrub lands	All land areas covered with small and scattered trees and cannot be classified as forest usually the height are less than 2 meters tall.
7.	Fadama	All marsh land covers.

4.2.2.5 Normalized Difference Vegetation Index (NDVI)

The NDVI is a spectral vegetation index widely used to detect variation in vegetation characteristics. The NDVI approach is based on the fact that healthy vegetation has low reflectance in the visible portions of the Electro Magnetic Spectrum (EMS) due to chlorophyll and other pigment absorption and has high reflectance by the mesophyll spongy tissue of green leaf (Campbell, 1987). NDVI is calculated as a ratio of Red and the NIR bands of a sensor system.

$$NDVI = NIR - RED/NIR + RED$$

The NDVI values range from -1 to +1. Because of high reflectance in the NIR portions of the EMS, healthy vegetation is represented between 0.1 and 1. Conversely, non-vegetated surfaces, such as water bodies yield negative values of NDVI, because of the electromagnetic absorption quality of water. Bare soil areas represent NDVI values which are closest to 0, due to high reflectance in both the visible and NIR portions of the EMS (Lillesand and Kiefer, 2004). For this study, the classification scheme in table 4.4 was used to classify and analyze the images. The range of values used in the table was obtained from the NDVI imageries used for this work.

Table: 4.4 NDVI Classification Scheme Adopted

S/n	Vegetation cover type	Range of value	Interpretation
1	No vegetation	-0.95 – 0.00	This are basically the water bodies, built-up areas, rock outcrops and bare surfaces
2	Sparse vegetation	0.01 – 0.50	Comprises basically of areas with scattered cultivation, grasses and farmlands
3	Dense vegetation	0.51 – 0.96	Areas that are highly vegetated, areas like forest, shrubs and fadama regions.

Source: Laboratory Analysis, 2012

4.2.2.6 Image crossing/Change detection

Image crossing is a process of overlaying two classified imageries. It detects changes that have occurred over time in an area. Change detection on the other hand is the process of determining and/or describing changes in the land-cover and land use properties. There are many techniques available to detect and record differences (e.g., image differencing, ratios or correlation) and these might be attributable to change (XiaoMei and RongQing 1999). However, the simple detection of change is rarely sufficient in itself, information is generally required about the initial and final land cover or types or land uses.

4.2.3 Ground Truthing and Detailed Field Survey

Both the ground truthing and field survey to determine key woody vegetation parameters were conducted concurrently. The main purpose of groundtruth is to verify the classified images done prior to groundtruth with the actual situation on ground observable during ground truth exercise. On the other hand, the purpose of field survey was to collect data on physiognomic characteristics of the vegetation cover and acquire any relevant information for the interpretation of observed conditions.

4.2.3.1 Sampling designs

Stratified random sampling was adopted in the ground truthing and measurement of woody vegetation characteristic. The strata were based on the initial classification of satellite imagery (Table 4.3), from where different classes of land cover were obtained. Based on the relative sizes and visual display of the different land use categories, varying number of sampling points was subsequently assigned randomly on the map and the coordinates were inputted into the way- point of the GPS for appropriate location on the ground (Appendix A). In all, 25 points were randomly picked on the map and traced on the ground (figure 4.3).

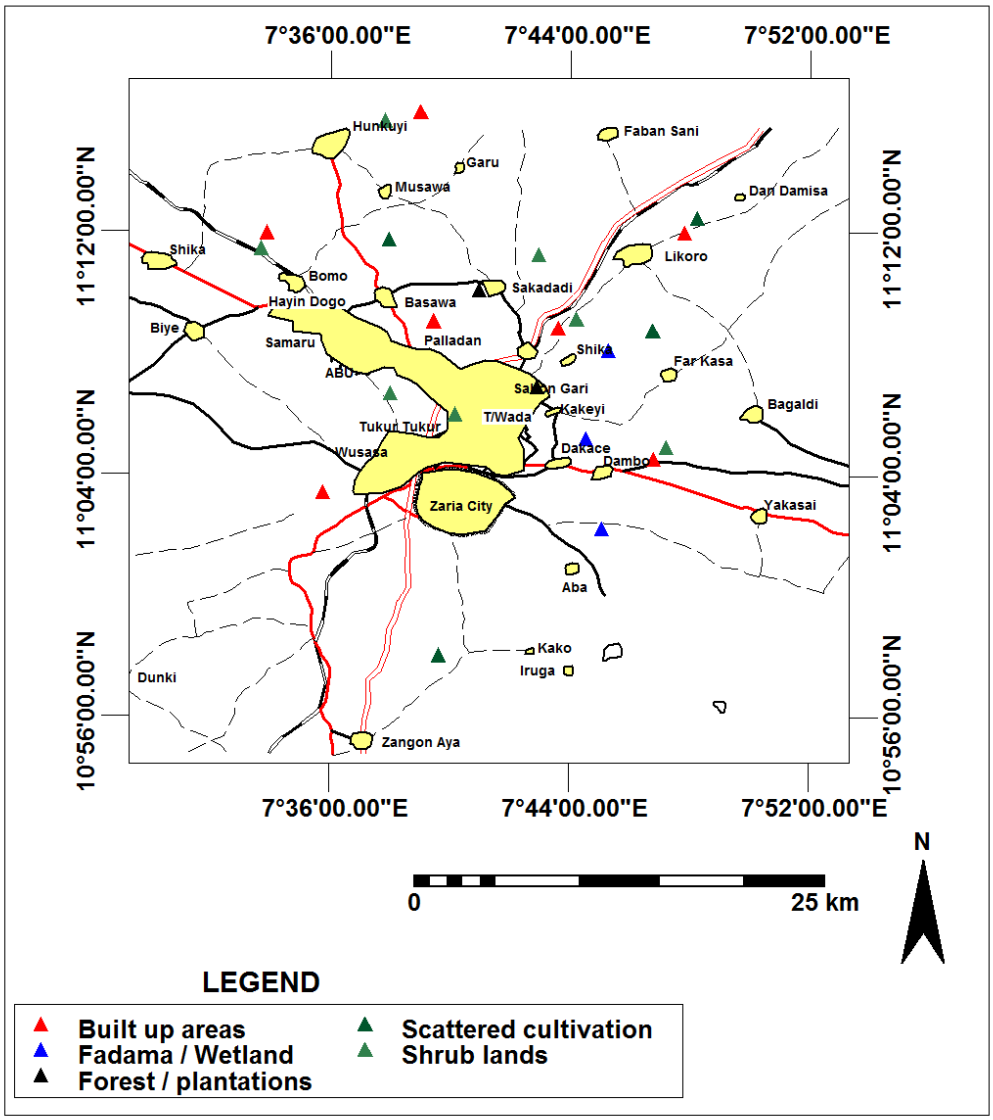


FIGURE4.3: Sample points of woody vegetation

4.2.3.2 Field procedure

The quadrant method was used to collect data on the characteristics of the woody tree species. A quadrant is used to define a fixed area, called plot, within which plant characters can be measured. For purposes of this study, a quadrant of 50 by 50 m was used because it allows for optimum inclusion of woody species in the area (Kent and Coker, 1992).

4.2.3.3 Measurement of vegetation parameters

Diameter at Breast Height (DBH):

Diameter at breast height is the most frequently measured variable in vegetation surveys and has multiple uses. It is done with the aid of a measuring tape. The tape has to be straight when records are taken (Eyre *et al,* 2006). A DBH tape is placed around the tree at 1.3m height and the diameter measured. If a DBH tape is not available a normal measuring tape can be used to measure the circumference and this value can be divided by Π(3.1416). Care should be taken to assure that the tape is accurately placed around the stem, and that stems or vines are not included in the measurement.



PLATE VII: Taking the Diameter at Breast Height (DBH)

Tree Height

An abney level is used to determine the angle of elevation, while the distance from the foot of the tree to the observer is recorded using the formula (Gareth, 1991)

$$X = Y \times \tan A + Z \quad \text{.....4.2}$$

Where

X= tree height

Y = distance from the tree to the observer

A = angle of elevation

Z = height of the observer at eye level

Total height is a straightforward parameter used for direct measurement purposes and also for the calculation of volume or biomass. The vertical length between the lowest part of the tree and the tallest living part for all trees more than 3 meters in height is measured and usually expressed in meters.



PLATE VIII: Taking the Angle of Elevation with the aid of Abney level

Tree species density and diversity:

This is the degree of concentration and frequency of tree species in a particular area and it is usually done by enumerating and recording total number of trees more than 3 meters in height and respective species found within the sample plot (Eyre *et al,* 2006). Density is expressed as number of trees per unit area.

Biomass

Biomass is the equivalent weight of an individual or group of individuals (e.g., trees and saplings). The method of calculation can be destructive (actually cutting and weighing what is being measured) or an estimation, based on algometric equations. For this work, algometric equation based on Snowdon's *et al* (2000) method of using the tree's circumference to obtain the above ground biomass value was used.

$$\text{Biomass} = \text{Exp}\ (1.4481 + (2.2364 * \text{LnDBH})$$

Where Exp = is the mean expansion factor

Ln = Natural log

DBH = Diameter at Breast Height

4.3 DATA ANALYSIS

Both descriptive and inferential statistics were employed in the analysis of data gathered in this study. Descriptive statistics concerns the summarization of raw data obtained in the field and also from the imageries analysed while inferential statistics concerns the test of the hypotheses drawn. For the hypothesis testing, several statistical techniques were employed. These include one way ANOVA (F- Ratio), t- test, regression and correlation

analysis. One way- ANOVA (F- Ratio) and t-test were used to analyse the land-use pattern and to note if there is any significant differences amongst and between the different periods. Regression and correlation analysis on the other hand was employed to test for significant relationships amongst the various land use patterns.

CHAPTER FIVE

RESULTS AND DISCUSSION

5.1 LAND USE/LAND COVER CHANGE

The land use/land cover of the study area for the four examined years is shown in figures 5.1, 5.2, 5.3, and 5.4. These maps are presented as it was obtained from National Centre of Remote Sensing, Jos.

The supervised classification system using the maximum likelihood classifier as explained in chapter four was used for the analyses of the imageries. Figures 5.5, 5.6, 5.7 and 5.8 shows the classified maps adopted in this study, while table 5.1 presents the statistics of the classified maps. After the maps were classified, they were overlaid/crossed in order to detect any change that has taken place over the examined period (see Appendix C). Figures 5.9, 5.10 and 5.11 shows the crossed maps, while table 5.2 show the statistics of the land use/ land cover analysis. From the table, data were taken to analyze the spatial growth that has occurred over time in the study area as well as for testing the hypotheses.

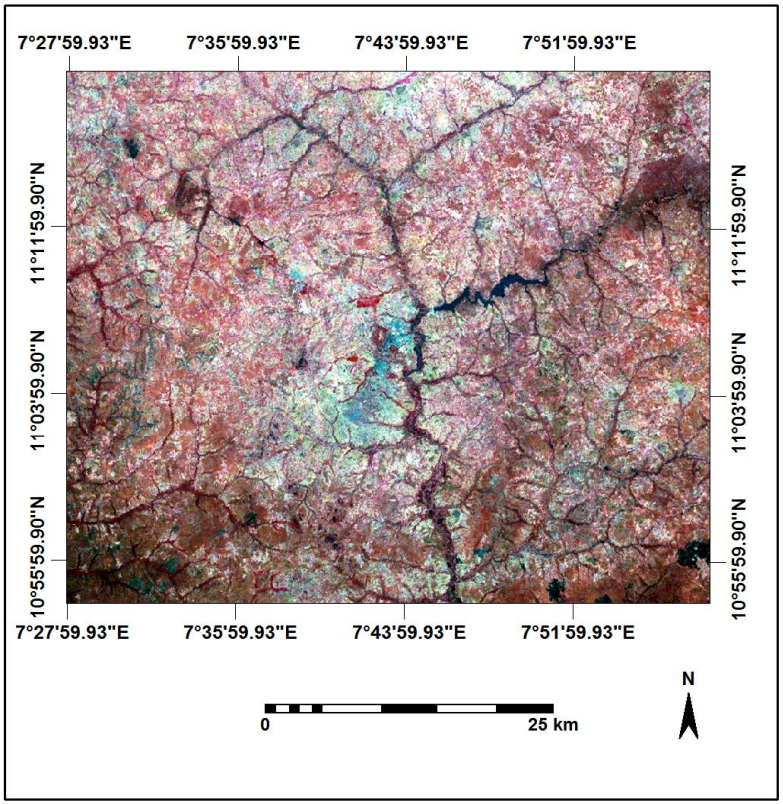


FIG.5.1 LAND USE LAND COVER IMAGERY OF THE STUDY AREA, MSS 1973

Source: National Centre for Remote Sensing (NCRS), Jos. 2011

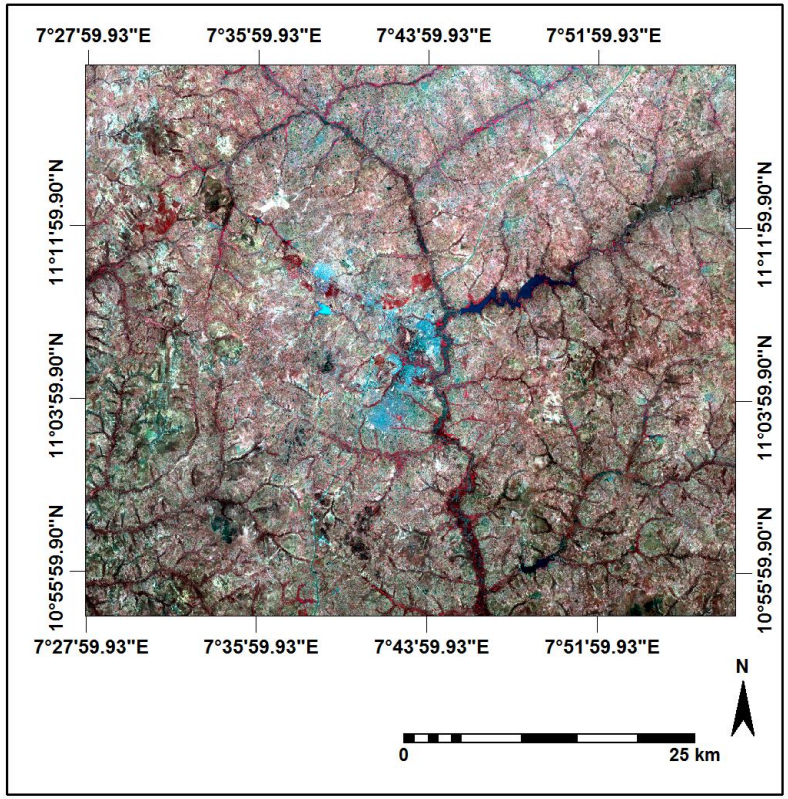


FIG.:5.2 LAND USE/LAND COVER IMAGERY OF THE STUDY AREA, TM 1990

Source: National Centre for Remote Sensing (NCRS), Jos. 2011

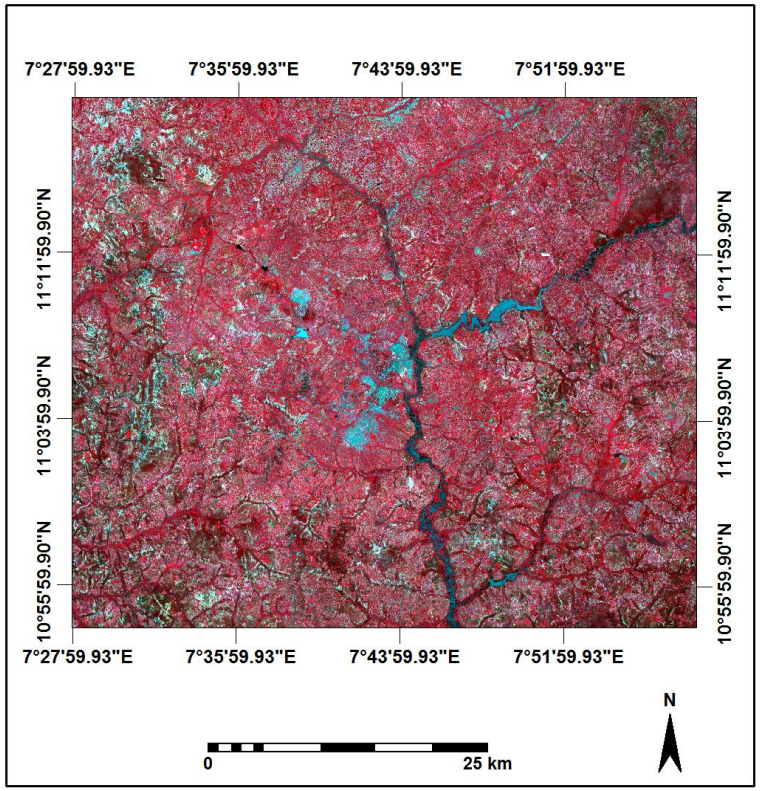


FIG.:5.3 LAND USE/LAND COVER IMAGERY OF THE STUDY AREA, ETM 1999

Source: National Center for Remote Sensing (NCRS), Jos, 2011

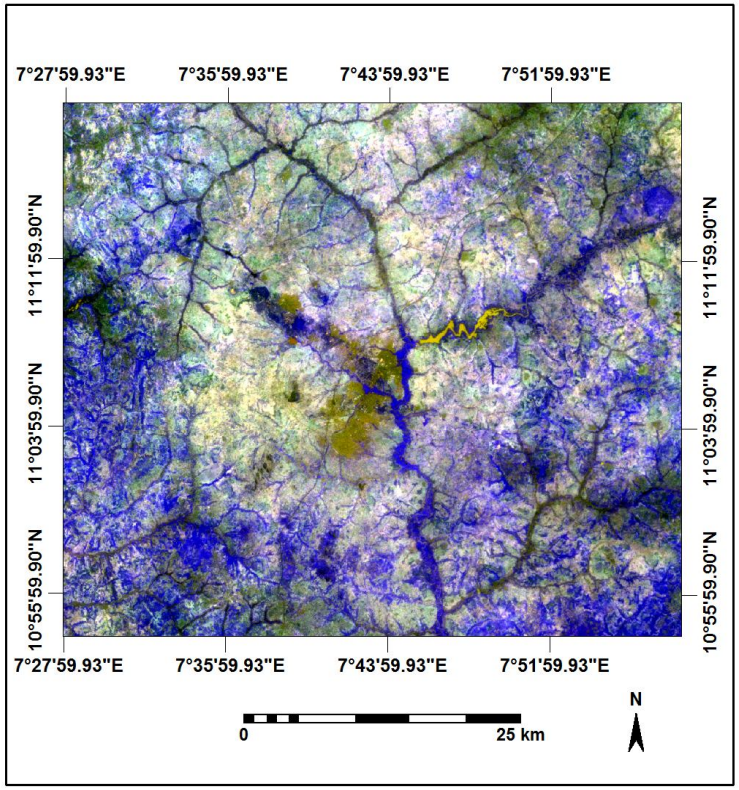


FIG.:5.4 LAND USE/ LAND COVER IMAGERY OF THE STUDY AREA, NIG. SAT-1, 2009

Source: National Centre for Remote Sensing (NCRS), Jos. 2011

5.1.1 The spatial and temporal variation of area of coverage of different land uses

As figures 5.5, 5.6, 5.7 and 5.8 and table 5.1 clearly indicate, that there is considerable variation in the land use/land cover of the studied area over the examined period. There is however no consistent variation in the area coverage of the different land uses over time. The only exception is the built-up area that showed a consistent increase over time.

The bare surfaces covered about 146km^2 (5.5%) in 1973 but decreased to about 33km^2 (1.2%) in 1999 and increased again to 85km^2 (3.2%) in 2009. In a similar fashion, the area covered by plantation/forest decreased from 89km^2 (3.4%) in 1973 down to 50km^2 (1.9%) in 1999 and increased again to 63km^2 (2.4%) in 2009. The scrubland also decreased from 1,766km^2 (66.9%) in 1973 down to 1,283km^2 (48.6%) in 1999, and increased slightly again to 1,350km^2 (51.2%) in 2009. By contrast, the fadama area increased from 146km^2 (5.5%) in 1973 to 634km^2 (24%) in 1999 and subsequently decreased to 571km^2 (21.7%) in 2009. The cultivated land increased from 409km^2 (15.5%) in 1973 to about 529km^2 (20%) both in 1990 and 1999, and decreased slightly to 433km^2 (16.4%) in 2009. The area of water body decreased from 38km^2 (1.5%) in 1973 to 18km^2 (0.68%) in 1990, and increased again to 28km^2 (1.1%) in 1999 before decreasing sharply to 4.2km^2 (0.16%) in 2009. Unlike the other land use categories, the built-up area revealed an increase value from 44km^2 (1.7%) in 1973, through 69km^2 (2.6%) in 1990 and 81km^2 (3.1%) in 1999 to 130km^2 (4.9%) in 2009.

