

**A STUDY TO ASCERTAIN THE GROWTH SITUATION OF THE KUMASI  
METROPOLITAN AREA (KMA): A REMOTE SENSING APPROACH**

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## ABSTRACT

Urban sprawl has led to the loss of lots of natural resources such as water bodies, wetlands, agricultural lands, forest, etc which are necessary biodiversities needed to create a balanced environment and ecosystem. As towns and cities expand due to the increase in urban population, enormous pressure is exerted on the surrounding natural resources in order to create space to cater for the increasing urban population. Urban sprawl generally leads to the wasteful development of land, and also poses health and other hazardous threat to people due to its overcrowded characteristic. This has made it essential to understand the phenomenon of urban sprawl, especially with the perspective of a developing country like Ghana. The problem of urban sprawl is known to be an outcome of improper planning, inadequate policies and lack of good governance due to diverse reasons. The inability of the planning mechanism to envisage probable areas of sprawl and its growth is persistent with the lack of appropriate spatial information and indicators. With the need for sustainable development, it is essential to integrate the various factors responsible for dynamic process and establish the complex relationships amongst them.

Remote System (RS) techniques applied on remotely sensed images and topographic data were carried out to assess the urban growth of the Kumasi Metropolitan Area (KMA) of the Ashanti region of Ghana. Semi-structured questionnaires were also administered to carry out a socioeconomic survey to ascertain its influence on the expansion of the KMA.

Spatial analysis and statistical analysis revealed the pattern and growth of the urban area from 1974 to 2007. The change in urban growth of the KMA was discovered to be three times more than the change in population growth. The reasons for uncontrolled development were also revealed by the socioeconomic survey.

The results suggested that the KMA is sprawled. The sprawl is due to the increasing population growth, unequal income (poverty), and noncompliance to laid down developmental plans within the KMA.

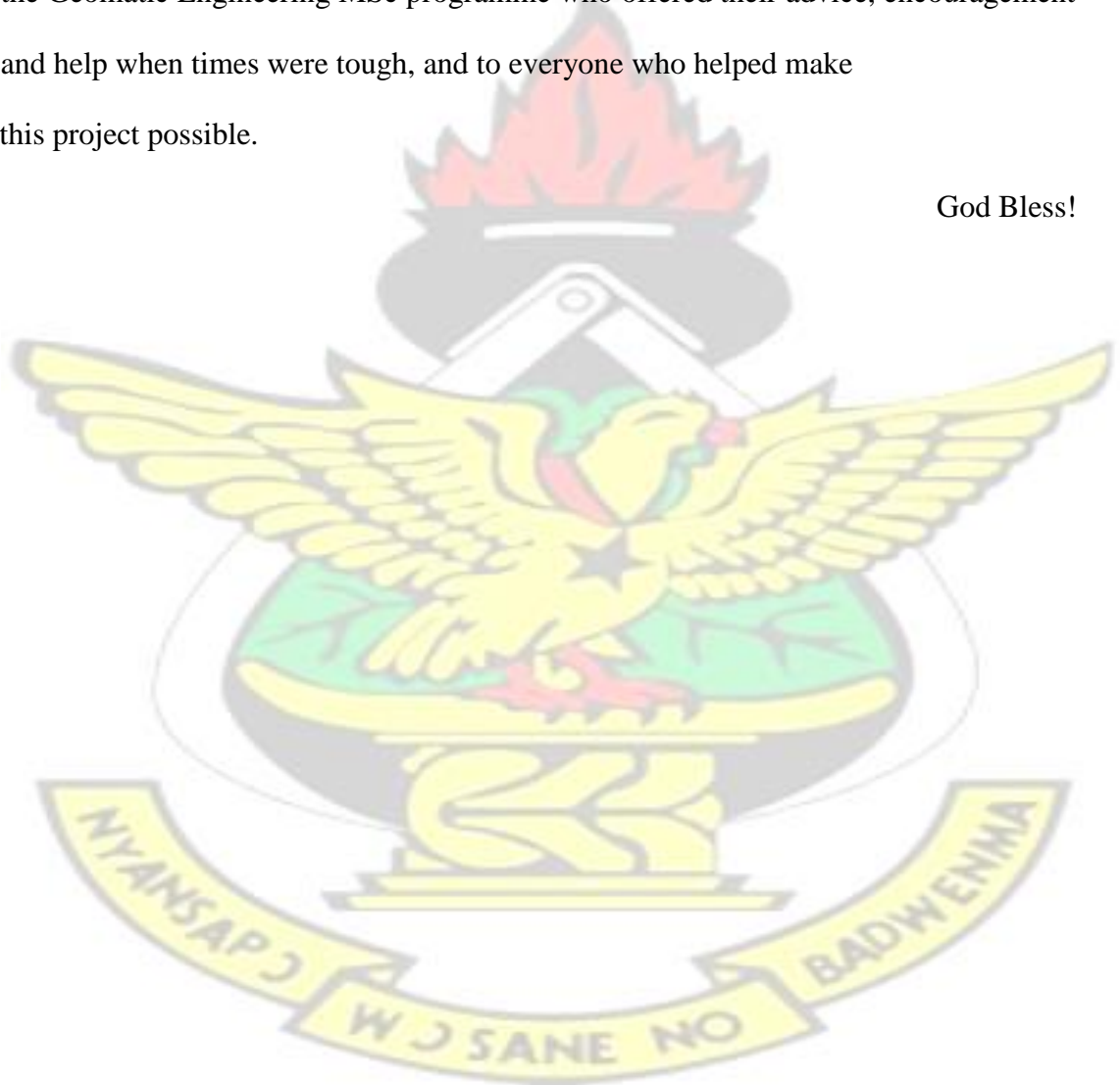
Keywords: Urban Sprawl, Remote Sensing, Population growth, Spatial, Socioeconomic, Demographic.

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God Bless!



## DEDICATION

To my family especially, my mother, Theresa Konadu Tontoh.

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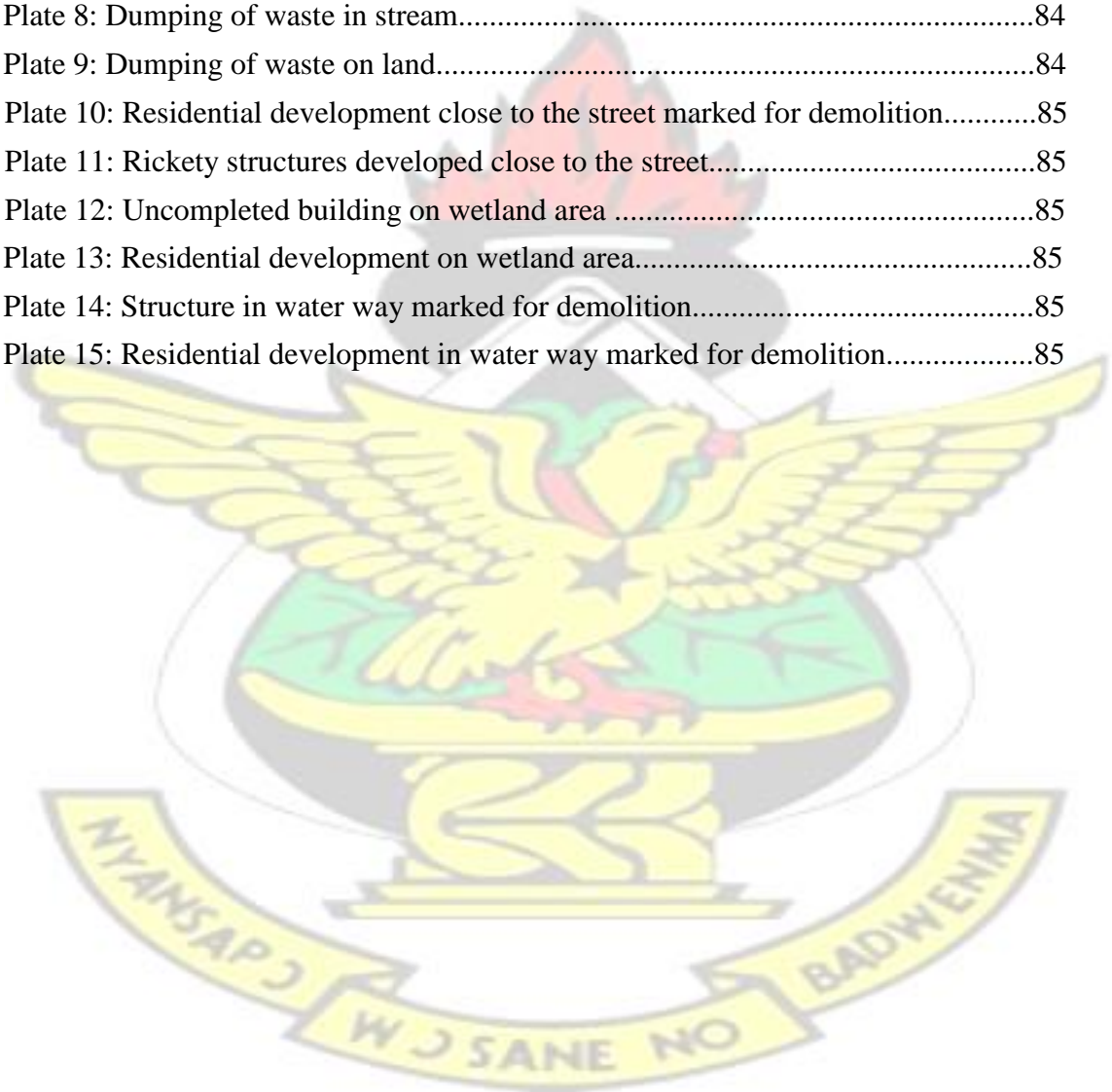
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## List of Abbreviations

CA	Class Area
ETM	Enhanced Thematic Mapper
FEMA	Federal Emergency Management Agency
GSS	Ghana Statistical Services
Ha	Hectare
KMA	Kumasi Metropolitan Area
LPI	Large Patch Index
LULC	Land Use Land Cover
NP	Number of Patches
PD	Patch Density
RS	Remote Sensing
TM	Thematic Mapper
WGS	World Geographic System



# CHAPTER ONE

## INTRODUCTION

### 1.1 Background

Rapid industrialization causes haphazard and unplanned growth of urban centres. This becomes more complicated for the fact that it takes place within built up areas. Pressure of continuous growing population results in overcrowding and becomes a burden to the limited civic cycle amenities. The situation forces the middle class as well as property developers to move to outward lying suburbs, a phenomenon called Urban Sprawl (Vinay, 2000).

Sprawl may be caused by population growth, economy, proximity to resources and basic amenities (Sudhira et al., 2003). In Ghana, unprecedented population growth coupled with unplanned development activities has led to urbanization, which lacks infrastructural facilities. This has also posed serious implications on the resource base of the country.

With the expansion of the country's road network coupled with the increase in the reliance of automobile, population had tended to shift from the cities to the suburbs. The type of sprawl associated with this form of development is either in radial direction around a well established city or linearly along transportation arteries.

The urban sprawl phenomenon has been subjected to considerable analysis by social critics, academicians, policy makers and planners since the shift of people and economic activities beyond the core of the city have vast socioeconomic and

environmental impacts. The direct effect of the sprawl phenomenon is the change in landuse landcover (LULC) of the region, consuming open and agricultural lands.

The ability to make efficient use of land greatly influences the economic and environmental quality of life in society (Turkstra, 1996). When the patterns of sprawl are identified and the spatial and temporal changes are known, it would help enormously in the planning for proper infrastructure facility (Sudhira et al., 2003).

The patterns of sprawl and the analysis of its spatial and temporal changes could be done cost effectively and efficiently with the use of Remote Sensing (RS) alongside the use of collateral data (such as topographic sheet of the study area, census data, etc).

RS applications are growing rapidly with the availability of high-resolution data from the state of the art satellites such as QUICK BIRD and LANDSAT. The advancement in computer hardware and software in these areas also enhances their applications.

Satellite RS imageries alongside conventional ground data can be used as information source to analytically map, monitor and accurately assess the spatial patterns of urban sprawl over different time periods (Lata et al., 2001). Mapping urban sprawl provides a “picture” of where this type of growth is occurring, helps to identify the environmental and natural resources threatened by such sprawl, and to suggest the likely future direction and patterns of sprawling growth (Sudhira et al., 2004).

## **1.2 Project Problem**

Urban sprawl has been one of the escalating issues of importance in the present development situation, where increasing population and migration trends for better

livelihood opportunities have paved way for rapid expansion of the urban centers. In most cases, this process occurs so fast that it overtakes the capacity of planning authorities to deal with the situation. Over the years, Kumasi city and its suburbs have been experiencing enormous and rapid growth. At Anloga town in Kumasi, activities by squatters have left the community congested, polluted and unhealthy as a habitat. In other parts of the city like Susanso and Kronom, buildings have sprouted up in water ways, leaving residents and properties at the risk of destruction by floods or rains. This has become a great concern to city authorities and implementation of plans to curb, monitor and control these non societal practices have become a burden. Kumasi is the second largest city in Ghana, and one of the fastest growing cities in the country (GSS, 2005). Due to the increase in urbanization, Kumasi has undergone rapid change with its LULC. Residents, Politicians, industrialists create the need for the development of land for houses, infrastructures, and social amenities. The pressure of continuously growing population has also resulted in overcrowding and has become a burden to the limited civic cycle amenities. This has compelled builders and developers to move to outlying suburbs where open spaces are available, in a much unplanned manner. This puts pressure on the natural resources of those areas, and thus makes it important to monitor changes in the urban growth that has occurred so far and those which are yet to occur to be managed.

Monitoring this growth and planning for its control has been made more difficult by the expanse of time involved in producing reliable and up-to-date maps. Existing maps are usually old, out dated and therefore difficult to use as effective information base for planning. However, the use of RS techniques on remotely sensed images can be efficiently used for this purpose. This project therefore seeks to use RS techniques such

as classification, change detection and fragmentation metrics on remotely sensed images, and by a topographic data, to assess the growth of the Kumasi Metropolitan Area.

### **1.3 Research Questions**

- What type and pattern of the urban growth can be identified in the KMA?
- How can the urban growth be analyzed using RS techniques?
- What are the causal factors of the urban growth?

### **1.4 Research Objectives**

- To identify the type pattern of urban growth of KMA
- To analyze the urban growth pattern using RS techniques
- To analyze the causal factors of the urban growth

### **1.5 Significance of Information on Urban Sprawl**

Understanding the patterns of urban sprawl facilitates effective natural resource planning, natural resource utilization and the provision of required infrastructure facilities (Sudhira et al., 2003).

Information on the urban growth of the Kumasi urban area will primarily help with effective planning. 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 housing demands of the people.

## 1.6 Structure of thesis

**Chapter two** contains the relevant literature reviewed to get acquainted with work that has been done in the field of urban sprawl and the materials and methods employed in this study.

**Chapter three** elaborates on the methods used and the mode of application of the methods to achieve results. It gives the step by step approach used in executing the research. This includes all the RS techniques applied on the images and the socio economic survey executed.

**Chapter four** accumulates the results obtained from the various methodologies used. It captures results obtained in the change detection from the classified images and the results from the socioeconomic survey. It further discusses all the results obtained.

**Chapter five** finally talks about the conclusions observed with regards to the objectives of this thesis and enumerates some recommendations regarded to be necessary and useful as a result of the study.

## CHAPTER TWO

### LITERATURE REVIEW

#### 2.1 Definition of Sprawl

There is lack of agreement over the definition of sprawl (Barnes et al., 2000). This makes the discussion of the issue of sprawl much disturbing. Many definitions were presented by Johnson (2001) but there is no common agreement over the definition of sprawl. The definition of sprawl thus depends on the perspective of the one who presents the definition.

The Sierra Club (2001) describes sprawl as irresponsible, poorly planned development that destroys green space, increase traffic and air pollution, crowds' school and wastes taxes. "Any area, which is under the jurisdiction of a municipality corporation, cantonment, or any notified town, which exceeds its administrative boundary and grows outward without any check, is considered to be a sprawl" (Nanda, 2005). Others compare sprawl to the disease process, calling it a cancerous growth or a virus (DiLorenzo, 2000). Less vociferous descriptions include "the scattering of urban settlement over the rural landscape" (Harvey and Clark, 1971), "low-density urbanization" (Pendall, 1999), and "discontinuous development" (Weitz and Moore, 1998).

Here are a few definitions which are non-technical in nature but do convey the meaning of the word sprawl:

Sprawl *noun*. to cover a large area of land with buildings which have been added at different times so that it looks untidy (Cambridge Advanced Learner's Dictionary, Cambridge Online Dictionary).

*Sprawl noun.* the scattered, unplanned and unchecked expansion of a town or city into the surrounding countryside (Microsoft Encarta, 2009).

According to the Concise Oxford English Dictionary (2004), the word sprawl refers ‘to spread out or stretch out (something) in a wide or straggling manner’.

These definitions compared with the phrase urban growth exhibits the difference between the two. Urban growth may have more of a planned appearance while the pattern of sprawl often appears awkward, uncontrolled, and haphazard. Sprawl is also considered at the metropolitan level as a measure of the rate of increase in land development relative to the population growth within the given area. If the rate at which land is converted to non-agricultural or non-natural uses exceeds the rate of population growth, sprawl is said to have occurred (USEPA, 2001).

This study however adapts the definition of sprawl in agreement with space-time. Sprawl defined from space-time is stated as “a pattern of land use land cover conversion in which the growth rate of urbanized land (land rendered impervious by development such as asphalt and concrete) significantly exceeds the rate of population growth over a specified time period, with a dominance of low-density impervious surfaces”.

Irrespective of how sprawl is defined and evaluated, it is perceived as a menace which has negative implications on the environment. It destroys natural resources, creates inefficient use of land, and loss of substantial fertile agricultural land (Gar-On Yeh et al.,

2001). Sprawl therefore is seen as a wasteful form of development (Ewing, 1994).

The seriousness of sprawl and the efforts to curb it are much discussed by many researchers. However, the lack of precise definition of the sprawl phenomenon undoubtedly complicates efforts to curtail this type of land development. This is because the opinion held by researchers, policy makers, critics, and the public sharply differs.

