KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI-GHANA

REMOTE SENSING AND SPATIAL METRICS IN MONITORING URBAN SPRAWL

BY

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**A THESIS SUBMITTED TO THE COLLEGE OF ENGINEERING,
DEPARTMENT OF GEOMATIC ENGINEERING,
KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF**

MASTER OF SCIENCE

JULY, 2019

DECLARATION

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma at Kwame Nkrumah University of Science and Technology, Kumasi or any other educational institution, except where due acknowledgment is made in the thesis.

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ABSTRACT

Urbanisation has become a universal truth found everywhere in the world. According to the United Nations the trend of inhabitant‟s growth in inner-cities is expected to heighten to 72% by 2050. Urbanisation, though an important international spectacle, has become a daunting challenge worldwide because dependable and precise data essential for growth of urban plans are not often readily available for planning. In the absence of such planning, quick development causes chaotic and unexpected growth of urban centres with a growing populace that results in congestion and turns into a problem of inadequate social infrastructure. It is through a collective effort of having material on historical and current land use, that scheduling and monitoring of the sprawl can become effective through the use of auxiliary plans for monitoring spatial (X, Y) positions and land use trends in its completest to produce an amalgamation of improved land use, the creation of real infrastructures to deal with the region‟s surroundings and pastoral areas, and the advancing synopsis for forecasting urban procedures for land use forms and land use modifications. Urban growth has an important impact on the rural peripheral territories located around the major urban centres which themselves soon become uncontrolled urbanised. To evaluate the geographical situation and the consequences of urbanisation in rural space, the urban sprawl of Ga Municipal Assembly (GA) which had evolved from Ga rural districts is monitored by remote sensing over a thirty-year period. The urban burden on these rural spaces is characterised by different land cover/land use conversions and land use conflicts. This study scrutinises the active change forms in the expansion course of the GA Municipalities over a period of 30 years and consequently attempts to categorise the urban growth forms and describe the probable driving forces causative to these variations in the GA municipalities by means of remotely sensed data and population count data. Spatial and time-based dynamics information of expansion progression was computed using Landsat imagery and socio-economic data, supervised classification procedure using the maximum likelihood technique in ENVI 5.0 software and the post-classification change detection method. The results indicate that the total population had increased from 157,985 persons in 1986 population projection census to 1,039,687 persons in 2016 census projection as a result of migration, displacement and natural population growth. The main land use in the study area currently is Settlements which had increased from 7.10% (55.395Km²) in 1986 to 62.09% (482.9175Km²) in 2016.

Dense Vegetation had decreased from 69.65% (539.1459Km²) coverage in 1986 to just 7.44% (57.834Km²) in 2016 due to transference to other uses. The foremost driver of Urbanisation was due to immigration. The study investigated the status of Ga area, by identifying, characterizing and quantifying the urban growth using remote sensing techniques coupled with statistical data calculation. This approach was effective in detecting LULC modification and measuring the range of the urban expansion. Moreover, it was discovered that, the Urbanization progression was powerfully associated with augmented inhabitants. It is recommended that, to protect Agricultural lands and proper Land use planning for an advancing economy, there should be:

i. A Strict Land Use planning policy developed and adhered to for any developmental project conducted in the District which must take into consideration Environmental Impact Assessment (EIA).
ii. The planning should include designated belt areas for agricultural lands and forests to prevent conversions as well as protection zones for water bodies.
iii. There should be decentralized development driven from the district for social amenities and infrastructures to preserve cultural identity instead of immigration driven that also imports city values to replace cultural values.

DEDICATION

To all who made this happen. I suppose it is possible that I feel like degree of affection towards my supervisors.

ACKNOWLEDGMENTS

Foremost, I would like to express my sincere gratitude to my advisors Rev. Dr. John Ayer and Dr. Edward M. Osei Jnr. for the continuous support of my MSc. study and research, for their patience, motivation, enthusiasm, and immense knowledge. Their fatherly love and friendship made it possible to complete this work. I could not have imagined having any better understanding mentors than these.

Besides my advisor, I would like to thank Dr. J. A. Quaye-Ballard and Prof. E. K. Forkuo, Dean of the Faculty of Civil and Geo-Engineering who came to my rescue when I was on the verge of giving up the attempt.

My sincere thanks also go to my Employers, the Geological Survey Department, who granted me study leave for two years to pursue this program.

I thank my fellow course mates and friends in KNUST. Last but not the least, I would like to thank my family especially my wife Hellen who always stand for me and supports me spiritually throughout my life.

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INTRODUCTION

1.1 Background Study

Urbanisation is the process by which people and economic activity increase in a place. It can also be defined as the change of rural culture into an urban culture as a result of socio-economic and political growth leading to creation and growth of urban clusters and city centres along with varying land use reforms (Roberts and Kanaley, 2003). The fast variations of land use and land cover than previously, predominantly in developing countries, are often associated with widespread urban expansive, land deprivation, or the conversion of cultivated land to other uses especially buildings warranting huge cost to the eco-system (Sankhala and Singh, 2014).

As cities are growing, the demands for possessions like aquatic, land-dwelling etc. increase correspondingly to the increasing proportion of the urban populace. This causes municipalities to experience growing cyphers of ecological pressure, particularly in the system of poor air eminence, extreme clamour, and traffic crowding (Ruangrit and Sokhi, 2004). Concurrently, uneven and unmaintainable postponement of municipalities has triggered devastation of urban vegetated zones and occasioned growing claim for land (Laghai and Bahmanpour, 2012). Also, the lawful clearing of vegetation for infrastructure such as transportation, communication networks, housing, schools, offices and markets have in a way led to an increase in the level of Urbanisation. In the world today, the advance in urban population principals to several inhabitant‟s densities, climatic variabilities and disintegration of land-dwelling tenancy and outdated development schemes. This contributes deprivation of soil and vegetation, lessening harvests and deteriorating food uncertainty in the rural areas mostly at the peripheries of the speedily rising urban communities (Vernon, 2002; UN-Habitat, 2011; Ifatimehin and Ufuah, 2003). Such difficulties in the less advanced nations might develop severely from its present state of being long-lasting. With only 2% of the world populace built-up in 1800, worldwide urban populace touched a 15% mark in 1900 and now nearly 180,000 persons are added to the world‟s urban populace every day (Pitale, 2011). Hence development is unavoidable and also a preferred wonder for expansion of any country.

Growth in inhabitants, devastations of ecological resources, ecological contamination, and overview of numerous methods of land use scheduling are the numerous complications intimidating the atmosphere nowadays (Vernon, 2002). Over the ages, man‟s dealings with his atmosphere has been documented as a main power influencing the environment, typically its scenery. Human activities relatively than normal phenomenon have been the foundations of greatest modern variations in the flow of the earth‟s disturbances (Fasal, 2000; Ifatimehin and Ufuah, 2003). The damage of the normal vegetation to expansion has excessive consequences, such as destruction of wildlife habitat, depreciation or outright wiping off of genetic pools, damage of food and therapeutic herbs, advancement of desertification and deficiency among others and the rising of greenhouse gases (Adesina, 2005). Spatial information has a vital role in responding to the complexity of urban growth. This is especially the cases when linked to the many advances of Geographic Information Systems (GIS) and Remote Sensing (RS) (Platino and Duque, 2013). Scenario based modelling approaches of urban and land use change allows one to establish more purposeful understanding of future urban change (Vliet *et al.*, 2009). The availability of decades of digital data in large urban as well as mid-resolution satellite imagery greatly contribute to scenario-based analyses of urban dynamics and land use change in more complex urban environments (Arsanjani *et al.*, 2014). Through the dawn of Remote Sensing and Geographic Information System techniques augmented with satellite images, a new era has emerged for assessing and mapping urban expansion patterns. Satellite image data offers the possibility for getting land cover evidence from inaccessible locations at more regular intermissions and it is additionally costeffective than classical methods of mapping (Treitz *et al.*, 1992; Trotter; 1996). This has benefited urban planners and geographers for predicting urban growth more effectively than the conventional approaches (Okabe, 2003; Kressler and Steinnocher, 2001).

Landsat images, a comparatively high-resolution terrain observation data that is attained through devices on cables has stood a decent foundation of data for investigation. The satellite devices obtain high veracity imageries of the globe outward in a methodical style. These images acquired can be used to control the wellbeing and type of flora, quantity of constructed surfaces, achievement of farming, or for assessing quantitatively temporal urban sprawl dynamics.

1.2 Research Problem

Urbanisation is a worldwide phenomenon identified with the growth of population as well as dramatically economic increases (Davies *et al.*, 2012). Urbanisation once established, tend to be centres of power and influence throughout the whole society. The Erstwhile Ga districts, considered a few years back as rural, has undergone significant changes with its Land-Use//Land-Cover (LULC). Residents, Politicians, Industrialists create the need for development of land for houses, infrastructure and social amenities in these areas leading to conflicting and competing land use demands.

The burden of an unceasingly rising populace has also resulted in congestion and has turned out to become a problem to the inadequate municipal cycle facilities. This has compelled builders and developers to move to outlying suburbs where open spaces are available, in much unplanned manner. This put pressure on the natural resources of those areas and makes it very difficult to monitor changes in the urban growth that has occurred so far and those which are yet to occur to be managed.

In Ghana, there has been evidence of towns expanding into Districts, as well as Districts into bigger municipalities. These have been characterised by massive population growth and developments in such areas. The GA East and GA West districts were both small rural Districts in the late 1980s and 1990s. However, by the late 1990s the comparative low cost of land coupled with improved road network systems attracted a lot of people to own land in these boroughs. By the early 2000s erstwhile GA districts had undergone drastic infrastructural transformations by the development of lands by owners into residential and commercial facilities. It is also believed that the growth process may have been aided by the proximity of the districts to Accra. Unfortunately, monitoring and evaluation of these changes (Urbanisation) for its control have been difficult by the expense of times involved in producing reliable and up-to-date maps. Existing maps are old, outdated and therefore inefficient to use for effective information base for planning. However, the use of Geographic Information System (GIS) on satellite images through multi-temporal Remote Sensing could afford such opportunities for monitoring and evaluation. The current study therefore, seeks to evaluate the level of urbanisation of these districts and their environs over the period of 1986-2016 (30 years).

1.3 Aim

The goal of this research is to use satellite images through Multi-temporal remote sensing and statistical data for monitoring and evaluation of urbanisation.

1.4 Objectives

- To assess the extent of urban expansion in GA Municipalities.
- To assess the rate of urban expansion in GA Municipalities
- To analyse the relation between population growth and urban settlement expansion using GIS and RS techniques

1.5 Research Questions

- What is the extent of urban expansion in GA Municipalities?
- What is the rate of urban expansion in GA Municipalities?
- What is the relation between population growth and urban settlement?

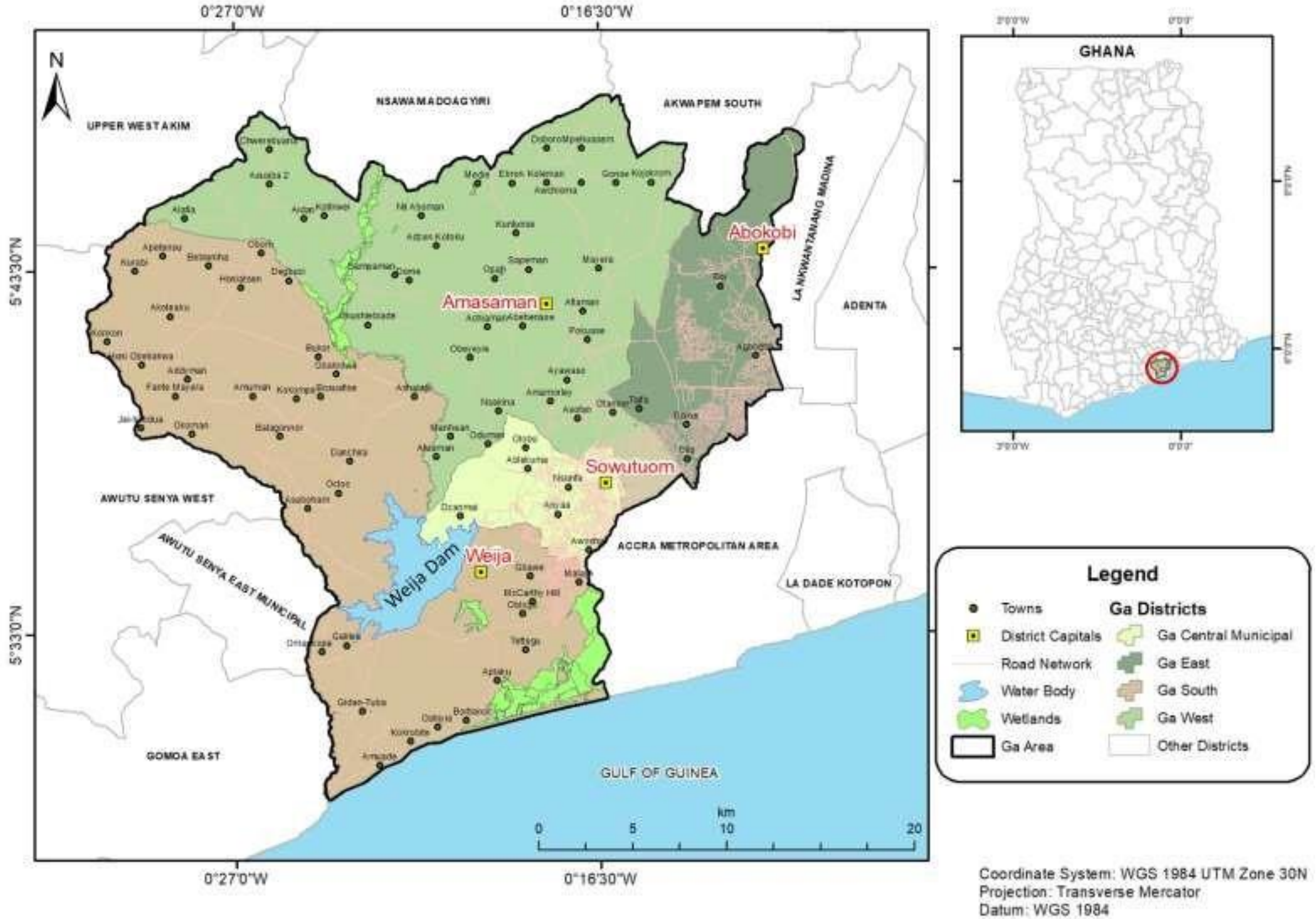
1.6 Significance of Study

Information on urbanisation of the districts would be of primary help for effective planning purposes. It will enormously assist decision makers in their effort to promote effective natural resource management such as loss of land and forest, reduction of environmental degradation such as water and air pollution and a more sustainable provision of required infrastructural facilities to meet the demands of people.

The significance of the study is to show how image classification of temporal images can be used to assess the level of urbanisation of the municipal and for that matter a necessary input for development planning and monitoring. One of the ways of assessing Urbanisation is the measurement of changes in the physical landscape as evident in the clearing of green space (Vegetation) for development (Infrastructure).

1.7 Scope of Study

The current study is limited to the Ga municipal Assemblies (GA). The Ga Municipal Assemblies consists of Ga- West, Ga- East, Ga South and Ga- Central municipalities (Figure 1.1).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AWUTU SENYA WEST
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ACCRA METROPOLITAN AREA
LA DADE KOTOPON
GOMOA EAST
GULF OF GUINEA
Abokobi
Amasaman
Sowutuom
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Weija Dam
km
0
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20
GHANA
Legend
Towns
District Capitals
Road Network
Water Body
Wetlands
Ga Area
Ga Districts
Ga Central Municipal
Ga East
Ga South
Ga West
Other Districts
Coordinate System: WGS 1984 UTM Zone 30N
Projection: Transverse Mercator
Datum: WGS 1984

Figure 1.1: Scope of Study

Geographically, the area is located between longitude 0°30'00''W to 0°07'30''W and 5°35'00''N to 5°47'30''N. The area under study covers a land area of about 727,116 square kilometres. The municipalities share boundaries from South-West with Gomoa-East, Awutu-Senya East, Awutu-Senya West, Upper-West Akim, NsawamAdoagyiri, Akwapim South, La Nkwantanang-Madina, Accra Metropolis and the Gulf of Guinea to the south.

1.7.1 Geology and Soil

The terrestrial zone is underlined by superficial stony soils and is widely established on the sharp slopes of the Akwapim range, Weija hills as well as elementary Gneiss inselbergs. On the Akwapim range, the earths are primarily pale and sandy with brushy quartzite happening to the surface in most spaces. These earths are rich in sandstone and limestone that are suitable source of material for the building commerce. The red soils are generally advanced in old and meticulously weathered parent materials. They are characteristically loamy in quality close to the surface becoming more clayey underneath. The red earths are porous and well weary and support road construction and also afford sufficient wetness storage at penetration for deep-rooting plants Nutrients supplies are focused in the humus top-soil (Ghana Statistical Service, 2014).

1.7.2 Climate and Vegetation

The Municipal lies in the grassland and environmental region. Rainfall form is bimodal with the normal yearly temperature ranging from 25.1°C in August to 32.2°C in March. February and March are normally the hotter months. The normal yearly rainfall ranges amid 790mm on the coast to about 1270mm in the northwards. The Community has two core vegetation namely shrubs and savannah. The shrubs happen typically in the Western peripheries and in the North near the Aburi hills and comprises of thick clusters of minor plants and vegetation that breed to a normal height of about five meters. The savannah, which is positioned to the southern part of the Municipal, has now been invaded upon by human events as well as settlements (Ghana Statistical Service, 2014).

1.7.3 Relief and Drainage

The terrestrial extent comprises of smoot slope landscape scattered with grasslands in the west. The Akwapim range increases sharply overhead the western close and falls usually at 375-420 meters north of Aburi in the Akwapim South District and fall to 300 meters southward in the Okaikwee North District. This contour of mountains endures through to the Weija hills with the maximum peak attainment of 192m near Weija. There are two key rivers explicitly, the Densu and Ponpon river, which gutter the metropolis. Densu is one of the key sources of water supply to more than half of the populace of Accra. There comprise the Sesemi watercourse at Sesemi and the Dakubi watercourse at Ajako. The community also has a lot of subversive water, some of which have been commissioned to provide drinkable water for minor towns and societies in the Municipality (Ghana Statistical Service, 2014).

1.8 Structure of Research

The research is ordered into five chapters.

- The Chapter One contains the introduction which consist of a background, the statement of the problem, research questions, significance of the study, and the structure of research.
- The Chapter Two consists of the review of the related literature on the subject under investigation.
- The Chapter Three is on methodology. Embedded in it are the research design, population and sample selection, and research instruments and data analysis.
- Findings and discussion of results of the research and the interpretation of data are all captioned under the Chapter Four.
- The Chapter Five deals with the summary, conclusion and recommendations of the whole research work.

CHAPTER TWO STRUCTURAL TRANSFORMATION CHALLENGES AND SUSTAINABLE URBANISATION

2.1 The concept of Urbanisation

The concept of urbanisation has been an issue of much concern both to stakeholders, urban planners, city authorities, as well as the general public due to the challenges it poses to the citizenry. Research has shown a correlation between urbanisation and accessibility to social amenities (UN-Habitat, 2011).

To say a nation or province is urbanising suggests that it is becoming more urban. Demographers have explained this to mean that an increasing share of the populace exists in urban settlements (Poston and Bouvier, 2010), with the level of development within the urbanized portion being higher than the corresponding rural segment (United Nations Population Division, 2014).

Urban development, both in populace and in infrastructure, alters the scenery from normal cover types to progressively impermeable urban land. Fasal, (2000) declared that land alteration is one of the most significant arenas of human tempted ecological alteration. The speedy land use variations by the growing populace decrease natural flora cover in most countries of the world (Nicholson-Lord, 1987).

The process of Urbanisation also expresses itself through a distinct set of land use and human behaviors. This brings about phenomenal socioeconomic transformation in the surrounding areas. The propagation of urban influence has marked differential radial tendencies measurable in terms of demographic components and land use assemblages and has led to serious environmental and ecological problems (Zhou *et al.*, 2004; Zhao *et al.*, 2004). Urbanisation impacts on the huge number of persons‟ resident in minor spaces and who are fundamentally involved in non-Agricultural activities. These depend on expansion of mechanisation and infrastructure within the localities. Thus, Urbanisation could be measurable as a directory of upgrading. The upsurge in the percentage of persons existing in municipalities and conurbations is powered by the drive of persons from rural zones (countryside) to municipal areas (towns and cities). In developing economies such as Ghana, expansion of rural areas into cities occurs largely as a result of population growth or influx.

According to Ankerl (1986), in most cases in less developed countries, population development is principally due to migration of rural based people to urban areas. Therefore, the growth in the percentage of the GA Municipalities is a result of migration of people from the core of cities to the peripheries triggered through ruralurban migration. Urbanisation is the procedure by which large populace of persons convert permanently concentrated in fairly small areas, forming municipalities.

A nation is measured to be developed when over 50 percent of its populace lives in the built-up areas (Long *et al.*, 2007). The United Nations predicted that a large proportion of the world‟s populace would live in built-up areas by the end of 2008 and by 2050, it is forecasted that 64.1% and 85.9% of the emerging and advanced world correspondingly will be built-up. Urbanisation can define a precise condition at a supposed period, i.e. the percentage of populace of areas in cites or towns, or the term can define the growth of this percentage over time. This makes the term Urbanisation characterise the level of urban comparative to total populace and also the rate at which the urban percentage is growing. Urbanisation is not simply a recent phenomenon, but a quick and significant change of human communal roots on a world-wide measure. It results in large community cultures being swiftly substituted by principally city cultures. Long *et al*., (2007) reported that, the major and wildest metropolises globally are in 10 emerging nations, because of the new urban-industrial growth.

2.2 Structural Transformation and Sustainable Urbanisation

Urbanisation is one of the maximum important universal tendencies in the 21st Era. More than 50 percent of the ecosphere populace now lives in built-up areas, while about 5 billion persons or 60 percent of the ecosphere‟s populace will live in built-up areas by 2030. About, 90 percent of ecosphere urban populace growing amid now and 2030 will take place in developed countries (Long *et al.*, 2007).

First, urban zones function as principal themes of profitable, manufacturing, managerial, entertaining, and communal facilities. Hence, Urbanisation joined with progression in expertise offers robust sustenance for quick monetary expansion. Local request is often an essential powerful driving demand for political monetary investment in the development of local communities in emerging countries, and Urbanisation provide the highest possible opportunity for that local request.

Maintainable Urbanisation meant the conversion of rural-urban sceneries that edifice mutually rural and urban economy, ecosystem and culture, in ways that prize the current cohort with higher excellence of life but deprived of imperilling and weakening the existing values of upcoming age groups with sophisticated excellence of life without jeopardizing and weakening the living values of such age groups.

This organisational shift must be supported by proper forecasting, maintained by enforceable legal instruments and, by so doing, bring about speedy monetary development and the unbiased expansion of inhabitants. When rural-urban change is appropriately accomplished together with mechanisation and strategic urban space, it tends to lead to advanced output and, ultimately, intensifying living values and healthier excellence of life. Maintainable Urbanisation offspring"s municipalities that advance into centres of alteration and modernisation, principally because the attentiveness of persons, possessions and happenings support human originality. Undoubtedly, a lively farming sector increases work efficiency in the rural economy, jerks up earnings and progressively eradicates the worse proportions of total poverty. Mostly, the normal ingesting levels of Ghanaians are far advanced amongst urban inhabitants than rural inhabitants. Consequently, the present drifts of Urbanisation in Ghana if well accomplished is proficient of bringing a huge number of rural inhabitants into municipalities and the upsurge in their ingesting levels and following promotion of the ingesting structure will lead to far bigger purchaser difficulties. Furthermore, as some of the rural strength transfers to urban zones, it will generate situations for large scale farming and competence of agricultural procedures to upsurge agriculturalist"s wage rises. When agriculturalists salary upsurges, customer request amongst persons in rural zone will equally keep on rising.

Development requires a huge amount of real estate asset demand necessitating a gigantic volume of industrious investment in order to generate works and meet the growing request for customer goods and services. Additionally, it also necessitates a gigantic quantity of savings in organisation and community amenities. This is critical in the hastening of the building of community facilities and other amenities for the supply of energy and water, leftover and sewage, as well as roads and communication also for the growth of indispensable community facilities including education and health and not the least for the expansion of the service manufacturing sector, including job and investment services.

Thus, Urbanisation entails a vast amount of real estate asset in order to meet the increasing difficulties for land for housing, manufacturing and profitable production. The requirement for these kinds of assets have an objective basis in real demand which does not usually create or lead to overcapacity. According to Stiglitz, (1999), new technology revolution and the process of Urbanisation are the two inordinate engines of economic growth in the 21st era. The upsurge in the percentage of persons living in townships and municipalities is fuelled by the drive of persons from countryside (Countryside) to built-up areas (Towns and Cities). In developing economy such as Ghana, expansion of rural areas into cities occurs as a result of population growth.

