ANALYSIS OF URBAN SPRAWL USING GEOSPATIAL TECHNIQUES IN GOMBE METROPOLIS, GOMBE STATE, NIGERIA

BY

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DECLARATION

I declare that the work in this dissertation titled **ANALYSIS OF URBAN SPRAWL USING GEOSPATIAL TECHNIQUES IN GOMBE METROPOLIS, GOMBE STATE, NIGERIA**was written by me in the Department of Geography under the supervision of Dr.I.J. MUSA and Dr. B. AKPU, The information gleaned from the literatures has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at any university.

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Signature Date

CERTIFICATION

This dissertation titled **ANALYSIS OF URBAN SPRAWL USING GEOSPATIAL TECHNIQUES IN GOMBE METROPOLIS, GOMBE STATE, NIGERIA**by WAKIRWA Adamu meets the regulation governing the award of the degree of Master of Science (M.Sc) in Remote Sensing and GIS, Ahmadu Bello University Zaria, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

I dedicated this work to God Almighty and my siblings Rahilla, late Musa, Dr. Yohanna, Arhyel, Diffi, Dauda, Emmanuel, Daniel, Mbwidiffu, and Grace.

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ABSTRACT

Cities and towns in developing countries all over the world are experiencing an unplanned and uncontrolled development known as Urban sprawl. Sprawl is often uncoordinated and extends along the fringes of metropolitan areas with incredible speed. This research is aimed at examining urban sprawl in Gombe metropolis between 1991 and 2014.The data used for the study were Landsat 5 Thematic Mapper (TM) of 1991, Landsat Enhanced Thematic Mapper plus (ETM+) data of 2005 and Enhanced Thematic Mapper plus (ETM+) of 2014.The extent of urban land use was determined by using the attribute and statistics data generated from the classification result and used for post-classification comparison among the years. The built-up was also extracted for each of the periods and the extent of the built up area was calculated in hectares.The extent of the urban sprawl was analyzed by subtracting the reference year of land cover of 2014 from the base year 1991. The resultsshow that urban land usewas high between 2005 to 2014 occupying about (51.43%) of the total land mass. The spatial extent of urban sprawl occupied about 12.78% between 1991 and 2014 andhigh annual rate of 12.78% were also witnessed in 2014.It was also found that there was a progressive increase of urban sprawl both in terms of extent and annual rate throughout the study period, especially between the period of 2005 and 2014. It is recommended that there is a need for a regular monitoringof urban sprawl and development in the study area by the state government especially with the aid of geospatial techniques for better decision making.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Developing countries are experiencing an unplanned and uncontrolled spread of population and development known as urban sprawl United Nation Population Fund (UNFPA, 1996). A phenomenon that involves the continuous growth of human population and a corresponding expansion of infrastructures that spread to absorb areas adjoining these towns/cities. Urban sprawl is the expansion of the urban area outside its borders into the suburbs.Urban sprawl affects the landscape, the ecology of an area, travel patterns, resource consumption and water discharge (Tewolde&Cabral, 2011). Urban sprawl is often uncoordinated and extends along the fringes of metropolitan areas with incredible speed. Commonly, sprawl invades upon prime agricultural and resource land in the process. Land is often developed in a fragmented and piecemeal fashion, with much of the intervening space left vacant or in uses with little functionality (Torrens &Alberti, 2002).

One of the prerequisites for understanding urban sprawl is successful land use change detection (Jain, 2009). Urban sprawl as a type of urban growth varies in terms of the pattern, density, and rate at which built-up land develops. This is however dependent on the way in which development occurs (Allen & Lu, 2003). Zhang (2001) stated that urban sprawl results from poorly planned, large scale new residential, commercial and industrial developments in areas previously not used for urban purposes. Sprawl often occurs faster than the development of the infrastructure (e.g. schools, roads, sewer systems, and water lines) needed for support (Pohanka, 2004). Allen & Lu (2003)

characterized sprawl as leapfrog land use patterns, strip commercial development along highways, and very low-density single-use developments.

Sprawl has been criticized for eliminating agricultural lands, spoiling water quality, and causing air pollution. 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& Walsh, 2004). As an output of population growth, it has created more air pollution, loss of precious farmlands often left unprotected from commercial or residential developers (Hathout, 2002). Monitoring urban sprawl is a vital part of assessing current trends with a view of improving urban quality of life in the future as sprawl affects man and his environment adversely (Alexakis, Hadjimitsis, Agapiou, Themistokleous&Retalis, 2012).

According to Siedentop (2005), there are two rivalling explanation patterns for causes of urban sprawl: firstly, sprawl is explained by the demand for urban land. Driving forces are land consumption of households, companies, and public uses. Factors such as income, wealth and car use provide the framework and location choices are made based on a comparison of utility effects and costs. Secondly sprawl is explained by specific regulation patterns. According to the author, the massive public subsidies for low density, suburban forms of living and the publicly financed construction of street networks and local infrastructure reinforce urban sprawl.

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). Over the past 50 years the processes of urbanization, suburbanization, counter-urbanization, and re-

urbanization have allowed for urban expansion into rural areas taking the form of low-density development, predominantly single family residential subdivisions and strip commercial development (Lee, Tian, Erickson &Kulikowski, 1998). According to the authors, the result of this development process is commonly called urban sprawl. In this form, urbanization spreads outward in a haphazard pattern, consuming more land than is necessary and creating excessive public costs for community facilities and services. Urban Sprawl has become the metaphor of choice for the shortcomings of the suburbs and the frustrations of central cities (Galster*et al*., 2001).

The most pressing problem is the substantial loss of fertile agricultural land in many coastal cities because of short-term economic considerations (Yeh& Xia, 1998). Ewing (1997) argues that suburbanization is not the issue, but rather the wasteful form of development known as sprawl with which many critics have a problem. Nechybaand Walsh (2004) listed a plethora (excess) of ills related to sprawl as the loss of open space, urban decay, unsightly strip mall developments, the loss of a sense of community, patchwork housing developments in the midst of agricultural land, increasing reliance on the automobile, the separation of residential and work locations, and the spreading of urbanized developments across the landscape.

The increasing urban sprawls in most cities in developing countries continue to attract attention of national and international agencies, but the efforts had not achieved much result at checking the sprawl (Donk, 2006). African cities in particular produce miseries that are often difficult to comprehend (Olurin, 2003).Most of the big African cities including those in Nigeria are faced with the problem of rapidly deteriorating physical and living environment. The deterioration manifests in the form of slums, urban sprawl and squatters' settlements, increasing traffic congestion,flooding and

erosion, deteriorating infrastructure and short falls in service delivery among others (Olurin, 2003).

Due to uncontrolled urbanization, one major feature of Nigerian cities is urban sprawl. Urban sprawl is characterized by haphazard housing development in the urban suburbs, where majority of the structures are without planning permit in uncoordinated layouts. Often times, these structures are products of squatters that choose to settle at the suburbs as a result of their inability to afford residential accommodation in the city. Unfortunately, there is no Nigerian city that can be exonerated from the stigmatization of urban sprawl (Ago, 2001).

Sprawl in Nigeria consists of informal housing developments on the urban periphery, on land that is mostly privately owned, sold in single small plots. These newly developed areas have been called peri urban areas (Imhoff, 2000) and the inter-metropolitan periphery (Berry, 1990). The ex-urban areas beyond the suburbs are sometimes called fringe developments (Daniel, 1999) and extended places (Bureau of the Census, 2000).

The urban sector of any country is never static. It changes per time. In fact, as days and years go by the urban landscape is altered. Developments as well as growth in infrastructural amenities affect the land use/land cover (Ago, 2001). In a developing country such as Nigeria, development in urban areas and miscellaneous land use types are isolated in the fringe areas followed by gradual filling of intervening spaces with similar uses. This is mainly due to rapid growth in population size which is usually uncontrolled (Alabi, 2009).

All cities in Nigeria are experiencing sprawl;Gombe is not an exception because of the scale and type of development on some of the city's most agriculturally productive land. In the past decade, the city's built up area burst outward in an explosion of sprawl that consumed former agricultural land at a break-neck pace (Lazarus, 2012). Hence there is a need to examine the nature and the pattern of sprawl in the area, for proper decision making and thereby, to enhance sustainable development.

GIS and Remote sensing can provide useful information for the monitoring of the urban land. GIS gives the opportunity to observe land use changes, visualize them, monitor them, and even forecast them. Remote sensing gives the ability to exquisite data via the space or air borne sensors, resulting in multispectral, multi-resolution, and multi-temporal data, which is used for the creation of land use maps (Herold, Scepan& Clarke., 2002).

1.2 STATEMENT OF THE RESEARCH PROBLEM

Urban sprawl is one of the foremost threat facing agricultural lands in Nigeria (Nwafor, 2006). Sprawl has been criticized for eliminating agricultural lands, spoiling water quality, and causing air pollution. Other frequently mentioned consequences are: green space consumption, high costs of infrastructure and energy, an increasing social segregation and land use functional division.Furthermore, the need to travel, dependence on private car and consequently increased traffic congestion, energy consumption and polluting emissions are associated with sprawl (Allen & Lu, 2003).

Siedentrop (2005) identified the impacts of sprawl as ecological impacts, building and sealing of land, as well as indirectly loss of natural potential of soils and the expulsion of endangered animal and plants. Social and health impacts, Sprawl leads to an erosion

of functioning urban cores. This has not only social and infrastructural consequences, but also impacts on innovation capacity of regional economies (Cervero, 2000). There is a significant connection between broadening of settlements and concentration of poverty in city cores. The degree of social interaction in sprawled areas has decreased (Putnam, 1994).

Michael (2009) examined urban sprawl, pattern and measurement in Lokoja, Nigeria. The study shows that Lokoja is experiencing growth along the major highways traversing the city. New development areas are concentrated along the workers village, tapering along the Kabba-Okene road. Another area of recent expansion is towards the Ganaja – Ajaokuta road where several government estates had sprung up and some privately owned estates.

Atu, Offiong, Eni, Eja and Esien (2012) analysed the effects of urban sprawl on peripheral agricultural lands in Calabar Nigeria. Their findings indicate that urban sprawl has impacted negatively on agricultural lands in Calabar, by reducing their spatial extent and density and fragmenting them into smaller sizes of less than 100 square metres. Hence, the challenge in the sustainability of agricultural activities lies in the conservation and management of existing fragments in the face of very rapid urbanization. This feat can be achieved via the integration of agricultural landscapes into urban land use planning systems and agricultural lands must also be taken into consideration as crucial part of urban development.

