THE IMPACT OF URBANIZATION ON ZARIA FLOODPLAINS, NIGERIA

BY

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A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIESAHMADU BELLO UNIVERSITY ZARIA, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE (M.Sc) DEGREE IN REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM.

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DECLARATION

I declare that the work in this dissertation entitled "THE IMPACT OF URBANIZATION ON ZARIA FLOODPLAINS" was conducted by me and has not been presented in the department or anywhere for a degree. All quotations and source of information are duly acknowledged by means of references.

_____ _____

ISHAKU Absalom Abdul Date

CERTIFICATION

This entitle dissertation "THE IMPACT OF URBANIZATION ON ZARIA FLOODPLAINS" by Ishaku Absalom Abdul meets the regulation governing the award of the degree of Master of Science (GIS and Remote Sensing) of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge.

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DEDICATION

This work is dedicated to the Faithful, Compassionate, Awesome Adonai the Lord God Almighty.

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ABSTRACT

Floodplains as integral part of riverine systems are strongly threatened by changing land use patterns undermining the balance they create in an ecosystem. This major threat is the so-called driving force of modernization, economic growth and development- urbanization, which creates increasing concern about the effects of expanding cities principally on human health, livelihood and environment.This study exploits the integrated approach of Remote Sensing and GIS techniques in urban land use change with the aim of analyzing its impacton floodplain encroachment in Zaria urban area. Zaria Topographic Map was scanned and digitized to extract the map of the study area and Landsat TM, ETM and ETM+ imageries of 1990, 1999 and 2014 respectively were processed and classified into land uses and were used to generate built-up layers which were extracted by digitization and converted to polygon shape files and later used for overlay (clipping) analysis. A Digital Elevation Model (DEM) of the area was created and used for delineation of floodplain boundary. ArcGIS software 10.1 operational tool was highly essential and flexible for mapping and analysis of urban growth and characterization of floodplain encroachment patterns after which the implications of such encroachments were examined. From the results, great changes in urban land uses were recorded with increasing trend in urban built-up and bare surface land use classes as well as decreasing vegetation and scattered cultivation land use classes. Water body indicated fluctuating values associated with seasonal variation, although pointing to a decrease. The result showed built-up change from 47.46km^2 in 1990 to 111.02 km^2 in 2014 increasing annually at the rate of 2.65 km^2 between 1990 and 2014. Built-up was found to have encroached into the floodplains by 3.51 km^2 in 1990 which increased to 13.67 km^2 of the total of 78.23km^2 floodplains. An annual rate of encroachment of 0.42 km^2 was found between 1990 and 2014. The study also identified multiple patterns of encroachment in different areas of the floodplains ranging from expansion to linear or strip patterns which are associated with urban sprawl due to uncoordinated urban development especially around river systems. As a result of this extent and pattern of encroachment, strong institutional framework and investment with active community participation towards effective floodplain management is recommended

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CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Urban growth is the relative or absolute increase in the number of people who live in towns and cities (UNICEF, 2012). The pace of urban population growth depends on the natural increase of the urban population and the population gained by urban areas through both net rural-urban migration and the reclassification of rural settlements into cities and towns (UNICEF, 2012). Urbanization in the form of urban sprawl was defined as 'horizontal spreading' or 'dispersed urbanization'; the uncontrolled and disproportionate expansion of an urban area into the surrounding countryside, forming low-density, poorly planned patterns of development (UNICEF, 2012). Urban growth and urban sprawl are often used interchangeably although they are different. Without urban growth there would be no appearance of urban sprawl (Almeida, 2005). Urban growth is one of the foremost threats facing agricultural lands in Nigeria. Sprawl occurs in ever widening bands surrounding large urban centers. Often times sprawl emanates from disconnected developments and single family homes that are established outside urban areas well beyond city limits (Atu, Offiong, Eni, Eja and Essien, 2012).

Organisation for Economic Cooperation and Development, OECD (1979) has documented the loss of peripheral agricultural land to sprawl in some European countries such as Netherlands and Norway which respectively lost 4.3 percent and 1.6 percent of their land annually to sprawl. Also the United States of America and Canada lose 4,800 km^2 of prime cropland annually to roads, buildings, reservoirs and other non-agricultural uses. Lopez, Mitchell and Thomlinson (2001) in a study on, 'Urban Expansion and the Loss of Prime Agricultural Lands in Puerto Rico', showed that between 1977 and 1994 the urban area of Puerto Rico increased from 11.3 percent to 27.4 percent. They therefore concluded that if the pattern of encroachment by urban

growth into farmlands continues, Puerto Rico's potential for production in the future will be dimmed. Humphrey (1985) observed that urban sprawl has transformed the landscape of Singapore and elevated the economy to almost a developed country status over the past decade. Correspondingly, in the face of this rapid urban and industrial growth, agriculture has to make significant adjustments. The first was the loss of agricultural land. During the 1960s approximately 250 hectares were required annually for public housing and industrial development, often at the cost of fertile agricultural land. Singapore, Japan, Indonesia, Thailand and recently Malaysia exhibited this trend. The implication of this is the importation of food as Asian countries lost their diversified food production capabilities. This according to Pernia (1983) is a reflection of a country's loss of comparative advantage in diversified farming practices as a country losses its fertile land to urban sprawl and heads up the economic ladder.

As urban development takes place within cities and around their fringes, urban sprawl or the lack thereof will continue to be a by-product of development practices and policies. Sprawl has been criticized for eliminating agricultural lands, spoiling water quality, and causing air pollution (Allen and Lu, 2003). As population increases, so does the need for new housing, schools, and transportation networks. In the urban world today, industrial, commercial, and residential districts are markedly different from years past.

Decentralization is a trend indicative of urban sprawl and present day industrial, commercial, and residential areas are no longer necessarily a part of the urban core (Nechyba and Walsh, 2004), rather, these types of development are often found in low-density areas that are separated from the major urban area by large tracts of homogeneous land. Hence, the need for larger transportation networks and in turn a greater dependency on automobiles, which produce more

air pollution. As new roads are put in place, precious farmland is often left unprotected from commercial or residential developers (Hathout, 2002).

Urban sprawl being an element of urban growth is often difficult to gauge because it can occur slowly over time. Urban sprawl is characterized by leapfrog land use patterns, strip commercial development along highways, and very low-density single-use developments, all of which occur over a relatively short period of time (Ewing, 1997). It has also been defined in terms of associated causes: urban sprawl is generally believed to result from poorly planned, large-scale new residential, commercial and industrial developments in areas not previously used for urban purposes (Zhang, 2001). However, there is one overriding theme in the recognition of urban sprawl: a spatial-temporal signature unique to the phenomenon.

Natural flood plains are among the most biologically productive and diverse ecosystems on earth and also among the most productive landscapes on earth, owing to continued enrichment by import and retention of nutrient-rich sediments from the headwaters and lateral sources. This makes them more productive than the Parent River and adjacent uplands. Globally, riverine floodplains cover over 2 000 000 km^2, however, they are among the most threatened ecosystems (Tockner and Standford, 2002).

Flood plains are defined as ‘areas of low lying land that are subject to inundation by lateral over-flow water from rivers or lakes with which they are associated’ (Junk and Welcome, 1990). This definition includes fringing flood plains of lakes and rivers, internal deltas and the deltaic flood plains of estuaries.

Floodplain is a vital part of the river/stream ecosystem that acts as flood buffer, water filter, nursery, major centre for biological life and provides fresh water for wetlands (Tadaferua, 2003).

Floodplain is the part of a river morphology that is most prone to flooding in the event of over bank spill accompanying high intensity rainstorm, surface-runoff, collapsed or deliberate discharge from reservoirs. Most early urbanization thrived along valleys and floodplains of major rivers (Langbein and Lichtman, 1978). The morphological features of floodplains which include fertile alluvial soils, flat topography and moderate gradient, make them less costly in terms of socio-economic development thus, have encouraged encroachment (Jaenig, 2006).

Encroachment into floodplain has seriously increased flood risk and damage potential, especially of urban floods due to heavy socio-economic infrastructural development on these floodplains. Gilbert (1991) asserted that urban encroachment into floodplain alters the integration of surface-runoff with the main channel, reduces surface water storage and conveyance capabilities, and reduces water quality of receiving waters and adjacent lands, in addition to other secondary effects such as depletion of water resources, cumulative impact on wetlands and pollution of downstream surface waters. The practice of urban encroachment on floodplains has also exacerbated the extension of internal flooding due to reduction in floodplain's capacity to attenuate flood, thereby bringing more areas of the urban built-up under flood vulnerability (Beyer, 1974; Burton, Kate and white, 1978, and Jaenig, 2006).

Encroachment into floodplain has caused urban floodplain management to become a major concern worldwide, especially the contemporary rising trends in urban flooding. The problem is even more critical in developing cities where there is poor control over land use practices within floodplains and inadequate institutional mechanism to enforce floodplain ordinances (George, 2006).

Floodplain management is largely directed towards alleviating the damage potential of existing development which is at risk of flooding and to ensure that there is no growth in the potential for loss due to future development by taking into account the dynamics of urban encroachment on flood prone areas (Correia, Saraiva, and DaSilva, 1999).

1.2 STATEMENT OF THE RESEARCH PROBLEM

Urban sprawl which is a form of urban growth creates inefficient use of land, land resources, and large-scale encroachment on agricultural land (Gar-On Yeh and Xia, 2001). The most pressing problem is the substantial loss of fertile agricultural land in many coastal cities because of short-term economic considerations (Gar-On Yeh and Xia, 1998). Ewing (1997) argues that suburbanization as we know it is not the issue, rather the wasteful form of development known as sprawl with which many critics have a problem.

Floodplains are among the most altered landscapes worldwide and they continue to disappear at an alarming rate (Vitousek, Mooney, Lubchenko and Melillo, 1997; Olson and Dinerstein 1998; Ravenga, Brunner, Henninger, Kassem and Payne, 2000). Floodplains and vulnerable lands are commonly used as informal settlements as development pressures lead to building on floodplains and the destruction of wetlands and floodplains- natural flood-absorbing sponges. In the last eight years, floods in the United States killed more than 850 people and caused more than $89 billion in property damage which occurred in places where weak zoning laws allowed developers to drain wetlands and build on floodplains (Alfano, 2012).

In a study conducted by Ndabula, Jidauna, Oyatayo, Averik andIguisi (2012) on the analysis of urban floodplain encroachment, it was observed that Kaduna metropolis has experienced significant spatial growth in built-up extents, from 21.10 km^2 in 1967 to 181.01 km^2 in 2009.

This growth has been accompanied by simultaneous encroachment on the River Kaduna floodplain, in an increasing trend from 2.02 km^2 (4.16%) in 1967 to 25.65km^2 (52.83%) in 2006. This showed that more than half of the floodplain of the metropolis segment of River Kaduna has been encroached upon by built-up. The fastest encroachment was observed in the 1980s which corresponds with the rapid industrialization and urbanization in Kaduna metropolis and has proceeded at a gradual rate since then to date.

In a study carried out by Ojanuga and Ekwoanya (1995) on Benue river floodplain encroachment, it was discovered that the floodplains were used mainly for the cultivation of rice in the rainy season and for vegetables in the distinct dry season. Only a small portion of the land (45 ha) had been built up in 1967 against 605ha in 1980. The area occupied by floodplain in 1967 was 177ha against 152ha in 1980. It was further added that the conversion of good agricultural land to urban dwellings and other non-agricultural uses is not peculiar to Makurdi town asother newly created state capitals are equally affected. Therefore, the situation calls for local, state and national policies on comprehensive land use planning in developing urban centres so as to protect vital agricultural lands, such as floodplain (fadama) against other competing uses, especially in the sub-humid and semi-arid regions of Nigeria within which urban Zaria is located.

From reviewed works above carried out in Nigeria and other researches such as Alfano (2012), Okonkwo (2013), Raskin, Sutton and Vanderbelt (1997), Ravenga, Murray, Abramovitz and Hammond (1998),Correia, Saraiva and DaSilva (1999),Ravenga, Brunner, Henninger, Kassem, and Payne (2000), lewis (2001), etc, the focus has been to only determine the extent of loss of urban floodplains without examining the all-round effects of the encroachment. It is against this background that this study fills in the gap by examining the effects of urban encroachment on

Zaria floodplain along rivers which traverse urban Zaria a kind of which has not been conducted toward sustainable urban land use in order to manage and tame deleterious land uses on the floodplains of urban Zaria. The following research questions guided this study:

i. Is there evidence of urban growth on the floodplains of the study area between 1990 and 2014?
ii. How much has urban growth occurred on the floodplains of the study area?
iii. Is there any pattern in the urban growth, and what class of pattern does it fall into?
iv. What are the possible implications of urban encroachment on the floodplains of the study area?

1.3 AIM AND OBJECTIVES OF THE STUDY

The aim of the study is to analyze the impact of urban growth on Zaria floodplains. To achieve the aim of the study, focus was placed on the following specific objectives to:

i. determinethe nature of land use/ land cover change in the study area between 1990 and 2014.
ii. assess how much urban growth has encroached into the floodplains of Zaria within the study period.
iii. assess patterns of new urban growth and to identify the classes of the patterns.
iv. examine the implications of urban growth on the floodplains.

1.4 SCOPE OF THE STUDY

In spatial extent, the study covered the whole of urban Zaria with the greatest priority placed on built-up areas traversed by rivers and streams which have corresponding floodplains (fadamas). The content reflected the extent of urban growth in the study area, the pattern of urban growth and the classification of these patterns, as well as examination of the implications of urban encroachment on floodplains in the study area. The study covered a period of 24 years between 1990 and 2014.

1.5 SIGNIFICANCE OF THE STUDY

Encroachment into floodplain has caused urban floodplain management to become a major concern worldwide, especially the contemporary rising trends in urban flooding (George, 2006). Floodplain management is largely directed towards alleviating the damage potential of existing development which is at risk of flooding and to ensure that there is no growth in the potential for loss due to future development by taking into account the dynamics of urban encroachment on flood prone areas (Correia, Saraiva, and DaSilva, 1999).

A study of urban encroachment on Zaria floodplain is an imperative so as to analyze the loss of urban agricultural land used for market gardening and the alteration of the floodplain which is a vital part of the river/stream ecosystem that acts as flood buffer, water filter, nursery, major center for biological life and provide fresh water for wetlands (Tadaferua, 2003). An awareness of this sort will aid policy makers in educating the people on the likely implications of urban floodplains encroachment and the need to preserve them.

The importance of fadama or lowland fields (floodplains) in the study area cannot be overemphasized as they support crops such as sugarcane, onion, tomatoes, pepper, spinach and

other garden vegetables which are grown throughout the year (Yusuf, 1999).The trend of encroachment into the floodplains call for local, state and national policies on comprehensive land use planning in developing urban centres so as to protect these vital agricultural lands, such as floodplain (or fadama) against other competing uses, especially in the sub-humid and semi-arid regions of Nigeria (Ojanuga and Ekwoanya, 1995).

Finally, the findings from this research should provide the much needed information to various stakeholders involved in environmental protection and sustainable urban development in Zaria and Kaduna State and as well provide a base line data for future researchers on the relevance of floodplains, implications of their encroachment and the need for their management and conservation as they serve as integral parts of the urban design.

CHAPTER TWO: CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

2.1 INRODUCTION

This chapter deals with various concepts such as urbanization, urban growth and encroachment, floodplains, importance of floodplains and implication of floodplain encroachment. It also deals with review of related literature.

2.2 CONCEPTUAL FRAMEWORK

The conceptual framework of this study is based on urbanization, urban growth and the environment, floodplains, importance of floodplains and implications of floodplains encroachment as well as the potency of Remote Sensing and GIS techniques in environmental studies. This is founded on Coccossis (1991) notion of concept of ecological equilibrium cited by Briassolis (2000) and adopted by Ejaro and Abdullahi (2013). According to this concept, a region has four sets of factors, population, resources, technology and institutions that are constantly in a state of dynamic equilibrium. Changes in the spatial structure of an area are the result of changes in the equilibrium between these factors. Extending the argument to the land use theme, Coccossis (1991) cited by Briassoulis (2000) and adopted by Ejaro and Abdullahi (2013) suggest that "in this conceptual framework, changes in land use are the result of changes in the size and distribution of population, technological innovation and economic restructuring, social organization and policy".

2.2.1 Concept of Urbanization

Urbanization is an increasing proportion of a population living in settlements defined as urban centers. This usually results from the net movement of people from rural to urban areas or natural increase; the excess of births over deaths (Isma'il, Salisu, Yusuf, and Muhammed, 2013).

However, the definition of what qualifies as urban center differs from one country to another depending on the criteria used. Whatever criteria used to define urban centers, Satterthwaite (2005) noted that many aspects of urban change during the period 1950-2000 were unprecedented.

Urbanization is a universal concept, signifying changes in man's interests, activities and values, and appearing to have been related to increasing functional specialization in human societies. It has characteristics and processes of manifestations which differ from place to place given environmental, socio-cultural and political conditions peculiar to the a particular geographical location. Thus, urban growth is a quantitative measure frequently associated with progress (Yichun, *et al*, 2007).

Urbanization, which refers to the expansion in the proportion of a population living in urban areas, is one of the major social transformations sweeping the globe. It represents the movement of people from rural areas to urban areas with population growth equating to urban migration (Jiboye, 2011). It is generally believed that urbanization has both direct and indirect impacts on land use transformation. According to Ejaro and Abdullahi (2013), Urban sprawl is one of the most noticeable effects of urbanization on land use. Though, sprawl can alter a region's unique rural character by creating miles of undifferentiated new developments that bring habitat loss along with traffic congestion. (Rimal, 2001) opined that urbanization is an inevitable process due to economic development and rapid population growth. Urbanization is a process of increase of modernization system which modifies the socioeconomic activities and revolutionizes the land use practice according to time frame (Ejaro and Abdullahi, 2013).

Developing countries are experiencing a rapid rate of urbanization. This is manifested more in Africa where the average annual growth rates were estimated as 4.7% and 4.6% between the period 1960 and 1980, and 1980 and 2000 respectively. The growth rate of urban population is more pronounced in Nigeria than most other countries in the African continent. The number of urban cities in Nigeria has risen drastically in the last one hundred years. The resultant effect has been the formation of more urban centres which are densely populated (projectfaculty.com, 2014).

Urbanization is a spatial (non-spatial) and social process which refers to the changes of behaviour and social relationships that occur in social dimensions as a result of people living in towns and cities. Essentially, it refers to the complex change of life styles which follow from the impact of cities on society. However, nowadays, the word 'urbanization' is commonly used in more broad sense and it refers to the physical growth of urban areas from rural areas as a result of population immigration to an existing urban area (Clark, 1982). Effects of urbanization include change in urban density and administration services. Urbanization is also defined as 'movement of people from rural to urban areas with population growth equating to urban migration' (United Nations 2005a). As more and more people leave villages and farms live in cities, urban growth results. Important to realize that, the urbanization process refers to much more than simple population growth; it involves changes in the economic, social and political structures of a region. Rapid urbanization is responsible for many environmental and social changes in the urban environment and its effects are strongly related to global change issues. The rapid growth of cities strains their capacity to provide services such as energy, education, health care, transportation, sanitation and physical security (Clark, 1982).