Table 5.1: land use land cover classification summary in Km^2

LULC	1973	1990	1999	2009
Bare surfaces	145.77	77.10	32.81	85.47
	(5.5%)	(2.9%)	(1.2%)	(3.2%)
Built-up area	44.27	68.89	80.93	130.25
	(1.7%)	(2.6%)	(3.1%)	(4.9%)
Fadama	146.35	171.55	634.38	571.29
	(5.5%)	(6.5%)	(24.0%)	(21.7%)
Plantation/forest	89.24	58.39	49.60	63.36
	(3.4%)	(2.2%)	(1.9%)	(2.4%)
Scattered cultivation	408.69	528.10	529.09	433.24
	(15.5%)	(20.0%)	(20.1%)	(16.4%)
Scrubland	1,765.72	1,716.36	1,283.02	1,350.39
	(66.9%)	(65.1%)	(48.6%)	(51.2%)
Water bodies	38.16	17.81	28.37	4.20
	(1.5%)	(0.68%)	(1.1%)	(0.16%)
TOTAL	**2638.20**	**2638.20**	**2638.20**	**2638.20**

Note: % cover in bracket

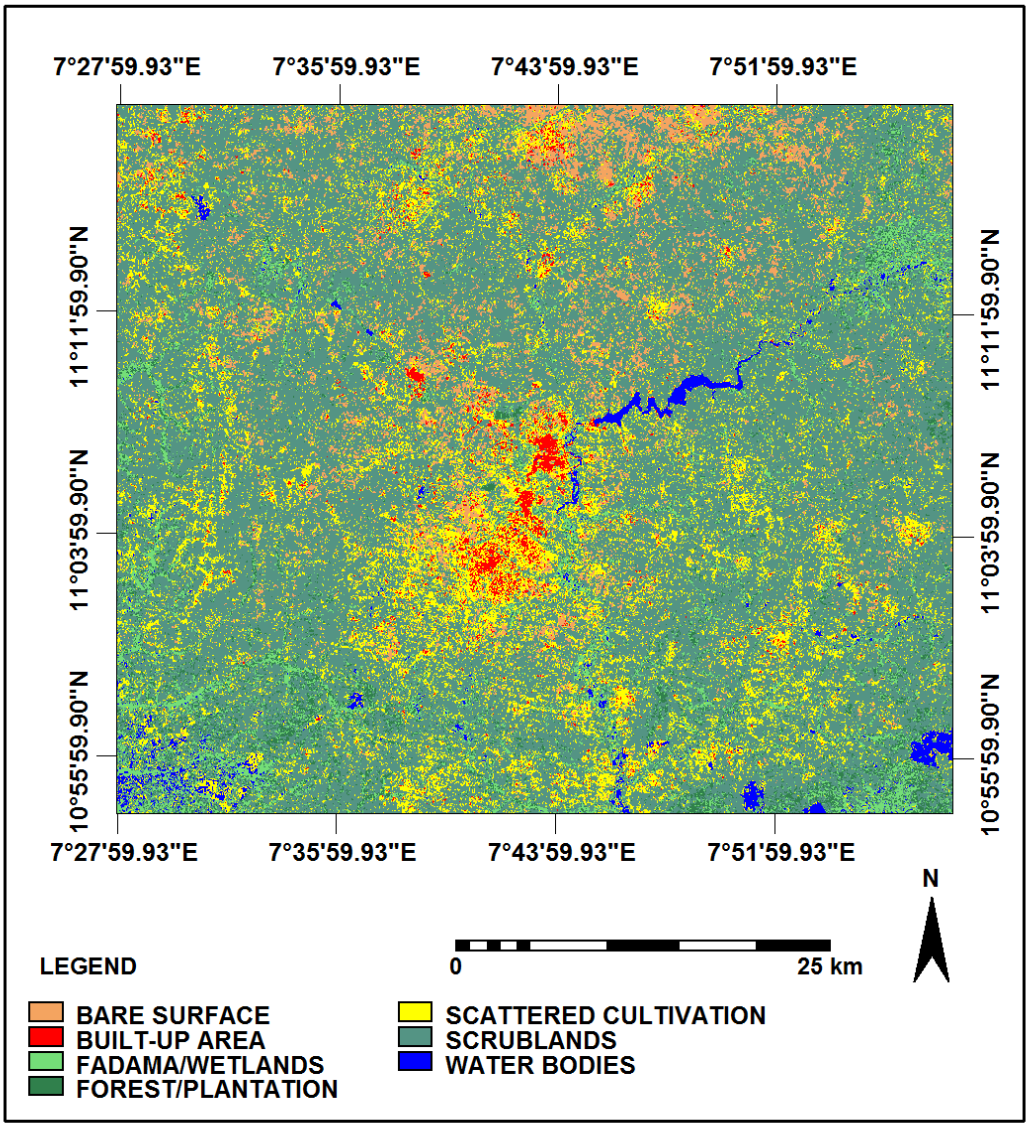


FIG.:5.5 MSS 1973 CLASSIFIED MAP OF THE SYUDY AREA

Source: Laboratory Analysis, 2012

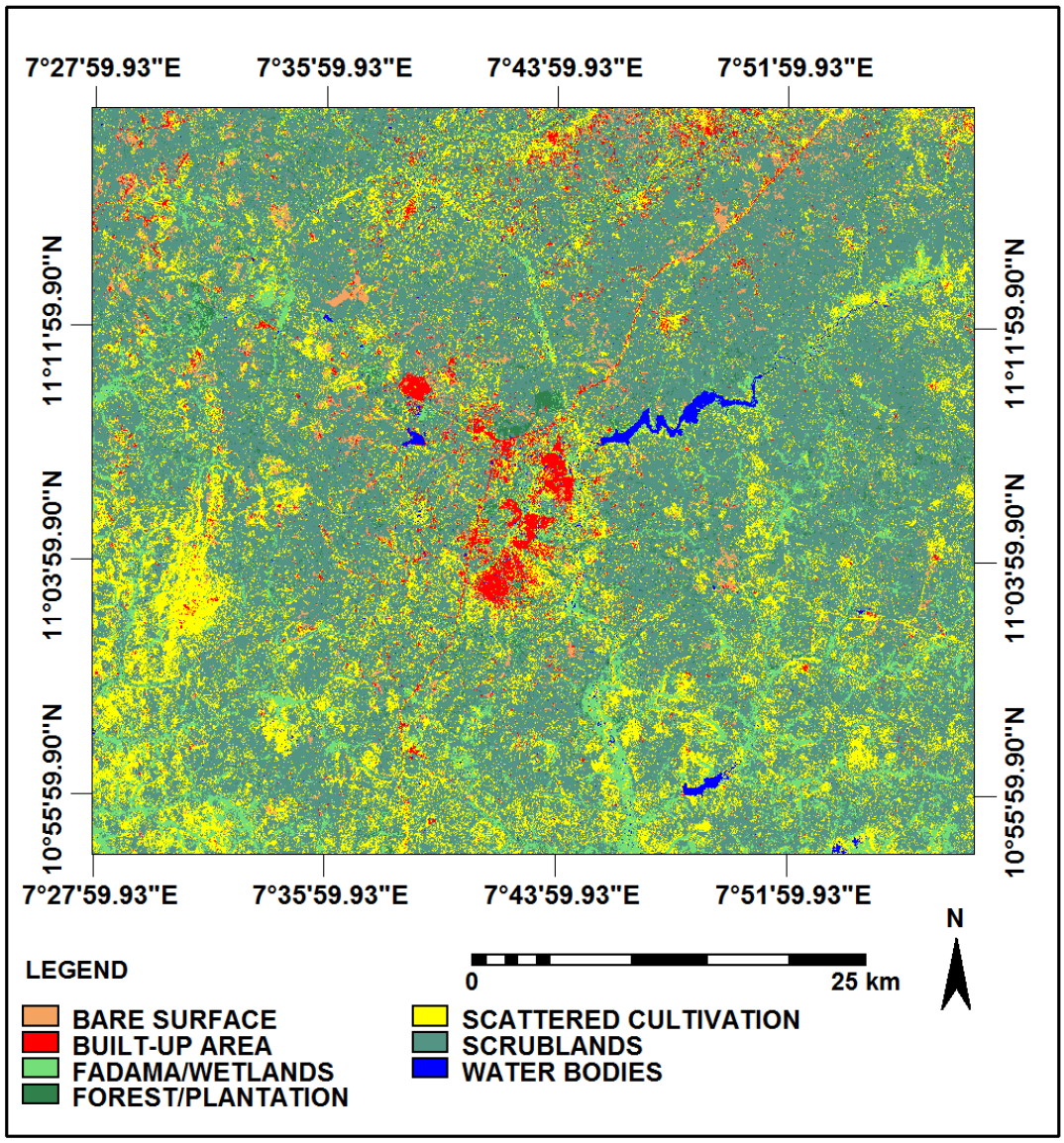


FIG:5.6 TM 1990 CLASSIFIED MAP OF THE STUDY AREA

Source: Laboratory Analysis, 2012

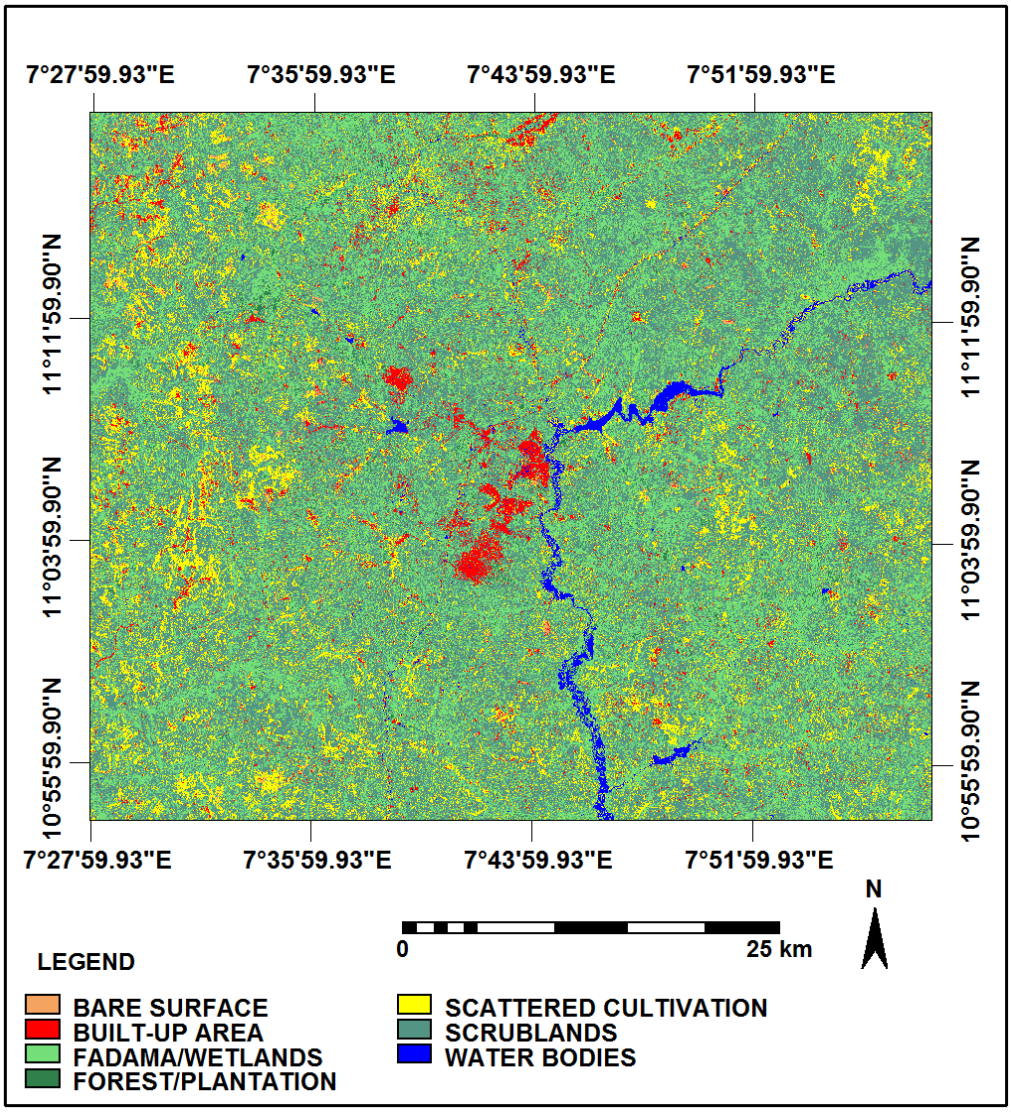


FIG:5.7 ETM 1999 CLASSIFIED MAP OF THE STUDY AREA

Source: Laboratory Analysis, 2012

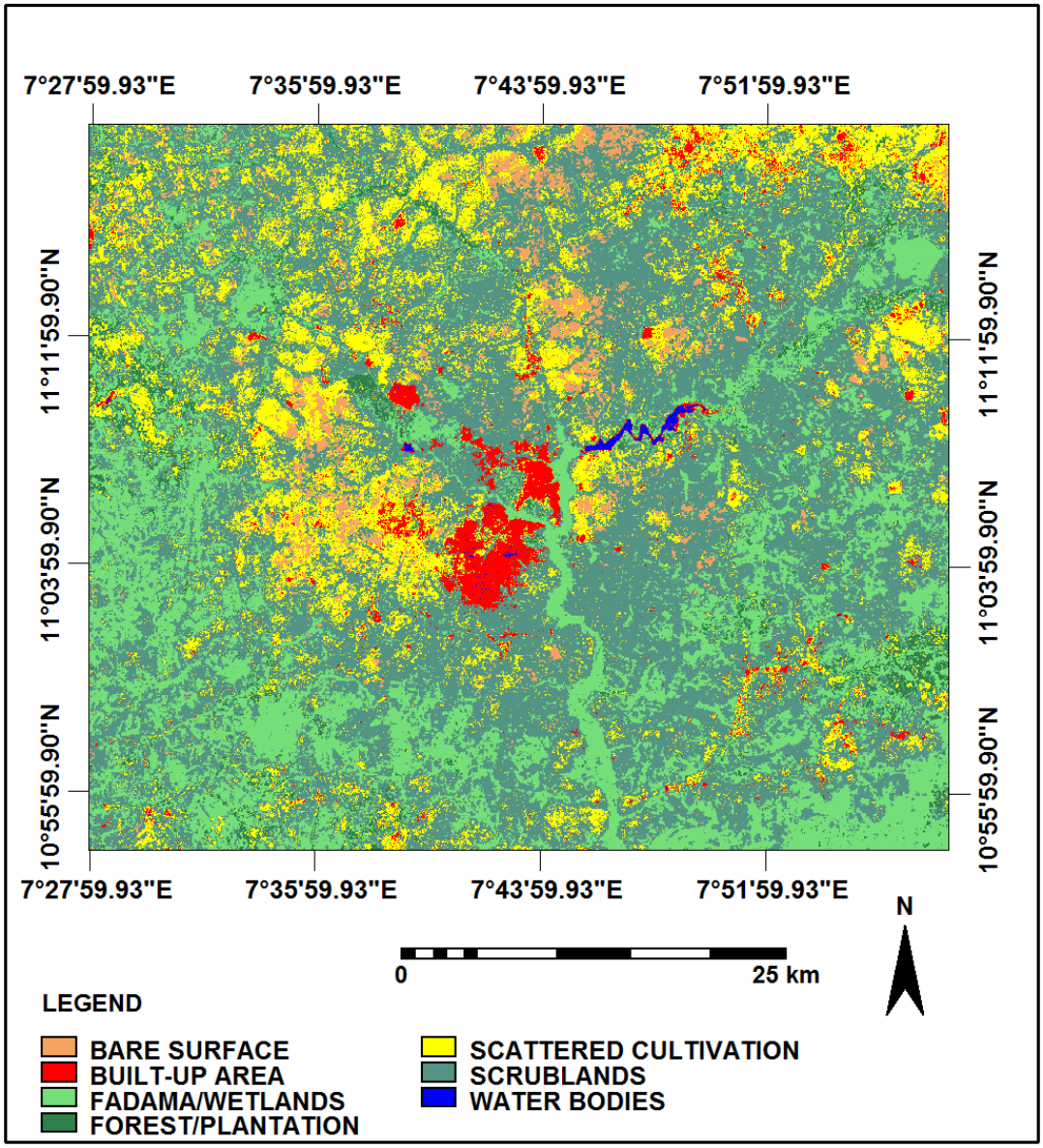


FIG.:5.8 NIG. SAT 1 CLASSIFIED MAP OF THE STUDY AREA

Source: Laboratory Analysis, 2012

5.1.2 Description of net change

The considerable fluctuation in the trend of some of the land use over time no doubt is ascribed, at least partially, to climatic factors (rainfall) and the period of the year during which the images used were obtained. The Multispectral Scanner (MSS) imagery of 1973 was taken in December, the Thematic Mapper (TM) imagery of 1990 taken in November, the Enhanced Thematic Mapper (ETM) imagery of 1999 taken in October and the Nig-Sat_1 imagery of 2009 taken in September. The bare surfaces in 1973 were about 146km^2 possibly because the image was obtained during the dry season when a lot of crops have been harvested and the land left bared. The fadama amounted to about 634km^2 in 1999 presumably because by the time the imagery was taken, the rainy season had stopped but the ground was still wet along the river banks. One other factor accounting for increased trend of the cultivated land over time is increased farming activity in the region.

The observed trend in the plantation/forest cover no doubt reflects the high deforestation rate in the area. Although even as far back as 1962, much of the natural forest has disappeared in Zaria, there were still a number of man-made forests in the region. For example, there used to be some known forests, such as Maje reserve located along Zaria-Funtua main road, Fatika reserve located west of Zaria town and the Guga plantation located west of Samaru. All existed until early 1980s. By the 1990s, the only visible forest left was the Kabama forest located north of Zaria which today has disappeared as well. The main factor responsible for this decline is clearing for city expansion and logging. There was a slight increase in the area of plantation in 2009. It rose from 1.88% in 1999 to 2.40% in 2009 and this was as a result of the tree planting that took place within the Ahmadu Bello University environment and some other institutions in the 90s'.

The upward trend in built-up area over the region no doubt reflects the increased population and consequent conversion of other land uses into residential areas. Today, most of the then isolated villages in the 60s' around Zaria metropolitan areas have actually coalesced into the town. Prominent among such settlements are Wusasa, Dan-magaji, Hanwa, Zango, Dogarawa among others.

The probable distortion in the trend of the different land uses in the study area caused by differences in the date and mode of acquisition of the imagery were taken notwithstanding, there are clear indication of increasing land degradation and consequent expansion of bare surfaces in the study area. The spiral of activities generating such surfaces usually set in when bushes with scattered trees are transformed into grassland and eventually to bare surfaces.

Reflecting the temporal variation of the coverage of the different land uses, the net change between pairs of years shows considerable variability. While the bare surfaces, plantation/forest and scrublands show respectively net negative values between 1973/1990 and 1990/1999 and net positive in the 1999/2009, the fadama and scattered cultivation showed net positive in the first two periods interval and net negative in the third period while the percentage changed showed somewhat constantly increasing values for the bare surfaces however, those for the plantation/forest and scrublands show rather concave and convex pattern respectively.

In the same fashion, the percentage net change for the fadama and cultivated land showed convex and concave pattern respectively. The net change in built up area is positive throughout the examined period, while that of the water body first showed a net negative

and then net positive and finally net negative change. While the magnitude of change for the former land use category first showed a decrease and then an increase that of the latter land use category showed somewhat upward trend throughout.

TABLE: 5.2 LULC CHANGE DETECTION

LULC	1973 and 1990		1990 and 1999		1999 and 2009	
	Area/ km^2	%	Area/ km^2	%	Area/ km^2	%
BARE SURFACES	-68.67	47.12	-44.29	57.44	+52.66	160.50
BUILT-UP AREA	+24.62	51.61	+12.04	17.48	+49.32	60.94
FADAMA	+25.20	17.22	+462.83	269.79	-63.09	9.95
PLANTATION/FOREST	-30.85	34.57	-8.79	15.05	+13.76	27.74
SCATTERED CULTIVATION	+119.41	29.22	+0.99	0.19	-95.85	18.12
SCRUBLANDS	-49.36	2.80	-433.34	25.25	+67.37	5.25
WATER BODIES	-20.35	53.33	+10.56	59.29	-24.17	85.20

Positive (+) indicates an increase in area coverage
Negative (-) indicates a decrease in area coverage

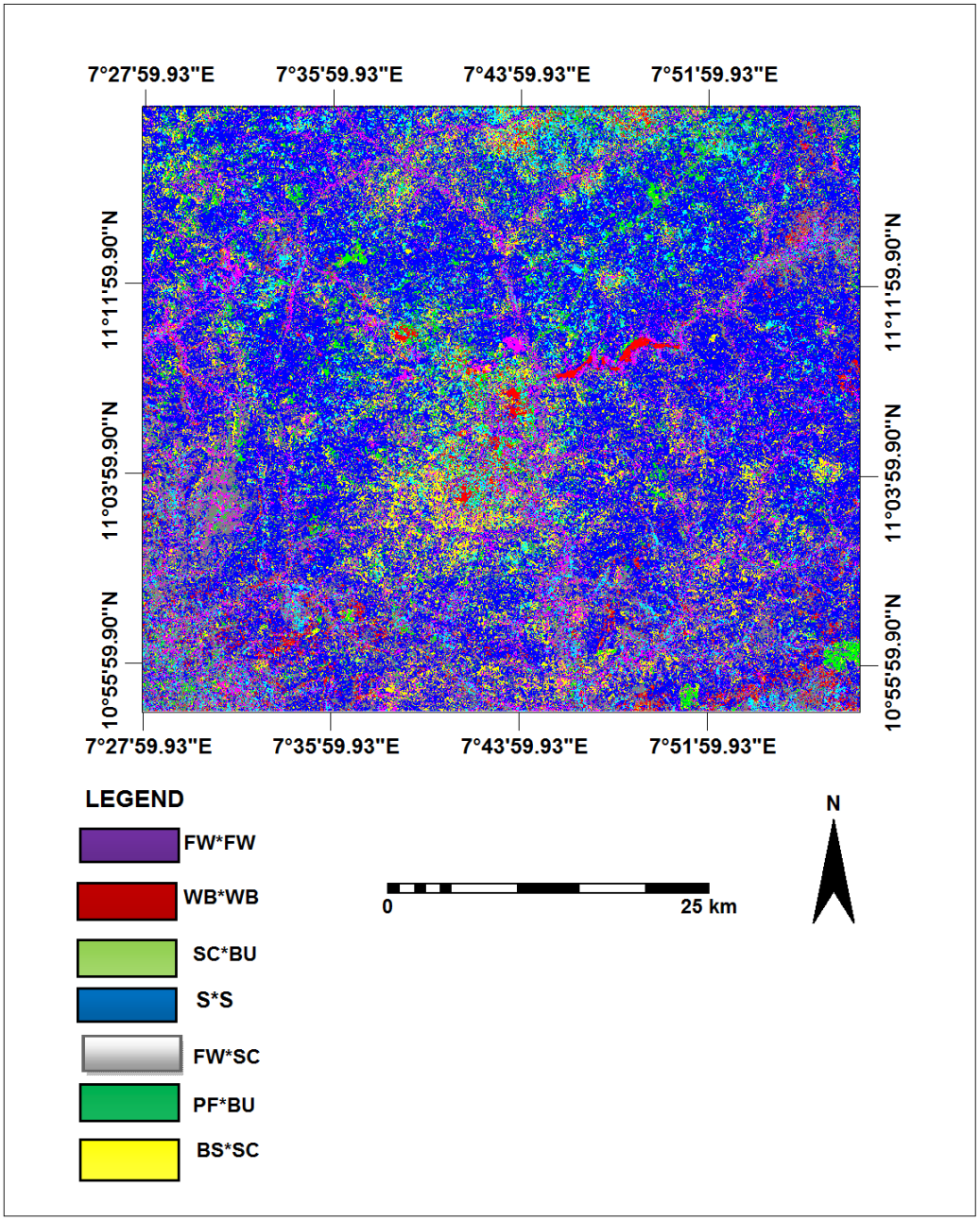


FIG.:5.9 MSS AND TM CROSSED MAP OF THE STUDY AREA

Source: Laboratory Analysis,

***FW: Fadama, WB: Water bodies, BU: Built-up, SC: Scattered cultivation, S: Scrublands, BS: Bare surfaces, PF: Plantation/forest**

