Application of Remote Sensing and GIS for Forest Cover Change Detection.

(A case study of Owabi Catchment in Kumasi, Ghana)

By

Adubofour Frimpong (Bsc. Geodetic Engineering)

April, 2011

Supervisor : Dr. E. K. Forkuo

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Chairperson: Prof. C. K. Kankam External Examiner: Dr. Appeaning Addo Internal Examiner: Dr. E. M. Osei Primary Supervisor: Dr. E. K. Forkuo

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Faculty of Civil and Geomatic Engineering

College of Engineering

Kwame Nkrumah University of Science and Technology (KNUST)

I hereby declare that this submission is my own work towards Msc. and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

Adubofour Frimpong	---------------------------------	-----------------
(Student Name)	Signature	Date

Certified By

Dr. Eric Kwabena Forkuo	---------------------------------	-----------------
(Supervisor‟s Name)	Signature	Date

Certified By

Dr – Ing Collins Fosu	---------------------------------	-----------------
(Head of Department)	Signature	Date

Disclaimer

This document describes work undertaken as part of a programme of study at the Kwame Nkrumah University of Science and Technology (KNUST), Kumasi – Department of Geomatic Engineering. All views and opinions expressed therein remain the sole responsibility of the author, and do not necessarily represent those of the institute.

Abstract

Farming activities, continued sand winning operations and the allocation of plots of land to prospective developers in and around the catchments of the Owabi Dam pose a serious threat to the forest covers and the lifespan of the dam. The aim of this study was to analyzing the Change detection of forest cover in Owabi catchment area in Kumasi, using multi-temporal Remote Sensing (RS) data and Geographic Information System (GIS) based techniques.

For this study, Landsat TM image of 11th January 1986, aster image of 15th January 2002 and Landsat ETM image of 24th February 2007 were analyzed using Erdas Imagine and ArcGIS software. After performing supervised classification on these images, a total of eight land use and land cover (LULC) classes were identified and mapped. These were water, bare soil/sand, grassland, built-up, sparse forest, high density forest, croplands and wetlands. An NDVI analysis was performed on these images and vegetation covers were identified. Using Fragstats software, changes in the landscape structure were analyzed and some fragmantation statistics of the LULC types were computed. Gain and loss to persistence ratio as well as the net change to persistence ratio of the various LULC classes were also computed. Topographic map of 1974 were used to identify the spatial distribution of the reserved forest.

The results of the analysis showed that from 1986 to 2002 and 2002 to 2007 the forest covers‟ has decreased by 2136.6 ha and 1231.56 ha respectively representing 24.7% and 14.2%. It emerged that from 1986 to 2007, forest covers‟ reduced by 3368.16 ha, representing 38.9%. These changes were as a result of an increase in human activities and population explosion within the catchment area. There was no significant difference between the NDVI classification and the supervised classification of the images. Overlay of the reserved forest of the 1974 and the classified maps of 1986, 2002 and 2007 shows that the reserved forest had been highly depleted over the past 33 years. The use of Satellite image data, GIS and RS technique is a valuable tool for detection and prediction of forest cover change and the identification of areas under risk of invasion.

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List of Acronyms.

ASTER………………. Advanced Spaceborne Thermal Emmission and Reflection Radiometer

AVHRR ……….…… Advanced Very High-Resolution Radiometer

CBD………….......... Convention on Biological Diversity CEDAR

………………Centre for Developing Areas Research

CO_2 ……………….……. Carbon Dioxide.

DN…………………… Digital Number

ERTS………………..... Earth Resources Technology Satellite

ETM…………….......... Enhanced Thematic Mapper

FAO………………...... Food and Agricultural Organization

GCPs………………….... Ground Control Points

GIS ………………….. Geographic Information System.

GWCL……….……….. Ghana Water Company Limited

IGBP/IHDP…………... International Geosphere - Biosphere Programme

ITTO……………….……. International Tropical Timber Organization

IUCN……………….…… The World Conservation Union

LULC………………… Land use and Land cover.

NASA………………..... National Aeronautics and Space Administration (US)

NDVI…………….…… Normalized Difference Vegetation Index.

NIR…………………... Near Infrared

NOAA……………….. National Oceanic and Atmospheric Administration (US)

O_2…………….………. Oxygen.

R………………...…… Red

RMSE……………….... Root-Mean-Square Error.

RS…………………..…… Remote Sensing.

SFM……………….…..... Sustainable Forest Management

SPOT………………… Système Pour l'Observation de la Terre (French remote sensing satellite).

TM……………..…….. Thematic Mapper

UNEP………………… Unite Nations Environment Programme

WGS………………… World Geodetic System

WRI…………..……….... World Resources Institute

CHAPTER ONE INTRODUCTION 1.1 Background

There are few landscapes remaining on the Earth‟s surface that have not been significantly altered or are not being altered by humans in some manner (Yang, 2001). Mankind‟s presences on the Earth and his modification of the landscape have had a profound effect on the natural environment. Anthropogenic activities such as agriculture, mining, deforestation and construction influence on shifting patterns of land use are a primary component of many current environmental concerns as land use and land cover (LULC) change is gaining recognition as a key driver of environmental change. Changes in LULC are pervasive, increasingly rapid, and can have adverse impacts and implications at local, regional and global scales (Yang, 2001).

Urban growth and its associated population increase is a major factor which has altered natural vegetation cover. This has resulted in a significant effect on local weather and climate. The use of remote sensing data in recent times has been of immense help in monitoring the changing pattern of vegetation. Change detection, as defined by Hoffer (1978) is the temporal effects as variation in spectral response involves situations where the spectral characteristics of the vegetation or other cover type in a given location change over time. Singh (1989) described change detection as a process that observes the differences of an object or phenomenon at different times.

Forests are a valuable resource providing food, shelter, wildlife habitat, fuel, and daily supplies such as medicinal ingredients and paper. Forests play an important role in balancing the Earth's carbon dioxide (CO_2) supply and exchange, acting as a key link between the atmosphere, geosphere, and hydrosphere. Tropical rainforests, in particular, house an immense diversity of species, more capable of adapting to, and therefore surviving and changing environmental conditions (Canada Centre for Remote Sensing Tutorials, 2008).