2.2.2 Urban Growth and the Environment

According to Clark (1982), urban growthis a spatial and demographic process and refers to the increased importance of towns and cities as a concentration of population within a particular economy and society. It occurs when the population distribution changes from being largely hamlet and village based to being predominantly town and city dwelling.

The world's population is put at about 6.572 billion people out of whom the United Nations data indicated that about 3 billion people (50 percent) live in urban areas (UNCHS, 2007). 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). 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 projecting a future of increasing environmental deterioration as a result of rapidly growing urban population without proportionate economic growth (UN-HABITAT, 2005a).

Urbanization being 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 (UN-HABITAT, 2003).

United Nations (2008) reports also indicate that more than half of the world's population now lives in urban areas, and by the year 2050, 70 percent will be city dwellers, with cities and towns in Asia and Africa registering the biggest growth. Consequently, urban population is anticipated to grow on an average 2.3% per year in the developing world between 2000 and 2030. Since the city is regarded as the engine of growth which propels national economic development, the

effects and problems emanating from these population increases have undoubtedly constituted critical challenges to sustainable housing and urban development (Jiboye, 2011).

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 this 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.

A 2005 published UN Report on Nigeria indicates that the annual urban population growth rate is 5.8 percent, while the national population growth rate is 2.8 percent. This urbanization rate has resulted in a total urban population of 62.66 million or 43 percent of the total population. The incidence of this population in urban centers has created severe housing problems, resulting in overcrowding, inadequate dwellings and deplorable urban environment (UN, 2005). The explosive rates of growth have progressively complicated and exacerbated inter-related problems of human settlements and environment (Jiboye, 2011).

As population increases, urban sprawl on a global scale is becoming more apparent than ever. Increase in population often leads to increase in development, which has a direct influence on agricultural land conversion. Moeser, (2000) states that urban growth is inevitable over the next two decades and that most of this growth will take place in less developed countries.

The extent to which urbanization affects land use change and the ways in which they interact to yield has both direct and indirect impacts on land use transformation (Yichun, et al 2007). Keating, *et al* (2003) asserts that the rapid unplanned urbanization observed in many parts of Africa is changing the context for human population and natural systems interaction. Land cover and land use changes associated with urbanization are important drivers of local geological, hydrological, ecological, and climatic change (Keating, et al 2003). The resources and environment of urban centres all over the world are increasingly being depleted partly due to the pressure from the concentration of people, as human population is growing fast especially in developing countries and the desire for land increase daily (World Bank, 1992).

Rapid urban growth is responsible for many environmental and social changes in the urban environment in Nigeria. It is also responsible for changes in the physical environment, and in the form and spatial organization of urban centers. Population increases and the consequences of unplanned urbanization are directly related to recent growth management practices that seek to influence the way in which built-up land can proliferate. As population increases, so does the need for new housing, schools, and transportation networks (Jiboye, 2011). In the urban world today, industrial, commercial, and residential districts are markedly different from years past (Almeida, 2005).

The environment can be viewed as all physical, non-physical, external, living and non-living situations surrounding an organism or groups of organisms that determine the existence, development and survival of organism(s) at a particular time. 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 and economic) systems which determine the

characteristic features, growth and sustainability of both the component elements of the environment and the environment itself (Muoghalu, 2004). It is therefore necessary to ensure environmental sustainability by curbing human developments that are detrimental to the environment and its supporting components.

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).

2.2.3 Concept of Floodplain and its Encroachment

As riparian zones, floodplains are usually defined as Eco-tones between terrestrial and aquatic realms that extend from the low-water mark to the high-water line and also include the terrestrial vegetation influenced by elevated groundwater tables or extreme floods (Malanson, 1993). Flood plains develop in all geographic regions and at different locations along river corridors as reported by Tockner, Baumgartner, Schiemer, and Ward (2000b) that for streams in the USA, the estimated average floodplain width ranges from 3m for small rivers to about 1km for the largest rivers. A floodplain is the low-lying land bordering a river, stream, lake or coastal zone over which water will flow during a flood (www.ghcma.vic.gov.au, 2013).

Floodplain is an area of land adjacent to a stream or river that stretches from the banks of its channel to the base of the enclosing valley walls and experiences flooding during periods of high discharge. It includes the floodway, which consists of the stream channel and adjacent areas that

actively carry flood flows downstream, and the flood fringe, which are areas inundated by the flood, but which do not experience a strong current. In other words, a floodplain is an area near a river or a stream which floods when the water level reaches flood stage. Floodplains are made by a meander eroding sideways as they travel downstream. When a river breaks its banks and floods, it leaves behind layers of alluvium (silt). These gradually build up to create the floor of the flood plain. Floodplains generally contain unconsolidated sediments, often extending below the bed of the stream. These are accumulations of sand, gravel, loam, silt, and/or clay, and are often important aquifers, the water drawn from them being pre-filtered compared to the water in the river (Ezekiel, Abowei and Charles, 2013).

Floodplains are land areas adjacent to rivers and streams that are subject to recurring inundation. Owing to their continually changing nature, floodplains and other flood-prone areas need to be examined in the light of how they might affect or be affected by development (Moore and North, 1974).

By their very nature, floodplains are the low, flat, periodically flooded lands adjacent to rivers, lakes and oceans and subject to geomorphic (land-shaping) and hydrologic (water flow) processes (www.friendsoftheriver.org, 2013).

The word “Fadama” is a local Hausa word (dominant language in the study area) for low–lying floodplains usually with easily accessible shallow groundwater (FDP, 2003).

The US Federal Emergency Management Agency defined floodplain encroachment as Construction, placement of fill, or similar alteration of topography in the floodplain that reduces the area available to convey floodwaters. The US FHWA (Federal Highway Administration)

defined floodplain encroachment as an action within the limits of the base floodplain (www.dot.ca.gov 2014).

Unfortunately, a river's floodplain has been viewed as completely separate from a river's active channel. The river and its floodway are usually the focus of construction and control, while fertile, flat and "reclaimed" floodplain lands are usually the focal points for other activities such as agriculture, commerce and residential development (en.wikipedia.org, 2014).

Globally, riverine floodplains covermore than 2,000,000 km^2, however, they are among the most threatened ecosystems. Floodplain degradation is closely linked to the rapid decline in freshwater biodiversity; the main reasons for the latter being habitat alteration, flow and flood control, species invasion and pollution. Riverine floodplains have also served as focal points for urban development and exploitation of their natural functions.In Europe and North America, up to 90% of floodplains are already ‘cultivated’ and therefore functionally extinct. In the developing world, the remaining natural floodplains are disappearing at an accelerating rate, primarily as a result of changing hydrology. Up to the 2025 time horizon, the future increase of human population will lead to further degradation of riparian areas, intensification of the hydrological cycle, increase in the discharge of pollutants, and further proliferation of species invasions. In the near future, the most threatened floodplains will be those in south-east Asia, Sahelian Africa and North America. (Tockner and Stanford, 2002).

2.2.4 Importance of Floodplains

The importance of maintaining natural floodplains is not a difficult idea to understand. However, humans have always been attracted to floodplains because of their many sustaining attributes (www.co.walton.fl.us, 2014).

Historically, many towns have been built on floodplains, where they are highly susceptible to flooding, for a number of reasons which including; access to fresh water, the fertility of floodplain land for farming, cheap transportation, via rivers and railroads, which often followed rivers and ease of development of flat land (Ecfr.gpoaccess.gov, 2013).

Natural floodplains are among the most biologically productive and diverse ecosystems on earth andamong most distinctive landscape features. In the natural state they are characterized by high biodiversity and productivity, and corresponding recreational and aesthetic values. Floodplains are of great cultural and economic importance; early civilizations arose in fertile floodplains and throughout history people have learned to cultivate and use their rich resources. Riverine flood plains have also served as focal points for urban development and exploitation of their natural functions (Tockner and Stanford, 2002).

Floodplains are hydrologically important, environmentally sensitive, and ecologically productive areas that perform many natural functions. They contain both cultural and natural resources that are of great value to society. Flood waters can carry nutrient-rich sediments which contribute to a fertile environment for vegetation. Floodplains are beneficial for wildlife by creating a variety of habitats for fish and other animals. In addition, floodplains are important because of storage and conveyance, protection of water quality, and recharge of groundwater. (www.co.walton.fl.us, 2014).

In terms of economic importance, the estimated worldwide value of the services provided by flood plains is US$ 3920×10^9 yr^{-1}, assuming that total floodplain area is about 2×10^6 km^2 and area-based value is US$ 19 580 ha yr^{-1} compared to US$ 969 ha yr^{-1} for forests and US$ 92 ha

yr^{-1} for cropland (Constanza*et al*. 1997). In total, floodplains contribute more than 25% of all terrestrial ecosystem services, although they cover only 1.4% of the land surface area.

One area that holds great potential for improved food production in Nigeria is the Fadamaland (floodplains). Of the total land used for rice cultivation in Nigeria, 35% is under swamp and floodplains (Oputa, Nanda, and Chadharry, 1985). Thus, floodplainsareas have the largest share of rice area and production and the highest priority for reduced production cost. Other crops grown in the floodplainsareas are maize, sorghum, guinea corn, yam, cowpea, beans and sugarcane. Floodplains (because of their high water table) present a vast potential for improving agricultural production in order to meet the food security needs of the people as well as increase the remuneration of the smallholder farmers who cultivate these areas (Jake, 2011).

Nigeria is endowed in underground and surface water reserves, rich pastures and favourable agro-ecological conditions in the country's low lying plains with alluvial deposits. There are over 3,000,000 ha of the fertile soils with residual moisture in the dry-season which are extensively used by smallholders for crop and livestock production. Due to the high moisture retention capability of the floodplains, they are widely and increasingly used for recession farming (*noman rani*). Thus, *fadamas*are of critical importance to the survival and economic development of smallholders especially in the savannah regions of Nigeria (Jake**,** 2011).

Floodplains serve a beneficial purpose to our quality of life. These low areas are where rainfall goes to drain. When the rainfall drains into the ground, it helps reduce flooding, and recharges our drinking water supply. These floodplains also serve as filters of storm-water runoff as it seeps through the ground and into our aquifer. The natural vegetation filters out impurities and uses excess nutrients. This aquifer is our only source of drinking water, and filtering helps

contain pollution before it reaches our aquifer! These benefits range from providing aesthetic pleasure to reducing the number and severity of floods, helping handle storm-water runoff and minimizing non-point water pollution. Such natural processes cost far less money than it would take to build facilities to correct flood, stormwater, water quality and other community problems. It is important that we appreciate our floodplains, and try to maintain, preserve and restore these areas whenever possible (www.polkcounty.net, 2014).

Ojanuga and Ekwoanya (1995), noted that it is important to state that the government at national level introduced the World Bank-assisted Fadama Agricultural Development Project nationwide as one of the strategies to boost food and agricultural production. The floodplains are the land base for the project, wherever they occur. Therefore, the need to declare them 'Floodplain Conservation Areas' in support of the project is apparent, especially with regard to the sub-humid and semi-arid regions.

While flood damage can be virtually eliminated by moving away from rivers and other bodies of water, since time out of mind, people have lived and worked by the water to seek sustenance and capitalize on the gains of cheap and easy travel and commerce by being near water. That humans continue to inhabit areas threatened by flood damage is evidence that the perceived value of living near the water exceeds the cost of repeated periodic flooding (David, David and Kenneth, 1981).

2.2.5 Implications of Floodplain Encroachment

Human-induced changes in river hydrology have caused major changes in the vegetative cover of the floodplain (Yin and Nelson, 1995). Habitat alteration includes both the degradation of the natural landscape and the modification of the hydrologic regime. Worldwide, more than

500000km of waterways have been altered for navigation and more than 63000km of canals have been constructed (Abramovitz, 1996).

In developing countries an estimated 90% of wastewater is discharged directly into rivers and streams without treatment, and in many parts of the world rivers are so polluted that their water is unfit even for industrial uses (Johnson, Revenga and Echeverria 2001). According to Food and Agricultural Organization of the United Nations; in China, 80% of the 50000km of major rivers are too polluted to sustain fisheries and 5% fish have been completely eliminated (FAO, 1999). Despite major treatment efforts, pollution is still a major problem in the Northern hemisphere (Van Dijk, Van Liere, Bannik, and Cappon, 1994).

Development in the floodplains causes decreases in water quality, loss of wildlife habitats, and an increase in severity and frequency of flood losses. Understanding the importance of maintaining the natural functions of floodplains can lead to better floodplain management approaches that will better protect the natural and beneficial functions of floodplains (Nachtnebel, 2000). Overexploitation of natural floodplains not only leads to biotic impoverishment, it also limits opportunities for developing a fuller understanding of the processes operating in these dynamic systems. For example, the limited knowledge of the dynamic hydrologic-morphologic interactions in natural wetlands/floodplains is the primary reason that so many restoration projects fail (Burby, 2002).

Wetlands and floodplains are inhabited by a variety of ‘endemic’ human societies that are well adapted to wetland conditions and that have developed a rich local culture. Many of these people are already listed as threatened by the Society of Threatened Peoples (http://www.gfbv.de), and there is a great risk that the ongoing environmental impact on large river-floodplain complexes

will also increase the future risk of their extinction. Examples include the Lozi people in the Borotse flood plain, the Tonga people in the Kafueflood plain, or the Ogoni in the Niger delta; the latter are threatened by oil exploitation in addition to changing hydrology (Tockner and Standford, 2002). The net result of floodplain encroachment is vast constriction of floodplains, sometimes by more than 50% of the historic expanse (Snyder,Eitemiller, Arango, Uebelacker, and Standforth, 2002).

Excluding famines and epidemics, some of the worst natural disasters in history (measured by fatalities) have been river floods, particularly in the YellowRiver in China. The worst of these, and the worstnaturaldisaster (excluding famine and epidemics) were the 1931Chinafloods, estimated to have killed millions. This had been preceded by the 1887 Yellow River Flood, which killed around one million people, and is the second-worst natural disaster in history (Ecfr.gpoaccess.gov, 2013).

Floods often cause damage to homes and businesses if they are placed in natural floodplains of rivers. Practical examples are the cases of flooding in Amassoma floodplain in the Niger-Delta (Ezekiel, Abowei and Charles, 2013). Oftentimes, human intervention causes more harm than good (Esu, 1999). Flooding of the rivers in the country (Nigeria) is not uncommon; the September 2012 devastating flood which was clearly a natural disaster was a pointer to prior preparations being a proactive effort at mitigation of impacts of such disasters, but little information exists on how these flood events affect water and overbank sediment quality within the affected areas.

Flood is among the most devastating natural hazards in the world claiming lives and properties more than any other natural phenomena (Ologunorisa, 2006; Alcira and Martha, 1991). In the

past decade in Nigeria, thousands of lives and properties worth millions of Naira have been lost directly or indirectly from flooding every year. In most urban centers of the country most especially in fast growing towns like Gwagwalada town of the Federal Capital Territory (FCT), human population increase, landscaping in paved areas, streams and channel obstruction due to bad waste disposal habit and other human activities at floodplains were considered to be the major causes of floods (Ishaya, Ifatimehin and Abaje, 2009).

Nigeria has only 35 percent of arable land (including floodplains) 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." The role of floodplains or fadamas in agriculture especially irrigation agriculture is highly critical to sustainable food supply in Zaria and Nigeria as a whole. The Fadama Project supported by World Bank and Nigerian government under River Basin Development Authority (RBDA) in which improved fadama (equipped lowland) and unequipped fadama (private farmers') under Irrigation occupy 55,000 hectares and 681,914 hectares respectively (Takeshima, Salau and Adeoti, 2010). This is a pointer to the importance of floodplains in sustainable food production. For agriculture to be a sustainable and productive means of livelihood, Nigeria must address the problems of land degradation, damage to the environment (urban built-up structures on floodplains) and destructive farming methods (World Bank, 2008d)

2.2.6 Remote Sensing/Geographic Information System Techniques in Urban Land use/Land cover Analysis

The complexity of urban systems makes it difficult to adequately address their changes using a model based on a single approach (Allen and Lu, 2003). Therefore, it is ideal to use a tool such

as a Geographic Information System (GIS) as part of research on urban sprawl because of its capacity to handle many different types of spatial data.

A Geographic Information System is useful for mapping the spatial distribution of urban areas. Unlike traditional cartographic methods, GIS allows for the manipulation of different types of data in one map frame. This type of mapping involves a temporal signature in which two or more time periods are used for comparing amounts of urbanization (Almeida, 2005).

A GIS is also an extremely powerful tool for creating new data from existing data and is often referred to as a decision support system (Burrough and McDonnell, 1998). In China, A GIS was used as a decision support system to test different development scenarios and land consumption parameters for use by planners and local government officials (Gar-On Yeh and Xia, 1998).

In East and West St. Paul, Winnipeg, Manitoba, Canada, most urban sprawl was occurring on prime agricultural land (Hathout, 2002). In that study, a GIS was used to predict future growth patterns and the impacts that such growth would have on agricultural land (Hathout, 2002).

To make planning and decision process more realistic, effective and sustained for managing land resources and environment in a particular region requires reliable quantitative information primarily on existing land use/ land cover and their dynamics. Such types of information are also essential for developing eco-friendly packages for optimizing production. The modern Geo-spatial technology of Remote Sensing (RS) coupled with Geographic Information System (GIS) provides a powerful mechanism, not only to monitor natural resources and environmental changes but also permits to analyze the information of other environment variables (Marble et al. 1983).

One of the most important distinguishing characteristics of RS, relative to other data acquisition approaches, is that it can provide detailed, quantitative land surface information at large spatial coverage and at frequent temporal intervals (Prenzel, 2004). The remote sensing data due to its perspective view, multi-spectral, multi-resolution and frequent monitoring capabilities make its well-suited for monitoring land use/land cover pattern and their dynamics over any large areas. The recent advancement in digital image processing techniques have brought about a profound acceptance of the application of satellite remote sensing data in land use/land cover inventory, mapping and change detection (Singh and Khanduri, 2011).

Reliable techniques of collecting and analyzing geospatial information are required in environmental studies and risk analysis over time. In this regard, an integrated approach of Remote Sensing (RS) and Geographic Information System (GIS) has proven to be the most effective (Jayasselan, 2006).

2.3 LITERATURE REVIEW

Loss of peripheral agricultural land to sprawl was reported in some European countries such as Netherlands and Norway which respectively lost 4.3 percent and 1.6 percent of their land annually to sprawl. Also the United States of America and Canada lose 4,800 km^2 of prime cropland annually to roads, buildings, reservoirs and other non-agricultural uses (OECD, 1979).

In mapping of growth distribution with the analytical capabilities in GIS during an assessment of urban sprawl in Richmond - Virginia, Almeida (2005) calculated approximate square kilometers of urban or built-up land for each year; 1992 and 2001. This allowed him to conclude initially that there was a clear increase in the amount of urbanization over the given time period. It was

observed that in 1992 there was approximately 559 square kilometers of urban or built-up land within the study area. In 2001 that number increased by 25% to 746 square kilometers of urban or built-up land indicating a large increase in the extent to which urban sprawl occurred between 1992 and 2001.