### ***2.1.1 Distinction between Growth and Sprawl***

Urban growth is often confused with urban sprawl. However, there is a distinction between urban growth and urban sprawl. Cities often experience growth either physically by infrastructure, by population growth, or by a combination of both. Urban sprawl is much more complicated because it may or may not qualify as urban growth. How a city grows can create the appearance of sprawl. Such urban growth may appear as a low-density leapfrog pattern, a linear or strip development pattern along highways, or a tightly condensed pattern of new development around pre-existing built-up landscapes (Nechyba et al., 2004). Without urban growth there would be no appearance of urban sprawl. Urban growth may have more of a planned appearance, while the pattern of sprawl often appears awkward, uncontrolled and haphazard.

### ***2.1.2 Spatial Forms of Sprawl***

Sprawl development is made up of three basic spatial forms (Figure 2.1). These are as follows:

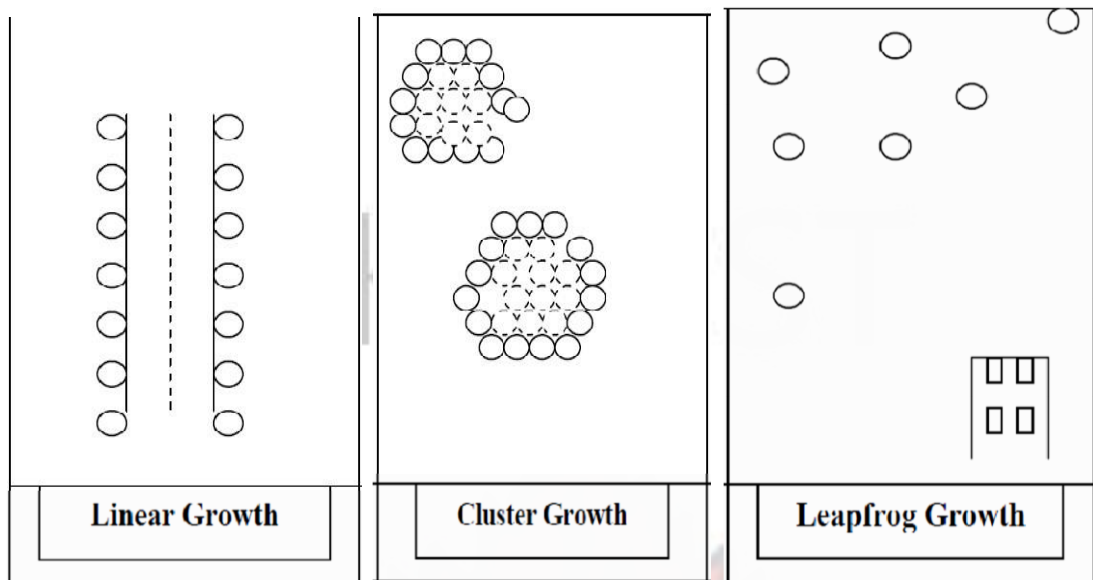
1. Ribbon sprawl or linear growth
2. Low-density continuous sprawl or cluster growth

3. Leapfrog development growth (Harvey and Clark, 1971).

Ribbon sprawl or strip commercial development along highways is development that follows major transportation arteries outward from urban cores. Lands adjacent to corridors are developed, but those without direct access remain in rural uses/covers. Over time, these nearby “raw” lands may be converted to urban uses as land values increase and infrastructure is extended perpendicularly from the major roads and lines.

Low-density continuous sprawl is the highly consumptive use of land for urban purposes along the margins of existing metropolitan areas. This type of sprawl is supported by piecemeal extensions of basic urban infrastructure and social amenities such as water, sewer, power, and roads.

Leapfrog development sprawl is a discontinuous pattern of urbanization, with patches of developed lands that are widely separated from each other and from the boundaries, albeit blurred in some cases, of recognized urbanized areas. This form of development incurs high expenditure to provide total urban services at the time of development (Harvey and Clark, 1971).



**Figure 2.1: Types of Urban Growth**

### ***2.1.3 Issues Related To Urban Sprawl***

Sprawl has been criticized for eliminating agricultural lands, spoiling water quality and causing air pollution (Allen et al., 2003). As population increases, so does the need for new housing, schools, and transportation networks. Decentralization is a trend indicative of urban sprawl and present day industrial, commercial and residential areas are no longer necessarily a part of the urban core (Nechyba et al., 2004). In the urban world today, industrial, commercial and residential districts are markedly different from years past. Hence, the needs for larger transportation networks and in turn a greater dependency on automobiles, which produce more air pollution. As new roads are built, farmlands are often left unprotected from commercial or residential developers (Hathout, 2002). The greater the imperviousness (such as asphalt and concrete) of an area the more water runoff one can expect, which is the catapult for water pollution (Wilson et al., 2003). Without regulations on urban growth, consequences of urban sprawl are likely to continue.

#### ***2.1.4 Visualization of Urban Sprawl***

Manual cartography for maps produced was designed well in advance of a due date. This manual technique has been used for map production a long time before the advent of RS. Different types of spatial data available enable a RS user to map virtually any geographic phenomena without even getting into contact with the place. Besides, RS facilitate the processing of large volumes of data with much less work and time, as compared to the manual cartographic methods.

Researchers on urban sprawl often use RS as a tool in the studying of urban sprawl 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 sprawl and its consequence on the environment (Gar-On Yeh et al., 2001).

#### ***2.1.5 Some Consequences of Sprawl***

Sprawl consequences are based on socioeconomic, environmental and natural impacts.

Socioeconomic impacts: Sprawl enforces wide physical, economic, emotional, and aesthetic costs on residents in the locality. Physical costs include higher traffic congestion, over-crowdedness, longer commuting times and more aggressive driving patterns. Economic costs become unfavourably higher and these include higher taxes, higher costs of infrastructure production, reduced worker productivity, and serious or adverse financial impacts on local governments. Emotional costs to the society are the loss of community spirit and values. Aesthetical cost of a sprawl metropolitan gives less leisure time and uglier monotonous suburban landscapes.

Environmental impacts: Sprawl has an extensive impact on ecosystems and other environmental resources, which provide societal and environmental benefits simply by existing and functioning. These ecosystems include wetlands that provide flood control and waste water restoration; atmosphere, forests, and grasslands that provide climate regulation; biodiversity factors that contribute to healthy, well-functioning ecosystems. Sprawl is a great threat to wildlife in the metropolitan area. Land sprawl widens space between remaining fragments of habitat and also degrades adjacent habitats with light and noise pollution given out from developed areas.

Natural Impacts: Natural resources are the building blocks of economic systems, without which economies would cease to function. Suburbs have become the dominant residential, retail, and commercial centers of growth as well as political strength. The continuation and replication of this trend place enormous pressure on land, water and other resources (Diamond and Noonan, 1996).

#### ***2.1.6 Other Concerns Related to Sprawl***

Due to sprawl and sprawl development, a high number of people have become exposed and vulnerable to natural hazards (Mileti, 1999). Physical development due to sprawl often encroaches upon flood plains and rivers, and upon areas prone to flash floods, slope failures, wildfires and tectonic activities (e.g. earthquake). This is as a result of the incompatibility between the land use due to sprawl and the natural processes operating in the area, such as natural hazards like as floods, earthquakes and wildfire (FEMA, 1997). Properties and lives are often lost due to these hazards. Sprawl contributes to the increase cost of natural disasters and the increasing number of people at risk (FEMA,

1997).

Again, as land development due to sprawl consumes agricultural and wildlife habitats, residents come closer to wildlife far away from metropolitan areas. This creates human-wildlife conflict, which often leads to death or injury of some wildlife due to traffic or vehicular impact. Residents and properties are also exposed to threats from the wildlife (Garrett, 1994).

### ***2.1.7 Trends in Urban Sprawl***

Globally, urban sprawl is becoming more apparent than ever. Increase in population often leads to increase in development, which negatively influences agricultural lands conversion. Urban growth is inevitable over the next two decades and that most of this growth will take place in less developed countries (Masser, 2000). Rapid land use change has occurred since economic reform in these nations. This is most severe in areas where the economy is developing very rapidly and the conflict between the environment and economic development is most severe. Under the above situation, detecting, monitoring, and planning for effective land use to combat and control the wasteful form of land development due to sprawl becomes crucial. Change detection techniques can be applied on satellite imagery to achieve these purposes.

## **2.2 Landsat Satellite Data and Change Detection**

Landsat satellites provide data with good spectral and spatial resolution. They generally have medium resolution and wide coverage capabilities to provide data with relatively

better resolution, coverage and revisit time to meet growing application needs. Remote sensing applications such as change detection, requires high resolution multi temporal images since change patterns are observed using a variety of metrics and visual interpretation techniques.

An outgrowth of previous work of mapping developed land surfaces for the Chesapeake Bay watershed and adjacent areas of Mid-Atlantic region of the United State of America was done using landsat satellite data (Chesapeake Bay and Mid-Atlantic from Space). In Ghana, the LULC in the Owabi catchment area was assessed by Gbekor, (2008) using landsat data. Urban Sprawl pattern recognition and modeling was also achieved using landsat satellite data (Sudhira et al., 2003). Landsat satellite data are therefore useful in change detection processes because of its spatial, spectral and temporal coverage characteristic, inspite of the presence of sparingly cloud covers on some of its images sometimes.

### **2.3 Change Detection**

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times. Essentially, it involves the ability to quantify temporal effects using multi-temporal data (Singh, 1989). RS provides a viable source of data from which updated land-cover information can be extracted efficiently and cheaply (Sudhira et al., 2001). It assists in monitoring changes effectively (Sudhira et al., 2003). Thus change detection has become a major application of remotely sensed data because of repetitive coverage at short intervals and consistent image quality (Mas, 1999).

Digital change detection is affected by spatial, spectral, temporal and thematic constraints. A wide variety of digital change detection algorithms have been developed over the last two decades (Singh, 1989). Change detection has been categorized into two and different reviewers have given varying definition and names to them. Lunetta (1999) named them as post classification and pre-spectral classification. Malila (1980) recognized the categories as change measurement (stratification) methods versus classification approaches.

Pilon et al., (1987) amplified the description of the first category to enhancement approaches involving mathematical combination of multi-date imagery, which when displayed as a composite image, shows change in unique colours. Singh (1989) changed the focus slightly by centering the definition more on a temporal scale: simultaneous analysis of multi-temporal data versus comparative analysis of independently produced classification for different dates. Other scientists (Nelson, 1983; Milne, 1988) have employed multi-class schemes. The type of method implemented can profoundly affect the qualitative and quantitative estimates of the analysis (Colwell and Weber, 1981).

In pre-classification spectral change detection, images of two dates are transformed into a new single-band or multi-band image, which contains the spectral changes. The resultant image must be further processed to assign the changes to specific land cover types (Yuan et al., 1999).

Since the methods are based on pixel-wise or scene-wise operations, they are sensitive to image registration and co-registration accuracy. Discrimination of change and no change pixel is of the greatest importance in successful performance of these methods. A common

method of discrimination is the use of statistical threshold (Yuan et al., 1999). In this method, a careful decision is required to place threshold boundaries to separate the area of change from no-change (Singh, 1989). Post classification deals with the classification of individual images independently followed by a comparison pixel label to identify the areas where change has occurred.

### ***2.3.1 Post classification comparison change detection***

This is the most straightforward method of change detection (Singh, 1989). It involves the overlay of two or more classified images. Change areas are simply those areas which are not classified the same at different times. Singh (1989) identified that this technique had the lowest accuracy when compared to various image algebra techniques and principal component analysis (PCA) classification of a multi-date composite. Muchoney and Haack (1994) found post-classification inferior to both PCA and image differencing for monitoring defoliation; pointing out that the method does not allow for normalizing differences between multi-temporal data. However, Jensen *et al.* (1995) performed postclassification change detection using classified images that were normalized previous to classification. The resulting change product was found to be satisfactory and useful as a display tool to exhibit an association between Cattail/Sawgrass mixture and high concentrations of porewater phosphorus.

Ferguson *et al.* (1993) used post-classification to produce effective maps of changes in Seagrass habitat and Jensen *et al.* (1987) did a post-classification change detection to monitor wetland change in the Savannah River swamp forest. Augenstein *et al.* (1991) found post-classification acceptable for kelp monitoring, while Hall *et al.* (1991) revealed

that post classification change detection provide appropriate input into their land transformation model.

Sudhira et al. (2003) studied the urban sprawl phenomenon in Mangalore and Udipi, India. The urban sprawl over a period of nearly three decades was quantified in terms of change in built-up area as well as Shannon's entropy index. They determined the pattern recognition and modeled the urban sprawl employing post classification change detection.

Previous studies have sought to combine change detection using remotely sensed data with impact analysis of these changes using landscape metrics, with the aim of taking into account the spatial distribution and arrangement of land cover changes. Some notable studies have been performed by Franklin et al. (2000), Narumalani et al. (2004), as well as Kamusoko and Aniya (2007). Herold et al. (2005, 2003 and 2002) have conducted extensive research on the use of spatial metrics to quantify the impact of urban growth in Santa Barbara, California. Studies like these have helped to provide urban and environmental planners with the spatial and temporal information necessary to make more informed decisions about future land use.

## **2.4 Landscape**

Several definitions of landscapes exist. Landscape has been defined as "an area of land containing a mosaic of patches or landscape elements (McGarigal and Marks, 1994). Forman and Gordon (1986) in (McGarigal and Marks 1994) defined a landscape as a

heterogeneous land area composed of a cluster of interacting ecosystems that is repeated in similar form throughout.

#### ***2.4.1 Landscape structure***

Landscape structure implies spatial heterogeneity (Lenore, 2008) and has two components; landscape composition and landscape configuration. “Landscape composition refers to the features associated with the presence and amount of each patch type without being spatially explicit” (McGarigal and Marks, 1994). On the other hand “landscape configuration refers to the physical distribution or spatial characteristics of patches within the landscape”. These two aspects of a landscape can independently or in combination affect environmental processes (McGarigal and Marks, 1994).

#### ***2.4.2 Fragmentation and Fragment analysis***

Crim et al. (2002) defined fragmentation as, “a sweeping term for a host of processes related to the disruption of continuity in predominantly natural landscapes”. Bennett (1998) defined fragmentation as a dynamic process of change that occurs when blocks of vegetation are completely cleared leaving multiple smaller blocks that are separated from each other. Landscape pattern metrics are measurements designed to quantify and capture aspects of landscape pattern and include such measures as fragmentation indices, patch shape indices, or the percentage of an area occupied by the largest contiguous patch of grassland (Griffith et al., 2000). Landscape metrics are increasingly being applied in ecology and urban studies (DiBari, 2006; Kamusoko and Aniya, 2007; Keleş et al., 2007; Weng, 2007).

## 2.5 Accuracy Assessment

Accuracy is considered to be the degree of closeness of results to the values accepted as true. Accuracy assessment is very important for understanding the developed results and employing these results for decision making. Some of the accuracy assessment methods are the variance analysis, minimum accuracy value used as an index of classification accuracy, spatial error and class attribute error, a probabilistic approach for change detection in land cover.

Error matrices and Cohen's Kappa (K) are commonly used for accuracy assessment. The most effective way to represent classification accuracy is via an error matrix (Jensen, 1996; Stehman and Czaplewski, 1998; Congalton and Green, 1999). The class of a given unit on the ground is compared to the class of that unit from the remotely sensed image. Correctly classified units are shown on the major diagonal of the matrix. For each error matrix, the overall accuracy, producer's accuracy, user's accuracy, errors of commission and errors of omission are calculated.

Overall accuracy is the measure of accuracy of the entire image. It is the total number of inputs correctly classified divided by the total number of sample units examined in the error matrix. Overall accuracies indicate how well the map identified the landcover on the ground. This is

$$\text{calculated as: Overall accuracy} = \frac{\text{sum of diagonal tallies}}{\text{total number of samples}} * 100 \text{ ----- (1)}$$

The producer's accuracy is a measure of the probability of a sample unit being correctly classified into a particular category. Producer's accuracy expresses how well the map producer identifies the landcover type on the map from the satellite imagery data. This is

calculated as: Producer's accuracy =  $\frac{\text{number of correctly identified samples}}{\text{Rows Total}} * 100$  ----

(2)

An error of omission occurs when sample points are omitted from the category they belong. Omission Error =  $100 - \text{Producer's accuracy}$  ----- (3)

User's accuracy is the probability that a sample unit classified on the map actually represents that category on the ground. User's accuracy expresses how well the user of the map will find that landcover type on the ground.

This is calculated as: User's accuracy =  $\frac{\text{number of correctly identified samples}}{\text{Columns Total}} * 100$  -- (4)

An error of commission occurs when there are incorrectly classified samples in a category. Commission Error =  $100 - \text{User's accuracy}$ ----- (5)

Every error in the classification is an omission from the correct category and a commission to a wrong category.

The accuracy assessment for change detection is particularly difficult due to problems in collecting reliable temporal field-based datasets. Because of this, much previous change detection researches do not have quantitative analysis of the research results (Campbell, 2002). Although standard accuracy assessment techniques were mainly developed for single date remotely sensed data, the error matrix based accuracy assessment method is still valuable for a valuation of change detection results. Therefore, sampling for assessing the accuracy of change detection requires more time and effort.

Kappa can be used as a measure of agreement between model predictions and reality (Congalton 1991) or to be determined if the values contained in an error matrix represents a result significantly better 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 the classification differ from a random matrix.



## **CHAPTER THREE**

### **MATERIALS AND METHODOLOGY**

#### **3.1 Study area:**

The research was undertaken in the KMA and its surrounding towns located in the Ashanti Region of Ghana. Ashanti Region is located in the central part of Ghana. It is bounded on the north by the Brong Ahafo Region, on the east by the Eastern Region and on the south by the Western and Central Regions, with Kumasi as its capital. The KMA was chosen for this research because it is one of the local administrative areas in Ghana, which is

experiencing rapid expansion in the form of urbanization. This has implications on the ecosystem, environment, water quality and the well-being of people who depend on these resources within the metropolis and its surrounding towns.