Forests have long been regarded as a national treasure in Ghana. With the current depletion of forested areas around the world, it is important that we manage these renewable resources in a sustainable manner. In order to formulate and exercise efficient forest management policies and practices, it is important to have reliable information about the LULC. Forest resource maps were traditionally prepared from forest inventories involving aerial photography and fieldwork (Suhaili et al., 2006). However modern technology, Geographic Information System (GIS) technique and Remote Sensing (RS) from Satellite platforms offer an alternative and economic tool for forest mapping (Suhaili et al., 2006).

LULC change has become a central component in current strategies for managing natural resources and monitoring environmental change. Since the late 1960‟s, the rapid development of the concept of vegetation mapping has lead to increased studies of LULC change worldwide (Yang, 2001). Providing an accurate assessment of the extent and health of the world‟s forest, grassland, and agricultural resources has become an important priority (Yang, 2001).

The conservation of biodiversity has become a major concern with the international community ever since the Secretariat of the Convention on Biological Diversity (CBD) drafted its conservation treaty in Rio de Janiero on June 1992. Forests and woodlands cover nearly 40% of the earth‟s land surface, and they are the most biologically diverse ecosystems in most parts of the world (WRI, IUCN and UNEP, 1992). Forests are arguably the single most important banks of global biodiversity (Kapos and Iremonger, 1998).

1.2 Problem Statement

Farming activities and continued sand winning operations in and around the catchments of the Owabi Dam, which provides portable water to the residents of Kumasi, are posing a serious threat to the lifespan of the dam (Figure 1). Officials feared unless action was taken to stop the development, Kumasi and its residents would face severe water shortage in the near future since the volume of water could reduce heavily (Frimpong, 2007). The sand winners have completely cleared parts of the forest reserve, which protects the Owabi River that empties into the dam. The forest prevents siltation as well as rapid evaporation of the water in the dam from the intense sun. There was serious logging and clearing of the bushes in the catchments to the extent that many trees have all been cut down to pave way for sand winning operations (Frimpong, 2007).

I detected that parts of the forest had been cleared and pillars had been erected giving an indication that someone was allocating the plots of land to prospective developers. The sand winners were mainly from Bokankye, Nyankyereniase and Apatrapa (Frimpong, 2007).

The Ghana Water Company Limited (GWCL) had on numerous occasions appealed to neighboring villages to desist from clearing the forest cover and to discontinue with the sand winning activities. Information gathered from the Department of Game and Wildlife

Division indicated that security personnel of the GWCL have on numerous occasions sacked the sand winners from the catchments and seized their equipment yet the practice is unrelenting. The practice started gradually and is now very vibrant (Frimpong, 2007). A number of houses totaling about 400 are known to have been illegally constructed in the Owabi catchment area and out of this 140 of them were demolished in 1998 (Frimpong, 2007). The natives have resolved to continue clearing the forest for farming purposes and sand winning as a means of livelihood unless compensation were paid to them (Frimpong, 2007). They claim that compensation for the land has not been paid to them since the construction of the dam and as a result their only source of livelihood depended on the land (Frimpong, 2007).

Figure 1: Photograph showing sand winning operation (August, 2009).

1.3. Research Questions

- Is change in forest cover attributed to anthropogenic activities in the study area?
- Is rapid urbanization a cause of deforestation of the area?

- Is there a reduction or expansion of forest coverage in the study area within the stipulated times?
- Is RS Image interpretation applicable for locating, identifying and quantifying forest cover and its change detection?
- Will the GIS techniques (integrated in this study) prove beyond reasonable doubt its capabilities of spatial analysis of the forest cover change?
- Is there an increase in agricultural needs in the study area?

1.4 Research Objectives

1.4.1 Main Objectives

This study aimed at analyzing the change detection of forest cover in Owabi catchments in Kumasi, using multi- temporal RS data and GIS based techniques.

1.4.2 Specific Objectives

- Identification of LULC classes within the Owabi catchment and their spatial distribution.
- To prepare the various thematic and Normalized Difference Vegetation Index (NDVI) maps of the area using GIS technology.
- Project areas under risk of invasion in future.

CHAPTER TWO

LITERATURE REVIEW

During the past millennium, humans have taken an increasingly large role in the modification of the global environment. With increasing numbers and developing technologies, man has emerged as the major, most powerful, and universal instrument of environmental change in the biosphere today. Globally, land cover today is altered primarily by direct human use. Any conception of global change must include the pervasive influence of human action on land surface conditions and processes (Yang, 2001).

Bruzzone (2003), defined change detection as the process of identifying differences in the state of an object or phenomenon by observing it at different times. Lambin and Strahler (1994), listed five categories of causes that influenced land-cover change: a) long-term natural changes in climate conditions, b) geomorphological and ecological processes such as soil erosion and vegetation succession, c) human-induced alterations of vegetation cover and landscapes such as deforestation and land degradation, d) interannual climate variability and e) the greenhouse effect caused by human activities.

Boakye et al. (2008), explain that vegetation changes are often the result of anthropogenic pressure (e.g. population growth) and natural factors such as variability in climate. They reported that Tropical forests are exploited for varied purposes such as timber, slash-and-burn cultivation and pasture development. They further explained that degradation of forest or woodland have impact on catchment processes and biochemical cycles and leads to soil erosion and water shortage not only in the regions immediately affected by deforestation, but also in reasonably distant areas. Due to increasing population growth rates, there have been increasing rates of conversion of forest and woodlands in developing economies all over the world, mainly for the slash-and-burn farming practice (Groten et al., 1999).

The Sustainable Forest Management (SFM) concept has been initiated to address many problems relating to deforestation, especially those in developing countries. International Tropical Timber Organization (ITTO) pioneered in defining criteria and indicators of natural tropical forest for sustainable forest management in the early 1990"s. ITTO is still aiming at achieving SFM by reviewing, assessing and monitoring forest lands (ITTO, 2004).

Many studies have been performed to identify factors that cause deforestation in developing countries. One of those factors is inappropriate agricultural technology used in farm land(s) located around the forest area (Angelsen and Kaimowitz, 2001). The misuse of forest resources due to the centralization of forest management policy is considered as another factor for deforestation (Rosyadi et al., 2003). Moreover, Boltz (2003), mentioned that conventional logging operation with unplanned-selective logging method also becomes one factor of deforestation. However, the most important factor that causes deforestation comes from Illegal logging and trade (Atmopawiro, 2004; Zaitunah, 2004). According to Casson and Obidzinski (2002), illegal logging is defined as the havesting of logs in contravention of laws and regulations that were designed to prevent the overexploitation of forest resources and to promote sustainable forest management. It is estimated that logging is generating between US$10 billion and $15 billion of forest losses every year (FAO, 2004).