Riverine systems are strongly threatened by changing land-use patterns in the whole catchment and especially along the riparian margin of rivers and streams. Based on data from 145 major catchments around the world (Ravenga, Murray, Abramovitz and Hammond,1998), human impacts at both the catchment and the riparian level can be discerned. Analysis of these data elucidates several patterns. Riparian areas are significantly more severely impacted than the total catchment. The most impacted riparian corridors with respect to land use are found in Europe and in the densely populated areas in Asia (catchments with population densities more than 200 people per km2). There, between about 60% and 99% of the entire riparian corridor has been transformed to cropland or is urbanized, the latter in particular to Europe. The Seine River (France) shows the highest impact of all rivers investigated. There is a positive and linear relationship between human population density and land use of the riparian zone for Asian and African rivers.

Many of the large African floodplains are still relatively untouched, however they are disappearing or are being transformed at an accelerating rate as a result of water management activities, in particular by large-scale irrigation schemes and the ongoing construction of dams. For example, the inundated area of the Hadejia-Nguru floodplain in northern Nigeria decreased within the last decade from 2350km^2 to between 700 and 1000km^2 as a result of altered hydrology (Barbier& Thompson 1998).

In a study carried out by Ojanuga and Ekwoanya, (1995) on the temporal changes in land use pattern in Benue river floodplain and adjoining uplands using Photogrammetric techniques, it was discovered that by 1967, only a small portion of the land had been built up both on the southern and northern banks of the river**,** and by 1975, not much expansion of the town had occurred. However, marked changes began in 1976 when Makurdi became the capital of the newly created Benue state. From that year, a rapid urban development ensued, spurred by the intense public and private land development activities for residential, military and industrial purposes. The development affected both the uplands and the floodplain. Worthy of emphasis is the encroachment of non-agricultural land use into the floodplain. The small portion of the land was 45 (ha) that had been built up in 1967 against 605 (ha) in 1980. The area occupied by floodplain in 1967 was 177 (ha) against 152 (ha) in 1980. Azoo cum recreational area, some institutions, residential quarters and a brewery had consumed portions of the floodplain south of the river.

Ndabula, Jidauna, Oyatayo, Averik and Iguisi(2012), in monitoring, mapping and characterization of floodplain encroachment patterns on the River Kaduna floodplain in Kaduna metropolis, Nigeria as part of the approach to flood hazard evaluation, flood risk assessment and effective flood and floodplain management using Remote Sensing and GIS techniques, it was observed that Kaduna metropolis has experienced significant spatial growth in built-up extents, from 21.10 km^2 in 1967 to 181.01 km^2 in 2009. This growth has been accompanied with simultaneous encroachment on the River Kaduna floodplain, in an increasing trend from 2.02 km^2 (4.16%) in 1967 to 25.65km^2 (52.83%) in 2006, that is about 52.83% of the urban segment of the River Kaduna total floodplain area of 48.55km^2, has been encroached by built-up. This

showed that more than half of the floodplain of the metropolis segment of River Kaduna has been encroached upon by built-up. The fastest encroachment was observed in the 1980s which corresponds with the rapid industrialization and urbanization in Kaduna metropolis and has proceeded at a gradual rate since then to date.

Abbas and Arigbede (2011) carried out a study on Sustainable land management in Zaria using Remote Sensing and GIS techniques which showed spatial variation in land use-land cover for the period 1985 to 2005. The period 1995 to 2005 reveals a drastic change in the normal course of urbanization. During the period, the built-up areas increased to 26.20% from around 7.80%. The year 2005 showed a remarkable growth of built up areas in large-sized settlements away from the city limits which resulted to elimination of the crop, forest and scrub lands. It was observed that the growth of built-up areas is mainly towards the east- west route in a linear fashion. The bare surface and cultivated lands declined to 14.43 and 4.07% respectively in the period 1995 to 2005 which is about 10% higher than the decline during the 1985 to 1995 period. A rapid decline in the major water bodies of Galma and Kubanni Rivers was reported in the later period which resulted mainly from the process of acquisition and occupancy of land by the dwellers; with the decreasing trend shown covering an area of 9568.149 (ha) representing 22.58% in 1985, 5639.176 (ha) representing 14.23% in 1995 and 3217.036 (ha) representing 6.53% in 2005 compared against other land uses in each period.

2.4 SUMMARY OF LITERATURE REVIEW

The relationship 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, Bernstein and Leitmann,* 1994).

A spectacular impact of urbanization in many parts of the world and Nigeria in particular is the outward expansion of cities and towns which results in changes in land use whereby prime agricultural land and floodplains are taken for residential and commercial purposes. This is evident in studies conducted on urban sprawl in Richmond - Virginia, USA where Almeida (2005) reported a tremendous rate of urbanization over other land uses. Ravenga, Murray, Abramovitz and Hammond (1998) reported that the loss of floodplains was reported in Europe and Asia where floodplains are transformed into crop land and urban settlement. Barbier and Thompson (1998) also reported the disappearance of Hadejia- Nguru floodplains at an accelerating rate within a decade. Abbas and Arigbede (2011) documented urban encroachment on agricultural land and floodplain in a study conducted on sustainable land management in Zaria, Kaduna State. All the reported studies above utilized GIS and Remote Sensing techniques in the assessment of urban land use change. Ojanuga and Ekwoanya (1995) utilized photogrammetric techniques to report tremendous floodplain encroachment along the Benue River in Makurdi, Nigeria.This conversion of farmlands and watersheds for residential purposes has negative consequences on food security, water supply as well as health of the people in urban areas (Michael, 2013).

CHAPTER THREE: STUDY AREA AND METHODOLOGY

3.1 INTRODUCTION

This chapter deals with the physiography of the study area on one hand which encompasses location, topography, drainage, soils, land use, vegetation and population. It deals with the methodology of the study on the other hand.

3.2 PHYSIOGRAPHY OF THE STUDY AREA

3.2.1 Location

Zaria has a geographical location between Latitude $11^0 2\square$ N– 11^0 $10\square$ N and Longitude 7^0 $38\square$ $30\square\square$ E– 7^0 $49\square$ $50\square\square$ E (see fig. 3.1)It is a town in northern Nigeria which lies in the northern part of Kaduna state. Zaria is the second largest city in Kaduna State consisting of six traditional districts; Birni Da Kewaye (Zaria town and its environs), Dutsen Abba, Gyallesu, Tudun Wada, TukurTukur, and Wuchichiri (the-nigeria.com, 2011). Zaria urban area is located in the central plains of the highlands of northern Nigeria standing at an average height of 670m above sea level.

As observed by Mortimore (1970), Zaria is 156km south-west of Kano, 84km north-east of Kaduna. Zaria is about 950km north of the Atlantic Ocean. Zaria is the second largest city in Kaduna covering a total urban landmass of about $61km^2$ making it a nodal point in terms of road and rail transport because of location factors (Arowolo, 2000). The area is bounded to the south by Igabi Local Government Area, to the north by Kudan Local Government Area, to the west by Giwa Local Government Area and to the east by Soba Local Government Area. The region traverses about 70km from the West to East and roughly covers 8,950 square kilometre. Zaria

urban area is essentially made up of two Local Government Areas namely; Zaria and Sabon-Gari Local Government Areas. Zaria is easily accessible from different parts of the country by air via Kaduna, Kano, and Abuja and by rail and road via Kaduna, Jos, Kano and Sokoto(abu.edu.ng, 2014).

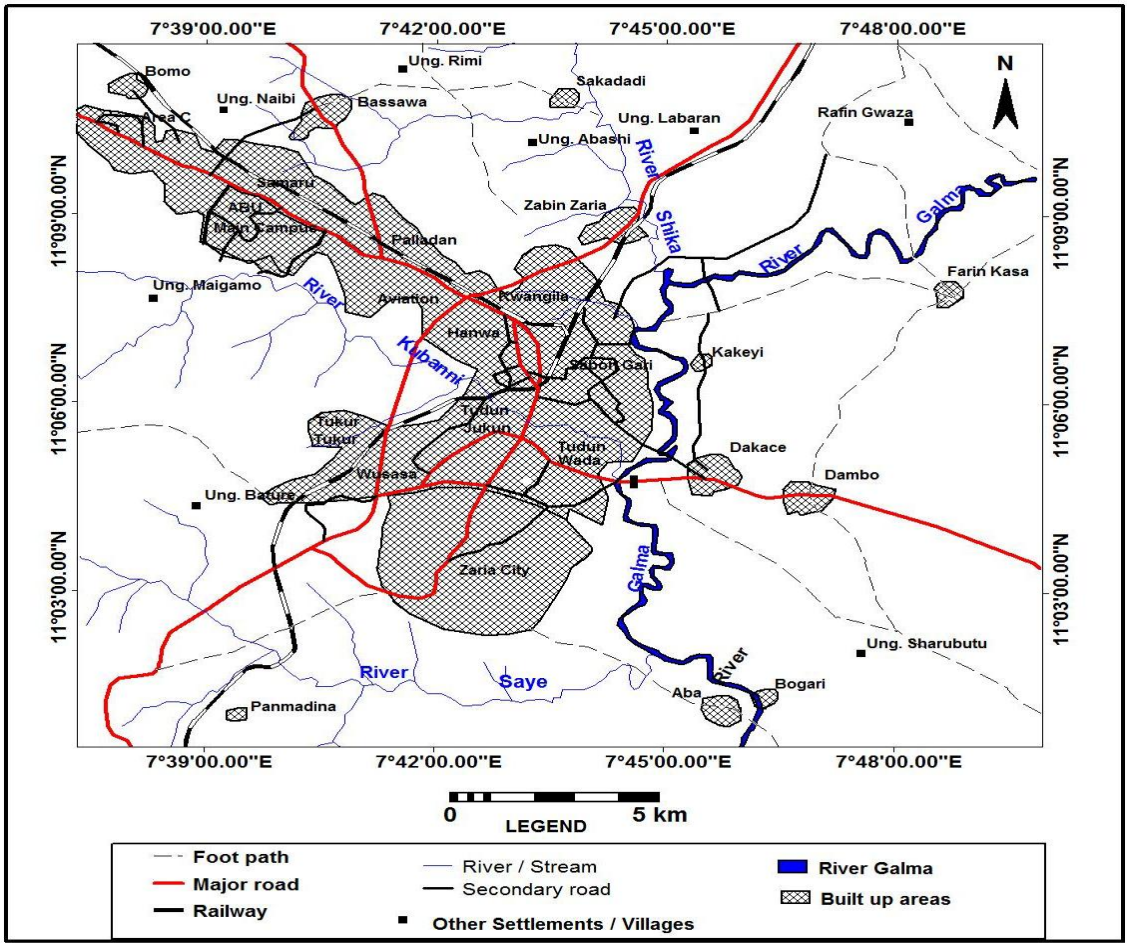


Fig. 3.1: The Study Area
Source: Modified from Topographic Map of Zaria, Sheet 102.

3.2.2 Climate

Owing to its interior location of about 670km north of the Atlantic Ocean, Zaria experiences a Tropical Continental Climate characterized by distinct wet and dry seasons subject to the movement of the Inter Tropical Discontinuity (ITD) associated with Tropical Continental and Tropical Maritime air masses. The former airmass originates from the Sahara desert and therefore dry, bringing dusty and hazy conditions known as 'harmattan' to the region in the dry season while the latter air mass originates from the Atlantic Ocean and hence moist and rain-bearing (Kowal and Knabe, 1972). The humidity also drops to less than 15% in December/January (dry season). After that, the South Westerly Monsoon winds (Tropical Maritime Air mass) laden with moisture bring the rain accompanied by thunderstorms and squalls with heavy fall of high intensities. The rainy season lasts from May to September/October with long-term annual rainfall of 1040mm in about 90 rain days (abu.edu.ng, 2014).

The region experiences convectional rainfall type with single maximum and a long-term average of about 1100mm per annum. Of great importance is the seasonal character of the rainfall. About 90% of the rains fall between April and October with the heaviest recorded in July and August. Monthly total can vary as well as the annual (Adejuwon, 1989). However, the mean annual rainfall of Zaria is 800mm (Ojo, 1982).

Onset of the rainy season is highly variable and unpredictable; although long-term average appears to be first week of May (Owonubi and Olorunju, 1985). Variability in the cessation date of the rainy season has also been observed. Akintola (1986), for example, reported that the expected mean cessation date of the rainy season is October 8th with an upper limit of October

23rd.The North East Trade wind (Tropical Continental Air mass) characterized by hazy to dusty conditions lowers temperatures to as low as 10^0C at night. In the afternoons, up to 42^0C is sometimes recorded.

Zaria experiences a brief period of hot but dry weather in March and April during which average temperatures get higher than the approximately 27^0C monthly mean, followed by a progressive incursion of tropical maritime air mass from the Atlantic Ocean which displaces the North East (Harmattan) winds. During this short period, the mean daily maximum temperatures are fairly stable, and they range from 38^0C to 42^0C. (Oguntoyinbo, 1998, abu.edu.ng, 2014).

3.2.3 Topography

Zaria is situated on a plain which is part of the extensive gentle rolling peneplain which extends from Sokoto to Lake Chad, and northwards from south of Kaduna to Tigueddi scarp near Agades in Niger Republic. This embraces most of the northern Nigeria and has been correlated with the mid-tertiary African planation surfaces recognized in other parts of the continent (King, 1962). The plain which is generally undulating varies in altitude from about 550m to 740m above the sea level and is dotted with outcrops of rocky inselbergs, with the Kufena hill attaining a height of 820m and flat top lateritic ironstone capped residuals (Iguisi, 1996).

Valley side slopes exhibit a convex-concave form with few rectilinear elements (Ojenya, 1989). Slope angles of the valley sides are generally low between 0.5^0 and $4^{0;}$ although relatively steeper slopes have been observed especially adjacent to isolated residual and erosional scarps (Bello, 1973). The characteristic slope angle of the valley side is however 1^0- 2^0 (Ibrahim, 1986). See fig. 3.2

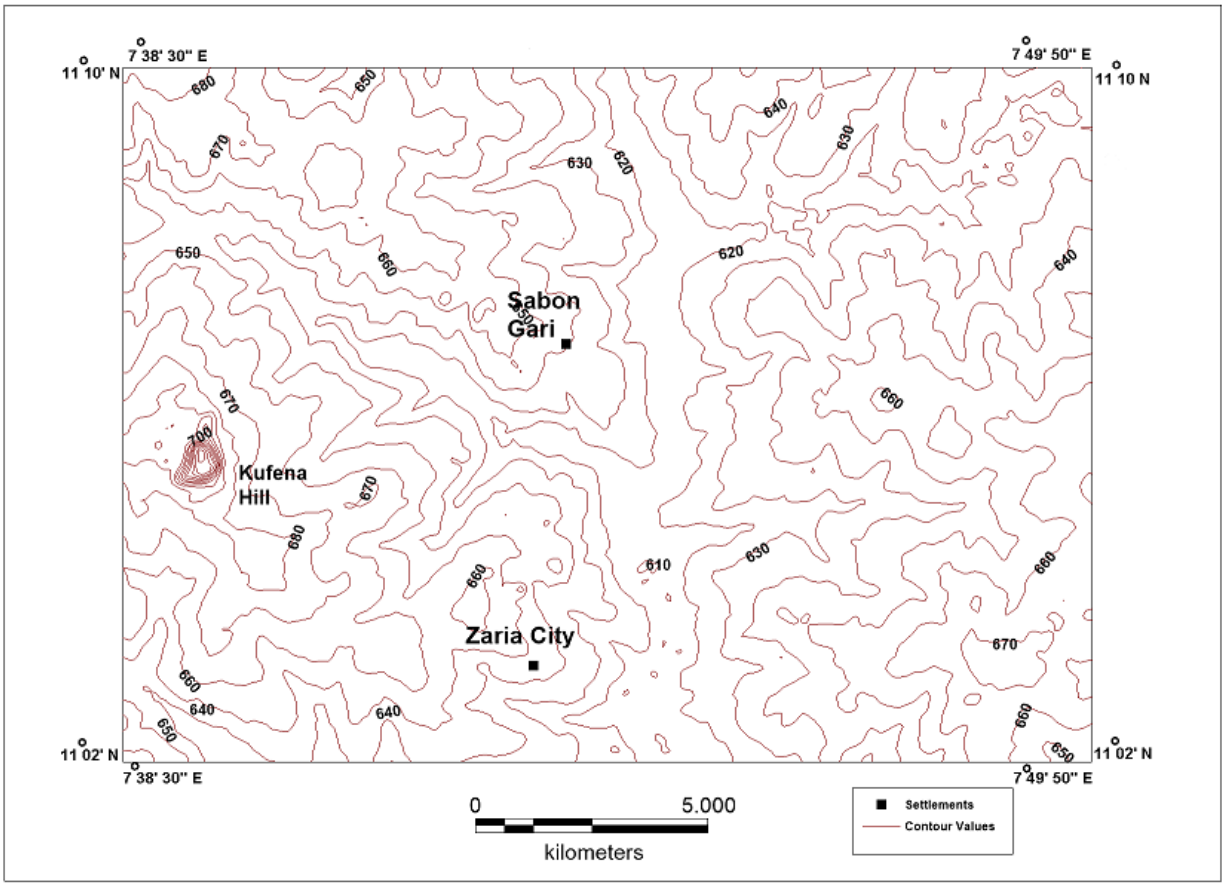


Fig. 3.2. Relief Map of Zaria.
Source: Modified from Topographic Map of Zaria, Sheet 102, 2013.

3.2.4 Drainage

The area is drained by three major rivers; Galma, Kubanni, and Saye rivers. The flow of these rivers is highly irregular and follows rainfall events. The drainage systems of Zaria focus mainly on River Galma. Except for Galma River, all streams in the area are seasonal, flowing only during and after rains, although the larger ones have surface water along stretches for much of the year. A very good example is the Kubanni River along Samaru (Mortimore, 1970, Mortimore and Wilson, 1965)

Du preez and Barber (1965) remarked that the geology of the area gave rise to its characteristic dendritic drainage pattern in the south eastern portion, trellis in the northern potion where the tributaries of Kubanni enter the main river at right angle (see fig. 3.3 and 3.4).