2.3 Key Origins of Urbanisation

Normal inhabitants rise (high natal than demise) and relocation are important issues in the development of municipalities in the emerging nations. Mechanisation has augmented engagement into employment opportunities by giving persons the chance to labour in contemporary sectors in job classes that aids to stir economic expansion.

Commercialisation and occupation originate with the universal awareness that the townships and municipalities offer improved commercial openings and revenues likened to the countryside areas. There are several societal welfares credited to life in the municipalities and townships. Instances comprise better informative amenities, better living values, and better hygiene and housing, better well-being upkeep, better recreation services, and better communal lifespan in overall. In municipalities and townships, there are sufficient work prospects that frequently lure persons from the countryside areas to seek better standard of living. Consequently, the widely held point of persons often journeying into built-up areas to access well-paying occupations.

Transformation plays a very significant part in the procedure of growth. As built-up areas become more expertise shrewdness together with exceedingly classy communication, organisation, therapeutic facilities, dressing style, information, liberalization, and other social facilities accessibility, individuals trust they could obtain a contented life in municipalities. As neighbourhoods develop more manufacturing industries and offices or sometimes extractive industries such as the finding of mineral resources, municipalities start developing as the countryside areas transform to urbanism. The upsurge in output leads to economic development and advanced value-added engagement chances.

This brings about the necessity to advance improved infrastructure, improved teaching organisation, healthier well-being services, restored transport systems, formation of investment organisations, better governance and more sophisticated housing and as this takes place, countryside societies start to adopt the built-up philosophy and eventually become built-up centres that continue to attract more persons to move to such places in exploration of an improved lifespan. Even though in several African nations the built-up areas offer few works for the youth, they are habitually fascinated by the sheer facilities of city life (Yu and Ng, 2006)

2.4 Urbanisation and Infrastructural Challenges

The antiquity of world growth demonstrations that growth happens in separate periods, and its expansion route look like an S moulded curvature. In general, the early phase is branded by sluggish growth when the level of development is lower 30%. The intermediate period, when the level of development is amongst 30-70%, contains impartially fast expansion. The last period, when development surpasses 70% is categorized by sluggish expansion and an equilibrium of level of development (Fransen, 2008). The percentage of a Nation‟s development should imitate to and not diverge from these rules. Disproportionately fast or unreasonably sluggish suburbanisation can generate a multitude of economic and social complications (Fransen, 2008).

The rate of movement of rural labour into non-agricultural manufacturing and the supplementary drive of the populace from the countryside to municipal areas is resolute by the level of mechanisation and economic growth. Hence, the unsuitability of industrialisation to sub-urbanisation may consequence in numerous social complications in the municipalities. Though, the delay of development behind that of mechanisation can disturb manufacturing accumulation and optimisation of the economic edifice, as well as interrupting the mechanisation and transformation procedures (Fransen, 2008).

In addition to the above, the form of development should resemble the nationwide circumstances of the country. The form of growth, including the figure, extent, assembly, three-dimensional layout, and methods of development of built-up areas, also varies from Nation to Nation. This is due to change in accepted topographical circumstances, resource endowments, inhabitant‟s magnitudes and antique and ethnic backgrounds. Normally, the majority of the nations and provinces with insufficiency of land, high concentration populaces and dynamism scarcities have highly focused growth. The majority of nations and provinces with massive land possessions, lowdensity populaces and high per capita liveliness resources have extensive development. Economically, industrialised nations usually have one or numerous internal significant urban agglomerations, which become the key drivers of a state‟s attractiveness. Conflicting to that, African nations undergoing development do not have internally powerful agglomeration to ambition their economics (Fransen, 2008).

When countryside inhabitants become municipal inhabitants, it improves people‟s superiority of lifespan, but if not held accurately it can lead them to becoming people without land, jobs, and social safety, and can even lead to the development of urban shantytowns. The attentiveness of businesses and inhabitants can lead to accumulative effects but it is often related with difficulties such a traffic overcrowding and ecological contamination. The city powers that be are often challenged with a host of crucial difficulties, like high urban concentrations, high transportation stresses, traffic overcrowding, energy insufficiency, urban water uncertainty, unexpected growth and lack of rudimentary amenities, prohibited edifice both within the urban and in the border, unceremonious real estate markets, formation of shantytowns and side-line land, poor natural danger administration in overpopulated zones, corruption, water, soil and air contamination leading to conservational squalor, weather variation and poor supremacy measures. Unceremonious build-ups leading to the upsurge formation of slum or unlawful tenant settlements are unruly in several municipalities.

A growing figure of inhabitants do not have either perpetual or provisional entree to land and acceptable housing. In numerous cases, this elimination is due to organisational social disparities, legacy restrictions, non-pro-poor or pro-gender land plans and land management schemes that are unsuccessful and luxurious for the end handler (Ward, *et al.*, 2000). Though the risk of floods, fires, earthquakes and other geo-hazards differ from municipal to municipal, ability to strategise, formulate, answer and recuperate from catastrophes is a common challenge. Even though natural hazards do not frequently occur, their occurrence and emergency management pose major challenges to most cities in Ghana. Although city authorities have little control over population growth, monitoring inhabitant‟s alteration successfully and being able to answer through preparation and infrastructural growth are foremost encounters

(Ward, *et al.*, 2000). As inhabitant‟s population surges, so does the requirement for new housing, schools and transportation systems. Decentralisation is a tread indicative of built-up growth and current day manufacturing, marketable and built-up areas are no longer automatically a part of city core (Nechyba and Walsh, 2004). As new road and rail network are put in place, valuable farmlands are regularly left undefended from profitable or housing designers (Hathout, 2002). Historically, the development of the world shows the inevitability and progress of urbanisation and there is a charge to pay for carrying out urbanisation seriously, as it leads to new contradiction and complications. Urbanisation holds both the prospects of unequalised development of urban areas and the serious danger of incomparable tragedy in future.

Therefore, to curtail the threat of unparalleled disaster in future, it is essential to grip properly the associations between city and countryside areas, economic and social development, and man and nature in order to preserve the healthy growth of expansion. It is also essential to make general strategies and take all issues into deliberation to lure on compensations while dodging drawbacks of growth (United Nations, 2010; UN-Habitat, 2011).

2.5 Remote Sensing and Land Cover Mapping

Remote sensing is the discipline and performance of finding information about an entity, extent, or phenomenon through the investigation of data attained by device that is not in interaction with entity area, or phenomenon under examination (Lillesand and Kiefer, 2000). The obtainability of several data attainment methods and data investigation classifications made this conceivable. The remote sensing systems improve the competence of human spectator. The restriction of line of vision, interference caused by un-levelled landscapes, impediment of sight by natural or nonnatural substances etc. are inevitably overcome as the devices are at a much-advanced altitude than most earthly matters. This has become possible owing to data procurement in inadequate and thin spectral bands, near Infra-Red and Thermal InfraRed imaging, microwave imaging etc. (Yang, 2005). Shosheng and Kutiel, (1994) examined the safeties of Remote Sensing methods in relation to ground surveys in providing a provincial explanation of flora cover. The outcome of their investigation was used to produce four vegetation cover maps that provided new material on spatial and temporal disseminations of vegetation in the area and permissible provincial measurable valuation of the flora cover.

Researchers on urban growth often use Remote Sensing and Geographical Information System as tools in the studying of urban growth effects on the natural environment. This is because they can reveal areas of growth, patterns of growth and allow for various statistical analyses to be made on the urban growth and its consequences on the environment (Gar-On Yeh and *Xia*, 2001).

Satellite images can quantitatively describe the spatial assemblage of urban location, and offer a profitable and imagined tool to sense Urbanisation footpaths (Gutman *et al.*, 2004). Multi-temporal and multi-spectral data can be obtained for investigating and monitoring urban increase forms by means of remotely sensed imagery *(Weng, 2002).* For example, Alberti *et al.*, (2004) specified that the remote sensing knowledge has the ability to define changes of land use based on apt and precise geospatial data.
Also, in amalgamation with Geographical Information System (GIS) that can deliver an operative tool to acquire, store, investigate, assimilate, and show geographical referenced information (Malczewski, 1999), GIS and Remote Sensing skills have been extensively useful in distinguishing land use and land cover changes and monitoring Urbanisation processes (Dewan and Yamaguchi, 2009; John, 2007). Remote Sensing offers spatially reliable data set with great terrestrial exposure, high spatial detail, and high time-based frequency (Martin, 2003). It can also offer reliable past time sequence data (Batty and Howes, 2001). The use of Remote sensing and GIS have been demonstrated to be an actual and reachable means for removing and dispensation of spatial information attained from satellite and aerial images for monitoring urban development (Masser, 2011). Nevertheless, assortment of a good revolution discovery technique could be occasionally problematic (Lu and Weng, 2005). GIS is a suitable tool for requests in the field of urban development and organisation because it assimilates information from diverse foundations (Masser, 2011).

According to USDA Forest Service (1989), land cover is well-defined as that which overlaps or currently covers the ground, particularly vegetation, perpetual snow and ice field, water bodies or edifices. Generally, and globally, the principal causes of land cover changes are by direct human activities or use. They vary from the original alteration of natural plantation into cropland to on-going savannah administration (Hobbs, 1997). However, factors other than anthropogenic (human activities) such as climate fluctuations, weather, fire, and ecosystem dynamics may as well change the land cover.

Fast increasing universal inhabitants, upsurge in scientific measurements and privileged circumstances; have controlled the revolution of the terrains land cover, particularly, in emerging nations. It is consequently one of the critical fundamentals in images cataloguing for precise investigation and real-life terrain science application (Campbell, 1996; Sellers, *et al.*, 1995).

In land cover planning, the purpose is to characterise the terrain‟s superficial as much as probable by outlining the changed feature as they signify in nature and remote sensing is crucial to this entire progression as information can be attained through satellite imageries and or airborne photography portraying spatial difference in land cover and monitoring temporal variations in land resources at different scales through organisations technique (Jupp and Walker, 1997).

As an effect of expense in procurement, processing and explanation, airborne photography that have been the focal source of land cover and use information, is giving way to multispectral satellite imagery which is less-expensive, cover large areas and is obtainable in digital presentations. The challenge to land cover mapping however, is that there is no acceptable global classification scheme; although many of such scheme have been proposed for some time now. The main reasons are that, compiled classification systems/map legends (Melillo *et al.*, 1993) as well as land cover datasets (Olson *et al.*, 1985) are not the same but differ in definition, spatial resolution, purpose, and outcome.

2.6 Image Processing and Classification

Prior to the extraction of information from satellite images through image classification, it may be necessary to conduct images transformation techniques such as Normalised Difference Vegetation Index and or Principal Component Analysis. The essence primarily is to highlight specific features that act as an aid to the classification process.

2.6.1 Vegetation Indices

Vegetation Indices are used to generate production images by scientifically scrutinising the digital number (DN) values of dissimilar bands. In many instances, these indices are ratios of band DN values (band rationing). In modest term, band rationing is a portion of the change in reflectance of the equivalent surface for two separate shares (Bands) of the electromagnetic reflectance. Band controlling is very useful in flora identification because of the high spectral captivation in the visible red and high reflection in the near-infrared region. Vegetation indices are therefore empirical formulae designed to emphasise the spectral contrast between the red and near-infrared. According to Campbell, (1996), it is an attempt to measure biomass and vegetation expected at the ground.

Normalized Difference Vegetation Index (NDVI) is one of the records extensively used vegetation indices and it was also functional in this project. It is an index or measure that relates to the proportion of photo synthetically captivated radiation. Chlorophyll in green leaves absorb strongly red light while Near-Infrared light also passes through or is reflected by life leave tissues, irrespective of their shade. In overall, advanced values of NDVI show better energy and quantity of vegetation. NDVI values arrays from -1 to 1, where vegetated zones will characteristically have values bigger than zero and negative values designate non-vegetated surface landscapes such as water, barren, snow, ice or clouds. Most vegetated areas have values of between 0 and 0.7. it can satisfactorily be used to differentiate amongst vegetated zones and non-vegetated zones. Zones of vegetation looks in optimistic tones whiles non-vegetated zones seem in dark tones.

2.6.2 Principal Component Analysis

Principal Component Analysis, shown to have special application in environmental monitoring, is an image transformation method that generates new images from the uncorrelated values of dissimilar images. As data decrease method, Principal Component analysis aided the researcher to reduce the number of bands to a desirable level. Since Principal Component Analysis functions effectively on all bands, it undisputedly improves the trouble of choosing suitable bands connected with the band rationing values. This, however, allowed the omission of insignificant portions of the data set and thus avoid the additional computer time (Campbell, 1996).

2.6.3 Image Classification

Image classification is the organisation of pixels in an image into groups (Classes) based on their spectral properties. These groups (classes) are obtained by identifying pixels that have similar spectral characteristics. Generally, classification is of two forms - Supervised and Unsupervised; namely pixel/spectral based classification which groups pixels into modules exclusively founded on their spectral properties and object-based classification, which in addition to the spectral properties, uses information on the spatial relationship of neighbouring pixels in classifying pixels into classes. In image classification, the aim is to categorise each pixel into classes that is (Crisp organisation) or associating the pixels with many modules that is (Fussy organisation), thereby matching the spectral modules in the data to the information model of attention.

Depending on the training process employed by analysis, the classification is termed supervised where the image analyst makes input that the image processing software (system) uses as guidelines to determine the classification of feature or unsupervised where the processing of the image is virtually an automated one, in which the classification is based on search for natural groups of pixels present in the image (Campbell, 1996).

In the case of the unsupervised classification however, to control the individuality and material standards of such spectral modules which are not known initially, there is the need for the analyst to compare the classified data to some form of orientation data such as large-scale images, maps, or site visits, (Lillesand and Kiefer, 1994). Coleman *et al.*, (2004) used unsupervised classification technique to identify land cover feature in their study of mangrove ecologies along the coast of Ghana.

Classification may also be considered parametric or non-parametric on the basis of theoretical models. Minimum Distance, Maximum Likelihood and Spectral Angle Mapper are some of the common algorithms that performs supervised classification whiles Isodata and K-Means are common algorithms for performing unsupervised classifications.

2.7 Accuracy Assessment

Valuation of organisation correctness of 1986 to 2016 imageries was agreed out to regulate the excellence of information resulting from the data. If organisation data are to be valuable in discovery of transformation investigation, it is important to accomplish accurateness valuation for discrete classification (Owojori and Xie, 2005). For the accuracy assessment of land cover maps obtained from satellite imageries, stratified random method was used to characterise dissimilar land cover modules of the zone. The exactness valuation was agreed out by means of using ground truth data and pictorial understanding. The assessment of reference data and cataloguing outcomes was accepted out statistically using error matrices. In totalling, a nonparametric Kappa test was also completed to quantify the range of organisation correctness as it not only justification for diagonal rudiments but for all rudiments in the confusion matrix (Rosenfield and Fitzpatirck-Lins, 1986) Error matrices quantifying overall accuracy, omission errors and commission errors were examined to assess the correctness and presentation of each organisation (Congalton and Green, 1999). In totalling, the Kappa statistic (KHAT) (Cohen, 1960), which regulates if organisational outcomes are meaningfully improved than outcomes arrived at a pure chance i.e. a random result (Lillesand and Kiefer, 1994; Green, 1999) was resultant for each classification. The error-based correctness valuation technique was appreciated for assessment of alteration discovery outcomes. Other significant accurateness valuation component, such as overall accuracy, omission and commission errors were developed using the error matrix. The user"s accuracy means the likelihood that a pixel is class "A" given that the classifier has determined the pixel into class A, while the producer"s accuracy designates the likelihood that the classifier has branded a pixel into class A given that the ground truth is class "A" (Jensen, 2004).

Properly classified elements are shown on the major diagonal of the matrix. For each error matrix, overall accuracy, producer"s accuracy, user"s accuracy, errors of commission and errors of omission are computed.

- Overall Accuracy: The overall correctness is computed by adding the figure of pixels classified properly and dividing by the total figure of pixels. The ground truth image or ground truth region of interest (ROI"s) explains the true class of the pixels. The pixels classified appropriately are initiate along the diagonal of the confusion matrix table which lists the figure of pixels that were classified into the precise ground truth class. The total figure of pixels is the sum of all the pixels in all the ground truth classes.

- Producer‟s Accuracy: The producer accuracy is a portion representing the likelihood that the classifier has branded an image pixel into Class A given that the ground truth is Class A. In the confusion matrix example, the settlement class has a total of 1,591 ground truth pixels where 1,524 pixels are classified correctly. The producer accuracy is the ratio (1,524 / 1591) * 100 = 0.958 or 58.9%.
- Omission: Errors of omission characterise pixels that have its place to the ground truth class but the organisation method has futile to categorise them into the appropriate class. The errors of omission are revealed in the columns of the confusion matrix. In the confusion matrix instance, the settlement class has a total of 1,524 ground truth pixels where 1,591 pixels are classified correctly and 5.83 settlement ground truth pixels are classified incorrectly. The ratio of the number of pixels classified incorrectly by the total number of pixels in the ground truth class forms an error of omission. For the Grass class the error of omission is (5.83 / 1,524) * 100 which equals 0.38%.

- Commission: Errors of commission characterise pixels that have its place to another class that are branded as fitting to the class of interest. The errors of commission are shown in the rows of the confusion matrix. In the confusion matrix instance, the settlement class has a total of 2,702 pixels where pixels are classified correctly and 2,700 other pixels are classified incorrectly as settlement (2,950 is the sum of all the other modules in the settlement row of the confusion matrix). The ratio of the number of pixels classified incorrectly by the total figure of pixels in the ground truth class forms an error of commission. For the settlement class the error of commission is (250 / 2950) which equals 8.47 %.

- Kappa Coefficient: The kappa coefficient (κ) is alternative measure of the correctness of the classification. It is calculated by multiplying the total quantity of pixels in all the ground truth classes (*N*) by the sum of the confusion matrix diagonals, subtracting the sum of the ground truth pixels in a class times the totality of the classified pixels in that class summed over all classes, and dividing by the total quantity of pixels squared minus the sum of the ground truth pixels in that class times the sum of the classified pixels in that class summed over all classes. The formula is giving by equation (a):

$$K = \frac{N\sum_{i=1}^{r} Xii - \sum_{i=1}^{r}(x_{i+} * x_{+i})}{N^2 - \sum_{i=1}^{r}(x_{i+} * x_{+i})} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(a)}$$

Where *r* is the number of rows, x_i is the number of observations in row *i* and column *i*, x_{i+} and x_{+i} are the marginal totals of row and column, and *N* is the total number of observed pixels (Congalton, 1991; Firdaus, 2014).

Every error in the cataloguing is an omission from the accurate grouping and a commission to an incorrect grouping.

The accurateness valuation for modification discovery is predominantly problematic due to complications in gathering unfailing time-based field-based datasets. Because of this, much preceding modification discovery investigations do not have quantitative examination of the investigation outcomes. Though standard accurateness valuation methods were mainly established for single date remotely sensed data, the error matrix-based accuracy valuation technique is still appreciated for an assessment of variation discovery outcomes. Therefore, selection for measuring the accurateness of modification discovery involves more time and hard work.

Kappa can be used as a measure of agreement between model forecasts and authenticity (Congalton, 1991) or to be strongminded of the standards delimited in an error matrix represents an outcome meaningfully improved than random (Jensen, 1996). It is the discrete multivariate technique for the expression of the overall accuracy by the comparison of two sources of data, that is, how much classification differ from a random matrix

2.8 Monitoring of Urban Growth Patterns with Remote Sensing

Analysis of Urbanisation processes with Remote Sensing has been studied by several authors (Moeller ,2004; Joshi, and Suthar, 2002; Yuan, *et al.*, 2005; Huang, *et. al*, 2007; Jat, *et. al*, 2008; Gadal, 2009; Bhatta, *et. al*, 2010; Saravanan and Ilangovan, 2010; Belal and Moghanm, 2011; Rahman, *et. al*, 2011; Rahman, *et. al*, 2012; Sharma and Joshi, 2013;). Multispectral satellite images such as Landsat 5 Thematic mappers (TM), Landsat 7 ETM+, Kompsat-2 high spatial resolution image and Spot 3 XS have been severally used for this purpose.

Satellite images gave a systematic view of spatial and territorial transformations and localization of possible areas of land use conflicts as well as predict the future urban extensions. The increase of the radiometric differentiation between urban objects and the geographic environment by local statistic filters and the fusion of the different filtered spectral bands or the automatic classification for settlement recognition were followed by the urban object extractions by structural segmentation. These results were used for image analysis and processing consisting of modelling the urban growth and its direct consequences in rural areas around the city.

The map settlements made at different dates were combined by arithmetic calculus to result in a map of urban land cover changes, showing the dynamic of urban sprawling and dispersion into rural spaces. The spectral image analyses of land cover maps permit prediction of future urban extensions as a geographical indicator for simulating future urban growth areas. The use of high-resolution multispectral satellite images as Kompsat-2 (16 m^2) and multispectral medium spatial resolution Spot-3 (400 m^2) make possible the identification of settlements‟ types by combining differently filtered images, processed with convolution calculus.

Land use and land cover change analysis revealed that built-up areas have increased drastically over the study periods. The agriculture land and open land have transformed into built-up areas, indicating the sprawl growth within the urban agglomeration. The overall result shows that urban expansion is not compact in nature and it is an evidence of concentration of sprawl growth over the municipalities. The analysis of long-term remote sensing imagery enabled an indepth monitoring of urban growth pattern. Based on this investigation growth indicator have been developed for a parameterization of development.

CHAPTER THREE

MATERIALS AND METHODOLOGY

The research was conducted on the Ga Municipality and its environing located in the Greater Accra Region of Ghana. Greater Accra Region is in the southern part of

Ghana and bounded by Central Region in the West, Eastern Region to the North, Volta Region to the East and the Gulf of Guinea to the South (Figure 3.1). The Ga Municipalities were chosen for the project because it is one of the municipalities experiencing rapid expansion, in the form of rapid Urbanisation which has implications for the environment, ecosystem, air pollution, water quality and wellbeing of people who depend on the resources within the metropolis and its environing towns.

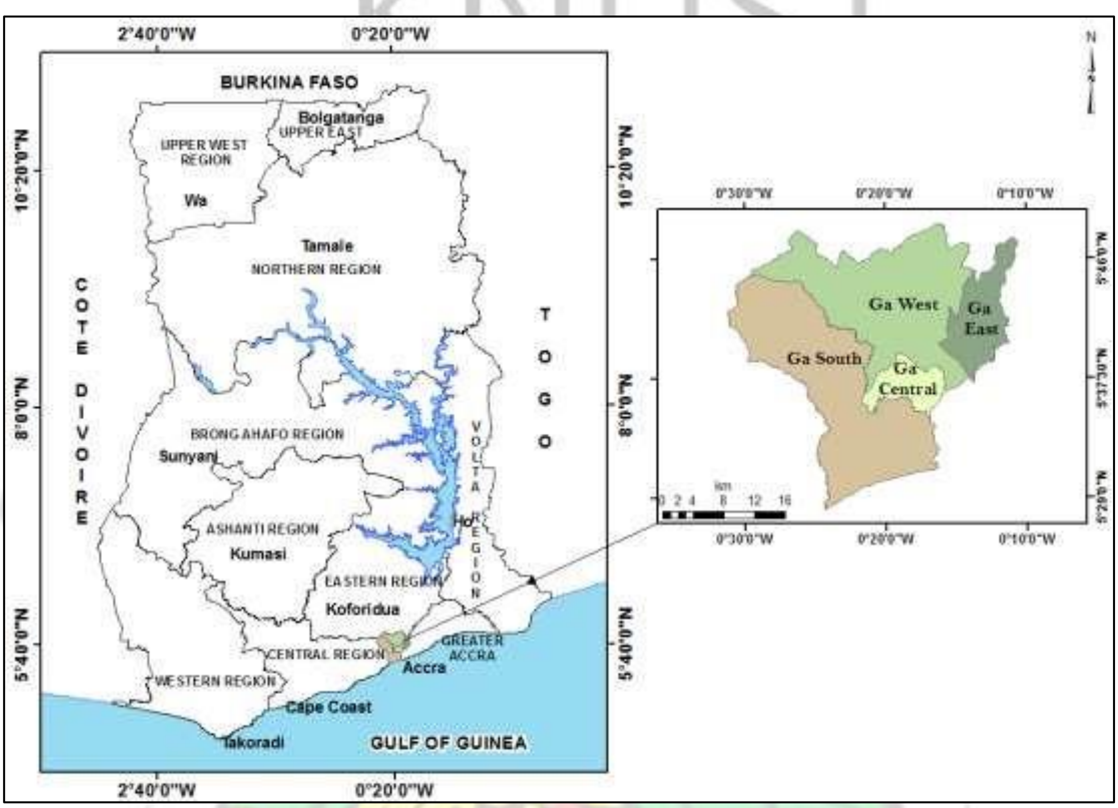


Figure 3.1 Study Area

3.1 Data

The data used in the investigation were satellite images and auxiliary data. Auxiliary data include ground truth data for the land cover/ use classes, airborne satellite imagery and topographic maps. The ground truth data were in the form of orientation data using Goggle Earth Imagery; very high-resolution imagery for Greater Accra Region from 2000 to 2016 was used for image cataloguing and overall accurateness valuation of the organisation results calculated. Topographic maps were also used for analysis for satellite images on 1986 and 1991. Landsat data were attained from the USGS Earth Resources Observation and Science Data Centre. Details of the satellite imageries together with the acquisition date are shown in Table 3.1. All the datasets are orthorectified and registered to a common coordinate system, UTM zone 30N with WGS 84 datum (Figure 3.3). Population census data was obtained from the Ghana Statistical Service (1986, 1991, 2003 and 2016) **Appendix A**.