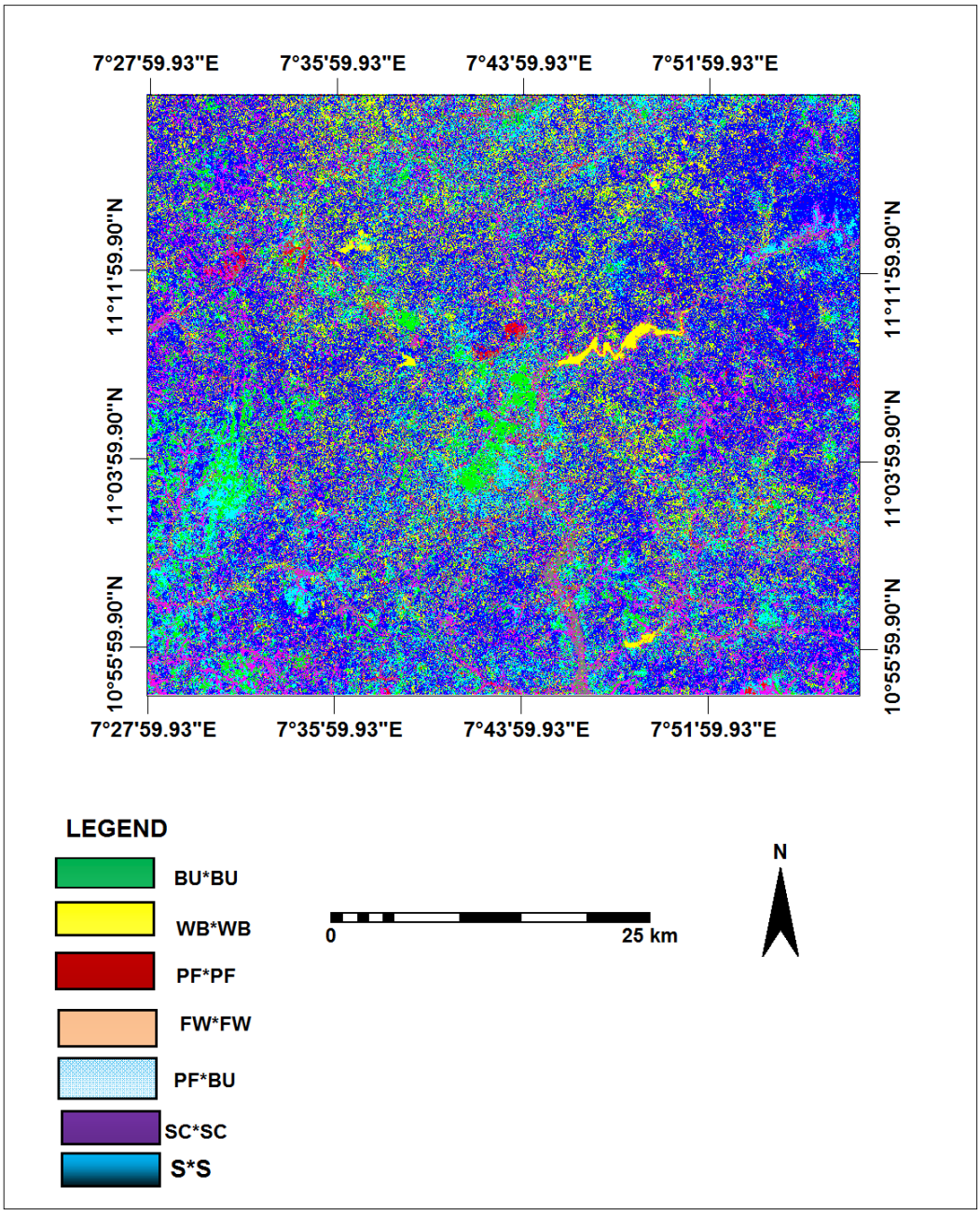


FIG.:5.10 TM AND ETM CROSSED MAP OF THE STUDY AREA

Source: Laboratory Analysis,

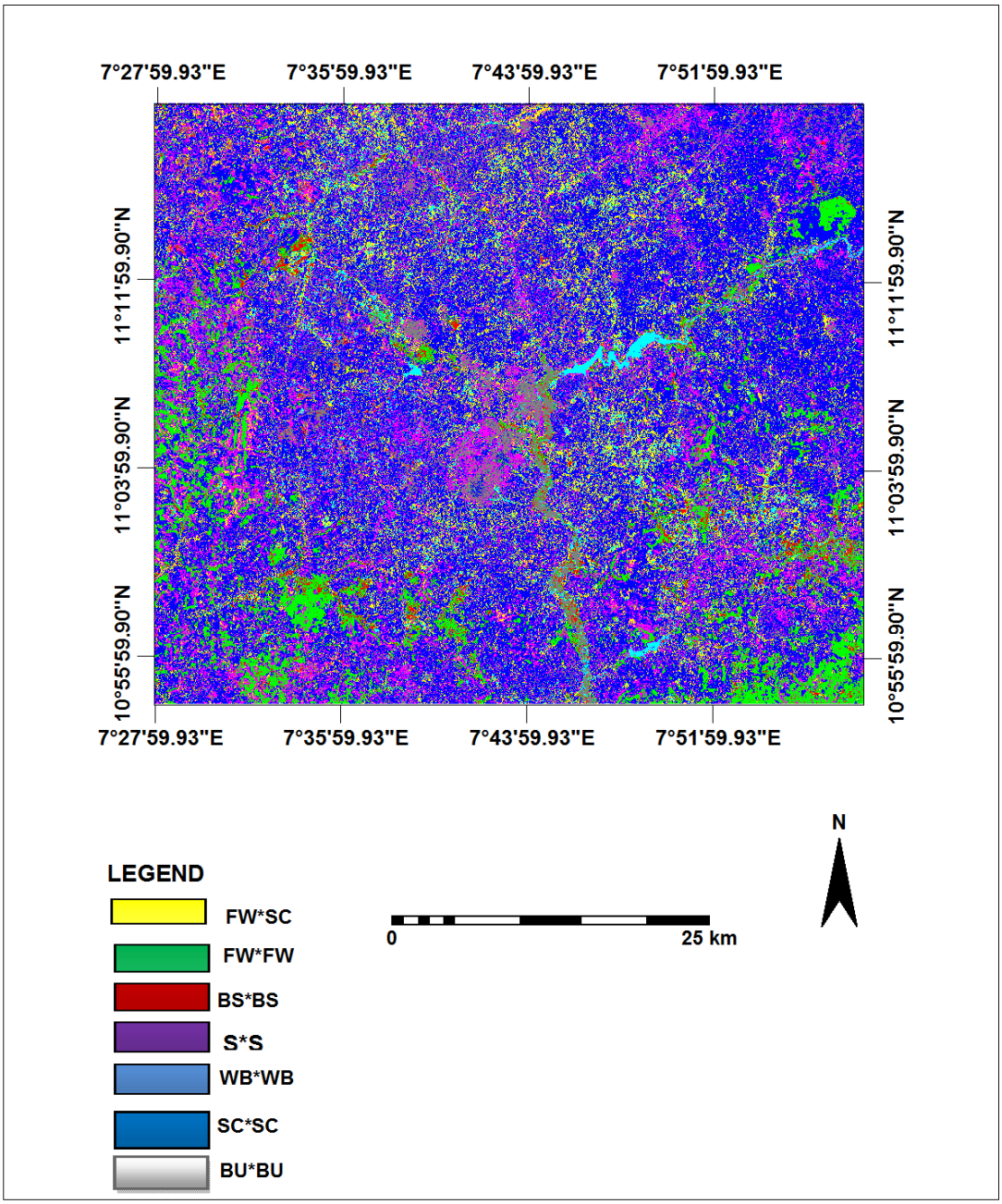


FIG.:5.11 ETM AND NIG. SAT-1 CROSSED MAP OF THE STUDY AREA

Source: Laboratory Analysis, 2012

***FW: Fadama, WB: Water bodies, BU: Built-up, SC: Scattered cultivation, S: Scrublands, BS: Bare surfaces, PF: Plantation/forest**

5.2 NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI)

The NDVI shows the degree of greenness of vegetation and therefore health of the plant cover over an area. It has also been used to estimate vegetation change, either as an index or as one input to dynamic vegetation models. NDVI is simply a ratio of red and near-infrared light reflected by the land surface. It is a quick effective indicator of biomass and chlorophyll content. It takes less time and it's unbiased in its result. Figures 5.12, 5.13, 5.14 and 5.15 shows the NDVI maps in their initial color of black and white. The areas with the brighter color (white) are areas with heavier vegetation while those with dark (black) color are without vegetation at all.

For the purpose of this project, the NDVI were classified into 3 classes as shown in table 4.4. The classified NDVI imagery for the four periods are shown in figures 5.17, 5.18, 5.19 and 5.20 respectively while the pictorial representation is shown in figure 5.16 and the associated statistics are summarized in Appendix I. The results obtained when the images were overlaid to determine the extent of changes that took place are presented in figures 5.21, 5.22 and 5.23 and table 5.3 summarizes the associated statistics (see Appendix D).

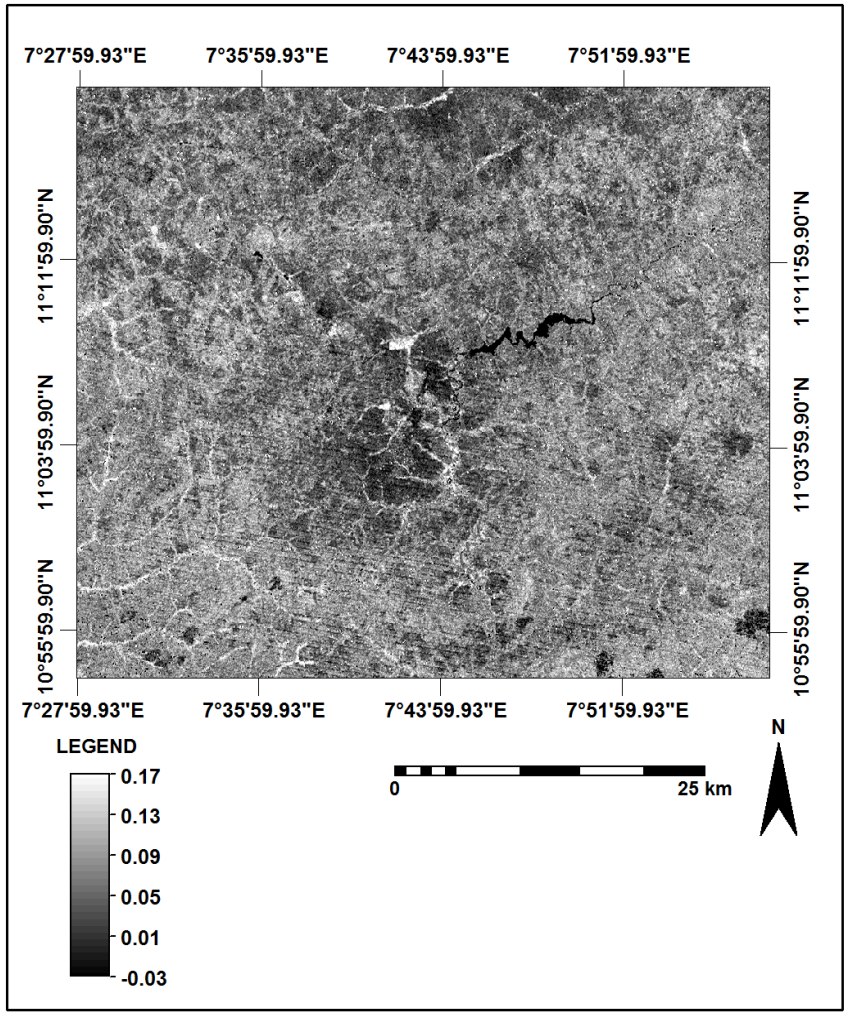


FIG.: 5.12 MSS 1973 NDVI IMAGERY OF THE STUDY AREA

Source: Laboratory Analysis, 2012

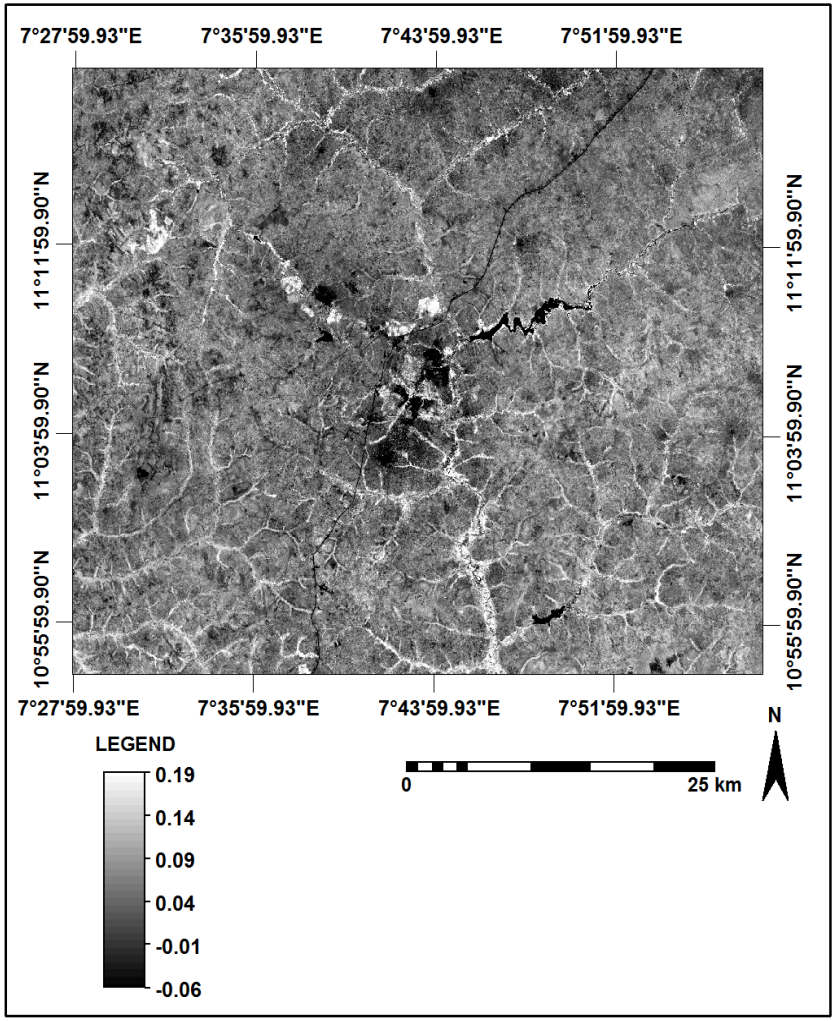


FIG.:5.13 TM 1990 NDVI IMAGERY OF THE STUDY AREA

Source: Laboratory Analysis, 2012

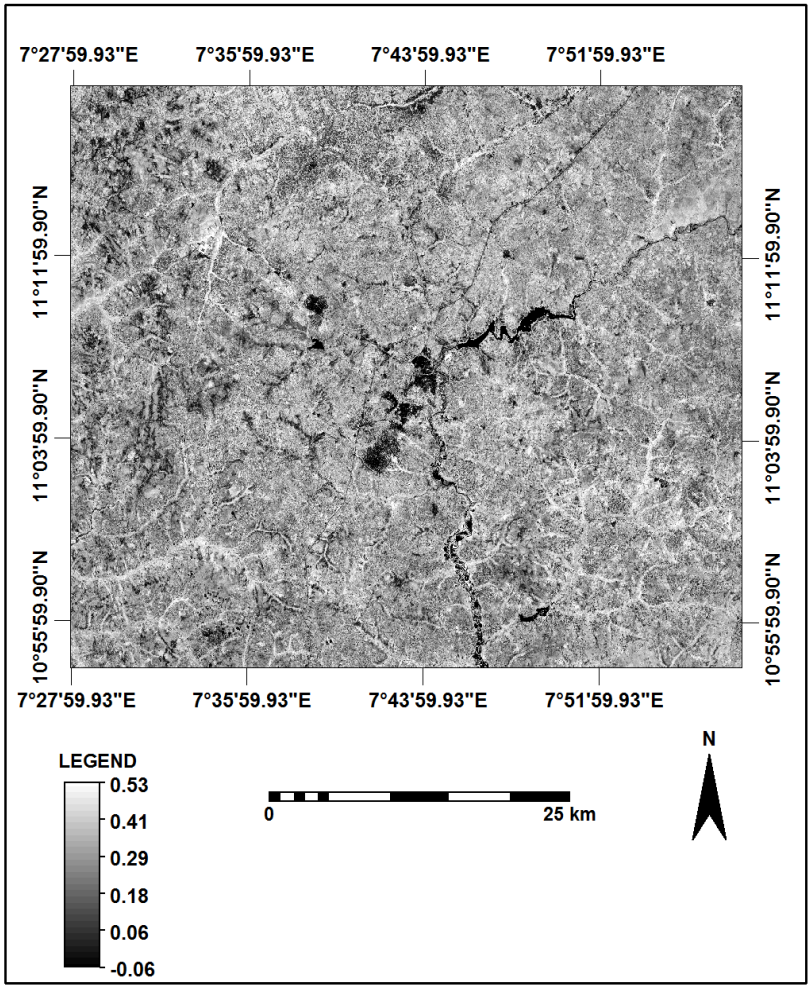


FIG.:5.14 ETM 1999 NDVI IMAGERY OF THE STUDY AREA

Source: Laboratory Analysis, 2012

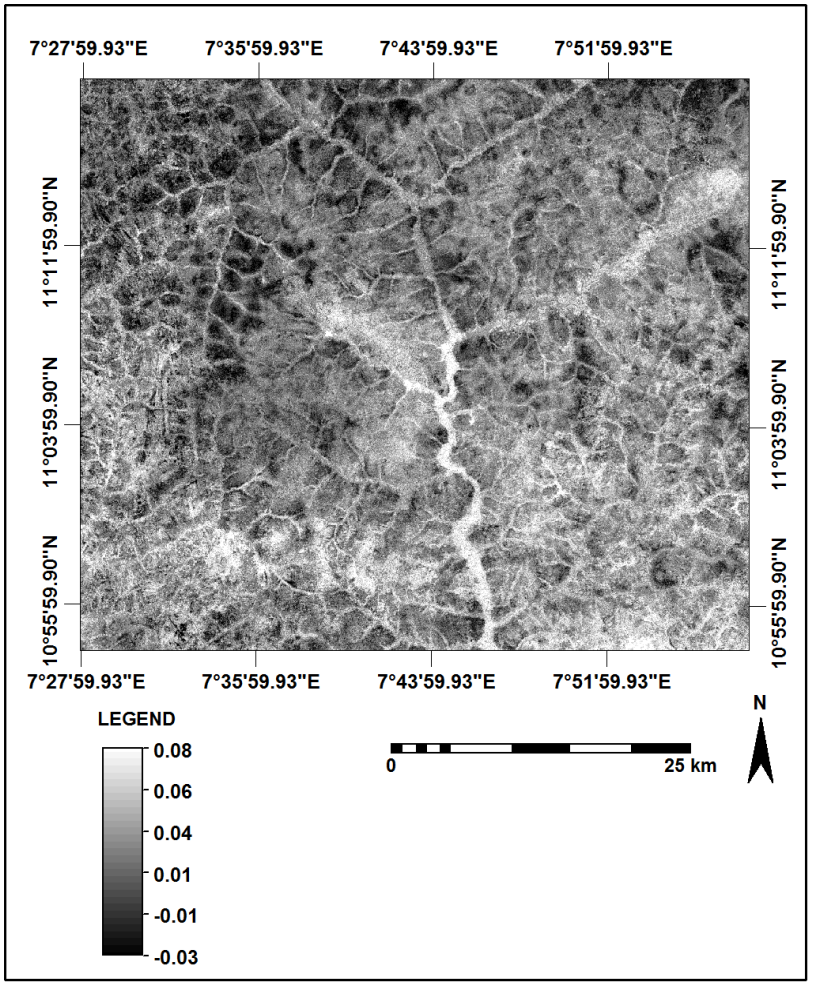


FIG.:5.15 NIG. SAT-1 2009 NDVI IMAGERY OF THE STUDY

Source: Laboratory Analysis, 2012

5.2.1 Variation of area coverage of the NDVI

Area of dense vegetation varies in reciprocal with areas of sparse vegetation over time. The value of dense vegetation decreased from 206km^2 (8%) in 1973 to 37km^2 (1%) in 1990, subsequently increased from 88km^2 (3%) in 1999 to 134km^2 (5%) in 2009. By contrast, areas of sparse vegetation increased slightly from 1,264km^2 (48%) in 1973 to 1,284km^2 (49%) in 1990 and thereafter decreased to 1,107km^2 (42%) in 1999 and 769km^2 (29%) in 2009. The areas with no vegetation show a fairly steady increase from 1,168km^2 (44%) in 1973, through 1,318km^2 (50%) and 1,442km^2 (55%) in 1990 and 1999, respectively to 1,736km^2 (66%) in 2009 (figure 5.16).