According to Ringrose et al. (1997), LULC change in Africa is currently accelerating and causing widespread environmental problems and thus needs to be mapped. This is important because the changing pattern of LULC reflect changing economic and social conditions. Monitoring such changes is important for coordinated actions at the national and international levels (Bernard et al., 1997).

Modern technologies such as RS and GIS, provide some of the most accurate means of measuring the extent and pattern of changes in landscape conditions over a period of time (Miller et al., 1998). Damizadeh et al. (2000) used satellite images, as an effective technique to study how changes in vegetation cover is growing. Satellite data have become a major application in change detection because of the repetitive coverage of the satellites at short intervals (Mas, 1999). According to the IGBP/IHDP (1999), change detection studies seek to know (i) pattern of land cover change, (ii) processes of land use change, and (iii) human response to LULC change.

Parviainen and Päivinen (1998) monitored and reported that natural or semi-natural old forests are important for preserving the original biodiversity, as they provide a habitat for certain specialised forest-related species. Ancient forest species are considered important in terms of nature of conservation because they combine both qualitative (forest quality) and quantitative (diversity) conservation criteria (Peterken, 1996). Natural forests are also important as a setting for outdoor recreation and tourism. The only means to preserve the floral and faunal species typical to such forests is by establishing a representative network of conservation areas including cores, buffers and corridors. Conservation of biodiversity requires management of entire landscapes, not just protection of individual reserves (Noss, 1990).

Yang (2001), illustrate that information about change is necessary for updating land cover maps and the management of natural resources. Based on the summarization of the methods on change information extracted from remotely sensed data, the study promotes the method of change detection based on remote sensing information model. It lays the foundation for research on how the change relations of natural and human activity have an impact on each other.

Miwei (2009), monitored emphemeral vegetation in Poyang Lake using ModerateResolution Imaging Spectrometer (MODIS) remote sensing image. The study monitored the change in Area of Ephemeral Vegetation (AEV) by analyzing time series of MODIS imagery and investigate how this change is related to changes in hydrological conditions.

Ahmad (2001), used remote sensing and GIS tools for mapping a dry shrub forest for biodiversity conservation planning by using salt range of Pakistan as a case study. The main objective of the study was to identify priority remnant forest patches for biodiversity conservation planning. Forest vegetation was selected as a subset of total biodiversity.

Joshi (2001), investigated spatial detection and prediction of Banmara (Chromolaena Odorata) invasion. Invasive of Chromolaena odorata (Banmara = Forest Killer) is one of the highly successful and established exotic weeds in Nepal. In his assessment, he illustrated the potential threat of Banmara invasion into forest areas disturbed by anthropogenic activities. The study concluded that intensive forest use, human interference and environmental conditions has lead to forest degradation resulting in an increased invasion of Banmara.

Adia et al. (2007), investigated the Spatio-Temporal change detection of vegetation cover of Jos and its surrounding areas. The study used Landsat images (TM and ETM+) of 17th

November, 1986 and 2nd Nov, 2001. For recognition of vegetation reflectance, layer stacking of band 4, 3 and 2 (false color composite) for TM and ETM+ was performed to generate change maps of the vegetation cover for the respective dates and find out the pattern of change.

2.1. RS and GIS in forest cover change detection.

Remote Sensing is a process of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing and applying that information. (Canada Centre for Remote Sensing, 2008).

RS technique for forest cover change detection and monitoring has been used to assess the dissimilarities in forest cover over two or more time periods caused by environmental conditions and human actions. RS and GIS are practical tools in estimating and validating ecosystem changes arising from forest use and forest management interventions. Quantitative knowledge about LULC changes enable the economic comparison of different ecosystem services within and across different countries (Kreuter et al., 2001; Zhongmin et al., 2003.)

Another unique quality of RS data is that it provides a means of quickly identifying and delineating various forest types, a task that would be difficult and time consuming using traditional ground surveys. Data is available at various scales and resolutions to satisfy local or regional demands. Species identification can be performed with multispectral, hyperspectral, or air photo data interpretation. Both imagery and the extracted information can be incorporated into a GIS to further analyze as slopes, ownership boundaries, or roads (Canada Centre for Remote Sensing Tutorials, 2008).

Satellite RS is a widely used technique to produce LULC maps and to study vegetation cover (Fung and Chan, 1994). A study done in northern California by May et al. (1997) reported that Thematic Mapper (TM) data were more effective than SPOT (Système Pour l'Observation de la Terre i.e.French remote sensing satellite) in separating shrubs from meadows, but neither TM nor SPOT data were effective in separating meadow types.

Normally, data about earth‟s features is acquired either from air (aerial photography) or from space (satellite imagery). Aerial photographs are in analogue form while images are basically in digital form. Remote sensing is based on the measurement of electromagnetic energy. The remote sensing sensor measures the energy that is reflected or backscattered by the earth‟s surface. The measured energy is converted and stored as a digital number (DN) value, which ranges from 0-255. Each pixel (picture element or unit area or ground cell) has a single DN value. Most sensors measure reflected sunlight (passive remote sensing) however, some sensors detect energy emitted by the earth itself or provide their own source of energy (active remote sensing) (Lillesand and Kiefer, 2000).

The reflective characteristics of vegetation are different from those of bare soil or water (Mather, 1999) and are dependent on the properties of the leaves including the orientation and the structure of the leaf canopy. Figure 2, shows the typical spectral reflectance curves for vegetation, bare soil surface and clear water. The proportion of the radiation which is reflected in the different parts of the spectrum depends on leaf pigmentation, leaf thickness and composition (cell structure) and on the amount of free water in the leaf tissue.

The reflectance is low in both the blue and red regions of the spectrum, due to absorption by chlorophyll for photosynthesis; however, it is high at the green region. In the near infrared (NIR) region, the reflectance is much higher than that in the visible band due to the cellular structure in the leaves. Hence, vegetation can be identified by the high NIR but generally low visible reflectances. This property has been used in early reconnaissance missions during war times for "camouflage detection". The reflectance of bare soil generally depends on its composition. However the reflectance of clear water is generally low.