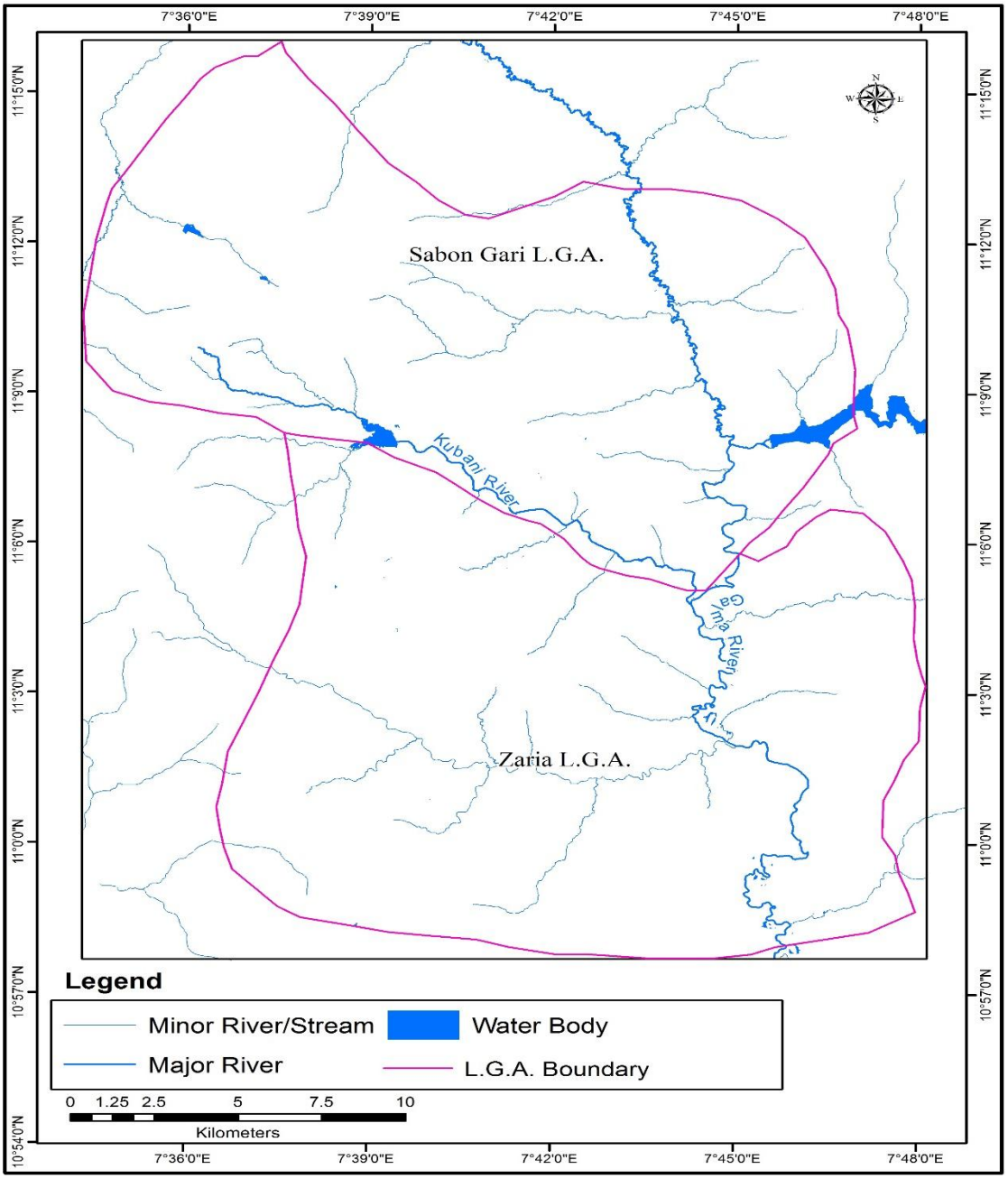


Fig. 3.3. Drainage Map of the Study Area.
Source: Modified from Topographic Map of Zaria, Sheet 102.

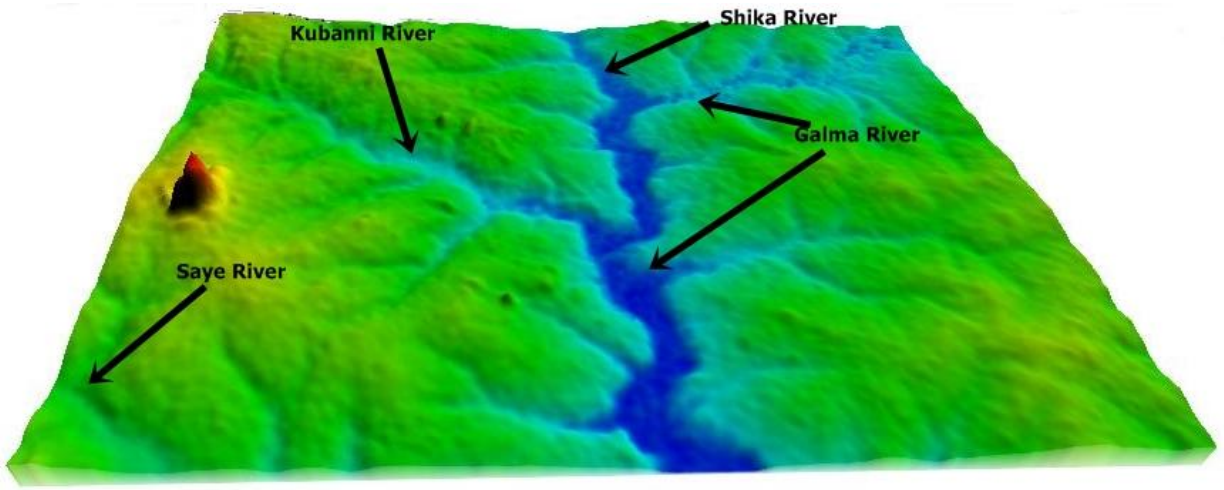


Fig. 3.4. 3D Drainage of the Study Area
Source: Laboratory Analysis, 2014.

3.2.5 Soils

The soil type of the study area is highly leached ferruginous tropical soils developed on weathered regolith overlain by a thin deposit of sand blown silt from the Sahara desert during many decades of the propagation of the tropical continental air mass into the area (Wright and McCurry 1970).

In the description of the soil pattern of Zaria by Klinkenberg (1970) based on geological units identified by Wright and McCurry (1970), soil types in Zaria include; *Fadama* soils, soils developed on metasediments (Schists and Quartzites) and Soils developed on granites.

The Fadama soils or soils of the floodplains occur in the bottom of extensive wide valley systems. They are generally classified as hydromorphic (Ipinmidun, 1972). Fadama soils are

mostly dark grey clays with poor to very poor drainage, most of which have been formed in alluvial material. They occur widely in Galma, Shika and Kubanni Basins.

Kowal and Kassam (1978) and Jaiyeoba (1986) observed that the organic matter and nitrogen content of the soil are very low (1-2%) which is the result of bush burning, overgrazing, continuous cultivation and oxidation decomposition of humified organic matter of the soil. Low Cation Exchange Capacity (CEC) and exchangeable bases due to low activity of clay particles. Low average pH of 7.1 which means that the soils are generally neutral in reaction with profiles less than 150cm deep, below which occurs partially weathered rocks of the parent material.

The Fadama soils are fairly rich in nutrients and have a good retention with excessive water supply which persists in the dry season. Many parts of the Fadamas are used for the cultivation of sugar cane, rice, etc, and during the dry season for vegetables farming usually called dry season farming (Lawes, 1964).

3.2.6 Land Use

Two types of lands are found in the study area; *Gona* or upland fields which support crops such as maize, millet, sorghum and groundnut during the wet season, and *Fadama* or lowland fields which support crops such as sugarcane, onion, tomatoes, pepper, spinach and other garden vegetables throughout the year. There is a relative buffering by the addition of organic manure and fertilizer application (Yusuf, 1999).

Sand mining is also conspicuous with their left overs as holes, pit, gullies etc. used as material for molding bricks and building of mud houses for both residential and animal shelter and in road

construction. Minor fishing activities usually take place especially during the dry season both on commercial and consumption scales (Yusuf, 2013).

Along the gentle rolling plains are human settlements. Settlement pattern in the river basins is highly concentrated in some areas and randomly scattered in other areas (Yusuf, 2013).

3.2.7 Vegetation

The relatively deep tropical ferruginous soil and climate condition of Zaria are suitable for and sustain a good cover of savanna woodland (Northern Guinea Savanna) with a variety of grasses, woody shrubs and short trees. Even though the study area lies within the Guinea savanna zone, the fact remains that there is little natural or climatic vegetation and the area has become a derived savanna type which is characterized by shrubs, stems, and trees along with some tuft cover and some clusters of trees along river courses. The characteristic vegetation cover is hardly preserved due to urbanization and poor management practices like; fuel wood harvesting, annual bush burning, cultivation and intensive grazing (abu.edu.ng, 2014).

The land management practices have resulted in the evolution of thorny shrub interspersed with short annual grasses. Also, trees have developed adaptive features such as thick cuticle and thick young twigs to enable them survive the high evapotranspiration and the annual bush burning.

The dorminant shrub around the area is *Isobeliniadoka*with an average height of 50cm. other less frequent shrub species include *Butyrispernum spp., Pilliostigma spp., and Terminaleaavicenniodes.*

The common grass communities in the area are mostly *Andropogon spp.* (Kwabe, 1987), which are almost completely absent during the long dry season. However, the grasses sprout during the rainy season, shrubs grow very rapidly, but no sooner than the rainy season ceased that they become dry. Grazing also contributes to their absence.

Trees here include*Mangiferaindica*dotting everywhere,*Parkiaclappertoniana, TamarindusIndica,* Shea butter trees and several others which are found to be useful. Yearly, the trees are left standing while the area is being cultivated. During the rainy season, the vegetation is thick and greenish, but are dry and brownish in the dry season with little of these plants retaining their foliage (abu.edu.ng, 2014; Yusuf, 2013).

3.2.8 Population

The population of Zaria has increased over the years. It is presently the second largest urban area after the state capital based on recent population figure.According to National Population Commission, the population of Zaria and SabonGari Local Government Areas were totaled to be 695, 069 people, with population density that ranges from 50-200 persons per square kilometer (NPC, 2006).

Zaria itself is a very large, heterogeneous city whose current 1.490,000 population comes from different parts of the world (abu.edu.ng, 2014). This is quite great increase when compared with about 110,000 population figure in 1970 (Mortimore, 1970).

Urban Zaria being the study area consists of mainly the Hausa/Fulani as indigenes and other ethnic groups which are settlers (Yusuf, 2012). . In terms of the diversity and size of student population, there is hardly any town in Nigeria which surpasses Zaria. The concentration of

institutions of higher learning has made Zaria famous regionally, nationally, and internationally (abu.edu.ng, 2014).

3.3 METHODOLOGY

3.3.1 Reconnaissance Survey

Preliminary survey was carried out in order to familiarize the researcher with the study area during which permission was obtained for access to the study area from the head of the wards under the area covered by the study.

3.3.2 Types and Sources of Data

The data used for this study include topographic map, satellite imageries and literatures. The data and their sources are given in table 3.1

Table 3.1Data Used for the Study and Sources

	Data Type	Source
1	Satellite imageries of Zaria for 1990, 1999 and 2014 for change detection analysis.	Global Land Cover Facility.
2	1:100,000 Zaria topographic map sheet 105 to produce map of study area.	Department of Geography Ahmadu Bello University Zaria
3	Shuttle Radar Terrain Mission (SRTM) Image, 2008 for Digital Elevation Model (DEM).	Global Land Cover Facility
4	Related literatures	Libraries and internet.

Table 3.2 summarizes the characteristics of imageries used. LandSat imageries of same spatial resolution were used. These include: 1990 LandSat Thematic Mapper (TM), 1999 LandSat Enhanced Thematic Mapper(ETM) and 2014 Landsat Enhanced Thematic Mapper Plus (ETM+).The interval in the study period should have had regular interval, but the period between

1999 and 2014 showed irregularity which is based on the need to capture current developments that have occurred in the study area and has proven to be a choice worthwhile.

Table 3.2. Satellite Imagery used for Satellite Image Processing

Date of acquisition	**Type of satellite image**	**Spatial resolution**
27th November, 1990	Landsat Thematic Mapper	30m
19th October, 1999	LandSat Enhanced Thematic Mapper (ETM)	30m
23th March, 2014	LandSat Enhanced Thematic Mapper Plus (ETM+)	30m

Source: Global Land Cover Facilty, 2014

3.3.2.1 Original Satellite Imageries of the Study Area

The presentation in Figures 3.5, 3.6 and 3.7 shows the unclassified satellite imageries of Zaria for 1990, 1999 and 2014 in False Colour Composite (FCC) prior to further processing.

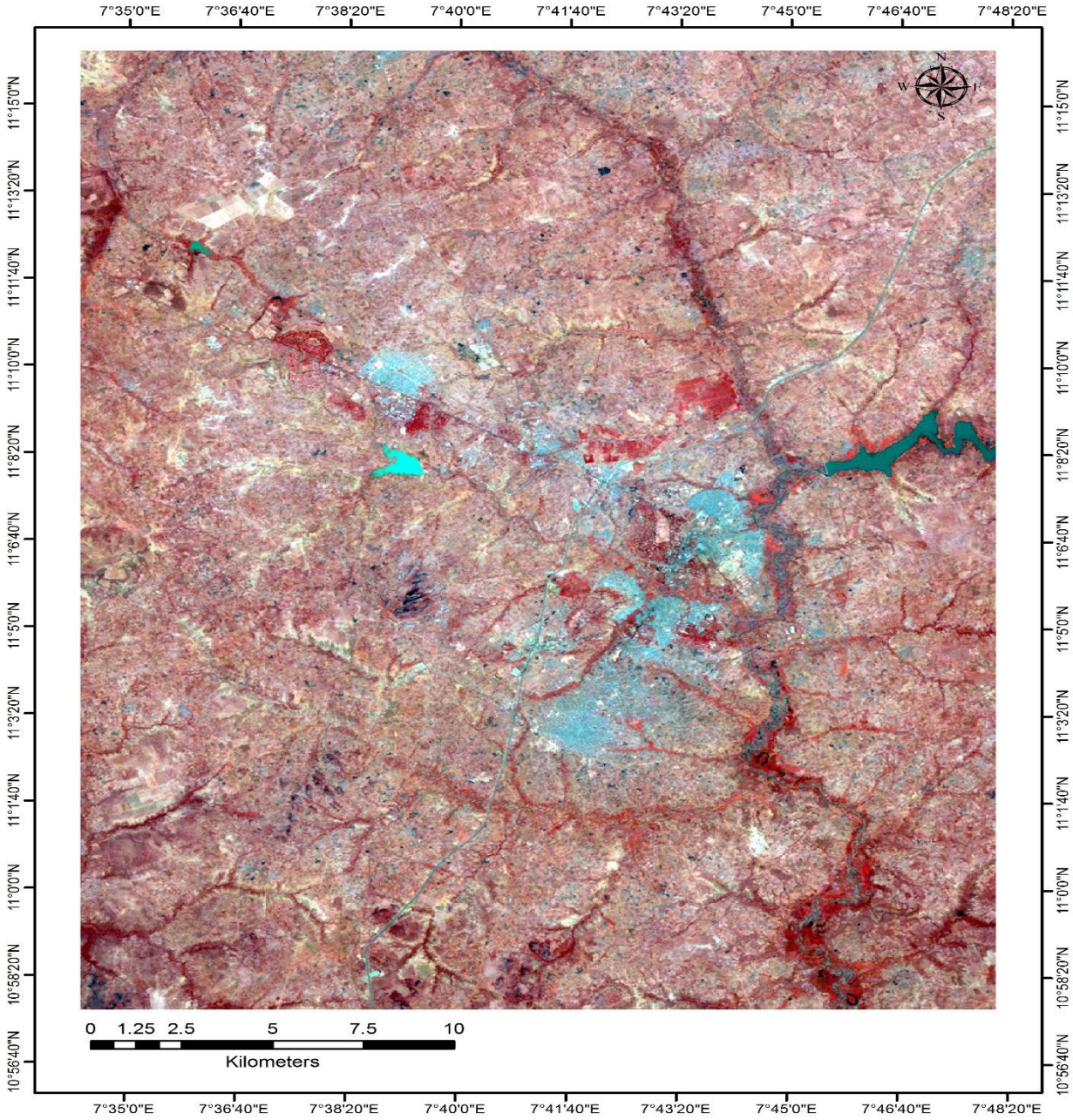


Fig. 3.5 Landsat TM 1990 Unclassified Image of the Study Area
Source:Global Land Cover Facility (2014).

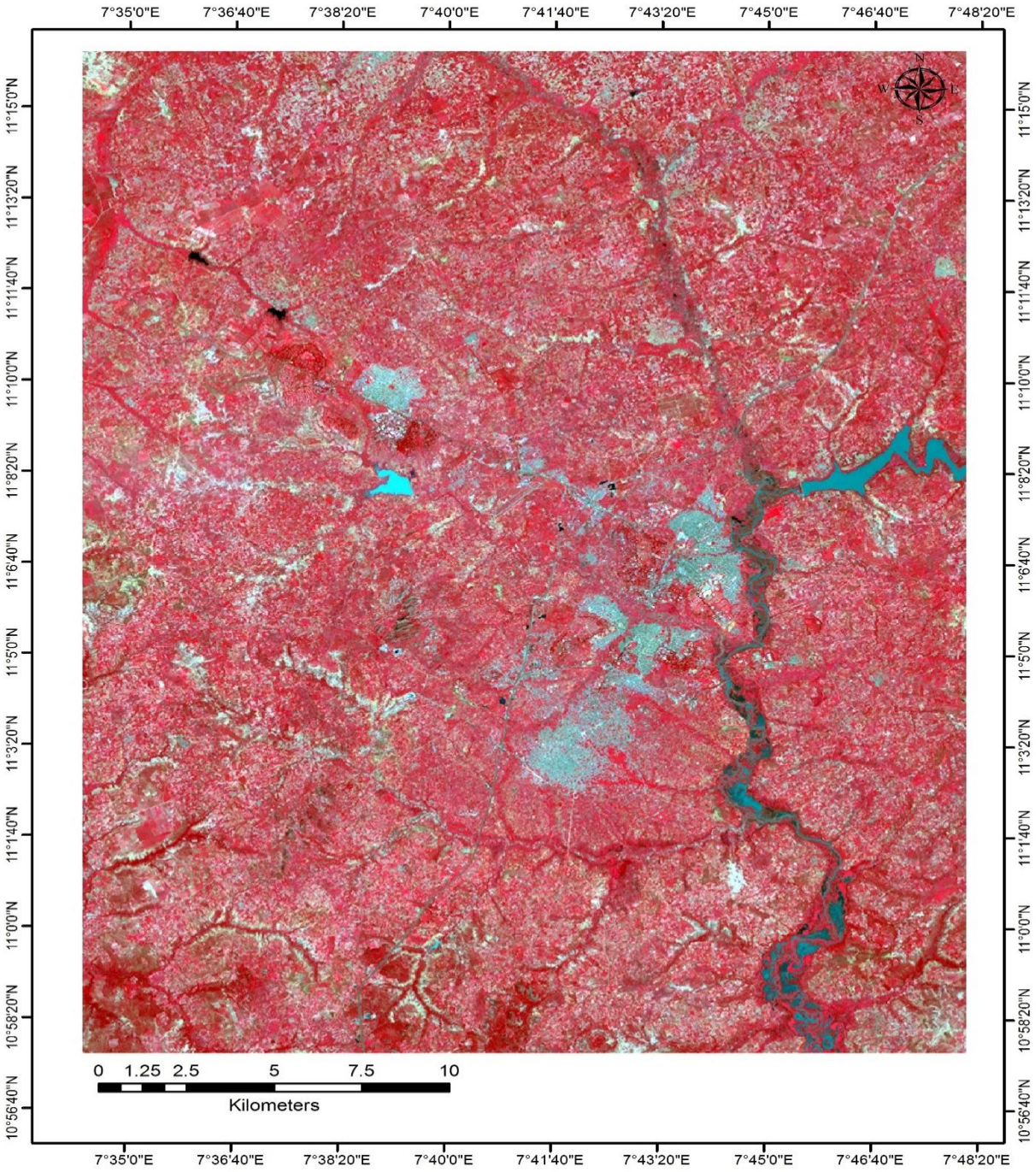


Fig. 3.6Landsat ETM 1999 Unclassified Image of the Study Area
Source:Global Land Cover Facility (2014).