Dabara, Gumnie, Nwosu and Abdulazeez (2012) analysed urbanization dynamics and incidences of urban flood disaster in Gombe metropolis, Nigeria. Their study shows that due to urban sprawl that has encouraged residential development,it resulted to

displacement of vegetation cover and hardness nature of the surfaces, thereby reducing the chance by which rainwater could infiltrate into the soil. Furthermore, Individuals build rampantly without control even on drainage channels, while others indiscriminately dump refuse on drainage channels, all these aggravate flood problem in Gombe metropolis.

Ade and Afolabi (2013) analysed urban sprawl in Abuja, using Remote Sensing and GIS techniques from 1987 to 2007. Their result show that built up area increased from 49.9km^2 in 1987 to 93.77 km^2 in 1999 and further increased to 179.48 km^2 in 2007. This growth extends not just inwards but outwards implying that satellite towns surrounding the city are being affected posing a threat to the limited available resources in the city resulting to high cost of living.

Aguda and Adegboyega (2013), evaluated spatio-temporal dynamics of urban sprawl in Osogbo, Nigeria. The study shows that the spatial extent of the total urban built-up areas of Osogbo city in 1962 was estimated at 3.95 km^2. The total urban built-up areas increased to 6.61 km^2 in 1972. This indicates that urban expansion has engulfed 2.66 km^2 of rural areas between 1962 and 1972. Thus, the rate of urban expansion within the period was estimated at 4.0 % with land consumption rate and land absorption coefficient estimated at 0.0036 and 0.0076 respectively. This rapid rate of urban expansion has been found to have encroached on agricultural lands thereby accounting for a total loss of 57.01 % in agricultural land.

Based on the literature review, a lot of research had been carried out globally and nationally on urban sprawl but none has been carried out in Gombe metropolis and there is a need for such research to be conducted because, the metropolis

experiencedchange in land use right from its inception as a State from 1996, as a results of development which resulted to the loss of vegetation, cultivated lands and forest reserve, loss of biodiversity and various erosional activities. So, there is need to conduct such a research in order to analyze the rate and pattern of the urban sprawl resulting from the development. To the best of the researcher's knowledge, no study has been carried out on the analysis of urban sprawl using Remote Sensing and GIS in the study area. Hence the need for this study. This is the knowledge gap this research intended to fill.

Therefore, in line with the problem already outlined, some fundamental research questions to which answers were sought are:

i. What is the extent of urban land use in 1991, 2005 and 2014?

ii. What is the extent of urban sprawl in Gombe metropolis between 1991, 2005 and 2014?

iii. What is the rate and pattern of urban sprawl in Gombe metropolis between 1991, 2005 and 2014?

1.3 AIM AND OBJECTIVES

The aim of this research is to analyze urban sprawl in Gombe metropolis, between 1991 and 2014 using Geographic Information System and Remote Sensing techniques. The specific objectives are to:

i. determine the extent of urban land use in 1991, 2005 and 2014;

ii. assess the extent of urban sprawl between 1991, 2005 and 2014; and

iii. estimate the rate and pattern of urban sprawl in the study area.

1.4 SCOPE ANDLIMITATION OF THE STUDY

The focus of this study is to analyze urban sprawl in Gombe metropolis. The metropolis comprises Gombe Local Government area and some fractional parts of Kwami and Akko LGAs. The study will cover the period between 1991 and 2014. The study intends to determine the extent, rate and pattern of urban sprawl in the area.

1.5 SIGNIFICANCE OF THE STUDY

For local governments it is interesting to have exact information about the extent of the urban area, how is the land currently used and the urban growth (the direction) (Jat*et al*., 2008). This kind of information is needed for the urban planning of fast changing regions, to make sustainable and smart decisions (Herold*et al*., 2002).

Since land use changes have indirect consequences on national economic growth, it is important to evaluate land use changes in the regional and the local context in order to assist in anticipating the impacts associated with change and contribute to an understanding of productive environmental sustainability (Laymon, 2003). This study will come out with the rate at which the city is growing.

Urban growth is widely regarded as an important driver of environmental and social problems. It causes the loss of informal open space and the fragmentation of wildlife habitats. Timely and accurate assessments of future urban growth scenarios and associated environmental impacts are crucial for urban planning, policy decision, and natural resource management. Gombe and its environs have been experiencing explosive growth recently due to the continuous urban development and as a result of rural-urban migration. This study will provide planners and decision makers in the

study area with the necessary information required for proper planning, development and management of the area for sustainable growth and development.

CHAPTER TWO

THEORETICAL FRAME WORK ANDLITERATURE REVIEW

2.1 INTRODUCTION

This chapter comprises the conceptual frame workand review of related literature to this research, among which include; urban sprawl, causes, characteristics of sprawl and their nature.

2.2 THEORETICAL FRAME WORK

2.2.1 The Term Urban Sprawl

The term sprawl was first used in 1937 by Earle Draper of the Tennessee Valley Authority in the context of a national conference of planners (Wassmer, 2002).According to Wassmer (2002) the term urban sprawl was first used in the opening paragraph of an article by the sociologist William Whyte; in Fortune magazine, in 1958. Planners have since then used the term to categorize an urban development, generating undesired social effects. Urban Economists also adopted the term and added to the debate terms like scatter, leapfrogging and ribbon development. In the 1990s, the phenomenon ofsprawl was adopted by other sciences as well as the general public in the US. At this time,the Anti-sprawl-movement arose and first measures of urban sprawl were conducted.

Urban sprawl is characterized by structure and form attributes of a settlement system.Sprawl is understood as an urban form building process that transforms a former monocentric compact structure into a discontinuous, polycentric and disperse settlement structure (Galster*et al*., 2000; Torrens &Alberti 2000).

Generally within these types of definitions, sprawl appears to be a multidimensional phenomenon. Galster (2001), understands sprawl as a condition of land use and states that general approaches to sprawl can be by aesthetics, efficiency, equity, and environmental aspects.

The European Environmental Agency (EEA 2000) defines sprawl as the physical pattern of low density expansion of large urban areas under market conditions into the surrounding ones.Urban Sprawl is an uncontrolled disproportionate expansion of urban area into the surrounding country side forming land density, poorly planned patterns of development. Therefore urban sprawl can be said to be continuous disperse development to low density residential units and isolated tracts, separated from other areas by vacant led, forming ribbon or leap frog pattern along highways or other driving agents, or forming spatial patch within undeveloped land (Torren, 2000; Lata*et al.,* 2001).

The magnitude and consequence of urban sprawl differs among countries, which depends on level of development and availability and productivity of land resources (Alabi, 2009). Urban sprawl is affecting the structural growth and economic system of an urban area as it increases the travelling distance and also requires more basic amenities than its equivalent agglomerate form. Moreover, it also increases the risk to life and property in the face of disaster (WUF, 2010; Abimbola, 2008; Verzosa& Gonzalez, 2010). Therefore, the term urban sprawl can be described as an unwanted and uneconomic settlement form. The concept urban sprawl means increase in spatial or peripheral area of a town or city. Therefore urban sprawl can lead to the following drawbacks;

i. Affect the infrastructural planning;

ii. Affect traffic by increasing travelling distance within the cities;

iii. Affect the distribution of services and making Administration of city extremely difficult.

2.2.1.1Causes of urban sprawl

According to Siedentop (2005) there are two rivaling explanation patterns for causes of urban sprawl: firstly, sprawl is explained by the demand for urban land. Driving forces are land consumption of households, companies, and public uses. Factors such as income, wealth and car use provide the framework and location choices which are made based on acomparison of utility effects and costs. Secondly sprawl is explained by specific regulationpatterns. The massive public subsidies for low density, suburban forms of living and the publicly financed construction of street networks and local infrastructure reinforce urban sprawl. According to this view, urban planning is the main cause of sprawl (Siedentop, 2005).

How much of this process is natural and unavoidable as long as we welcome rising incomes and declining transportation costs. In our view, given the state of discussion itwould be severely misleading to attribute all these changes to urban sprawl. On the other hand, there are substantial structural differences between urban areas so that depending on certain factors. These processes may work quite differently. This suggests a concept like the one suggested by Mills (1999), who describes sprawl as excessive suburbanization (Siedentop, 2005).

2.2.1.2Characteristics of urban sprawl

Burchell*et al.*, (1998) characterise sprawl in two ways, on the one hand, residential low densityscattered development and on the other hand, non-residential scattered

commercial and industrial development. Scattered development is a form that is commonly associated with urban sprawl. He further describes points that characterise urban sprawl; these following characteristics are based on a review of research findings of (Burchell*et al.*, 1998)

- Low residential density
- Unlimited outward extension of new development
- Spatial segregation of different types of land uses through zoning regulations
- Leapfrog (discontinuous) development
- No centralized ownership of land or planning of development
- All transportation dominated by privately owned motor vehicles
- Fragmentation of governance authority over land uses between many local governments
- Great variances in the fiscal capacity of local governments because the revenue rising capabilities of each are strongly tied to the property values and economic activities occurring within their own borders
- Widespread commercial strip development along major roadways
- Major reliance upon the filtering or trickle down process to provide housing forlow income households.

This categorization brings a lot of points into the discussion, the problem is that withinthis list, the limits between causes, characteristics and consequences of sprawl areambiguous and a clear distinction between these categories is not entirely possible. The tenpoints stated can be subdivided in spatial patterns, main causes and main consequences of sprawl.

One of the most elaborated characterizations of urban sprawl is given by Galster*et al.*, (2001). Galster contends that sprawl is characterized by eight dimensions.

- Density: is a widely used indicator of sprawl whereby different types of density can be described.
- Continuity: is the degree to which the unused land has been built densely in anunbroken fashion. Sprawl can be continuous or discontinuous in other places.
- Concentration: describes the degree to which development is located disproportionately rather than spread evenly.
- Clustering: sprawl is frequently clustered. That means that, it only occupies a small portion of the respective land area.
- Centrality: the loss of centrality is one of the most serious concerns about sprawl.
- Nuclearity: describes the extent to which an urban area is characterized by a mononuclear pattern of development.
- Mixed uses: sprawl is seen as a process that separates the different kinds of landuses (separation of homes, workplaces, conveniences, income segregation along residential communities).
- Proximity: proximity is the degree to which land uses are close to each other (housing, work, shopping, etc.). The lack of proximity contributes to many of theexternalities attributed to urban sprawl (Galster*et al.*,2001)

2.2.1.3Consequences of urban sprawl

According to OECD (2000), urban sprawl has a range of negative consequences.Frequently mentioned consequences are: green space consumption, high costs of infrastructure and energy, an increasing social segregation and land use functional division. Furthermore, the need to travel, dependence on the private car and as a consequence increased traffic congestion, energy consumption and polluting emissions are associated with sprawl.