Digital (computer based) or visual image-interpretation techniques are applied to extract information from the satellite image data. For an accurate image classification, data collected from ground truthing or ground survey is linked to image data. In this way a map showing various land cover types of the area is produced. This study uses satellite imagery to detect and map areas of forest cover by taking advantage of unique reflective characteristics of forest vegetation.

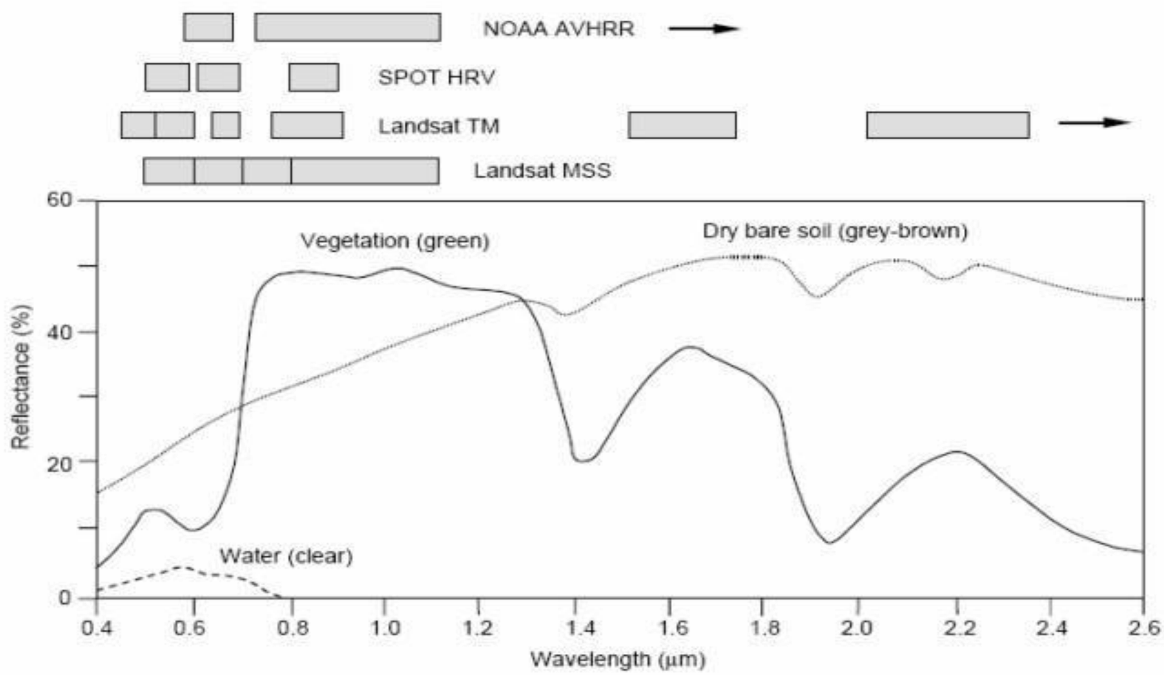


Figure 2: Typical spectral reflectance curves for vegetation, bare soil surface and clear water. (Lillesand and Kiefer, 2000).

2.2. Concepts and Definitions

2.2.1. Land-use and land-cover (LULC) change

Land-use and land-cover (LULC) change also known as land change, is a general term for the human modification of Earth's terrestrial surface. Though humans have been modifying land to obtain food and other essentials for thousands of years, current rates, extents and intensities of LULC change are far greater than ever in history, driving unprecedented changes in ecosystems and environmental processes at local, regional and global scales (Ellis, 2007).

2.2.2 Land Cover

Land cover refers to the physical and biological cover over the surface of land, including water, vegetation, bare soil, and/or artificial structures (Ellis, 2007). Land-cover denotes the surface cover over land, including vegetation, rock and human-modified surfaces such as buildings (Ellis et al., 2009). Land-cover is a characteristic of the land that can be observed physically, as by remote sensing. This is different than land-use, because a single land-cover type can be used in various ways by humans (Ellis et al., 2009).

2.2.3. Land use

Land use is a more complicated term. Natural scientists define land use in terms of syndromes of human activities such as agriculture, forestry and building construction that alter land surface processes including biogeochemistry, hydrology and biodiversity. Social scientists and land managers define land use more broadly to include the social and economic purposes and contexts for and within which lands are managed (or left unmanaged), such as subsistence versus commercial agriculture, rented vs. owned, or private vs. public land (Ellis, 2007).

2.2.4. Natural and semi-natural forest.

2.2.4.3. Natural Forest

Forest naturalness is characterized by elements such as a complex spatial structure, a composition and distribution of climax species, a wide range of ages in tree species and the presence of coarse woody debris. All of the following loosely defined terms, that is natural forest, old-growth forest, ancient forest, virgin forest and primary forest have been used interchangeably in literature (FAO, 1997).

Natural forests have unique features that distinguish it from other forest types. A more natural forest is one that is only slightly modified, contains primarily native species and requires less human input to maintain system functions (Peck, 1998).

2.2.4.4. Semi-natural Forest

Semi-natural forests are defined as those forests, which have been modified by humans through use and management. A stand which is composed predominantly of native trees and shrub species which have not been planted. Also, a forest which has developed gradually or accidentally, as its location or site quality was not suited for intensive exploitation or production-oriented management (e.g. mountainous regions) (FAO, 1997).

2.2.5. 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). Remote sensing provides a viable source of data from which updated land-cover information can be extracted efficiently and cheaply in order to inventory and monitor changes effectively.

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).

2.2.6. Biodiversity conservation

A number of slightly different definitions of the term biological diversity or in short biodiversity exist in literature. According to McNeely et al. (1990), it includes all species of living organisms and the ecosystems and ecological process of which they are part. It includes both the number and frequency of ecosystems, species, or genes in a given assemblage. WRI-IUCN-UNEP (1992) has defined biodiversity as the totality of genes, species and ecosystems in a region.

2.2.7. Accuracy assessment

The general acceptance of the error matrix as the standard descriptive reporting tool for accuracy assessment of remotely sensed data has significantly improved the use of such data. An error matrix is a square array of numbers organized in rows and columns which expresses the number of sample units (i.e. pixels and clusters of pixels) assigned to a particular category relative to the actual category as indicated by reference data (Congalton, 1996).

The average accuracy is the average of the accuracies for each class, and the overall accuracy is a similar average with the accuracy of each class weighted by the proportion of test samples for that class in the total training or testing sets. Thus, the overall accuracy is a more accurate estimate of accuracy (Yang, 2001).