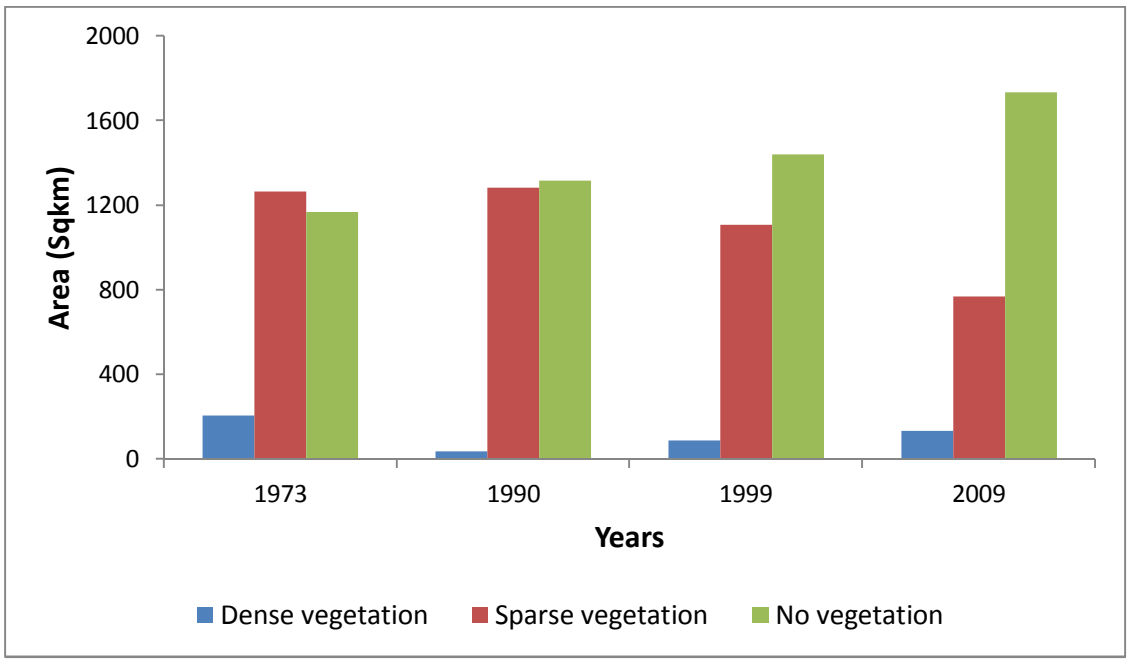


Figure 5.16 Area coverage of the NDVI over the examined period

This result confirms the conclusion reached earlier that land degradation is on gradual increase in the study area. While the area of dense vegetation cover is negatively correlated with the trend of built-up area, those of the sparse vegetation and no vegetation showed positive relationship (table 5.3).

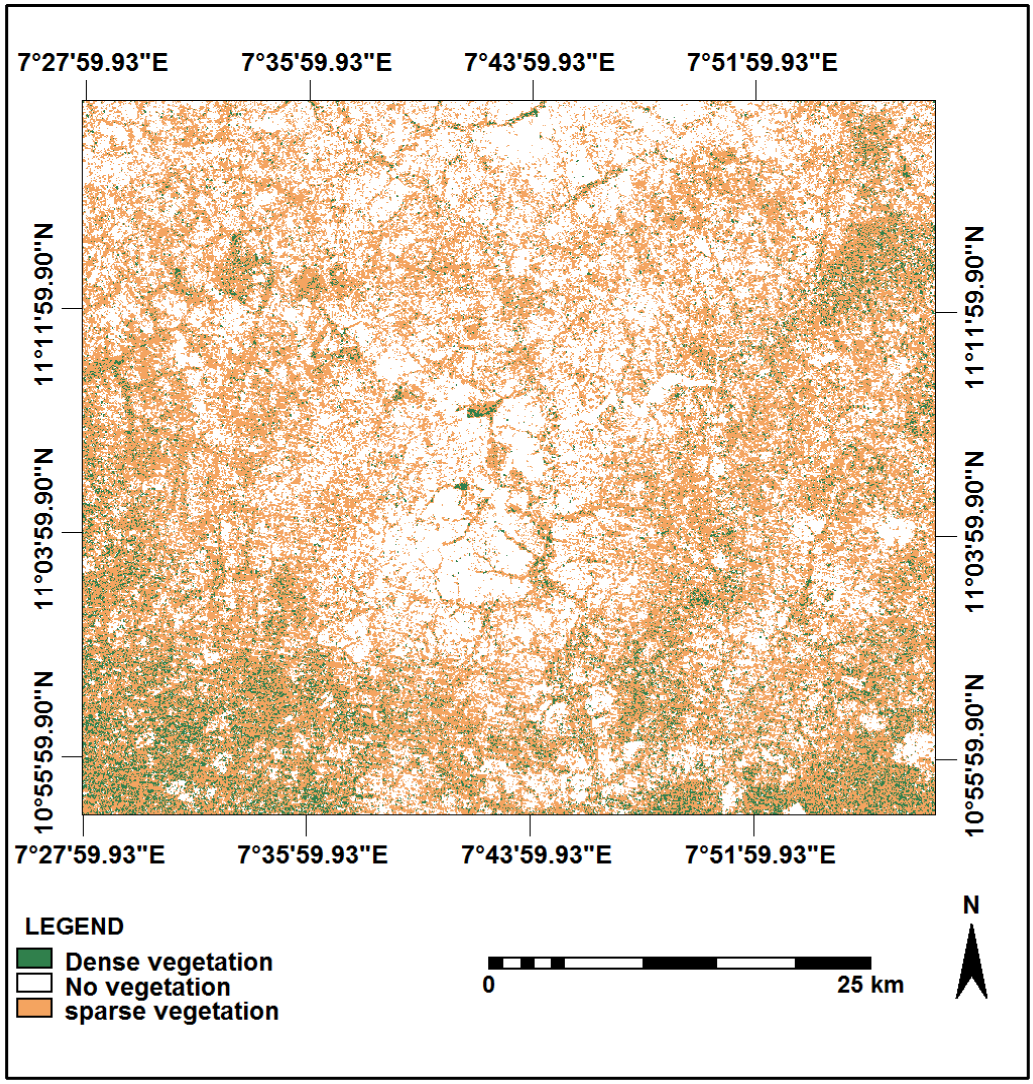


FIG.:5.17 1973 MSS NDVI CLASSIFIED MAP OF THE STUDY AREA

Source: Laboratory Analysis, 2012

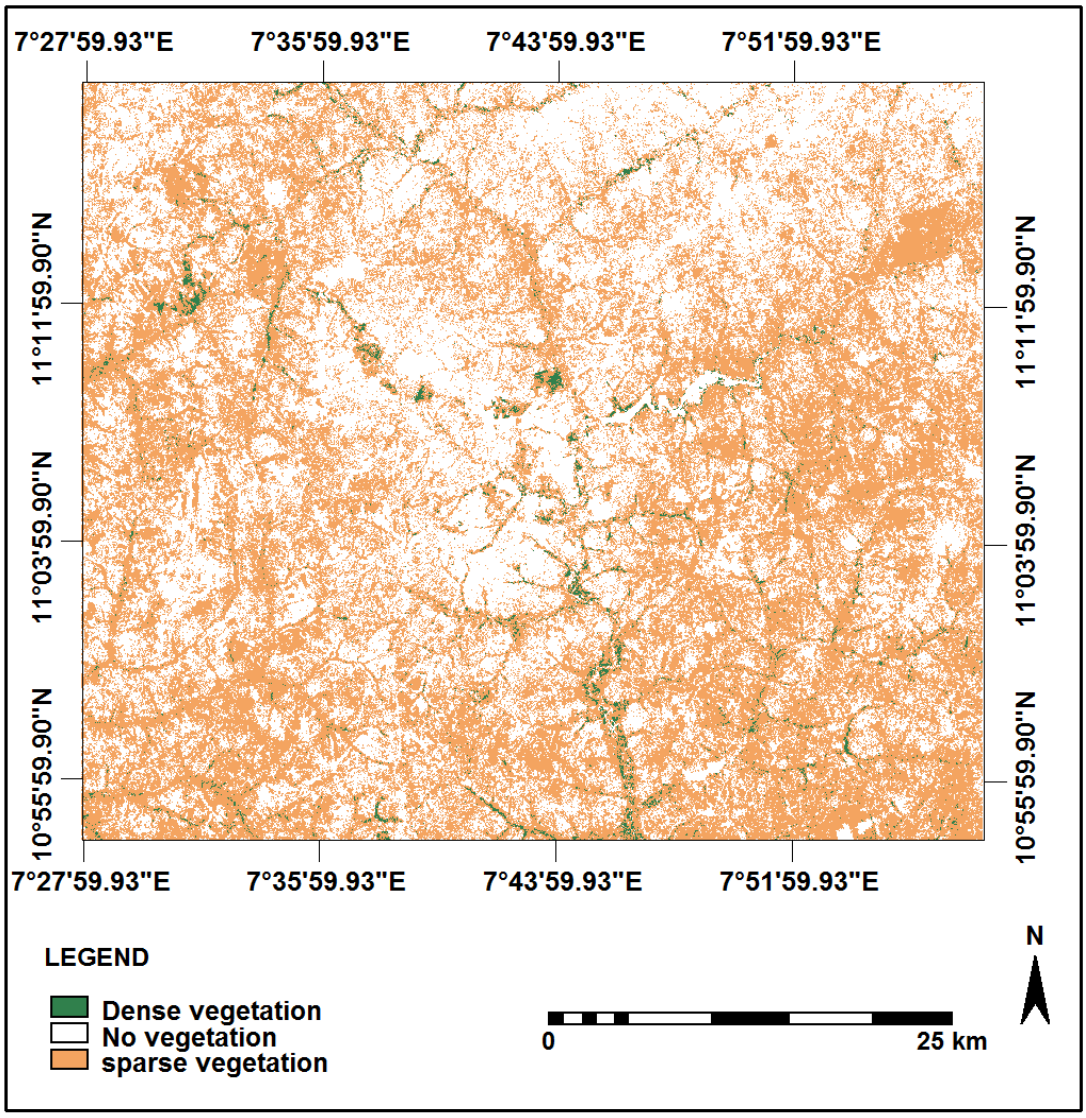


FIG.:5.18 1990 TM NDVI CLASSIFIED MAP OF THE STUDY AREA

Source: Laboratory Analysis, 2012

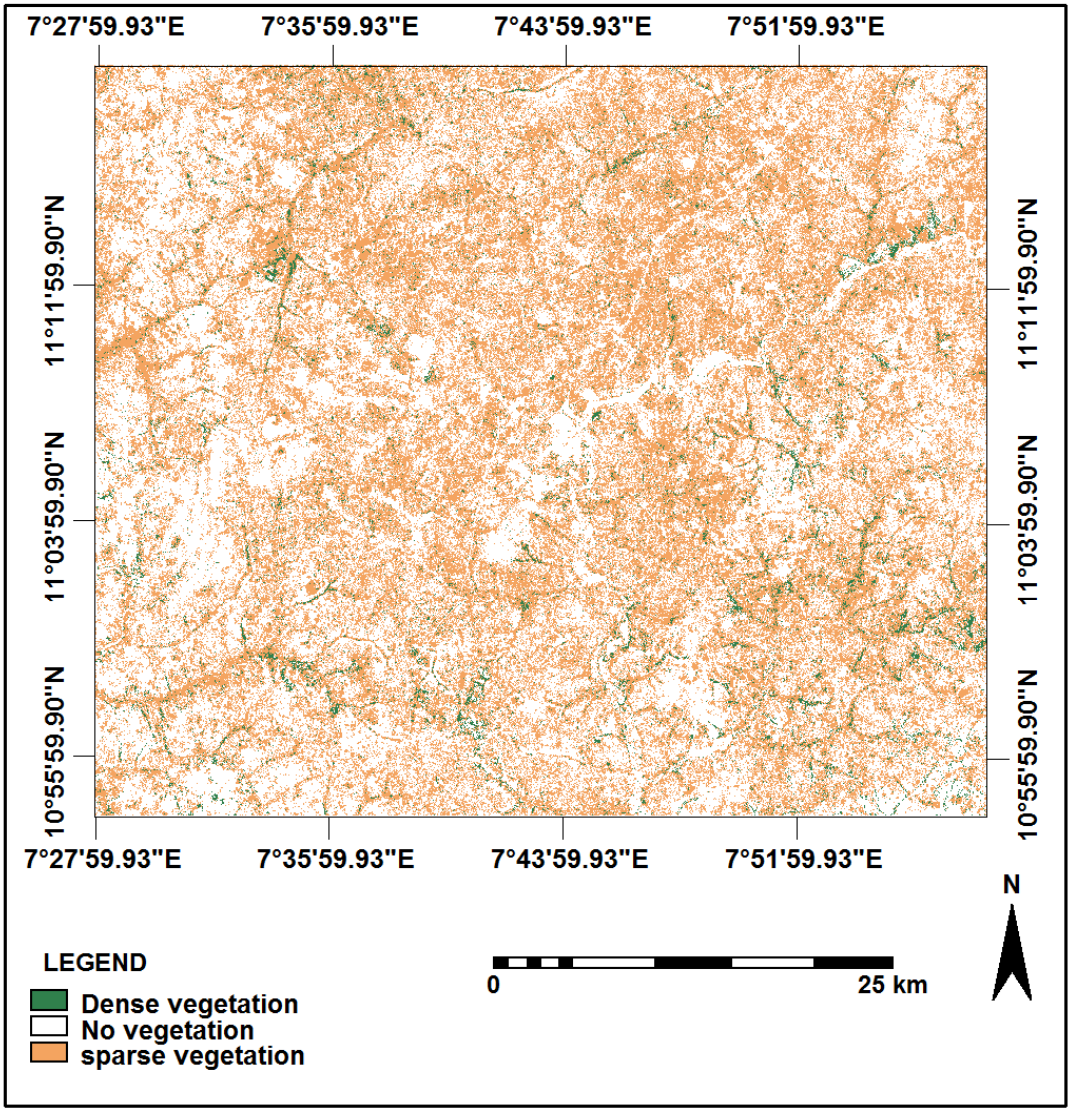


FIG.: 5.19 1999 ETM NDVI CLASSIFIED MAP OF THE STUDY AREA

Source: Laboratory Analysis, 2012

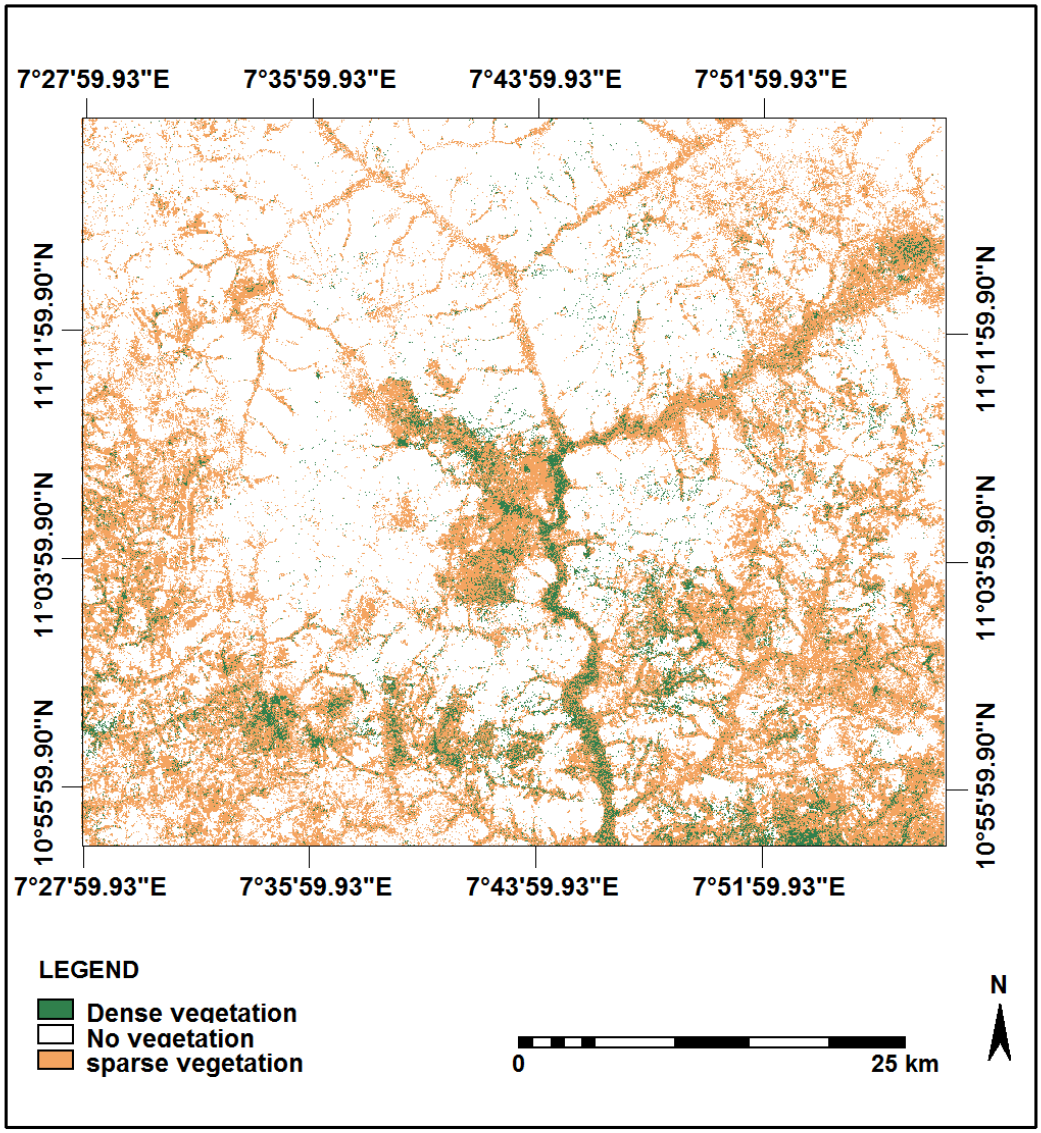


FIG.:5.20 2009 NIG. SAT-1 NDVI CLASSIFIED MAP OF THE STUDY AREA

Source: Laboratory Analysis, 2012

TABLE: 5.3 AREA COVERAGE OF THE NDVI CHANGE DETECTION

Vegetation cover type	1973 & 1990 Area/ha	%	1990 & 1999 Area/ha	%	1999 & 2009 Area/ha	%
Dense vegetation	-168.73	82.06	+51.40	139.33	+45.47	51.50
Sparse vegetation	+19.20	1.52	-176.00	13.71	-338.82	30.59
No vegetation	+149.53	12.80	+124.60	9.46	+293.35	20.34

Positive (+) indicates an increase in area coverage
Negative (-) indicates a decrease in area coverage