According to Wassmer (2005) a lot of negative urban consequences can be attributed to sprawl, but sprawl also has positive effects. When it comes to negative effects he mentions: the car and its polluting effects, a lack of functional open space, air and water pollution, a loss of farmland, tax money spent on duplicative infrastructure, concentrated poverty, racial and economic segregation, a lack of employment accessibility etc. Talking about positive effects of sprawl; there have to be considered increased satisfaction of housing preferences, the convenience of car travel, the filling in of leapfrogging land, lower crime rates and better public schools in suburban local governments.

Glaeser*et al*., (2003) analyse the impacts of sprawl in form of traffic congestion, environmental consequences, infrastructure costs and social consequences. They conclude that cars are producing externalities in form of congestion and pollution. However because of the decentralization of jobs, the pollution problem is reduced. As people move to edge cites, commuting are getting shorter. Sprawl uses up formerly undeveloped land.

Siedentop (2005) identifies the following impacts of sprawl:

- Ecological impacts: Building and sealing of land, as well as indirectly loss of natural potential of soils and the expulsion of endangered animal and plants. According to him, the problem is not that agricultural space is used, but the fact that connected agricultural land is destroyed.
- Traffic impacts: It is argued that there is a negative correlation between built density and traffic costs. Inhabitants of densely built cites have to bear lower traffic costs. Efficiency of public transport is higher than in urban areas with lower density.

However, critics say that density has little influence on traffic behaviour. Since households and firms suburbanize, radial commuting to the city centre is more and more replaced by cross-commuting within the urban area. With jobs nearby, transportation costs may actually be lower, even in a more decentralized structure. The time cost of commuting would have increased even more without suburbanization.

- Social and health impacts: Sprawl leads to an erosion of functioning urban cores. This has not only social and infrastructural consequences, but also impacts on innovation capacity of regional economies in formless space, creative milieus may develop worse (Cervero*et al.,* 1997). There is a significant connection between broadening of settlements and concentration of poverty in city cores. The degree of social interaction in sprawled areas has decreased (Putnam 1994).

2.2.1.4Use of GIS and Remote Sensing Techniques in Urban Sprawl

One of the most important paradigms in Geography and related disciplines that manage or use spatial data, associated with methodological changes is the advancement in satellite Remote Sensing and Computer aided Geographical Information System and the availability of satellite imageries. Remote sensing technology has been the subject of research in a variety of contexts and situations and has been successfully introduced as sole, complementary or corroborative source of data for many applications (Batty, 2000)

Remote Sensing technology has great potential for acquisition of detailed and accurate land use information for management and planning of urban regions. However, the determination of land use data with high geometric and thematic accuracy is generally limited by the availability of adequate Remote Sensing data in terms of spatial and

temporal resolution and digital image analysis techniques (Herold, 2002). The technique of Remote Sensing provides a powerful tool for studying urban issues, like land use/cover changes, urban growth modelling, urban sprawl etc. Remote Sensing image classification is one of the important application aspects for Remote Sensing technique, through computer processing with specific software, like ERDAS, the results of the classification of landuse can be auto-patted (Li, 2009).

For decades the visual interpretation of aerial photography of urban area has been based on the hierarchical relationships of basic image elements. The spatial arrangement and configuration of the basic elements (tone and colour) combine to give higher order interpretation features of quarters complexity such as size, shape and texture or pattern and association, that are significant and characteristics for urban areas and urban land use (Bowden, 1975). Much of the expert knowledge of the human image interpretations was lost in the transition from air photo interpretation to digital analysis of satellite imagery. The great strength of Remote Sensing is that it can provide spatially consistent data sets that cover large areas with both high detail and high temporal frequency, including historical time series. Mapping of urban areas has been accomplished at different spatial scales e.g. with different spatial resolutions, varying coverage or extent of mapping area and varying definitions of thematic mapping objects (Herold, Conclelis& Clarke, 2005). Global and regional scale studies are often focused on mapping just the extent of urban areas (Schneiders, Mclver, Friedl& Woodcock, 2001). One of the basic difficulties of mapping urban area from remotely sensed data is that of indistinct demarcation between urban and rural areas on the edge of the city. Remote Sensing provides an additional information that more closely respects the actual physical extent of a city extent still remains problematic and

individual studies must determine this own rules for differentiating urban from rural land (Clarke&Gaydos, 1998).

2.3 LETRATURE REVIEW

2.3.1 Measurement of Urban Sprawl

In modelling the complex nature of urbanization, it is often necessary to apply more than one technique to understand how to measure an increase in urban growth or urban sprawl.

In South Carolina, Allen & Lu (2003) used an integrated approach to model urban sprawl in which aspects of three different techniques were employed to model urbanization. The first enlisted a logistic regression model to predict urban transition probabilities. Next, a relative probability model was used to test different growth scenarios. Later, they organized focus groups to help set growth scenarios. The results indicate that South Carolina did experience an increase in urban land from 1992 to 2001 and that urban growth in the study area can be classified as urban sprawl with the use of GIS mapping, neighbourhood statistics, and analysis of jurisdictional planning documentation coupled with interviews with developers, land owners, and local planners.

Claire, Jantz, Scott and Goetz., (2005) in their study‘analysis of scale dependencies in an urban land-use-change model’ found that plotting parameter values against the full range of fit scores was useful for revealing parameter behaviour and sensitivity, resulting in 16 sets of plots that compared parameter behaviour across four cell sizes for four different fit statistics. Each parameter was considered separately and, due to the coarse calibration procedure, parameters could only take on the values 1, 25, 50, 75 and

100. The mean fit score was calculated for each parameter value, and the maximum and minimum fit values indicate the total range of fit scores.

Dennis Weijers, (2012). Analysesuitability of GIS methods for analyzing urban sprawl in Green Heart and he found the size of the urban class grew by 9,7% with a cell size of 5 meters, 9,8% with a cell size of 50 meters, and 23,9% with a cell size of 500 meters for the period 1989 – 2008. Remarkable is that, there is no difference between the growth of the urban class for the 5 meter resolution and the original vector dataset, meaning the conversion from the vector file to a 5 meter resolution raster file had no significant influence.

Atiqur, Maik, Alka, and Javed., (2009). Assess urban environmental issues using remote sensing and GIS techniques in India and their study indicated major urban environmental problems occur due to high population growth (the 46.31% increase during 1991-2001) and the uncontrolled and mismanaged urban expansion which has led to the doubling of the densely built-up area during last decade in Delhi. There is a reduction of 16.8% in agricultural land because of urban expansion in the fringe areas. Pollution loads affecting the air, water and land in Delhi have also increased considerably,and average night-time temperatures (heat pollution) have increased significantly. Management of huge volumes of garbage and solid waste, including medical waste, is very difficult, and has led to increasing environmental health burdens. Increasing surface temperatures and noise pollution also lead to health impacts.

Sprawl Cityin 2005,A study done on Sprawl City, shows that there is a correlation between the amount of population growth and the consumption of land in what the

United States Bureau of the Census calls urbanized areas. Urbanized areas are comprised of the contiguous developed land of the central city and its suburbs.

Gar-On Yeh and Xia (2001) measured the urban form of an area to examine a change in shape, size, and configuration of the built-up environment. They used Shannon's entropy, which measures the degree of spatial concentration or dispersion of a geographic variable, coupled with a GIS and remote sensing technology to calculate sprawl and their result shows that deferent shapes were seen. This type of research keys in on aspects of sprawl such as density, connectivity, and location of new urbanization.

Zhang (2001) examined local and regional factors related to urban sprawl such as federal policy on mortgage interest taxation and public spending, community location, transportation accessibility, and community features of a neighbourhood. A great deal of Zhang's (2001) data came from local zoning ordinances and interviews with local government planners, which provided information on land use regulations. Zhang (2001) also examined transportation conditions and educational quality indicators to further gauge the attraction of a community to new development.

Cohen,(2004).Assess urbanisation on African countries, Africa witnessed fastest rate of urbanization which was put at about 67% compared with the other developed and developing countries. According to the World Bank Regional Report (2005), the rate of urbanization in Africa is the highest in the world. Also, the report estimated that more than half of the African population will be urban. This posed a sustainable urban development challenge, because African countries are characterized by ineffective and unsustainable urban planning and this has been compounded by the complexity of the development arena, which present myriad of systems. These systems exhibit a number

of problems including rapid urbanization, poverty and inadequate shelter, poorly maintained physical infrastructure, environmental degradation and poor land management and allocation method (United Nations Centre for Human Settlement, UNCH 2002).

According to the UN (2010) report on state of African cities report observes that urbanization has been associated with improved human development, bring incomes and better living standards. But rapid urbanization can said to be a curse as well as blessing, unless strong and immediate and decisive policy action is taken, the phenomena could be burden from opportunity to a region.

Balzerek, (2003).Analysed achievements and problems in the Evolution of urban centres in Nigeria and his result shows in 1950, less than 15% of the total population of Nigeria was dwelling in urban centres, between 1975 and 2000, it had risen to 23.4% and 43.5% respectively, and was projected to rise above 50% by 2010. By focusing on the achievements of the urbanization, it becomes obvious that the evolved processes generate a rather broad spectrum, starting from dynamic town expansion based on high construction activities and its structural as well as functional development leading towards a spatial divergence of centrality, continuing with strong economic display and increased social living standard

Adesina (2005).Monitor Urban Sprawl in the federal Capital Territory and he discovered rapid urbanization and urban sprawl is affecting about 400,000 hectares of vegetation in Nigeria annually. Moreover, Jat (2008), observed that the process of urbanization in Nigeria has an adverse effect on ecology especially hydro-

geomorphology and vegetation. The process of urbanization ofNigerian cities is attributed to three principal factors: they are economical, social and political. Policies of government have affected the urbanization of many Nigerian cities/towns through increased decentralization of governance in forms of state and local government councils creation, which encourages population movement from older states and local government to newly created ones (Daura, 2006).

2.3.2 Applications of Geospatial Technique in Urban Sprawl studies

Urban sprawl is initially detected by gauging urban growth in many ways. Masek, (2000) measures urban growth by using remote sensing and GIS to measure rates of urbanization. Other studies have measured sprawl in terms of data layers within a GIS to detect patterns of urban sprawl (Clarke &Gaydos 1998). Wilson, Hurd, Civco, Prisloe and Arnold (2003) not only measure change of an individual pixel, but also changes within a framework of a neighbourhood of pixels. This technique is known as neighbourhood statistics and is extremely useful in visualizing densities of new growth areas.