The importance and power of the Kappa analysis is that it is possible to test if a LULC map is significantly better than if the map had been generated by randomly assigning labels to areas (Congalton, 1996). It is widely used because all elements in the classification error matrix, and not just the main diagonal, contribute to its calculation and because it compensates for change agreement (Rosenfield & Fitzpatrick-Lins, 1986). The Kappa coefficient represents the proportion of agreement obtained after removing the proportion of agreement that could be expected to occur by chance (Foody, 1992).

The Kappa coefficient lies typically on a scale between 0 (no reduction in error) and 1 (complete reduction of error). The latter indicates complete agreement, and is often multiplied by 100 to give a percentage measure of classification accuracy. Kappa values are also characterized into 3 groupings: a value greater than 0.80 (80%) represents strong agreement, a value between 0.40 and 0.80 (40 to 80%) represents moderate agreement, and a value below 0.40 (40%) represents poor agreement (Congalton, 1996).

Kappa can be used as a measure of agreement between model predictions and reality (Congalton 1991) or to determine if the values contained in an error matrix represent a result significantly better than random (Jensen, 1996). Kappa is computed as,

$$K = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+} \times x_{+i})}{N^2 - \sum_{i=1}^{r}(x_{i+} \times x_{+i})} \quad ---------(1)$$

Where

N is the total number of sites in the matrix, r

is the number of rows in the matrix,

x_{ii} is the number in row i and column i,

x_{+i} is the total for row i, and

x_{i+} is the total for column i (Jensen, 1996).

2.2.8. Normalized Difference Vegetation Index (NDVI)

NDVI is a simple numerical indicator that can be used to analyze remote sensing measurements, typically but not necessarily from a space platform, and assess whether the target being observed contains live green vegetation or not.

Since early instruments of Earth Observation, such as NASA's ERTS and NOAA's AVHRR, acquired data in the red (R) and near-infrared (NIR), it was natural to exploit the strong differences in plant reflectance to determine their spatial distribution in these satellite images. These spectral reflectances are themselves ratios of the reflected over the incoming radiation in each spectral band individually. Subsequent work has shown that the NDVI is directly related to the photosynthetic capacity and hence energy absorption of plant canopies (Myneni et al., 1995).

R and NIR channels of the sensors on board satellites are particularly well suited to the study of vegetation (Mather, 1999). Several vegetation indices have been developed of which, NDVI is still the most widely used one despite the development of many new indices that take into account soil behavior (Bannari et al., 1995; Groten et al., 1999).

Theoretically, NDVI value ranges between -1 to +1. Measured value range from -0.35 (water) through zero (soil) to +0.6 (dense green vegetation). Vegetation cover can be compared between different soil types at NDVI values of 0.05 or higher (Groten et al., 1999). This corresponds to a DN value of 135 or higher after the NDVI image has been re-scaled to the image domain (0-255). It can be concluded that the more positive the NDVI the more green vegetation there is within a pixel. Mathematical formulae for calculating NDVI is

$$NDVI = \frac{NIR - R}{NIR + R} \quad ------ (2)$$

Where;

NIR = the spectral reflectance measurements acquired in the near-infrared region (band)

R = the spectral reflectance measurements acquired in the red region (band)

In the case of Landsat Thematic Mapper remote sensing data, the formula is

$$NDVI = \frac{TM4 - TM3}{TM4 + TM3} \quad ------- (3)$$

Where;

TM4 = near infrared band TM3 = red band

CHAPTER THREE STUDY AREA, MATERIALS AND METHODS 3.1. Study Area

Owabi forest researve is located between latitudes 6º 47‟ 3.32” -- 6° 41‟ 52.31” N and longitudes 1° 44‟ 0.81” -- 1° 37‟ 53.04” W of Kumasi in Ashanti region. It is one of the smallest forest conservation areas in Ghana (Figure 3) (National Wetlands Conservation Strategy, 1999). Responsibility for protection of the reserve forest was turned over to the Department of Game and Wildlife in the early 1960‟s when the lands were designated a

Wildlife Sanctuary. Despite its status as a wildlife refuge, poaching is not uncommon. There are well-worn footpaths throughout Sanctuary which is an ample evidence of human encroachment from the outer boundaries of the reserve. Although the forest is far from pristine, large sections remain mostly intact (Forestry Commission of Ghana, 2006).

The study area is bounded by the districts of Atwima, Kwabre and Kumasi Metro. Until the construction of the Barekese Dam in 1971, Owabi was the only source of water to Kumasi-Metropolitan. The Wildlife Sanctuary is the smallest of four Wildlife Protected areas in Ghana. It is 13 km² in size, and lies approximately 23 km northwest of Kumasi. It has an inner Sanctuary of about 7 km, which surrounds a lake, formed by the damming of the Owabi River in 1928 (Figure 4 b, c, e and f). The Wetland/Ramsar site was designated on 22nd February 1988 with Ramsar site number 393 (Forestry Commission of Ghana, 2006). It is also the only inland Ramsar Site in Ghana.. The reservoir is designed to produce 20% of the total potable water requirement in the

Kumasi metropolis and nearby villages. The streams which serve the Owabi reservoir have been encroached with various human activities due to the high population density within the catchment area (Akoto et al., 2008).

The region is invariably rich with indigenous water birds including Ardeidae (herons, bitterns, etc.), and various species of wintering and staging birds during migration (National Wetlands Conservation Strategy, 1999). There are about 161 kinds of birds consisting of 29 families in this area. The area is suitable for arranging picnics and bird watching. It has a potential for boating, recreational fishing and particularly famous for its educational tours and ecological studies (National Wetlands Conservation Strategy, 1999).