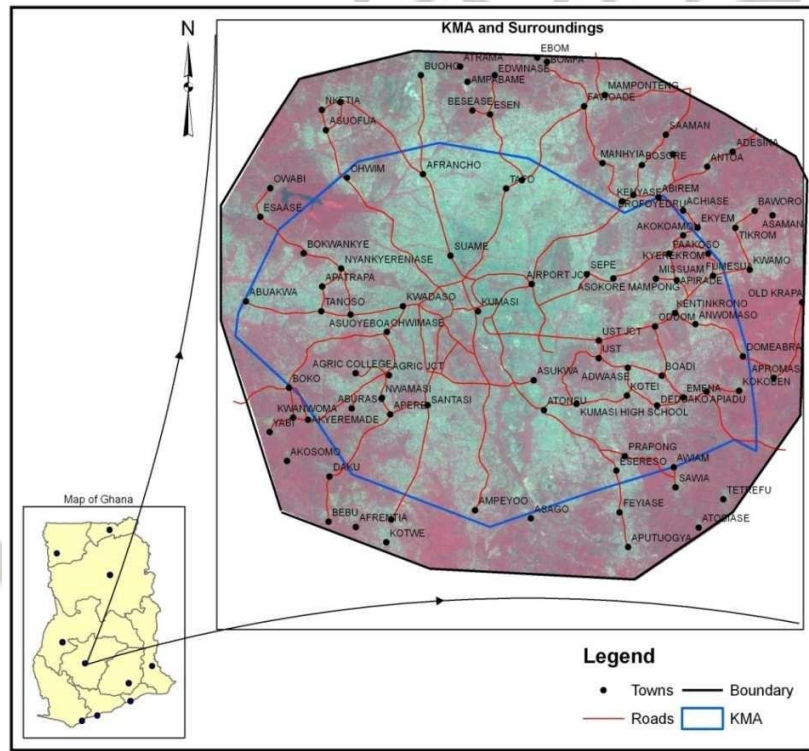


Figure 3.1: Map of Ghana showing the location of the study area.

### 3.1.1 Location

The KMA of the Ashanti Region of Ghana is one of the twenty one administrative and political districts of the Ashanti Region of Ghana. It lies between latitudes  $6^{\circ}30'$  N and  $6^{\circ}45'$  N, and longitudes  $1^{\circ}35'$  W and  $1^{\circ}45'$  W. The study area is covered by topographic map sheets 0602A4 and 0602C4, and covers an area of approximately 55558.17 hectares (ha).

### ***3.1.2 Climate***

The study area experiences tropical rainfall, that is, the bi-modal rainfall pattern and the wet semi-equatorial climate. The zone is marked by double maximum rainfall ranging between 170cm and 185cm per annum. The major rainfall season is from mid-March to July and the minor season is between September and mid-November. The mean annual rainfall is about 120cm. Temperature is fairly uniform ranging between 20°C in August and 32°C in March. Fairly moderate relative humidity is characteristic of the study area (Ministry of Local Government Rural Development & Environment, 2006).

### ***3.1.3 Geology and soil***

The study area is underlain by the pre-cambrian rocks of the Birimian and Tarkwaian formations (Gaespenu and Associates, 1996). The geology consist of phyllites, schists, tuffs and greywackes of the Birimian system (Precambrian, 2000). The soils are forest Ochrosols. They also include other types such as Kumasi-Offin Compound, Bekwai-Oda Compound, Bomso-Offin Compound, etc (Gaespenu and Associates, 1996).

### ***3.1.4 Vegetation***

The study area falls within the rain forest zone of Ghana and is popularly known as "The Garden City" because of its many beautiful species of flowers and plants. However, part of the study area lies within the semi-deciduous zone, which does not differ much in appearance from the rain forest. Most of the trees shed their leaves during the dry season, but not at the same time for all trees of the same species. Unfriendly vegetation practices such as illegal chain saw operations, stone quarrying and human encroachment have

resulted in the degradation of the natural vegetation cover. The area is covered by several patches of forest. There is however, the Owabi forest reserve which protects the Owabi dam, and consists of about sixty percent secondary forest and plantations of an exotic species such as *Cassia siamea*. Other tree species found in the vegetation of the study area include *Terminalia superba*, *Aningeria robusta*, *Triplochiton scleroxylon*, *Nesogodonia pavaveria* etc. Small areas of riverine vegetation consisting of raffia palm, aquatic vegetation and bamboo species are also found along the river courses and marshy areas within the study area (Bureau of Integrated Rural Development, 2001).

### **3.1.5 Topography and Drainage**

The Study area falls within the dissected plateau terrain region. It rises from about 240 meters (787.40 feet) to 300 meters (984.25 feet) above mean sea level. The KMA generally has an undulating terrain with relatively flat surroundings. The study area is drained by a number of streams and rivers which include Susan, Wewie, Owabi, Sukobri, Brofonti, Anyinasu, Akufosu, and Punpunasi. Most of the rivers flow in a north-east to north-west direction (Bureau of Integrated Rural Development, 2001).

### **3.1.6 Demography**

Kumasi is Ghana's second biggest city. It is a highly populated town only comparable to Accra (the capital town of Ghana). Between 1990 and 2000 its population almost tripled to more than a million (Ghana Statistical Service, 2005). KMA has witnessed high population growth rate in recent years. The Ashanti Region within which the study area is located has a population growth rate of about 3.4% per annum, being attributed to high fertility and migration (Ghana Statistical Service, 2005).

### **3.1.7 Migration Trends**

The Kumasi metropolis is the most populous district in the Ashanti Region. During the 2000 Population Census it recorded a figure of 1,170,270. It has been projected to have a population of 1,625,180 in 2006 based on a growth rate of 5.4% p.a and this accounts for just under a third (32.4%) of the region's population (Kumasi Metropolitan Assembly, 2006).

Migration, one of the three factors of population change, is discussed in terms of place of birth, place of enumeration and the population born elsewhere (in or out of Ghana).

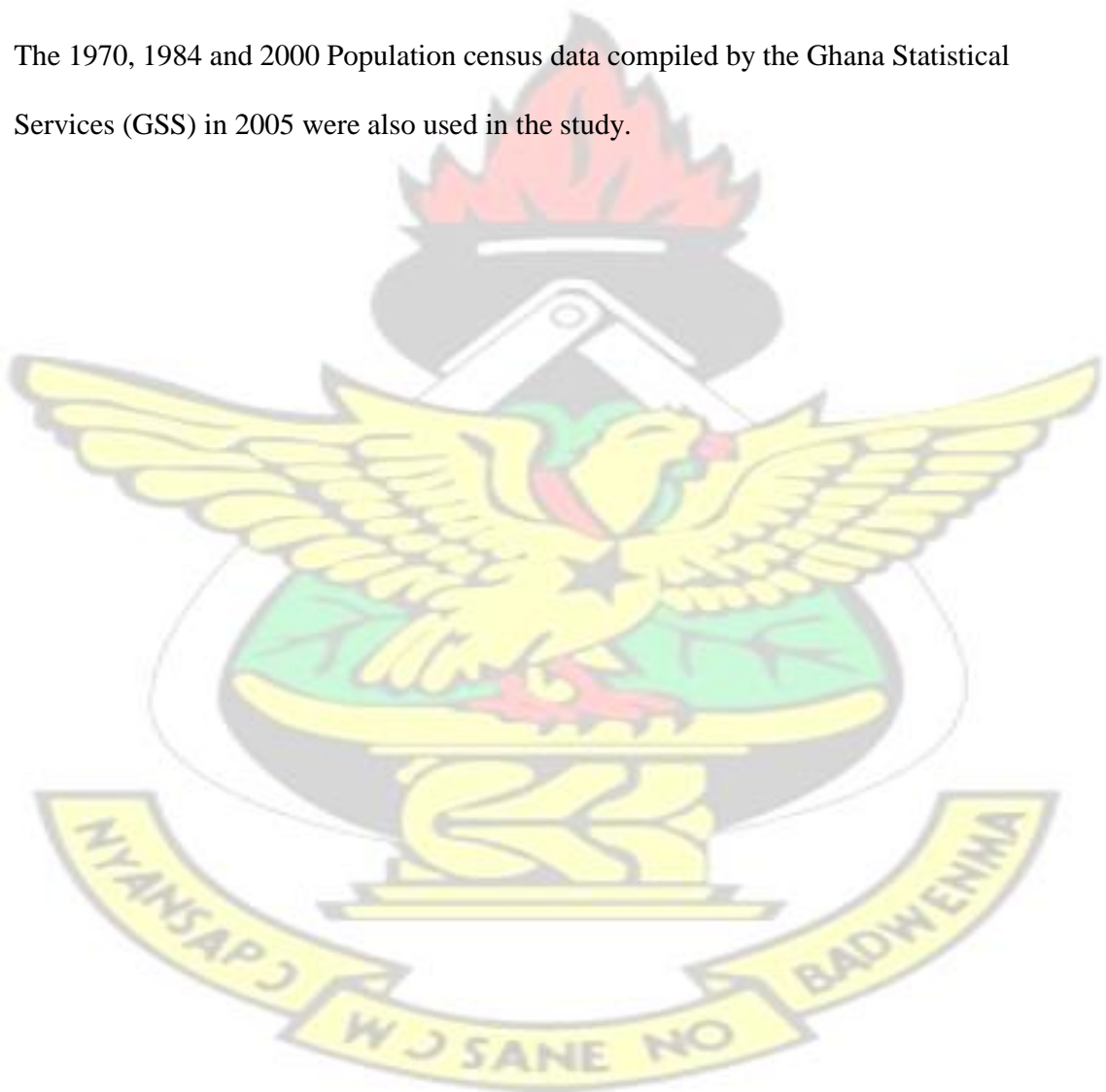
About two-thirds (65.7%) of the population in the Ashanti Region were born where they were enumerated, the remaining one-third (34.3%) are immigrants to the region. The strategic location of KMA and its status as a brisk administrative and commercial centre has made the city a destination of both internal and international migrants. The Metropolis attracts a number of migrants from several parts of Ghana and neighbouring African countries such as Togo, Burkina Faso, Mali, Nigeria, Ivory Coast and abroad especially, Europe (Kumasi Metropolitan Assembly, 2006).

### **3.2 Materials**

The study was based on one Landsat TM image acquired on the 11<sup>th</sup> of January, 1986 and one Landsat ETM+ image acquired on 24<sup>th</sup> February 2007, of Path 194 and Row 55 respectively. The images have a spatial resolution of 30 metres. These images were chosen based on their availability, their low cloud cover and their usefulness as they fall within the same time period (season), (Courtesy ITC database).

A 1974 topographic data was used to serve as a base data for built-up areas. A 1:50000 district topographic map (sheets 0602A and 0602B), prepared by the Survey and Mapping Division of the Lands Commission of Ghana, was used in digitizing the KMA boundary of the study area. A handheld GPS (5m accuracy) was also employed in this study for field data collection.

The 1970, 1984 and 2000 Population census data compiled by the Ghana Statistical Services (GSS) in 2005 were also used in the study.



### 3.3 Methods

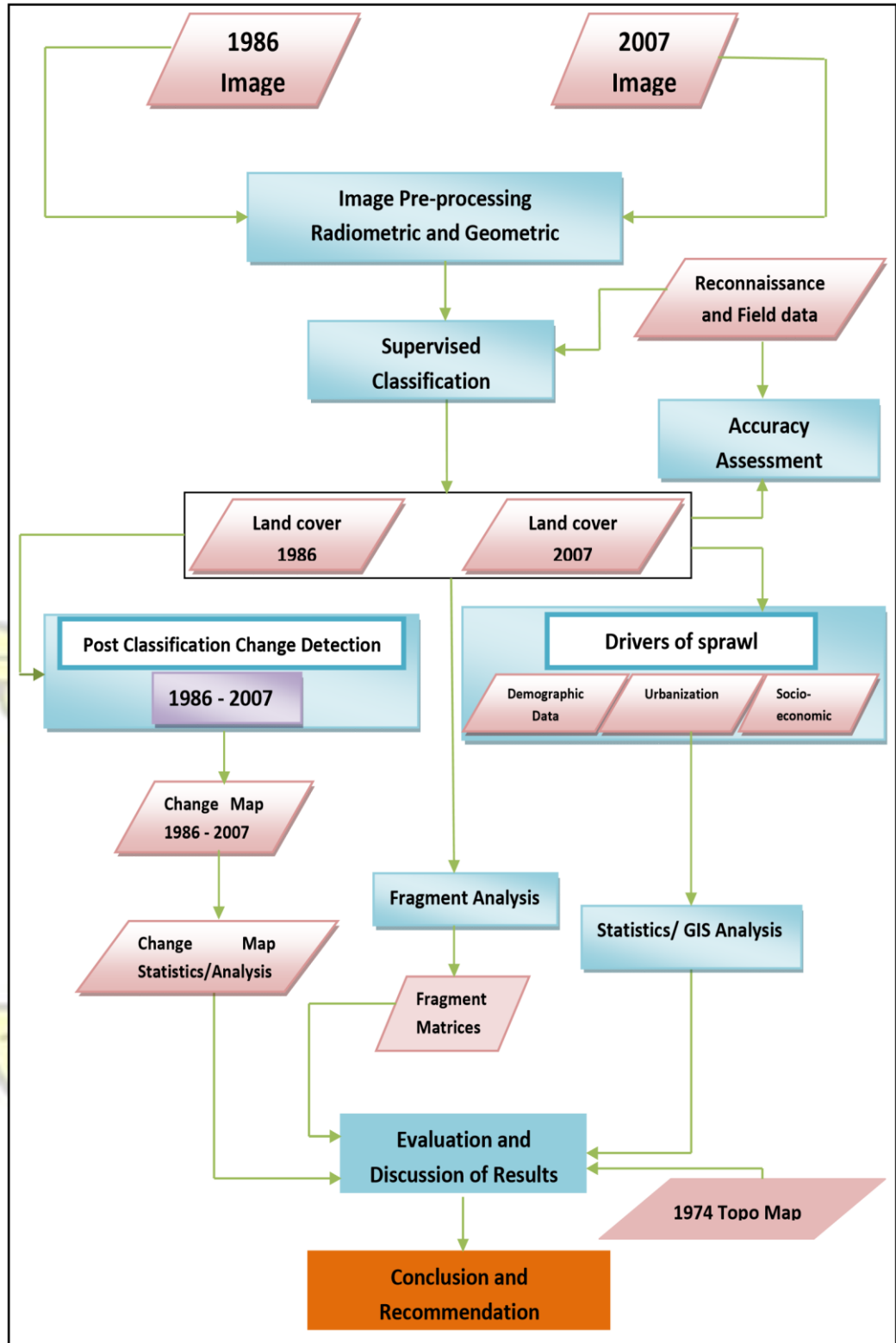


Figure 3.2: Flow chat of methodology

### ***3.3.1 Image Acquisition and Pre-processing***

#### ***3.3.1.1 Geometric and radiometric correction***

The images were imported into the ERDAS Imagine 9.2 image processing software using the built-in import dialog. The world geographic system (WGS) 84 coordinate system of the images was maintained to avoid image registration and referencing errors. However, 15 geographic positioning system (GPS) ground control points (GCP) also in WGS 84 were used as check for root-mean-square-error (RMSE). A RMSE of approximately 0.4pixel was obtained, representing 11.88m. The images were then radiometrically corrected (haze and atmosphere).

The method of histogram matching was used to normalize the images before they were used for analysis. This was done to account for difference in sun angle and atmospheric effects. The process involves the conversion of the histogram of one image to match the histogram of the other. The 2007 ETM+ (because of its reliability due to its determined accuracy) was used as a reference image for the conversion of the other. This was done in ERDAS Imagine 9.2

#### ***3.3.1.2 Subset of study area***

Subsets of the images (Plate 1) were made with an area of interest (AOI) created from the study area in ERDAS Imagine 9.1. This reduces the size of the image file to include only the AOI. This does not only eliminate extraneous data in the file, but also speeds up data processing due to the smaller amount of data to process (Leica Geosystems Geospatial Imaging, 2005).

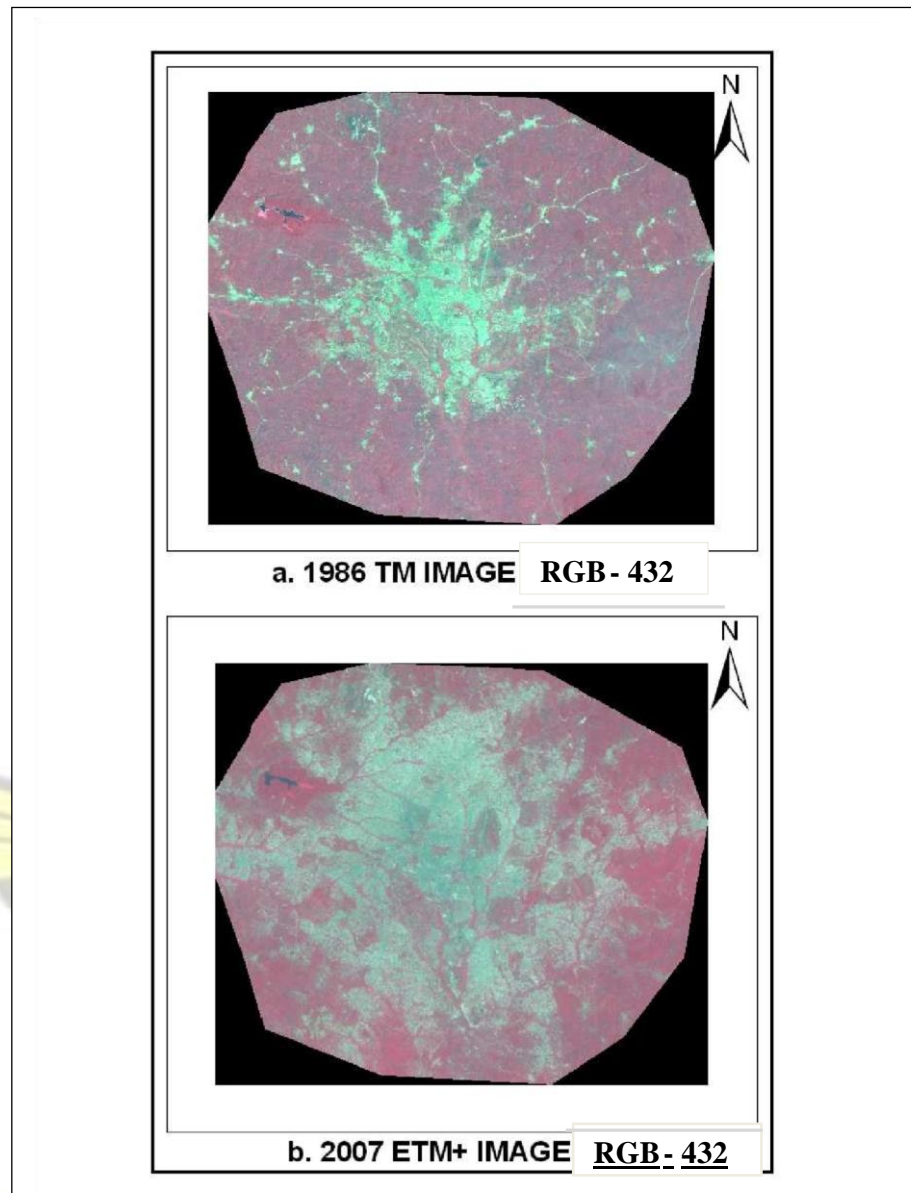


Plate 1: Subset of Satellite images used in the study

### 3.3.2 Image Classification

Supervised classification with the Gaussian's maximum likelihood algorithm was used to monitor the LULC change (Li and Yeh, 1998). One hundred and fifty (150) stratified random sample points were used to train the data. Five (5) land cover classes were observed in 1986 and 2007. These are described in Table 3.1.