Allen and Lu,(2003).Modelling and prediction of future Urban Growth in the Charleston Region of South Carolina, they calibrated their model of urban growth with data from 1973, 1975, 1981, 1985, 1989, and 1994 in order to predict growth scenarios up to the year 2030. The researchers used a logistic regression technique to generate probabilities that parcels of land would be converted to urban land use based on land suitability,by using remote sensing and GIS to examine different urbanization scenarios for different years.

The complexity of urban systems makes it difficult to adequately address their changes using a model based on a single approach (Allen & Lu 2003). Therefore, it is ideal to use a tool such as a GIS as part of research on urban sprawl because of its capacity to handle many different types of spatial data. In South Carolina, a GIS-based integrated approach to modelling and prediction of urban growth in terms of land use change was employed to meet the challenge of studying urban sprawl (Allen & Lu 2003). The researchers used satellite imagery incorporated into a GIS to map predictions of urban growth in the study area. The predictions were based on variables such as road density, forest, slope of the land, and population density. Each variable was entered into the system as a data layer and multiplied by a coefficient to determine how likely it was that a given parcel of land would be converted to urban land use (Allen & Lu 2003).

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). Hathout (2002) used the data base analysis capabilities found in a GIS to analysed aerial photographs of the study area from 1960 and 1989 to determine impacts on agricultural land. For that study, land use derived from the aerial photographs in the GIS was placed in one of three main categories urban, agricultural, and other (Hathout 2002).

A study conducted on the Washington-Baltimore CMSA used a cellular automata model combined with historical maps in a GIS to determine where future development may occur (Clarke &Gaydos 1998). The cellular automata model assumes an action within a given space, viewed in this case through a GIS grid, a set of initial conditions,

and a set of behaviour rules (Clarke &Gaydos 1998). GIS grid data layers were incorporated into IDRISI, GIS software, and iterations were performed to show different growth scenarios given different behavioural rules (Clarke &Gaydos 1998). The same study was also able to use the GIS to produce maps of different growth scenarios, which allowed visualization of the results. A GIS will not only allow for powerful visualization of urban sprawl within the study area by providing maps, but it will also allow for an in-depth analysis of the data by providing the capability to examine all of the data in one system therefore facilitating the measurement of urban sprawl.

The complexity of urban development is so dramatic that it demands immediate attention and perspective physical planning of the cities and towns (Sokhi& Rashid 1999). The dynamic nature of urban environment, calls for a need of integrating an intensive spatial analysis technique of remote sensing and GIS into urban planning and management, as traditional approaches and technique in operation presently in most of the Nigerian town/cities proved to be inadequate tools when dealing with metropolis.

Ndabula*et al.,* (2014) characterized urban sprawl in Kaduna Metropolis Using GIS-based cartographic modelling, the changes in urban growth was determined and used for quantitative analysis of sprawling indices based on land conversion, which include; Built-up land use Change Intensity Index (Ti), Dynamic Index (K), and Rate of Growth (L). The spatial attributes of fragmented form sub centres of the Kaduna Metropolis were determined and used to compute Fragmentation Index (F1). Similarly, both Rate of built-up growth (L) and Population growth (PL) were used to quantitatively express

sprawling based on land use intensity parameters such as population density and urban form which include Net Population Density Index (D1), Marginal Density Index.

CHAPTER THREE

STUDY AREA AND METHODOLOGY

3.1 INTRODUCTION

This chapter comprises the method adopted, the analysis, study area, geology and relief, soil and vegetation, demography etc.

3.2 THE STUDY AREA

3.2.1 Location and Extent

Gombe metropolis is located between Latitudes 10° 14′ 20” and 10° 19′ 20” North of the equator and Longitudes 11° 7′ 10” and 11° 12′ 10” East of the Greenwich meridian. It is located in the middle of Gombe state and is bounded by Kwami LGA to the North, Akko LGA to the South & West andYamaltu-Deba to the East. The study area has a total land area of 52km^2.

A large part of the existing town is at the foot of the Akko escarpment and on a shallow dish-like site (Obaje, 1999).Figure 1 shows the study area.

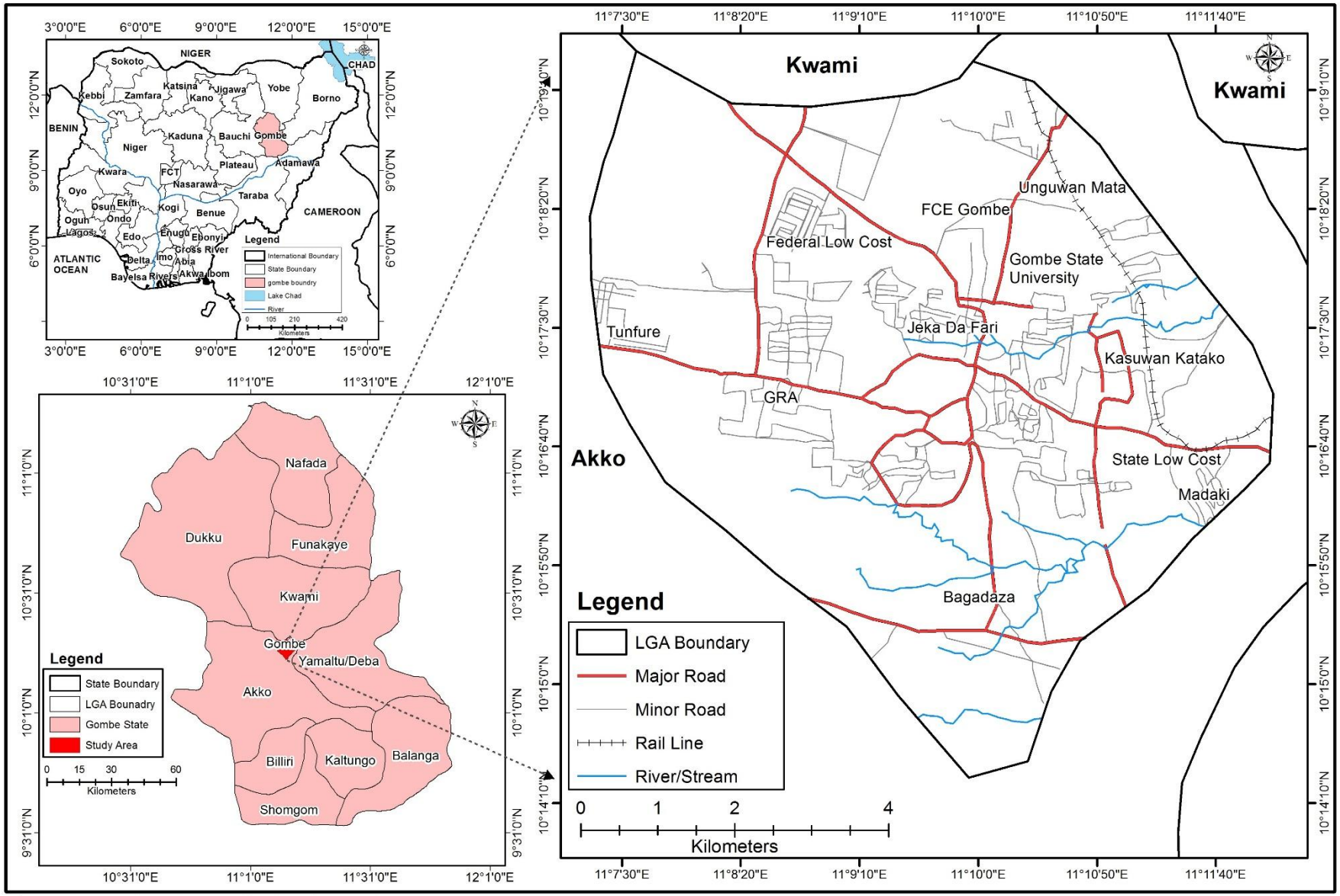

Figure 1: Gombe Metropolis (Study Area)
Source: Adapted and modified from the administrative map of Gombe State

3.2.2Climate

Gombe has two distinct seasons, the dry season (November-March) and the rainy season (April-October) with an average rainfall of 907 mm.Central and Southern parts Groundwater occurs between 0180m depth on the sandstones. The climate is tropical in Gombe. In winter, there is much less rainfall in Gombe than in summer. The Köppen-Geiger climate classification is Aw. The average annual temperature is 25.4 °C in Gombe. The rainfall here averages 907 mm.The driest month is January. There is 0 mm of precipitation in January. With an average of 254 mm, the most precipitation falls in August. The precipitation varies 254 mm between the driest month and the wettest month. During the year, the average temperatures vary by 6.9 °C (climate-data.org/region/405/, 2015).

3.2.3 Soils and Vegetation

The neoloav of Gombe State has exerted an enormous influence on soil development. Hence,over half of the state (central) that is underlain by the Kerri Kerri Formation has shallow to moderately shallow impoverished soils, with sandy loams on iron pan. On the Chad Formation in the northern part of the state, the soils are deep but sandy, and developed on clays and silt clays but are mostly blanketed by sand dunes(GOSADP, 1998).

Soils in the Eastern part of Gombe State are shallow to deep loamy, sandy clay, loamandvertisols with cracking clays that have weathered from shales. Vegetation in Gombe State is predominantly wooded shrub land in the central part, with the plant community comprising Anogeissus, Combretum, Affrormosia andDetarium.

The Northern part of the State exhibits a mosaic of shrubbed grassland and grassed shrub land with the preponderance of Acacia. In the hilly southern areas, the vegetation is shrubbed woodland with mostly Affrormosia and Detarium. Gombe State has the cultivated and urban areas constituting over 35 per cent of the land use/land cover (GOSADP, 1998).

3.2.4Demographics

Gombe Metropolis is mainly populated by Fulani, constituting more than half of the state population and other minor ethnic groups like Bolewa, Hausa, Kanuri, Tera, Tangale, Waja to mention but a few, Gombe Metropolis with total land area of 52 km^2 has a population figure ofabout 266,844 persons according to 2006 population census (NPC, 2009). As of 2014 the population was projected to be 443,760 persons using 3.2% growth rate (National Population Commission Gombe State, 2014).

3.3 METHODOLOGY

The methodology of this study includes; reconnaissance survey, types and sources of data, data processing and data analysis.

3.3.1 Reconnaissance Survey

A reconnaissance survey was carried out in the study area. This was aimed at getting the researcher acquainted with the general knowledge of the study area. This knowledge is very useful for the selection of training area before and after classification.