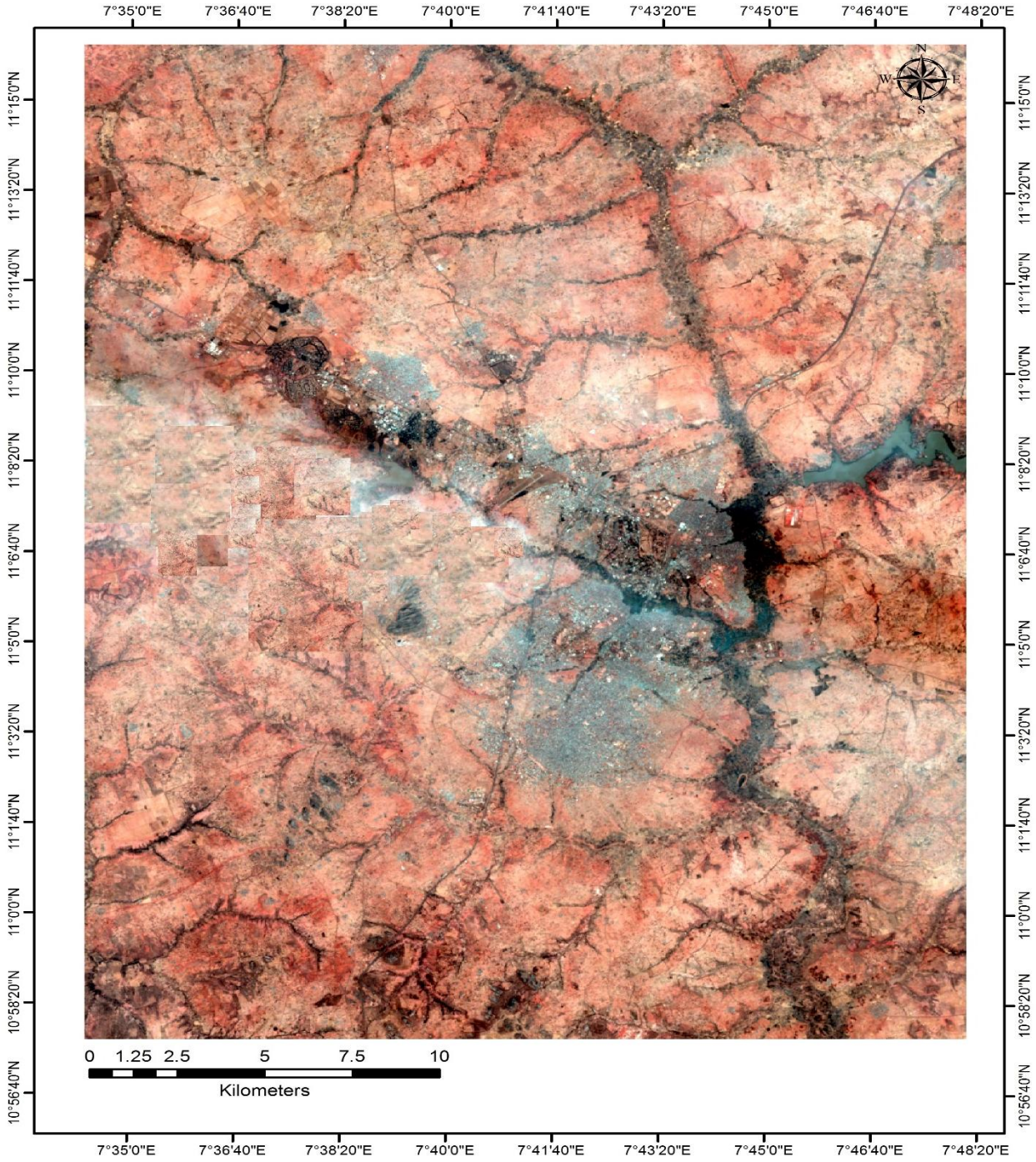


Fig. 3.7Landsat ETM+ 2014 Unclassified Image of the Study Area
Source:Global Land Cover Facility (2014).

3.3.3 Tools used for Data Collection and Analysis

A. Hardware

- Laptop
- Global Positioning System (GPS) for field verification of features on the imageries.

B. Software

- ArcGIS 10.1 software for data extraction, production of drainage and urban map as well as digital image processing and spatial analysis.
- Microsoft office word for report and result preparation.
- Microsoft Excel for calculating the landuse/landcover change, percentage change and the annual rate of change.

3.3.4 Research Design

The research was designed to collect and analyze information on the land use as well as the pattern of urbanization in the study area and its effects on the floodplain. Figure 3.8 summarizes this approach.

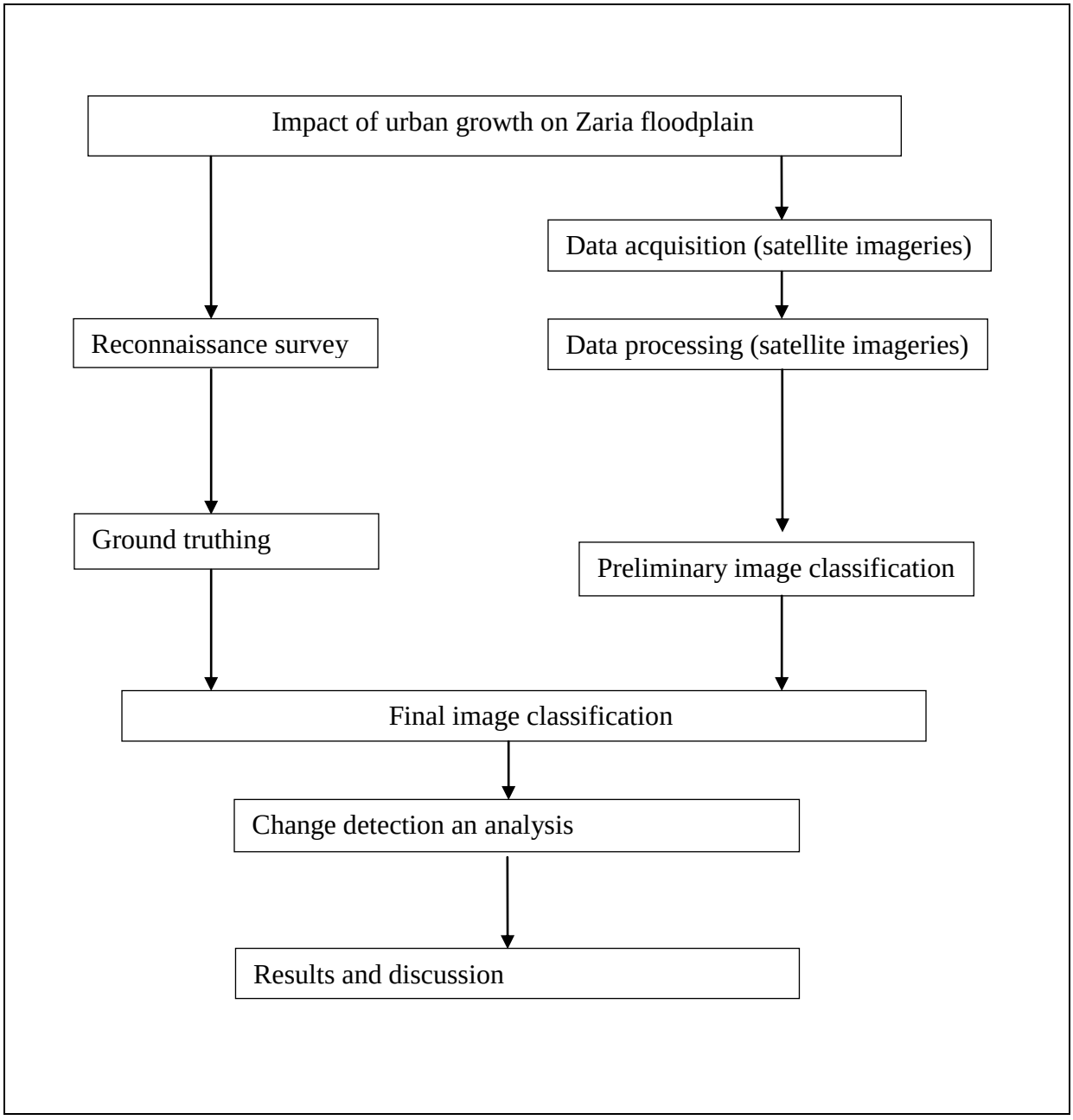


Figure 3.8. Summary of the Methodological Approach Employed in the Study.

3.3.5 Analysis of Satellite Imageries for Urban Land Uses

The procedure followed in the image processing and analysis of urban land uses was by first sub-setting the satellite imageries according to the coordinates from Zaria topographical map sheet 105, 1:100, 000 and the official administrative map of Kaduna State to delineate the study area, as well as utilization of Digital Elevation Model (DEM) obtained fromShuttle Radar Topography Mission (SRTM, 2008) for floodplain area delineation. Figure 3.9 summarizes the procedure that was followed in the satellite image processing and analysis.

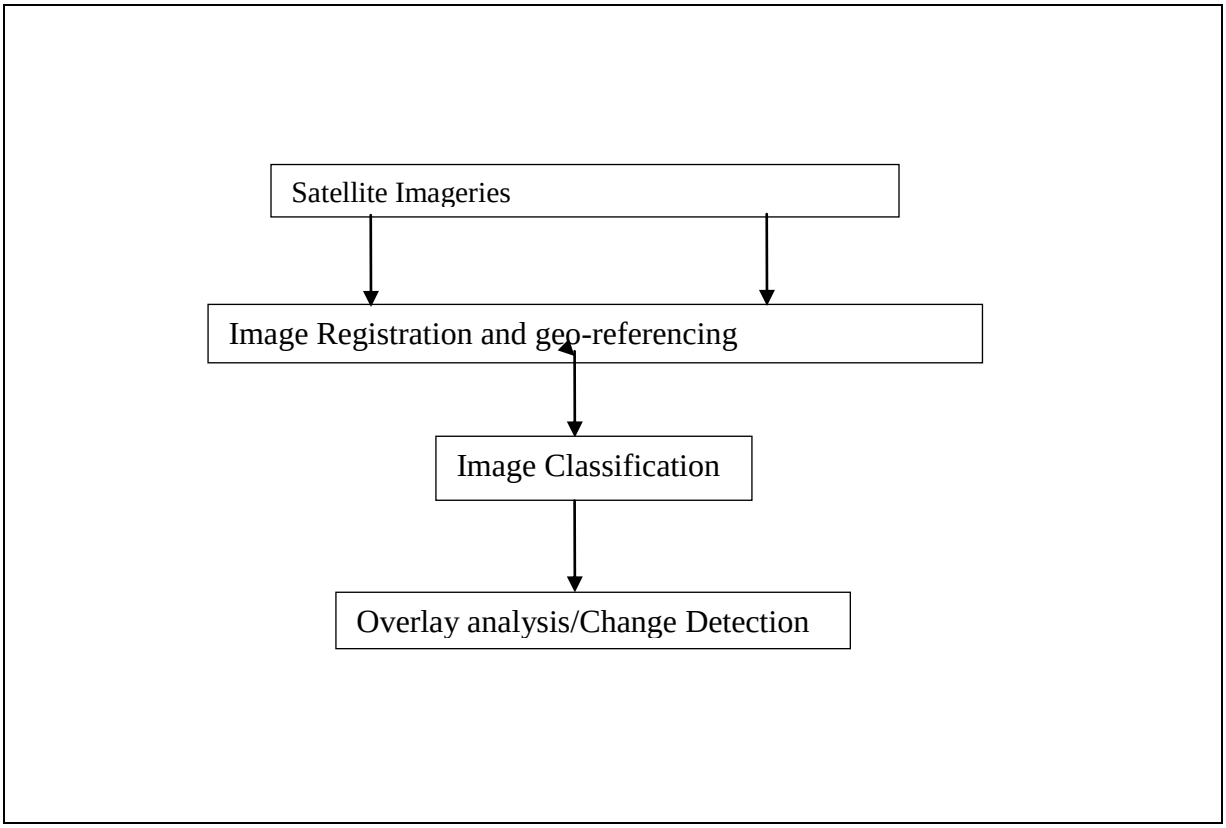


Figure 3.9. Flow Chart for Method of Analysis of Satellite Imageries

3.3.5.1Image RegistrationandGeo-referencing

Feature-based image registration was employed which involved transforming the different satellite images into one coordinate systems in order to be able to compare or integrate the three

images. Even though all the images had already been geo-referenced from the ground receiving station, coordinates of some known point were used to verify the positional accuracy of the images. The map projection of the images(Universal Transverse Mercator (UTM) WGS ’84 Zone 32 North) was retained.

3.3.5.2 Image Classification

Image classification is considered 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 (Mather, 1999). Classification involves three main issues: creating samples, image sampling and generalizing the sampled features (Jeb, 2008).

This study employed supervised classification based on five classes. The supervised classification technique using ‘Maximum Likelihood Classification Algorithm’entails training of the image data into various themes or classes based on the drawn out land use/land cover scheme. With this technique, samples of the different features on the image were given sample pixel identities to depict a given land use and land cover type. Images were classified based on the prepared classification scheme. The table below shows the classification scheme adapted.

Table 3.3 Classification Scheme Adapted for the Study

S/No.	Land Use/ Land Cover Type	Interpretation
1	Built-up areas	These include all developed land such as roads, residential, administrative, educational, industrial and commercial land uses.
2	Scattered cultivation	All agricultural land uses under cultivation.
3	Vegetation	To includes all green areas that tend to stand out.
4	Bare surfaces	All bare surfaces such as sites of building under construction, rocks and mountains, dilapidated buildings and fallowed farmland.
5	Water bodies	All water surfaces such as rivers, streams, ponds and dams.

Source:Adapted and modified from Anderson, Hardy, Roach and Witmer (1976).

3.3.5.3 Overlay Analysis, Change Detection and Calculation

Overlaying two classified imageries detects changes that have occurred over time in an area. Change detection on the other hand is a process of determining and/or describing changes in the land use and land cover properties. There are many techniques available to detect and record differences e.g. image differencing, ratios or correlation (Xiaomei and Ronqing, 1999). For this study, image differencing was utilized in which urban growth was monitored by extracting built-up layers using the multi-temporal satellite data. These built-up vector layers were composed by GIS overlay and extent of built-up was measured from the respective data sets for the periods they represent.To calculate aerial extent of each landuse/land cover class of the classified images so as to be able to calculate the changes and annual rate of changes, the classified images were converted from raster to polygon. A field named "area" was created on each layer of the converted image (polygon). The aerial extent of each land use class was calculated using ArcGIS "calculate geometry" function

After the three data sets have been compared to determine the amount of urban growth based on land use change from non-urban to urban land use between 1990 and 2014, new patterns of development were classified as one of these three types of urban growth: linear, expansion or cluster, and leapfrog or relocation based on the density of new growth areas by visualization of the spatial distribution of built-up land in the periods under study. This ensured the achievement of objective 3.

Reviews of related literatures on current issues (hazards) associated with encroachment on floodplains in and outside Nigeria as well as creating encroachment map to delineate areas with risk potential aided the achievement of objective 4.

3.4. DATA ANALYSIS

3.4.1 Land Use and LandCover Change Detection

To determine land use and land cover change in the study area between 1990 and 2014, each land use and land cover size was calculated and obtained from clipping or overlay analysis.The calculated aerial extent of each land use class for each study year was copied to Microsoft Excel for easy calculation.

3.4.1.1 Change in Area in Square Kilometers

The change in square kilometers = the subsequent area minus the preceding area

For example, to determine the land use and land cover change in built-up area between 1990 and 2014:

The change in square kilometers = the area (sq.km) of built-up in 1999 minus the area (sq.km) of built-up in 1990.

3.4.1.2 Percentage Change

Percentage change = the subsequent area minus the preceding area divided by the preceding area multiplied by 100

Or simply

Percentage change = change divided by preceding area multiplied by 100

For example, to calculate the percentage change (km^2) in built-up between 1990 and 1999:

Percentage change in built-up = (area in 1999 minus the area in 1990, divided by area in 1990 multiplied by 100).

3.4.1.3 Annual Rate of Change

In calculating the annual rate of change, the change was divided by thenumber of study years (the difference between the two years) as shown in the following formula:

Annual Rate of Change = Change divided by number of study years

The number of study years between 1990 and 1999 for example is 1999 minus 1990 = 9

3.4.2 Encroachment of Urban Built-up Area into the Zaria Floodplains within the Study Period

In order to assess how much urban growth has encroached into Zaria floodplains, a digital elevation model was prepared from which the floodplain was delineated in order to create an encroachment map. An area with an elevation of between 605-624m was extracted as the floodplain area. The built-up area in each study year was extracted and overlaid on the delineated floodplain. An overlay analysis (clipping) was used where the built-up areas were clipped to the floodplain. Areas that clipped to the floodplain were identified as areas that have encroached into the floodplains. The aerial extent of the clipped built-up areas were calculated in square kilometers and presented as the areas that have encroached into the floodplains. Change detection calculations were applied for the clipped aerial extent of all the study years to arrive at the extent of encroachment of urban built-up on the floodplains. See fig. 3.10 below for the Digital Elevation Model

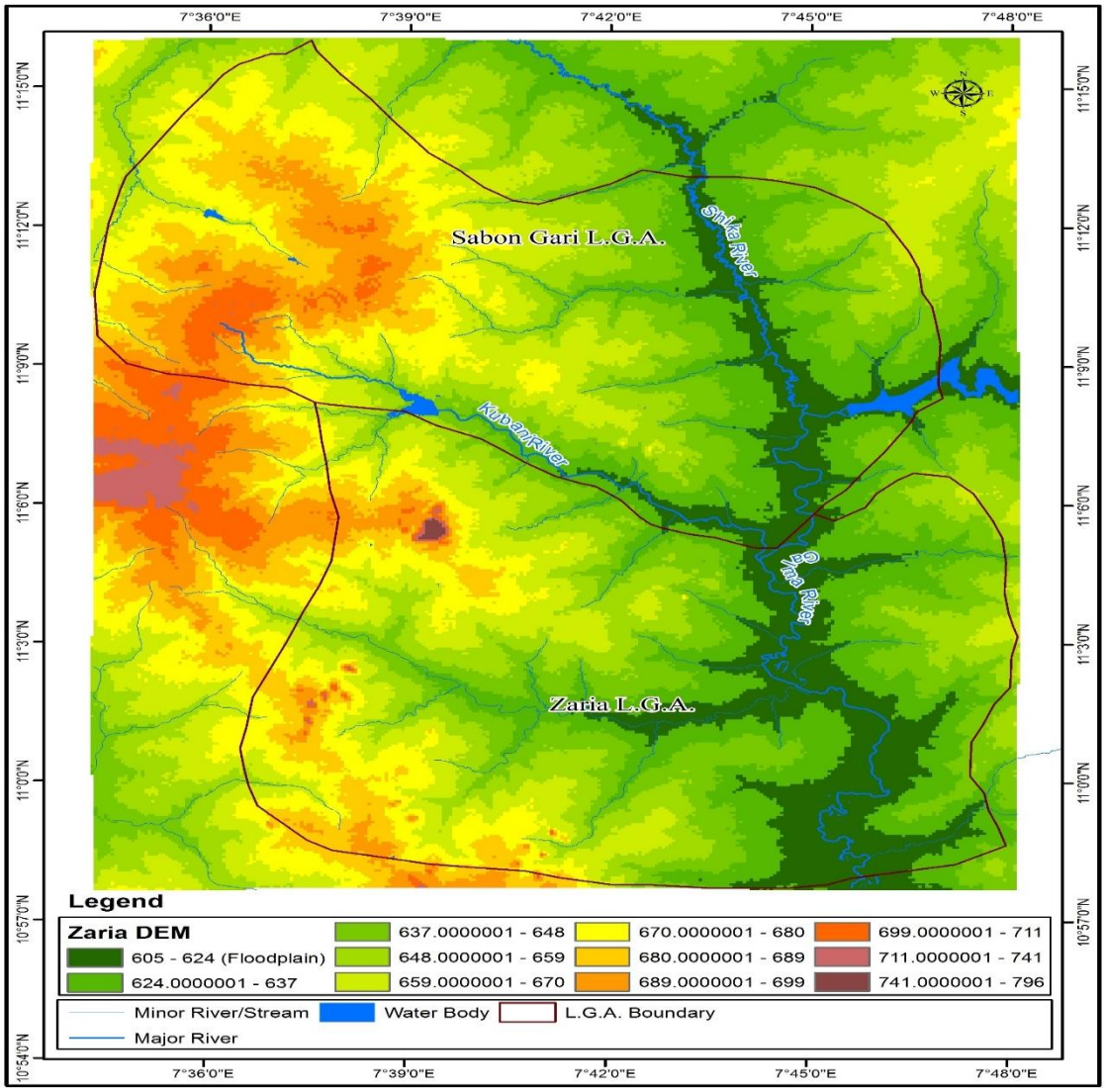


Fig. 3.10 Digital Elevation Model of Zaria (SRTM, 2008).
Source: Laboratory Analysis (2014).