This data was thus used to analyse the association between urban growth and population development.

Table 3.1. Imagery Attributes: Appendix B

Acquisition date	Sensor	Spatial Resolution	Path/Row	Landsat	Number of Bands	Radiometric Resolution
22nd Dec,1986	Multi-Spectral Scanner	30m	193/56	Landsat 5	7	8 bits
10th Jan, 1991	Thematic Mapper	30m	193/56	Landsat 4	7	8 bits
12th Feb, 2003	ETM+	30m	193/56	Landsat 7	7	16 bits
1st Dec, 2016	ETM+	30m	193/56	Landsat 7	7	16 bits

3.2 Methodology

The methodology is summarised in the methodology flow chart Figure 3.2

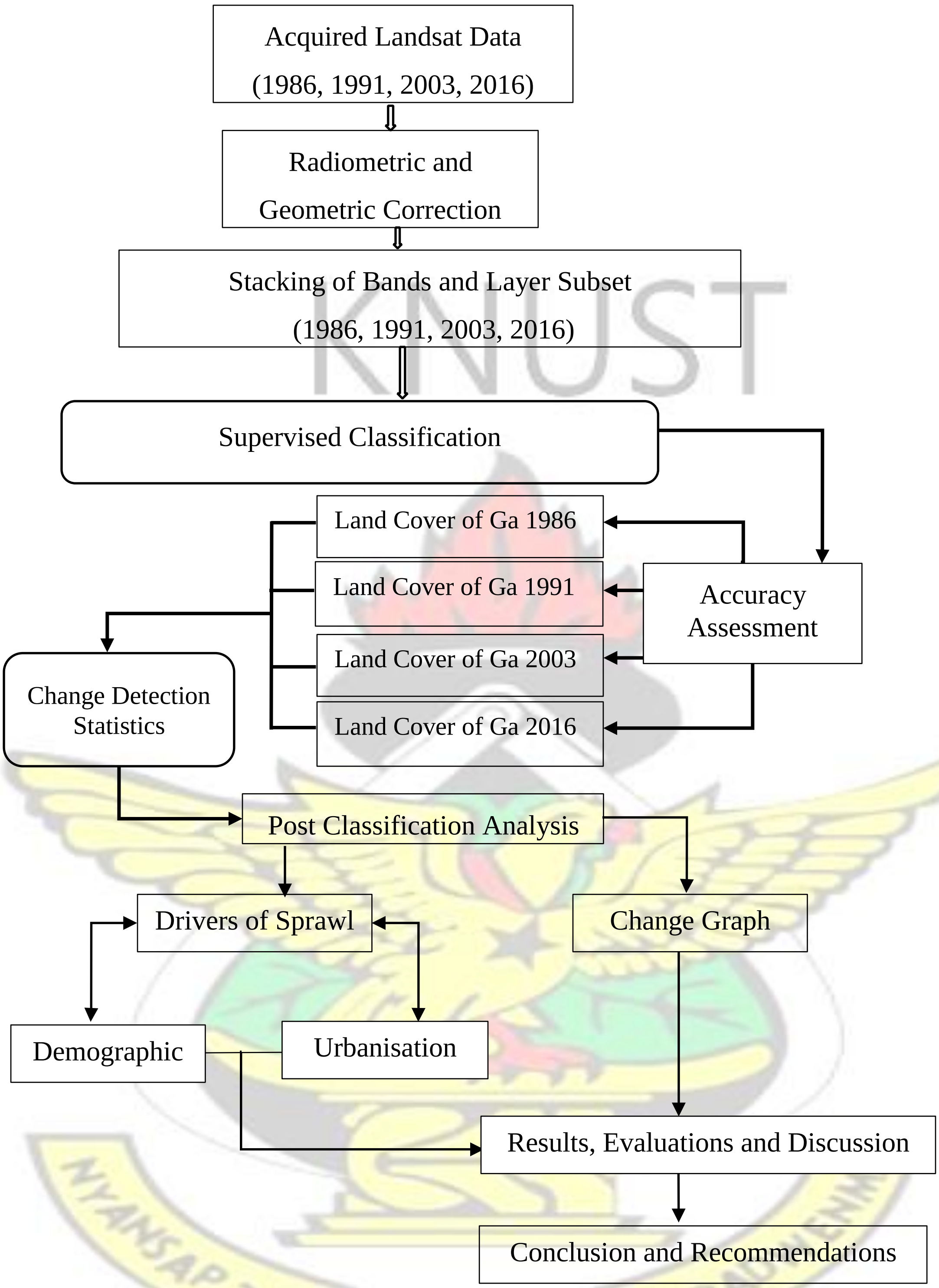


Figure 3.2 Methodology flowchart

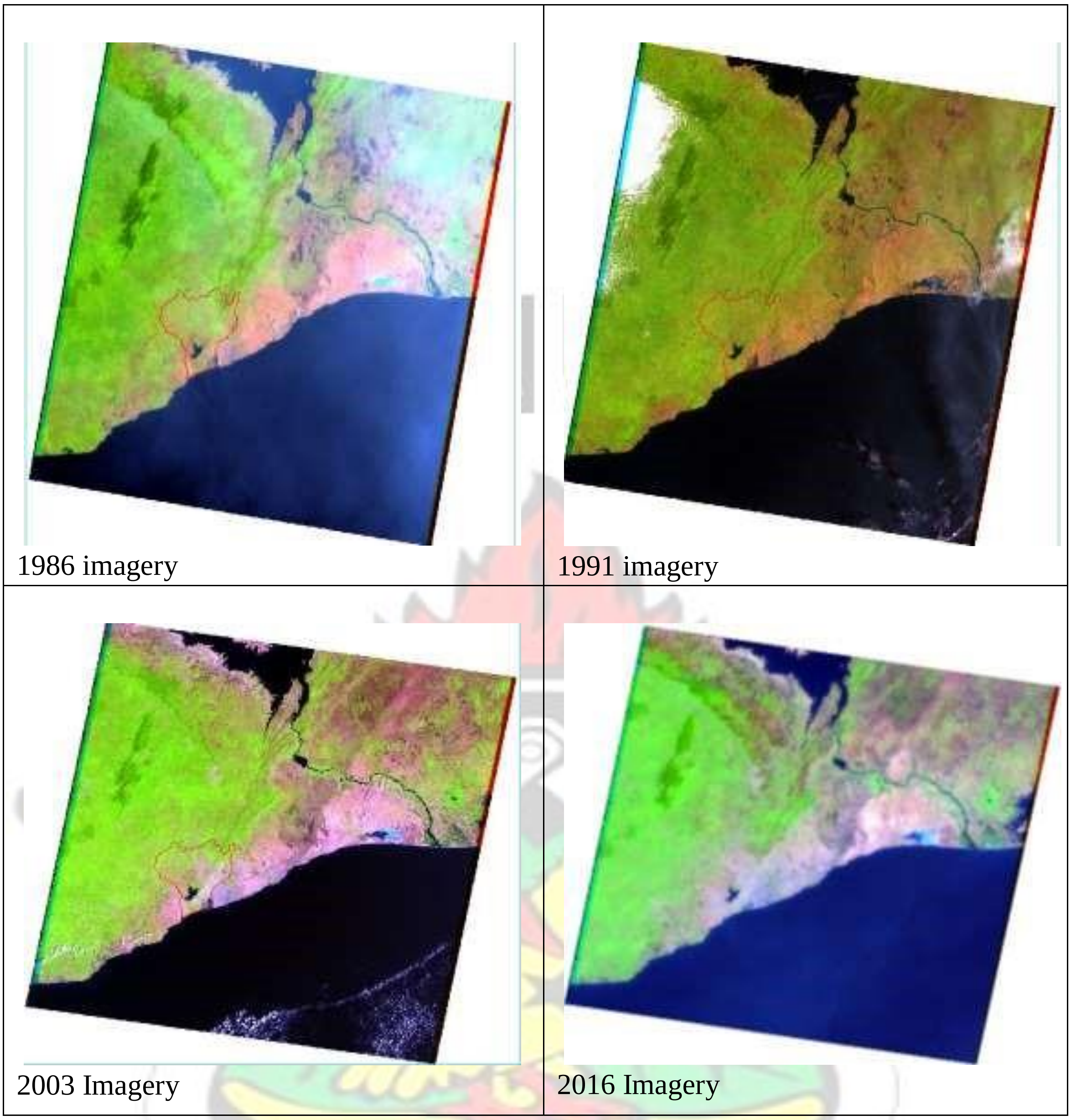
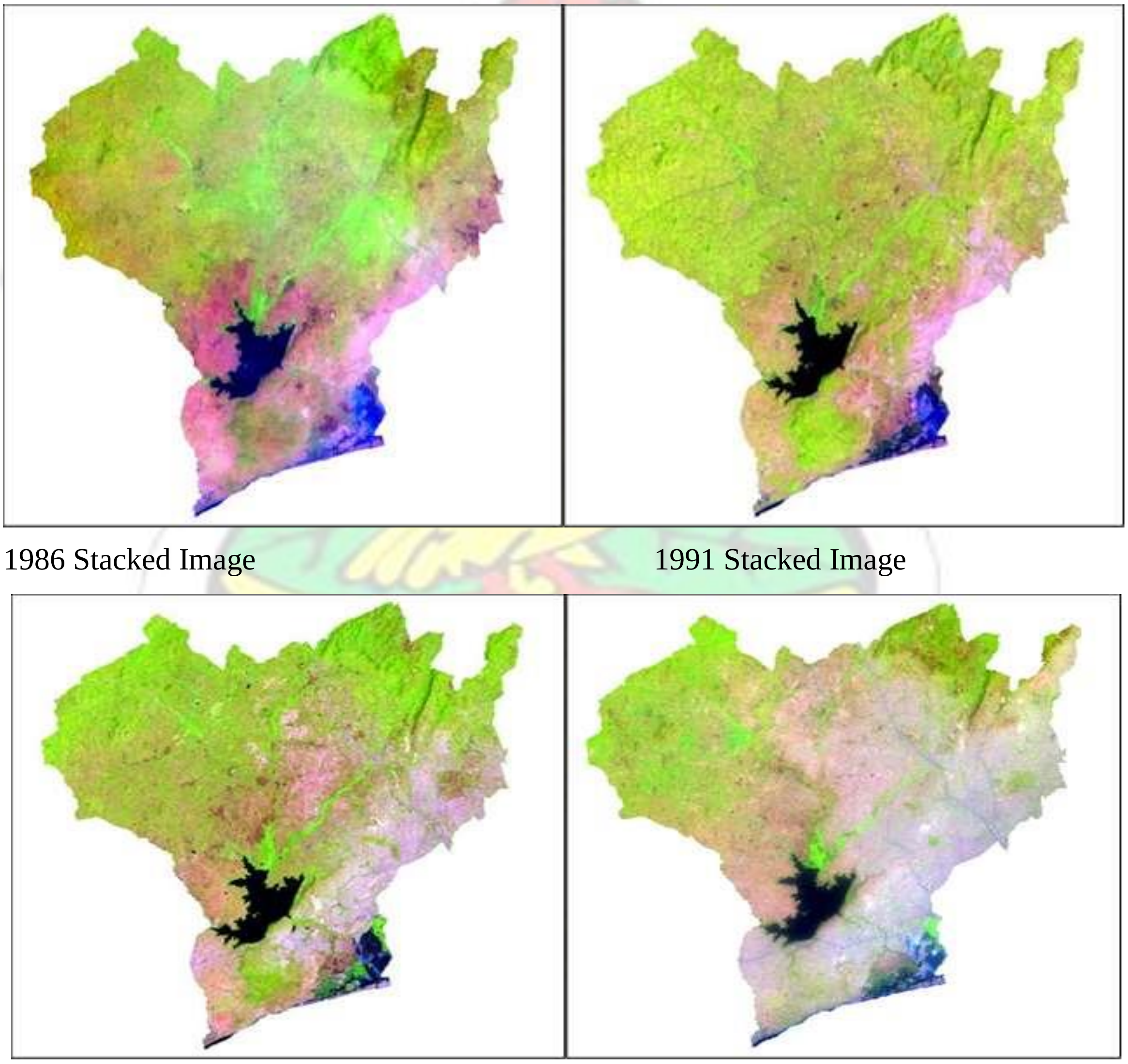


Figure 3.3 Land Sat Images from 1986 to 2016 of Study Area

3.3 Image Pre-Processing

Satellite image pre-processing prior to the discovery of modification is immeasurably desirable and has a key exclusive objective of creating a more direct relationship amid the developed data and biophysical singularities (Coppin, *et al.*, 2004). The sections were carefully chosen to be geometrically modified, standardised and detached from their dropout. These data are stratified into „regions", where land cover types within a region have alike spectral belongings. Other image enhancement methods like histogram equalization are also completed on each image for refining the superiority of the image. With reference to survey of Ghana topographic maps (0501B3, 0501B4) **Appendix C** of 1: 50,000 scale and urban strategy map gotten from the Lands Commission the study area was Demarcated. Ground truth data were modified for each single classifier formed by its spectral signatures for creating succession of organisation maps. The software, Environment of Visualizing Images (ENVI) and ArcGIS were used to assess image pre-processing. Layer stacking for all imageries was carried out followed by image registration. Finally, seamless mosaic device in ENVI was used for mosaicking images with colour steadiness and all mosaicked images were clipped to the study area and sub-setting of the image based on Region of Interest (ROI) (Figure 3.4).



1986 Stacked Image | 1991 Stacked Image

2003 Stacked Image | 2016 Stacked Image

Figure 3.4 Stack Images of the Study Area

3.4 Classification

Multispectral image classification is used in remote sensing to catalogue all pixels in an image to produce thematic maps of the current land cover (Levin, 1999). All satellite data were examined by assigning per-pixel signatures and differentiating the classes into five modules on the bases of the specific Digital Number (DN) value of different scenery fundamentals. The outlined modules are Water Body, Dense Vegetation, Grassland/Shrubs, Settlements and Open Areas (Table 3.2).

Table 3.2. Classes delineated based on supervised classification

Numbers	Class names	Description
1	Water body	Rivers, lakes, ponds reservoirs and open water.
2	Dense vegetation	Deciduous forest, mixed forest and coniferous forest.
3	Grassland/Shrubs	Farms, natural vegetation, spar vegetation and plantation
4	Settlements	Residential, commercial, industry, roads and mixed urban
5	Open areas	Exposed soils, landfill sites and areas of active excavation.

For each of the determined land cover/land use type, training models were nominated by demarcating polygons around characteristic locations. Spectral signatures for the individual land cover categories resulting from the satellite images were chronicled by using the pixels bounded by these polygons. A suitable spectral signature is the one certifying that there is „minimal confusion" among the land covers to be recorded (Gao and Liu, 2010). After that, maximum likelihood algorithm was used for the supervised classification of the images. The algorithm will categorise the image based on the training sets (signatures) provided by the user based on his field acquaintance.

To progress organisation correctness and decrease of misclassification, post organisation modification was therefore used for uncomplicatedness and efficiency of the technique (Harris and Ventura, 1995). After image organisation, a 3×3 majority filter is functional to eradicate the noise to advance organisation accurateness (Wang *et. al*., 2015). Additionally, using data having average spatial resolution such as that of Landsat mixed pixels are a mutual problem (Lu and Weng, 2005); particularly for the urban exteriors that are a varied combination of topographies principally including buildings, grass, road, soil, trees, water (Jensen and Im, 2007). The problematic nature of mixed pixels was addressed by pictorial clarification. For improvement of organisation accurateness and therefore the superiority of the land cover/land use maps formed, pictorial understanding was very significant. Thus, pictorial examination, reference data, as well as local acquaintance, significantly enhanced the outcomes attained using the supervised algorithm. Figure 3.5 shows the final classified maps obtained for the various years in the study area.

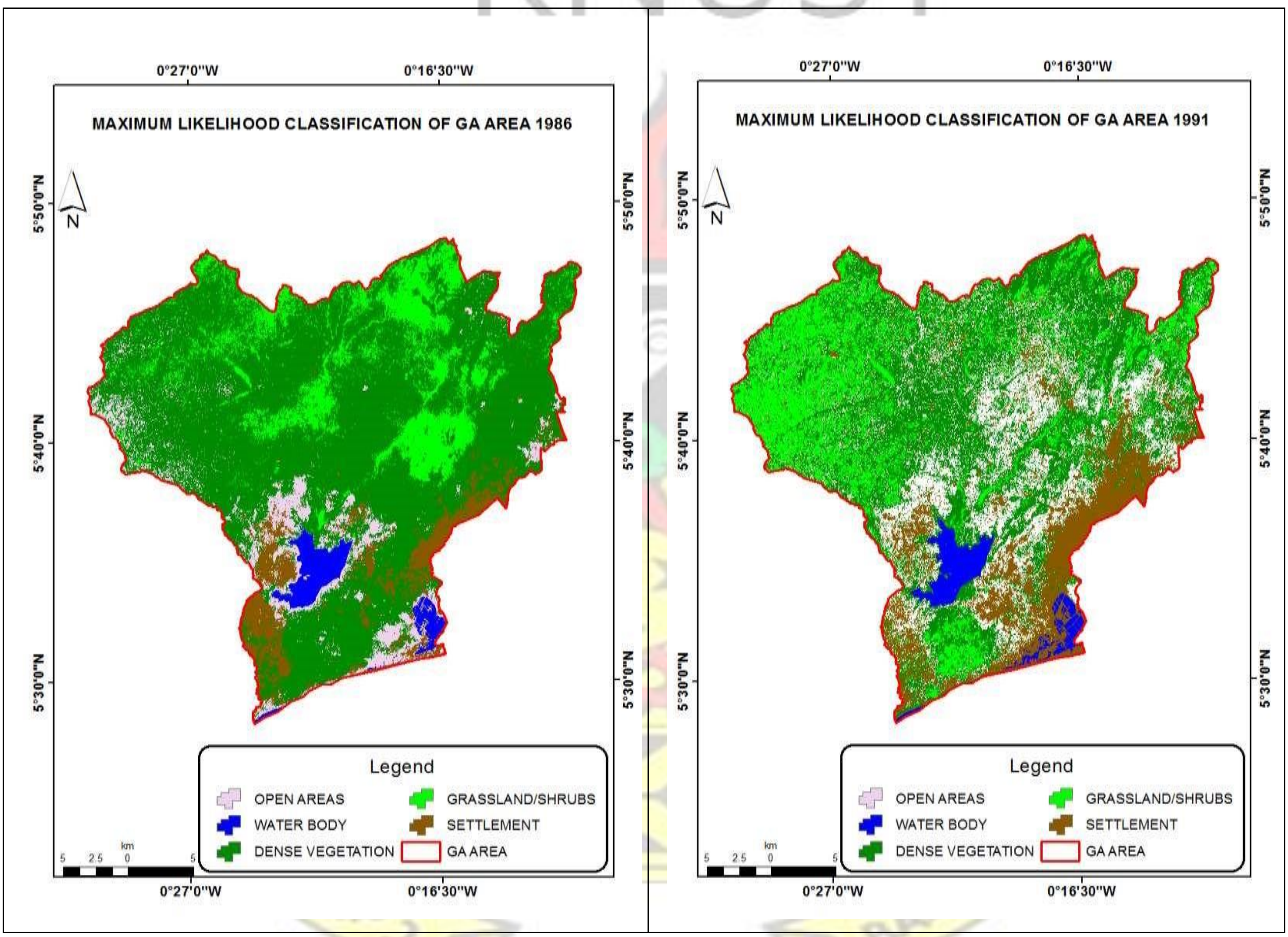


Figure 3.5 Classified Images for 1986 and 1991

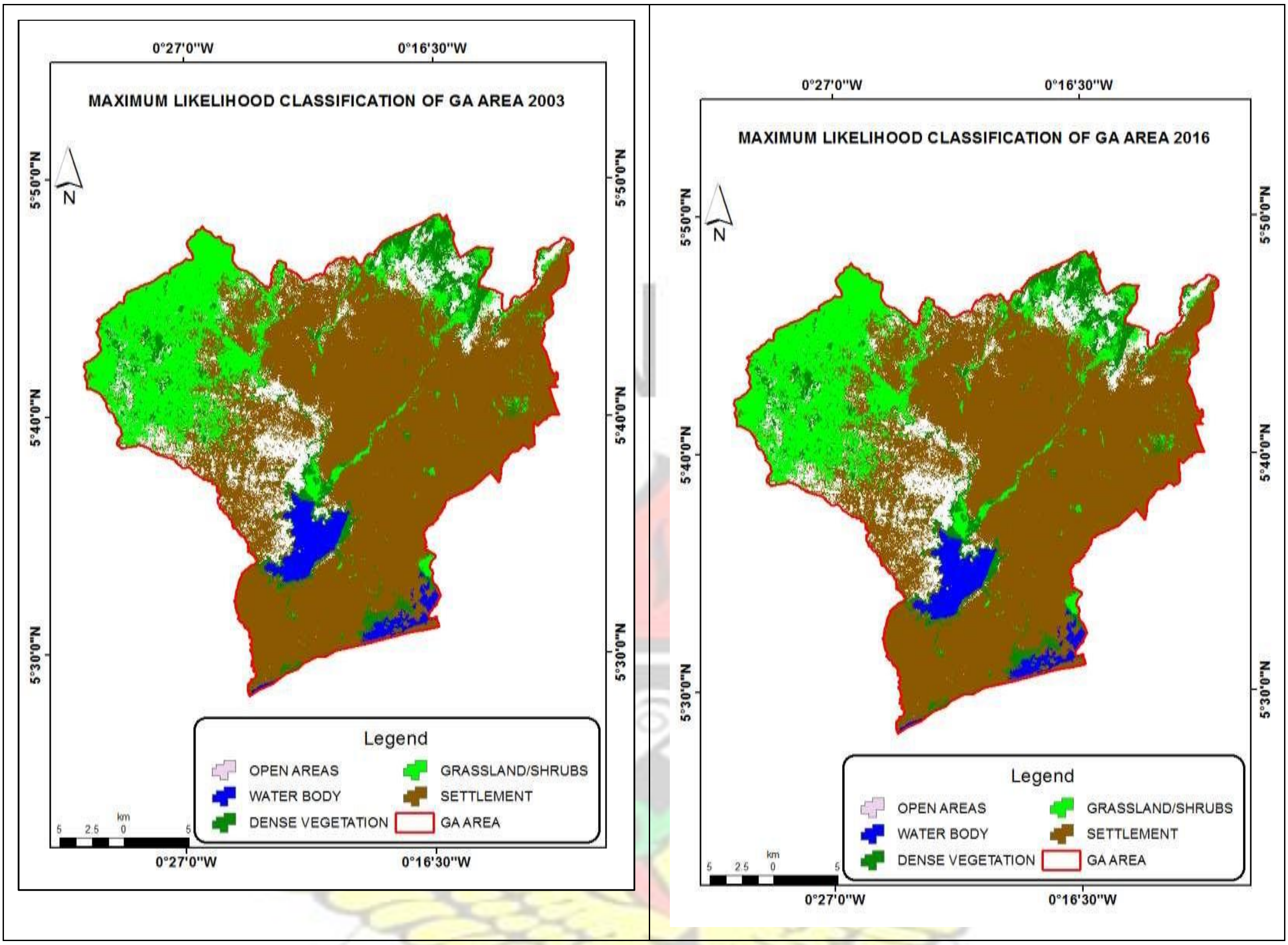


Figure 3.6 Classified Images for 2003 and 2016

3.5 Change Detection Analysis

Modification discovery investigation defines and measures changes between images of the same section at different periods. The classified images of the four dates were used to compute the area of dissimilar land covers and detect the variations that are taking place in the duration of data. To investigate variations in urban land cover during the past 30 years, post classification assessments and figures are used. Post classification has been effectively used by several investigations in urban location due to its effectiveness in distinguishing the location, nature and frequency of variations (Hardin, *et al.,* 2007). Thematic maps (Alphan, *et al.,* 2009) are then assembled founded on distinctly classified multi-temporal imagery and assessment amid the classified images are applied in terms of per-pixel basis. This method affords comprehensive „from-to" information for each class in the procedure of growth (Jensen, 2004). Since we wished to scrutinise urban development forms, the classified modules were amalgamated into the following two main types before applying the modification discovery procedure: the urban area and the non-urban area, which can circumvent the effects of misclassification or organisation errors. The Urban development is then investigated based on bi-temporal and multi-temporal change detection maps.