3.3.2 Data Types and Sources

3.3.2.1 Primary data

The types of data used include;

1. Landsat 5 Thematic Mapper (TM) data of 4th April 1991 with spatial resolution of 30m and 7 bands.
2. Landsat Enhanced Thematic Mapper plus (ETM+) data of 8th April 2005 with 8 spectral bands, where bands 1-7 has spatial resolution of 30meters and band 8 (pancromatic band) with a higher spatial resolution of 15meters were obtained.
3. Enhanced Thematic Mapper plus (ETM+) of 15th April, 2014 with spatial resolution of 30m while band 8 of the spectral bands has a spatial resolution of 15meter was also obtained.

The imageries were obtained from Global Land Cover Facility (GLCF) and Earth Science Data Interface. Table 1 shows the source and data types used in achieving the aim and objectives of this study.

Table: 3.1 Data Types and Sources

S/N	DATA TYPE	DATE OF AQUISITIONS	RESOLUTION	SOURCE
1.	Landsat image	1991-04-03	30m ETM+	GLCF
2.	Landsat image	2005-04-08	30m ETM+	GLCF
3.	Landsat image	2014-04-15	30m ETM+	GLCF

Source: Author, 2014

3.3.2.2 Relevant materials

Relevant literature materials were obtained fromtextbooks, journals and other existing literatures that are related to the research problem.

3.3.3 Data Processing

3.3.3.1 Image pre-processing

All images were clipped out according to the study area by using "Subset" function in ArcGIS 10.1. Since the image had been ortho rectified, there was no need for radiometric and geometric corrections. However, the images were geometrically corrected to Universal Transverse Mercator (UTM) coordinate system using ArcGIS 10.1. Ground Control Points (GCPs) was collected through an extensive field survey throughout the study area using Global Positioning System (GPS). This is to obtain accurate locational point data for each land use and land cover class included in the classification scheme as well as for the creation of training sites and for signature generation.

3.3.3.2 Image classification

To detect changes in the land use/cover at different years, post classification comparison of the change detection techniques was used. (Yuan, Sawaya, Loeffelholz& Bauer, 2005) argued that change detection is the most common approach used to compare data from different source and dates. The advantage of post classification techniques is that it bypasses the associated difficulties with the analysis of images acquired at different times.

ERDAS imagine software was used for the pixel-based classification. Supervised classification was performed using maximum likelihood classifier. The three images were classified into different land cover types. Supervised classification allows natural spectral clusters to be distinct with high degree of objectivity (Hudak&Brockett, 2004). This method of classification involves the procedure of identifying pixels possessing the same spectral features. ERDAS imagine software was used in digitally processing and identifying the spectral clusters on the Landsat images. By carrying out this classification, the signature editor was used via the classifier icon of the ERDAS IMAGINE to identify the spectral signature of different features. Maximum likelihood algorithm was used to classify the images and the digital numbers of the pixels was grouped with pixels arranged and organized otherwise known as land cover classes such as build-up area, bare surface, vegetation, water body and scattered cultivation.

Classification System: Based on Anderson, Hardy, Roach and Witmer (1976) land-use/land-cover classification scheme, the various land-use/land-cover types is modified in to five classes within the study area as presented on Table 3.2

Table 3.2: Classification scheme

CODE	LAND USE CATEGORIES	DESCRIPTION
1	Built-up	Land used for residential and transportation/communication purposes (i.e. settlements and roads, high residential area, industry and administrative block).
2	Bare surface	Exposed soils, lands devoid of vegetal cover.
3	Vegetation	Land covered with natural forest and natural vegetation that is predominantly grasses, shrubs and grass-like plants.
4	Water body	Areas covered by body of water e.g. dam, lake and rivers.
5	Scattered cultivation	Areas that is spatially cultivated e.g. farmland, irrigation areas etc.

Source: Modified from Anderson, 1967.

3.3.4 Data Analysis

3.3.4.1To determine the extent of urban land use in 1991, 2005, and 2014.

The attribute and statistics from the classification result was generated and used for post-classification comparison among the years. The built-up was also extracted for each of the periods and the extent of the built up area will be calculated in hectares.

3.3.4.2To analyze the extent of urban sprawl between 1991 and 2014.

The extent of the urban sprawl was analyzed by subtracting the reference year of land cover of 2014 from the base year 1991.

It is represented mathematically as:

$E_T = B - A$

A = the base year (1991)

B = the reference year (2014)

E_T = the total extent of urban sprawl between 1991 and 2014

3.3.4.3To determine the rate and pattern of urban sprawl in the study area

To determine the rate and pattern of urban sprawl, statistical analysis was used to show the rate of urban sprawl using the resulting value generated in objective two above to compare the set data for 1991, 2005 and 2014, the total extent of the sprawl in hectares was divided by the number of years within the period i.e 1991-2014

$$R = \frac{E_T}{\text{number of years}}$$

Where R =Rate of urban sprawl

E_T =Total extent of urban sprawl

To get the percentage

$$R = \frac{E_T}{\text{number of years} \times 100}$$

Pattern indicators which include the shape change of built-up area, fragmentation and open space efficiency, adopted from the work of Siedentop and Fina (2008), was used to determine the pattern of urban sprawl.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter is concerned with the presentation and discussion of result obtained from the analysis. The presentation of results and discussion has been carried out under the following subthemes: the extent of all landuse/landcover classes (classification result); the extent of urban land use in 1991, 2005 and 2014;the extent of sprawl and the rate and pattern of urban sprawl.

The results are presented using tables and figures.

4.2 SPATIAL EXTENT OF LANDUSE/LANDCOVER CLASSES (CLASSIFICATION RESULT)

Table 4.1: The result of classification of 1991, 2005 and 2014 images

Land use	1991		2005		2014	
	km²	%	km²	%	km²	%
Built-up (Urban)	12.78	10.41	33.02	26.89	48.49	39.50
Agricultural Land	81.43	66.33	70.20	57.18	60.08	48.93
Natural Vegetation	13.13	10.70	10.58	8.62	6.63	5.40
Bare Surface	15.42	12.56	8.98	7.31	7.57	6.16
Total	**122.77**	**100.00**	**122.77**	**100.00**	**122.77**	**100.00**

Source: Author's analysis, 2015

As shown on table 4.1,the built-up (urban) has been progressively increasing throughout the study period occupying 12.78km² (10.41%) in 1991, 33.02km² (26.89%) in 2005 and 48.49km² (26.89%) in 2014. This progressive increase in built-up area is in agreement with the work of Ade and Afolabi (2013).Agriculture,which occupied 81.43km² (66.33%) in 1991 decreased to 70.20km² (57.18%) and60.08km² (48.93%) in 2005 and 2014 respectively.The decrease in agricultural land throughout the study

period must have been caused by the increase in built-up area which led to the conversion of agricultural lands to built-up land. This is in line with the work of Nwafor (2006) who also found that agricultural lands decreased as built-up area increased.

Natural vegetationoccupied 13.13km² (10.70%) in 1991and decreased to10.58km² (8.62%) in 2005 and to 6.63km² (5.40%) in 2014. Bare surface decreased progressively from15.42km² (12.56%) in 1991,to 8.98km² (7.31%) in 2005 and 7.57km² (6.16%) in 2014. This could be due to the conversion of bare surfaces to built-up areas.

Figure 4.1, 4.2, and 4.3 show the spatial extent of Landuse/Landcover classes (classification result). Figure 4.4, 4.5 and 4.6 show thespatial extent of built-up/Urban land in Gombe Metropolis.

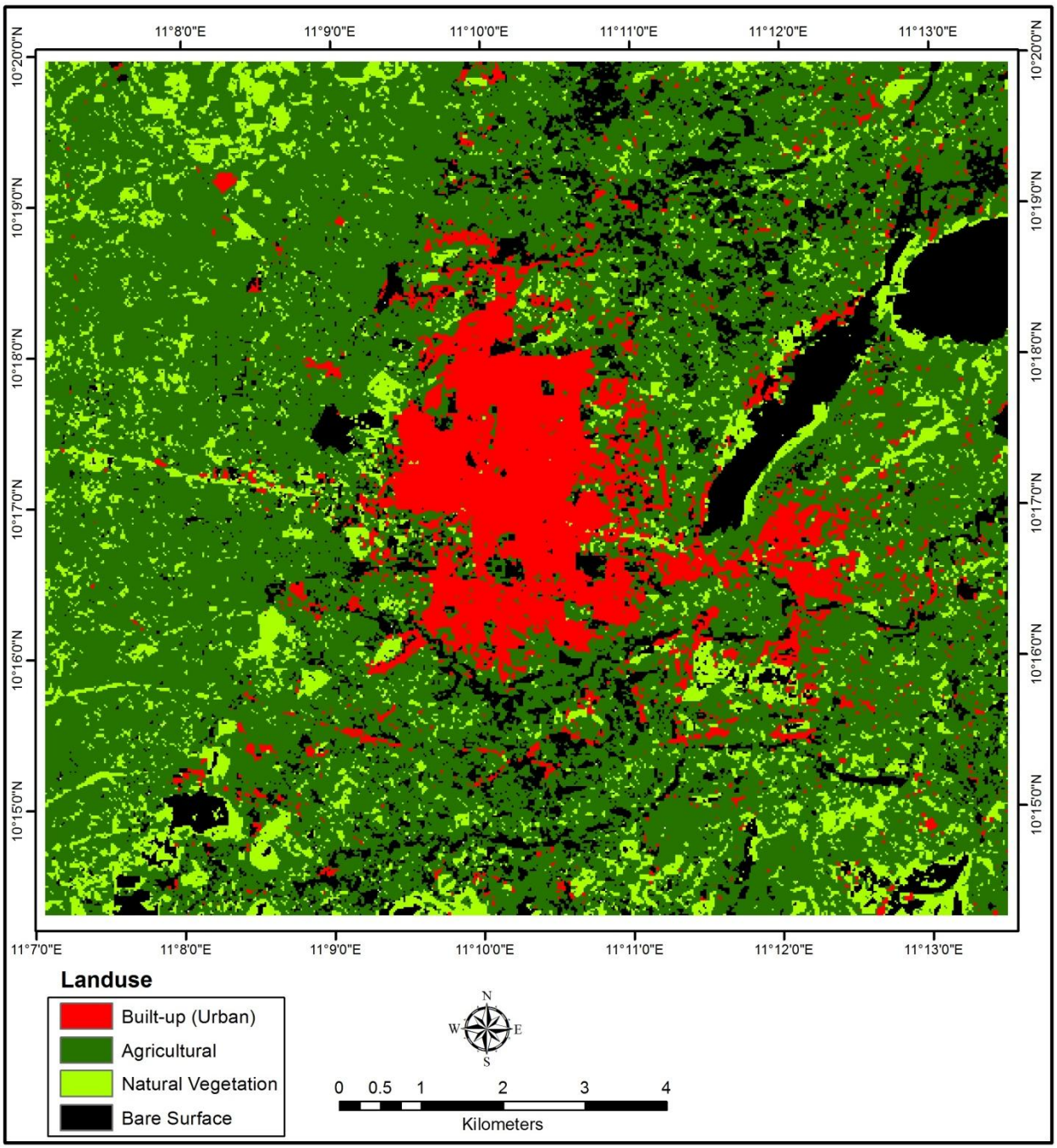

Fig. 4.1:Spatial Extent of Landuse/Landcover Classes (Classification Result) 1991