3.4.3 Pattern of New Urban Growth and Classification

New urban growth were visually determined from the encroachment map and classified as either Linear or Strip, Expansion or Cluster and Leapfrog or Relocation.

3.4.4 Examining the Implication of Urban Growth on the Floodplains

Reviews of related literatures on current issues (hazards) associated with urban encroachment of floodplains, information obtained from field survey and the trend of encroachment from the analysis of satellite imageries of urban Zaria were used to examine the implication and potential risk associated with urban floodplains encroachment.

3.4.5. Ground Truthingand Detailed Field Survey

Ground truthing and field survey were conducted simultaneously. The main essence of ground truthing was to verify that image classification corresponds with the actual features on the ground. On the other hand, field survey ensured that relevant data on settlement pattern, information that aided the interpretation of observed features and photographic proofs of urban built-up on Zaria floodplains were obtained.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter deals with the presentation and discussion of result obtained from the analyses. The presentation of the results is based on landuse and landcover change and the trend between 1990 and 2014, annual rate of landuse and landcover change within the study period, pattern of growth of urban built up and the implications of such growth on the floodplains of the study area.

4.2 CLASSIFIED SATELLITE IMAGERIES OF THE STUDY AREA

Figures 4.1, 4.2 and 4.3 show the classified satellite imageries of Zaria for 1990, 1999 and 2014 which all carry the same land use classes including built-up, scattered cultivation (agricultural land), vegetation, water body and bare surface. These classified imageries were used for change detection across all land use classes over the study years.

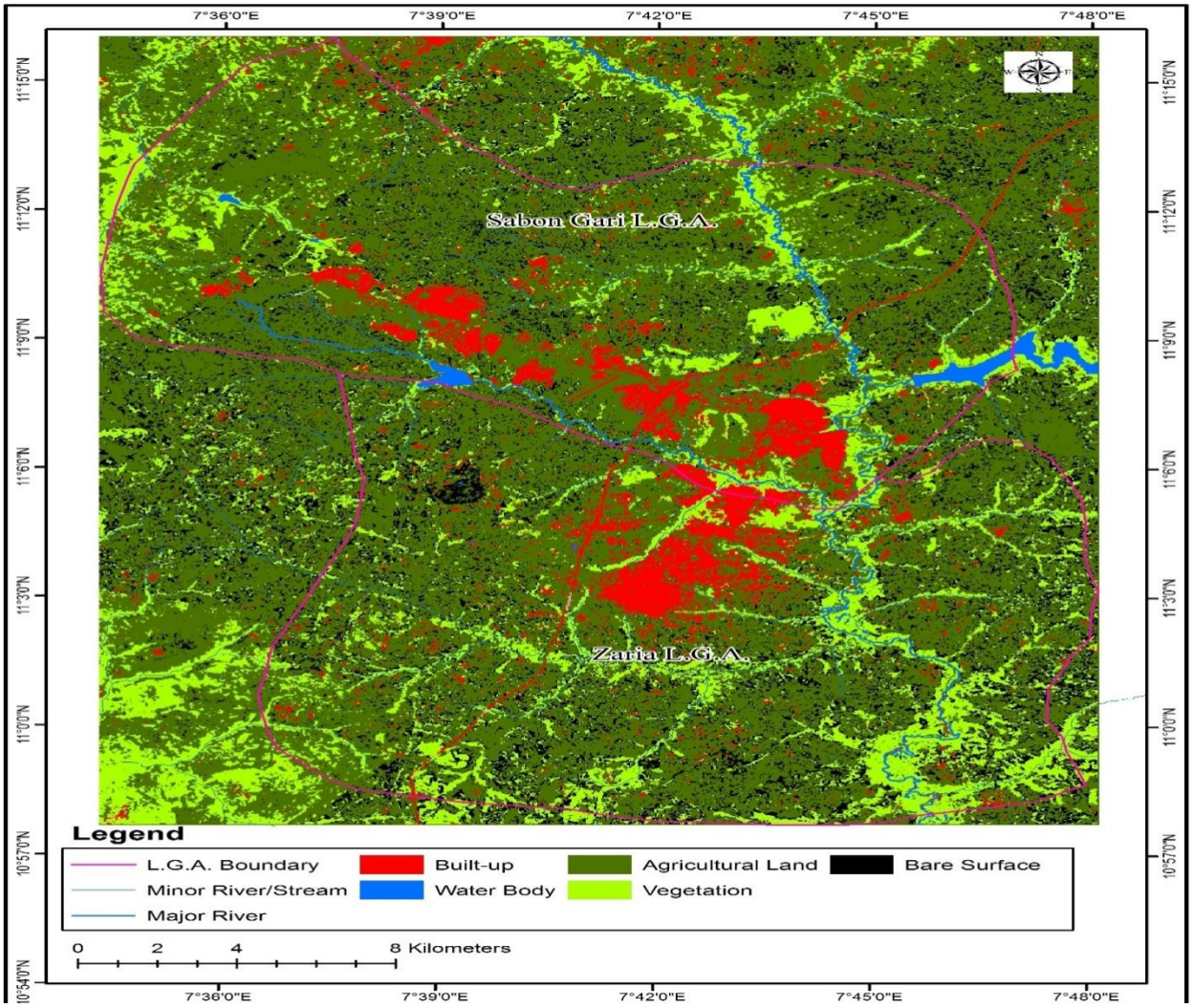


FIG. 4.1 LANDSAT TM 1990 CLASSIFIED IMAGE OF THE STUDY AREA.
Source: Laboratory Analysis (2014).

The 1990 satellite image of the study area above shows the land use classes depicted in various colours with built-up represented as red, agricultural land as lush-green, bare surfaces as black, water body as blue and vegetation found especially along water courses depicted as light-green.

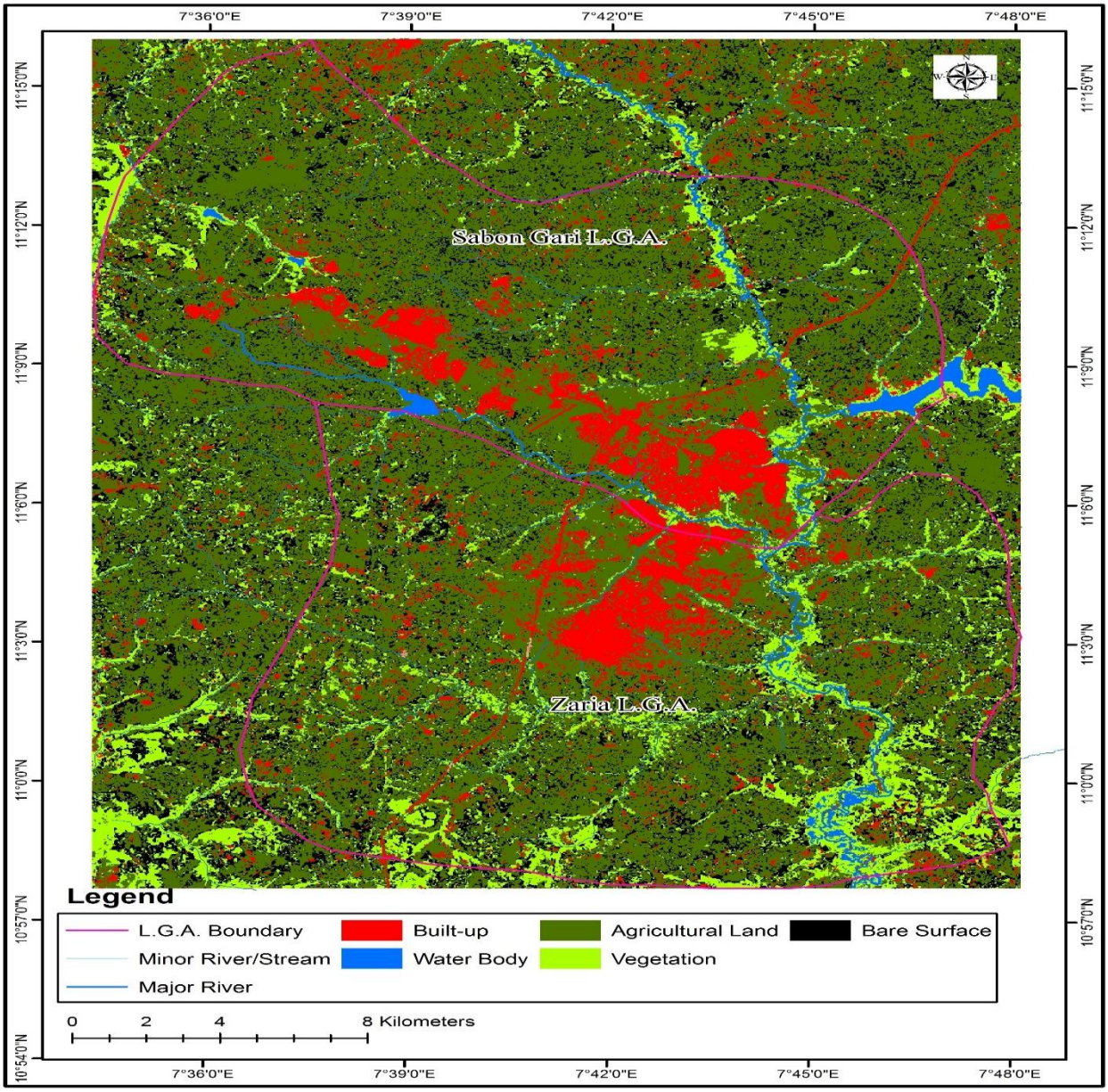


FIG. 4.2 LANDSAT ETM 1999 CLASSIFIED IMAGE OF THE STUDY AREA.
Source: Laboratory Analysis (2014).

The 1999 classified satellite image in figure 4.2 showed visible evidence of greater concentration or density and coverage of built-up land use which is more conspicuous than that observed from the classified satellite image of 1990 in figure 4.1.

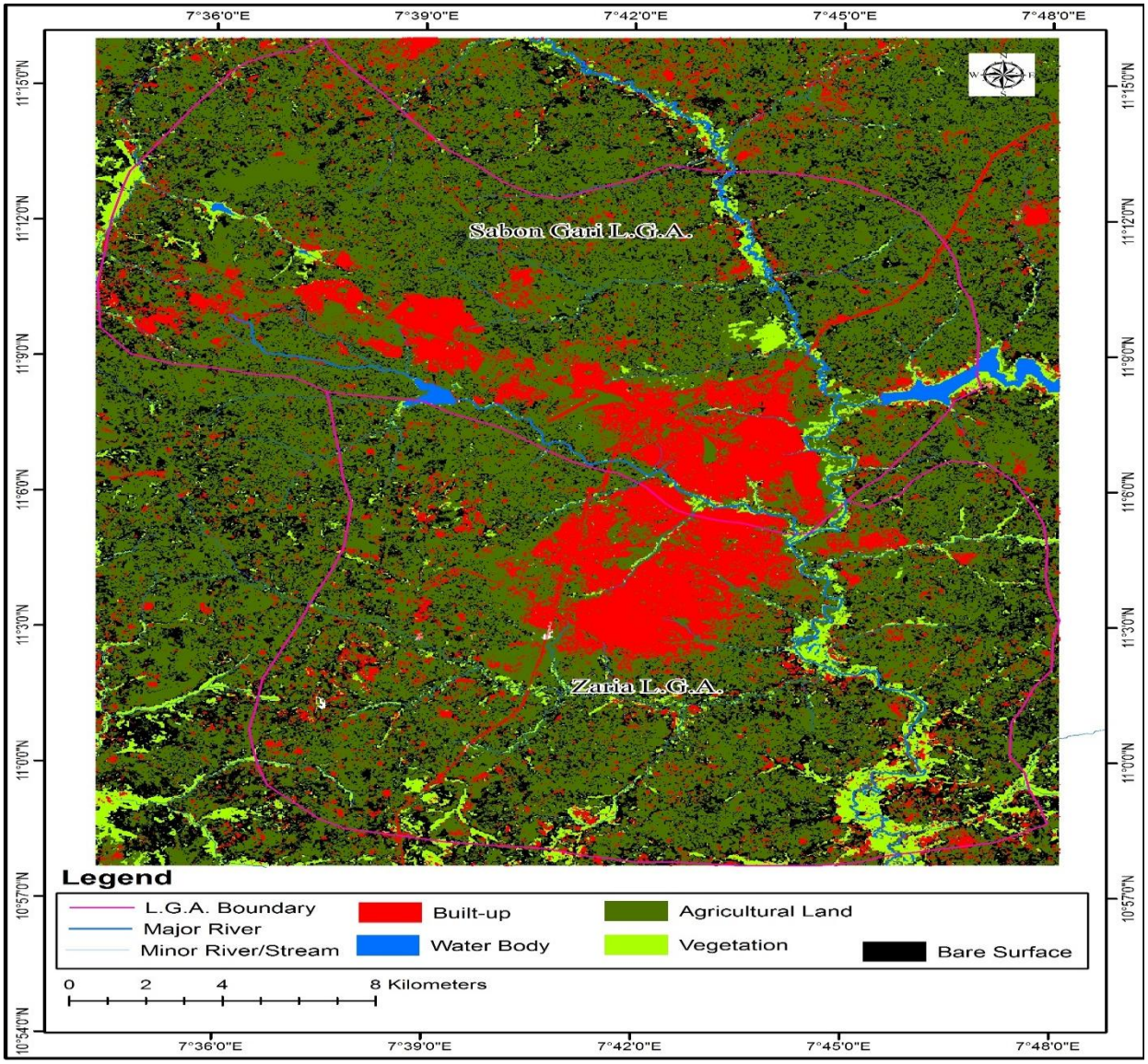


FIG. 4.3 LANDSAT ETM+ 2014 CLASSIFIED IMAGE OF THE STUDY AREA. Source: Laboratory Analysis (2014).

The classified image of 2014 in figure 4.3 above showed the greatest density in built-up land use class which suggests the occurrence of urban growth or sprawl across the 24 year study period. Increases or decreases in other land use classes may not be observable but were determined from digital image processing techniques utilized in the study. The comparative view in built-up change for 1990, 1999 and 2014 images can be observed in figure 4.4 below

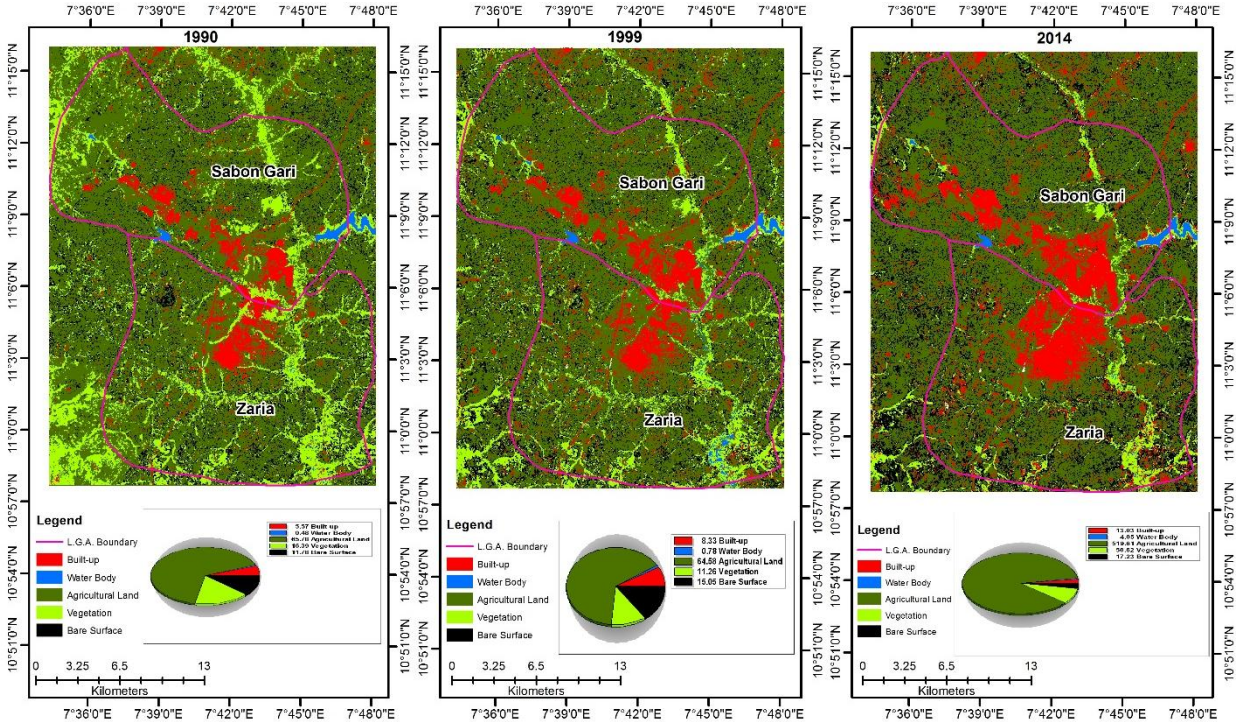


FIG. 4.4 Comparative View of Landuse/Landcover Distribution between 1990 and 2014
Source: Laboratory Analysis (2014).