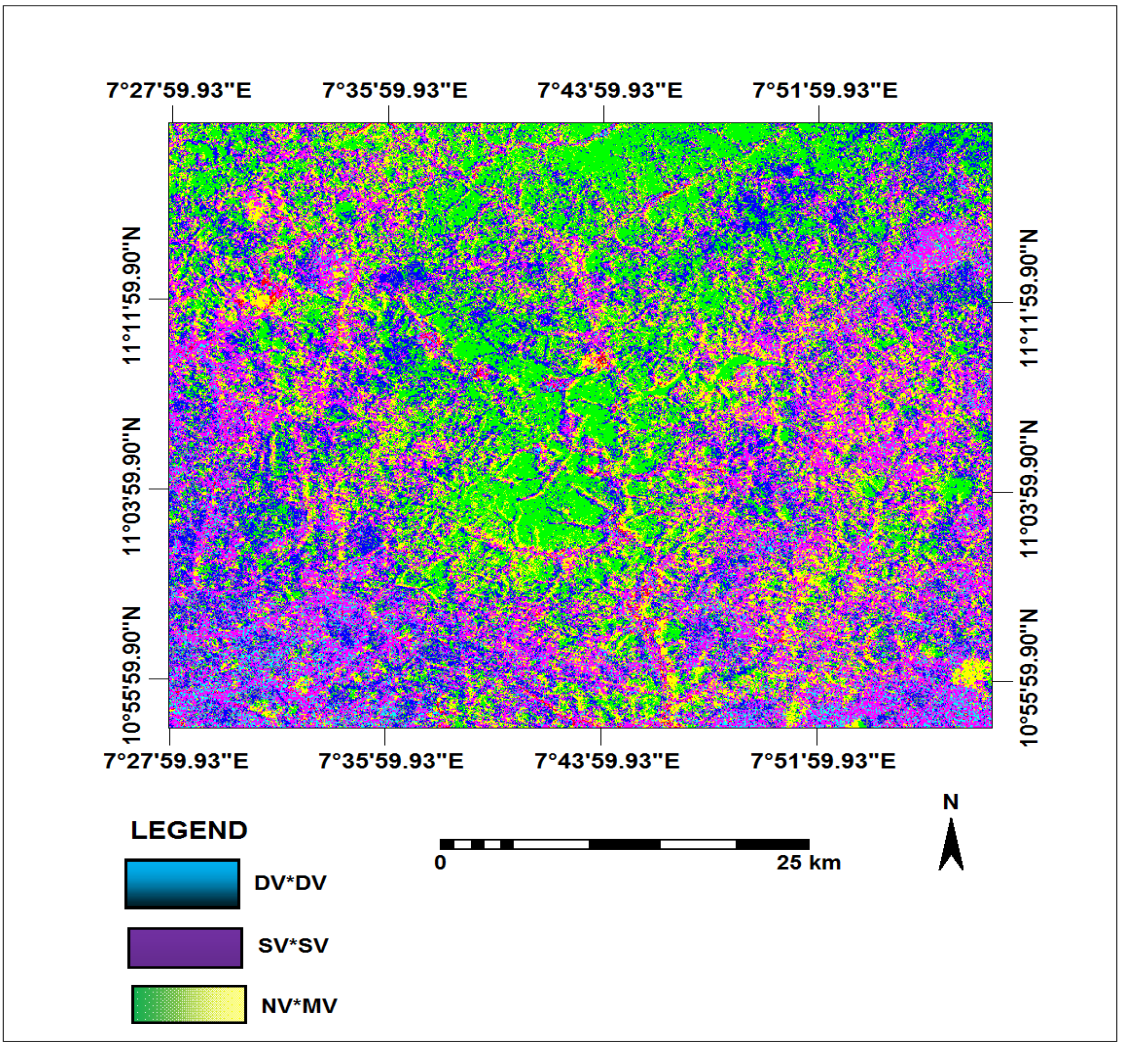


FIG.:5.21 MSS AND TM NDVI CROSSED MAP OF THE STUDY AREA

Source: Laboratory Analysis, 2012

*** DV: Dense vegetation, SV: Sparse vegetation, NV: No vegetation**

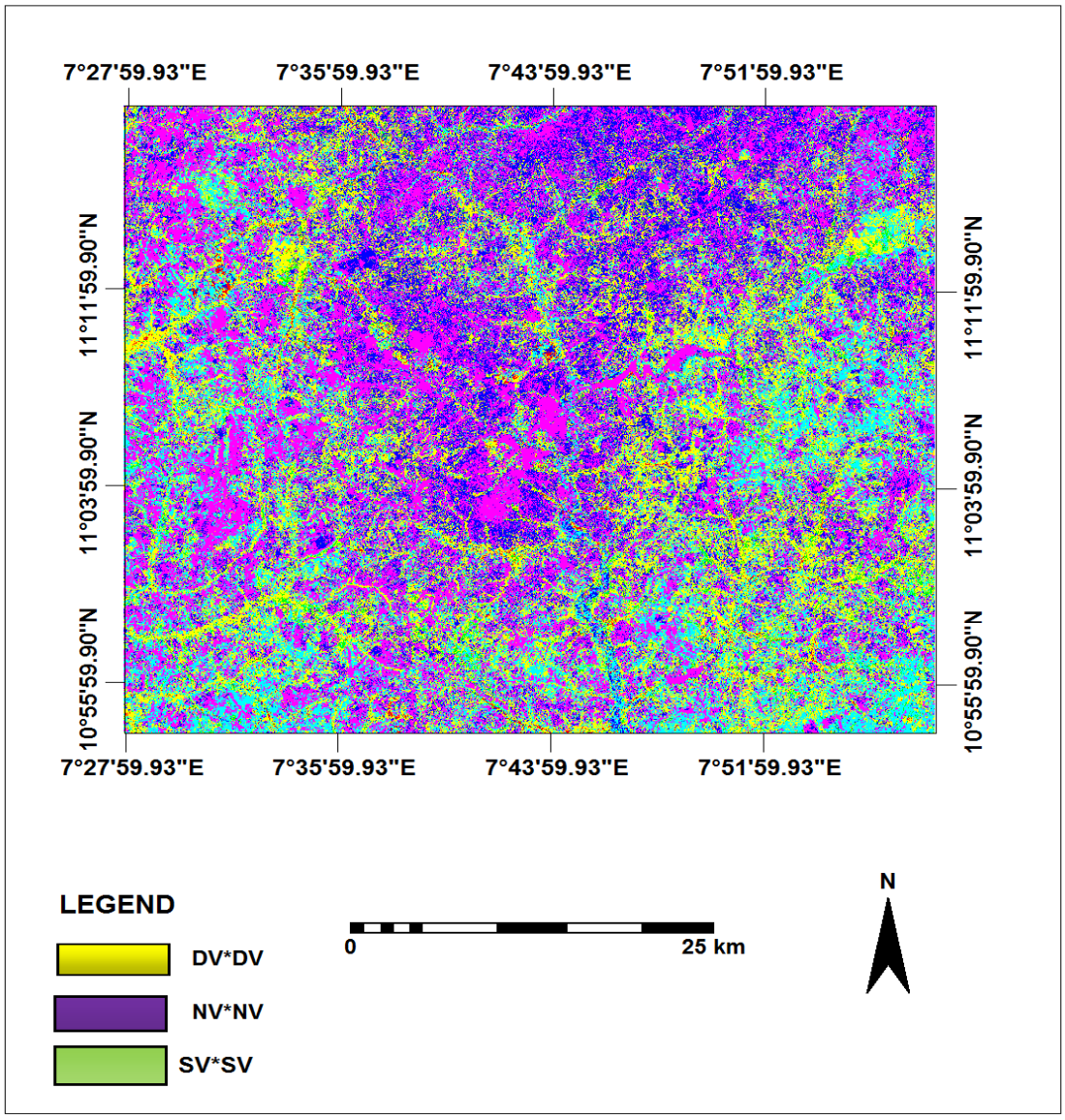


FIG.:5.22 TM AND ETM NDVI CROSSED MAP OF THE STUDY
Source: Laboratory Analysis, 2012

*** DV: Dense vegetation, SV: Sparse vegetation, NV: No vegetation**

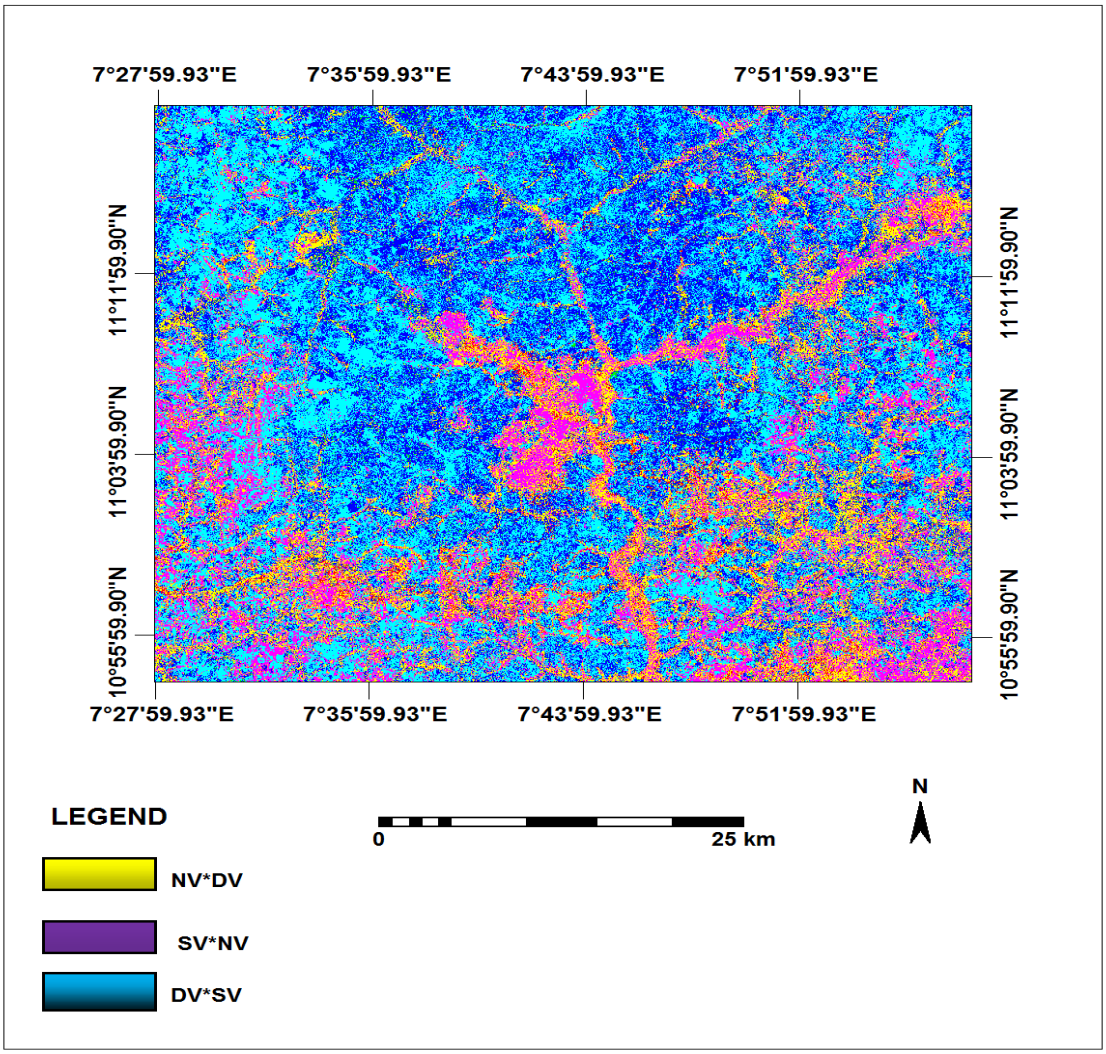


FIG.:5.23 ETM AND NIG. SAT-1 NDVI CROSSED MAP

Source: Laboratory Analysis, 2012

*** DV: Dense vegetation, SV: Sparse vegetation, NV: No vegetation**

5.2.2 Correlation of different land uses, population figures and NDVI

There is a positive relationship between the trend of built-up area, bare surfaces, NDVI sparse vegetation and no vegetation cover, and population trend. Although some of the relationships are not significant statistically, in general, all are pointing to increasing loss of woody biodiversity with increasing population

growth and expansion of city. The population figures were projections from the 1963, 1991 and 2006 Census figures (Appendix E). Table 5.4 shows the relationship between the land use types, the NDVI and the population figures (see Appendix H for the values of the correlation).

Table 5.4 Correlation coefficient matrix of area coverage of different land use types, population figure and NDVI.

	BS	BU	FW	FP	SC	SL	WB	POPN	DV	SV	NV
BS											
BU	-0.42										
FW	-0.72	0.73									
FP	0.98	-0.48	-0.65								
SC	-0.83	-0.04	0.21	-0.85							
SL	0.74	-0.74	-1.00	0.68	-0.25						
WB	0.33	-0.90	-0.42*	0.47	-0.07	0.43					
POPN	-0.60**	0.95**	0.91**	-0.61**	0.09**	-0.91**	-0.74**				
DV	0.75	-0.19	-0.15	0.85	-0.92	0.19	0.41	-0.20			
SV	0.24	-0.95*	-0.75	0.26	0.29	0.74	0.75	-0.92*	-0.12		
NV	-0.46	1.00*	0.79*	-0.51	-0.02	-0.79	-0.87	0.97*	-0.18	-0.96*	1.00

Level of significance: *= 0.05; ** 0.01

***FW: Fadama, WB: Water bodies, BU: Built-up, SC: Scattered cultivation, SL: Scrublands, BS: Bare surfaces, PF: Plantation/forest, DV: Dense vegetation, SV: Sparse vegetation, NV: No vegetation, POPN: Population**

From the table 5.4 it could be clearly seen that there is a high correlation between the population figures and the different land use type. It is clear to note that population paired with the bare surfaces, built-up areas, fadama, plantation/forest, scattered cultivation, scrublands, water bodies and the NDVI classes all showed that the relationships are highly significant and the P value is less than 0.01. Thus, as the population increased so was the demand for built-up areas, cultivated lands and fuel wood.

5.3 THE CHARACTERISTICS OF THE TREE STAND OVER DIFFERENT LAND USES

This aspect deals with the analysis of the ground data collected over the 25 quadrats (sampling points). Table 5.5 and 5.6 presents the summary of the inferential statistics and test of significance on the variations in the vegetation parameter characteristics. The actual data of the 25 quadrats surveyed are presented in Appendix F.

TABLE 5.5: Variation of Characteristics of Tree Stands over different Land Uses

Physiognomic characteristics		**LAND USE LAND COVER**					
Tree height (m)		**Scrubland**	**Built-up area**	**Scattered cultivation**	**Fadama**	**Plantation/ forest**	**F-VALUE**
	X□	5.64	8.59	6.70	9.22	6.76	
	SD	2.70	5.93	3.53	6.03	3.14	2.486*
DBH (cm)	X□	54.04	59.07	59.21	58.19	42.70	
	SD	28.42	49.26	46.22	21.51	22.55	1.593
Tree Basal Area (cm)	X□	2,877.92	4,603.21	4,344.41	3,010.06	1,822.21	
	SD	2,676.37	11,175.10	9,883.28	2,132.33	2,035.49	1.003
Tree Biomass (kg)	X□	2,386.46	4,415.65	4,120.11	1,448.17	2,462.48	
	SD	2,435.81	12,964.91	10,941.10	1,963.38	1,825.74	0.914
Density (Ha^{-})	X□	7.00	28.00	20.00	32.00	94.00	
	SD	6.74	21.04	7.30	19.87	48.08	6.973*
Species diversity	X□	1.25	2.43	1.75	3.75	2.00	
	SD	1.39	1.13	0.50	0.96	1.41	3.355*

x□= mean, SD= Standard Deviation * significance at 0.05 level

Table 5.6: Summary result of t- test analysis on paired land use/land cover.

Vegetation parameters	t-test for equality of means t-value
Built-up verses scrublands	
Tree height	2.608*
DBH	0.352
Basal area	0.549
Biomass	0.558
Density	2.119
Built-up verses scattered cultivation	
Tree height	1.331
DBH	-0.011
Basal area	0.090
Biomass	0.090
Density	0.722
Built-up verses plantation/forest	
Tree height	1.899
DBH	2.107*
Basal area	1.713
Biomass	1.586
Density	-3.090*
Built-up verses fadama	
Tree height	-0.460
DBH	0.110
Basal area	0.795
Biomass	0.844
Density	-0.309
Scrublands verses scattered cultivation	
Tree height	-0.918
DBH	-0.360
Basal area	-0.520
Biomass	-0.559
Density	-2.282
Scrublands verses plantation/forest	
Tree height	-1.173
DBH	1.515
Basal area	1.543
Biomass	1.522
Density	-2.453
Scrublands verses fadama	
Tree height	-2.743*
DBH	-0.534
Basal area	-0.175
Biomass	-0.111
Density	-2.364*
Scattered cultivation verses plantation/forest	
Tree height	-0.074
DBH	1.971
Basal area	1.131
Biomass	1.086
Density	-2.164
Scattered cultivation verses fadama	
Tree height	-1.899
DBH	0.107
Basal area	0.741

Biomass	0.841
Density	-1.134
Plantation/forest verses fadama	
Tree height	-2.115*
DBH	-3.053*
Basal area	-2.498*
Biomass	-2.365*
Density	2.422

***Significant at 0.05 level**

5.3.1 Species diversity

Table 5.7 summarizes the diversity of woody species over the study area while table 5.8 gives the breakdown according to land use category. The total trees counted over the 25 (50 by 50m) sample plots were 161 in all. From figure 5.24, *Khaya senegalensis* was found to be the dominant species of the plant community with a total of 45 trees. This is followed by *Mangifera indica,* 26 trees*, Azadirachta indica,* 17 trees and *Adansonia digitata,* 14 trees. The reasons for the comparatively high value recorded for the fadama/wetlands and built-up areas lie in the fact that over the study area, farmers/ residents deliberately plant trees to demarcate their plots and to act as shade respectively. A staff of the Savannah forestry unit, Zaria assisted in the identification of the tree and shrub species. Subsequently, they were confirmed in the Biological Sciences department Ahmadu Bello University herbarium.

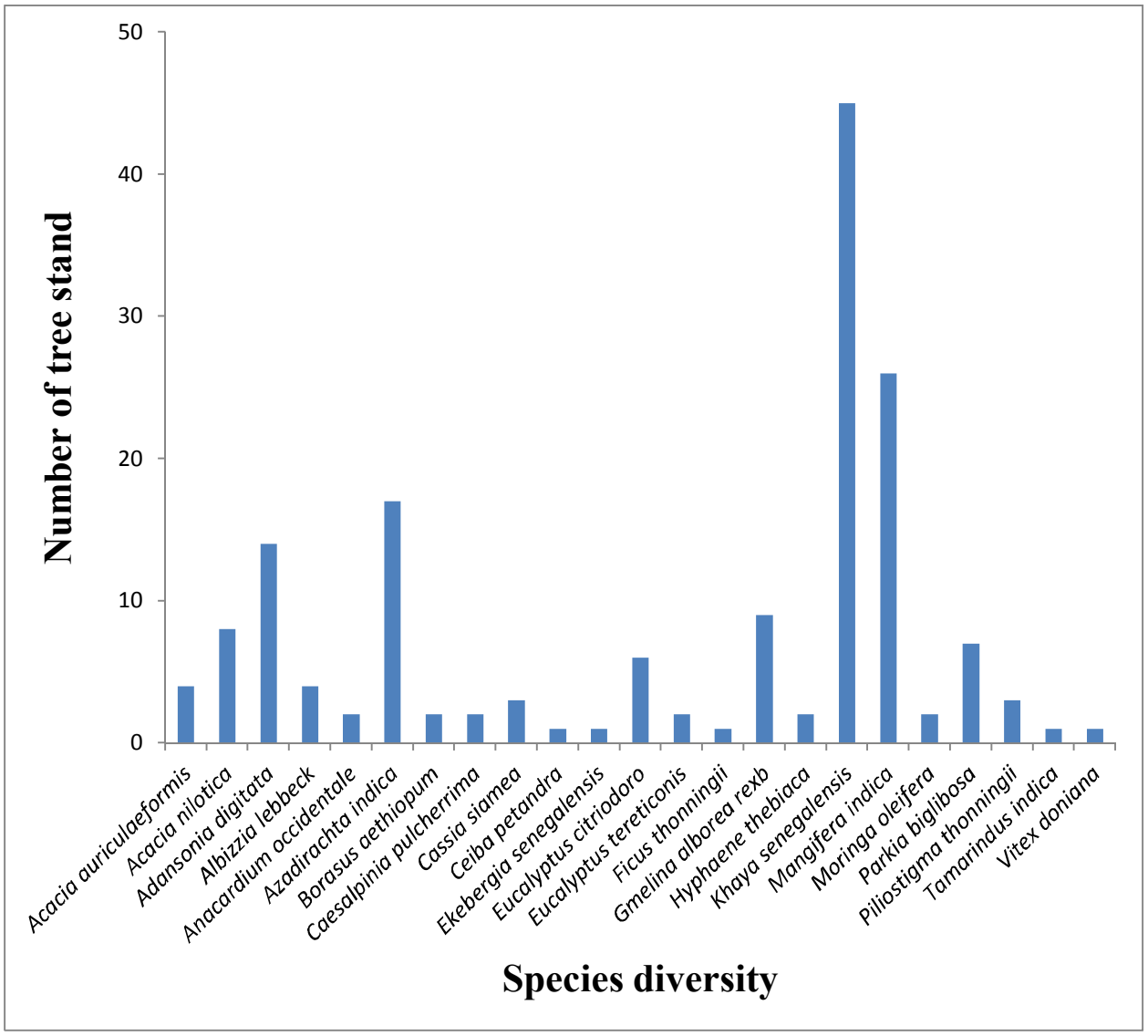


Figure 5.24 Compositions of Woody Species over the Study Area

Table 5.7: List of Trees species, their family and common names and frequency of occurrence

S/n	Scientific names	Family	Common names	Frequency of occurrence	Voucher number
1	*Acacia auriculaeformis*	Fabaceae:M	Earleaf acacia	4	1079
2	*Acacia nilotica*	Fabaceae:M	Acacia	8	698
3	*Adansonia digitata*	Bombacaceae	Baobab	14	2512
4	*Albizzia lebbeck*	Fabaceae:M	Slik flower/lebbeck	4	1486
5	*Anacardium occidentale*	Anacardiaceae	Cashew	2	184
6	*Azadirachta indica*	Meliaceae	Neem	17	900151
7	*Borassus aethopium*	Palmae	Fan palm	2	900277
8	*Caesalpinia pulcherrima*	Fabaceae:C	Pride of barbados	2	75
9	*Senna siamea*	Fabaceae:C	Blackwood cassia	3	168
10	*Ceiba pentandra*	Bombacaceae	White silk Cotton tree	1	1979
11	*Ekebergia senegalensis*	Meliaceae	Stavewood	1	766
12	*Eucalyptus citriodora*	Myrtaceae	Eucalyptus	6	2667
13	*Eucalyptus tereticornis*	Myrtaceae	Eucalyptus	2	2510
14	*Ficus thonningii*	Moraceae	Fig tree	1	7084
15	*Gmelina arborea*	Verbenaceae	Gmelina	9	900056
16	*Hyphaene thebaica*	Palmae	Doum palm	2	900675
17	*Khaya senegalensis*	Meliaceae	Mahogany	45	900181
18	*Mangifera indica*	Anacardiaceae	Mango	26	1944
19	*Moringa oleifera*	Moringaceae	Drumstick tree	2	571
20	*Parkia biglobosa*	Fabaceae:M	Locust beans	7	2846
21	*Piliostigma thonningii*	Fabaceae:C	Camel's foot	3	171
22	*Tamarindus indica*	Fabaceae:C	Tamarind	1	26
23	*Vitex doniana*	Verbenaceae	Black plum	1	1162

The species found were broken down into the different land uses and the projection for the entire study area is shown in table 5.8. The plantation/ forest area recorded the highest average tree stand of 23.5. This is followed by the fadama with an average of 8 tree stand. The built-up area has an average of 7 tree stand and the cultivated lands 5. The scrubland has the least average of 1.6 tree stand. When the results of the field samples were

extrapolated to cover the entire study area, the result showed that the built-up area recorded the lowest number of trees with about 364,700 tree stands, the reasons being that most trees within there are been cut down for residential and other infrastructural purposes. This is followed by the plantation/forest with a total of 595,584 tree stands and this is basically because of the tree logging and other activities taking place within these land use type. The scrublands and cultivated land have almost the same number of tree stands with about 864,250 and 866,480. The fadama have the highest number with about 1,824,128 tree stands. Thus, the total number of trees within the study area as projected from the 2009 LULC classification is 4,519,142.

Table 5.8 Variation of Woody Tree over different Land Uses.