THE STUDY AREA

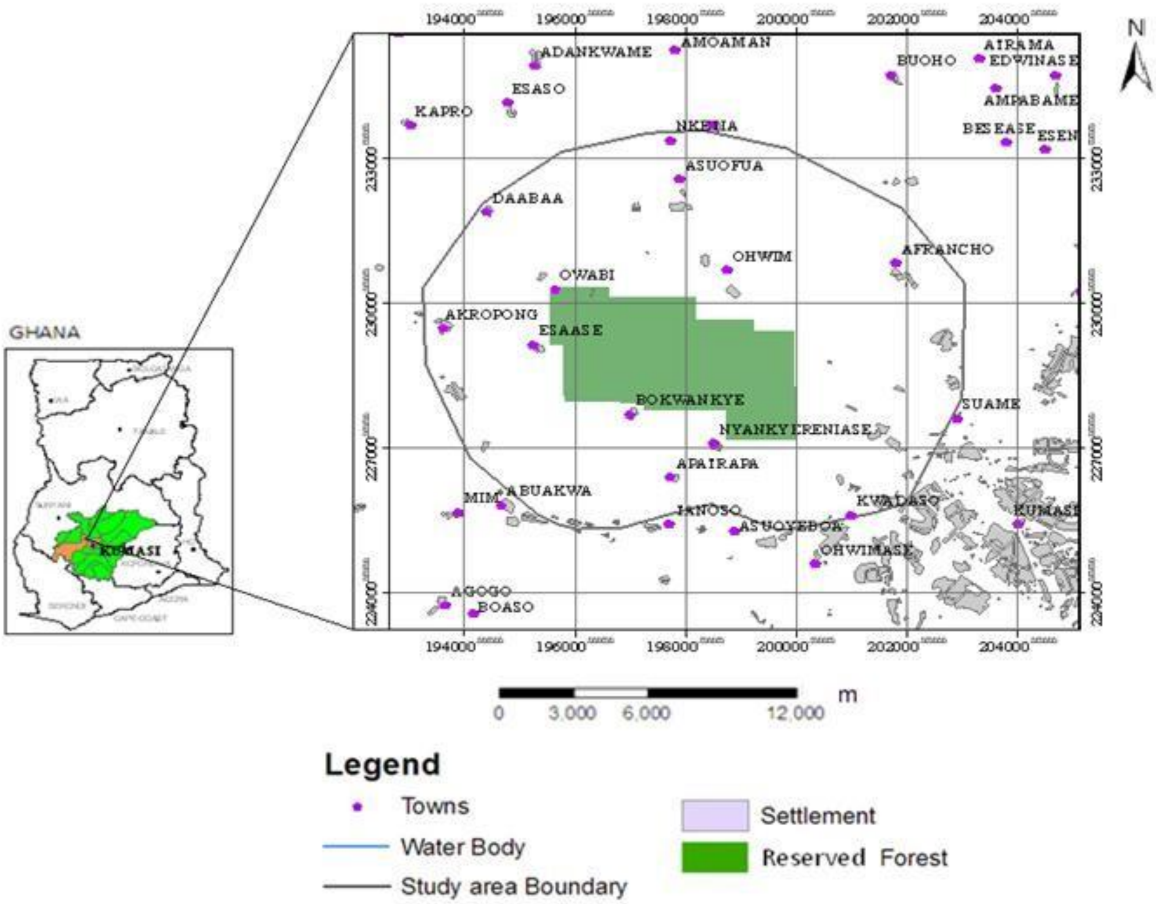


Figure 3: Physiological Map of Ghana and Ashanti Region depicting Kumasi and Districts of Owabi Ramsar Site.

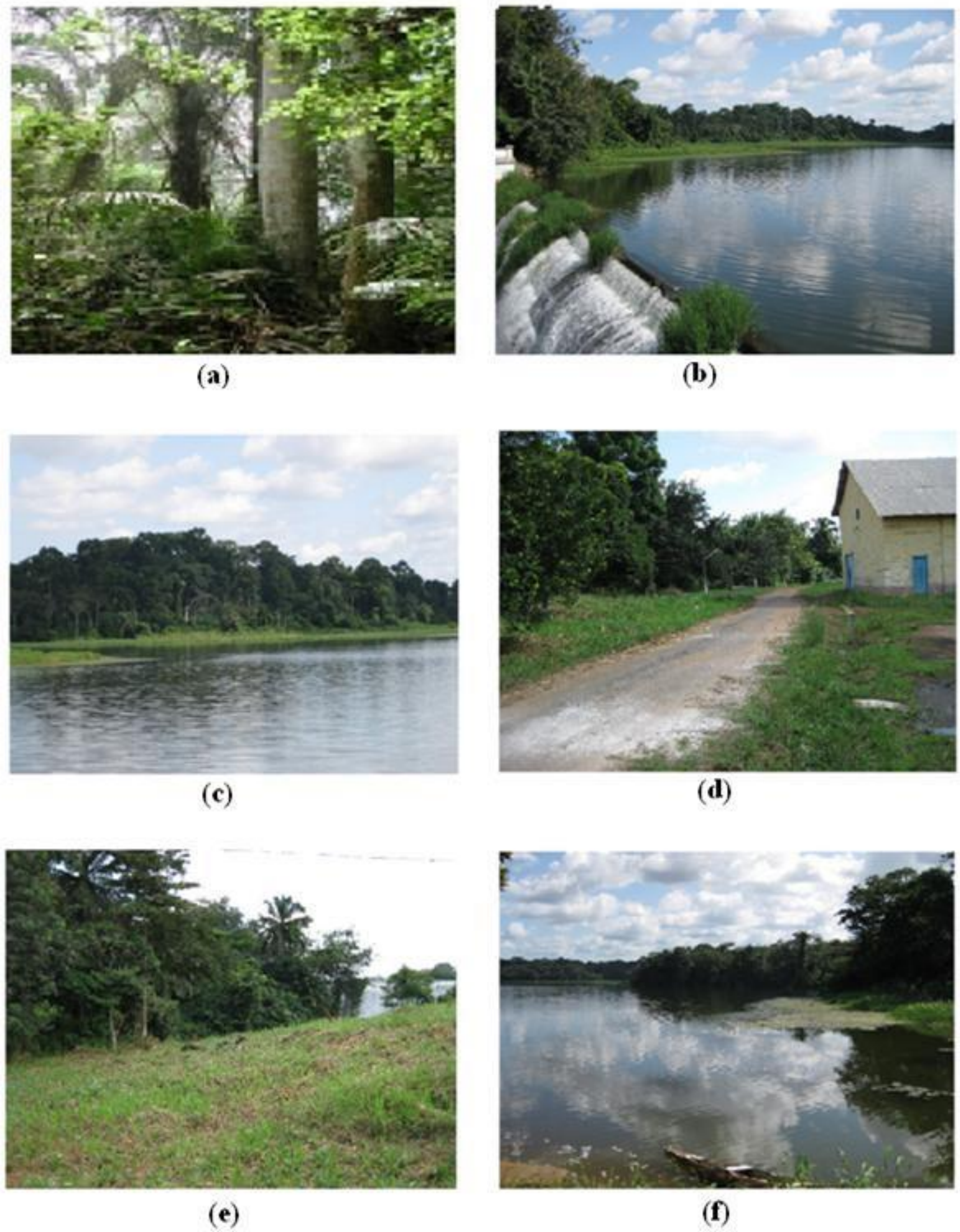


Figure 4: Photograph showing the forest cover in parts of Owabi Ramsar Site

3.1.1. Landuse

The total area of Owabi Ramsar site encompasses approximately 8658.18 ha that surrounds Owabi Reservoir out of which 1363.95ha (15.75%) of land is covered by high density forest, 1458.9ha, (16.85%) by sparse forest and 4351.95ha (50.26%) built-up and the rest is covered by grassland, bare soil/sand, croplands, wetlands and water.