4.3LANDUSE AND LANDCOVER DISTRIBUTION BETWEEN 1990 AND 2014

Thearea of landuse and landcover classes were identified in 1990, 1999 and 2014 in kilometer square and percentage as shown in table 4.1

Table 4.1 Landuse and Landcover Distribution of Zaria

	1990		1999		2014	
Land use	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
Built-up	47.46	5.57	71.03	8.33	111.02	13.03
Scattered cultivation	560.72	65.78	550.45	64.58	520.73	61.09
Vegetation	139.66	16.39	95.94	11.26	47.39	5.56
Bare Surface	100.40	11.78	128.25	15.05	169.22	19.85
Water Body	4.12	0.48	6.69	0.78	4.00	0.47
Total	**852.36**	**100.00**	**852.36**	**100.00**	**852.36**	**100.00**

Source: Laboratory Analysis(2014).

Table 4.1 shows that built-up area occupied 47.46km² (5.57%) of the total area in 1990, which increased to 71.03km² (8.33%) and 111.02km² (13.03%) in 1999 and 2014 respectively attributed to population increase and the need for new housing, schools, hospitals and transportation networks. Scattered cultivation which occupied 560.72km² (65.78%) in 1990 gradually decreased to 550.45km² (64.58%) and 520.73km² (61.09%) in 1999 and 2014 respectively consequent uponurban expansion into peripheral agricultural land and the associated dry season.Vegetation decreased from 139.66km² (16.39%) in 1990 to 95.94km² (11.26%) in 1999 and to 47.39km² (5.56%) in 2014 which can be associated with dry conditions characterized by deciduous trees and shrubs as well as dry grasses (except along water courses) atthe time the image was captured especiallyin 2014 satellite imagery, as well as human interference over time such as harvesting of wood for domestic fuel. Bare surface progressively increased from 100.40km² (11.78%) in 1990 to 128.25km² (15.05%) in 1999 and 169.22 (19.85%) in 2014 which is mainly attributed to dry season and the depletion of vegetation by competing land uses such as land clearing for agriculture and urban development.

Water body occupied 4.12km² (0.48%) in 1990 increased to 6.69km² (0.78%) in 1999 and dropped to 4.00km² (0.47%) in 2014. The fluctuation in water body reflects variation in the time of data capture in the month of November, October and March for 1990, 1999 and 2014 respectively. The drop in water body in 2014 is due to the fact that the 2014 imagery was acquired very much in the dry season (March) coupled with intensive irrigation farming in the fadamas (floodplains) along Galma and Kubanni Rivers. The trend of change depicts that increase in built-up area is inversely proportional to the other land use classes suggesting that urban expansion fundamentally depends on consumption of other land use classes. See figures 4.4, 4.5 and 4.6

4.4LANDUSE AND LANDCOVER CHANGE BETWEEN 1990 AND 2014

Table 4.2 shows the land use and landcover change between 1990 and 2014.

Table 4.2: Landuse/Landcover Change between 1990 And 2014

	1990	1999	2014	1990-1999		1999-2014		1990-2014	
Land use	(km^2)	(km^2)	km^2	km^2	Percent	km^2	Percent	km^2	Percent
Built-up	47.46	71.03	111.02	23.57	49.66%	39.99	56.30%	63.56	133.92%
Scattered Cultivation	560.72	550.45	520.73	-10.27	-1.83%	-29.72	-5.40%	-39.99	-7.13%
Vegetation	139.66	95.94	47.39	-43.72	-31.30%	-48.55	-50.60%	-92.27	-66.07%
Bare Surface	100.40	128.25	169.22	27.85	27.74%	40.97	31.95%	68.82	68.55%
Water Body	4.12	6.69	4.00	2.57	62.38%	-2.69	-40.21%	-0.12	-2.91%
Total	**852.36**	**852.36**	**852.36**						

Source: Laboratory Analysis, 2014 NB: negative= decrease, positive= increase

As shown in table 4.2, the built-up area showed increasing trend and has changed by 23.57km^2 with a percentage change of 49.66% between 1990 and 1999. Between 1999 and 2014 built-up has changed by 39.99km^2 representing 56.30 %. There was a net change in built-up area by 63.56% with a percentage change of 133.92% between 1990 and 2014 indicating an increase more than double over the study period which corresponds with the increase in investments, the influx of students and increase in staff strength of the various institutions in the study area. Hence, increase in the construction of buildings to accommodate the increase in the population and administrative structures that resulted in the consumption of other land uses. Scattered cultivation changed (decreased) by -10.27km^2 with a percentage change of -1.83% between 1990 and 1999. A change of -29.72km^2 which is -5.40% was recorded for scattered cultivation

between 1999 and 2014.It has a net decrease of -39.99km^2 with a percentage change of -7.13% between 1990 and 2014. This reflects the haphazard pattern of urbanization consuming more land amongst other land uses. Vegetation decreased by -43.72km^2 with a percentage change of -31.30% between 1990 and 1999. The vegetation also decreased by -48.55km^2 with a percentage change of -50.60% between 1999 and 2014. A net decrease in vegetation of -92.27km^2 with a percentage change of -66.07% was recorded between 1990 and 2014. The remarkable growth of built-up areas in large-sized settlements away from the city limits associated with various human activities has led to elimination or depletion of the vegetation coupled with the dry season which is evident by the continuous linear vegetation mainly along river banks. Bare surface increased by 27.85km^2 with a percentage of 27.74% between 1990 and 1999. Between 1999 and 2014, bare surface increased by 40.97km^2 with a percentage increase of 31.95%. Net increase of 68.82km^2 with a percentage of 68.55% was recorded for bare surface between 1990 and 2014 which reflects the dry season when the imageries were captured as well as expansion in urban built-up.

Moreso, water body changed by 2.57km^2 with about 62.38% between 1990 and 1999, as well aswith a decrease of -2.69km^{2}which accounted for -40.21% between 1999 and 2014. Net decrease of -0.12km^2 with a percentage of -2.91% was recorded for water body between 1990 and 2014. The decrease is associated with excessive utilization of water for domestic, industrial and agricultural purposes as well as the dry season characteristic of the climate during which the satellite imageries were collected. Generally, the urban built-up showed the greatest increase over all other land uses which could mean that reduction in the area of other land use classes is the product of the recorded urbanization.

4.5 ANNUAL RATE OF LANDUSE/LANDCOVER (LULC) CHANGE (1990-2014)

Table 4.3 shows the annual rate of landuse/landcover change between 1990 and 2014.

Table 4.3Annual Rate of Landuse/Landcover Change between 1990 And 2014

Landuse	Change 1990-1999	Change (1999-2014)	Change (1990-2014)	Annual Rate of Change (1990-1999)		Annual Rate of Change (1999-2014)		Net Annual Rate of Change (1990-2014)	
	(km^2)	(km^2)	(km^2)	km^2	%	km^2	%	km^2	%
Built-up	23.57	39.99	63.56	2.62	5.52%	2.67	3.75%	2.65	5.58%
Scattered cultivation	-10.27	-29.72	-39.99	-1.14	-0.20%	-1.98	-0.36%	-1.67	-0.30%
Vegetation	-43.72	-48.55	-92.27	-4.86	-3.48%	-3.24	-3.37%	-3.84	-2.75%
Bare Surface	27.85	40.97	68.82	3.09	3.08%	2.73	2.13%	2.87	2.86%
Water Body	2.57	-2.69	-0.12	0.17	6.93%	-0.18	-2.68%	-0.01	-0.12%
Total	**852.36**	**852.36**	**852.36**						

Source: Laboratory Analysis, 2014 NB: negative= decrease, positive= increase

Table 4.3 shows that built-up areachanged annually at the rate of 2.62km^2/yearand 2.67km^2 between 1990 – 1999 and 1999 – 2014 respectively with a net annual change rate of 2.65km^2 between 1990 and 2014.Scattered cultivation showed -1.14km^2 annual rate of change between 1990 and 1999. It also changed annually at the rate of -1.98km^2 between 1999 and 2014. The net annual rate of change of scattered cultivation between 1990 and 2014 is -1.67km^2/year. Vegetation showed an annual rate of change of -4.86km^2 between 1990 and 1999. Between 1999 and 2014, the annual rate of change in vegetation is -3.24km^2. The net annual change rate of vegetation is -3.84km^2 between 1990 and 2014. Bare surface showed 3.09km^2 annual change rate between 1990 and 1999. Its annual change rate between 1999 and 2014 is 2.73km^2. The net annual change rate for bare surface between 1990 and 2014 is 2.87km^2. Water Body depicted an

annual change rate of 0.17km^2 between 1990 and 1999. It also showed -0.18km^2 annual rate of change between 1999 and 2014. Water body has a net annual change rate of -0.01km^2 representing -0.12% between 1990 and 2014.

The period 1999 to 2014 showed increased annual rate of change in built-up with 2.67km^2/year against 2.62km^2/year between 1990 and 1999. The increase in the rate of built-up change corresponds with the negative rate of change of other land use classes identified above. This suggests increased urbanization against decreasing other land uses. It is noteworthy that the decreasing rates of other land use classes also reflect the dry season within which the satellite imageries were collected which influences the drying of grasses that increases bare surfaces, shedding of leaves that reduces vegetation cover and high evaporation that shrinks water body in conjunction with human activities and urban expansion.

4.6ENCROACHMENT OF URBAN BUILT-UP AREA INTO ZARIA FLOODPLAINS BETWEEN 1990 AND 2014

Table 4.4 shows the magnitude of built-up area encroachment into the floodplains.

Table 4.4 Encroachment of Urban Built-up into Zaria Floodplains between 1990 and 2014

Built-up Encroachment Extent1990	Built-up Encroachment Extent1999	Built-up Encroachment Extent2014	Built-up Encroachment Change 1990-1999	Built-up Encroachment Change 1999-2014	Built-up Encroachment Change 1990-2014	Built-up Encroachment Annual Change Rate 1990-1999	Built-up Encroachment Annual Change Rate 1999-2014	Built-up Encroachment Annual Change Rate 1990-2014
(Km^2)	(Km^2)	(Km^2)	(Km^2)	(Km^2)	(Km^2)	(Km^2)	(Km^2)	(Km^2)
3.51	6.59	13.67	3.08	7.08	10.16	0.34	0.47	0.42

Source: Laboratory Analysis(2014).

The delineated floodplain lies between 605 and 624m above sea level with a calculated area of 78.23km^2. In 1990 built-up land use class was calculated to have encroached into the floodplains by 3.51km². In 1999, 6.59km^2 built-up was found to have encroached into the floodplains, and by 2014 a total of 13.67km² encroached into the floodplains. A total built-up encroachment change of 10.16km^2 was recorded between 1990 and 2014. From the encroachment extents of the respective years above, between 1990 and 1999 built-up has encroached into the floodplains by 3.08km² at the rate of 0.34km² annually. Furthermore, between 1999 and 2014 built-up has encroached into the floodplains by 7.08km² at the rate of 0.47km² annually. This means that there is 10.16km^2 of floodplains encroached upon by urban built-up areas between 1990 and 2014. The annual encroachment rate for built-up area between 1990 and 2014 was calculated to be 0.42km^2.

Figures 4.5, 4.6 and 4.7 are extracted and clipped or overlayed built-up layers on the delineated floodplains showing the extent of encroachment of urban built-up area into Zaria floodplains in 1990, 1999 and 2014 respectively.

4.7NEW PATTERN OF URBAN GROWTH AND CLASSIFICATION

Urbanization could take place in either a radial direction around a well-established city or linearly along the highways over a given period of time. Urban growth or sprawl could take linear or strip, expansion or cluster and leapfrog or relocation patterns (Almeida, 2005).

4.7.1 New Pattern of Urban Growth (1990).

The pattern of urban growth in the floodplains of Zaria in 1990 is presented in fig. 4.5. From 1990 built-up encroachment map, there is evidence of disconnected spread (leapfrog pattern) of

built-up from urban clusters in all direction with more towards the floodplains of Galma River in its southwestern portion of Zaria Local Government Area. There is also growth in urban built-up ranging from expansion to linear in the northwestern portion of Galma River in SabonGari Local Government Area. Similarly, expansion and linear growth are visible in the south bank of Kubanni River around Gaskiya-TudunJukun and Tudun Wada-Gyellesu areas with few strip development towards the north bank portion of PZ area. The linear pattern of Zaria urban growth coincides with that reported by Abbas and Arigbede (2011).

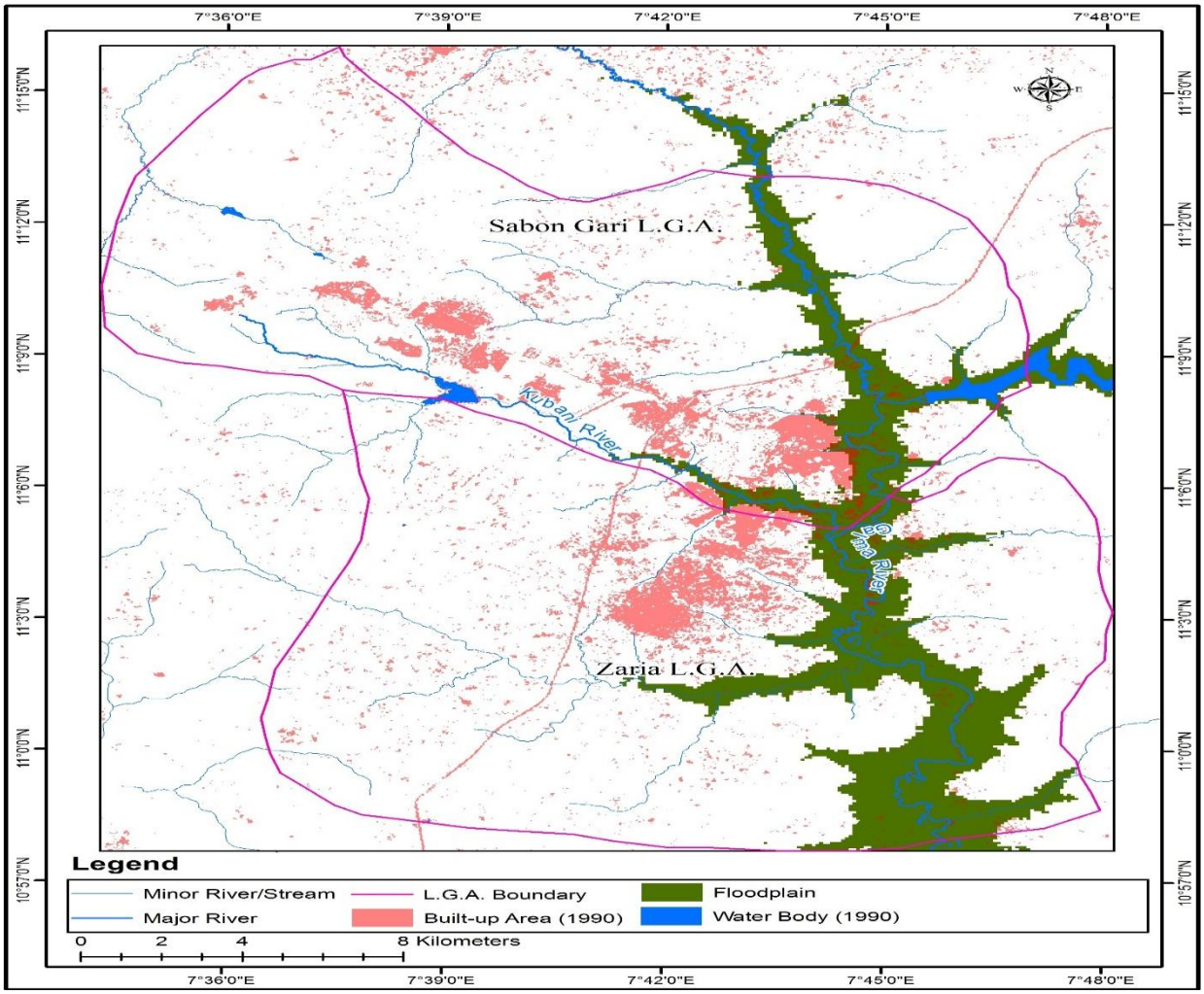


Figure 4.5: Encroachment of Built-up Area into Floodplain in 1990 (Area= 3.51km²). Source: Laboratory Analysis (2014).

4.7.2 New Pattern of Urban Growth (1999).

The pattern of urban growth in the floodplains of Zaria in 1999 is presented in fig. 4.6

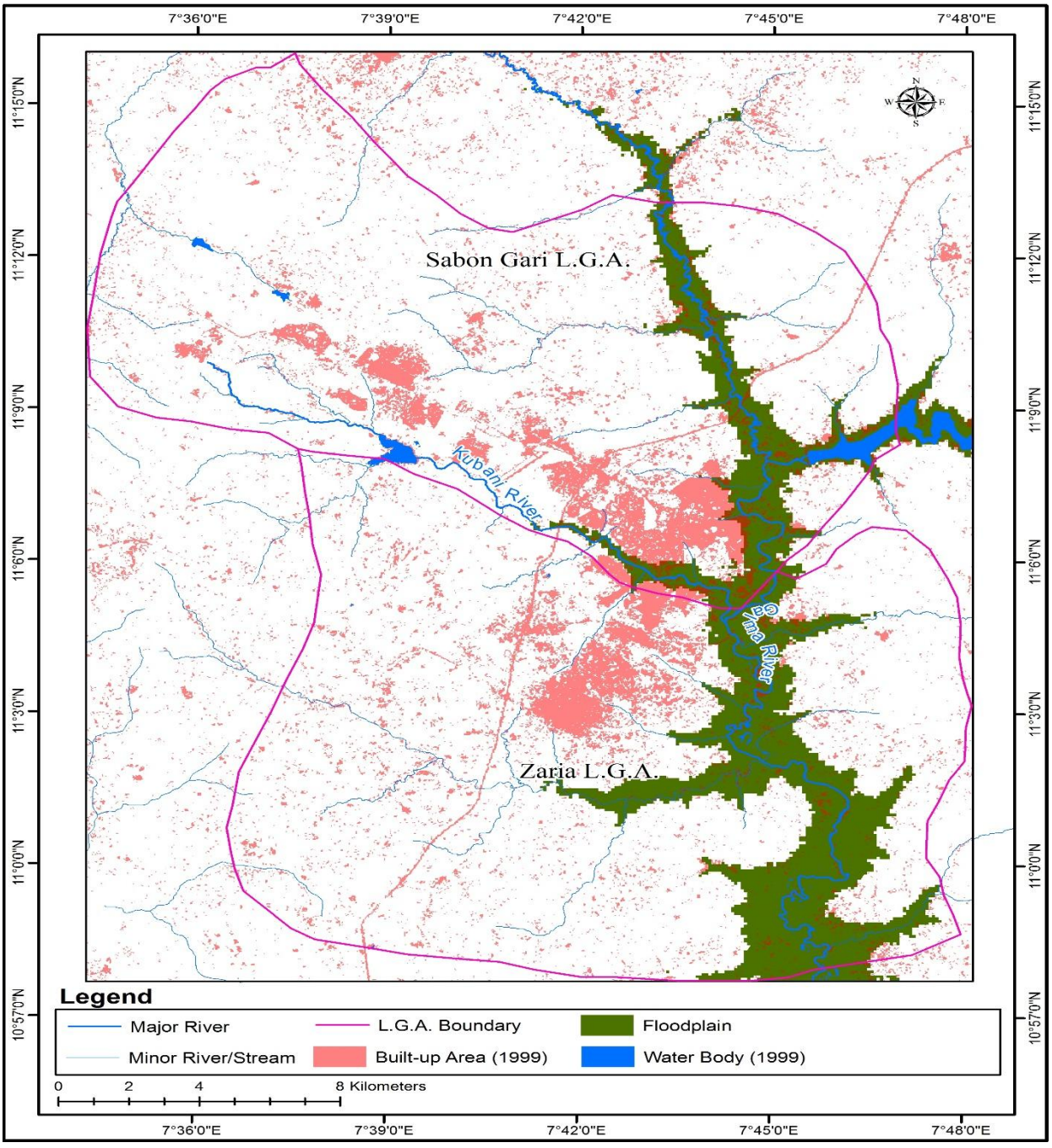


Figure 4.6: Encroachment of Built-up Area into Floodplain in 1999 (Area= 6.59km²). Source: Laboratory Analysis (2014).