Source: Author's Analysis, 2015

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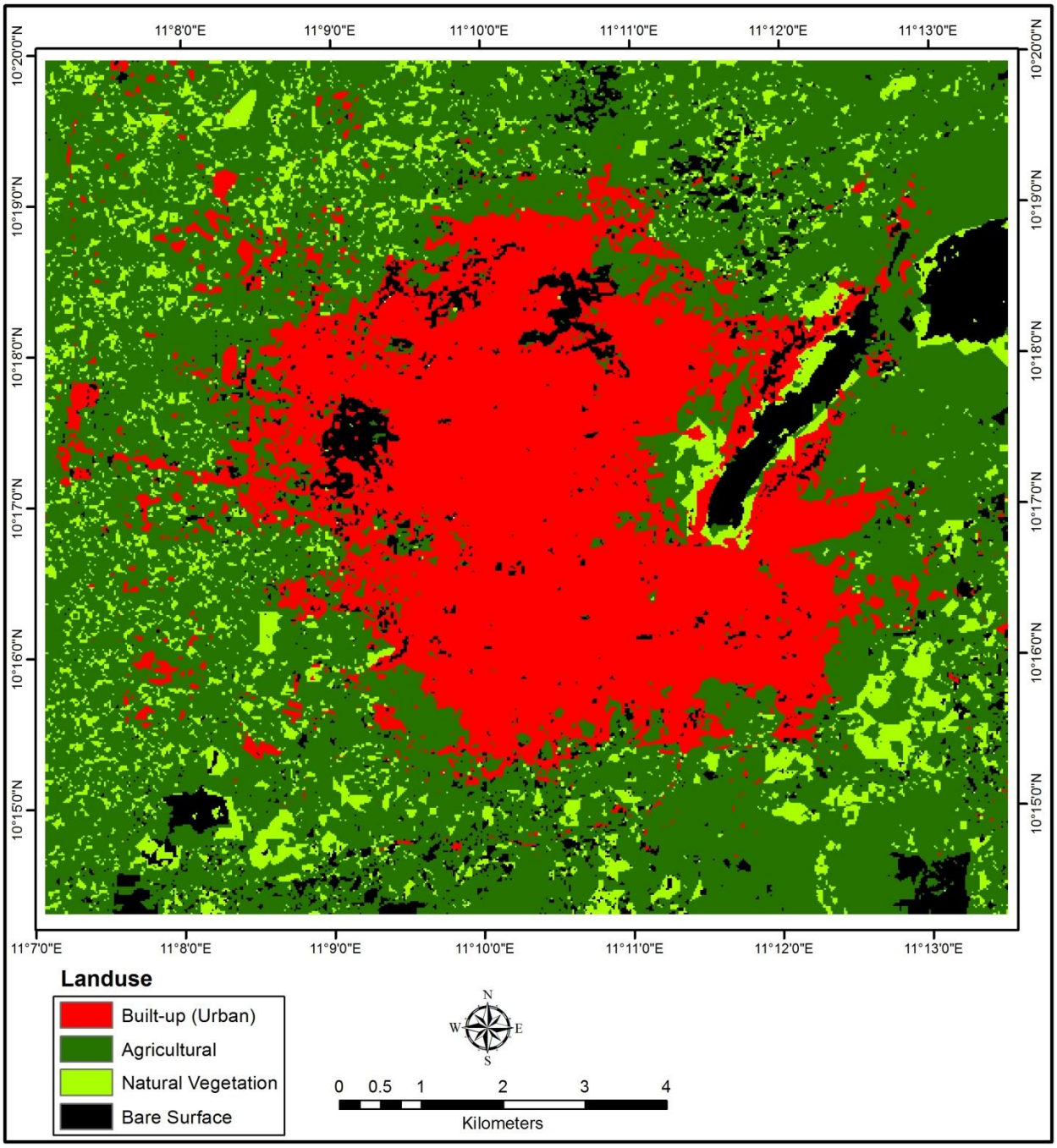

Fig. 4.2:Spatial Extent of Landuse/Landcover Classes (Classification Result) 2005

Source: Author's Analysis, 2015

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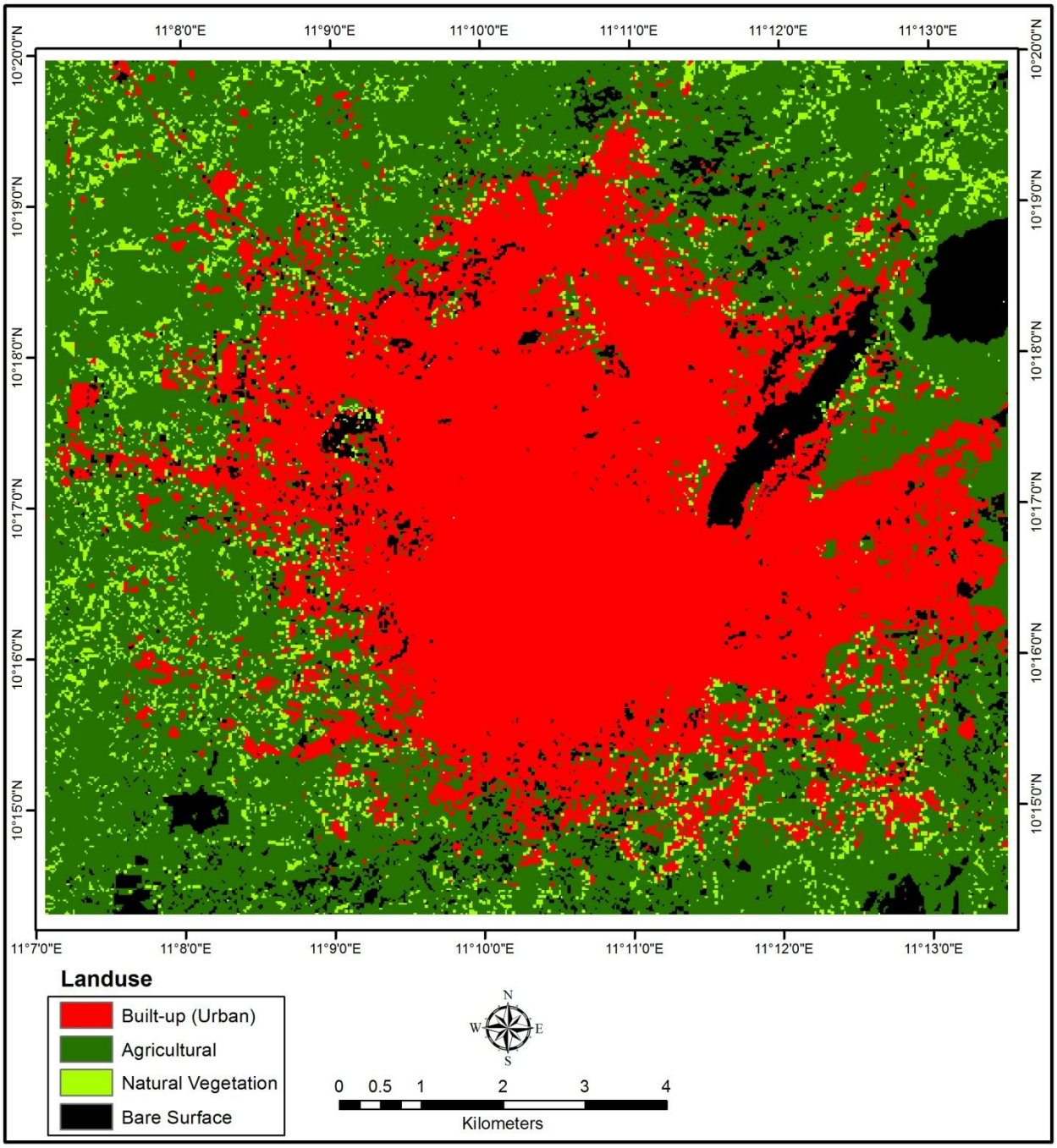

Fig. 4.3:Spatial Extent of Landuse/Landcover Classes (Classification Result) 2014
Source: Author's Analysis, 2015

4.3 THE SPATIAL EXTENT OF UI .NDUSE IN GOMBE

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The quantitative extent of urban landuse in 1991, 2005 and 2014 is shown on Table 4.2 while the spatial extent of same is shown on figures 4.2.

Table 4.2: The Extent of Urban Landuse in 1991, 2005 and 2014

Year	Urban Land (km^2)	(%)
1991	12.78	10.40
2005	33.02	26.89
2014	48.49	39.49

Source: Author's analysis, 2015

The extent of urban land use has been progressively increasing throughout the study period as shown on table 4.2. The year 1991 which represents the development that took place prior to the time the study area became the administrative state capital, had the least extent of urban land which constituted 12.78km^2 (10.40%). This was preceded by the years 2005 (14 years later) where the extent of urbanization rapidly increased to 33.02km^2 (26.89%). This rapid increase could however be accounted for by the increase in the construction of government office for its ministries and parastatals, housing facilities for staff as well as the influx of the rural population coming to seek for a greener pasture in the urban area. More urban expansion resulting from continuous dividends of democracy which increased administrative and commercial activities resulted in an increase in the extent of urban area to 48.49km^2 (39.49%) in 2014 as observed by Balzerek (2003) high construction activities and its structural as well as functional development leading to a yearly increase in built-up areas every year just as in the case of Gombe Metropolis which is not exceptional.