3.1.2. Climate

The Kumasi area has a semi-humid tropical climate with an average annual rainfall of 1488mm. The rainfall distribution is weakly bimodal **(**Figure 5**)**, with a principal wet season between March and June, and a subsidiary wet period in September-October (Adu, 1992).

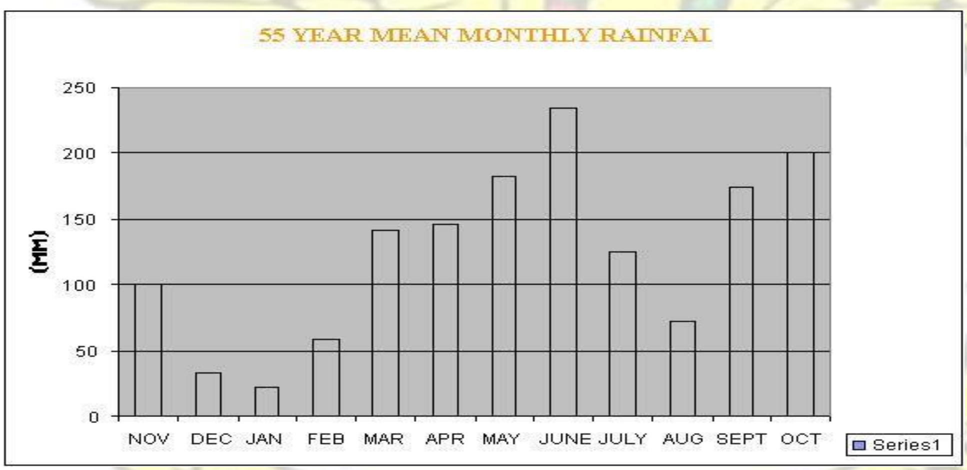


Figure 5: Graphical representation of rainfall data derived from meteorological station at Kumasi airport (CEDAR, 1999).

3.1.3 Vegetation

Owabi forest reserve can best be described as a secondary forest surrounding a large water reservoir. It has a beautiful plantation of an exotic species, *Cassia Siamea* that covers an area of about 10% land (http://www.travel.mapsofworld.com, 2007). The rest of the area is covered with small bushes and other riverine forest and aquatic vegetation. The sanctuary is a home to many species of plants and animals especially reptiles and snakes. About 199 species of vascular plants had been identified. These include 91 tree, 19 shrub, 40 herb, 14 grass, 1 parasite, 6 ferns, and 29 climber species (Forestry Commission of Ghana, 2006). It is a tranquil site with a great variety of birdlife and fascinating forest walks. It is an ideal place for winter migratory birds and hundreds of Mona Monkeys (http://www.travel.mapsofworld.com, 2007).

3.1.4. Geology and soil.

The geology of both catchments is dominated by granites and granodiorites of the Birimian Series. The occurrence of groundwater is controlled by jointing and fracturing of the local rocks, while the granites, due to their highly-weathered condition, produce some of the most productive groundwater bodies (Ministry of Works and Housing, 1998).

3.1.5. Drainage

Many steams drain the catchment area of the Owabi reservoir. River Owabi which is the main stream in the catchment flows through agricultural lands close to the village of Maase, upstream of Kumasi. Some of the streams are River Sukobri, Akyeampomene, Pumpunase and Afu. The streams join other tributaries from the urban area at Atafoa, a rapidly-urbanizing agricultural village (McGregor et al., 2002).

3.2. Materials

3.2.1. The research materials used in this study, are listed in Table 1

Table 1: Research Materials used

Landsat TM Satellite image of $11^{th.}$ January 1986
Aster image of 15^{th} January 2002
Landsat ETM Satellite image of $24^{th.}$ February 2007
Global Positioning System (GPS)
1974 Topographic map of Kumasi.

3.2.2. Software

The processing of the satellite imagery during this research was carried out using the ERDAS Imagine software version 9.1. Some specific image processing operations were done using the ArcGIS software version 9.3 while some fragmentation statistics of the LULC types were computed using Fragstats software version 3.3. Spatial projection of LULC was carried out using IDRISI Kilimanjaro software.

3.3. Methods

3.3.1. Image Acquisition and Pre-processing

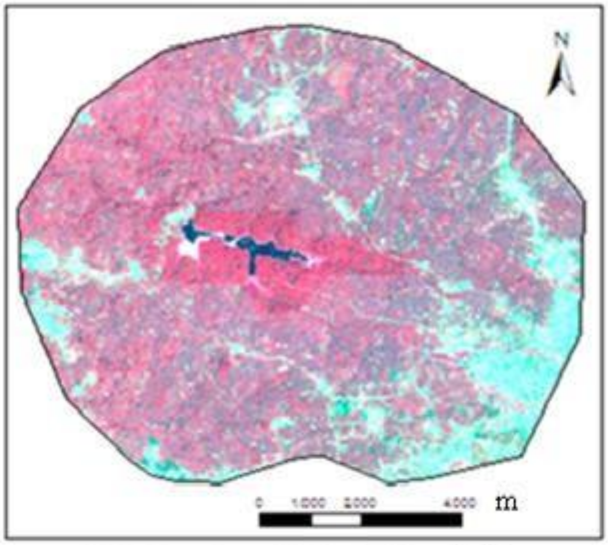
Landsat TM and ETM satellite image of the study area taken on 11^{th} January 1986 and

24th February 2007 and having row and path of 194 and 55 were used in this study (Figure 6). Acquisition dates of the multi- temporal satellite data of different sensors TM and ETM Scenes employed in the change detection process fall within an acceptable anniversary window of equivalent season. Both sensors have spatial resolution of 30m with a projection type of transverse mercator.