**Table 3.1: Description of landcover classes within the study area.**

<b>CLASS COVER</b>	<b>DESCRIPTION</b>
Urban or Built-up Land	Residential and Commercial, Transportation, Mixed Urban or Built-up Land, Sandy Areas, Bare Exposed Rock, Transitional Areas, Barren Land.
Agricultural Land	Cropland and Pasture, Shrub and Bush, Grassland, Other Agricultural Land.
Forest Land	Deciduous Forest Land, Evergreen Forest Land, Mixed Forest.
Water	Lakes, Streams, Reservoirs.
Wet Land	Forested Wetland, Non-forested Wetland.

### ***3.3.3 Sampling Design***

Sampling design was one of the most important considerations in the collection of ground truth data. Three hundred (300) GPS points were sampled for the study using the stratified random sampling method, for implementing the change detection and accuracy assessment (Biging et al., 1999).

### ***3.3.4 Change Detection***

Post classification change detection was carried out to assess changes from 1986 to 2007 due to its ability to provide quantitative information on the nature of changes that occur (Mundia and Aniya, 2006). Local and specialist knowledge served as a good input for evaluating the changes and maintaining a link with reality (Van Der Zee, 2006). GIS analysis and cross tabulation was used to assess the trends in the major classes from 1986 to 2007.

### **3.3.5 Accuracy Assessment**

Accuracy assessment is important for understanding the developed results and employing these results for decision-making. Error matrices quantifying overall accuracy, omission errors, and commission errors were examined to evaluate the accuracy and performance of each classification (Congalton and Green, 1999). In addition, the kappa statistic (KHAT) (Cohen, 1960), which determines if classification results are significantly better than results arrived at by pure chance (i.e. a random result) (Lillesand and Kiefer, 1994; Jensen, 1996; Congalton and Green, 1999), was derived for each classification.

The error matrix-based accuracy assessment method was valuable for evaluation of change detection results. Other important accuracy assessment elements, such as overall accuracy, omission errors and commission errors were developed using the error matrix.

### **3.3.6 Fragment Analysis**

The landscape fragment structure was analyzed using FRAGSTATS version 3.1. FRAGSTATS is a program developed to quantify landscape structure with a comprehensive choice of landscape metrics that can be used to describe the characteristics of individual patches, classes of patches, or entire landscapes (McGarigal and Marks, 1994; McGarigal *et al.*, 2001). This was done for the whole study area for the two year periods, 1986 and 2007, to compare and assess changes in the landscape due to the growth of the study area. The two classified maps were exported in generic binary 8 bit formats in ERDAS Imagine for input into FRAGSTATS. At the class level, the Class Area, Number of Patches and Patch Density were analysed. Previous research (Griffith *et al.*,

2000; DiBari, 2006) identified these as important landscape-patch characteristics. The metrics used in the study are presented in Table 3.2.

**Table 3.2: Class level metrics used in the study**

<b>Class level metrics [unit]</b>	<b>Description</b>
Class Area (CA)(ha)	Equals the area (m <sup>2</sup> ) of the patch, divided by 10,000 to convert to ha.
Large patch index (LPI) [%]	Percent of landscape comprised by the largest patch.
Number of patches (NP)	Number of patches of the corresponding patch type (class).
Patch Density (PD) [number per 100 ha]	PD equals the number of patches of the corresponding patch type divided by the total landscape area (m <sup>2</sup> ).

### **3.3.7 Socioeconomic Survey**

A socioeconomic survey was carried out within the study area to investigate its influence on the growth of the study area. Semi-structured questionnaires (Appendix 4) were administered using a multi-stage (random) sampling technique. The survey was carried out in the localities of Ohwim in the north western portion of the study area, Afrancho, Esereso, Apere, Tafo, Ayeduasi and Fumesua. Sample units were selected based on the fact that the images revealed significant changes in these areas. They all represented areas referred to as “new sites”, that is areas of new residential development. In total 81 respondents were interviewed (due to lack of cooperation of most prospective respondents). Approximately eighty percent (80.2 %) of the respondents interviewed are native Akan speakers from the Ashanti region while 19.8% can be considered migrants that are not natives of the region. The data obtained were input into SPSS for analysis.

Descriptive statistics of the data are presented in chapter 4.

### 3.3.8 Demographic Data

Demographic data for the study was obtained from the 1984 and 2000 population census data of Ghana (Ghana Statistical Service, 2005). Population figures are based on localities located within the delineation of the study area. Population densities (total population of towns within the study area divided by the total area of the study area) were then calculated for the years 1984 and 2000. Population density has been used as a measure of the intensity of urbanization (Yin *et al.*, 2005).

The population for 1974, 1986 and 2007 were projected using the mathematical formula below (Ghana Statistical Service, 2005), assuming a constant fertility rate, migration rate and mortality rate.

$$P_x = P_0 e^{rn} \quad \text{----- (6)}$$

where  $P_x$  = prospective projection population,  $P_0$  = population of current census,  $r$  = rate of growth, and  $n$  = number of years between  $P_0$  and  $P_x$ .

The rate of growth,  $r$  is also calculated as shown below:

$$r = \frac{\ln(P_1 / P_2)}{n} \quad \text{----- (7)}$$

where  $P_1$  = population of the current census,  $P_2$  = population of last census before current census,

$n$  = number of years between  $P_1$  and  $P_2$ , and  $r$  = rate of growth.

### ***3.3.9 Digital Elevation Model (DEM) Generation***

A digital elevation model was generated for the study area to ascertain whether topography had any influence on the pattern of land development within the study area (Nanda, 2005). Contours were extracted from the 1:50,000 topographic map cover of the study area. The contour vertices were converted to point as spot heights. The Spot heights were then interpolated using the Inverse Distance Weighted (IDW) algorithm to generate DEM using the 3D Analyst extension in ArcGIS 9.2. The resultant DEM generated is shown in Chapter 4.

### ***3.3.10 Topographic Map as Base Data***

An image of the study area in WGS 84 coordinate system was projected onto the local coordinate system (War Office) of the 1974 district topographic map. The image was converted to a shape file. The topographic sheets (sheets 0602A and 0602B) were merged and then also converted to shape files using ArcGIS 9.2. The delineation of the study area was digitized from the image. The digitized boundary was then overlaid on the merged topographic map to clip the study area out of the topographic map. The total area of urban development was then evaluated from the attributes of the clipped map.

## CHAPTER FOUR

### RESULTS AND DISCUSSION

#### 4.1 Results

##### 4.1.1 Accuracy assessment

The overall accuracy of the 2007 classified image was 83.33%, with a kappa coefficient of 0.74. All the classes had accuracies of above 65%. The scenario of the class accuracies is similar with the user's accuracy and producer's accuracy. Accuracy could not be determined for the 1986 image as aerial photos and (or) a land cover map which could have helped in classifying them were not available. The accuracy report is presented in Appendix 1.

##### 4.1.1.1 Error Matrix

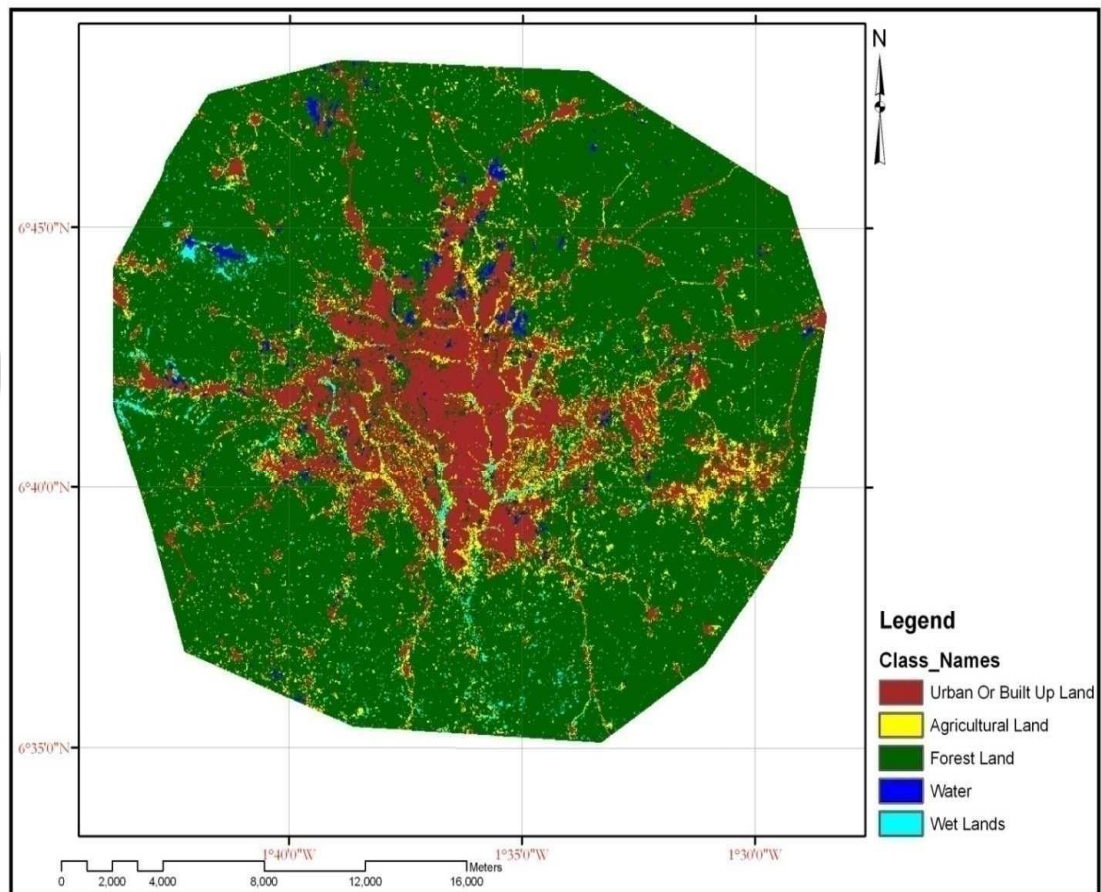
Table 4.1: Error matrix table for 2007

CLASS NAMES	Forest	Wet Land	Water	Agricultural land	Urban or built-up Land	TOTAL
Forest	13	3	0	3	1	20
Wet Lands	2	13	0	3	2	20
Water	0	0	0	0	0	0
Agricultural land	2	3	0	24	1	30
Urban or built-up Land	2	1	0	2	75	80

<b>TOTAL</b>	19	20	0	32	79	<b>150</b>
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#### 4.1.2 Land Cover Classes

The classification approach yielded two land cover maps of the study area for the 1986 and 2007 Landsat images. The thematic Change maps are presented in Figures 4.1, 4.3 and 4.6 below.



**Figure 4.1: Landcover within the study area in 1986**

In the 1986 Land Cover map (Figure 4.1), forest covers a greater part of the study area, approximately 41158.08ha (74.08%). This is followed by urban or built-up land 9533.79ha (17.16%), mainly concentrated in the central portions of the study area (i.e. Kumasi metro).

Agricultural land covers 3633.39ha (6.54%), seemingly scattered over the study area in smaller patches. Wetland covers 714.51 ha (1.29%), found along river courses, marshlands and a portion of the Owabi reservoir, while water occupies a surface area 518.4 ha (0.93%). Below is a Figure 4.2 and Table 4.2 showing the distribution of Land Cover classes within the study area for 1986.

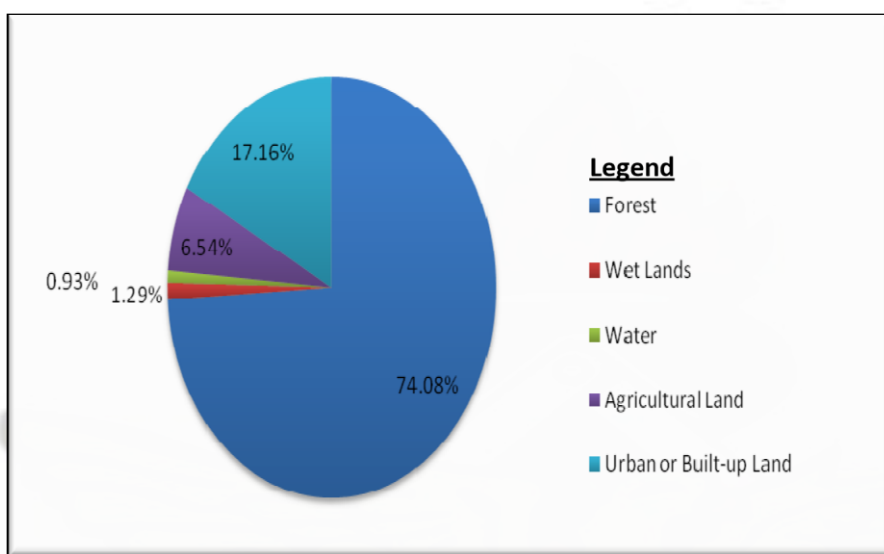
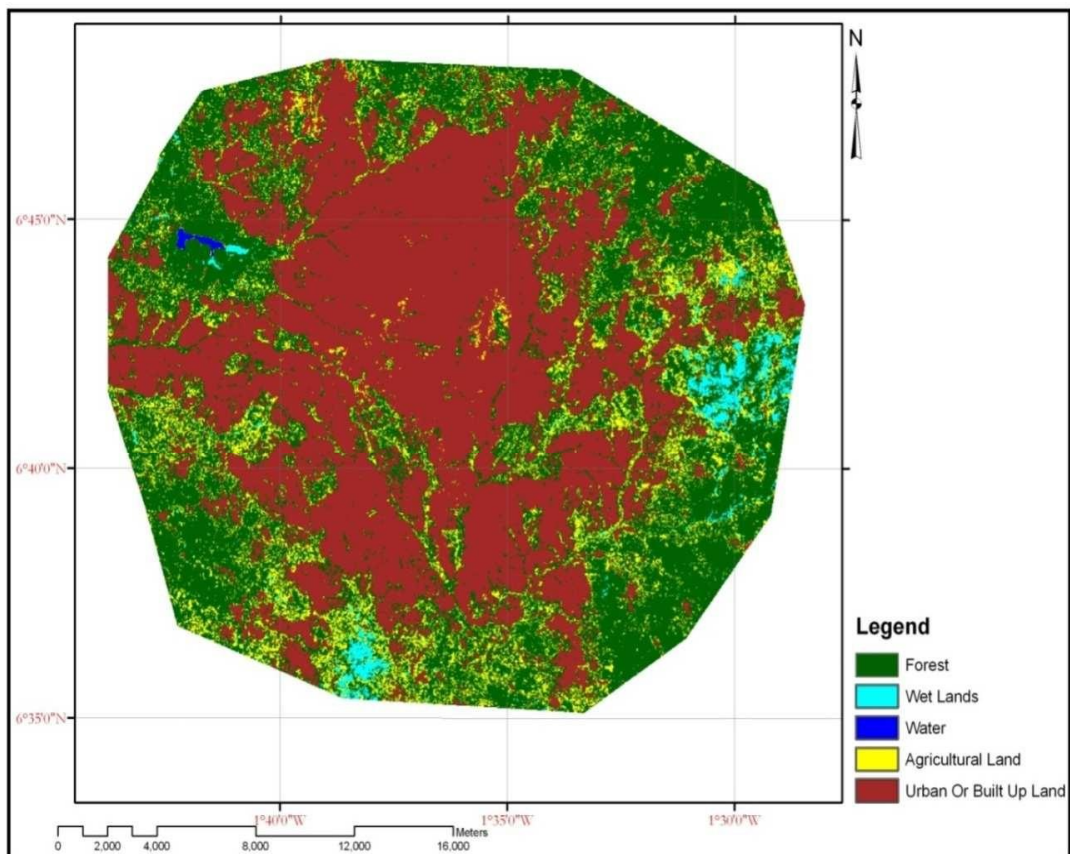


Figure 4.2: Distribution of 1986 landcover classes

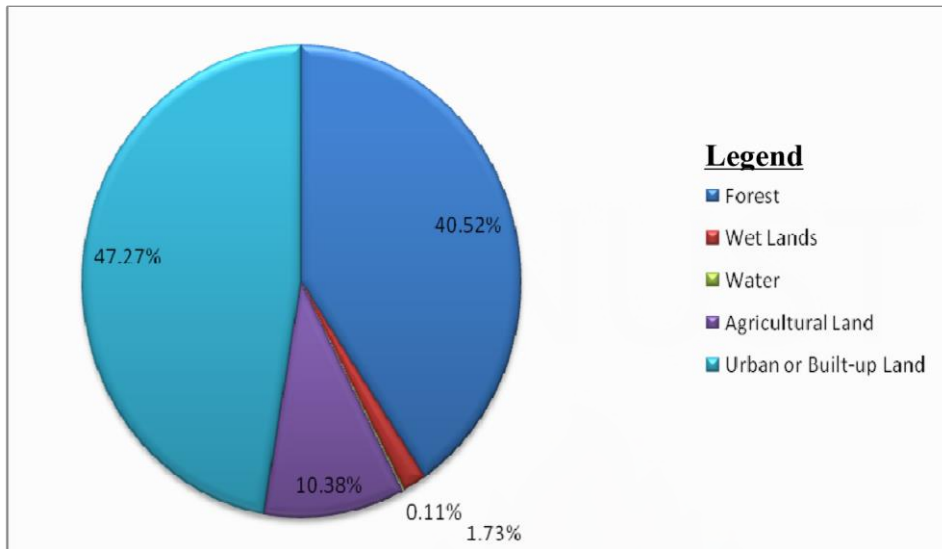
Table 4.2: Distribution of 1986 landcover classes

CLASS NAMES	Area (ha)	Area (%)
Forest	41158.08	74.08
Wet Lands	714.51	1.29
Water	518.4	0.93
Agricultural land	3633.39	6.54

In the 2007 landcover map (Figure 4.3), urban or built-up land occupies a greater part of the study area, approximately 26259.66 ha (47.27%) and mainly concentrated in the central portions of the study area. This is followed by forest which covers 22513.41 ha (40.52%); agricultural land covers 5766.57 ha (10.38%), and it appears scattered over the study area in smaller patches. Wetland covers 958.86 ha (1.73%) and are mainly found along river courses, marshlands and a portion of the Owabi reservoir, while water occupies a surface area 59.67 ha (0.11%). Figure 4.4 is a chart and Table 4.3 show the distribution of land cover classes within the study area for the year 2007.