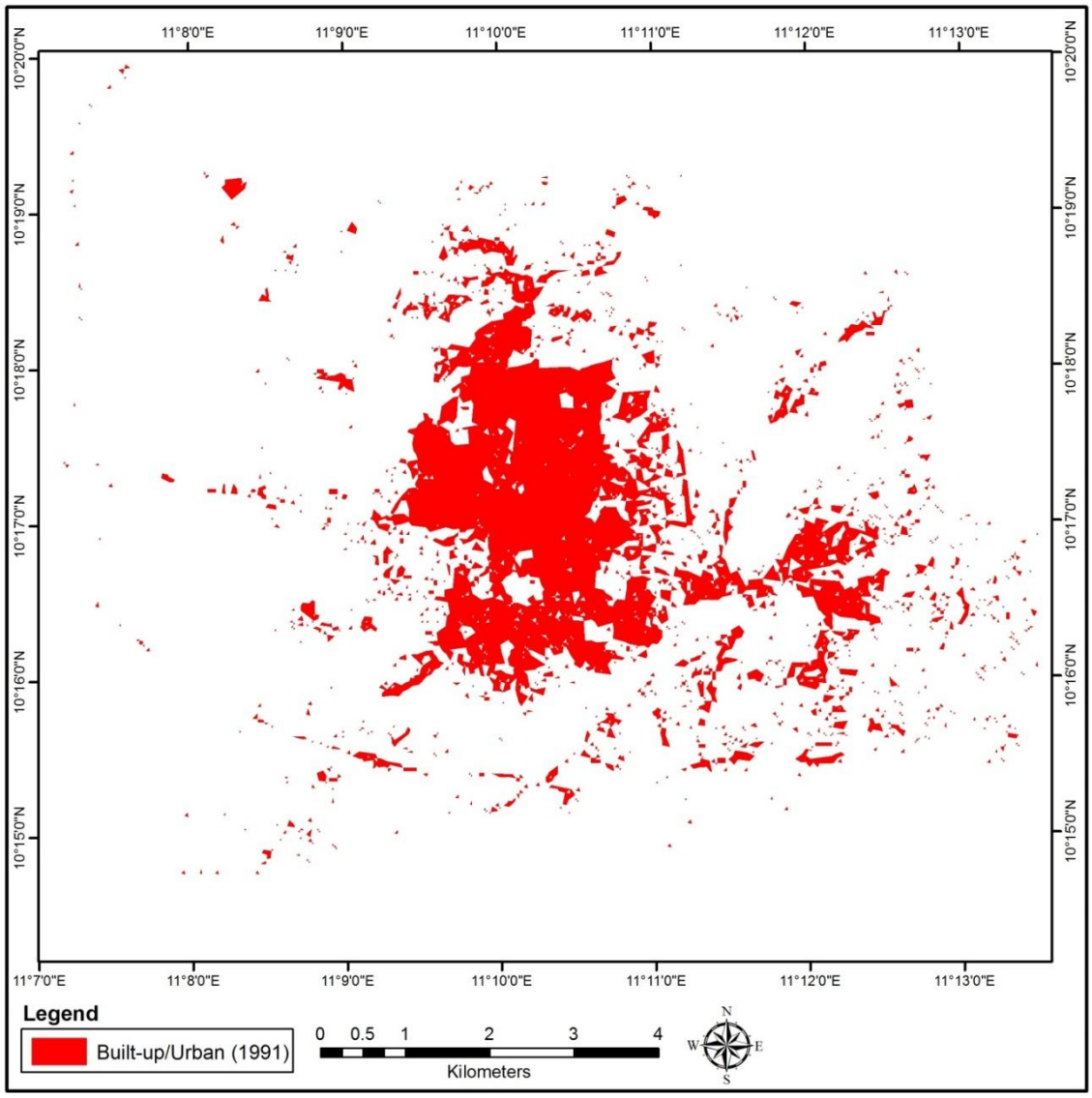

Fig 4.4: The Spatial extent of Built-up/Urban land inGombe Metropolis in 1991.

Source: Author's Analysis, 2015

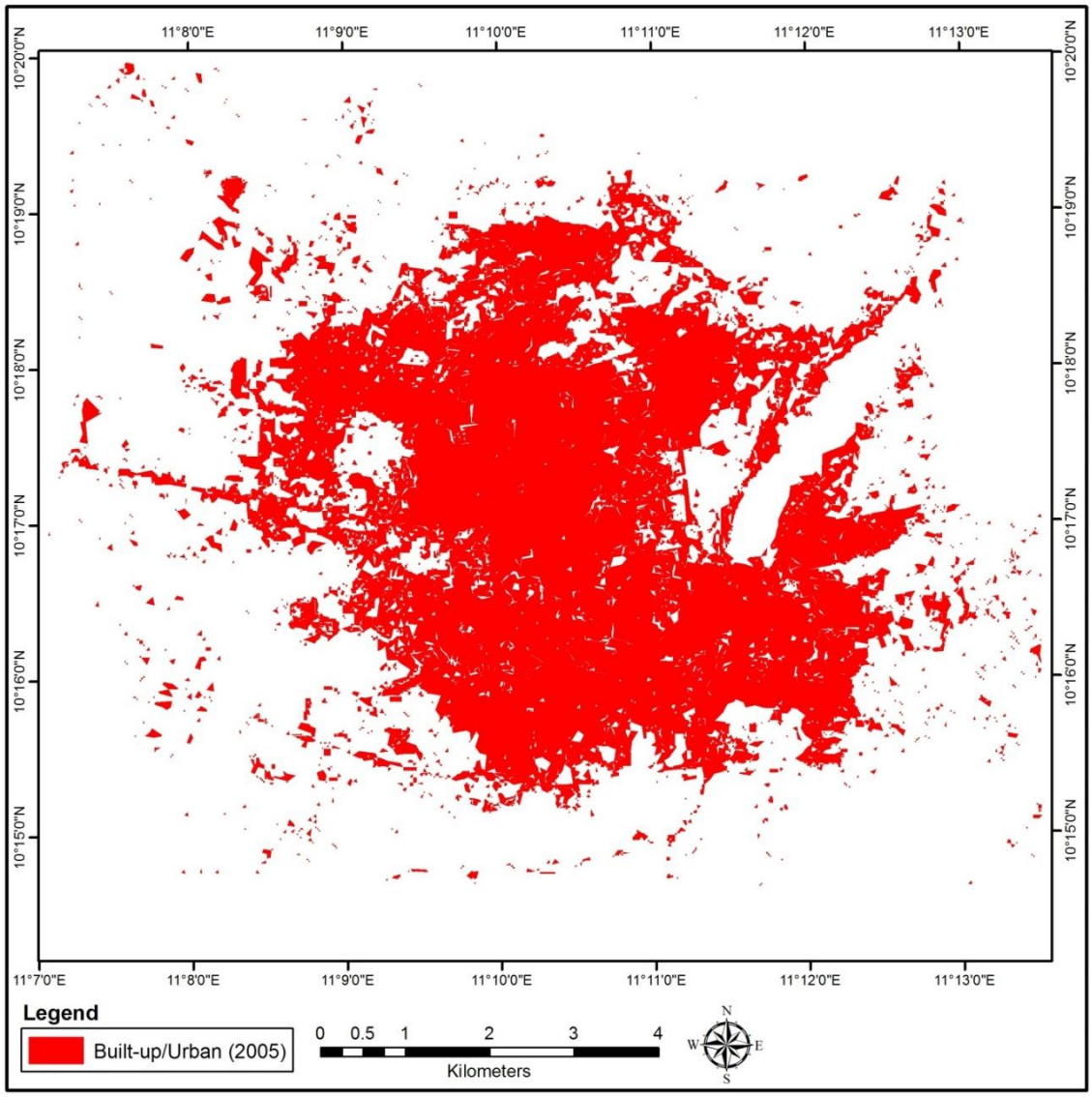

Fig 4.5: The Spatial extent of Built-up/Urban land inGombe Metropolis in 2005.

Source: Author's Analysis, 2015

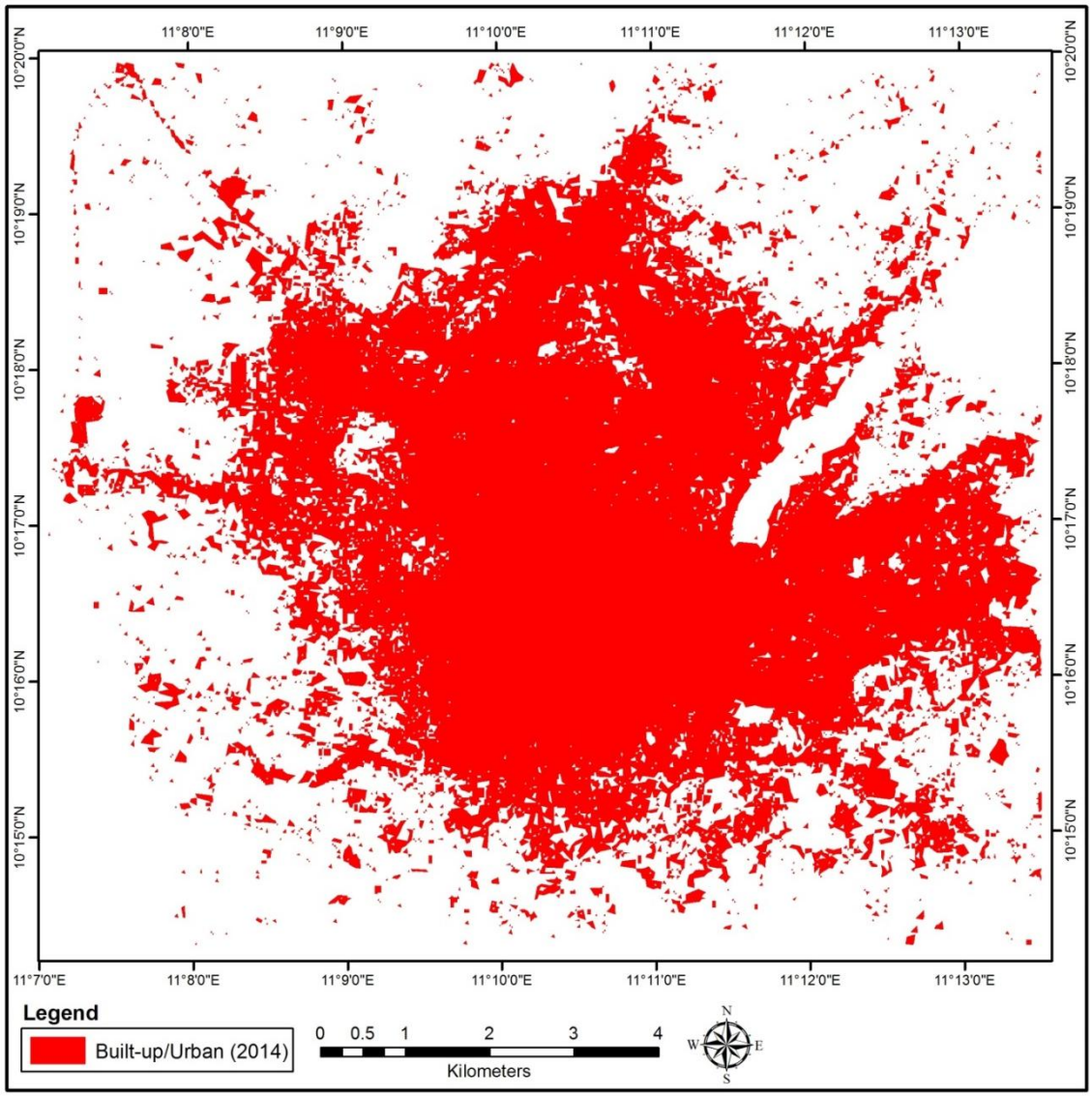

Fig 4.6: The Spatial extent of Built-up/Urban land inGombe Metropolis in 2014.
Source: Author's Analysis, 2015

4.4 THE EXTENT AND RATE OF URBAN SPRAWL IN GOMBEMETROPOLIS.

The extent of urban sprawl is described in terms of changes (increase) in the built-up area over the years.Table 4.3 shows the extent and rate of urban sprawl in Gombe Metropolis.