3.6 Accuracy Assessment

Kappa is a degree of treaty between predefined manufacturer evaluations and user allotted. It is computed by a formula: K= P (B) - P (C) / 1-P (E). Where P (B) is the number of times the ***k*** rates agree, and P (C) is the amount of times the ***k*** rates are predictable to agree only by coincidental (Gwet, 2002; Viera and Garret, 2005). **Appendix D.**

The overall accuracy for the 2003 classified image was 95.50%, with a kappa coefficient of 0.94. all other classes had accuracies above 86%. Also, the 2016 data had an accuracy overall classification of 98.60%, with a kappa coefficient of 0.98 and all other classes had accuracies above 96.65%. The accuracy assessment was carried out on 2003 Landsat imagery using a total pixel count of 1,836 for water, 1,596 was accurately classified as Water body whereas 2 and 238 was misclassified as Grassland/Shrubs and Settlements respectively. Secondly with a total pixel count of 1338 for Grassland/shrubs, 1215 was rightfully classified for Grassland/shrubs whereas 121 and 2 was misclassified for Dense Vegetation and Settlements respectively. Again, with a total count of pixels of 1353 for Dense Vegetation; 1345 was accurately classified for Dense Vegetation and 4, 3 and 1 was omitted to Grassland/Shrubs, Open areas and Settlements respectively. Furthermore, Open Areas had a total pixel count of 1486 but 1467 was classified correctly whereas 2, 8 and 9 were pixels that were misclassified for Dense Vegetation and Settlements respectively. Finally, out of a total pixel counts of 2702, 2700 was correctly classified for Settlements whereas 1, 1 was omitted for Grassland/shrubs and Dense Vegetation respectively.

The 2016 Landsat imagery accuracy assessment also had a total pixel count of 1524 for Settlements and all was accurately classified as Settlements. Secondly, with a total pixel count of 1834 for Grassland/shrubs; 1828 was rightfully classified for Grassland/shrubs whereas 6 pixels were misclassified for Dense Vegetation. Thirdly, with a total count of pixels of 1052 for Dense Vegetation; 1036 was accurately classified while 13 and 3 were omitted to Grassland/shrubs and Settlements respectively. Furthermore, total pixel counts of 1709, 1656 was correctly classified for Water Body while 50 and 3 pixels were misclassified for Settlements and Dense Vegetation respectively.

Finally, Open Areas had a total pixel count of 537 but 519 was classified correctly; losing 14 and 4 pixels for Settlements and Dense Vegetation respectively. All accuracy assessment was based on goggle for ground truth data and visual interpretation verification. Accuracy assessment were determined for 1986 and 1991 using topographic sheets of such periods, since goggle imagery were not accessible at those periods.

3.7 Demographic Data

Demographic data for the study was obtained from the 1986, 1991, 2003 and 2016 (All projected census data) of Ghana Statistical Service. Population figures are based on that of localities located within the delineated area of the study area. Population densities (total population divided by the total area) were then calculated for the years 1986-2016. Population density has been used as a measure of the intensity of Urbanisation (Yin, *et al.,* 2005). All population for the various years was projected using a mathematical formula by (Ghana Statistical Service), assuming a constant fertility rate, migration rate and mortality rate.

Table 3.3. Population Projection Formula

Formula	Where

The Rate of Growth, *r* is also calculated as shown below table (3.4)

Table 3.4. Formula for Growth Rate

Formula	Where
$r = [In(\rho_1/\rho_2)] \div n$	$\rho_1 = Population\ of\ the\ Current\ Census$ $\rho_2 = population\ of\ last\ census\ before\ current$ $n = number\ of\ years\ between\ \rho_1\ and\ \rho_2$ $census$ $r = rate\ of\ growth$

3.8 Urban Expansion Statistical Analysis

Wang *et. al,* (2015) designated that mutually urban growth rate and urban growth spatial assembly can be variable across periods. In this research, we regulate the rate of urban growth using the Land Use Change Index (LUCI) offered by (Haregeweyn *et. al,* 2012), which can be an important index to evaluate urban growth.

$ChangeIndex = \left(\frac{V_n - V_m}{K \times V_m}\right) x100\%$. Where V_n characterises the area of urban at Time n; V_m characterises the area of urban at Time m; K is the time amid Time „n‟ and Time „m‟. LUCI then can define yearly rate of urban areas if K‟s unit is in years. Subsequently, the relationship amid the urban areas and populace can be computed using Pearson correlation coefficient investigation (Wang *et. al,* 2015).

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results

The classification approach yielded cover maps of the study area for the years 1986 ,1991, 2003 and 2016. Figure 4.1 shows the thematic classified map using maximum likelihood classification for 1986.

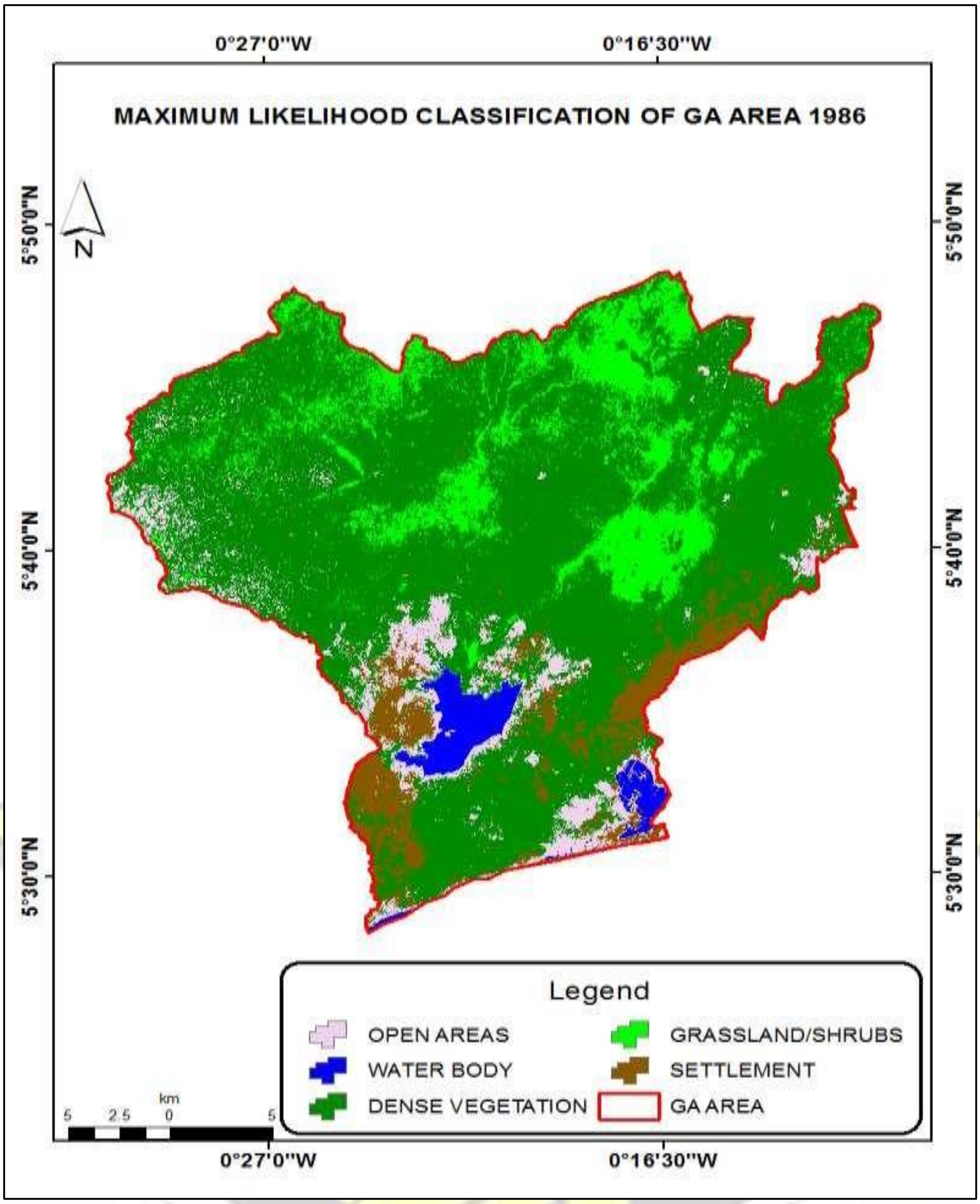


Figure 4.1: LULC within the study area in 1986

The distribution by size of each class in 1986 is given in Table 4.1 and shows that Dense vegetation covered 69.07 percent of the total land space with Grassland covering 13.52 percent, open areas 7.41 percent and settlements covering only 7.12 percent of the total land space with Water Body covering 2.88 percent. The distribution by area is represented in Figure 4.2 as a bar chart.

Table 4.1: Distribution of 1986 LULC Classes

Class	Area (km²)	Area (%)
Water Body	22.36	2.88
Dense Vegetation	537.16	69.07

Grassland/ Shrubs	105.18	13.52
Settlements	55.40	7.12
Open Areas	57.62	7.41
Total	777.72	100

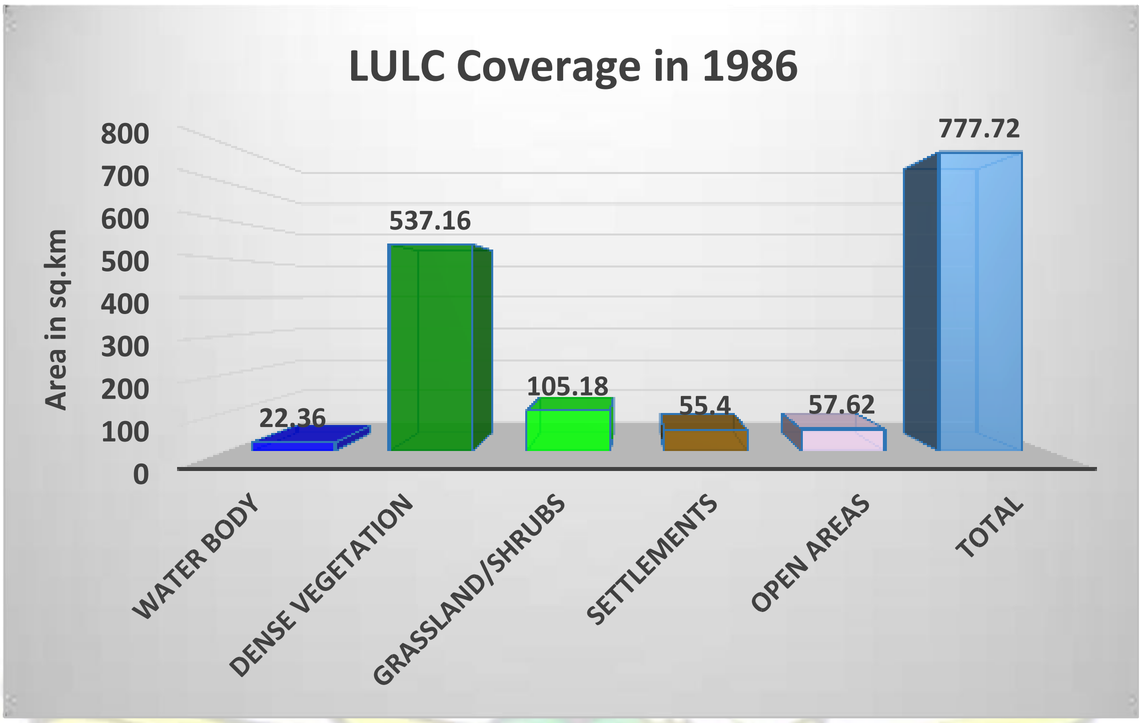


Figure 4.2: The Bar Chart Representation of 1986 Classification

In the 1986 Landcover map (Figure 4.2), dense vegetation covers a greater part of the study area, approximately 537.16 km² (69.07%). This is followed by Grassland/Shrubs land 105.15 km² (13.52%). Open Areas follows by 57.62 km² (7.41%) mostly scattered in smaller patches across the map. Settlements cover an area of 55.40 km² (7.12%) mainly intense in the east and western part of the study area.

Water bodies cover 22.36 km² (2.88%), found along river courses, marshlands and portion of the Densu River.

Figure 4.3 shows the thematic classified map using maximum likelihood classification for 1991. The analysis of distribution by area and percentages is shown in Table 4.2.

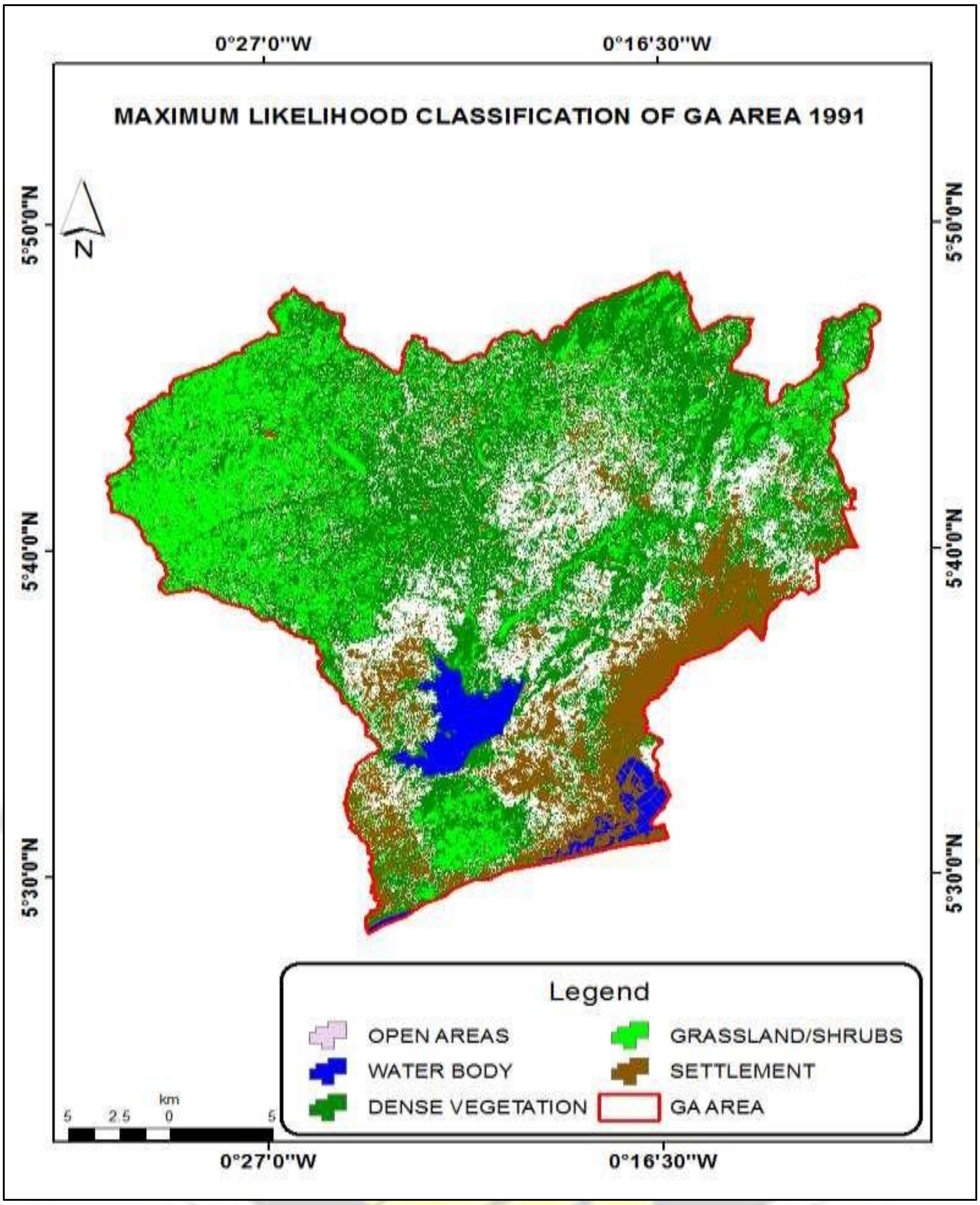


Figure 4.3: LULC within the Study Areas in 1991

In the 1991 Landcover map (figure. 4.3), Dense Vegetation had declined greatly within the study area, to approximately 323.84 km² (41.64%). This is followed by Grassland/shrubs of 151.56km² (19.49%), Open Areas increased to 153.33km² (19. 72%) with Settlements increasing to 124.55km² (16.01%) which gradually spread from East and West towards the south and with isolated settlements within the central portions of the map. Water Body also changed marginally upwards to 24.43km² (3.14%) from 1986 to 1991 (Table 4.2). These are represented in the bar diagram (Figure 4.4)

Table 4.2: Distribution of 1991 LULC Classes

Class	Area (km²)	Area (%)

Water Body	24.43	3.14
Dense Vegetation	323.84	41.64
Grassland/ Shrubs	151.56	19.49
Settlements	124.55	16.01
Open Areas	153.33	19.72
Total	777.72	100

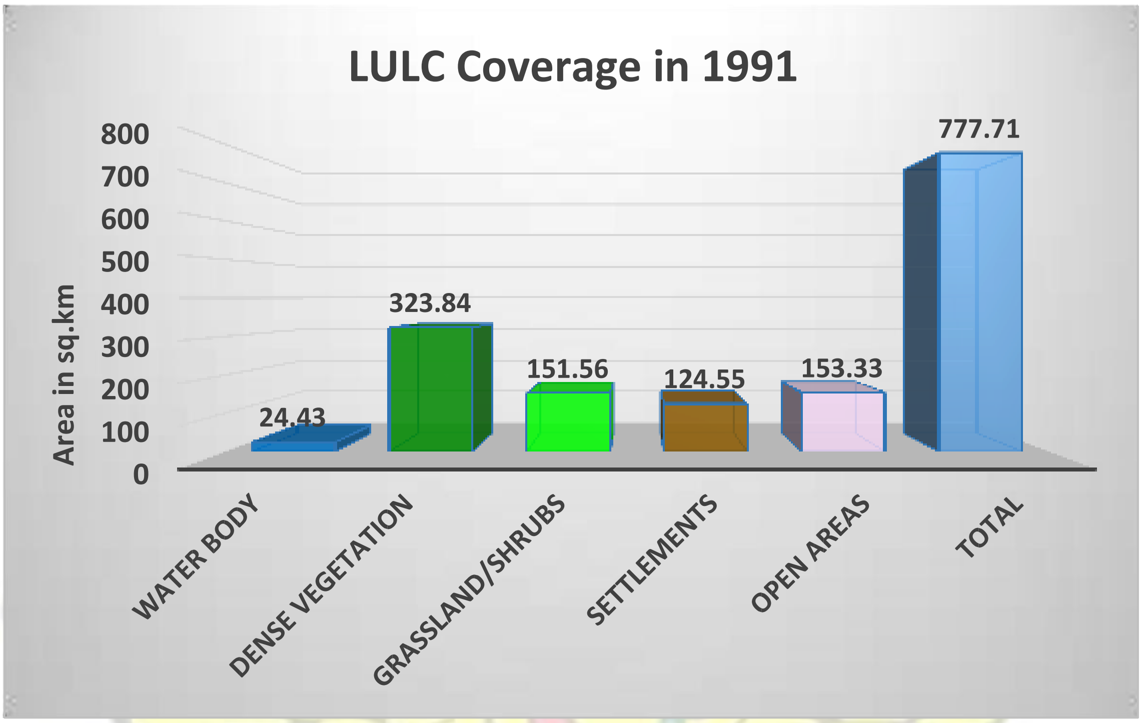


Figure 4.4: The Bar Chart Representation of 1991 Classification

In 2003, settlements‟ land occupied a greater part of the study area, approximately 310.22km² (39.89%) mainly concentrated from the eastern towards the south-western and scattered in the central part of the map (Figure 4.5). Settlement doubled within this period. Dense Vegetation, Grassland/Shrubs and Open Areas also decreased respectively by 216.15km² (27.79%), 133.85km² (17.21%) and 91.33km² (11.74%). Finally, Water Body increased to 26.17km² (3.3%), which could be due to the different timing of image acquisitions for that year. The analysis by area and percentages is given in Table 4.3 and represented in the bar diagram (Figure 4.6).

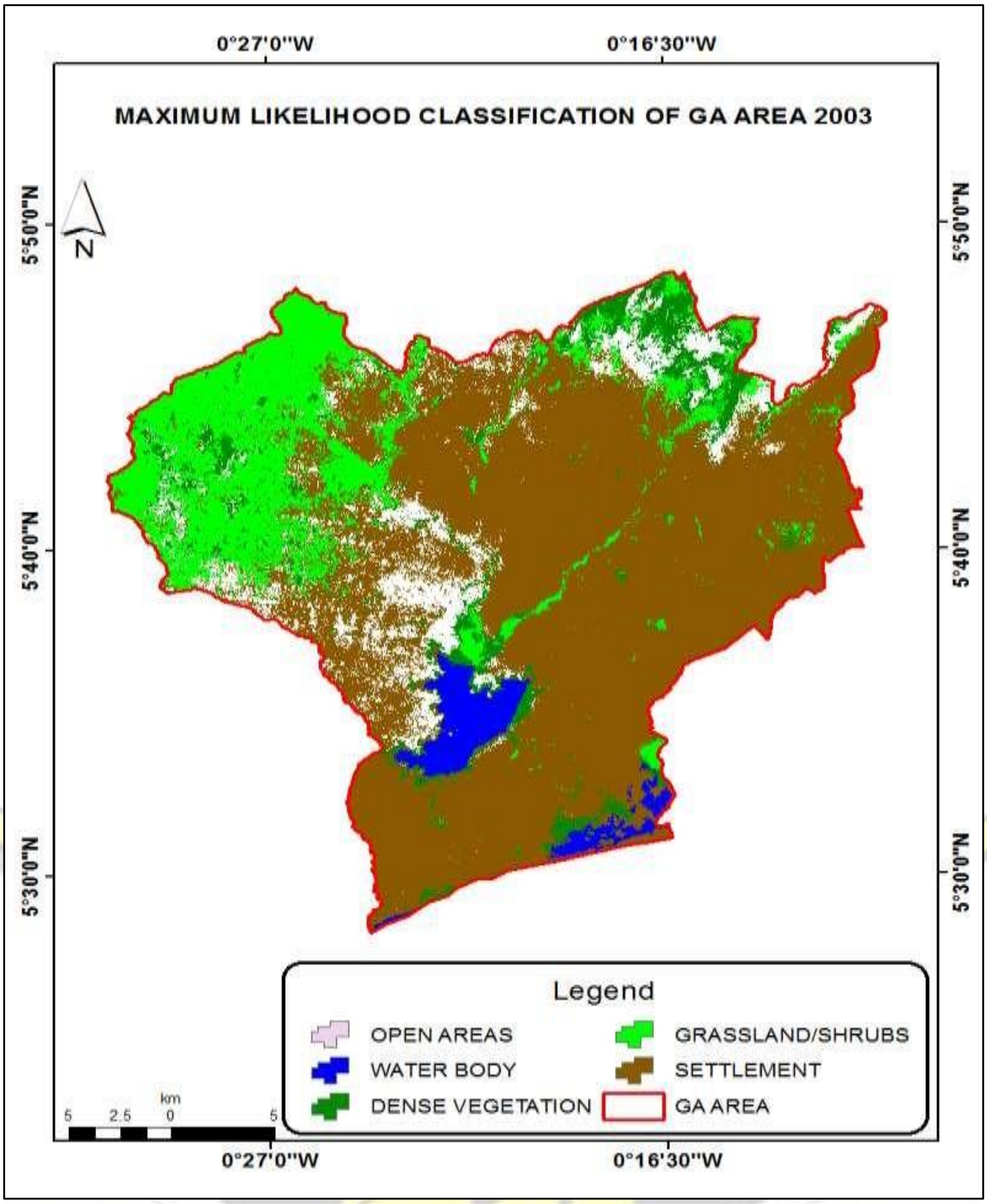


Figure 4.5: LULC within the study areas in 2003

Table 4.3: Distribution of 2003 LULC Classes

Class	Area (km²)	Area (%)
Water Body	26.17	3.37
Dense Vegetation	216.15	27.79
Grassland/ Shrubs	133.85	17.21
Settlements	310.22	39.89
Open Areas	91.33	11.74
Total	777.72	100

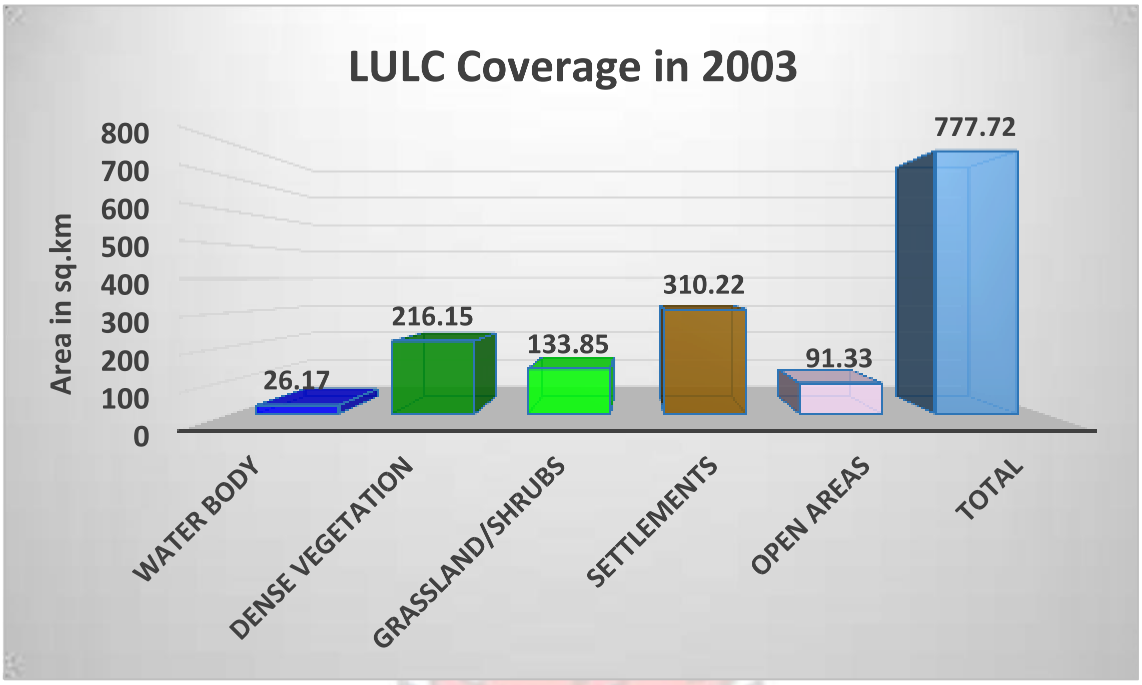


Figure 4.6: The Bar Chart Representation of 2003 Classification

In 2016, Settlements has increased significantly to 482.92km² (62.09%) representing more than half of the study area. It gained land from all other Landcover forms except Grassland/Shrubs which also gained marginally to cover 138.64km² (17.83%). Dense Vegetation reduced tremendously to 57.83km² (7.44%). Open Areas and Water Body also reduced respectively to cover 72.58km² (9.33%) and 25.74km² (3.31%) respectively (Figure 4.7). The distribution by size and percentages is shown in Table 4.4 and represented as a bar diagram in Figure 4.8.