**Figure 4.3: Landcover within the study area in 2007**



**Figure 4.4: Distribution of 2007 landcover classes**

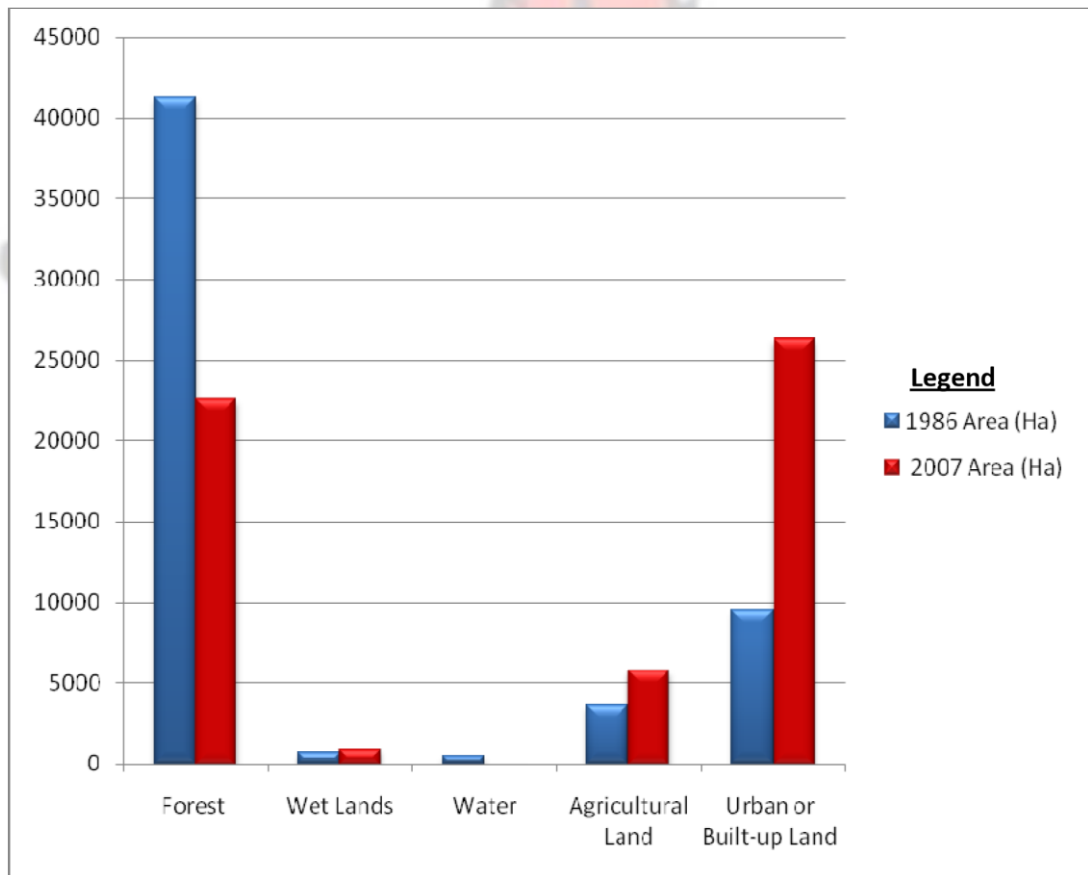
**Table 4.3: Distribution of 2007 landcover classes**

CLASS NAMES	Area (ha)	Area (%)
Forest	22513.41	40.52
Wetland	958.86	1.73
Water	59.67	0.11
Agricultural land	5766.57	10.38
Urban or built-up	26259.66	47.27

Table 4.4 and Figure 4.5 shows the distribution of the landcover proportions from 1986 to 2007. The major changes took place in forest and the urban or built-up land, whilst the other cover classes changed slightly over the period. In 1986, forest occupied a greater proportion of the study area followed by urban or built-up land, agricultural land, wet land and water. However the reverse happened in 2007, urban or built-up land occupied the largest area followed by forest, agricultural land, wetland and water.

**Table 4.4: Landcover proportions within the study area 1986 to 2007**

	Area	(ha)	Area	(%)
CLASS NAMES	1986	2007	1986	2007
Forest	41158.08	22513.41	74.08	40.52
Wet Land	714.51	958.86	1.29	1.73
Water	518.40	59.67	0.93	0.11
Agricultural land	3633.39	5766.57	6.54	10.38
Urban or built-up Land	9533.79	26259.66	17.16	47.27
Total Area	55558.17	55558.17	100.00	100.00



**Figure 4.5: Landcover proportions within the study area 1986 to 2007**

### 4.1.3 Change Detection

#### 4.1.3.1 LULC change within the study area

A comparison of the Landcover maps for the years 1986 and 2007 clearly show that some changes have taken place within the study area (Figure 4.6). This involves multiple transfers from one LULC to the other.

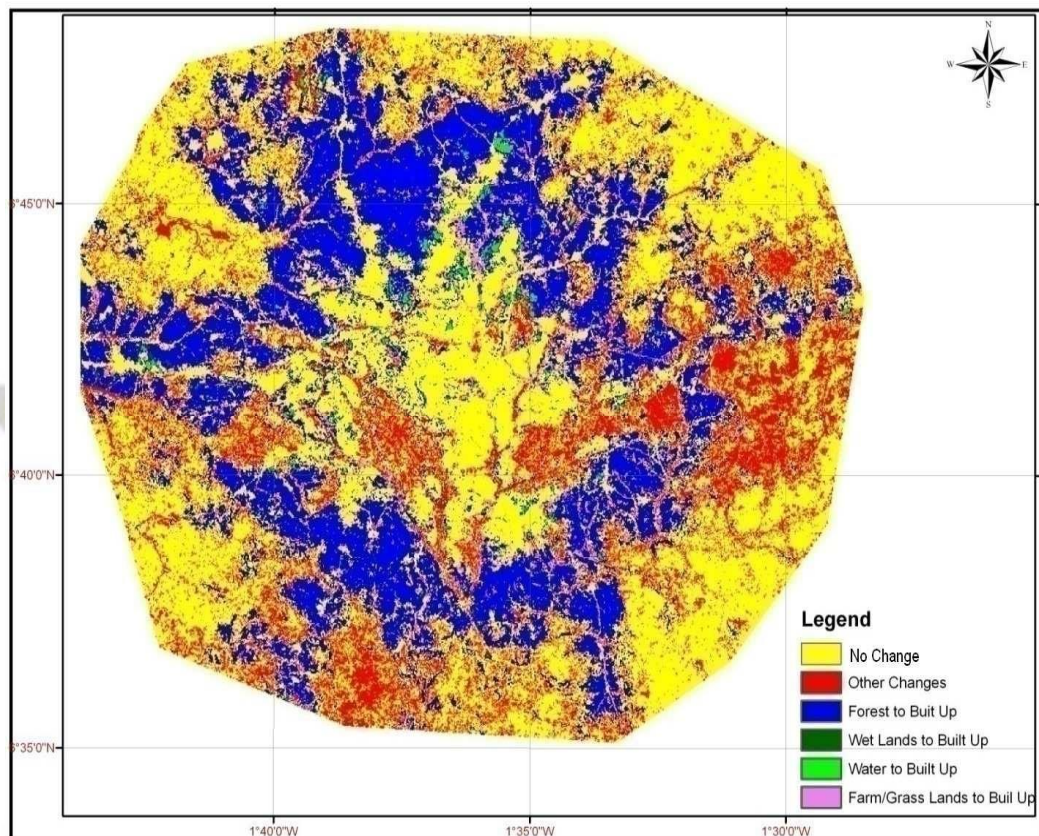
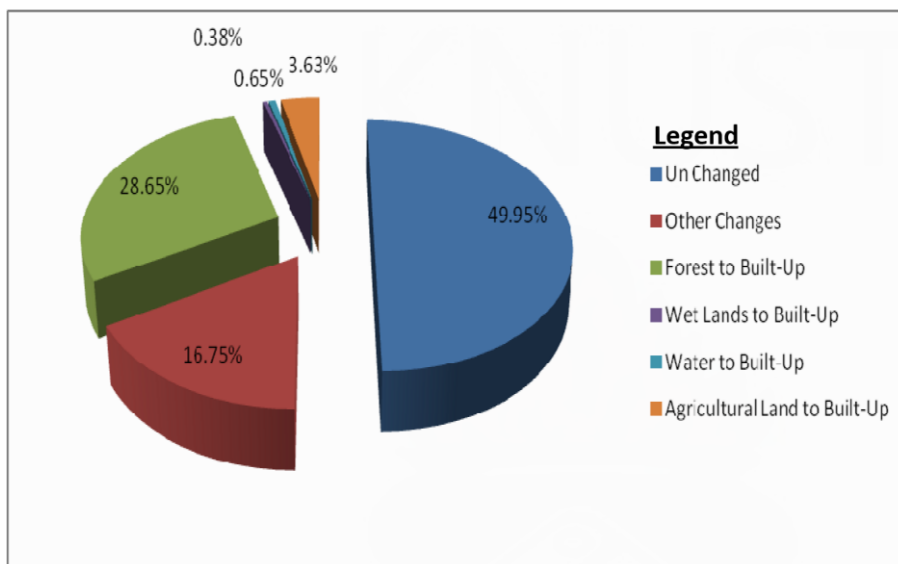


Figure 4.6: Change map of the study area 1986 to 2007

#### 4.1.3.2 Changes to Urban or Built-up Land

Figure 4.6 and Table 4.5 show the results of the change to Built-up Land. It can be seen from the table that 15920.19 ha representing 28.65% of forest was converted to urban or

built-up Land. About 211.23ha, 358.35ha, 2014.11 of wetlands, water and agricultural lands respectively were also converted to urban or built-up Land.



**Figure 4.7: Distribution of changes that occurred in study area from 1986 to 2007**

**Table 4.5: Distribution of changes that occurred in study area from 1986 to 2007**

CLASS CHANGES	Area (ha)	Area (%)
Unchanged	27748.8	49.95
Other Changes	9305.46	16.75
Forest to Built-Up	15920.19	28.65
Wet Lands to Built-Up	211.23	0.38
Water to Built-Up	358.38	0.65
Agricultural land to Built-Up	2014.11	3.63

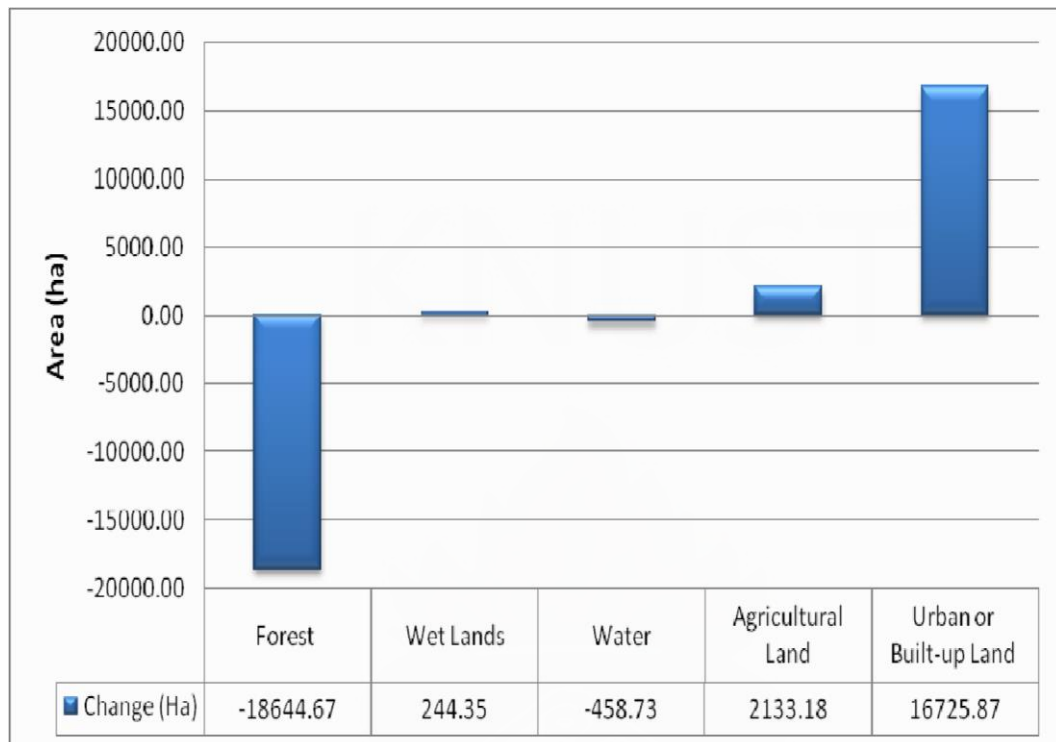
#### 4.1.3.3 LULC change trends 1986 to 2007

Table 4.6 and Figure 4.8 depict the trends of landcover transfers within the study area from 1986 to 2007. All five landcover classes experienced a change in the size of their cover

over the 21 year period. Forest decreased by 18644.67 ha from 1986 to 2007 representing 45.3 % of the original forest cover, representing the most negative change. Urban or built-up land, however, increased by 16725.87 ha. It increased from 9533.79ha in 1986 to 26259.66ha in 2007 representing 175.44 %, ie the most positive change. Water also decreased by 88.49% while wetland and agricultural land increased by 34.20% and 58.71% respectively.

**Table 4.6: Landcover change trends 1986 to 2007**

<b>CLASS NAMES</b>	<b>1986 (ha)</b>	<b>2007 (ha)</b>	<b>Change (ha)</b>	<b>Change (%)</b>
Forest	41158.08	22513.41	-18644.67	-45.30
Wet Lands	714.51	958.86	244.35	34.20
Water	518.4	59.67	-458.73	-88.49
Agricultural land	3633.39	5766.57	2133.18	58.71
Urban or built-up Land	9533.79	26259.66	16725.87	175.44



**Figure 4.8: Landcover change trends from 1986 to 2007**

#### *4.1.3.4 LULC transfers within the study area (1986 to 2007)*

From 1986 to 2007, the majority of the transfers that took place within the study area were from other classes to urban or built-up. The diagonal of Table 4.7 shows the proportions of the land cover classes that remained stable or persisted from 1986 to 2007 in the landscape. Forest made the highest transfer to built-up/bare (15920.19ha), followed by agricultural land (2014.11ha), water (358.38ha) and then wetlands (211.23ha).

**Table 4.7: Landcover transfers 1986 to 2007**

<b>Class Name</b>	Forest	Wet Land	Water	Agricultural land	Urban or builtup Land	TOTAL
Forest	<b>19552.41</b>	873.99	16.92	4794.57	15920.19	41158.08
Wet Lands	351.45	<b>24.93</b>	14.67	112.23	211.23	714.51
Water	80.55	7.02	<b>25.38</b>	47.07	358.38	518.4
Agricultural land	1190.07	36.36	2.52	<b>390.33</b>	2014.11	3633.39
Urban or builtup Land	1338.93	16.56	0.18	422.37	<b>7755.75</b>	9533.79
TOTAL	22513.41	958.86	59.67	5766.57	26259.66	<b>55558.17</b>

#### **4.1.4 Fragmentation analysis**

##### **4.1.4.1 Large Patch Index (LPI) and Class Area (CA), 1986 to 2007**

The LPI for forest decreased over the years under study, whilst that for built-up/bare increased. Farm/ grasslands land, wetlands and water bodies all increased respectively. The CA of urban or built-up, agricultural land, and Wetland, all increased from 9533.79 ha, 3633.39 ha, and 714.51ha to 26259.66 ha, 5766.57 ha, and 958.86 ha respectively. Forest and water decreased from 41158.08ha and 518.4ha to 22513.66ha and 359.67ha respectively (Table 4.8).

**Table 4.8: 1986 to 2007 class level metrics for LPI and CA**

COVER TYPE	LPI (%)		CA(ha)	
	1986	2007	1986	2007
Urban or built-up	7.99	33.20	9533.79	26259.66
Forest	32.00	9.44	41158.08	22513.41
Agricultural land	0.061	0.18	3633.39	5766.57
Wet land	0.04	0.37	714.51	958.86
Water	0.05	0.08	518.40	59.67

#### 4.1.4.2 Number of Patches (NP) and Patch Density (PD), 1986 to 2007

The number of patches for urban or built-up, forest, agricultural land and Wetland all increased by 247.9%, 135.7%, 133.3%, and 289.3% respectively, except for water which declined by 37.5% (Table 4.9). Patch density for urban or built-up and agricultural land decreased, while that of forest, wetland and water increased (Table 4.9).