Land uses	No. of Sample sites	No. of species	Total no. of tree stand	Average no. of tree stand	Total area coverage using 2009 LULC classification (km^2)	Area in Ha^-	Projection total no. of trees to entire study area
Built-up area	7	11	49	7.0	130.25	13,025	364,700.0
Plantation/forest	2	4	47	23.5	63.36	6,336	595,584.0
Scrub lands	8	9	13	1.6	1,350.39	135,039	864,249.6
Scattered cultivation	4	4	20	5.0	433.24	43,324	866,480.0
Fadama	4	9	32	8.0	571.29	57,129	1,828,128.0
Total	**25**	**37**	**161**	**45.1**	**2,548.53**	**254,853**	**4,519,142.0**

5.3.2 Tree Density

In terms of density of woody species (table 5.5), the plantation recorded the highest number of trees within the quadrat size with an average of 94 trees while the scrubland recorded the lowest number of trees with an average of 7 trees. The built-up area recorded 28 trees on

the average while the cultivated land and fadama recorded an average of 20 and 32 trees respectively. When the differences in the density of tree cover over the different land uses were subjected to ANOVA, the result showed significant value at 0.05 level.

5.3.3 Other physiognomic features

The Diameter at Breast Height (DBH) is one of the characteristics that describe the physiognomic attributes of tree stands. The values recorded over the different land uses are fairly similar and they range between about 43cm over the plantation/forest plot through 54cm over the scrubland to about 59cm over the built-up area and scattered cultivation. Analysis of variance thus, did not show significant differences amongst the land use types at 0.05 level (table 5.5).

The variation of the tree basal area is similar to that of the DBH. Thus the values are fairly similar across all land use category ranging from about 1,822cm over the plantation cover, through 2,878cm over the scrubland to about 4,603cm and 4,344cm over the built-up area and scattered cultivation, respectively. Consequently, the differences amongst the various land uses are not significant statistically. Similar results were obtained when t-test was applied to the data (table 5.6). The only exception is between plantation/forest and fadama that showed significant differences at the 0.05 level.

With respect to tree height, result obtained shows that the fadama cover has the highest mean value of 9.22metres followed by the built-up area with a value of 8.59metres. The plantation/forest and scattered cultivation both showed a mean of about 6.7metres, while the scrublands with a value of 5.64metres recorded the lowest. The result of ANOVA

shows that the differences amongst the land uses are statistically significant at 0.05 level (table 5.5).

In terms of the biomass of the trees, the built-up area recorded an average mean of 4,415.65kg. This is followed by the scattered cultivation with a value of 4,120.11kg. The scrublands and plantation/forest recorded 2,386.46kg and 2,462.48kg, respectively, while the lowest was recorded over the fadama 1,448.17kg.

It is significant to note that most surviving trees in the area generally have moderate girth, basal area and height presumably because older trees have been cut new ones are currently rarely planted.

5.4 DISCUSSION

5.4.1 Land use/land cover change

It is clear from the analysis in the preceding section that the vegetation cover of Zaria area has undergone considerable changes over the examined period. While the built-up areas, scattered cultivation, scrublands and fadama have expanded significantly during the thirty six years period under study, the bare surfaces, plantation/forest and water bodies has declined. Growth and development has led to the sprawling of houses and this is shown by the rapid increases in population size over the period. For instance, the kabama forest was cleared for housing and infrastructure (stadium) (plate IX and Xab). Farming activities also contributed to the threat and disturbances on the vegetation.



PLATE IX: A stadium structure located within the former kabama forest



PLATE Xa: Residential buildings now in the location of the kabama forest



PLATE Xb: Residential buildings under construction now in the location of the kabama forest

Land use/land cover changes reflect the dynamics observed in the socio-economic condition of a given area. As many researchers indicated in Nigeria, several factors have been modifying the original form of land cover. These include human activities such as

agricultural colonization and spread of rural settlements. In addition to this, the forest resource indirectly contributes to household food security through income generation and employment (FAO, 1991; Abiola, 1997).

The vegetation cover of Zaria and that of Nigeria in general is changing based on the national goal of transforming the country from oil based to agricultural-based economy during the past decades. The growth puts pressure on the vegetation cover, this in turn leads to the opening up of more natural forests for cultivation. Hence, the expansion of built-up areas and cultivated land is partially responsible for the disappearance of the vegetal cover of the area in the study period.

In line with the highlighted findings in the foregoing paragraphs, Ricketts and Imhoff (2003), Azocar *et al* (2003) and Romero and Ordenes (2004) argued that conversions of agricultural land and forest for urban and infrastructural purposes are associated with widespread removal of vegetation and are both a direct and indirect threat to surrounding ecosystem. According to these authors, the direct threat are through habitat conversion and the indirect threat is through the effects human population typically have on their environment, economic activities, technological change, and human demographic factors such as population growth, density and migration. As revealed in this study, mostly economic trees are to be found as other trees have been cut down for various uses, including fuel wood, for farming purposes and this can be attributed to unavailable alternative source of energy, increasing population size and poverty.

In Nigeria, records of fuel wood consumption are relatively scanty and the available ones not reliable. Enabor (1981), Onuaha (1981), Ay (1979) and Edu (1981) among others, have confirmed these inaccurate measures of fuel wood consumption. Most of them at best give

estimates. Mendie and Sani (1991) reported that fuel wood is the most dominant and widespread source of energy used for domestic purposes in the Jos Tin mining region of Plateau State, Nigeria and that dependence on fuel wood showed an upward trend, and is rapidly increasing. This is especially so following the introduction of Structural Adjustment Programme (SAP), which brought about high prices of other competing fuel sources, such as gas, kerosene and electric stoves far beyond the reach of an average income earner.

Other available records also show that in northern Nigeria, the fuel consumption rate was given as 23.3 million cubic meters per year (Anderson and Fishwick, 1988). Although Nigeria has crude oil and gas resources, the levels of gas and kerosene cookers and cooking stoves adoption are far below the levels that could make any impact. Available information indicate that at national level and in most States about 40% of heat and cooking energies are derived from fuel wood (FOS, 1992). The situation is worsened by the ever increasing prices of the alternative energy sources following the gradual withdrawal of subsidy on petroleum products, accompanied by the depreciated value of the Naira. Although, the alternative energy sources are renewable and versatile, they have proven unacceptable to several households in Nigeria because the traditional fuels (especially firewood etc) are said to be safe, convenient and more reliable in terms of supply. With the gradual removal of subsidy on petroleum products since 1986 in the country, the pressure on fuel wood has been so intense (Gbadegesin and Olorunfemi, 2011).

Elkan (1988) asserted that reforestation efforts have failed because commercial production of fuel wood cannot compete with 'free' wood from common lands. However, he maintains that prices of fuel wood will inevitably, rise as free fuel wood is exhausted and that only increases in incomes, especially of the lower income groups, will protect them from

increase in the cost of cooking. In addition, literature on the economics of deforestation tend to suggest that economic growth which raises the income level of the population will induce a switch from fuel wood to kerosene or other higher forms of energy and thus reduce deforestation associated with fuel wood demand. Interestingly, today the cost of kerosene and some other alternative sources of energy both in the west and central Africa are not very different from the cost of fuel wood in the cities. Meludu, (2004) noted that the forest sub-sector accounts for about 8% of the agricultural gross domestic product of the country. He also noted that the estimated benefit of biodiversity in general (in billion dollars), by the Federal Environmental Protection Agency in Nigeria amounts to $03.75 GDP. Current benefits (various species, subsistence, ecosystem, scientific and recreational) are $06.00; non-current, option, existence and inheritance uses are $01.00; and direct employment benefits are $15.60. All these will amount to about $26.35 billion. Despite these numbers, biodiversity depletion continues unchecked. Also, using data from Ghana and a simple linear model, Abakah (1990), investigated the link between real incomes, inflation and fuel wood consumption. His regression analysis indicates that the quantity of fuel wood consumed is negatively correlated to real incomes and positively related to inflation levels.

The disturbing aspect of fuel wood extraction is that it can hardly be replaced. Farmers, research institutes and afforestation and reafforestation programmes concentrate mainly on substitution of indigenous plants with exotic and economic trees, herbages, legumes and other shrub plants. Therefore, it is unusual to allow the regrowth or reestablishments of indigenous and naturally occurring plants. However, the role played by forestry as an important sector of the agricultural sector in providing fuel wood, industrial wood and other products is often not adequately captured by official statistics.

In addition to the above noted human factors, climate change has significant impact on land use/land cover changes observed during the study period. In this regard, Fasona and Omojola (2005) report rainfall changes, which is a critical element of climate and climatic changes in tropical Africa, in the guinea-sudan-sahel (GSS) zone of Nigeria over a six decade (1940 - 2000) period. According to their report, the decade 1950s recorded the highest rainfall while the decade 1980s had the least rainfall from the total decadal mean. The pattern of land cover changes between 1976 and 1995 strongly indicated loss of prime arable lands resulting from climate change, which is in turn leading to opening up of new virgin lands towards the south (Fasona and Omojola, 2005).

Land use/land cover change has far reaching ecological consequences. According to Olaniran (2002), in Nigeria, deforestation has been seen to cause erosion that is affecting reservoirs, decreasing the aquatic populations, reducing the navigability of canals and also the quality of soil. He also noted that the problem of desertification and environmental degradation caused by land use/ land cover change threatens the country.

Land use/land cover change also has an adverse effect on the biodiversity of the study area, in the survey carried out it was noted that only economic species were found standing around the villages surrounding Zaria others were cleared mainly for fuel wood and create space for cultivation. Thus, it has been noted that land degradation is both a part and consequence of environmental changes leading to loss of valuable land resources. There is the need therefore to strike equilibrium in the uses to which the land is put in order to minimize the far reaching ecological consequences of land use/land cover change as highlighted in this study.

CHAPTER SIX

SUMMARY AND CONCLUSION

6.1 SUMMARY

The aim of this study was to assess the impact of the growth of Zaria town on the vegetation cover. Both descriptive and inferential statistical instruments were employed in the analysis of data. The first part of the study employed remote sensing/ GIS techniques in the development of accurate and general Land use land cover maps derived from satellite imageries- MSS, TM, ETM and NIGERIASAT-1. From the results of this study, the built-up area showed a consistent increase over time and this is basically because of increased population and consequent conversion of other land uses into residential areas. Also, the considerable fluctuation in the trend of some of the land uses over time no doubt is ascribed at least partially to climatic factors (rainfall) and the period in which the images used were obtained. An NDVI was also run and the area of dense vegetation varies in reciprocal with areas of sparse vegetation over time. The areas with no vegetation show a fairly steady increase from 44% in 1973 through to 66% in 2009. This confirms the conclusion reached that land degradation is on gradual increase in the study area.

The Second part of the research adopted field survey method to generate data on tree stands within the different land use areas (Appendix B shows a sample of the collection sheet used in field). The findings revealed that the built-up areas, plantation/forest and the fadama have comparatively taller trees, trees with higher DBH, biomass, basal area and density. The bare surfaces and water bodies were not sampled for the tree stand parameters as other land cover types because none were found there.

Finally, some observed threats to the structural characteristics of the vegetation cover are the increasing rate of development and the rise in population. As these increases, so will the demand for more land for development and thus a threat to the vegetation cover. Thus, the changes in the rate and pattern of growth over the period under study are statistically significant and the relationships between the rate of growth and changes in the vegetation cover of the surrounding area are also statistically significant.

6.2 CONCLUSION

This study has demonstrated that the recent advancements in remote sensing and GIS technologies provide powerful tool for mapping and detecting changes in land use/land cover. For understanding the pattern and dynamics of vegetation loss, digital image processing techniques (Remote sensing and GIS) has enable speedy, accurate and objective interpretation of the multispectral data received from satellites. This has helped in a major way to observe the LULC at local regional and global levels.

The general trend observed by the present study is a decrease in forests, bare surfaces and a corresponding increase in scrubland, scattered cultivation and built-up areas. Land use/land cover mapping and change detection may not provide the ultimate explanation for all problems related to land use/land cover changes and cannot be an end in itself rather. It serves as a base to understand the patterns and possible causes and consequences of land use/land cover changes in the area. The ecological problems associated with the land use/land cover changes discussed are linked with the socio economic change of the local population as well as to a certain extent, with population growth. Settlement expansion and cultivation are also the major factors behind the land use/land cover changes observed in

the area. Thus the consequences of vegetation degradation are devastating and the impact affects not only the surrounding area but the entire environment.

6.3 RECOMMENDATIONS

As in all parts of the country, the endowment value of forests and woodlands is enormous. Such can be used to promote a wide range of livelihood opportunities, including increased income and enhanced livelihood security. However, as forests and woodlands are declining, primarily as a result of increased wood fuel collection, clearing of forests for agriculture, illegal and poorly regulated timber extraction, increasing urbanization and industrialization, these opportunities are diminishing.

Throughout the region, policy, legal, institutional, technical and economic constraints have undermined wider adoption of sustainable forest management as well as limited opportunities for development.

Weak institutions have paved way for large-scale illegal logging. Information obtained from forestry departments in the region confirms that acute shortage of staff and equipments are major constraint to forest conservation and management. Forestry education is also said to have also declined considerably over the past few decades; the situation is made worse by declining donor investments (FAO and others). One consequence of this is that there is an acute shortage of trained forestry practitioners in the region.

Agricultural expansion and overgrazing are also an increasing problem and major causes of the loss of woody vegetation cover. Above all, given the high dependence on agriculture,

there is growing pressure to increase the area under agriculture to meet the food requirements of the growing population at the expense of forest.

In the light of the above, strategies to improve forest conservation in the region should include:

- Strengthening plans and programmes for forest management, inventory and monitoring. This includes improving the participation of stakeholders, such as communities and the private sector, in new approaches and initiatives as well as the promotion of the wide range of roles played by forests. Also included here are measures to improve and integrate mapping and knowledge (scientific as well as traditional knowledge) and to strengthen monitoring and assessment.
- Maintaining protected areas, among other measures, improving capacities, and restoring ecosystems; and
- Strengthening forest law and governance, by encouraging the sharing of information on trade in illegally harvested forest products, and more effective implementation of measures to reduce corruption.
- Maintenance of greeneries within the city.

Special attention, therefore, needs to be given to enhancing the quality of forest resources in the region and to maximizing the benefits that can be derived from forests and woodlands. In the recent past, the country has developed policies that can support and influence sustainable use of forest and woodland resources, including national environment action plans and national sustainable development strategies. These policies aim at sound sustainable development by reconciling economic development and conservation of resources, and they provide a good basis for the proper management of natural resources.

Their effective implementation is among the best opportunities the Zaria region has to conserve their woodland resources and maximize benefits for the citizens. Other measures to reduce the loss of forests include integrated land-use planning; conservation and sustainable use of natural and planted forests; community involvement in all aspects of forest management; developing markets for a wider range of forest goods and services, including carbon sequestration and watershed protection services.

Needless to say there is need for adoption of aggressive programmes of forestation and reforestation, with demonstrated results in the short run. Additionally, the residents' attitudes toward the environment need transformation: awareness of the impacts of ecological decline need stepping-up, along with public interest in defending the environment, including forests and public parks and open spaces. Tree planting should also provide an entry point for the other initiatives, including civic and environmental education, capacity building and advocacy. As natural forest areas shrink, there is also the need to conserve the remaining areas for environmental services

Improving the opportunities available to local users will also have considerable benefits. The importance of community and public involvement in the management of forests has been recognized and promoted across Africa, with many countries adopting new laws and policies to support this (World Bank, 1992). There is increased community involvement in several sectors including forest management, ecotourism, advocacy, public education, and forestation and reforestation. Governments are also increasingly recognizing the value local users bring to resource management as their primary custodians. Non-governmental

organizations and CBOs have equally played an important role in promoting sustainable forest management.

Human resources development, particularly in terms of professional training, is also crucial for sustainable management of forests, as well as enhancing development opportunities. Finally, while forests are valued for their timber, fruits and medicinal values, the opportunity presented by agroforestry to communities in the region is not well known. Agroforestry technologies that can be readily adopted include planting of nitrogen-fixing trees, the domestication of indigenous fruit trees, medicinal trees, live fences, and woodlots for timber and fuelwood. Thus, this will entail more annual tree planting and providing tree seedlings to farmers to encourage agroforestry or to encourage them to plant more trees where they are fell.

REFERENCES

Abbas I.I and Arigbede, Y.A. (2011). Sustainable land management in Zaria using Remote Sensing and GIS techniques. *Journal of Ecology and the Natural Environment* Vol. 3(4), pp. 131-138.

Abakah, E.M. (1990). "Real Incomes and Consumption of Wooddfuels in Ghana". *Energy Economics* Vol. 12, No. B, pp. 227-231.

Abdulraheem, H.B. (2011). An Assessment of some heavy metals content of soils under Urban Agriculture in Zaria, Nigeria. Unpublished undergraduate project submitted to the department of Geography, Ahmadu Bello University, Zaria.

Abiola, J.O (1997). Forestry for Sustainable Development Towards the 21st Century. *Proceedings of the 11th World Forestry Congress* 12th –13th October, Vol. 8.

Acho, C. (1998). "Human Interference and Environmental Instability: Addressing the Environmental Consequences of Rapid Urban Growth in Bamenda, Cameroon" *Environment and Urbanization*, Vol.10 (2) 161-174.

Adedeji, Y.M.D. (2005). "Sustainable Low- Cost Housing Technology in Cities: Accelerated Construction Initiative Option" *Journal of Land Use and Development Studies 1(2)pp 66-73.* Department of Estate management, Federal university of Technology, Akure

Adejuwon, S.A., Adejuwon, J.O. and Balogun, E.E. (1989). The annual and seasonal patterns of rainfall fluctuations in sub- Saharan West Africa. *International journal of climatology*, vol. 10, Pp 839-843.

Agbola, T. and Agbola, E.O. (1997). "The Development of urban and Regional Planning Legislation and their impact on the morphology of Nigerian Cities" *Nigerian Journal of Economics and Social Studies,* 39. (1) 123-143.

Agukoronye, O. C. (2004). "Urban Poverty and Environmental Degradation in Nigerian Cities" in H.C.Mba et al (eds) Management of Environmental Problems and Hazards in Nigeria, Hants: Ashgate Publishing Ltd ,161-170.

Anderson, D. and Fishwick, R. (1988). "Fueldwood Consumption and Deforestation in African Countries". *World Bank Staff Working Papers*, No. 704.

Anih, S. C. (2004). "Effective Survival measures against Natural hazards in settled areas" in H.C.Mba *et al* (eds) Ibid 29-40.

Aniah, E.J (2001). "The role of secondary cities in Regional economic development in Nigeria" *Journal of Environmental sciences*. pp 112-119. Faculty of environmental sciences, university of Jos Nigeria.

Areola, O. (2001). in T. Agbola and E.O. Agbola (1997). "The Development of urban and Regional Planning Legislation and their impact on the morphology of Nigerian Cities*"* *Nigerian Journal of Economics and Social Studies* Vol.39 (1) PP 123-143.

Aribigbola, A. (2008). "Housing Policy Formulation in Developing Countries: Evidences of Programme Implementation from Akure, Ondo State Nigeria" *Journal of Human Ecology* Vol.23(2):125-134.

Ay, P. (1979). Fuel and charcoal in West African Forest. Field Research in Western Nigeria: Rural Energy System in Humid Tropics: *Workshop Proceedings (*S.B. Morgan, R.D. Moss and G.J.A. Ojo). Ile-Ife, pp. 44-48.

Azocar, G., Sanhueza, R., and Henriquez, C., (2003). Changes in growth patterns in an intermediate city: the case of Chillan in Central Chile. *EURE-Revista Latinoamericana de Estudios Urbano Regionales* 29 (87), 79–92.

Bain, J. S. (1973). Environmental Decay: Causes and Remedies, Little Brown and Co Inc. pg.9.

Bartone, C.,Bernstein, J., Leitmann, L. and Eigen, J. (1994). Toward Environmental Strategies for Cities: Policy Considerations for Urban Environmental Management in Developing Countries. Urban Management program, World Bank.

Bell, D.V.J. (2001). Sustainable urban communities in Canada: From Rio to Johannesburg. York Centre for Applied Sustainability York University. Prepared under contract for Stratos as background documentation for the report of the Government of Canada to the World Summit.

Bell, D.V.J., Tilman, A. & Cheung, A. (1999). Advancing sustainability in the great lakes basin, York Centre for Applied Sustainability York University. Prepared for Environment Canada.

Brennan E. M.,(1999). Population, Urbanization, Environment, and Security: A Summary of the Issues. Washington,D.C.: Woodrow Wilson International Center for Scholars (*Comparative Urban Studies Occasional Papers* Series, 22).

Bulama, M. (2005). "The Nigerian Built Environment Challenges' in A.S.Alabi and Sam Epelle(eds) Proceedings of the first National Built Environment Summit on Built Environment Disasters: For National Action Plan Nigerian Institute of International Affairs 8th-10th February, Lagos: Nigerian Institute of Architects , 185-196.

Campbell, J.B. (1987*). Introduction to remote sensing*, New York. The Guilfor press Pp 54-60.

Carvalho, E. T. and Prandini, F. L. (1998). Urban areas. In: *Nívea Adriana Dias Pons & Osni José Pejon*: Study of the urban expansion of Sao Carlos, Brazil and related increases in environmental degradation. IAEG2006 pp 151.

Clarke, K. and Gaydos, J. (1998). Loose-coupling a cellular automation model and GIS: longterm urban growth prediction for San Francisco and Washington/Baltimore. *International Journal of Geographic Information Science,* 12(7), 699–714.

Congalton, R. (1991). A review of assessing the accuracy of classifications of remotely sensed data' *in Remote Sensing of the Environment* vol 37, Pp 35-46.

Conacher A.J. and Sala M. (1998). The main problems of land degradation: their nature extent and severity. Erosion and soil deterioration, flooding vegetation loss and degradation, in Land Degradation in Mediterranean Environments of the World: *Nature and Ectent, Causes and Solution*. A.J. Conacher and M. Sala (edited by), John Wiley & Sons, Ltd, 1998.

Danish International Development Agency (DANIDA) (2000). "Improving the Environment and Reducing poverty" *Workshop Papers Copenhagen*.

Daramola, A. and Ibem, E.O. (2010). Urban environmental problems in Nigeria: Implications for Sustainable development *Journal of Sustainable Development in Africa (Volume 12, No.1, Pp 2-22)*.