Table 4.3: The Extent and Rate of Urban Sprawl in Gombe Metropolis.

	Urban		Extent of Urban Sprawl		Rate of Urban Sprawl	
Period	**Year**	**(km²)**	**(km²)**	**%**	**Km²/Year**	**%/Year**
1991-2005	1991	12.78	20.24	158.37	1.45	11.31
(14Years)	2005	33.02				
2005-2014	2005	33.02	15.48	46.88	1.72	5.21
(9Years)	2014	48.49				
1991-2014	1991	12.78	35.71	279.45	1.55	12.15
(23Years)	2014	48.49				

Source: Author's Analysis, 2015

The analysis reveals that theextent and rate of urban sprawl in the study area increased appreciably.As shown in Table 4.3, the period when the study area became an administrative capital of the state, 1991-2005 sprawled by 20.24km² (158.37%) at a rate of 11.31% each year. This is the highest sprawl experienced resulting from new urban developments in a new state capital. The period between 2005 and 2014 witnessed a sprawl of 15.48km² (46.88%) at a rate of 5.21% annually. Generally speaking, the overall period of the entire study (1990-2014), urban land has sprawled by279.45% at an annual rate of 12.15%. This result is in agreement with the work of Ade and Afolabi (2013) which they analysed urban sprawl in Abuja and their result shows that the extent of growth increased not just inward but outwards. Figure 4.7 shows extent of urban sprawl in the study area.

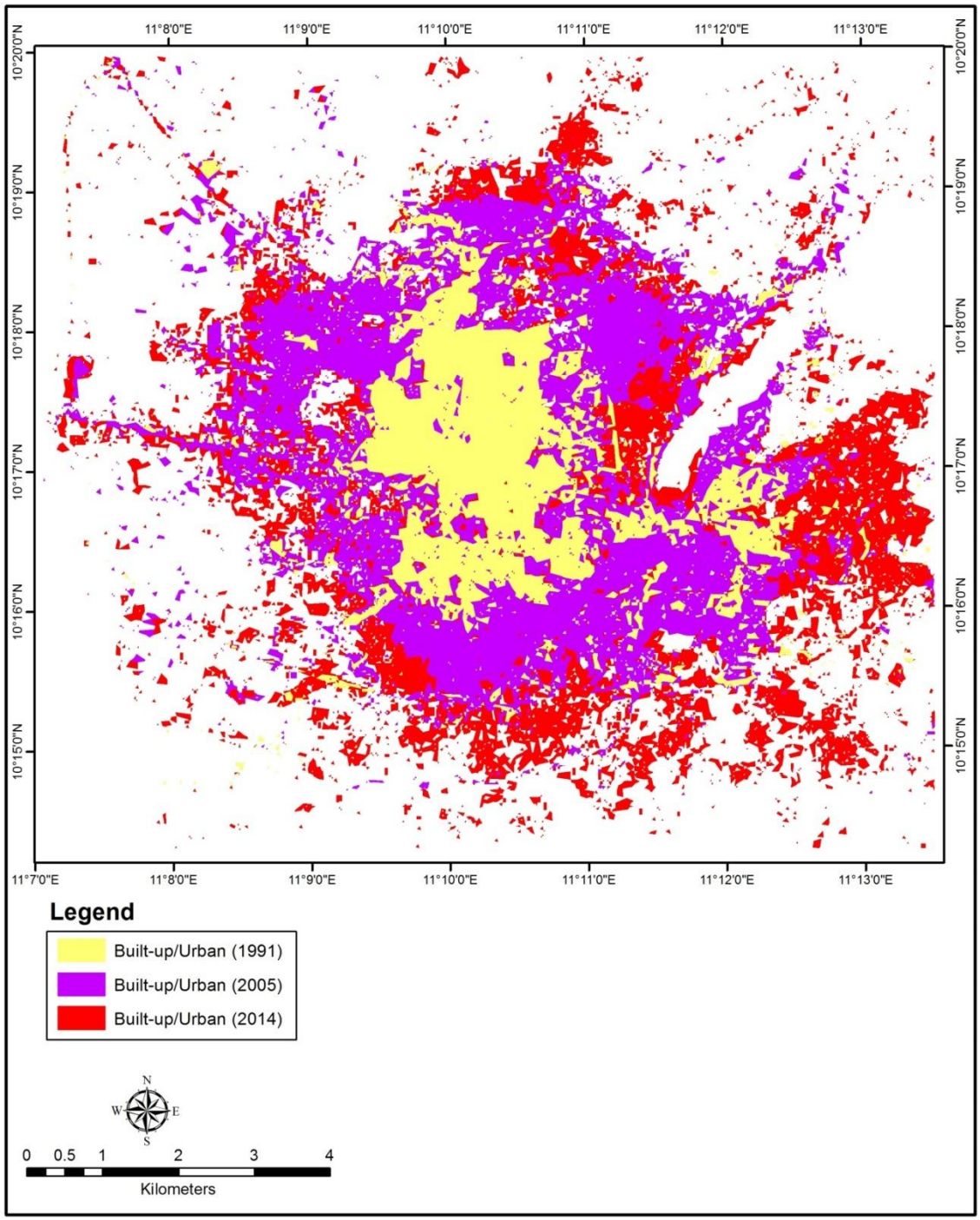

Fig 4.7: Spatial Extent of Urban Sprawl.
Source: Author's Analysis, 2015

4.5PATTERN OF URBAN SPRAWL BETWEEN 1990 AND 2014

The pattern of urban sprawl was derived from the three imageries of the study area, overlays analysis from the results of figure 4.7 and visual interpretation was carried out in determining the patterns of the sprawl. On the bases of the results obtained from the

analysis, three patterns of urban sprawl namely; cluster, radial and leapfrog were found which varied from different study periods (1991, 2005 and 2014). Though, all of the study periods witnessed cluster within the central business district of the study area there still is variation in other periods. It was found that in 1991 the pattern of the sprawlwas cluster while 2005 and 2014 witnessed both radial and leapfrog pattern of urban sprawl as show in figure 4.7.

Based on the nature of the pattern of urban sprawl in the study area, it was also found out that there was an uncontrolled disproportionate sprawl of urban area into the surrounding study area forming land density and poorly planned patterns of development as supported by Torren (2000) and Lata*et al.*, (2001); therefore the pattern of urban sprawl can be said to be continuous disperse development to low density residential units and isolated tracts, separated from other areas by vacant space forming leap frog pattern along highways or other driving agents, or forming spatial patch within undeveloped land which was in conformity with the research of (Torren, 2000; Lata*et al.,* 2001). The result was also in agreement with the research of (Abimbola, 2008; Verzosa& Gonzalez, 2010 & WUF, 2010) which pointed out that urban sprawl affect the structural growth and economic system of an urban area and that means increase in pattern, hence lead to the drawbacks by affecting the infrastructural planning and making administration of the study area extremely difficult which is in conformity with the results of the findings in the case of Gombe metropolis.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter described the summary of the research work, conclusions derived from the findings as well as recommendations for effective urban land-use/land-cover management and practices within the study area.

5.2 SUMMARY OF FINDINGS

Gombe metropolis became the capital of Gombe state in 1996. As a result there was an influx of people from other part of the state and the country mounting pressure on the land for development purposes. Since then the area had been growing spatially to the detriment of other land cover types like vegetation and agricultural land.The aim of this research is to analyse urban sprawl in Gombe metropolis between 1991 and 2014 using Geographic Information System and Remote Sensing techniques

The study explored urban sprawl in terms of the spatial extent of urban landuse, spatial extent of urban sprawl and, the rate and pattern of urban sprawl in the study area between 1991 and 2014.It was found that urban landuse occupied: 12.78km² (13.55%); 33.02km² (35.01%) and; 48.49km² (51.43%) in 1991, 2005 and 2014 respectively. The spatial extent of urban sprawl was found to be: 1.45km² (11.30%); 1.72km² (5.21%) and; 1.55km² (12.15%) between: 1991 and 2005, 2005 and 2014 and, 1991 and 2014 respectively.High annual rates rate of urban sprawl of 1.45km² (11.31%), 1.72km² (5.21%), 1.55km² (12.15%) were witnessed between 1991 and 2005, 2005 and 1991 and 2014 respectively.

5.3. CONCLUSION

This research work demonstrates the ability of geospatial techniques in the analysis of urban sprawl. The results obtained from this study revealed that there has been a continuous increase in build-up areas throughout the study period. There has also been

a progressive increase of urban sprawl both in terms of spatial extent and annual rate throughout the study period. The period of between 2005 and 2014 had the highest rate of urban sprawl which could be attributed to the fact that it was the period within which the state was created and the study area being the seat of the state government served as the population pull factor to the study area.

5.4 RECOMMENDATIONS

Owing to the continual increase in urban sprawl in both extent and the rate in the study area, the following are recommended:

i. There is need for a regular monitoring of urban sprawl and development by the state Government in the study area especially with the aid of geospatial techniques for better decision making.

ii. There is need for all stakeholders like Ministry of Land and Survey, Ministry of Environment, State Development Board and NGOs in urban land use management to ensure strict adherence to urban land use legislations.

iii. There is a need for a regular appraisal by the state government on analysis of urban dynamics and development using geospatial techniquesso as to easily detect areas that are fast growing and need attention in the study area.

iv. Government should encourage researchersto further carry out urban-related studies with socio-economic effect in the study area for a more in-depth understanding of the dynamics of urbanization.

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