**Table 4.9: 1986 to 2007 class level metrics for NP and PD**

CLASS TYPE	NP		PD (per 100ha)	
	1986	2007	1986	2007
Urban or built-up	2136	5296	22.40	20.16
Forest	3616	4905	8.79	21.79
Agricultural land	10292	13716	283.26	237.84
Wet land	895	2589	125.26	270.01
Water	8	3	1.54	5.027

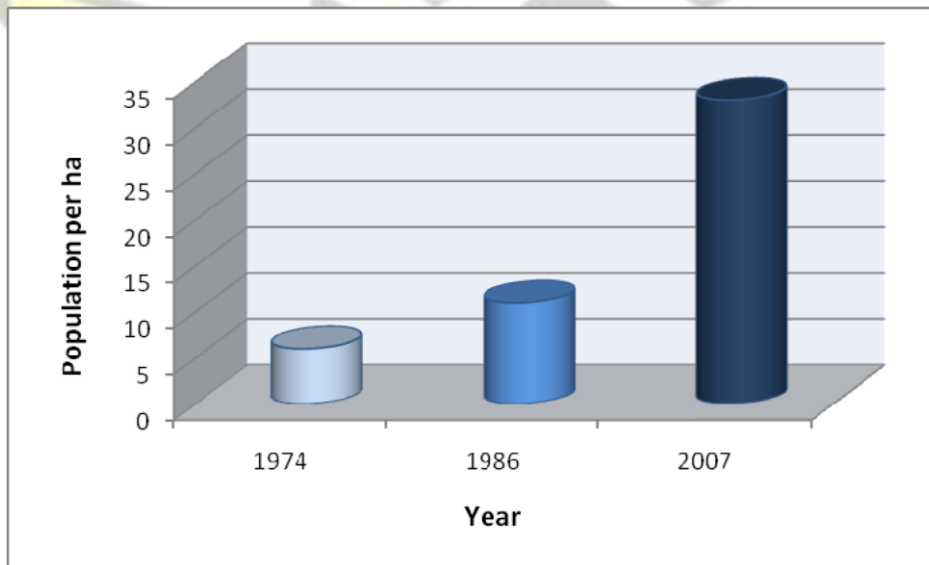
#### 4.1.5 Population growth within the study area

The population of the study area increased steadily over the years. From an initial population of 329,971 in 1974, the population rose by 181.6% to 599,128 in 1986, and then

the population further rose by 307.8% to 1,844,023 in 2007. In terms of population density, there was an increase in the concentration of people living within the delineation of the study area over the period of the study. In 1974, the population density stood at 6 persons per square ha. It rose to 11 persons per square ha in 1986 and then trebled to 33 persons per square ha in 2007 from 1986 (Table 4.10 and Figure 4.9).

**Table 4.10: Projected Population and population density growth within the study area**

Year	Population	Population density (per ha)
1974	329971	6
1986	599128	11
2007	1844023	33

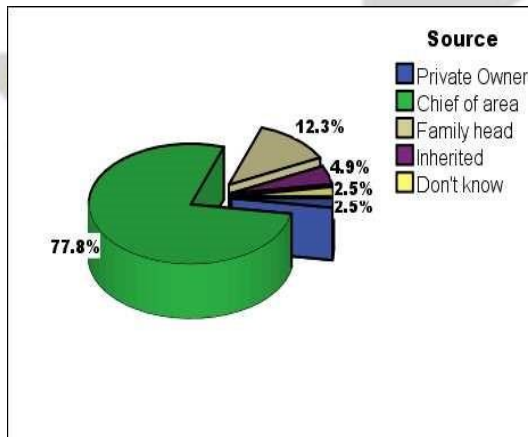


**Figure 4.9: Population density growth within the study area**

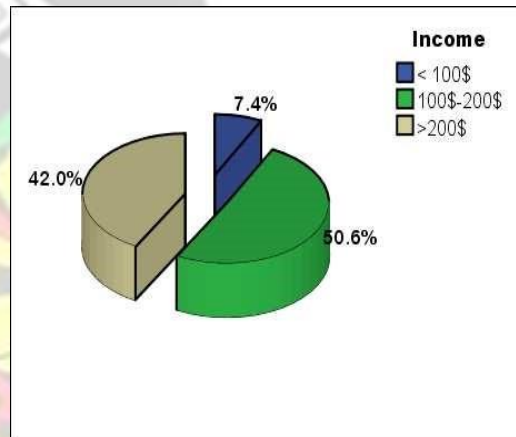
#### ***4.1.6 Socio-economic characteristics of the study area***

A total of 77.8% of respondents acquired their land from the chief of the area, 12.3% from a family head, 2.5% did not know from whom the land was acquired. Another 2.5%

acquired the land from a private individual, while 4.9% acquired the land by way of inheritance, (See Figure 4.10). Fifty-one percent (50.6%) of respondents fall within the middle income group, 42.0% the high income group and 7.4% the low income group (Figure 4.11). Of the total respondents, 40.7% said the land cover at the time of acquisition was fallow/bush followed by forest (33.3%), grassland (14.8%) and wetland (11.1%) (Figure 4.12). Land availability was the greatest influence for the choice of locations (72.8% of the respondents), 18.5% based on proximity to city of Kumasi, 6.2% based on the serenity of the location and 2.5% based on the availability of water (Figure 4.13).



**Figure 4.10: Sources of land for development within the study area**



**Figure 4.11: Level of income of respondent within the study area**

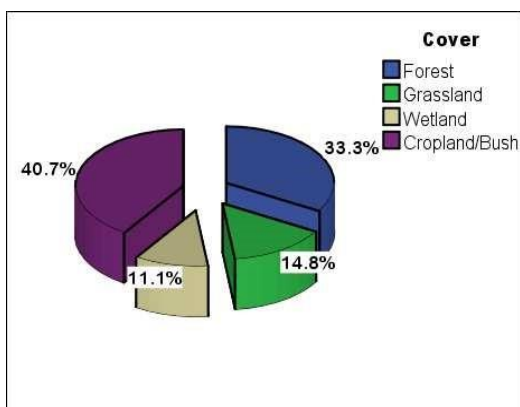


Figure 4.12: LULC at the time of land acquisition by respondent

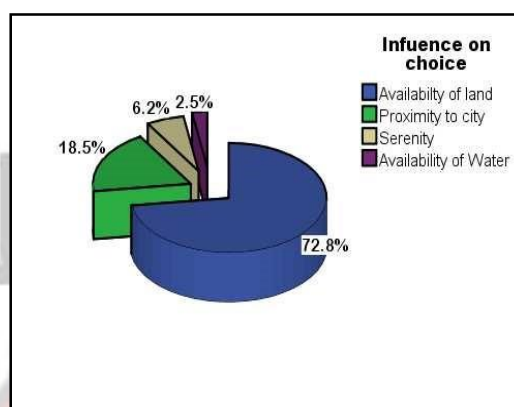


Figure 4.13: Reason for the choice of land within the study area for development

Table 4.11: Purpose of acquisition of land by respondent

Purpose of acquisition	%
Residential	92.6
Other Reasons	7.4
<b>Total</b>	<b>100</b>

Ninety-three percent (92.6%) of the respondents acquired the land for residential purposes whilst 7.4% acquired the land for other reasons including investment and as a security.

About sixty-one percent (60.5%) of respondents had been in residency for less than 5 years, 25.9% for between 6-10 years, 8.6% for 11-20 years and 4.9% for more than 21 years (Figure 4.14). About sixty two percent (61.7%) of respondents were from within the Kumasi Metropolitan Area, 13.6% from Ejisu/Juabeng District, 12.3% from the Bosomtwi/Kwawonma District, 6.2% from the Atwima District, 3.7% from the Kwabre District and 2.5% from the Asante Akim District (Figure 4.15). Approximately twenty percent (19.8%) of the respondent are into agriculture as a profession, 18.5% are in Civil and Financial services, 14.8% in private Business and Wholesale and Retail activities,

6.2% in Forestry, while 4.9% are in Manufacturing, and 2.5% in Construction (Figure 4.16).

Eighty-three percent (82.7%) of respondents had building permits while 17.3% of them did not (Figure 4.17).

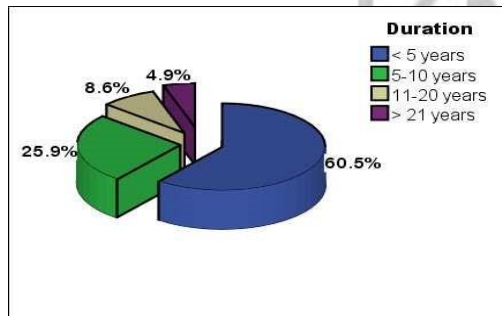


Figure 4.14: Length of residency of respondent within respondent the Study area

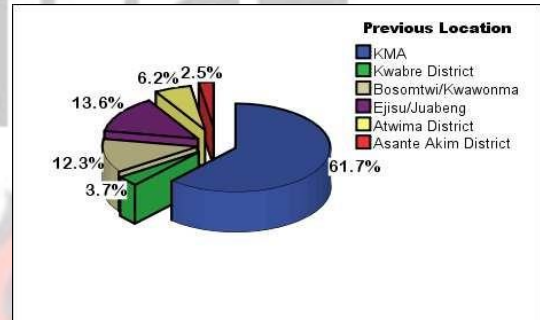


Figure 4.15: Previous place of residence of respondent

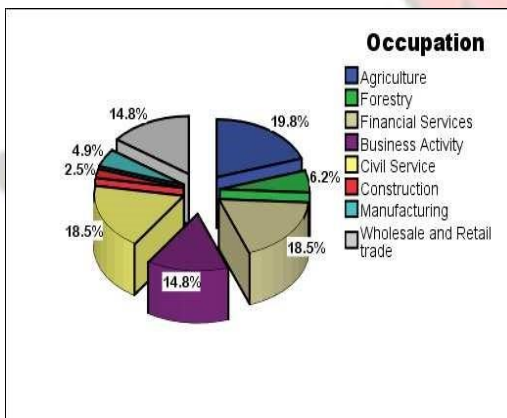


Figure 4.16 Type of occupation of respondent

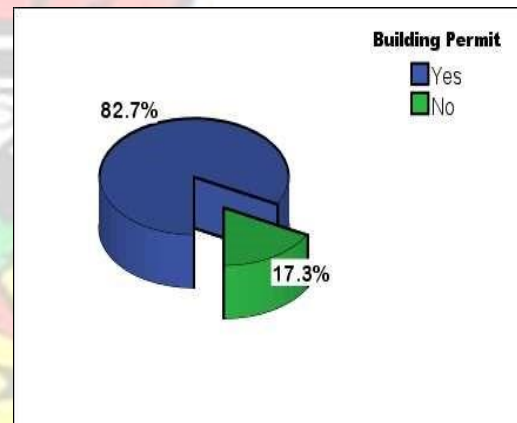


Figure 4.17 Acquisition of building permit

The locations within the study area where the socioeconomic survey were taken are shown forth in Figure 4.18.



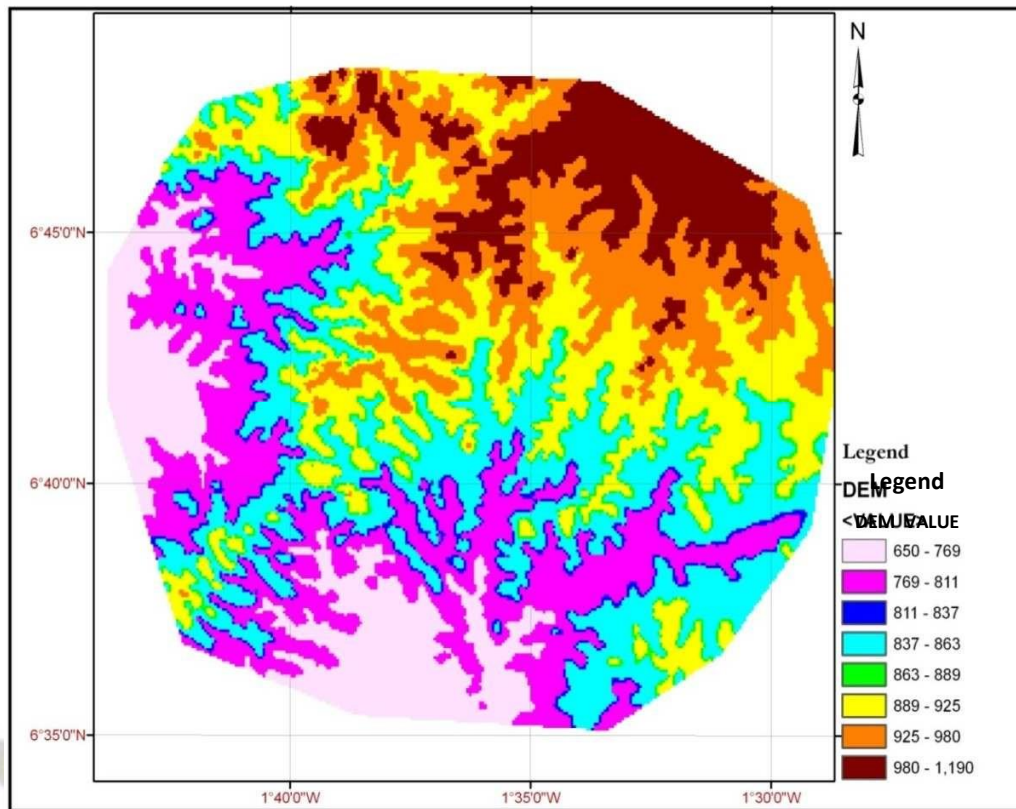


Figure 4.19: Digital elevation model of the study area

#### 4.1.8 Built-up/Settlement of Topographic Map as Supplementary Data

The study area clipped from 1974 district topographic map aided in evaluating the total area of built-up or development. The total built-up area evaluated is about 1614.01ha. This information was useful in order to quantitatively analyse the urban growth of the study area consecutively to appreciate the trend of development. Table 4.12 and Figure 4.20 show both the population and built-up area growth of the study area from 1974 to 2007.

Table 4.12: Built-up and Population Growth of study area

Year	Built-up Area (ha)			Population		
	1974	1986	2007	1974	1986	2007

<b>Growth</b>	1614.0 1	9533.7 5	26259.66	32997 1	599128	1844023
<b>Change in Growth (%)</b>	1526.98			458.84		

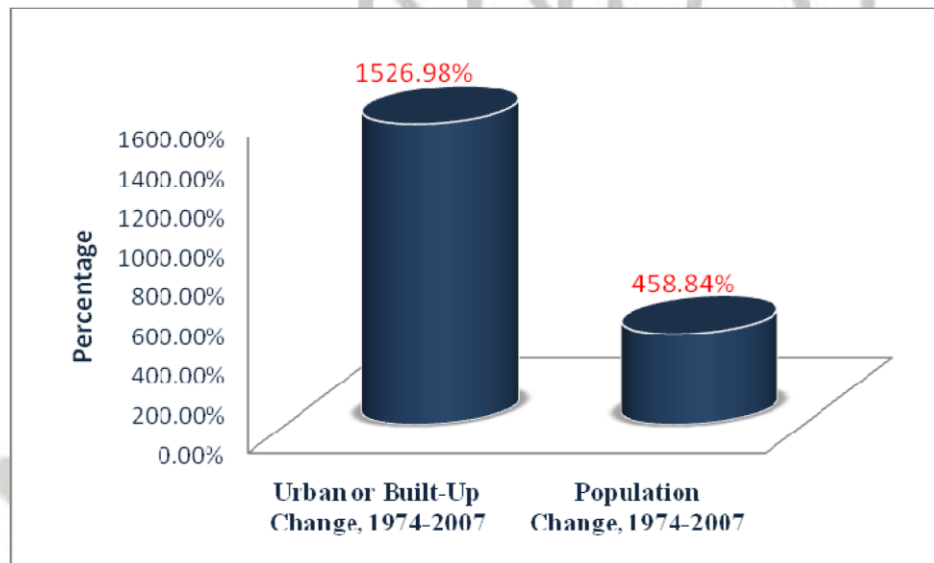


Figure 4.20: Rates of Growth in Built-up and Population of study area

## 4.2 Discussion

### 4.2.1 Image interpretation and accuracy assessment of classified images

There were five landcover classes in the classification method. These aided enormously in assessing the various changes and their trends over the 21 years study period (i.e. 1986-2007). The quality of a thematic map from a satellite image is determined by its accuracy. Thus one important step in image classification is the accuracy assessment of the classified image (Gbekor, 2008). For a map derived from image classification procedure to actually mimic real world cover types, an accuracy of at least 85% is required (Campbell, 2002). The overall accuracy of the 2007 image was 83.33% with a Kappa statistic of 0.74%. This is lower than the 85% postulated by Campbell (2002). Reasons for misclassification can be

attributed to the spatial heterogeneity of the landscape. Again, the rapid nature of conversion of land cover types resulted in significant changes since the time the satellite image was taken.

The accuracy of the 1986 images was not assessed due to the lack of reference materials such as land cover maps with a credible accuracy and aerial photographs. This has been a key problem for remote sensing analysis in Ghana (Asubonteng, 2007). The interpretation of the result is therefore within the accuracy obtained.

#### ***4.2.2 Changes in landscape structure***

The provision of quantitative change information on the scenery of changes that occurred during the temporal period of study in the form of a change matrix (refer to Table 4.4), of a change map (refer to Figure 4.6), is a distinctive advantage of using post classification change detection. It also provides information on whether or not a LULC is losing or gaining in terms of its aerial extent. Several major changes occurred in the structure of the LULC classes within the study area during the period of the study as a result of anthropogenic activities. Notable among the complex transfers is the expansion of urban or built-up and the loss of forest.

##### ***4.2.2.1 Persistence and class level metrics***

Forest failed to persist in the landscape, in that it lost out to the other LULC. Over 45% of forest was lost from 1986 to 2007. The greatest converter of forest is urban or built-up (about 39% of the 45% of forest lost, transferred to urban or built-up), followed by agricultural land gaining about 11% of the lost forest (refer to Figure 4.5). The spill-over effects of the rapid expansion of KMA is affecting the study area in terms of forest clearing

for residential development. The increase in NP (from 3616 to 4905) from 1986 to 2007 indicates that the forest is fragmented into smaller patches. An increase in the PD (from 8.79 to 21.79) from 1986 to 2007 shows that structurally the forest has become much fragmented, and the number of patches per 100ha has increased. This is attributable to urban or built-up and agricultural land expansions within the study area, disintegrating the forest block into disjoint patches. This shows that forest is easily transferred to other LULC. The LPI (from 32.00 to 9.44) of forest observed in 1986 further indicates that forest was less fragmented in that year as compared to 2007. The reduction in the size of the core forest and the remaining patches indicates that forest is less dominant in the landscape.

Wetland experienced a high transfer to other LULC classes. About 96.5% of wetland was lost, with its largest transfer gained by forest (about 51% of the loss) followed by urban or built-up (about 31% of the loss) as evident in Table 4.7. However, the CA of the wetland cover increased by about 34.2% (i.e. from 714.51ha in 1986 to 958.86 ha in 2007). The clearing of trees along river courses and in water logged areas due to the demand for land has probably exposed more wetland areas. This has led to an increase in the area of wetland from 714.51ha in 1986 to 958.86ha in 2007, thus increasing its NP, PD and LPI.