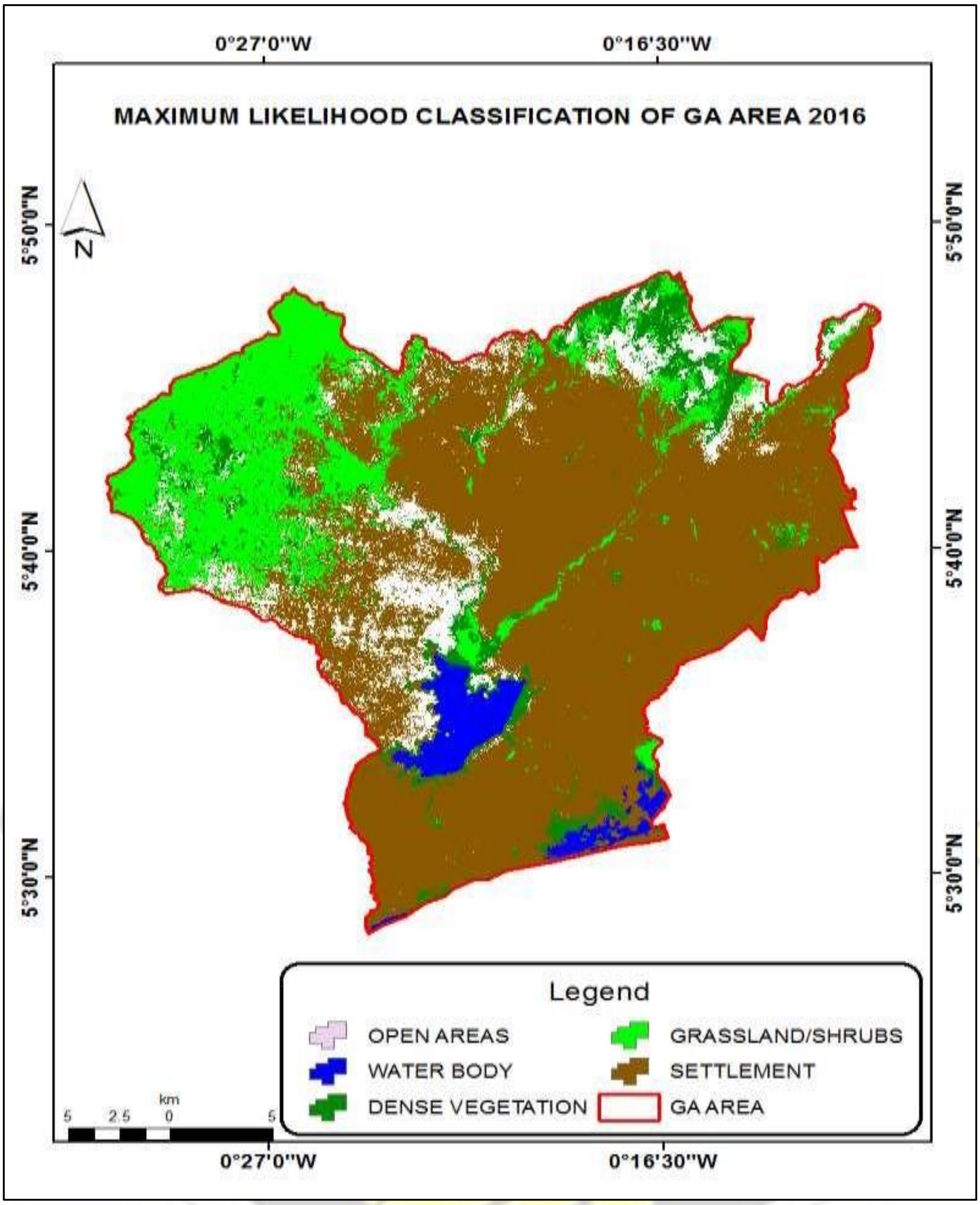


Figure 4.7: LULC within the study areas in 2016

Table 4.4: Distribution of 2016 Landcover Classes

class	Area (km²)	Area (%)
Water Body	25.74	3.31
Dense Vegetation	57.83	7.44
Grassland/ Shrubs	138.64	17.83
Settlements	482.92	62.09
Open Areas	72.58	9.33
Total	777.72	100

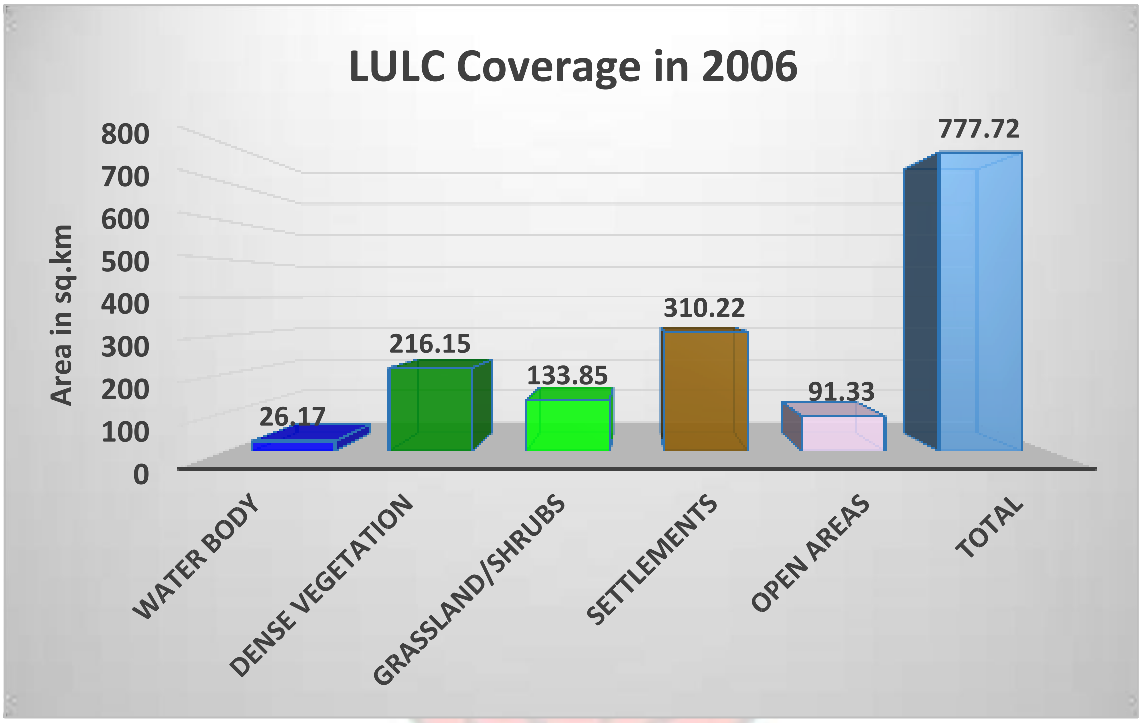


Figure 4.8: The Bar Chart Representation of 2016 Classification

4.2 Comparative Land Cover Changes over periods

This is the quantification of land cover classes that have changed within the years of study. It is the statistical changes that has occurred between 1986-1991, 1991-2003, 2003-2016 and finally the extent of change that has occurred between 1986-2016. It is distinguishably represented by graphs that reveal trends over the time scales of data (Table 4.5).

From 1986 to 1991, there was a declined change in the dense vegetation area from 69.07% of total study area to 41.64%. All other landcovers appreciated as a result of the loss/conversion of vegetation cover. For instance, the open areas gained from 7.41% to 19.72%, settlements from 7.12% to 16.01%, grassland/shrubs from 13.52% to 19.49%, water body from 2.88% to 3.14% in that order (Figure 4.9).

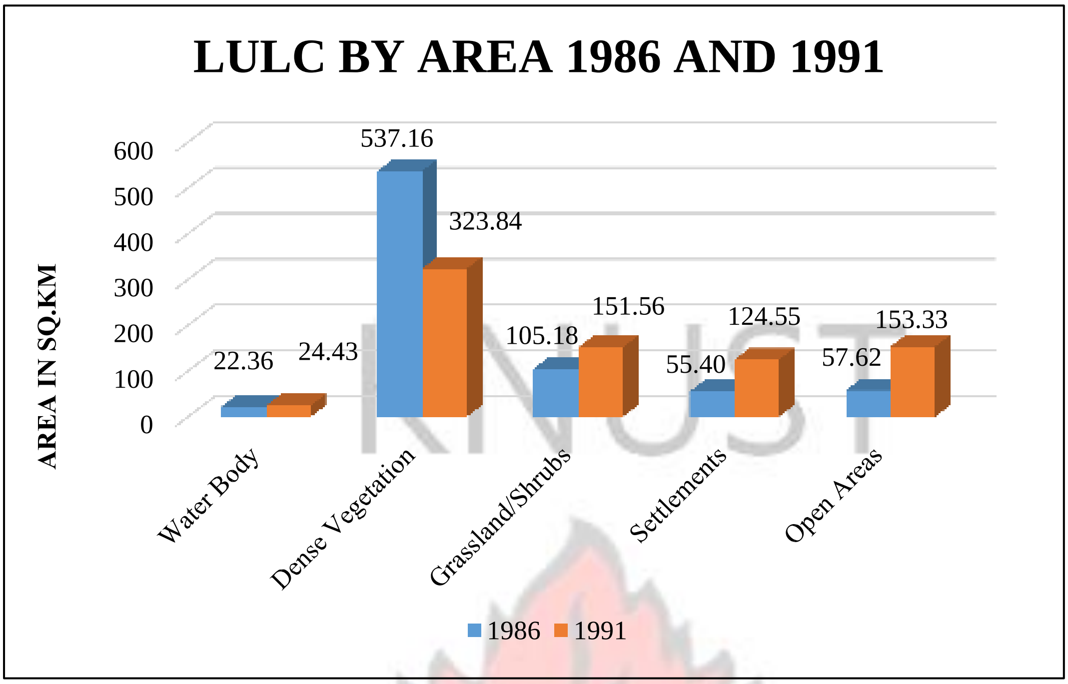


Figure 4.9: Bar Chart Representation of LULC for 1986 and 1991

Similarly, the landcover change between 1991 to 2003 showed Dense vegetation continuing its downward trend from 41.64% to 27.79%. This downward trend caused settlements to double within that period from 16.01% to 39.89% of total land cover. Water bodies also gained marginally from 3.14% to 3.37% of total coverage area. Open areas and Grassland/shrubs also declined from 19.72% to 11.74% and 19.49% to 17.21% respectively (Figure 4.10).

Table 4.5: Coverage by land Size for each LULC between 1986 to 2016

Class Names/years	**Area (Km²)**				**Area (%)**			
	1986	**1991**	**2003**	**2016**	**1986**	**1991**	**2003**	**2016**
Water Body	22.36	24.43	26.17	25.74	2.88	3.14	3.37	3.31
Dense Vegetation	537.16	323.84	216.15	57.83	69.07	41.64	27.79	7.44
Grassland/Shrubs	105.18	151.56	133.85	138.64	13.52	19.49	17.21	17.83
Settlements	55.40	124.55	310.22	482.92	7.12	16.01	39.89	62.09
Open Areas	57.62	153.33	91.33	72.58	7.41	19.72	11.74	9.33
Total	777.72	777.72	777.72	777.752	100	100	100	100

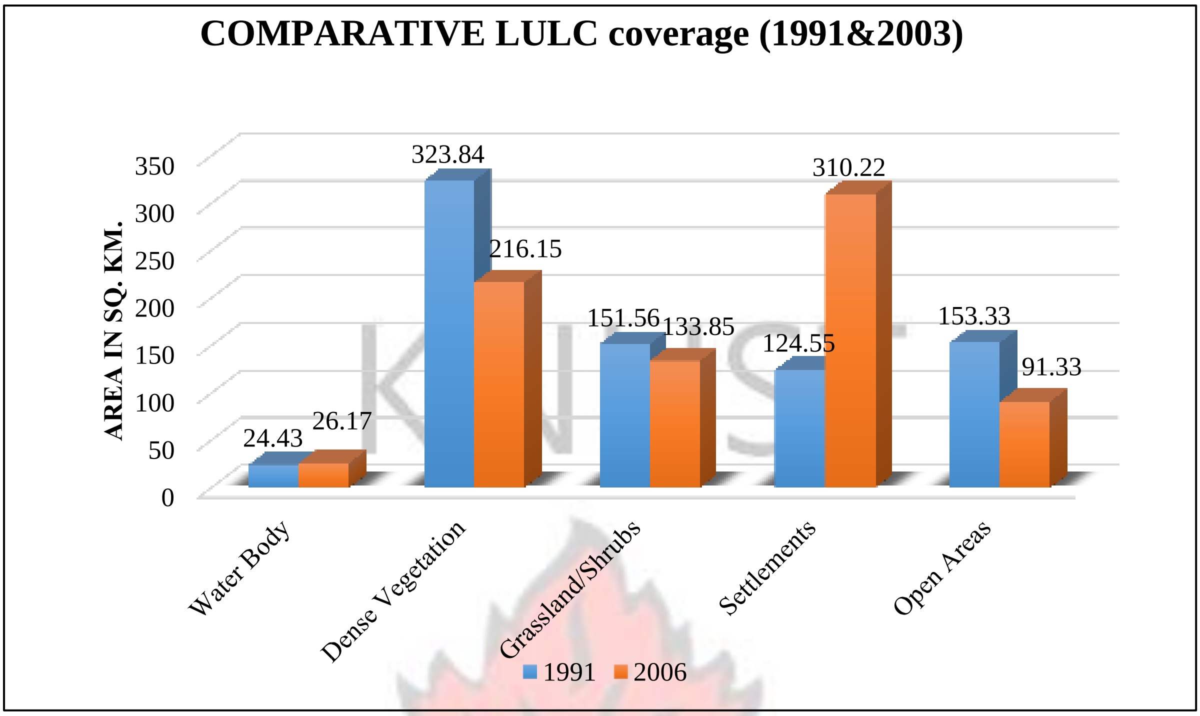


Figure 4.10: Bar Chart Representing LULC for 1991 and 2003

Between 2003 to 2016, Dense vegetation reduced drastically from 27.79% to 7.44% with Open areas and Water body also reducing by 11.74% to 9.33% and 3.37% to 3.31% whereas Settlement appreciated significantly from 39.89% to 62.09% and Grassland/shrubs from 17.21% to 17.83% (Figure 4.11).

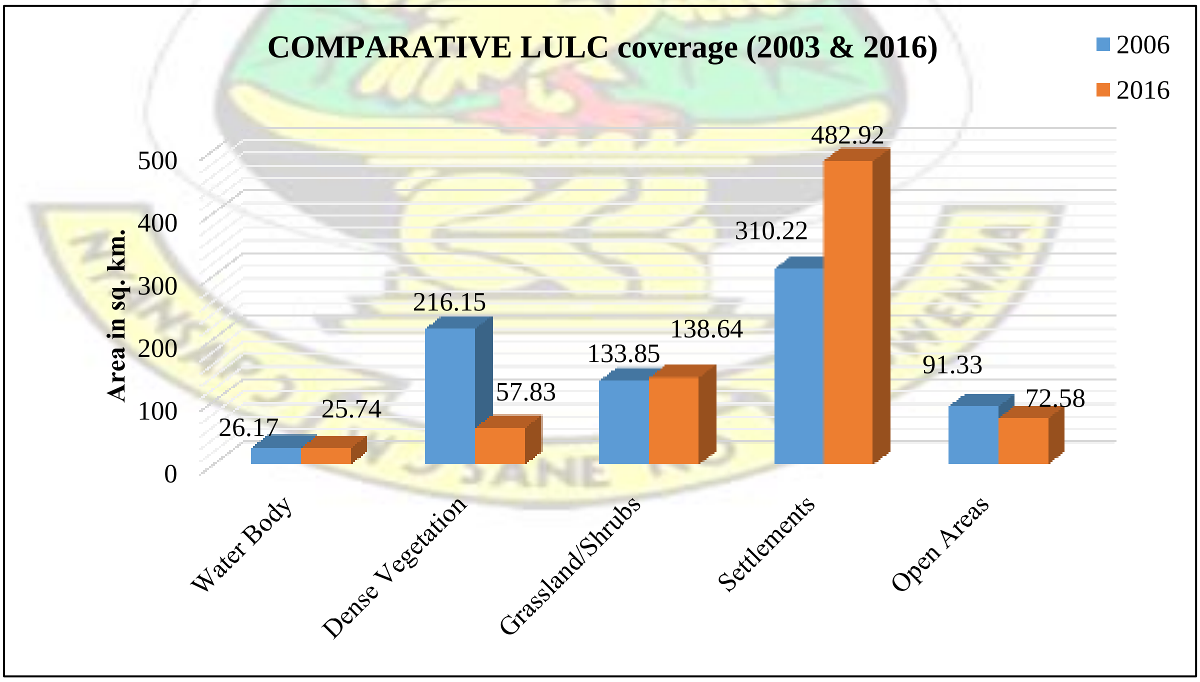


Figure 4.11: Bar Chart Representing LULC for 2003 and 2016

Figure 4.12 shows the comparative Landcover extents for 1986 and 2016. This comparison shows the extent of LULC conversion and transferences detected within the period of 1986 to 2016. The increase in settlements in the study area is clearly noticeable from the figure and indicates an increase in percentage coverage from 7.12% in the year 1986 to 62.09% in 2016. Most landcover have been converted to settlements. Also, Grassland/Shrubs, Open areas and Water Body have increased marginally by 13.52% to 17.83%, 7.41% to 9.33% and 2.88% to 3.31% respectively. Dense vegetation decreased significantly to settlement from 69.07% to 7.44%. Figure 4.13 shows the percentage distributions for each year studied for different LULC classes.

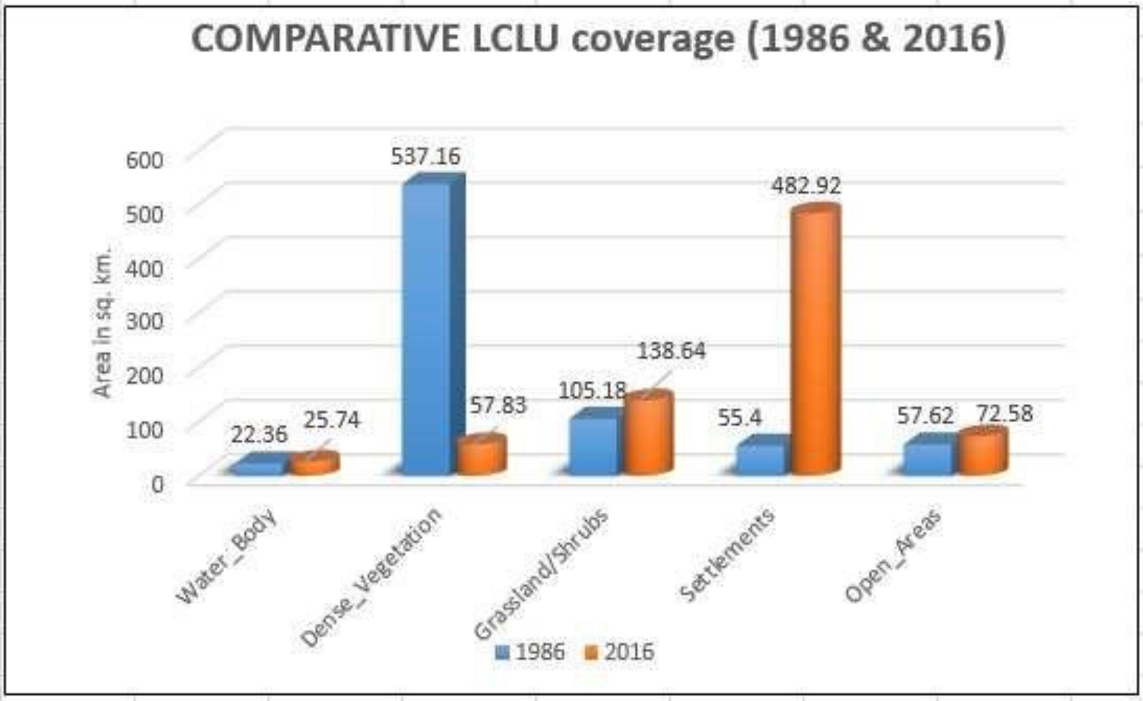


Figure 4.12: Graph Representing Extent of Change of LULC between 1986 to 2016

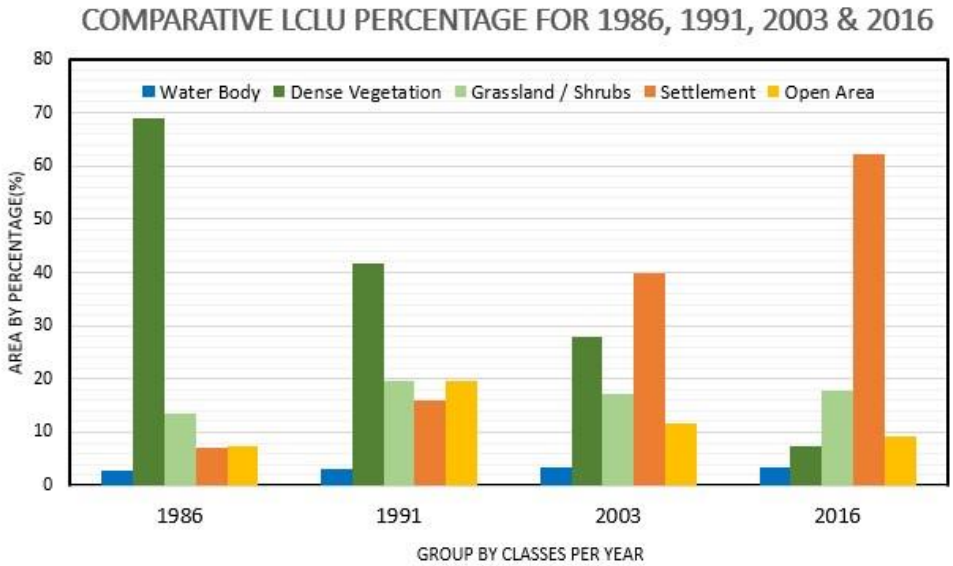


Figure 4.13: LULC classifications for 1986, 1991, 2003 and 2016

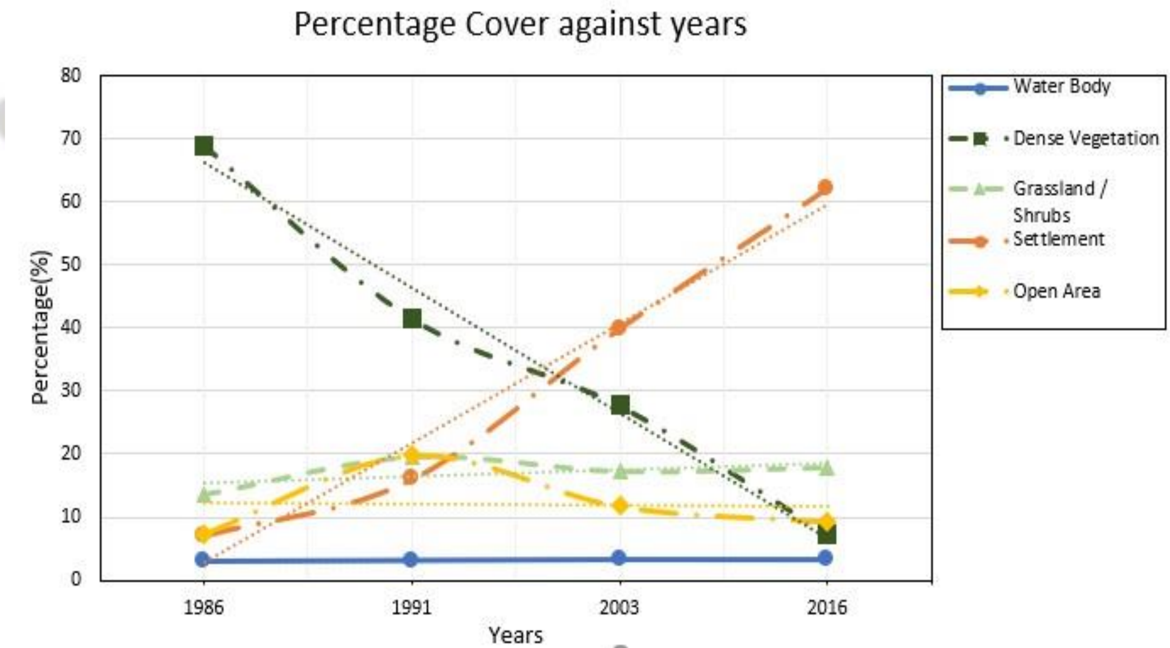


Figure 4.14: Regression Plot of Percentage coverage of each LULC type against year

Figure 4.14 shows a graph of the percentage coverage of each landuse/Landcover type plotted against the years. Using this model, it is seen that by 2020, settlements alone would have taken up 70 percent of the total land space.