D'Hoore, J. (1963). *La carie des soils d'Afrique au*. 1:5000,000, Colloque CCTA/FAO, Lovanium (Congo – Leopoldville).

Douglas, M.G. (1994). Sustainable Use of Agricultural Soils. *A Review of the Prerequisites for Success or Failure. Development and Environment Reports* No. 11, Group for Development and Environment, Institute for Geography, University of Berne, Switzerland.

Dregne, H.E and Chou, N. (1993). Global desertification dimensions. In Degradation and Restoration of Arid Lands (Dregne HE ed.). International Center for Arid and Semiarid Studies, Texas Tech University, Lubbock, Texas, USA. pp 249-282.

Edu, N.E. (1981). Consumption of Domestic fuel in Jos Town, Unpublished M.Sc. Thesis, University of Jos.

Efobi, K. O. (1994). *Studies in Urban Planning*, Enugu. Journal of Sustainable Development in Africa. Fidelity Publishers and Printers Co.Ltd.

Egbeifo, C. (1978). "Hydrology of Kubanni Drainage Basin, Zaria". Unpublished M.Sc. Thesis. A.B.U., Zaria, Nigeria.

Enabor, E. (1981). "Meeting the Demand for forest products in Nigeria: A Critical Review of Policy". The Journal of Forest Association of Nigeria, Vol. 2(1), pp. 49-53.

Elkan, W. (1988). "Alternatives of fuelwood in African Towns". World Development. Vol. 16, 527-533.

Eyre, T.J., Kelly, A.L. and Neldner, V.J. (2006). *Methodology for the establishment and survey of reference site for Bio conditions.* Version 1.4, Environmental protection Agency, Biodiversity science unit,Brisbone.

FAO (1991). Household Food Security and Forestry an Analysis of Socio-economic Issues. *Community Forestry Note 1*. FAO, Rome. pp. 140-148.

Fasona, M.J. and Omojola, A.S. (2005). Climate Change, Human Security and Communal Clashes in Nigeria. *An International Workshop* Holmen Fjord Hotel, Asker, near Oslo, pp 21–23.

Federal Environment Protection Agency (FEPA) (1989). *National Policy on Environment*, Lagos: FEPA.

Federal Republic of Nigeria (FRN) (2007). Official Gazette on the breakdown of the National and State Provisional Totals 2006 census, S.I N0 23 of 2007, N024, Vol.94.

Forman, R.T.T. (1995). Land mosaics: The Ecology of Landscapes and Regions. (Cambridge: Cambridge University Press.

Federal Office of Statistics (FOS) (1992). Annual Report.

Gareth, W. (1991). *Techniques and fieldwork in Ecology*, Collins educational, Great Britain, Pp 36-47.

Gbadegesin, A. and Olorunfemi, F. (2011). Socio-Economic Aspects of Fuel Wood Business in the Forest and Savanna Zones of Nigeria: Implications for Forest Sustainability and Adaptation to Climate Change. *Global Journal of Human Social Science* Volume XI Issue I Version I.

Gillanders, S.N., Coops, N. C., Wulder, M.A., Gergel, S.E. and Nelson, T. (2008). Multitemporal remote sensing of landscape dynamics and pattern change: describing natural and anthropogenic trends. Progress in Physical Geography, 32 (5), 503–528.

Goldstein, G. (1990). "Urbization, Health and Wellbeing: A Global Perspective" *The Statistician – Special Issue: Health of Inner Cities and Urban Areas*, Vol.39 (2) 121-133. Available Online: http://www.jstor.org . Retrieved in June 18, 2007.

Gove, N., Edwards, R.T. and Conquest, L.L. (2001). Effects of Scale on Land Use and Water Quality Relationships, *Journal of American Water Resource Association*, 37(6), 1721-1734.

Gyabaah, K. N. (2003). Urbanization Processes – Environmental and Health effects in Africa; Urban Spatial Expansion by PERN Steering Committee member and Principal, Sunyani Polytechnic, Sunyani, BA, Ghana.

Hales, D. F. (2000). "Practical Steps Toward Healthier Cities and a Cleaner Global Environment" Global Issue-*An Electronic Journal of the U.S. Department of State*, March 5 (1) 11-16.

IAIA (2005). Biodiversity in Impact Assessment. *Special Publication* Series Number 3.

Ibitoye, M. and Eludoyin, A. (2010). Urban Growth and Development of Soil Erosion in Part of Humid Region in Southwest Nigeria FIG Congress 2010.Facing the Challenges – Building the Capacity Sydney, Australia, 11 – 16 April 2010. 1/14.

Ichimura, M. (2003), "Urbanization, urban environment and land use: challenges and opportunities. An issue paper", paper presented at Asia-Pacific Forum for Environment and Development Expert Meeting, Guilin, People's Republic of China, 23 January, APFED3/EM/02/Doc.5.

Ifatimehin, O. O. and Ufuah, M.E. (2006). An Analysis of Urban Expansion and Loss of Vegetation Cover in Lokoja, Using GIS Techniques *The Zaria Geographer (2006), Vol. 17, No.1, pp.28-36* Department of Geography, Ahmadu Bello University, Zaria.

Ifatimehin, O.O, Musa,S.D and Adeyemi, J.O (2009). An Analysis of the Changing Land Use and its Impact on the Environment of Anyigba Town, Nigeria. *Journal of Sustainable Development in Africa* (Volume 10, No.4.

Ijioma, M. A. and Agaze, U. (2004). "Erosion Phenomenon and Development Dynamics in South-Eastern Nigeria" in H.C.Mba et al (eds) Ibid pp 1-12.

Ike, E.C. (1988). "Late Stage Geological Phenomena in the Zaria Basement Granites". *Precambrian Geology of Nigeria*. 1:83-89. Information, Wageningen.

Ikya, S. G. (1993). Urban Passenger Transport in Nigeria, Ibadan: Heinemann Books Plc.

Ishaya S., Ifatimehin, O.O. and Okafor, C. (2008). Remote Sensing and GIS Applications in Urban Expansion and Loss of Vegetation Cover in Kaduna Town, Northern Nigeria, *Am.-Eurasian Journal of Sustainable Agriculture, 2(2): 117-124.*

Jaiyeoba, I.A .(2010). The Zazzau environment: situation analysis, challenges and opportunities. *Paper presented at the Zazzau History Conference*. May 2010.

Jaiyeoba, I.A. and Ologe, K.O. (1990). Soil erodibility measurement in Nigeria. Z. Geomorph. N.F vol 34 (3) pp 307-312. Berlin-Stuttgart.

Jeb, N.D. (2008b). *Introduction to Remote sensing and Geospatial Information System* Techniques. Journal article of National Centre for Remote Sensing, Jos, Nigeria., pp 1-7.

Jeje, L.K. (1973). Erosion along Ife-Ondo Road in Western Nigeria, *Nigerian Geographical Journal*, 16, 67-75.

Jeje, L.K. (2005). Urbanization and Accelerated Erosion: Examples from South Western, Nigeria. *Environmental Management Journal,* Vol.2 pp 1-17.

Jimoh, H.I. (2005). Tropical rainfall events on erosion rates in a rapidly developing urban area in Nigeria, *Singapore Journal of Tropical Geography*, Vol. 26 No 1 pp 74-81.

Johnson, V. (1992). "What is Environmental Education" in Michael Atchia (ed) Environmental Education in the African School Curriculum, Ibadan; African Curriculum Organization.

Kadir, K. O. (2006). "Planning Sustainable Cities in Nigeria" *Research Journal of Social Science* 1(1) 40-50.

Kent, M. and Coker, P. (1992). Vegetation Description and Analysis. A practical approach. Belhaven press. London.pp 363.

Kjellstrom, T. and Mercado, S. (2008). "Towards Action on Social Determinants for Health Equity in Urban Settings" *Environment and Urbanization*, Vol.20 (2)551-574.

Kowal, J.M and Knabe, O.T. (1972). An Agro-Climatological Atlas of Northern states of Nigeria. A.B.U press, Zaria. Pp 111.

Kufoniyi, O. (1995). Spatial coincidence modeling: automated database updating and data consistency in Vector GIS, Unpublished PhD thesis, Department of Surveying and Remote Sensing, Wageningen Agricultural University, The Netherlands and ITC Publication No. 28. 200p.

Kumar J., Mahesh, P.K. and Deepak, K. (2008). Monitoring and modeling of urban sprawl using remote sensing and GIS techniques. *International Journal of Applied Earth Observation and Geoinformation*, 10: 26– 43.

LeHouerou, H.N. (1992). An overview of vegetation and land degradation in world arid lands. In Degradation and Restoration of Arid Lands (Dregne HE ed.). International Center for Arid and Semiarid Land Studies, Texas Tech University, Lubbock, Texas, USA. Pp 127-164.

Lele, U., Mitra, K. and Kaul O.N. (1994). Environment, Development and Poverty: *A Report of the International Workshop on India's Forest Management and Ecological Revival. CIFOR Occasional Paper no. 3.* Center for International Forestry Research, Bogor, Indonesia.

Lewis, L.A. and Berry,L. (1988). African Environments and Resources. Unwin Hyman Winchester Massachusetts, USA.

Lews, D.A.(1962). The influence of rainfall conservation on the loess soils of northern Nigeria. *Nigerian Geographical journal* vol. 5, Pp 33-38.

Lillesand T., Kiefer R. and Chipman J.W. (2004). *Remote Sensing and Image Interpretation*. Fifth edition, John Willey and Sons, Inc., New York.

Lillesand T. and Kiefer R. (2004). *Remote Sensing and Image Interpretation.* Fifth edition, John Willey and Sons, New York.

Lo, C.P. and Yang, X. (2002). Drivers of land-use/land-cover changes and dynamic modeling for the Atlanta, Georgia Metropolitan area. Photogrammetric Engineering & Remote Sensing, 68(10), 1073–1082.

Marcuse, P. (1998). "Sustainability is not Enough" *Environment and Urbanization* Vol.10 (2) 103-111.

Marmot, M. (2006). "Harveian Oration, Health in an Unequal World", Lancet (368) 2081-2094.

Martine, G. (1996). "Population and Environment in the Current Development Scenario" Manuscript. pp 44.

Mather, P.M. (1999). Computer Processing of remotely sensed images – An Introduction; John Wiley and sons, Toronto.

Mba, H. C. (2004). "Towards Environmental Awareness in Nigeria" in H.C.Mba et al (eds) Ibid pp 177- 187.

Meale, A. (1991). "Sustainable Development: The view from Government" *British Geological Services, Earthwise Journal issue* 13 pp 4-5.

Meludu, N.T. (2004). Assessment of income generating activities that influence sustainable livelihoods of forest communities in Nigeria: Implications for policy enhancement in Nigeria. In: Baumgartner, David M.; ed. *Proceedings of Human Dimensions of Family, Farm, and Community Forestry International Symposium*, March 29 – April 1, 2004. Washington State University, Pullman, WA, USA. Washington State University Extension.

Mendie, A. and Sani, A. (1991). "Problems and Issues in Afforstation: A Case Study of Fuelwood Situation in the Jos Tin Mining Region". A Paper Presented at the International Workshop on Ecology and Society in the History of the Sahel and Savanna, Centre for trans-Saharan Studies, University of Maiduguri.

Meng, D., Gong, H., Li, X., Zhao, W. and Li, Y. (2010). Impervious Surface Coverage and their Impact on other Components of the Urban Ecosystem In Beijing. *IGARSS.* pp. 2731-2734.

Mortimore, M.J. (1970). Zaria and its Region, Occasional paper No. 4 Department of Geography, A.B.U. Zaria, published for the 14th *Annual conference of Nigerian Geographical Association, Zaria*. Pp 15.

Muoghalu, L. N. (2004). "Environmental Problems and their Effects on Human Life: From Awareness to Action" in H.C. Mba *et al* (eds) Ibid. pp 93-107.

National Economic Empowerment and Development Strategy (NEEDS) (2004). Abuja: National Planning Commission.

Nigeria Environmental Study/Action Team (NEST) (1991). Nigeria's Threaten Environment: A National Profile, Ibadan: Interface Printers Ltd.

National Population Commission (NPC) (1998). 1991 Population Census of the Federal Republic of Nigeria: Analytical Report at the National Level. Abuja: National Population Commission.

National Population Commission (2006). *Official gazzatte.* Legal notice on publication of the details of the breakdown of the national and state provisional totals, 2006 census.

Netsanet, D. M.(2007). Land Use and Land Cover changes in Harenna forest and surounding area, bale mountains National park, Oromia National Regional State, Ethiopia. Addis Ababa.

Netzband, M. and Jurgens, C. (2010). Remote Sensing of Urban and Suburban Areas: Remote Sensing and Digital Image Processing vol.10 Geography Department, Ruhr-University, Bochum, Germany. Springer Dordrecht Heidelberg, London. New York.

Ogbazi, J. (1992). "Historical Development of Urban Planning in Nigeria" in H.Chike Mba et al (eds) Principles and Practice of Urban and Regional Planning in Nigeria, Awka: Mekslink publishers (Nig) pp 12-19.

Ogunleye, E.K. (2010). A study of urban growth dynamics using geoinformatics techniques in Zaria, Kaduna state. Unpublished M.Sc thesis, submitted to the Department of Geography and Regional Planning, Ambrose Alli University, Ekpoma.

Ojeshina, A. (2005). "Paper presented at the Built Environment Summit" in A.S. Alabi and A.O.Sam- Epelle (eds) Ibid.

Okeke, D. C. (2002). Environmental and Urban Renewal Strategies: Theoretical and analytical Framework, Enugu: Institute of Development Studies.

Okoye, T.O. (1988). Urbanization and erosion with particular reference to Aba, Workshop Papers. Downloaded from http://web.mit.edu/urbanupgrading/urban environment/issues/introduction html.

Olaniran Y.A.O. (2002). Strategic and Policy Issues in Poverty Reduction: the forest Perspective. *Proceedings of the 28th Annual Conference of the Forestry Association of Nigeria* held in Akure, Ondo State. pp. 103-113.

Onibokun, A.G. (1989). cited in Urban Growth and Management in Nigeria in Aniah, E.J "The role of secondary cities in Regional economic development in Nigeria" *Journal of Environmental sciences* 2001 pp 112-119. Faculty of environmental sciences, university of Jos Nigeria.

Onuaha, K.M. (1981). How to Improve the Rural Energy Situations in Nigeria. Daily Times, May 28, p.7.

Padisson, R. (ed.) (2001). Hand Book of Urban Studies, London: Sage Publications.

Paul, J.C. (1992). Principles of Remote sensing, 1st ed. New York: John Wiley and sons Inc.

Parry J.T. (1996). Land degradation in tropical drylands. In Land Degradation in the Tropics.

Peters, M., Tetzlaff, G. and Wolfgang, J. (1988). Rainfall intensity of west African squalls lines. Annals Geophysicae vol 3, Pp 228-236.

Peters, W. (ed.) (2000). Green Cities- Urban Environmental Solutions, Global Issues-An Electronic *Journal of the U.S Department of State*, March 5(1) 1-39.

Porteous, J. D. (1977). Environment and Behaviour, Planning and Every Life, Addison: Wesley Publishing Company.

Rashid, H. (1982). "Urban Flood problem in Benin City- Nigeria: Natural or Man-made?" *Malaysian Journal of Tropical Geography* vol.6 pp17-30.

Ricketts, T. and Imhoff, M.. (2003). Biodiversity, urban areas, and agriculture: locating priority ecoregions for conservation. Conservation Ecology 8(2) [online] URL: http://www.consecol.org/vol8/iss2/art1

Ridd, M. K. and Liu, J. (1998). A comparison of four algorithms for change detection in an urban environment. *Remote Sensing of Environment,* 63(2), 95–100

Romero, H. and Ordenes, F. (2004). Emerging urbanization in the southern Andes – environmental impacts of urban sprawl in Santiago de Chile on the Andean Piedmont. *Mountain Research and Development* 24, 197–201.

Rogan, J. and Chen, D. (2004). Remote sensing technology for land cover and land use mapping and monitoring. Progress in Planning, 61(4), 301–325

Russ, W. (1951). The geology of parts of Niger, Zaria and Sokoto Provinces, with special reference to the occurrence of gold.

Salama, A. M. and Alshawaikhat, H.M. (2005). "A Trans-Disciplinary Approach for a Comprehensive Understanding of Sustainable Affordable Housing" *Global Built Environment Review* 5 (3) 35- 50.

Saleh,Y. (2006). An Assessment of Land Use/ Land cover Changes Using Remote Sensing and GIS. A case study of Zaria Urban Area. Unpublished Masters Thesis submitted to the Department of Geography. Bayero University, Kano.

Simond, J. O. (1994). Garden Cities 21: *Creating a liveable Urban Environment*, New York: Mc Graw- Hill Inc.pp 231.

Snowdon P, Eamus D, Gibbons P, Khanna P, Keith H, Raison J and Kirschbaum, M. (2000). *Synthesis of allometrics, review of root biomass and design of future woody biomass sampling strategies*. Australian Greenhouse Office, Canberra, Australia, National Carbon Accounting System Technical Report 17.

Sohl, T.L., Sayler, K.L., Drummond, M.A. and Loveland, T.R. (2007). The FORE-SCE model: a practical approach for projecting land cover change using scenario-based modeling. *Journal of Land Use Science,* 2(2), 103–126.

Southworth, J., Munroe, D. and Nagendra, H. (2004). Land cover change and landscape fragmentation – comparing the utility of continuous and discrete analysis for a western Honduras region. Agriculture, *Ecosystems and Environment*, 101, 185–205.

Stoel, T. B. (1999). Reining in Urban Sprawl, Environment, Vol.41 (4) 6-11.

Stren, R.and White, R. (1989). "African cities in crisis: managing rapid urban growth." Boulder: Westview Press.pp 20-36.

Suliman M.M. (1988). Dynamics of range plants and desertification monitoring in the *Sudan.Desertification Control Bulletin* 16: 27-31.

Tannerfeldt, G. (1995). Towards An Urban World: *Urbanization and Development Assistance*.Stockholm: Swedish International Development Agency.

Tang, J., Wang, L. and Yao, Z. (2007). Spatial-temporal urban landscape change analysis using the Markov chain model and a modified genetic algorithm. *International Journal of Remote Sensing*, 28(15), 3255–3271.

Taylor, R.W. (2000). Urban Development Policies in Nigeria*: Planning, Housing, and Land Policy*, New Jersey: Centre For Economic Research in Africa, Montclair State University.

Thorp, M.P. (1970). "Landforms" cited in Zaria and its region, Mortimore M.J. (ed.) *Occasional paper No. 4 Department of Geography, A.B.U., Zaria*. Pp 13-18

Tomlinson, P.R. (1963). Soils of Northern Nigeria, Samaru. Institute for Agricultural. Research, ABU, Samaru.Zaria

Torres-Vera, M.A., Prol-Ledesma, R.M. and Garcia-Lopez, D. (2009). Three decades of land use variations in Mexico City. *International Journal of Remote Sensing,* 30(1), 117–138.

Udeh, C. (1992). "Urban Design and City Appearance" in H. Chike Mba et al (eds) *Principles and Practice of Urban and Regional Planning in Nigeria*, Awka: Mekslink Publishers (Nig) Pp110- 125.

UNCHS (1996). "An Urbanizing World". World Global Report on Human Settlements, Oxford University Press, New York.

UNCHS (2007). Urbanization: A Turning Point in History, Global Report on Urbanization www.unhabitat.org.

UN-Habitat, (2003). The Challenge of Slums. Global Report on Human Settlements 2000. Earthscan, London.

UN-Habitat (2005b). "Air Quality Monitoring in Africa" *Urban Environment,* Kenya: UN Urban Environment Section.

UNCED (United Nations Conference on Environment and Development (1992). Agenda 21, Rio de Janeiro.

UNDP (2008). Human Development Report 2007/2008: *Country fact sheets*: Nigeria. United Nations, New York.

UNEP (United Nations Environmental Protection) (2002). Global Environmental Outlook 3. Past, Present and Future Perspectives.

Urquhart, A.W. (1970). Morphorlogy of Zaria in Mortimore, M.J. (ed) Zaria and its Region, Ahmadu Bello University, Zaria. Department of Geography.) *Occasional paper* No. 4.

Veldkamp, A. and Lambin, E.F. (2001). Predicting land-use change. Agriculture, *Ecosystems and Environment*, 85, 1–6.

Wang, Y. and Moskovits, D.K. (2001). Tracking fragmentation of natural communities and changes in land cover: applications of landsat data for conservation in an urban landscape (Chicago Wilderness). Conservation Biology, 15(4), 835–843.

Ward D., Phinn, S. and Murray, A. (2003). Monitoring growth in rapidly urbanizing areas using remotely sensed data. *The Professional Geographer*, 52(3), 371–386.

WCED (1987). Our Common Future, The Bruntland Report, New York: Oxford University Press.

Widen, N. (2004). Assessing the accuracy of land surface characteristics estimated from multi-angular remotely sensed data. *International journal of Remote Sensing*, vol 25, no. 6.,1105-1117.

Wiedenhoeft, R. (1981). Cities for the People: Practical Measures for improving Urban Environment, Van Nostrand: Reinhold Company.pp 224

World Bank (2008d). World Development Indicators 2008. Washington, DC.

World Bank (1992). Environment and Development, Washington DC: World Bank.

Wright, S.B. and McCurry, P. (1970). Geology, In Mortimore M.J. (ed) Zaria and its Region, *Occasional Paper* department of Geography, A.B.U., Zaria No. 4 pp 5-12.

XiaoMei, Y. and Rong,Q. (1999). *Change Detection Based on Remote Sensing Information model and its Application on Coastal Line of yellow River Delta*. Earth Observation Center, NASDA, China.

Yankson, P.W.K.and Gough, K.V. (1999). The environmental impact of rapid urbanization in the peri-urban area of Accra, Ghana. *Geografisk Tidsskrift, Danish Journal of Geography 99: 89-100.*

Yuan, F. 2008). Land-cover change and environmental impact analysis in the Greater Mankato area of Minnesota using remote sensing and GIS modeling. *International Journal of Remote Sensing*. 29(4): 1169–1184.