Agricultural land, like other land covers, could not persist in the landscape. About 89% of agricultural land was lost to the other landcovers with urban or built-up gaining majority of the transfer, (i.e. 62% of the lost agricultural land). This might be due to the fact that it is easier converting agricultural lands for development as compared to other land covers such as forest which may contain a great number of relatively big trees. However, agricultural land increased in its landcover over the period of study. Its CA increased from 3633.39 ha

in 1986 to 5766.57 ha in 2007. The increase might be due to the transitions from forest to agricultural land. About 22.19% of landscape was transferred from forest to agricultural land, over the period of study. This resulted in the increase in its NP and LPI. This may be explained by the fact that government incentives are being driven in the direction of large scale agricultural farming (such as cocoa, citrus, banana, etc) since the year 2000. Individual farms are becoming much bigger as a result, and agricultural lands are merging with other land covers such as grassland. The PD of agricultural land decreased over the period of study. This might also be the reason why a high number of respondents are into agricultural practice as indicated in the socioeconomic survey (refer to Figure 4.16).

The decrease in surface area of water from 1986 to 2007 can be attributed to human encroachment near water bodies and within wetland areas for residential purposes. Significant number of buildings may be found closer to water bodies and in wetland areas, because these encroached lands cost relatively less. For instance, at Owabi, some encroachers were driven away from the water reservoir, and where trees have been planted around the dam to preserve it. Most water bodies which are shallow and small in size are easily encroached and sometimes narrowed to the size of a gutter. In times of heavy rains, the situation often lead to damage and loss of properties or lives through floods, since the natural route of the water bodies are impeded by structural development. Thus the decrease in the surface area of water.

Urban or built-up increased within the study area, due to the conversion of other LULC classes to residential dwellings. The developed areas increased from 9533.79 ha in 1986 to 26259.66 ha in 2007, representing a total of 71.08% of all land cover transfer losses. Instead

of forest transferring to agriculture and then subsequently to urban or built-up, it is direct forest conversion to urban or built-up within the study area (refer to Table 4.7). Urban or built-up remained the most persistent landcover within the landscape from 1986 to 2007, retaining over 81% of its land cover (refer to Table 4.7). An increase in the NP (from 2136 to 5296) indicates an increase in land development for residence, hospitals, schools, business complexes, etc. The agglomeration or merging of previously separate urban or built-up areas within the study area has led to a reduction in its PD (from 22.40 to 20.16) with a corresponding increase in the CA (from 9533.8 to 26259.6). LPI (from 7.99 to 33.20) increase over the years is indicative of the fact that urban or built-up is increasingly becoming dominant in the landscape.

#### ***4.2.3 Urban expansion within the study area***

Between 1974 and 2007, population within the study area grew by about 459% while the corresponding amount of developed lands grew by about 1527% i.e. exceeding three times the rate of population growth (refer to Figure 4.20). This indicates the presence of sprawl in the study area as defined in accordance with space-time (Chesapeake Bay and Mid-Atlantic from Space, Glossary). The rate of conversion of land for development far outstrips the rate of population growth in the study area. This implies that lands within the study area have been consumed at excessive rates and probably in unnecessary amounts as well. It is important to emphasize here that sprawl is not the mere expansion of the urban area but the result of the misuse and haphazard development of land as the urban area expands due to some social factors. The urban expansion within the KMA is generally characterized by a few factors. These factors may include high population growth, income inequality (poverty), socioeconomic growth and noncompliance with laid down developmental plans.

The KMA is the most urbanized and highly commercialized district in the Ashanti region. The district is also fluxed with relatively good educational and health facilities. These attract a lot of traders, civil workers, businessmen, students, patients, etc from neighbouring districts and even foreigners, into the metropolis. Because of the geographical location of the KMA, which is much strategic and centrally located in Ghana, all road networks linking the northern to the southern sector, and the eastern to the western sector of Ghana, pass through it (the KMA). It is also well connected with regional and district centres. This makes it relatively easy for a lot of people to find their way into the Kumasi metropolis each day. The KMA district has a sizable tourist and historic sites which attract a significant number of people into the city each day. The metropolis experiences a high influx of rural-urban migrants (especially the 'kayaye' from the northern sector where development is less) each day. This has led to an enormous increase of population, and overcrowding most sectors within the KMA. The population density of the study area increased from 6 persons per square ha in 1974 to 11 persons per square ha in 1986. Later it tripled from 11 persons per square ha in 1986 to 33 persons per square ha in 2007, an indication that more people were occupying the same fixed land area than before. The result could explain the high human and vehicular traffic congestion in all parts of the city. In areas like Suame, Asukwa, Atonsu, KNUST junction, Kwadaso, etc, the congestion is so high that travelling time from one point of the city to the other, increases by the hour each day. Noise and air pollutions (e.g. carbon mono-oxide, CO) are also at their peak in these areas due to vehicular traffic. The increase in population has also led to the greater demand for affordable shelter, employment and urban services. This is because, the large number of people from the north and south (where development is less) move into the KMA for non-existing jobs, hence, increasing the number of unemployed persons in the city, and also put pressure on the

limited public amenities available. This situation may also account for the high criminal and robbery cases experienced in the city, since most of the youth who flock the KMA for non-existing jobs are not bothered if they make ends meet by fair or foul means.

Majority of the migrants (especially the 'kayaye') who flock the city to seek better livelihood are often uneducated and poor, and therefore cannot afford the high rent in the city. They therefore end up living in the 'Zongos' or slummy areas in the informal sectors of the city, increasing the population in these areas. In order to create space for shelter for new settlers (especially in the 'zongos'), the frontage of houses are extended or where possible rickety houses are built closely or elsewhere irrespective of the land cover or direction of development. Sometimes they extend buildings so close to the streets such that portions of the streets are partially lost for the provision of shelter. Neighbouring wetlands are overlooked and converted for the development of accommodation. Water bodies or streams found in these areas are used as waste dumping sites and places of convenience (e.g. at Aboabo, a community in KMA where the ground water is contaminated with waste from human activities). It is then gradually encroached for the provision of shelter. Apart from the fact that these forms of land development are usually awkward and haphazard (wasteful form of land development), they do not conform to the development structural plan of the city and the natural processes occurring in the area. The sanitation conditions in these areas have also decreased due to the pollution of water, air and the over-crowdedness, exposing the inhabitants to various health hazards. Most of these areas are made up of weak structures (wood and sandy block structures) and are located in low lying areas susceptible to flooding. Properties are often damaged or lost during the rainy seasons (in areas like Atonsu). The illegal connection to electric power (aimed at evading payment of bills)

practiced in these informal sectors (slummy areas) makes the outbreak of electrical fire common. In times of fire outbreaks, fire service personnel are often not able to render effective fire services due to the inaccessibility of their service vehicles in these areas (because of inaccessible roads and the clustered nature of settlements), leading to the loss of properties and sometimes lives.

The wasteful form of land development and the deplorable state of these habitats, which are to the disadvantage of the development of the KMA, are often overlooked by the government in order not to lose the political nod of the high populace in these areas (e.g. the recent issue of 'Sodom and Gomorah' in Accra and the expatriation of carpenters at Anlonga junction, Kumasi). Again, since slum dwellers often provide services which are useful to the general public (such as vulcanizers, cobblers, cheap labourers, etc), the existence of slum communities are generally over looked by the city authorities.

In order to escape the litigations associated with land acquisition, high cost of land and rent of apartments in the city, significant number of people settle along the fringes of the KMA and beyond, where land is much available and affordable. Majority of these people are middle income earners, industrialists, and educationists etc, who desire to own their personal homes or properties. This has led to the rapid expansion of the KMA urban area to the fringes. The rapid expansion is also facilitated by the extension of infrastructural developments by the local government such as the construction of roads, the provision of potable water and electricity beyond the metropolitan area.

Owing to the varying income levels, literacy levels and material circumstances, a sense of class consciousness evolves. This leads to the isolation of people with certain level of class

consciousness from their previous social affiliations. This is usually seen in their new residential dwellings that often correspond with their social class. There is also, the issue of culture and prestige, where the affluent in the society want to live in the most elegant of residential dwellings in the KMA. This puts enormous pressure on the urban land and also contributes to the vast expansion of the KMA urban area.

This process of urban growth has negative environmental implications within the study area, which include degradation of the environment and biodiversity. Wetlands which are useful for floods control and waste water restorations are being lost. They have been sold at cheaper and affordable prices such that more buildings have been developed in wetland zones. Due to the indiscriminate sale of land in these areas, the forms of physical development are also often haphazard and irregular in nature. Land has been obviously used wrongly in this process. Because of the incompatibility between the land use and the natural processes in these areas, natural hazards such as floods sometimes occur (e.g. Bohyen). Since a number of buildings are situated in water ways and flood flush zones, significant number of properties and lives are sometimes lost due to the hazards. Most people purchase the land during the dry seasons and hastefully develop the land for settlement to avoid the attention of city authorities, only to realise their predicaments in the rainy seasons. Even though a few of such constructions have been identified and halted, a lot more structures are still standing inhabited. This has put more people at risk and increased the cost of natural disaster. These developmental situations are predominant in areas like Kronom, Atonsu, Ahinsan, Bohyen, Susanso etc.

Green covers, especially forest, has been lost at an alarming rate. Trees have been cut down, a lot of bushes have been cleared and more land parcels have been sold by chiefs who are usually the custodians of these lands. This has led to the tremendous decrease in the forest area from 41158.08 ha to 22513.41ha. Even though most of the people who buy these lands obtain building permit from the appropriate government functionaries, the construction of their buildings are however, not monitored. This has led to land development which does not comply to planned developmental patterns. The lack of enforcement of regulations, the non-compliance to laid down developmental plans coupled with the indiscriminate sale of land by chiefs have led to the development of structures which look unplanned and awkward (e.g. Kumasi Race Course area). Most of these developed areas do not have good roads, potable water, drainage, electricity. This is generally because the rate of development supersedes the rate of provision of services by the central government. This situation is experienced in most areas referred to as “new sites” i.e newly developed areas such as Emena, Deduako, Esreso, Esaase, etc. The rapid form of land development in the study area has also consumed agricultural lands and some wildlife habitats due to encroachment. This has brought residents closer to some wildlife such as snakes, deer, monkeys, etc. Thus exposing lives and properties to threats from these wildlife. At Owabi, the wildlife sanctuary has now been placed under strict protection and constant surveillance to prevent human encroachment.

The establishment of “traffic nodes” (transportation artery) facilitates the beginning of settlement and gives direction, pattern and rate to the growth of settlement. The impetus associated with socioeconomic, commercial, and industrial activities, influence the direction, pattern and the growth rate of an urban area (Nanda, 2005). During the past 20

years, a good number of transportation arteries of various lengths, sizes and standard classes have been constructed within the KMA. A large number of industries, administrative firms and educational institutions have been established in and around the Kumasi sub metro. The impact finds expression not only in overall pattern of spatial growth but also in the economy of fringe community. In the course of time the workers employed in these units change their residence to live near their place of work and so move to new houses built in the fringe areas or outgrowth towns. This has brought economic expansion to the fringe area and has accelerated the expansion of residential landuse and also led to the increase in the demand of vegetated lands for residential landuse.

The northern sector of the study area witnessed a tremendous compact growth (refer to Figure 4.3). The expansion of the urban area is much concentric in nature, moving outwardly away from the city centre in all directions in a radial form. This gives the urban growth much of a clustered look. However, the pattern of land development away from the city centre is different from that along the road. On exiting to the east of the study area (refer to Figure 4.3), the growth obviously looks much linear. This is probably due to the existence of the main Kumasi-Accra transportation corridor, along which people find it more convenient to develop their properties for easy accessibility of transport. Physical factors of a region such as rivers, plains, hills, etc, traditionally were factors for determining the direction and pattern of growth of a city (refer to Nanda, 2005). However, the nature of the terrain of the study area is not considered to have had any effect or constraint on the process of growth of the study area. From the DEM generated (refer to Figure 4.18), it is observed that the slope is generally gentle with a flat terrain (650ft minimum to 1190ft maximum), and the growth is experienced in all directions as long as land is available,

except for the restriction in the expansion at the north-western portions of the study area (refer to Figure 4.3). This is attributable to the presence of the Owabi Forest Reserve and Wildlife Sanctuary.

Land development in the form of urban or built up expansion has converted forest and agricultural land to urban or built-up. This has implications for wildlife habitats, availability of natural resource and the health of the overall environment and ecosystem.

Xian et al. (2007) came to the same conclusions in a study in the Tampa Bay watershed. The process of urban change involving the growth of urban population (urbanization), the growth of the built-up area (urban growth) and the spread of urban functions into the urban hinterland (urban sprawl) with its associated population densities and land prices are operating within the study area.

Development within the study area is moving at a faster pace than services in the form of roads, drainage, electricity, potable water, etc. This may possibly be due to late planning or non-enforcement of regulations that have been laid down, and can also be related to development pressures from the rapid expansion of the KMA.

# KNUST

## CHAPTER FIVE

### CONCLUSION AND RECOMMENDATION

#### 5.1 Conclusion

The study through the use of Landsat (TM and ETM+) images in combination with topographic sheets, demographic data and socioeconomic survey, has determined the pattern of sprawl, analyse the pattern and derive the main drivers of the sprawl. This indicates that the objectives set out for this thesis have been achieved.

The study revealed that the KMA was sprawled. The area occupied by the urban or built-up land in 1974 was 1614.01 hectare. The urban or built-up area increased to 26259.66 hectare in 2007. The magnitude of growth of the urban area was over three times more than the population growth of the urban area within the same period of study. This situation identifies the KMA to be sprawled as defined by the Chesapeake Bay and Mid-Atlantic from space, glossary.

For the 1986 and 2007 landsat images, two landcover maps were generated using some applications of RS techniques. A comparison between the two land cover maps revealed the spatial pattern of the expansion of the urban area by visual interpretation. The expansion of the urban area showed a clustered growth pattern. This is further observed in the pattern

of landcover transfers to the urban or built-up which was visually interpreted in the change map. Land under urban or built-up area forms a major use of the total land in the study area. About 47.27 percent of the total developed land is under this category. The present pattern of residential land use has a mixed character of both planned and unplanned growth in the city. Like other cities the heart of the inner zone is highly congested. Existing physical features like topography had no effect on the pattern of land development except for the presence of the Owabi water reserve and wildlife sanctuary which influenced the pattern of land development to the north-western portions of the study area.

The rapid expansion of the KMA may be attributed to the demographic trends of the study area. The ever-increasing population experienced in the KMA has tremendously required the conversion of large portions of forest, wetlands and agricultural lands to urban or built-up lands. Income which is basic for transformation in other economic parameters such as standards of living, housing conditions etc observed majority of people (over 50% of respondents) falling within the middle income group category, living in the fringe areas where the expansion of the urban area is rapid. In the core of the city, the scarcity and high cost of houses has led to the mushrooming of slums and rickety housing for majority of migrants, resulting in the haphazard pattern of development.

The growth of the urban area has taken over surrounding vegetated lands including forest and agricultural lands leaving the study area derelict of vegetation causing general degradation of the environment. The study has also demonstrated the ability of using RS techniques in spatio-temporal studies.

### **5.1.1 Limitations**

The spatial non-heterogeneity of the landscape often causes misclassification. This is due to the situation where different spatial classes can be found within the same pixel (30m x 30m resolution). This scenario is often referred to as the ‘salt and pepper’ classification.

Another limitation of this project lays in the resolution of the image data. The resolution of the images, TM1986 and ETM+2007 made it difficult for any object of size or width below 30 metres to be identified. This may have also influenced the RMSE even though it was meticulously evaluated.

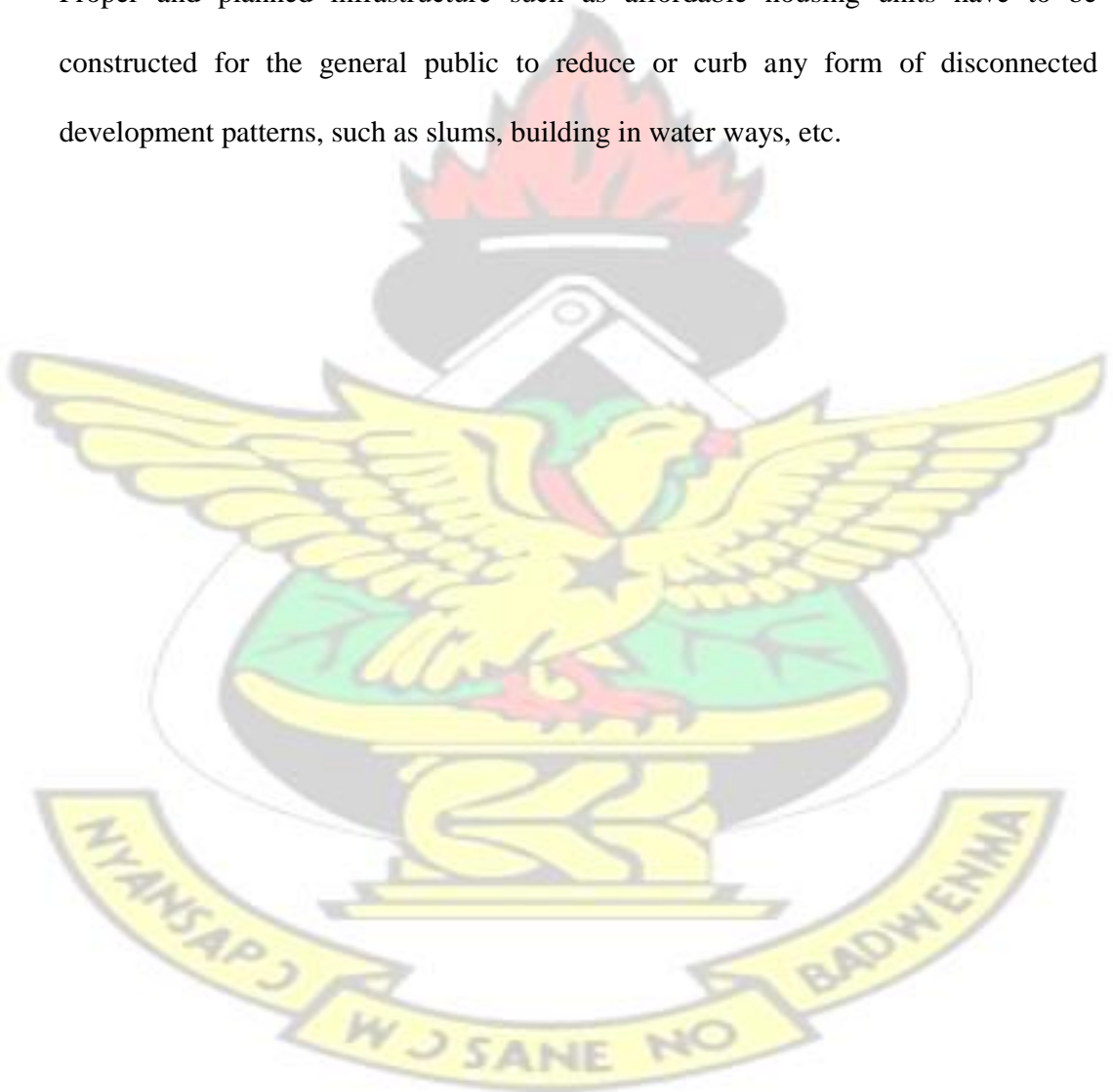
### **5.2 Recommendation**

In order to ensure the prudent use of land and safeguard the remaining natural resources within the study area and others like it, the following recommendations are proposed:

The study should be further pursued in order to develop a mathematical model from which the future model of the landscape can be projected. This will preview city planners to future situations and enable them plan and implement measures to ensure proficient use of land and natural resources.