Regression fit, Settlements = - 9140919 + 13729*Year - 6.874*Year^2 + 0.001*Year^3

R-Sq = 100.0%

For vegetation, the Regression fitting equation gives, Dense Vegetation = 72988261 – 109335*Year + 54.59 *Year^2 - 0.009*Year^3 also with R-Sq = 100.0%

4.3 Population Trends within the Study Area

The population of the study area expanded steadily over the years. From an initial population of 157,985 in 1986, the populace rose to 216,226 in 1991. It continued to appreciate to 695,191 in the year 2003 and further rose to 1,039,687 in 2016 (projected data). In terms of population density, there was an upsurge in the concentration of persons existing within the study area over the period of the project. In 1986, population density stood at 203.14 per square km. This then rose to278.03 per square km in year 1991. It continued to ascend to 893.89 per square km in the year 2003 and furthered in the 2016(projected population) to 1,336.85per square km (Table 4.6). Figure 4.15 shows a Population density pie chart for the study area.

Table 4.6 Population and Population Density Growth within the Study Area

Year	population	Population Density (per km²)
1986	157,985	203.14
1991	216,226	278.03
2003	695,191	893.89
2016	1,039,687	1,336.85

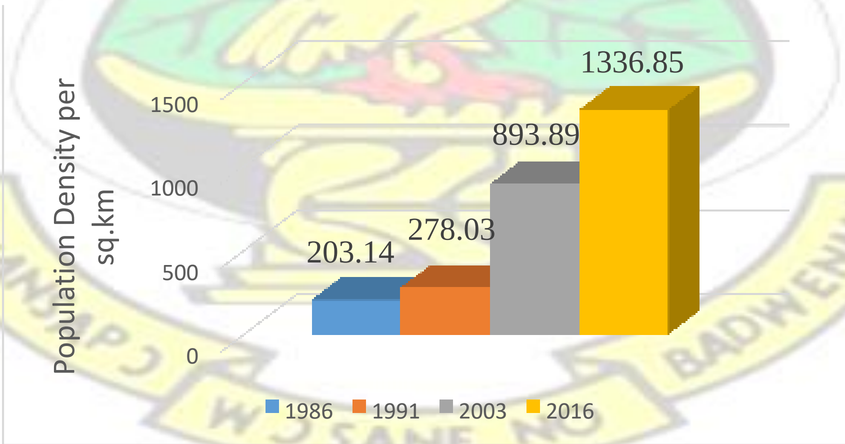


Figure 4.15: Graph of Population in Study Area

4.4 Correlation between Population and Urbanisation

Table 4.7 shows the Raw Population, Population density, Settlement Cover and Percentage of Settlement Cover for the years 1986, 1991, 2003 and 2016. These values were used to investigate correlation and trend between Population and Urbanisation in the study area.

Table 4.7 Population Density and Percentage Settlement coverage over years' of study

Year	Raw Population	Population Density	Settlement cover(Km^2)	Percentage Settlement cover
1986	157,985	203.14	55.40	7.12
1991	216,226	278.03	124.55	16.01
2003	695,191	893.89	310.22	39.89
2016	1,039,687	1,336.85	482.92	62.09

Using the Change Index offered by (Haregeweyn *et. al*, 2012), as $ChangeIndex = \left(\frac{V_n - V_m}{K \times V_m}\right) x100\%$ where $V_n = characteristics\ at\ time\ n,\ V_m = characteristics\ at\ time\ m$ and K is time interval, the rates of change computed are as in Table 4.8.

Table 4.8 Change Index by Permutation Year Intervals

Intervals	1986-1991(%)	1991-2003(%)	2003-2016(%)	1986-2016(%)	1986-2003(%)	1991-2016(%)
Settlement	24.96	9.94	5.57	25.72	23.00	11.51
Population	7.37	14.77	4.96	18.60	17.00	15.23

The results show the greatest rate of settlement increases in the study area had occurred between 1986 to 1991 at a rate of 24.96%. During this period, population increase rate was 7.37 percent. Between 1991 and 2003, the rate of settlement expansion was 9.94% but there was a sharp percentage rise in population at 14.77%. There is a further decline in settlement rate between 2003 and 2016 (5.57% per year). Population increase rate within the same period was 4.96%. Between 1986 and 2003, settlement increase rate is 23.00% with corresponding population expansion rate of 17.00%, whereas between 1991 and 2016, settlement increase rate is 11.51% with corresponding population increase rate of 15.23%. Aggregately however, between 1986 and 2016, it can be deduced that settlement had increased at a rate of 25.72% per year and population has also increased annually at 18.6%.

The spearman"s Rank correlation rho for Settlement and Population = 0.657 with a PValue of 0.156. But the Pearson correlation coefficient gave 0.393 with a P-Value of 0.441 which is a not too strong linear relationship. This may be interpreted to mean that the relationship between settlement and population may not be linear. Figure 4.16 shows a plot of settlement increase rates against rates of population increase.

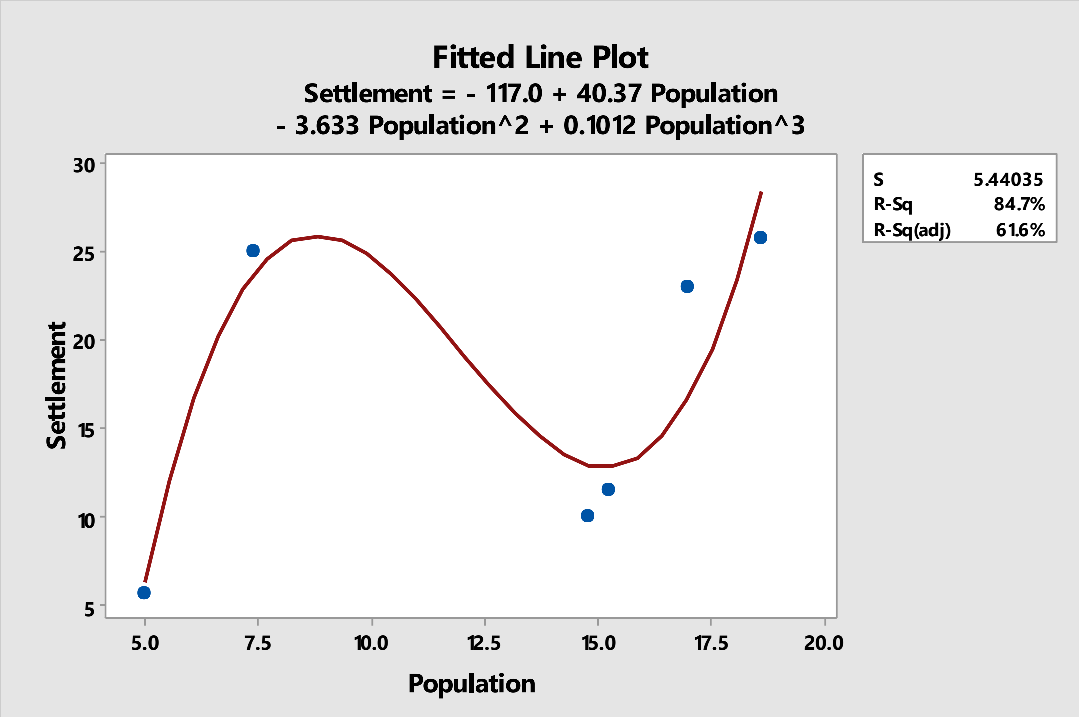


Figure 4.16: Graph of Rates of settlement change with population rates

The regression equation is given by: $\boldsymbol{Settlement = -117.0 + 40.37 * Population - 3.633 * Population^{\wedge}2 + 0.1012 * Population^{\wedge}3}$

The coefficient of multiple determination of 84.7% obtained shows that in spite of the seemingly weak linear correlation observed earlier as revealed in the Pearson"s coefficient, there is still a strong multiple regression between settlement and population. The adjusted R^2 value of 61.6% further emphasised that the contribution of data points to the regression coefficient is not due to pure chance but there truly exists correlation between settlements and population.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The study conducted in the erstwhile Ga municipalities of the Greater Accra region (Ghana) illustrate that multi temporal satellite images play an important part in quantifying spatial and temporal spectacles as a replacement for the extremely tedious traditional mapping methods. Assimilating Landsat imagery and census data is practicable to investigate urban growth in area, provincial and universal balances.

The study investigated the status of Ga area, by identifying, characterizing and quantifying the urban growth using remote sensing techniques coupled with statistical data calculation. This approach was effective in detecting LULC modification and measuring the range of the urban expansion. Moreover, it was discovered that, the Urbanization progression was powerfully associated with augmented inhabitants.

The results indicate that the total population increased from 272,716 persons in 1986 population census to 1,039,687 persons in 2016 census as a result of migration, displacement and natural population growth. Also, the study uncovered that the main land use in the study area currently is Settlement. The catchment area under Settlement increased from 7.10% (55.40 Km^2) in 1986 to 62.09% (482.92Km^2) in 2016. The second major Landcover/landuse in the study area is Dense Vegetation which had decreased from 69.65% (539.15Km^2) in 1986 to 7.44% (57.83Km^2) in 2016 due to transference to other uses.

The foremost driver of Urbanization in the study area was swift inhabitants growing. Though the relationship between settlement expansion and population growth do not indicate a direct linear trend, yet there is a strong multiple regression of coefficient of determination of 84.7%. This phenomenon desires serious attention and research, through a multi-dimensional field of expertise to protect Agricultural lands and proper Land use planning for an advancing economy.

5.2 Recommendations

i. Strict Land Use planning policy should be developed and adhered to for any developmental project conducted in any District which must take into consideration Environmental Impact Assessment (EIA).

ii. There should be decentralized development driven from the district for social amenities and infrastructures to preserve cultural identity instead of immigration driven that also imports city values to replace cultural values.

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APPENDIXES

Appendix A

A-1 Projected Population Data For 1986 and 2003

Population by sex - 1984, 1986, 1991, 2000 and 2006, Ga South, Ga West, Ga East and Ga Central

Year	Male	Female	Total
1984	68,377	67,981	136,358
1986	79,405	78,580	157,985
1991	111,719	104,507	216,226
2000	276,531	273,937	550,468
2003	339,430	355,761	695,191

Source: Ghana Statistical Service

18th January, 2019

Appendix A-2 Projected Population Data For 2016

INDICATOR Name	2016 Total	2016 Male	2016 Female
Population Size: Ga South Municipal	488,678	233,181	255,497
Population Size: Ga West Municipal	250,915	124,910	126,005
Population Size: Ga East Municipal	167,715	84,153	83,562
Population Size: Ga Central Municipal	132,379	65,829	66,550
Source: Ghana Statistical Service, Projected Population Figures, 2016			

Appendix B

Appendix B-1 MetaData LANDSAT_5 Image 1986

```
ROUP = L1_METADATA_FILE
  GROUP = METADATA_FILE_INFO
    ORIGIN = "Image courtesy of the U.S. Geological
Survey"
    REQUEST_ID = "0601406264029_00010"
    LANDSAT_SCENE_ID = "LT51930561986356XXX09"
    FILE_DATE = 2014-07-01T22:55:10Z
    STATION_ID = "XXX"
    PROCESSING_SOFTWARE_VERSION = "LPGS_12.4.1"
    DATA_CATEGORY = "NOMINAL"
  END_GROUP = METADATA_FILE_INFO
  GROUP = PRODUCT_METADATA
    DATA_TYPE = "L1T"
    DATA_TYPE_L0RP = "TMR_L0RP"
    ELEVATION_SOURCE = "GLS2000"
    OUTPUT_FORMAT = "GEOTIFF"
```

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EPHEMERIS_TYPE = "DEFINITIVE"
SPACECRAFT_ID = "LANDSAT_5"
SENSOR_ID = "TM"
SENSOR_MODE = "SAM"
WRS_PATH = 193
WRS_ROW = 056
DATE_ACQUIRED = 1986-12-22
SCENE_CENTER_TIME = 09:34:42.2220560Z
CORNER_UL_LAT_PRODUCT = 6.73258
CORNER_UL_LON_PRODUCT = -1.08835
CORNER_UR_LAT_PRODUCT = 6.71992
CORNER_UR_LON_PRODUCT = 1.00438
CORNER_LL_LAT_PRODUCT = 4.86374
CORNER_LL_LON_PRODUCT = -1.09463
CORNER_LR_LAT_PRODUCT = 4.85461
CORNER_LR_LON_PRODUCT = 0.99126
CORNER_UL_PROJECTION_X_PRODUCT = 711300.000
CORNER_UL_PROJECTION_Y_PRODUCT = 744600.000
CORNER_UR_PROJECTION_X_PRODUCT = 942900.000
CORNER_UR_PROJECTION_Y_PRODUCT = 744600.000
CORNER_LL_PROJECTION_X_PRODUCT = 711300.000
CORNER_LL_PROJECTION_Y_PRODUCT = 537900.000
CORNER_LR_PROJECTION_X_PRODUCT = 942900.000
CORNER_LR_PROJECTION_Y_PRODUCT = 537900.000
REFLECTIVE_LINES = 6891
REFLECTIVE_SAMPLES = 7721 THERMAL_LINES
= 6891
THERMAL_SAMPLES = 7721
FILE_NAME_BAND_1 = "LT51930561986356XXX09_B1.TIF" FILE_NAME_BAND_2 =
"LT51930561986356XXX09_B2.TIF" FILE_NAME_BAND_3 =
"LT51930561986356XXX09_B3.TIF"
FILE_NAME_BAND_4 = "LT51930561986356XXX09_B4.TIF"
FILE_NAME_BAND_5 = "LT51930561986356XXX09_B5.TIF"
FILE_NAME_BAND_6 = "LT51930561986356XXX09_B6.TIF"
FILE_NAME_BAND_7 = "LT51930561986356XXX09_B7.TIF"
GROUND_CONTROL_POINT_FILE_NAME =
"LT51930561986356XXX09_GCP.txt"
REPORT_VERIFY_FILE_NAME =
"LT51930561986356XXX09_VER.txt"
BROWSE_VERIFY_FILE_NAME =
"LT51930561986356XXX09_VER.jpg"
METADATA_FILE_NAME = "LT51930561986356XXX09_MTL.txt"
CPF_NAME = "L5CPF19861120_19861231.09"
END_GROUP = PRODUCT_METADATA
GROUP = IMAGE_ATTRIBUTES
CLOUD_COVER = 50.00
IMAGE_QUALITY = 7
SUN_AZIMUTH = 131.12370659
```

SUN_ELEVATION = 44.29434491
GROUND_CONTROL_POINTS_MODEL = 82
GEOMETRIC_RMSE_MODEL = 5.355
GEOMETRIC_RMSE_MODEL_Y = 3.257
GEOMETRIC_RMSE_MODEL_X = 4.251
GROUND_CONTROL_POINTS_VERIFY = 1001
GEOMETRIC_RMSE_VERIFY = 0.234
GEOMETRIC_RMSE_VERIFY_QUAD_UL = 0.201
GEOMETRIC_RMSE_VERIFY_QUAD_UR = 0.275
GEOMETRIC_RMSE_VERIFY_QUAD_LL = 0.252
GEOMETRIC_RMSE_VERIFY_QUAD_LR = 0.304
END_GROUP = IMAGE_ATTRIBUTES
GROUP = MIN_MAX_RADIANCE
RADIANCE_MAXIMUM_BAND_1 = 169.000
RADIANCE_MINIMUM_BAND_1 = -1.520
RADIANCE_MAXIMUM_BAND_2 = 333.000
RADIANCE_MINIMUM_BAND_2 = -2.840
RADIANCE_MAXIMUM_BAND_3 = 264.000
RADIANCE_MINIMUM_BAND_3 = -1.170
RADIANCE_MAXIMUM_BAND_4 = 221.000
RADIANCE_MINIMUM_BAND_4 = -1.510
RADIANCE_MAXIMUM_BAND_5 = 30.200
RADIANCE_MINIMUM_BAND_5 = -0.370
RADIANCE_MAXIMUM_BAND_6 = 15.303
RADIANCE_MINIMUM_BAND_6 = 1.238
RADIANCE_MAXIMUM_BAND_7 = 16.500
RADIANCE_MINIMUM_BAND_7 = -0.150
END_GROUP = MIN_MAX_RADIANCE
GROUP = MIN_MAX_PIXEL_VALUE
QUANTIZE_CAL_MAX_BAND_1 = 255
QUANTIZE_CAL_MIN_BAND_1 = 1
QUANTIZE_CAL_MAX_BAND_2 = 255
QUANTIZE_CAL_MIN_BAND_2 = 1
QUANTIZE_CAL_MAX_BAND_3 = 255
QUANTIZE_CAL_MIN_BAND_3 = 1
QUANTIZE_CAL_MAX_BAND_4 = 255
QUANTIZE_CAL_MIN_BAND_4 = 1
QUANTIZE_CAL_MAX_BAND_5 = 255
QUANTIZE_CAL_MIN_BAND_5 = 1
QUANTIZE_CAL_MAX_BAND_6 = 255
QUANTIZE_CAL_MIN_BAND_6 = 1
QUANTIZE_CAL_MAX_BAND_7 = 255
QUANTIZE_CAL_MIN_BAND_7 = 1
END_GROUP = MIN_MAX_PIXEL_VALUE
GROUP = PRODUCT_PARAMETERS
CORRECTION_GAIN_BAND_1 = "CPF"
CORRECTION_GAIN_BAND_2 = "CPF"
CORRECTION_GAIN_BAND_3 = "CPF"

```
    CORRECTION_GAIN_BAND_4 = "CPF"
    CORRECTION_GAIN_BAND_5 = "CPF"
    CORRECTION_GAIN_BAND_6 = "INTERNAL_CALIBRATION"
    CORRECTION_GAIN_BAND_7 = "CPF"
    CORRECTION_BIAS_BAND_1 = "CPF"
    CORRECTION_BIAS_BAND_2 = "CPF"
    CORRECTION_BIAS_BAND_3 = "CPF"
    CORRECTION_BIAS_BAND_4 = "CPF"
    CORRECTION_BIAS_BAND_5 = "CPF"
    CORRECTION_BIAS_BAND_6 = "CPF"
    CORRECTION_BIAS_BAND_7 = "CPF"
  END_GROUP = PRODUCT_PARAMETERS
GROUP = RADIOMETRIC_RESCALING
    RADIANCE_MULT_BAND_1 = 0.671
    RADIANCE_MULT_BAND_2 = 1.322
    RADIANCE_MULT_BAND_3 = 1.044
    RADIANCE_MULT_BAND_4 = 0.876
    RADIANCE_MULT_BAND_5 = 0.120
    RADIANCE_MULT_BAND_6 = 0.055
    RADIANCE_MULT_BAND_7 = 0.066
    RADIANCE_ADD_BAND_1 = -2.19134
    RADIANCE_ADD_BAND_2 = -4.16220
    RADIANCE_ADD_BAND_3 = -2.21398
    RADIANCE_ADD_BAND_4 = -2.38602
    RADIANCE_ADD_BAND_5 = -0.49035
RADIANCE_ADD_BAND_6 = 1.18243
    RADIANCE_ADD_BAND_7 = -0.21555
  END_GROUP = RADIOMETRIC_RESCALING
  GROUP = PROJECTION_PARAMETERS
    MAP_PROJECTION = "UTM"
    DATUM = "WGS84"
    ELLIPSOID = "WGS84"
    UTM_ZONE = 30
    GRID_CELL_SIZE_REFLECTIVE = 30.00
    GRID_CELL_SIZE_THERMAL = 30.00
    ORIENTATION = "NORTH_UP"
    RESAMPLING_OPTION = "CUBIC_CONVOLUTION"
    MAP_PROJECTION_L0RA = "NA"
  END_GROUP = PROJECTION_PARAMETERS
END_GROUP = L1_METADATA_FILE
END
```

Appendix B-2 MetaData LANDSAT_4 Image 1991