APPENDICES

APPENDIX A: Location of sample points by their co-ordinates

s/n	LULC	Sample points	co-ordinates	
			Latitude (North)	Longitude (East)
	Built up areas			
1		1	$11^0$07’12”	$7^0$43’01”
2		2	$11^0$11’55”	$7^0$33’48”
3		3	$11^0$04’84”	$7^0$40’31”
4		4	$11^0$09’01”	$7^0$39’62”
5		5	$11^0$04’28”	$7^0$46’44”
6		6	$11^0$11’84”	$7^0$47’66”
7		7	$11^0$14’39”	$7^0$40’26”
	Plantation/forest			
8		1	$11^0$10’04”	$7^0$40’54”
9		2	$11^0$07’84”	$7^0$39’47”
	Fadama			
10		1	$11^0$02’63”	$7^0$38’94”
11		2	$11^0$05’10”	$7^0$44’28”
12		3	$11^0$08’42”	$7^0$46’44”
13		4	$11^0$12’94”	$7^0$34’99”
	Scattered cultivation			
14		1	$11^0$08’05”	$7^0$45’10”
15		2	$11^0$12’23”	$7^0$48’08”
16		3	$11^0$10’00”	$7^0$37’55”
17		4	$10^0$59’54”	$7^0$42’94”
	Scrublands			
18		1	$11^0$09’98”	$7^0$36’24”
19		2	$11^0$07’02”	$7^0$42’25”
20		3	$11^0$11’43”	$7^0$35’25”
21		4	$11^0$15’00	$7^0$38’05”
22		5	$11^0$11’09”	$7^0$45’55”
23		6	$11^0$04’90”	$7^0$47’49”
24		7	$11^0$09’06”	$7^0$44’10”
25		8	$11^0$07’00	$7^0$37’58”

APPENDIX B: Data collection sheet for field inventory

Location (GPS)		Land use type	DBH	Tree height	Tree species
Latitude	**Longitude**				

APPENDIX C: LAND USE LAND COVER CHANGE DETECTION

MSS AND TM

LULC	MSS(1973)	TM (1990)	AREA (km^2)
Built-up Area	Built-up Area	Built-up area	9.26
Built-up Area	Built-up Area	Fadama/wetland	1.43
Built-up Area	Built-up Area	Forest/plantation	0.83
Built-up Area	Built-up Area	Scrublands	19.38
Built-up Area	Built-up Area	Scattered cultivation	11.18
Built-up Area	Built-up Area	Bare surfaces	1.64
Built-up Area	Built-up Area	Water bodies	0.57
Fadama/wetland	Fadama/wetland	Built-up area	1.40
Fadama/wetland	Fadama/wetland	Fadama/wetland	25.14
Fadama/wetland	Fadama/wetland	Forest/plantation	2.83
Fadama/wetland	Fadama/wetland	Scrublands	80.59
Fadama/wetland	Fadama/wetland	Scattered cultivation	33.24
Fadama/wetland	Fadama/wetland	Bare surfaces	1.93
Fadama/wetland	Fadama/wetland	Water bodies	1.22
Forest/plantation	Forest/plantation	Built-up area	0.63
Forest/plantation	Forest/plantation	Fadama/wetland	11.58
Forest/plantation	Forest/plantation	Forest/plantation	1.65
Forest/plantation	Forest/plantation	Scrublands	54.17
Forest/plantation	Forest/plantation	Scattered cultivation	19.66
Forest/plantation	Forest/plantation	Bare surfaces	1.11
Forest/plantation	Forest/plantation	Water bodies	0.45
Scrublands	Scrublands	Built-up area	29.74
Scrublands	Scrublands	Fadama/wetland	98.77
Scrublands	Scrublands	Forest/plantation	40.39
Scrublands	Scrublands	Scrublands	1,206.42
Scrublands	Scrublands	Scattered cultivation	332.00
Scrublands	Scrublands	Bare surfaces	50.72
Scrublands	Scrublands	Water bodies	7.69
Scattered cultivation	Scattered cultivation	Built-up area	18.87
Scattered cultivation	Scattered cultivation	Fadama/wetland	24.27
Scattered cultivation	Scattered cultivation	Forest/plantation	9.15
Scattered cultivation	Scattered cultivation	Scrublands	241.33
Scattered cultivation	Scattered cultivation	Scattered cultivation	100.24
Scattered cultivation	Scattered cultivation	Bare surfaces	11.90
Scattered cultivation	Scattered cultivation	Water bodies	2.93
Bare surfaces	Bare surfaces	Built-up area	8.67
Bare surfaces	Bare surfaces	Fadama/wetland	1.66
Bare surfaces	Bare surfaces	Forest/plantation	2.97
Bare surfaces	Bare surfaces	Scrublands	99.26
Bare surfaces	Bare surfaces	Scattered cultivation	22.97

Bare surfaces	Bare surfaces	Bare surfaces	9.64
Bare surfaces	Bare surfaces	Water bodies	0.60
Water bodies	Water bodies	Built-up area	0.32
Water bodies	Water bodies	Fadama/wetland	8.69
Water bodies	Water bodies	Forest/plantation	0.57
Water bodies	Water bodies	Scrublands	15.18
Water bodies	Water bodies	Scattered cultivation	8.81
Water bodies	Water bodies	Bare surfaces	0.81
Water bodies	Water bodies	Water bodies	4.37
AVERAGE			**53.84**
TOTAL			**2638.20**

TM AND ETM

LULC	TM (1990)	ETM (1999)	AREA (km^2)
Built-up Area	Built-up Area	Built-up area	29.00
Built-up Area	Built-up Area	Fadama/wetland	5.69
Built-up Area	Built-up Area	Forest/plantation	0.96
Built-up Area	Built-up Area	Scrublands	23.22
Built-up Area	Built-up Area	Scattered cultivation	7.64
Built-up Area	Built-up Area	Bare surfaces	1.44
Built-up Area	Built-up Area	Water bodies	0.94
Fadama/wetland	Fadama/wetland	Built-up area	1.13
Fadama/wetland	Fadama/wetland	Fadama/wetland	45.50
Fadama/wetland	Fadama/wetland	Forest/plantation	8.18
Fadama/wetland	Fadama/wetland	Scrublands	98.99
Fadama/wetland	Fadama/wetland	Scattered cultivation	9.00
Fadama/wetland	Fadama/wetland	Bare surfaces	0.08
Fadama/wetland	Fadama/wetland	Water bodies	8.68
Forest/plantation	Forest/plantation	Built-up area	1.25
Forest/plantation	Forest/plantation	Fadama/wetland	16.43
Forest/plantation	Forest/plantation	Forest/plantation	5.05
Forest/plantation	Forest/plantation	Scrublands	31.01
Forest/plantation	Forest/plantation	Scattered cultivation	3.85
Forest/plantation	Forest/plantation	Bare surfaces	0.27
Forest/plantation	Forest/plantation	Water bodies	0.53
Scrublands	Scrublands	Built-up area	36.27
Scrublands	Scrublands	Fadama/wetland	310.69
Scrublands	Scrublands	Forest/plantation	71.99
Scrublands	Scrublands	Scrublands	1,100.03
Scrublands	Scrublands	Scattered cultivation	178.33
Scrublands	Scrublands	Bare surfaces	16.51
Scrublands	Scrublands	Water bodies	2.50

Scattered cultivation	Scattered cultivation	Built-up area	19.62
Scattered cultivation	Scattered cultivation	Fadama/wetland	62.49
Scattered cultivation	Scattered cultivation	Forest/plantation	15.54
Scattered cultivation	Scattered cultivation	Scrublands	291.88
Scattered cultivation	Scattered cultivation	Scattered cultivation	128.11
Scattered cultivation	Scattered cultivation	Bare surfaces	4.69
Scattered cultivation	Scattered cultivation	Water bodies	5.78
Bare surfaces	Bare surfaces	Built-up area	4.33
Bare surfaces	Bare surfaces	Fadama/wetland	7.83
Bare surfaces	Bare surfaces	Forest/plantation	1.99
Bare surfaces	Bare surfaces	Scrublands	33.71
Bare surfaces	Bare surfaces	Scattered cultivation	18.63
Bare surfaces	Bare surfaces	Bare surfaces	10.55
Bare surfaces	Bare surfaces	Water bodies	0.08
Water bodies	Water bodies	Built-up area	0.63
Water bodies	Water bodies	Fadama/wetland	1.30
Water bodies	Water bodies	Forest/plantation	0.32
Water bodies	Water bodies	Scrublands	4.09
Water bodies	Water bodies	Scattered cultivation	1.12
Water bodies	Water bodies	Bare surfaces	0.06
Water bodies	Water bodies	Water bodies	10.29
AVERAGE			**53.84**
TOTAL			**2638.20**

ETM AND NIG.SAT-1

LULC	**ETM (1999)**	**NIG.SAT-1 (2009)**	**AREA (km^2)**
Built-up Area	Built-up Area	Built-up area	41.33
Built-up Area	Built-up Area	Fadama/wetland	1.41
Built-up Area	Built-up Area	Forest/plantation	0.24
Built-up Area	Built-up Area	Scrublands	32.34
Built-up Area	Built-up Area	Scattered cultivation	9.25
Built-up Area	Built-up Area	Bare surfaces	0.24
Built-up Area	Built-up Area	Water bodies	0.60
Fadama/wetland	Fadama/wetland	Built-up area	28.52
Fadama/wetland	Fadama/wetland	Fadama/wetland	293.81

Fadama/wetland	Fadama/wetland	Forest/plantation	6.93
Fadama/wetland	Fadama/wetland	Scrublands	35.14
Fadama/wetland	Fadama/wetland	Scattered cultivation	51.41
Fadama/wetland	Fadama/wetland	Bare surfaces	0.34
Fadama/wetland	Fadama/wetland	Water bodies	0.07
Forest/plantation	Forest/plantation	Built-up area	6.55
Forest/plantation	Forest/plantation	Fadama/wetland	6.94
Forest/plantation	Forest/plantation	Forest/plantation	2.29
Forest/plantation	Forest/plantation	Scrublands	12.57
Forest/plantation	Forest/plantation	Scattered cultivation	74.62
Forest/plantation	Forest/plantation	Bare surfaces	0.05
Forest/plantation	Forest/plantation	Water bodies	0.00
Scrublands	Scrublands	Built-up area	75.97
Scrublands	Scrublands	Fadama/wetland	185.31
Scrublands	Scrublands	Forest/plantation	14.75
Scrublands	Scrublands	Scrublands	1,128.81
Scrublands	Scrublands	Scattered cultivation	197.03
Scrublands	Scrublands	Bare surfaces	1.58
Scrublands	Scrublands	Water bodies	0.24
Scattered cultivation	Scattered cultivation	Built-up area	16.54
Scattered cultivation	Scattered cultivation	Fadama/wetland	26.43
Scattered cultivation	Scattered cultivation	Forest/plantation	3.49
Scattered cultivation	Scattered cultivation	Scrublands	67.44
Scattered cultivation	Scattered cultivation	Scattered cultivation	257.69
Scattered cultivation	Scattered cultivation	Bare surfaces	0.21
Scattered cultivation	Scattered cultivation	Water bodies	0.08
Bare surfaces	Bare surfaces	Built-up area	0.73
Bare surfaces	Bare surfaces	Fadama/wetland	0.17
Bare surfaces	Bare surfaces	Forest/plantation	0.02
Bare surfaces	Bare surfaces	Scrublands	0.58
Bare surfaces	Bare surfaces	Scattered cultivation	8.28
Bare surfaces	Bare surfaces	Bare surfaces	19.46
Bare surfaces	Bare surfaces	Water bodies	0.00
Water bodies	Water bodies	Built-up area	1.51
Water bodies	Water bodies	Fadama/wetland	10.71
Water bodies	Water bodies	Forest/plantation	0.94
Water bodies	Water bodies	Scrublands	8.77
Water bodies	Water bodies	Scattered cultivation	0.17
Water bodies	Water bodies	Bare surfaces	0.00
Water bodies	Water bodies	Water bodies	6.64
AVERAGE			**53.84**
TOTAL			**2638.20**

APPENDIX D: NDVI CHANGE DETECTION

MSS AND TM

Vegetation cover type	MSS (1973)	TM (1990)	AREA (km^2)
Dense vegetation	Dense vegetation	Dense vegetation	3.73
Dense vegetation	Dense vegetation	Sparse vegetation	123.41
Dense vegetation	Dense vegetation	No vegetation	78.48
Sparse vegetation	Sparse vegetation	Dense vegetation	18.56
Sparse vegetation	Sparse vegetation	Sparse vegetation	681.87
Sparse vegetation	Sparse vegetation	No vegetation	563.99
No vegetation	No vegetation	Dense vegetation	14.58
No vegetation	No vegetation	Sparse vegetation	478.34
No vegetation	No vegetation	No vegetation	675.24
TOTAL			**2638.20**
AVERAGE			**293.13**

TM AND ETM

Vegetation cover type	TM (1990)	ETM (1999)	AREA (km^2)
Dense vegetation	Dense vegetation	Dense vegetation	7.46
Dense vegetation	Dense vegetation	Sparse vegetation	16.93
Dense vegetation	Dense vegetation	No vegetation	12.50
Sparse vegetation	Sparse vegetation	Dense vegetation	61.36
Sparse vegetation	Sparse vegetation	Sparse vegetation	630.76
Sparse vegetation	Sparse vegetation	No vegetation	591.49
No vegetation	No vegetation	Dense vegetation	19.45
No vegetation	No vegetation	Sparse vegetation	459.92
No vegetation	No vegetation	No vegetation	838.33
TOTAL			**2638.20**
AVERAGE			**293.13**

ETM AND NIG.SAT-1

Vegetation cover type	ETM (1999)	NIG.SAT-1(2009)	AREA (km^2)
Dense vegetation	Dense vegetation	Dense vegetation	11.66
Dense vegetation	Dense vegetation	Sparse vegetation	42.21
Dense vegetation	Dense vegetation	No vegetation	34.42
Sparse vegetation	Sparse vegetation	Dense vegetation	57.97
Sparse vegetation	Sparse vegetation	Sparse vegetation	334.05
Sparse vegetation	Sparse vegetation	No vegetation	715.60
No vegetation	No vegetation	Dense vegetation	64.11
No vegetation	No vegetation	Sparse vegetation	392.54
No vegetation	No vegetation	No vegetation	985.64
TOTAL			**2638.20**
AVERAGE			**293.13**

APPENDIX E: Population estimation for 1973, 1990, 1999 and 2009

The census figures for Zaria (comprising of Sabon gari and Zaria Local Government Areas)

POPULATION TABLE

YEAR	BASE POPULATION	POPULATION	PROJECTION	GROWTH RATE %
1973	1963	179,488	263,574	2.8
1990	1963	179,488	378,311	2.8
1999	1991	489,858	610,963	2.8
2009	2006	698,348	767,558	3.2

The estimated population was projected from the growth rate value shown in the table above using the formula below:

$P_0 = (1+r)^n$
Where P_0 = base population or population of the year
r = growth rate in %
n = number of years

Population of Zaria for 1973

base population 1963 = 179,488
r = 2.8% = 0.028
n = 10
$P_0 = (1+r)^n$
$179,488(1+0.028)^{10}$
179,488*1.318047758
263,574

Population of Zaria for 1990

Base population 1963 = 179,488
r = 2.8% = 0.028
n = 27
$P_0 = (1+r)^n$
$179,488(1+0.028)^{27}$
179,488*2.107725723
378,311

Population of Zaria for 1999

Base population 1991 = 489,858
r = 2.8% = 0.028
n = 8
$P_0 = (1+r)^n$

$179{,}488(1+0.028)^{8}$
$489{,}858*1.247225315$
610,963

Population of Zaria for 2009

Base population 2006 = 698,348
r = 3.2% = 0.032
n = 3

$P_0 = (1+r)^{n}$
$698{,}348(1+0.032)^{3}$
$698{,}348*1.099104768$
767,558

APPENDIX F: Data on structural composition of vegetation

Number of trees per quadrat

Quadrat	Shrubland	Quadrat	Buiit up	Quadrat	Scattered cultivation	Quadrat	Fadama	Quadrat	Plantation
1	2	**9**	3	**16**	4	**20**	5	**24**	15
2	2	**10**	1	**17**	3	**21**	8	**25**	32
3	0	**11**	9	**18**	7	**22**	4		
4	0	**12**	5	**19**	6	**23**	15		
5	0	**13**	4						
6	2	**14**	16						
7	2	**15**	11						
8	5								

Tree height (M)per quadrat

Quadrat	Shrubland	Quadrat	Buiit up	Quadrat	Scattered cultivation	Quadrat	Fadama	Quadrat	Plantation
1	8.56	**9**	8.47	**16**	4.22	**20**	6.76	**24**	8.54
2	3.48	**10**	8.82	**17**	3.24	**21**	5.73	**25**	6.39
3	0	**11**	5.82	**18**	9.18	**22**	7.70		
4	0	**12**	6.22	**19**	7.19	**23**	12.30		
5	0	**13**	10.69						
6	4.98	**14**	5.21						
7	5.21	**15**	16.11						
8	5.78								

Diameter at breast height (DBH) (cm) per quadrat

Quadrat	Shrubland	Quadrat	Buiit up	Quadrat	Scattered cultivation	Quadrat	Fadama	Quadrat	Plantation
1	73.22	**9**	62.39	**16**	82.76	**20**	50.29	**24**	66.59
2	28.67	**10**	315.13	**17**	39.79	**21**	42.37	**25**	55.16
3	0	**11**	56.80	**18**	59.34	**22**	80.54		
4	0	**12**	31.12	**19**	53.05	**23**	63.30		
5	0	**13**	48.89						
6	50.93	**14**	59.53						
7	32.95	**15**	81.86						
8	66.21								

Tree density (ha^{-}) per quadrat

Quadrat	Shrubland	Quadrat	Buiit up	Quadrat	Scattered cultivation	Quadrat	Fadama	Quadrat	Plantation
1	8	**9**	12	**16**	16	**20**	20	**24**	60
2	8	**10**	4	**17**	12	**21**	32	**25**	128
3	0	**11**	36	**18**	28	**22**	16		
4	0	**12**	20	**19**	24	**23**	60		
5	0	**13**	16						
6	8	**14**	64						
7	8	**15**	44						
8	20								

Basal area (cm) per quadrat

Quadrat	Shrubland	Quadrat	Buiit up	Quadrat	Scattered cultivation	Quadrat	Fadama	Quadrat	Plantation
1	4239.75	**9**	3099.66	**16**	12038.27	**20**	2200.71	**24**	3867.999
2	644.35	**10**	77960.88	**17**	1248.63	**21**	1791.22	**25**	2521.18
3	0	**11**	3513.73	**18**	2929.92	**22**	5431.03		
4	0	**12**	1225.36	**19**	2413.29	**23**	3284.30		
5	0	**13**	2679.94						
6	2235.14	**14**	2793.93						
7	873.70	**15**	5681.15						
8	4285.41								

Biomass (kg) per quadrat

Quadrat	Shrubland	Quadrat	Buiit up	Quadrat	Scattered cultivation	Quadrat	Fadama	Quadrat	Plantation
1	3512.02	**9**	2478.04	**16**	12962.24	**20**	1732.77	**24**	3243.56
2	426.32	**10**	90930.74	**17**	894.49	**21**	1425.05	**25**	606.57
3	0	**11**	3038.17	**18**	2353.79	**22**	4697.58		
4	0	**12**	994.12	**19**	1898.88	**23**	2662.98		
5	0	**13**	2281.79						
6	1751.82	**14**	2201.42						
7	603.23	**15**	4930.73						
8	3687.44								

APPENDIX G: Some common shrubs, their family and common names found in the study area

S/n	Scientific names	Family	Common names	Voucher number
1	*Acacia ataxacantha*	Fabaceae	Benin rope acacia	1706
2	*Borreria verticellata*	Rubiaceae	African borreria	672
3	*Combretum lamprocarpun*	Combretaceae	/	257
4	*Crotalaria falcate*	Fabaceae:P	Rattlepod	1114
5	*Diospyros mespiliformis*	Ebenaceae	Ebony tree	901431
6	*Guiera senegalensis*	combretaceae	/	1823
7	*Isoberlinia doka craib*	Fabaceae:C	/	188
8	*Jatropha curcas*	Euphorbiaceae	Physic nut	1911
9	*Lantana camara*	Verbenaceae	Lantana	68
10	*Leptadenia hastate*	Ascleipaceae	Leptadenia	900220
11	*Senna sigueana*	Fabaceae:C	/	900109
12	*Sida acuta*	Malvaceae	Common wireweed	664

APPENDIX H: Correlation matrix values

Years	Land use/land cover, population figure and NDVI										
	BS	BU	FW	FP	SC	SL	WB	POPN	DV	SV	NV
1973	145.77	44.27	146.35	89.24	408.69	1765.72	38.16	263,574	205.6	1,264.41	1,168.19
1990	77.1	68.89	171.55	58.39	528.1	1716.36	17.81	378,311	36.89	1,283.61	1,317.72
1999	32.81	80.93	634.38	49.6	529.09	1283.02	28.37	610,963	88.29	1,107.61	1,442.32
2009	85.47	130.25	571.29	63.36	433.24	1350.39	4.2	767,558	133.76	768.79	1,735.67

APPENDIX I: AREA COVERAGE OF THE NDVI OVER THE EXAMINED PERIOD

Vegetation cover type	**1973 (km^2)**	**1990 (km^2)**	**1999 (km^2)**	**2009 (km^2)**
Dense vegetation	205.60 (7.8%)	36.89 (1.4%)	88.29 (3.4%)	133.76 (5.1%)
Sparse vegetation	1,264.41 (47.9%)	1,283.61 (48.7%)	1,107.61 (41.9%)	768.79 (29.1%)
No vegetation	1,168.19 (44.3%)	1,317.72 (49.9%)	1,442.32 (54.7%)	1,735.67 (65.8%)
Total	**2638.20**	**2638.20**	**2638.20**	**2638.20**