- Streamlining of land management, especially within the regulatory bodies responsible for land administration (Ministry of Lands, Forestry and Mines, Land Title Registration, Lands Commission, Administrator of Stool Lands and District/Municipal Assemblies) to implement strict regulations on land owners and users, to ensure decency in land trade and usage.

- An efficient data collection system and data base on land cover in Ghana, as relevant data needed for in-depth analysis of LULC change is lacking.
- Enforcement of laws protecting water bodies and wetlands by the Environmental Protection Agency, Water Resources Commission and the District/Municipal Assemblies.
- Proper and planned infrastructure such as affordable housing units have to be constructed for the general public to reduce or curb any form of disconnected development patterns, such as slums, building in water ways, etc.



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# KNUST



## APPENDIX 1: Classification Accuracy Assessment Report ACCURACY TOTALS

<b>CLASS NAMES</b>	<b>reference total</b>	<b>Classified total</b>	<b>Number Correct</b>	<b>Producer Accuracy</b>	<b>User Accuracy</b>
Forest	19	20	13	68.42%	65.00%
Wet Lands	20	20	13	65.00%	65.00%
Water	0	0	0	0.00%	0.00%
Agricultural Land	32	30	24	75.00%	80.00%

Urban or Built-up Land	79	80	75	94.94%	93.75%
<b>TOTAL</b>	150	150	125		

Overall Classification Accuracy = 83.33%

### KAPPA STATISTICS

Conditional Kappa for each Category

CLASS NAME	KAPPA
Forest	0.5992
Wet Lands	0.5963
Water	0.0000
Agricultural Land	0.7458
Urban or Built-up Land	0.8680

Overall Kappa Statistics = 0.7403

### APPENDIX 2: Population of localities within the study area

TOWN NAME	POPULATION YEAR					
	1970			Projected Population		
	1970	1984	2007	1974	2006	1986
ABOABO	16,724	22,636	34,206	18928	25063	48846
ABREPO KESE	651	1,330	5,146	737	1473	7348
ABREPO KUMA	0	254	5,000	0	281	7140
ADAMANU	32	35	3,434	36	39	4904
ADIEBEBE	762	1,408	4,113	862	1559	5873
ADIEMBRA	698	1,059	3,666	790	1173	5235

ADOATO	0	1,002	6,493	0	1109	9272
ADUKROM	1,034	3,991	11,190	1170	4419	15979
ADUM	12,991	9,693	8,016	14703	10732	11447
AHINSAN/AHISN ES	0	10,601	25,170	0	11737	35943
AHODWO	707	2,712	4,265	800	3003	6090
AKOREM	3,168	6,914	14,025	3586	7655	20028
AMAKOM	14,787	26,582	39,060	16736	29432	55778
AMANFROM	336	460	2,526	380	509	3607
AMPABAME	1,591	3,382	5,894	1801	3745	8417
ANOMANYE	832	1,379	5,939	942	1527	8481
ANWOMASO	0	1,235	5,410	0	1367	7725
ANYINAM	166	257	1,006	188	285	1437
APATRAPA	622	869	5,028	704	962	7180
APEMSO	338	581	587	383	643	838
APERADE	298	474	1,666	337	525	2379
APIRI	0	0	911	0	0	1301
APPEADU	526	656	2,114	595	726	3019
APROBO	60	66	588	68	73	840
ASABI	135	397	1,427	153	440	2038
ASAFO	7,689	20,375	18,457	8702	22559	26357
ASAWASI/ZONGO	8,097	36,429	46,243	9164	40334	66035
ASH TOWN (MANHYI)	1,754	7,600	24,458	1985	8415	34926
ASH TOWN (MBROM)	1,269	4,071	3,337	1436	4507	4765
ASH TOWN (ODUMAS)	18,667	21,596	20,031	21127	23911	28604
ASOKORE MAMPONG	795	1,077	6,102	900	1192	8714
ASOKWA	700	8,123	18,747	792	8994	26771
ASUOYEBOA	4,098	2,280	15,226	4638	2524	21743
ATAFUA	0	127	455	0	141	650
ATASOMANSO	830	971	7,837	939	1075	11191
ATONSU-AGOGO	2,923	4,178	45,778	3308	4626	65371

ATWIMA AMANFROM	0	1,189	4,170	0	1316	5955
AYEDUASE	1,311	1,834	7,438	1484	2031	10621
AYIGYA	8,548	13,148	30,283	9675	14557	43244
BANTAMA	12,666	14,984	22,060	14335	16590	31502
BOADI	226	622	3,196	256	689	4564
BOHYEN	2,112	1,860	10,771	2390	2059	15381
BOHYEN KROPO	0	1,556	3,177	0	1723	4537
BOMPATA	2,629	5,400	12,905	2976	5979	18428
BOMS0	335	4,502	9,005	379	4985	12859
BREMAN	3,778	5,131	41,956	4276	5681	59913

BREMANG	0	0	421	0	0	601
BUOBAL	0	10	353	0	11	504
BUOKROM	1,363	3,627	12,374	1543	4016	17670
BUOKROM ESTATES	243	1,689	11,100	275	1870	15851
DABAN	238	463	9,392	269	513	13412
DAKODWOM	629	1,144	1,750	712	1267	2499
DANYAME	355	725	5,340	402	803	7626
DANYAME	0	26	2,951	0	29	4214
DEDUAKO(KODIEKR)	547	582	3,111	619	644	4443
DENKYEMUOSO	311	369	2,145	352	409	3063
DICHEMSO	5,196	14,695	21,281	5881	16270	30389
DOMPOASE	2,345	3,605	3,179	2654	3991	4540
DOTE	432	556	1,662	489	616	2373
DUASI	0	68	2,207	0	75	3152
DWENASE	1,710	3,656	4,113	1935	4048	5873
EHWEMASE	821	1,194	12,470	929	1322	17807
EMENA	0	0	1,507	0	0	2152
FANKYENEBRA	632	1,430	5,895	715	1583	8418
FANTI NEW TOWN	4,197	6,668	12,407	4750	7383	17717
GARRISON BARRACK	3,480	1,293	3,113	3939	1432	4445
GYINYASE	1,579	3,169	10,914	1787	3509	15585
KAASE	2,359	917	11,130	2670	1015	15894
KENTENKRONO	1,473	1,250	3,222	1667	1384	4601
KOKOBENG	189	243	583	214	269	833
KOKOSO	0	0	2,285	0	0	3263
KATH	2,225	1,172	953	2518	1298	1361
KONKROMASE	122	112	376	138	124	537
KONTOPONI AFERE	0	262	314	0	290	448
KOTEI	1,084	1,376	4,373	1227	1524	6245
KRONOM	1,763	2,424	13,988	1995	2684	19975
KUMASI AIRPORT	484	407	480	548	451	685
KWADASO ESTATE	902	2,233	8,773	1021	2472	12528
KWADASO NSUOM	10,877	1,321	24,255	12311	1463	34636

KYIRAPATRE	545	1,935	7,440	617	2142	10624
MESUOM	0	56	240	0	62	343
MPATASIE	0	275	2,671	0	304	3814
NEW KAGYASI	0	0	1,746	0	0	2493

NEW SUAME	2,595	14,164	16,881	2937	15682	24106
NEW TAFO	7,875	24,163	47,506	8913	26753	67839
NEW TA (YENAWOSO)	2,545	3,155	7,254	2880	3493	10359
NORTH SUNTRESO	5,373	8,066	10,127	6081	8931	14461
NSENIE	2,486	226	2,715	2814	250	3877
NSIMA	734	1,114	6,970	831	1233	9953
NSIMA-KOKODE	0	648	2,072	0	717	2959
NWAMASE	333	540	2,879	377	598	4111
NYENKYERENEASE	0	1,496	3,896	0	1656	5563
ODENEHO-KWADASO	689	869	4,657	780	962	6650
ODUOM	0	56	2,203	0	62	3146
OFORIKROM	78	24,725	38,155	88	27376	54485
OFORIKROM	0	2,285	6,823	0	2530	9743
OHWIM	439	887	3,279	497	982	4682
OLD SUAME	4,815	17,259	15,392	5450	19109	21980
OLD TAFO (MILE PT 3)	20,661	21,318	56,417	23384	23603	80563
OLD TA (MOSH-ZNGO)	4,377	12,097	34,980	4954	13394	49951
PAMPASO	634	901	2,966	718	998	4235
PANKRONO	2,080	5,670	36,683	2354	6278	52383
PARKOSO	450	590	1,105	509	653	1578
PATASI	919	2,237	9,364	1040	2477	13372
SANTASI	2,070	3,000	9,421	2343	3322	13453
SAWABA	410	1,438	8,661	464	1592	12368
SEPE APAMPRAM	1,529	2,446	8,375	1731	2708	11960
SEPE WUSUANSA	0	1,486	2,675	0	1645	3820
SIPE TINPON	908	1,340	5,189	1028	1484	7410
SOKOBAN	292	565	902	330	626	1288
SOUTH SUNTRESO	5,278	7,784	12,079	5974	8618	17249
SUNTRESO EXTENSIN	0	3,267	3,535	0	3617	5048
TAKYIMAN	364	618	2,877	412	684	4108
TANOSO	1,319	2,948	13,536	1493	3264	19329
TARKWA MAAKRO	988	1,575	20,232	1118	1744	28891
TIKESE	0	8	999	0	9	1427
TWUMDUASI	197	327	1,132	223	362	1616
UST	5,357	2,475	4,705	6063	2740	6719
WEST NHYAESO	0	1,783	4,602	0	1974	6572
ABANKRO	728	544	558	824	602	797
ABIRA	1765	2141	3746	1998	2371	5349

ABUAKWA	970	3581	16582	1098	3965	23679
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ABURASO	607	773	3157	687	856	4508
ACHIASE	91	367	2418	103	406	3453
ACHIASE	1871	3167	3914	2118	3507	5589
ADESINA	220	759	478	249	840	683
AFRANCHO	1046	1825	4418	1184	2021	6309
AFRENTIA	0	0	147	0	0	210
AKOKOAMON	247	322	472	280	357	674
AKOSOMO	388	606	505	439	671	721
AKROPONG	1545	2520	4045	1749	2790	5776
AKYEREMADE	208	377	912	235	417	1302
AMPABAME	623	914	1204	705	1012	1719
AMPEYOO	140	238	1111	158	264	1587
ANTOA	1368	2628	2673	1548	2910	3817
APROMASI	1125	1288	1813	1273	1426	2589
APUTUOGYA	0	313	1096	0	347	1565
ASAGO	273	527	926	309	583	1322
ASAMAN	236	286	224	267	317	320
ATOBIASE	456	548	548	516	607	783
BAWORO	563	622	869	637	689	1241
BEBU	566	856	978	641	948	1397
BEKWAMING	127	246	619	144	272	884
BESEASE	31	74	240	35	82	343
BOKO	486	677	1618	550	750	2311
BOKWANKYE	479	805	1845	542	891	2635
BROFOYEDRU	257	231	352	291	256	503
BROFOYEDRU	124	384	1107	140	425	1581
BUOHO	526	589	4183	595	652	5973
DAKU	436	631	1125	493	699	1607
DOMEABRA	952	1028	1500	1077	1138	2142
EKYEM	135	98	139	153	109	198
ESAASE	689	885	2014	780	980	2876
ESEN	0	0	198	0	0	283
ESERESO	441	673	4871	499	745	6956
FAWOADE	545	850	2506	617	941	3579
FEYIASE	511	795	1842	578	880	2630
FUMESUA	1526	1518	4576	1727	1681	6535

KENYASE	1335	3292	6139	1511	3645	8766
KOKOBEN	711	1074	3404	805	1189	4861
KWAMO	1184	1764	5470	1340	1953	7811
KWANWOMA	612	977	1442	693	1082	2059
KYEREKROM	727	910	1271	823	1008	1815
MAMPONTENG	3213	4098	9121	3636	4537	13025
MIM	0	457	1432	0	506	2045
NKETIA	187	269	760	212	298	1085
NKORANSA	261	511	1226	295	566	1751
NWAMASI	0	0	641	0	0	915
SAAMAN	0	0	57	0	0	81
SAWIA	1318	1640	2288	1492	1816	3267
TETREFU	969	1207	1175	1097	1336	1678
TWEDIE	1279	1777	3010	1448	1967	4298
<u>YABI</u>	<u>667</u>	<u>954</u>	<u>2097</u>	<u>755</u>	<u>1056</u>	<u>2995</u>
<b>TOTAL</b>	<b>291545</b>	<b>541120</b>	<b>1291332</b>	<b>329971</b>	<b>599128</b>	<b>1844023</b>



APPENDIX 3: Some LULC within the study area

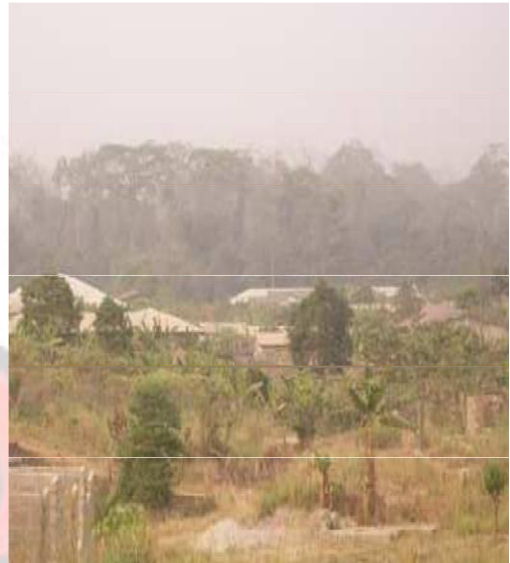


Plate 5: Uncompleted residential

Plate 2: New developing house within area

Plate 3: Uncompleted residential houses within study area



**Plate 4: Land being advertised for sale**



**Plate 5: Development close to Owabi Forest**



**Plate 6: Fence wall close to Owabi Forest Reserve**



**Plate 7: Sign prohibiting encroachers**



**Plate 8: Dumping of waste in stream**



**Plate 9: Dumping of waste on land**



**Plate 10: Residential development close to the street marked for demolition**



**Plate 12: Uncompleted building on wetland area**



**Plate 11: Rickety structures developed close to the street**



**Plate 13: Residential development on wetland area**



**Plate 15: Residential development in water way marked for demolition**

**Plate 14: Structure in water way marked for demolition**

**APPENDIX 4: Questionnaire for socio-economic survey**

**COLLEGE OF ENGINEERING**  
**FACULTY OF CIVIL AND GEOMATIC ENGINEERING**  
**KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY**

**QUESTIONNAIRE**

This questionnaire forms part of an MSc research on “Assessment of Urban Sprawl in the KMA using GIS and RS techniques”. Kindly take time to answer the questions. Thank you in advance for your time.

**District:** .....(e.g. Kwabre, KMA, Bosomtwi/Kwawonma, Ejisu-Juabeng, Atwima, etc)

**Locality:** .....(Kwamo, Fumesua, Atimatim, Sepe, Asokore-Mampong, Kenyasi, etc)

1. AGE: 0-20  21-30  31-40  41-50  51-60  61+

2. GENDER: M  F

3. ETHNICITY

Akan  Ga-Dangme  Ewe  Guan  Gurma  Mole-Dagbani  Grusi [

] Mande  All other tribes

4. HOW LONG HAVE YOU STAYED IN THIS AREA?

< 5 Years  5 – 10 years  11-20 years  >21 years

5. MARITAL STATUS

Married  Single  Separated  Divorced  Widowed

6. HOUSEHOLD SIZE

Single  2-5  6-10  10+

7. EDUCATIONAL LEVEL

No formal education  Primary  Secondary  Tertiary  Other

**8. OCCUPATION**

- |   |  |
|---|--|
| Agriculture <input type="checkbox"/>        | Financial Services <input type="checkbox"/>                    |
| Forestry <input type="checkbox"/>           | Real Estate <input type="checkbox"/>                           |
| Mining & Quarrying <input type="checkbox"/> | Business activity <input type="checkbox"/>                     |
| Manufacturing <input type="checkbox"/>      | Wholesale & Retail trade <input type="checkbox"/>              |
| Civil service <input type="checkbox"/>      | Community, Social & Personal services <input type="checkbox"/> |
| Construction <input type="checkbox"/>       | Hotels & Restaurants <input type="checkbox"/> Transport,       |
| Storage & Comm. <input type="checkbox"/>    | Unemployed <input type="checkbox"/>                            |

9. INCOME (\$) 0-100  101- 200  >200

10. Do you own this property/land? YES  NO

**11. OWNERSHIP STATUS**

Landlord  Lease  Tenant/ Farmer

12. From whom did you acquire the land?

- a. Individual private owner
- b. Chief of the area
- c. Family head
- d. Inherited
- e. Don't know

13. What is the purpose of purchase?

- a. Residential
- b. Commercial
- c. Investment
- d. Other

.....  
.....

14. What was the LULC at the time of purchase?

.....

15. What influenced you choice of this location?

.....

16. Where did you live/work before relocating here?

.....

17. What were the reasons for relocating?

.....

18. Have you registered your interests/rights to the land? YES  NO

19. Which departments have processed/registered your documents?

- a. Lands Commission [ ]
- b. Land Title Registration Department [ ]
- c. District Assembly [ ]

20. Is your locality subject to any building regulations? **YES** [ ] **NO** [ ]

21. If **YES**, what building regulations exist?

.....

.....

22. Who is enforcing these regulations?

.....

.....

23. Do you have a building permit? **YES** [ ] **NO** [ ]

24. If **NO** why not?

.....