```
GROUP = L1_METADATA_FILE
```

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  GROUP = METADATA_FILE_INFO
    ORIGIN = "Image courtesy of the U.S. Geological
Survey"
    REQUEST_ID = "0101405010588_00001"
    LANDSAT_SCENE_ID = "LT41930561991010XXX03"
    FILE_DATE = 2014-05-02T02:19:20Z
    STATION_ID = "XXX"
    PROCESSING_SOFTWARE_VERSION = "LPGS_12.4.1"
    DATA_CATEGORY = "NOMINAL"
  END_GROUP = METADATA_FILE_INFO
  GROUP = PRODUCT_METADATA
    DATA_TYPE = "L1T"
    DATA_TYPE_L0RP = "TMR_L0RP"
    ELEVATION_SOURCE = "GLS2000"
    OUTPUT_FORMAT = "GEOTIFF"
    EPHEMERIS_TYPE = "DEFINITIVE"
    SPACECRAFT_ID = "LANDSAT_4"
    SENSOR_ID = "TM"
    SENSOR_MODE = "SAM"
    WRS_PATH = 193
    WRS_ROW = 056
    DATE_ACQUIRED = 1991-01-10
    SCENE_CENTER_TIME = 09:40:08.8410810Z
    CORNER_UL_LAT_PRODUCT = 6.72450
    CORNER_UL_LON_PRODUCT = -1.10195
    CORNER_UR_LAT_PRODUCT = 6.71195
    CORNER_UR_LON_PRODUCT = 0.98536
    CORNER_LL_LAT_PRODUCT = 4.86106
    CORNER_LL_LON_PRODUCT = -1.10816
    CORNER_LR_LAT_PRODUCT = 4.85201
    CORNER_LR_LON_PRODUCT = 0.97235
    CORNER_UL_PROJECTION_X_PRODUCT = 709800.000
    CORNER_UL_PROJECTION_Y_PRODUCT = 743700.000
    CORNER_UR_PROJECTION_X_PRODUCT = 940800.000
    CORNER_UR_PROJECTION_Y_PRODUCT = 743700.000
    CORNER_LL_PROJECTION_X_PRODUCT = 709800.000
    CORNER_LL_PROJECTION_Y_PRODUCT = 537600.000
    CORNER_LR_PROJECTION_X_PRODUCT = 940800.000
    CORNER_LR_PROJECTION_Y_PRODUCT = 537600.000
```

```
    REFLECTIVE_LINES = 6871
    REFLECTIVE_SAMPLES = 7701
    THERMAL_LINES = 6871
    THERMAL_SAMPLES = 7701
    FILE_NAME_BAND_1 = "LT41930561991010XXX03_B1.TIF"
    FILE_NAME_BAND_2 = "LT41930561991010XXX03_B2.TIF"
    FILE_NAME_BAND_3 = "LT41930561991010XXX03_B3.TIF"
    FILE_NAME_BAND_4 = "LT41930561991010XXX03_B4.TIF"
    FILE_NAME_BAND_5 = "LT41930561991010XXX03_B5.TIF"
    FILE_NAME_BAND_6 = "LT41930561991010XXX03_B6.TIF"
    FILE_NAME_BAND_7 = "LT41930561991010XXX03_B7.TIF"
    GROUND_CONTROL_POINT_FILE_NAME =
"LT41930561991010XXX03_GCP.txt"
    REPORT_VERIFY_FILE_NAME =
"LT41930561991010XXX03_VER.txt"
    BROWSE_VERIFY_FILE_NAME =
"LT41930561991010XXX03_VER.jpg"
    METADATA_FILE_NAME = "LT41930561991010XXX03_MTL.txt"
    CPF_NAME = "L4CPF19910101_19910331.08"
  END_GROUP = PRODUCT_METADATA
  GROUP = IMAGE_ATTRIBUTES
    CLOUD_COVER = 10.00
    IMAGE_QUALITY = 7
    SUN_AZIMUTH = 128.81947859
    SUN_ELEVATION = 44.43591373
    GROUND_CONTROL_POINTS_MODEL = 169
    GEOMETRIC_RMSE_MODEL = 4.801
    GEOMETRIC_RMSE_MODEL_Y = 3.823
    GEOMETRIC_RMSE_MODEL_X = 2.905
    GROUND_CONTROL_POINTS_VERIFY = 1148
    GEOMETRIC_RMSE_VERIFY = 0.205
    GEOMETRIC_RMSE_VERIFY_QUAD_UL = 0.186
    GEOMETRIC_RMSE_VERIFY_QUAD_UR = 0.240
    GEOMETRIC_RMSE_VERIFY_QUAD_LL = 0.197
    GEOMETRIC_RMSE_VERIFY_QUAD_LR = 0.238
  END_GROUP = IMAGE_ATTRIBUTES
  GROUP = MIN_MAX_RADIANCE
    RADIANCE_MAXIMUM_BAND_1 = 171.000
    RADIANCE_MINIMUM_BAND_1 = -1.520
    RADIANCE_MAXIMUM_BAND_2 = 336.000
RADIANCE_MINIMUM_BAND_2 = -2.840
    RADIANCE_MAXIMUM_BAND_3 = 254.000
RADIANCE_MINIMUM_BAND_3 = -1.170
    RADIANCE_MAXIMUM_BAND_4 = 221.000
    RADIANCE_MINIMUM_BAND_4 = -1.510
    RADIANCE_MAXIMUM_BAND_5 = 31.400
    RADIANCE_MINIMUM_BAND_5 = -0.370
    RADIANCE_MAXIMUM_BAND_6 = 15.303
```

```
    RADIANCE_MINIMUM_BAND_6 = 1.238
    RADIANCE_MAXIMUM_BAND_7 = 16.600
    RADIANCE_MINIMUM_BAND_7 = -0.150
  END_GROUP = MIN_MAX_RADIANCE
  GROUP = MIN_MAX_PIXEL_VALUE
    QUANTIZE_CAL_MAX_BAND_1 = 255
QUANTIZE_CAL_MIN_BAND_1 = 1
    QUANTIZE_CAL_MAX_BAND_2 = 255
QUANTIZE_CAL_MIN_BAND_2 = 1
    QUANTIZE_CAL_MAX_BAND_3 = 255
QUANTIZE_CAL_MIN_BAND_3 = 1
    QUANTIZE_CAL_MAX_BAND_4 = 255
    QUANTIZE_CAL_MIN_BAND_4 = 1
    QUANTIZE_CAL_MAX_BAND_5 = 255
QUANTIZE_CAL_MIN_BAND_5 = 1
    QUANTIZE_CAL_MAX_BAND_6 = 255
    QUANTIZE_CAL_MIN_BAND_6 = 1
    QUANTIZE_CAL_MAX_BAND_7 = 255
QUANTIZE_CAL_MIN_BAND_7 = 1
  END_GROUP = MIN_MAX_PIXEL_VALUE
  GROUP = PRODUCT_PARAMETERS
    CORRECTION_GAIN_BAND_1 = "CPF"
    CORRECTION_GAIN_BAND_2 = "CPF"
    CORRECTION_GAIN_BAND_3 = "CPF"
    CORRECTION_GAIN_BAND_4 = "CPF"
    CORRECTION_GAIN_BAND_5 = "CPF"
    CORRECTION_GAIN_BAND_6 = "INTERNAL_CALIBRATION"
    CORRECTION_GAIN_BAND_7 = "CPF"
    CORRECTION_BIAS_BAND_1 = "INTERNAL_CALIBRATION"
    CORRECTION_BIAS_BAND_2 = "INTERNAL_CALIBRATION"
    CORRECTION_BIAS_BAND_3 = "INTERNAL_CALIBRATION"
    CORRECTION_BIAS_BAND_4 = "INTERNAL_CALIBRATION"
    CORRECTION_BIAS_BAND_5 = "INTERNAL_CALIBRATION"
    CORRECTION_BIAS_BAND_6 = "INTERNAL_CALIBRATION"
    CORRECTION_BIAS_BAND_7 = "INTERNAL_CALIBRATION"
  END_GROUP = PRODUCT_PARAMETERS
GROUP = RADIOMETRIC_RESCALING
    RADIANCE_MULT_BAND_1 = 0.679
    RADIANCE_MULT_BAND_2 = 1.334
    RADIANCE_MULT_BAND_3 = 1.005
    RADIANCE_MULT_BAND_4 = 0.876
    RADIANCE_MULT_BAND_5 = 0.125
    RADIANCE_MULT_BAND_6 = 0.055
    RADIANCE_MULT_BAND_7 = 0.066
    RADIANCE_ADD_BAND_1 = -2.19921
    RADIANCE_ADD_BAND_2 = -4.17402
    RADIANCE_ADD_BAND_3 = -2.17461
    RADIANCE_ADD_BAND_4 = -2.38602
```

```
    RADIANCE_ADD_BAND_5 = -0.49508
RADIANCE_ADD_BAND_6 = 1.18243
    RADIANCE_ADD_BAND_7 = -0.21594
  END_GROUP = RADIOMETRIC_RESCALING
  GROUP = PROJECTION_PARAMETERS
    MAP_PROJECTION = "UTM"
    DATUM = "WGS84"
    ELLIPSOID = "WGS84"
    UTM_ZONE = 30
    GRID_CELL_SIZE_REFLECTIVE = 30.00
    GRID_CELL_SIZE_THERMAL = 30.00
    ORIENTATION = "NORTH_UP"
    RESAMPLING_OPTION = "CUBIC_CONVOLUTION"
    MAP_PROJECTION_L0RA = "NA"
  END_GROUP = PROJECTION_PARAMETERS
END_GROUP = L1_METADATA_FILE
END
```

Appendix B-3 MetaData LANDSAT_7 Image 2003

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GROUP = L1_METADATA_FILE
  GROUP = METADATA_FILE_INFO
    ORIGIN = "Image courtesy of the U.S. Geological
Survey"
    REQUEST_ID = "0101411126333_00006"
    LANDSAT_SCENE_ID = "LE71930562003043EDC00"
    FILE_DATE = 2014-11-15T14:19:25Z
    STATION_ID = "EDC"
    PROCESSING_SOFTWARE_VERSION = "LPGS_12.5.0"
    DATA_CATEGORY = "NOMINAL"
  END_GROUP = METADATA_FILE_INFO
  GROUP = PRODUCT_METADATA
    DATA_TYPE = "L1T"
    ELEVATION_SOURCE = "GLS2000"
    OUTPUT_FORMAT = "GEOTIFF"
    EPHEMERIS_TYPE = "DEFINITIVE"
    SPACECRAFT_ID = "LANDSAT_7"
    SENSOR_ID = "ETM"
    SENSOR_MODE = "SAM"
    WRS_PATH = 193
    WRS_ROW = 056
    DATE_ACQUIRED = 2003-02-12
    SCENE_CENTER_TIME = 10:04:22.3110977Z
    CORNER_UL_LAT_PRODUCT = 6.74613
    CORNER_UL_LON_PRODUCT = -1.08558
```

```
    CORNER_UR_LAT_PRODUCT = 6.73325
    CORNER_UR_LON_PRODUCT = 1.02887
    CORNER_LL_LAT_PRODUCT = 4.85559
    CORNER_LL_LON_PRODUCT = -1.09195
    CORNER_LR_LAT_PRODUCT = 4.84634
    CORNER_LR_LON_PRODUCT = 1.01550
    CORNER_UL_PROJECTION_X_PRODUCT = 711600.000
    CORNER_UL_PROJECTION_Y_PRODUCT = 746100.000
CORNER_UR_PROJECTION_X_PRODUCT = 945600.000
    CORNER_UR_PROJECTION_Y_PRODUCT = 746100.000
    CORNER_LL_PROJECTION_X_PRODUCT = 711600.000
    CORNER_LL_PROJECTION_Y_PRODUCT = 537000.000
    CORNER_LR_PROJECTION_X_PRODUCT = 945600.000
    CORNER_LR_PROJECTION_Y_PRODUCT = 537000.000
    PANCHROMATIC_LINES = 13941
    PANCHROMATIC_SAMPLES = 15601
    REFLECTIVE_LINES = 6971
    REFLECTIVE_SAMPLES = 7801
    THERMAL_LINES = 6971
    THERMAL_SAMPLES = 7801
    FILE_NAME_BAND_1 = "LE71930562003043EDC00_B1.TIF"
    FILE_NAME_BAND_2 = "LE71930562003043EDC00_B2.TIF"
    FILE_NAME_BAND_3 = "LE71930562003043EDC00_B3.TIF"
    FILE_NAME_BAND_4 = "LE71930562003043EDC00_B4.TIF"
    FILE_NAME_BAND_5 = "LE71930562003043EDC00_B5.TIF"
    FILE_NAME_BAND_6_VCID_1                                =
"LE71930562003043EDC00_B6_VCID_1.TIF"
    FILE_NAME_BAND_6_VCID_2                                =
"LE71930562003043EDC00_B6_VCID_2.TIF"
    FILE_NAME_BAND_7 = "LE71930562003043EDC00_B7.TIF"
    FILE_NAME_BAND_8 = "LE71930562003043EDC00_B8.TIF"
    GROUND_CONTROL_POINT_FILE_NAME                         =
"LE71930562003043EDC00_GCP.txt"
    METADATA_FILE_NAME = "LE71930562003043EDC00_MTL.txt"
    CPF_NAME = "L7CPF20030101_20030331.09"
  END_GROUP = PRODUCT_METADATA
  GROUP = IMAGE_ATTRIBUTES
    CLOUD_COVER = 0.00
    IMAGE_QUALITY = 9
    SUN_AZIMUTH = 121.41963890
    SUN_ELEVATION = 52.25092263
    GROUND_CONTROL_POINTS_VERSION = 1
    GROUND_CONTROL_POINTS_MODEL = 183
    GEOMETRIC_RMSE_MODEL = 3.837
    GEOMETRIC_RMSE_MODEL_Y = 2.888
    GEOMETRIC_RMSE_MODEL_X = 2.526
  END_GROUP = IMAGE_ATTRIBUTES
  GROUP = MIN_MAX_RADIANCE
```

```
    RADIANCE_MAXIMUM_BAND_1 = 293.700
    RADIANCE_MINIMUM_BAND_1 = -6.200
    RADIANCE_MAXIMUM_BAND_2 = 300.900
RADIANCE_MINIMUM_BAND_2 = -6.400
    RADIANCE_MAXIMUM_BAND_3 = 234.400
    RADIANCE_MINIMUM_BAND_3 = -5.000
    RADIANCE_MAXIMUM_BAND_4 = 241.100
    RADIANCE_MINIMUM_BAND_4 = -5.100
    RADIANCE_MAXIMUM_BAND_5 = 47.570
    RADIANCE_MINIMUM_BAND_5 = -1.000
    RADIANCE_MAXIMUM_BAND_6_VCID_1 = 17.040
    RADIANCE_MINIMUM_BAND_6_VCID_1 = 0.000
    RADIANCE_MAXIMUM_BAND_6_VCID_2 = 12.650
    RADIANCE_MINIMUM_BAND_6_VCID_2 = 3.200
    RADIANCE_MAXIMUM_BAND_7 = 16.540
    RADIANCE_MINIMUM_BAND_7 = -0.350
    RADIANCE_MAXIMUM_BAND_8 = 243.100
    RADIANCE_MINIMUM_BAND_8 = -4.700
  END_GROUP = MIN_MAX_RADIANCE
  GROUP = MIN_MAX_PIXEL_VALUE
    QUANTIZE_CAL_MAX_BAND_1 = 255
QUANTIZE_CAL_MIN_BAND_1 = 1
    QUANTIZE_CAL_MAX_BAND_2 = 255
QUANTIZE_CAL_MIN_BAND_2 = 1
    QUANTIZE_CAL_MAX_BAND_3 = 255
QUANTIZE_CAL_MIN_BAND_3 = 1
    QUANTIZE_CAL_MAX_BAND_4 = 255
    QUANTIZE_CAL_MIN_BAND_4 = 1
    QUANTIZE_CAL_MAX_BAND_5 = 255
    QUANTIZE_CAL_MIN_BAND_5 = 1
    QUANTIZE_CAL_MAX_BAND_6_VCID_1 = 255
    QUANTIZE_CAL_MIN_BAND_6_VCID_1 = 1
    QUANTIZE_CAL_MAX_BAND_6_VCID_2 = 255
    QUANTIZE_CAL_MIN_BAND_6_VCID_2 = 1
    QUANTIZE_CAL_MAX_BAND_7 = 255
    QUANTIZE_CAL_MIN_BAND_7 = 1
    QUANTIZE_CAL_MAX_BAND_8 = 255
QUANTIZE_CAL_MIN_BAND_8 = 1
  END_GROUP = MIN_MAX_PIXEL_VALUE
  GROUP = PRODUCT_PARAMETERS
    CORRECTION_GAIN_BAND_1 = "CPF"
    CORRECTION_GAIN_BAND_2 = "CPF"
    CORRECTION_GAIN_BAND_3 = "CPF"
    CORRECTION_GAIN_BAND_4 = "CPF"
    CORRECTION_GAIN_BAND_5 = "CPF"
    CORRECTION_GAIN_BAND_6_VCID_1 = "CPF"
    CORRECTION_GAIN_BAND_6_VCID_2 = "CPF"
    CORRECTION_GAIN_BAND_7 = "CPF"
```

```
    CORRECTION_GAIN_BAND_8 = "CPF"
    CORRECTION_BIAS_BAND_1 = "INTERNAL_CALIBRATION"
    CORRECTION_BIAS_BAND_2 = "INTERNAL_CALIBRATION"
    CORRECTION_BIAS_BAND_3 = "INTERNAL_CALIBRATION"
    CORRECTION_BIAS_BAND_4 = "INTERNAL_CALIBRATION"
    CORRECTION_BIAS_BAND_5 = "INTERNAL_CALIBRATION"
    CORRECTION_BIAS_BAND_6_VCID_1                        =
"INTERNAL_CALIBRATION"
    CORRECTION_BIAS_BAND_6_VCID_2                        =
"INTERNAL_CALIBRATION"
    CORRECTION_BIAS_BAND_7 = "INTERNAL_CALIBRATION"
    CORRECTION_BIAS_BAND_8 = "INTERNAL_CALIBRATION"
    GAIN_BAND_1 = "L"
    GAIN_BAND_2 = "L"
    GAIN_BAND_3 = "L"
    GAIN_BAND_4 = "L"
    GAIN_BAND_5 = "L"
    GAIN_BAND_6_VCID_1 = "L"
    GAIN_BAND_6_VCID_2 = "H"
    GAIN_BAND_7 = "L"
    GAIN_BAND_8 = "L"
    GAIN_CHANGE_BAND_1 = "LL"
    GAIN_CHANGE_BAND_2 = "LL"
    GAIN_CHANGE_BAND_3 = "LL"
    GAIN_CHANGE_BAND_4 = "LL"
    GAIN_CHANGE_BAND_5 = "LL"
    GAIN_CHANGE_BAND_6_VCID_1 = "LL"
    GAIN_CHANGE_BAND_6_VCID_2 = "HH"
    GAIN_CHANGE_BAND_7 = "LL"
    GAIN_CHANGE_BAND_8 = "LL"
    GAIN_CHANGE_SCAN_BAND_1 = 0
    GAIN_CHANGE_SCAN_BAND_2 = 0
    GAIN_CHANGE_SCAN_BAND_3 = 0
    GAIN_CHANGE_SCAN_BAND_4 = 0
    GAIN_CHANGE_SCAN_BAND_5 = 0
    GAIN_CHANGE_SCAN_BAND_6_VCID_1 = 0
    GAIN_CHANGE_SCAN_BAND_6_VCID_2 = 0
    GAIN_CHANGE_SCAN_BAND_7 = 0
    GAIN_CHANGE_SCAN_BAND_8 = 0
  END_GROUP = PRODUCT_PARAMETERS
GROUP = RADIOMETRIC_RESCALING
    RADIANCE_MULT_BAND_1 = 1.181
    RADIANCE_MULT_BAND_2 = 1.210
    RADIANCE_MULT_BAND_3 = 0.943
    RADIANCE_MULT_BAND_4 = 0.969
    RADIANCE_MULT_BAND_5 = 0.191
    RADIANCE_MULT_BAND_6_VCID_1 = 0.067
    RADIANCE_MULT_BAND_6_VCID_2 = 0.037
```

```
    RADIANCE_MULT_BAND_7 = 0.066
    RADIANCE_MULT_BAND_8 = 0.976
    RADIANCE_ADD_BAND_1 = -7.38071
    RADIANCE_ADD_BAND_2 = -7.60984
    RADIANCE_ADD_BAND_3 = -5.94252
    RADIANCE_ADD_BAND_4 = -6.06929
    RADIANCE_ADD_BAND_5 = -1.19122
    RADIANCE_ADD_BAND_6_VCID_1 = -0.06709
    RADIANCE_ADD_BAND_6_VCID_2 = 3.16280
    RADIANCE_ADD_BAND_7 = -0.41650
    RADIANCE_ADD_BAND_8 = -5.67559
  END_GROUP = RADIOMETRIC_RESCALING
  GROUP = PROJECTION_PARAMETERS
    MAP_PROJECTION = "UTM"
    DATUM = "WGS84"
    ELLIPSOID = "WGS84"
    UTM_ZONE = 30
    GRID_CELL_SIZE_PANCHROMATIC = 15.00
    GRID_CELL_SIZE_REFLECTIVE = 30.00
    GRID_CELL_SIZE_THERMAL = 30.00
    ORIENTATION = "NORTH_UP"
    RESAMPLING_OPTION = "CUBIC_CONVOLUTION"
  END_GROUP = PROJECTION_PARAMETERS
END_GROUP = L1_METADATA_FILE
END
```

Appendix B-4 MetaData LANDSAT_7 Image 2016

```
GROUP = L1_METADATA_FILE
  GROUP = METADATA_FILE_INFO
    ORIGIN = "Image courtesy of the U.S. Geological
Survey"
    REQUEST_ID = "9991602250998_00258"
    LANDSAT_SCENE_ID = "LE71930562016031ASN00"
    FILE_DATE = 2016-02-25T11:20:44Z
    STATION_ID = "ASN"
    PROCESSING_SOFTWARE_VERSION = "LPGS_12.7.0"
    DATA_CATEGORY = "NOMINAL"
  END_GROUP = METADATA_FILE_INFO
  GROUP = PRODUCT_METADATA
    DATA_TYPE = "L1T"
    ELEVATION_SOURCE = "GLS2000"
    OUTPUT_FORMAT = "GEOTIFF"
    EPHEMERIS_TYPE = "DEFINITIVE"
    SPACECRAFT_ID = "LANDSAT_7"
```

```
    SENSOR_ID = "ETM"
    SENSOR_MODE = "BUMPER"
    WRS_PATH = 193
    WRS_ROW = 056
    DATE_ACQUIRED = 2016-01-31
    SCENE_CENTER_TIME = "10:17:29.9561678Z"
    CORNER_UL_LAT_PRODUCT = 6.73536
    CORNER_UL_LON_PRODUCT = -1.10462
    CORNER_UR_LAT_PRODUCT = 6.72209
    CORNER_UR_LON_PRODUCT = 1.06939
    CORNER_LL_LAT_PRODUCT = 4.85022
    CORNER_LL_LON_PRODUCT = -1.11090
    CORNER_LR_LAT_PRODUCT = 4.84069
    CORNER_LR_LON_PRODUCT = 1.05595
    CORNER_UL_PROJECTION_X_PRODUCT = 709500.000
    CORNER_UL_PROJECTION_Y_PRODUCT = 744900.000
    CORNER_UR_PROJECTION_X_PRODUCT = 950100.000
    CORNER_UR_PROJECTION_Y_PRODUCT = 744900.000
    CORNER_LL_PROJECTION_X_PRODUCT = 709500.000
CORNER_LL_PROJECTION_Y_PRODUCT = 536400.000
    CORNER_LR_PROJECTION_X_PRODUCT = 950100.000
    CORNER_LR_PROJECTION_Y_PRODUCT = 536400.000
    PANCHROMATIC_LINES = 13901
    PANCHROMATIC_SAMPLES = 16041
    REFLECTIVE_LINES = 6951
    REFLECTIVE_SAMPLES = 8021
    THERMAL_LINES = 6951
    THERMAL_SAMPLES = 8021
    FILE_NAME_BAND_1 = "LE71930562016031ASN00_B1.TIF"
    FILE_NAME_BAND_2 = "LE71930562016031ASN00_B2.TIF"
    FILE_NAME_BAND_3 = "LE71930562016031ASN00_B3.TIF"
    FILE_NAME_BAND_4 = "LE71930562016031ASN00_B4.TIF"
    FILE_NAME_BAND_5 = "LE71930562016031ASN00_B5.TIF"
    FILE_NAME_BAND_6_VCID_1 =
"LE71930562016031ASN00_B6_VCID_1.TIF"
    FILE_NAME_BAND_6_VCID_2 =
"LE71930562016031ASN00_B6_VCID_2.TIF"
    FILE_NAME_BAND_7 = "LE71930562016031ASN00_B7.TIF"
    FILE_NAME_BAND_8 = "LE71930562016031ASN00_B8.TIF"
    GROUND_CONTROL_POINT_FILE_NAME =
"LE71930562016031ASN00_GCP.txt"
    METADATA_FILE_NAME = "LE71930562016031ASN00_MTL.txt"
    CPF_NAME = "L7CPF20160101_20160331.05"
  END_GROUP = PRODUCT_METADATA
  GROUP = IMAGE_ATTRIBUTES
    CLOUD_COVER = 0.00
    IMAGE_QUALITY = 9
    SUN_AZIMUTH = 129.63210563
```