By 1999 in figure 4.6, there is more expansion of urban built-up into the floodplain of Galma River on its western bank along Shika, AnguwanMallamai, Wuchichiri and Jushi-AnguwanGwado areas. There is leapfrog growth into the floodplains around Jushi-AnguwanGwado area. In the southwestern bank of Galma River in Zaria Local Government Area, the leapfrog growth pattern or spread of built-up seems gradually increasing density. Urban built-up showed evident expansion into the floodplains of Kubanni River on both sides of the river banks.

4.7.3 New Pattern of Urban Growth (2014).

The pattern of urban growth in the floodplains of Zaria in 2014 is presented in fig. 4.10.

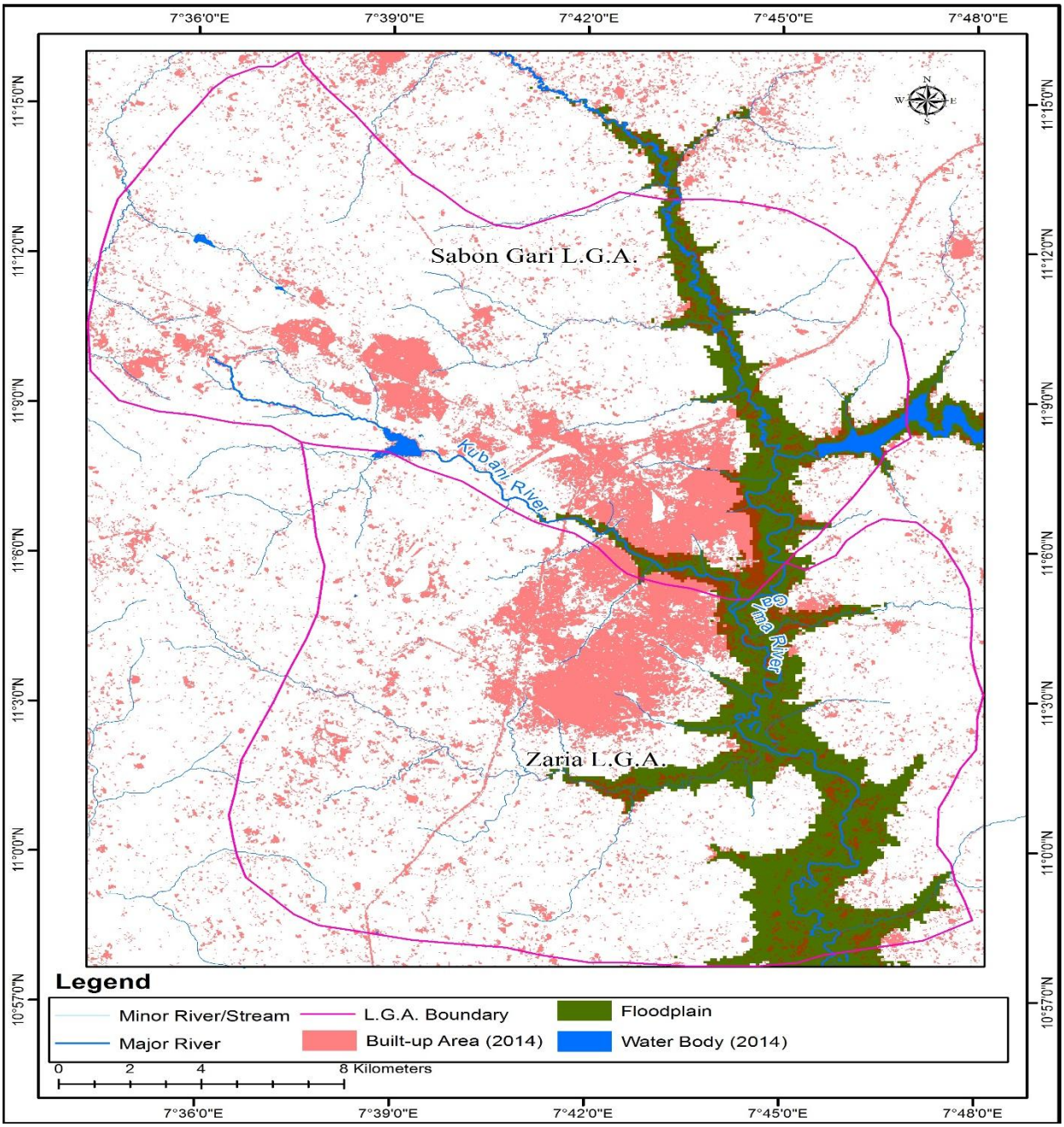


Figure 4.7: Encroachment of Built-up Area into Floodplain in 2014 (Area= 13.67km²). Source: Laboratory Analysis (2014).

In figure 4.7 of 2014, there is evident clustered expansion of urban built-up into the floodplains of Kubanni River on either sides from PZ on the north bank and Gaskiya-TudunJukun and Gyellesu-Tudun Wada areas on the south bank. Gyellesu built-up also witnessed expansion into the floodplains of Galma River on the west bank around Kubanni-Galma confluence. Southwards of Gyellesu, Nagoyi and Madarkachi settlements also expanded into the floodplains of Galma on its western bank. The floodplains on the western bank of Galma River from SabonGari to Zaria Local Government Areas is dotted with strip of urban built-up ranging from connected to disconnected developments.

4.8 PICTORIAL EVIDENCE OF URBAN ENCROACHMENT INTO FLOODPLAINS OF ZARIA

Pictorial evidence of urban built-up encroachments are shown in plates I and II



Plate I. Urban Encroachment around Kubanni – Galma River Confluence (2014). Source: Field Survey (22-8-2014).

From plate I, the expansion of urban settlement into the floodplains is evident around the confluence of the two major rivers (Galma and Kubanni) in Zaria directly behind Federal College of Education en route to Dakache.



Plate II. Urban Encroachment along River Kubanni – AnguwanMaje (2014).
Source: Field Survey (22-8-2014).

Plate II shows the encroachment of urban built-up beyond the floodplains and almost into the Kubanni river channel in AnguwanMaje of Tudun Wada Zaria. Similar developments are obtainable on the western bank of Galma River in SabonGari area which is visible in fig. 4.7

4.9 IMPLICATIONS OF URBAN GROWTH ON THE FLOODPLAINS

There is a school of thought which is of the view that there have been a lot of abuses heaped on the physical environment of man; and that the environment is only responding to the abuses heaped on it. The abuses include but not limited to poor planning of the physical environment, poor management of wastes, inadequate drains for the built up areas and others (Kersh and Simon 2005).

Altering or removing a floodplain in order to construct road or building, reduces the local floodplains' capacity to capture, store, and slowly release water runoff, exacerbating local flooding. In general, there is ample empirical evidence that urbanization increases not only runoff volume, but also peak discharges and associated flood magnitudes (Brody et al., 2007).

The people living along the floodplains of both the majorand minor rivers of Nigeria even though illegallyare constantly being ravaged by the menace of flooding and this keeps recurring without any end in sight posing a problem of undue stress to the agencies of Government saddled with Emergency Management responsibilities when these disasters occur (Okonkwo, 2013).

Floods experienced in Nigeria had caused more harm in Nigeria without any notice of benefit. From the report of National Emergency Management agency (NEMA) in 2012, between June and September 2012, over 363 lives were lost and about 1.2 million Nigerians were displaced. The report also declared that over one million Nigerians may die due to the effects of floods before 2015, if precautionary measures are not taken (Adetunji, and Oyeleye, 2013).

A total of N17.6 Billion was released by the Federal Government as a palliative measure in 2012 Flooding as was distributed as follows:States – N13.3 Billion,Federal Agencies – N4.3 Billion

National Emergency Management Agency (NEMA) Report on 2012 Flood Disaster in Nigeria. (Okonkwo, 2013 and NEMA, 2012).

Floodplains being among the most altered landscapes worldwide continue to disappear at an alarming rate much higher than for most other landscape types. The net result is vast constriction of floodplains, sometimes by more than 50% of the historic expanse. As a consequence, the decline of freshwater biodiversity, including the rich floodplain diversity, is much greater than in terrestrial systems (Vitousek*et al*. 1997; Olson &Dinerstein 1998; Ravenga*et al*. 2000 and Snyder *et al*. 2002). The finding on the encroachment of urban built-up into the floodplains of Zaria suggests decline in rich freshwater biodiversity and alteration of the urban riverine ecosystem.

Floodplains form a complex physical and biological system that not only supports a variety of natural resources but also provide natural flood and erosion control. In addition, the floodplain represents a natural filtering system, with water percolating back into the ground and replenishing groundwater. When a river is divorced from its floodplain with levees and other flood control facilities, then natural built-in benefits are lost, altered, or significantly reduced (www.friendsoftheriver, 2013). Development pressures lead to building on floodplains and the destruction of wetlands which are natural flood-absorbing sponges (Alfano, 2012). Although, urban Zaria has not experienced any historic flood scenario, but with the recorded pace of built-up encroachment on the floodplains, it can be envisaged as having the potential for risk of flooding.

Land use change apart from its implications for environmental sustainability also has important consequences for food security. Conversion of cultivated land to non-farm uses such as housing,

factories and infrastructure in combination with a growing population are for some countries, regarded as serious threat to future food security (Millennium Ecosystem Assessment (2005).

The word “Fadama” is a local Hausa word for low–lying floodplains usually with easily accessible shallow groundwater (FDP, 2003). The use of *Fadama* resource in urban Zaria ensures all year round farming of some staple food and vegetables especially where *Fadama* resources is more pronounced. The river floodplain contains the best agricultural soils vital for dryseason cropping and hence food production for Zaria and other towns and cities within the country, but the increased rate of urban built-up encroachment in the form of sprawl on the floodplains poses impending adverse consequences for food security to the urban dwellers.

It is important to state that the government at national level introduced the World Bank assisted Fadama Agricultural Development Project (FDP) nationwide as one of the strategies to boost food and agricultural production. The floodplains are the land base for the project, wherever they occur (Ojanuga and Ekwoanya, 1995). In order to ensure sustainable food production and empower small scale farmers, the Fadama Development Project I and II were aimed at utilization of floodplain resources at full capacity. It was observed that the net farm income of the project beneficiaries increases from N302, 796.95 before Fadama II to N709, 492.52 after Fadama II (Simonyan and Omolehin, 2012). Therefore, the increased urban sprawl on Zaria floodplains is undermining and would continue to undermine the objective of the FDP geared toward economically empowering small scale farmers if not adequately managed and curbed.

CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter consists of the review of the entire work with appropriate conclusions drawn from the research findings. Recommendations were also made and presented.

5.2 SUMMARY

Natural flood plains are among the most biologically productive and diverse ecosystems on earth and also among the most productive landscapes on earth, owing to continued enrichment by import and retention of nutrient-rich sediments from the headwaters and lateral sources. This makes them more productive than the Parent River and adjacent uplands.However, they are among the most threatened ecosystems. As population increases, so does the need for new housing, schools, and transportation networks. With urban population in Nigeria growing at a rapid rate of 3.6% annually (United Nations Population Division, 2008), rapid urbanization has resulted in development pressure of built-up on virtually all other urban land uses including the vulnerable floodplains.

The study employed remote sensing and GIS techniques in the development of accurate land use and land cover maps derived from satellite imageries – Landsats TM, ETM and ETM+. The data analysis was mainly laboratory and descriptive.

Land use and land cover change is evident from a comparative look at the classified satellite images of Zaria in figure 4.4. Results obtained from laboratory data analysis indicated rapid increase in built-up from 47.46km^2 in 1990 to 71.03km^2 in 1999 and increasingly to111.02km^2 in 2014 which is basically due to increased population growth and consequent conversion of other land uses into residential areas. Other land use classes in the study such as scattered cultivation

and vegetation showed decreasing trend over the years. Bare surface depicted increase in size over the years due to continuous deforestation. The fluctuation in water body recorded was due to seasonal nature of the climate which corresponded with the period the satellite imageries were captured.

Aside land use and land cover change determined over the study period, the rate at which these land uses changed annually was calculated using land use and land cover change formula. The results were presented on tables and given graphical representations. Urban built-up was found to have encroached into the floodplains by 10.16km^2 between 1990 and 2014. The consequences of the encroachment of built-up into the floodplains has implication including environmental degradation, flooding and its associated consequences, water pollution and threat to quality of aquatic and human life. The pattern of urban encroachment showed variation from one place to another as it included expansion from urban clusters, linear and leapfrog patterns into and along the floodplains.

5.3 CONCLUSION

The utilization of remote sensing and GIS techniques in analyzing the effects of floodplain encroachment has proven to be a potent modern tool for mapping and detecting changes in land use and land cover. For understanding the extent and dynamics of floodplain encroachment, digital image processing techniques has enabled speedy, accurate and objective interpretation of multispectral satellite data. This study was hence initiated with the central aim of making use of remote sensing and GIS techniques in mapping out areas that are vulnerable to encroachment and its associated consequences.

The findings in this study established that urban growth in the form of sprawl has impacted negatively on floodplains in Zaria, Nigeria by reducing their spatial extent. Urban Zaria has experienced rapid urban growth, which has extended into rivers Galma and Kubanni floodplain with increasing annual rates. The general trend observed is increase in urban built-up and a corresponding increase in bare surface. Scattered cultivation and vegetation depicted decreasing trends with water body showing fluctuating values. The floodplain encroachment is particularly highest in the major centers of high socio-economic investments like SabonGari, PZ and Tudun Wada. The ecological problems associated with the land use and land cover changes are linked with the socio-economic changes of the local population inducing population growth and the need for settlement expansion.Encroachment into the floodplains has seriously increased flood risk and damage potential, especially of urban floods due to heavy socio-economic infrastructural development on these floodplains. This study revealed that floodplain is a key feature of hydrological landscapes, which provides natural flood mitigation by maintaining a properly functioning water cycle (Lewis, 2001).

The consequences of floodplain encroachment by built-up are devastating which affect not only the floodplains and river systems but the environment and its inhabitants in general. This study established that 13.67km^2 of the total 78.23km^2 of Zaria floodplains has witnessed encroachment from urban built-up. The study has also identified multiple patterns of encroachment in different areas of the floodplains which are associated with urban sprawl due to uncoordinated urban development especially around river systems.

5.4 RECOMMENDATIONS

The analysis of the present state of riverine floodplains in this study conveys a dismal prognosis indeed, despite recognition of the important services provided by these ecosystems. Although, this situation could be attributed to little or no policies and public awareness that should enable the growing population to view floodplains as conservatories of regional biodiversity and as fundamental units of river ecosystems. However, we must act now to protect these valuable ecosystems, based on the incomplete yet considerable information available.

Perhaps the only hope for sustaining functional floodplains over the long term lies with highly enlightened management and restoration efforts in the following ways:

i. A more robust and predictive understanding of how changes in hydrological connectivity and habitat fragmentation affect floodplain communities is required to foster better and more proactive conservation practices. Floodplains need to be understood by the general public for the values they provide in the form of natural goods (harvestable fisheries, etc.) and services (natural cleansing of water, etc.). Restoration projects carefully planned and monitored, may serve as large-scale field experiments for a better understanding of the dynamics and complexity of riverine floodplains.

ii. Non-governmental organizations and multinational institutions such as United Nations Environment Programme (UNEP), United Nations Educational, Scientific and Cultural Organization (UNESCO), International Union for Conservation of Nature (IUCN), World Resource Institute, Friends of the River, Friends of the Earth, among many others, play a leading role in transferring basic research information to

the public and to decision makers and in securing protection for biodiversity hot spots such as floodplains. Hence, their role in conserving and restoring floodplains and wetlands must increase in the near future in relation to the fast-growing scientific knowledge about the strategic importance of floodplains to healthy rivers that parallels the accelerating deterioration of remaining systems (Tockner and Standford, 2002).

iii. A national database on the location and size of floodplains in particular and wetlands in general is urgently needed. Major biophysical features, including information on the expansion/contraction of floodplain areas and the timing of floods must be included in the database. There is also the need for a compilation of threats, land tenure, management and studies on the benefits and values of different wetland types such as floodplains are required. Greater conservation of floodplains through creation of floodplain natural areas should be initiated. Conservation easements and purchases (buyouts) to silence development rights (e.g. for gravel and mining and exurban development) to protect remaining intact floodplains are urgently needed (Tockner and Standford, 2002). These should be the task of various levels of government through agencies such as the Federal Environmental Protection Agency (FEPA), State Environmental Protection Agency (SEPA) and Local Governments for Sustainability officially known as International Council for Local Environmental Initiative (ICLEI). Research institutions and Universities should work in partnership with the governments developing river systems conservation framework and its achievement.

iv. Floodplains encroachment is not solely a function of urban growth, but also driven by planning decisions affecting the natural landscape. In terms of policy issues, the government of Nigeria has not provided regulations on urban development setbacks around river systems neither has Kaduna State government, except for NEMA's a hundred year flood ambiguous regulatory warnings of building along river channels against flooding which is not applicable to places that have not recorded or previously witnessed flood disaster. However, only Nasarawa State Government via its Ministry of Land, Survey and Town Planning (2012) published a public notice stating a 30m setback of buildings off river channels in the state. Therefore, there is the need for improved land Use Planning policies to spell out unambiguous setbacks from river corridors, the violation of which should include heavy penalties placed on any encroachment of floodplains designated for conservation or restoration and removal of illegal structures within conservation areas. The goal is to maximize human benefits by capitalizing on the natural functional attributes of river landscapes because natural uses of floodplains far outweigh the value of human activities that constrain floodplain structure and function. A new era of naturalization of floodplains is needed to protect the integrity of river systems. Hence, the clear and unavoidable conclusion is that governments must find the will and way to preserve existing intact rivers floodplains as strategic global resources with greater community involvement.

v. Finally, a long run study on the effectiveness of government policies in urban land use planning with respect to riverine ecosystem conservation especially floodplains would be complementing this work greatly.

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