```
    SUN_ELEVATION = 53.11480198
    EARTH_SUN_DISTANCE = 0.9851578
    GROUND_CONTROL_POINTS_VERSION = 3
    GROUND_CONTROL_POINTS_MODEL = 100
    GEOMETRIC_RMSE_MODEL = 5.828
    GEOMETRIC_RMSE_MODEL_Y = 4.357
    GEOMETRIC_RMSE_MODEL_X = 3.870
  END_GROUP = IMAGE_ATTRIBUTES
  GROUP = MIN_MAX_RADIANCE
    RADIANCE_MAXIMUM_BAND_1 = 293.700
RADIANCE_MINIMUM_BAND_1 = -6.200
    RADIANCE_MAXIMUM_BAND_2 = 300.900
    RADIANCE_MINIMUM_BAND_2 = -6.400
    RADIANCE_MAXIMUM_BAND_3 = 234.400
RADIANCE_MINIMUM_BAND_3 = -5.000
    RADIANCE_MAXIMUM_BAND_4 = 241.100
    RADIANCE_MINIMUM_BAND_4 = -5.100
    RADIANCE_MAXIMUM_BAND_5 = 47.570
    RADIANCE_MINIMUM_BAND_5 = -1.000
    RADIANCE_MAXIMUM_BAND_6_VCID_1 = 17.040
    RADIANCE_MINIMUM_BAND_6_VCID_1 = 0.000
    RADIANCE_MAXIMUM_BAND_6_VCID_2 = 12.650
    RADIANCE_MINIMUM_BAND_6_VCID_2 = 3.200
    RADIANCE_MAXIMUM_BAND_7 = 16.540
    RADIANCE_MINIMUM_BAND_7 = -0.350
    RADIANCE_MAXIMUM_BAND_8 = 243.100
    RADIANCE_MINIMUM_BAND_8 = -4.700
  END_GROUP = MIN_MAX_RADIANCE
  GROUP = MIN_MAX_REFLECTANCE
    REFLECTANCE_MAXIMUM_BAND_1 = 0.454568
    REFLECTANCE_MINIMUM_BAND_1 = -0.009596
    REFLECTANCE_MAXIMUM_BAND_2 = 0.498074
    REFLECTANCE_MINIMUM_BAND_2 = -0.010594
REFLECTANCE_MAXIMUM_BAND_3 = 0.461986
    REFLECTANCE_MINIMUM_BAND_3 = -0.009855
    REFLECTANCE_MAXIMUM_BAND_4 = 0.704139
    REFLECTANCE_MINIMUM_BAND_4 = -0.014895
REFLECTANCE_MAXIMUM_BAND_5 = 0.642633
    REFLECTANCE_MINIMUM_BAND_5 = -0.013509
REFLECTANCE_MAXIMUM_BAND_7 = 0.614562
    REFLECTANCE_MINIMUM_BAND_7 = -0.013005
REFLECTANCE_MAXIMUM_BAND_8 = 0.541431
    REFLECTANCE_MINIMUM_BAND_8 = -0.010468
  END_GROUP = MIN_MAX_REFLECTANCE
GROUP = MIN_MAX_PIXEL_VALUE
    QUANTIZE_CAL_MAX_BAND_1 = 255
    QUANTIZE_CAL_MIN_BAND_1 = 1
```

QUANTIZE_CAL_MAX_BAND_2 = 255
QUANTIZE_CAL_MIN_BAND_2 = 1
QUANTIZE_CAL_MAX_BAND_3 = 255
QUANTIZE_CAL_MIN_BAND_3 = 1
QUANTIZE_CAL_MAX_BAND_4 = 255
QUANTIZE_CAL_MIN_BAND_4 = 1
QUANTIZE_CAL_MAX_BAND_5 = 255
QUANTIZE_CAL_MIN_BAND_5 = 1
QUANTIZE_CAL_MAX_BAND_6_VCID_1 = 255
QUANTIZE_CAL_MIN_BAND_6_VCID_1 = 1
QUANTIZE_CAL_MAX_BAND_6_VCID_2 = 255
QUANTIZE_CAL_MIN_BAND_6_VCID_2 = 1
QUANTIZE_CAL_MAX_BAND_7 = 255
QUANTIZE_CAL_MIN_BAND_7 = 1
QUANTIZE_CAL_MAX_BAND_8 = 255
QUANTIZE_CAL_MIN_BAND_8 = 1
END_GROUP = MIN_MAX_PIXEL_VALUE
GROUP = PRODUCT_PARAMETERS
CORRECTION_GAIN_BAND_1 = "CPF"
CORRECTION_GAIN_BAND_2 = "CPF"
CORRECTION_GAIN_BAND_3 = "CPF"
CORRECTION_GAIN_BAND_4 = "CPF"
CORRECTION_GAIN_BAND_5 = "CPF"
CORRECTION_GAIN_BAND_6_VCID_1 = "CPF"
CORRECTION_GAIN_BAND_6_VCID_2 = "CPF"
CORRECTION_GAIN_BAND_7 = "CPF"
CORRECTION_GAIN_BAND_8 = "CPF"
CORRECTION_BIAS_BAND_1 = "INTERNAL_CALIBRATION"
CORRECTION_BIAS_BAND_2 = "INTERNAL_CALIBRATION"
CORRECTION_BIAS_BAND_3 = "INTERNAL_CALIBRATION"
CORRECTION_BIAS_BAND_4 = "INTERNAL_CALIBRATION"
CORRECTION_BIAS_BAND_5 = "INTERNAL_CALIBRATION"
CORRECTION_BIAS_BAND_6_VCID_1 = "INTERNAL_CALIBRATION"
CORRECTION_BIAS_BAND_6_VCID_2 = "INTERNAL_CALIBRATION"
CORRECTION_BIAS_BAND_7 = "INTERNAL_CALIBRATION"
CORRECTION_BIAS_BAND_8 = "INTERNAL_CALIBRATION"
GAIN_BAND_1 = "L"
GAIN_BAND_2 = "L"
GAIN_BAND_3 = "L"
GAIN_BAND_4 = "L"
GAIN_BAND_5 = "L"
GAIN_BAND_6_VCID_1 = "L"
GAIN_BAND_6_VCID_2 = "H"
GAIN_BAND_7 = "L"
GAIN_BAND_8 = "L"
GAIN_CHANGE_BAND_1 = "LL"

```
    GAIN_CHANGE_BAND_2 = "LL"
    GAIN_CHANGE_BAND_3 = "LL"
    GAIN_CHANGE_BAND_4 = "LL"
    GAIN_CHANGE_BAND_5 = "LL"
    GAIN_CHANGE_BAND_6_VCID_1 = "LL"
    GAIN_CHANGE_BAND_6_VCID_2 = "HH"
    GAIN_CHANGE_BAND_7 = "LL"
    GAIN_CHANGE_BAND_8 = "LL"
    GAIN_CHANGE_SCAN_BAND_1 = 0
    GAIN_CHANGE_SCAN_BAND_2 = 0
    GAIN_CHANGE_SCAN_BAND_3 = 0
    GAIN_CHANGE_SCAN_BAND_4 = 0
    GAIN_CHANGE_SCAN_BAND_5 = 0
    GAIN_CHANGE_SCAN_BAND_6_VCID_1 = 0
    GAIN_CHANGE_SCAN_BAND_6_VCID_2 = 0
    GAIN_CHANGE_SCAN_BAND_7 = 0
    GAIN_CHANGE_SCAN_BAND_8 = 0
  END_GROUP = PRODUCT_PARAMETERS
  GROUP = RADIOMETRIC_RESCALING
    RADIANCE_MULT_BAND_1 = 1.1807E+00
    RADIANCE_MULT_BAND_2 = 1.2098E+00
    RADIANCE_MULT_BAND_3 = 9.4252E-01
    RADIANCE_MULT_BAND_4 = 9.6929E-01
    RADIANCE_MULT_BAND_5 = 1.9122E-01
    RADIANCE_MULT_BAND_6_VCID_1 = 6.7087E-02
    RADIANCE_MULT_BAND_6_VCID_2 = 3.7205E-02
    RADIANCE_MULT_BAND_7 = 6.6496E-02
    RADIANCE_MULT_BAND_8 = 9.7559E-01
    RADIANCE_ADD_BAND_1 = -7.38071
    RADIANCE_ADD_BAND_2 = -7.60984
    RADIANCE_ADD_BAND_3 = -5.94252
    RADIANCE_ADD_BAND_4 = -6.06929
    RADIANCE_ADD_BAND_5 = -1.19122
    RADIANCE_ADD_BAND_6_VCID_1 = -0.06709
    RADIANCE_ADD_BAND_6_VCID_2 = 3.16280
    RADIANCE_ADD_BAND_7 = -0.41650
    RADIANCE_ADD_BAND_8 = -5.67559
    REFLECTANCE_MULT_BAND_1 = 1.8274E-03
    REFLECTANCE_MULT_BAND_2 = 2.0026E-03
    REFLECTANCE_MULT_BAND_3 = 1.8576E-03
    REFLECTANCE_MULT_BAND_4 = 2.8308E-03
    REFLECTANCE_MULT_BAND_5 = 2.5832E-03
    REFLECTANCE_MULT_BAND_7 = 2.4707E-03
    REFLECTANCE_MULT_BAND_8 = 2.1728E-03
    REFLECTANCE_ADD_BAND_1 = -0.011423
    REFLECTANCE_ADD_BAND_2 = -0.012596
    REFLECTANCE_ADD_BAND_3 = -0.011712
    REFLECTANCE_ADD_BAND_4 = -0.017726
```

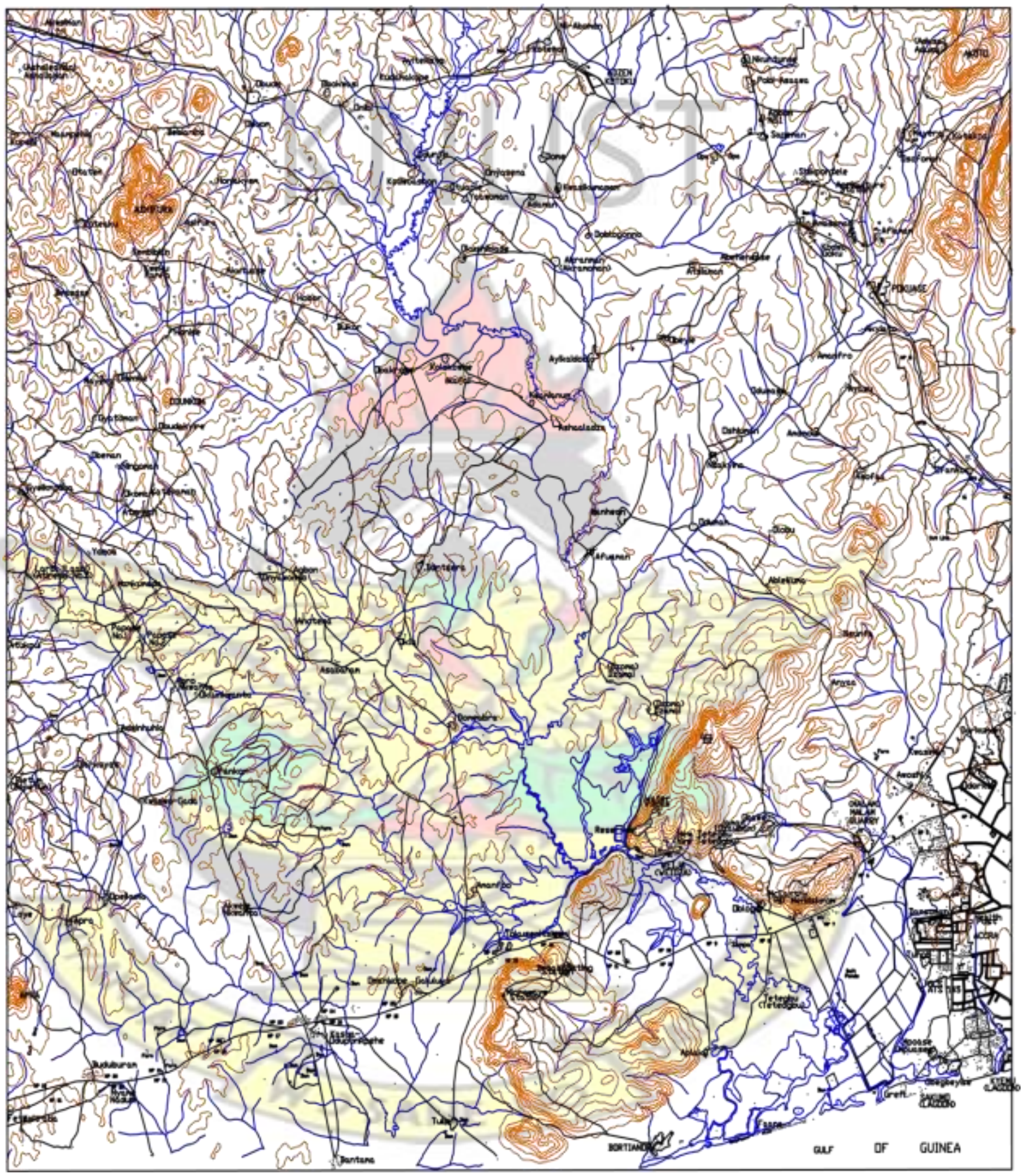
```
    REFLECTANCE_ADD_BAND_5 = -0.016092
    REFLECTANCE_ADD_BAND_7 = -0.015475
    REFLECTANCE_ADD_BAND_8 = -0.012641
  END_GROUP = RADIOMETRIC_RESCALING
  GROUP = THERMAL_CONSTANTS
    K1_CONSTANT_BAND_6_VCID_1 = 666.09
    K2_CONSTANT_BAND_6_VCID_1 = 1282.71
K1_CONSTANT_BAND_6_VCID_2 = 666.09
    K2_CONSTANT_BAND_6_VCID_2 = 1282.71
  END_GROUP = THERMAL_CONSTANTS
  GROUP = PROJECTION_PARAMETERS
    MAP_PROJECTION = "UTM"
    DATUM = "WGS84"
    ELLIPSOID = "WGS84"
    UTM_ZONE = 30
    GRID_CELL_SIZE_PANCHROMATIC = 15.00
    GRID_CELL_SIZE_REFLECTIVE = 30.00
    GRID_CELL_SIZE_THERMAL = 30.00
    ORIENTATION = "NORTH_UP"
    RESAMPLING_OPTION = "CUBIC_CONVOLUTION"
    SCAN_GAP_INTERPOLATION = 2.0
  END_GROUP = PROJECTION_PARAMETERS
END_GROUP = L1_METADATA_FILE
END
```


Appendix C

Appendix C-1 Topographic Sheet of Study Area

APPENDIX C

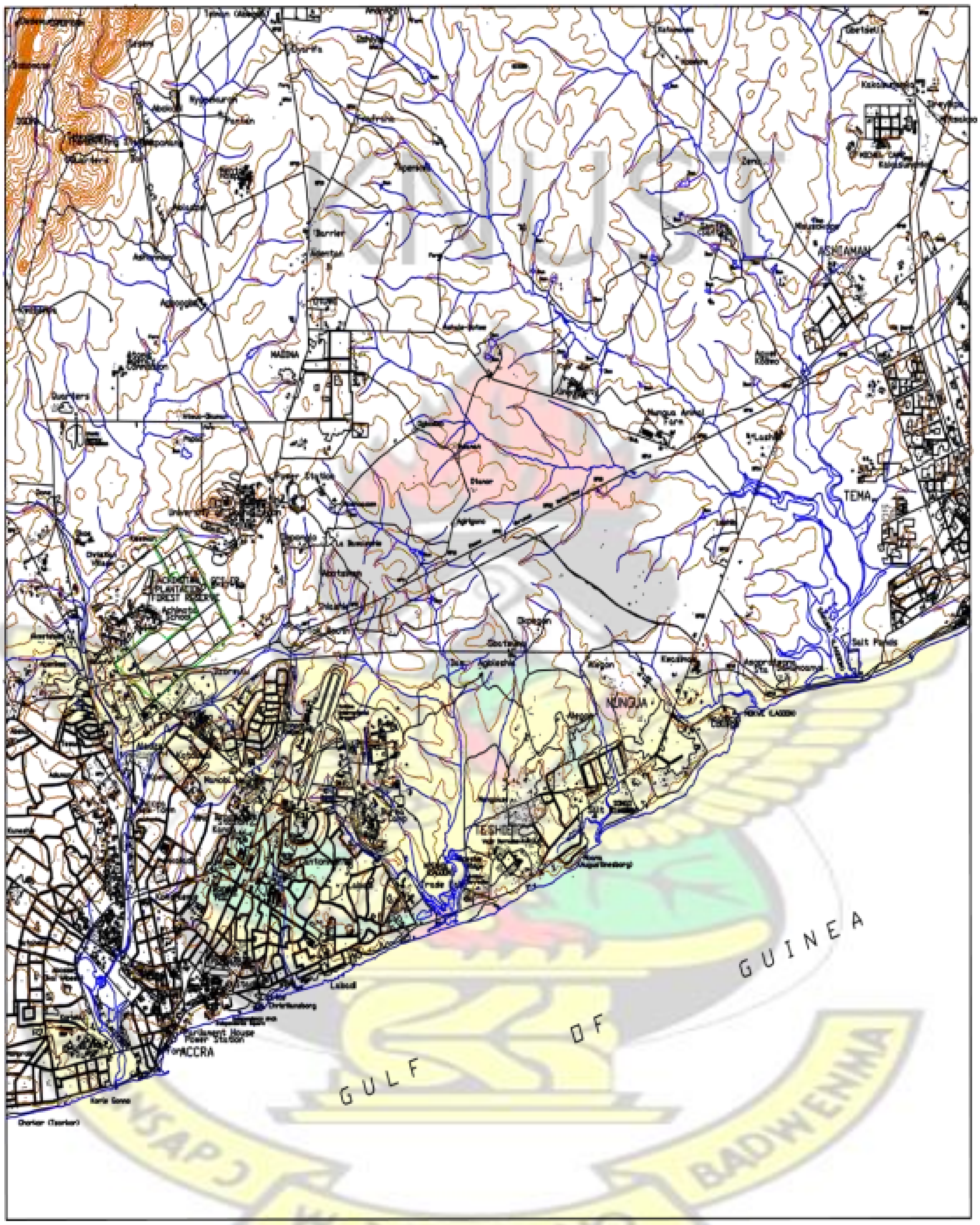
C1 - TOPO SHEET NO. 0501B3



Appendix C-2 Topographic Sheet of Study Area

APPENDIX C

C2 - TOPO SHEET NO. 0501B4



Appendix D

Appendix D-1 Accuracy Assessment For 2006

Class Confusion Matrix

File

Confusion Matrix: C:\Users\HeLEN\Documents\data RS\PROCESS\ARHMED\WORK\CLASSIFICATION\2006MAXIMUM

Overall Accuracy = (8323/8715) 95.5020%
Kappa Coefficient = 0.9423

Class	Ground Truth (Pixels) WATER BODY	GRASSLAND	DENSE VEGETAT	OPEN AREAS	SETTLEMENT
Unclassified	0	0	0	2	0
WATER BODY	1596	0	0	0	0
GRASSLAND/SHR	2	1215	4	0	1
DENSE VEGETAT	0	121	1345	8	1
OPEN AREAS	0	0	3	1467	0
SETTLEMENT	238	2	1	9	2700
Total	1836	1338	1353	1486	2702

Class	Ground Truth (Pixels) Total
Unclassified	2
WATER BODY	1596
GRASSLAND/SHR	1222
DENSE VEGETAT	1475
OPEN AREAS	1470
SETTLEMENT	2950
Total	8715

Class	Ground Truth (Percent) WATER BODY	GRASSLAND	DENSE VEGETAT	OPEN AREAS	SETTLEMENT
Unclassified	0.00	0.00	0.00	0.13	0.00
WATER BODY	86.93	0.00	0.00	0.00	0.00
GRASSLAND/SHR	0.11	90.81	0.30	0.00	0.04
DENSE VEGETAT	0.00	9.04	99.41	0.54	0.04
OPEN AREAS	0.00	0.00	0.22	98.72	0.00
SETTLEMENT	12.96	0.15	0.07	0.61	99.93
Total	100.00	100.00	100.00	100.00	100.00

Class	Ground Truth (Percent) Total
Unclassified	0.02
WATER BODY	18.31
GRASSLAND/SHR	14.02
DENSE VEGETAT	16.92
OPEN AREAS	16.87
SETTLEMENT	33.85
Total	100.00

Appendix D

-2 Cont. Accuracy Assessment For 2006

Class Confusion Matrix

File

Class	Total
Unclassified	2
WATER BODY	1596
GRASSLAND/SHR	1222
DENSE VEGETAT	1475
OPEN AREAS	1470
SETTLEMENT	2950
Total	8715

	Ground Truth (Percent)				
Class	WATER BODY	GRASSLAND	DENSE VEGETAT	OPEN AREAS	SETTLEMENT
Unclassified	0.00	0.00	0.00	0.13	0.00
WATER BODY	86.93	0.00	0.00	0.00	0.00
GRASSLAND/SHR	0.11	90.81	0.30	0.00	0.04
DENSE VEGETAT	0.00	9.04	99.41	0.54	0.04
OPEN AREAS	0.00	0.00	0.22	98.72	0.00
SETTLEMENT	12.96	0.15	0.07	0.61	99.93
Total	100.00	100.00	100.00	100.00	100.00

	Ground Truth (Percent)
Class	Total
Unclassified	0.02
WATER BODY	18.31
GRASSLAND/SHR	14.02
DENSE VEGETAT	16.92
OPEN AREAS	16.87
SETTLEMENT	33.85
Total	100.00

Class	Commission (Percent)	Omission (Percent)	Commission (Pixels)	Omission (Pixels)
WATER BODY	0.00	13.07	0/1596	240/1836
GRASSLAND/SHR	0.57	9.19	7/1222	123/1338
DENSE VEGETAT	8.81	0.59	130/1475	8/1353
OPEN AREAS	0.20	1.28	3/1470	19/1486
SETTLEMENT	8.47	0.07	250/2950	2/2702

Class	Prod. Acc. (Percent)	User Acc. (Percent)	Prod. Acc. (Pixels)	User Acc. (Pixels)
WATER BODY	86.93	100.00	1596/1836	1596/1596
GRASSLAND/SHR	90.81	99.43	1215/1338	1215/1222
DENSE VEGETAT	99.41	91.19	1345/1353	1345/1475
OPEN AREAS	98.72	99.80	1467/1486	1467/1470
SETTLEMENT	99.93	91.53	2700/2702	2700/2950

Appendix D

-3 Accuracy Assessment For 2016

Class Confusion Matrix

File

Confusion Matrix: C:\Users\HeLEN\Documents\data RS\PROCESS\ARHMED\WORK\CLASSIFICATION\2016MAXIMUM

Overall Accuracy = (6563/6656) 98.6028%
Kappa Coefficient = 0.9819

Ground Truth (Pixels)					
Class	SETTLEMENT	GRASSLAND	DENSE VEGETAT	WATER BODY	OPEN AREAS
Unclassified	0	0	0	0	0
SETTLEMENT	1524	0	3	50	14
GRASSLAND/SHR	0	1828	13	0	0
DENSE VEGETAT	0	6	1036	3	4
WATER BODY	0	0	0	1656	0
OPEN AREAS	0	0	0	0	519
Total	1524	1834	1052	1709	537

Ground Truth (Pixels)	
Class	Total
Unclassified	0
SETTLEMENT	1591
GRASSLAND/SHR	1841
DENSE VEGETAT	1049
WATER BODY	1656
OPEN AREAS	519
Total	6656

Ground Truth (Percent)					
Class	SETTLEMENT	GRASSLAND	DENSE VEGETAT	WATER BODY	OPEN AREAS
Unclassified	0.00	0.00	0.00	0.00	0.00
SETTLEMENT	100.00	0.00	0.29	2.93	2.61
GRASSLAND/SHR	0.00	99.67	1.24	0.00	0.00
DENSE VEGETAT	0.00	0.33	98.48	0.18	0.74
WATER BODY	0.00	0.00	0.00	96.90	0.00
OPEN AREAS	0.00	0.00	0.00	0.00	96.65
Total	100.00	100.00	100.00	100.00	100.00

Ground Truth (Percent)	
Class	Total
Unclassified	0.00
SETTLEMENT	23.90
GRASSLAND/SHR	27.66
DENSE VEGETAT	15.76
WATER BODY	24.88
OPEN AREAS	7.80
Total	100.00

Appendix D

-4 Cont. Accuracy Assessment For 2016

Class Confusion Matrix

File

Class	Total
Unclassified	0
SETTLEMENT	1591
GRASSLAND/SHR	1841
DENSE VEGETAT	1049
WATER BODY	1656
OPEN AREAS	519
Total	6656

	Ground Truth (Percent)				
Class	SETTLEMENT	GRASSLAND	DENSE VEGETAT	WATER BODY	OPEN AREAS
Unclassified	0.00	0.00	0.00	0.00	0.00
SETTLEMENT	100.00	0.00	0.29	2.93	2.61
GRASSLAND/SHR	0.00	99.67	1.24	0.00	0.00
DENSE VEGETAT	0.00	0.33	98.48	0.18	0.74
WATER BODY	0.00	0.00	0.00	96.90	0.00
OPEN AREAS	0.00	0.00	0.00	0.00	96.65
Total	100.00	100.00	100.00	100.00	100.00

	Ground Truth (Percent)
Class	Total
Unclassified	0.00
SETTLEMENT	23.90
GRASSLAND/SHR	27.66
DENSE VEGETAT	15.76
WATER BODY	24.88
OPEN AREAS	7.80
Total	100.00

Class	Commission (Percent)	Omission (Percent)	Commission (Pixels)	Omission (Pixels)
SETTLEMENT	4.21	0.00	67/1591	0/1524
GRASSLAND/SHR	0.71	0.33	13/1841	6/1834
DENSE VEGETAT	1.24	1.52	13/1049	16/1052
WATER BODY	0.00	3.10	0/1656	53/1709
OPEN AREAS	0.00	3.35	0/519	18/537

Class	Prod. Acc. (Percent)	User Acc. (Percent)	Prod. Acc. (Pixels)	User Acc. (Pixels)
SETTLEMENT	100.00	95.79	1524/1524	1524/1591
GRASSLAND/SHR	99.67	99.29	1828/1834	1828/1841
DENSE VEGETAT	98.48	98.76	1036/1052	1036/1049
WATER BODY	96.90	100.00	1656/1709	1656/1656
OPEN AREAS	96.65	100.00	519/537	519/519