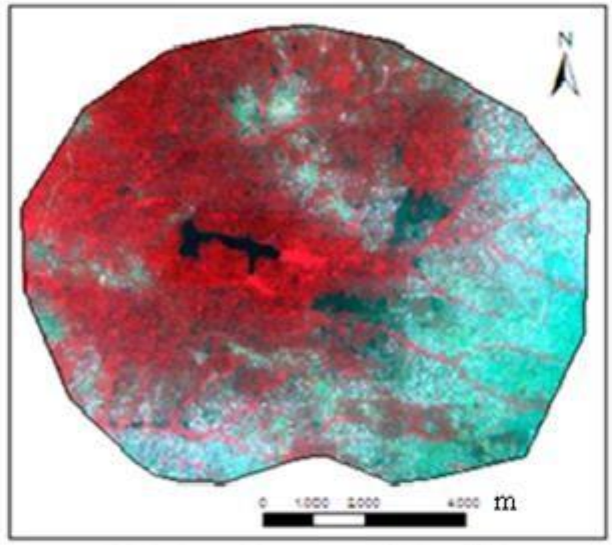
The 2002 aster image was obtained by a mosaic of two aster image files to form a single image (Figure 6). The resolution was down sampled from 15 by 15 to 30 by 30 and was reprojected into WGS 84 with a projection type of transverse mercator. Acquisition date of the image is 15th January 2002 which falls within the same season as that of the Landsat images.

In addition, Aster imagery has limited duty cycle and relatively small scene size, however, its bandwidths and spatial resolution is similar to Landsat imagery and is an important component of the mid-resolution data archive (Gao, 2008).

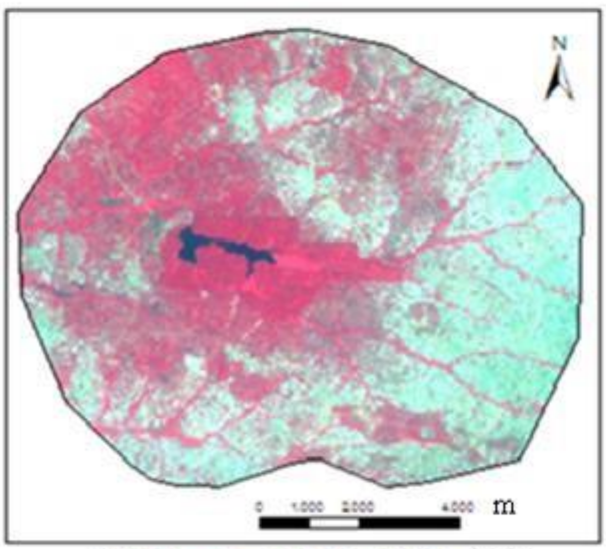
The appropriate selection of imagery acquisition dates for change detection is an integral component of a projects success. Acquisition dates have become essential in change detection studies because they minimize discrepancies in reflectance caused by seasonal vegetation fluxes and sun angle differences (Coppin and Bauer, 1996).



1986 Landsat TM—RGB 4 3 2
(30 x 30)



2002 Aster Image—RGB 4 3 2
(30 x 30)



2007 Landsat ETM—RGB 4 3 2
(30 x 30)

Figure 6: Satellite Images of the study area

3.3.2. Data Collection (Fieldwork)

Landsat ETM 2007-satellite image, topographic maps and a Global Positioning System (GPS) were used to find the location of the GCPs in the field. The geographic coordinates of the observation sites from the GPS reading were recorded, and the locations were indicated on the ETM image (Figure 7).

During the data collection, the number, the accuracy and the distribution of the GCPs were taken into consideration and a small sample points (GPS points) of a LULC type were randomly selected in the field. This was done throughout the study area by moving around the feature with the GPS instrument and a total of 341 sample points were picked. About half of the GPS points (171 sample points) were used for classification accuracy assessment and the remaining 170 points were used as a check.

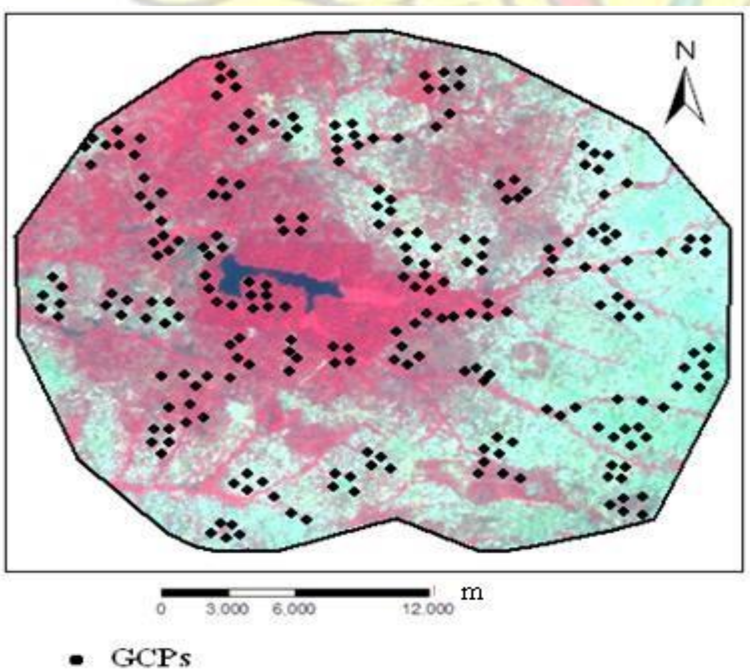


Figure 7: Landsat ETM 2007-satellite image and distribution of the sample points in the study area.

3.3.3. Image classification

The main aim of image classification was to automatically categorize all pixels in an image into land cover classes (Figures 9, 12 and 15). The classification legend was made based on spectral characteristics.

Supervised classification was done by following three stages that included training data sets, classification and output. Training samples were taken for each LULC type to be classified in the image. To obtain true representation of the cover classes, training samples were repeatedly selected, assessed and analyzed by either delete or merge.

Classification was done by using maximum likelihood classifier (Lillesand and Kiefer, 1994). This option evaluated to which class the pixel most likely belongs, based on the pixel value.

3.3.4. Visual Interpretation

Using TM bands 4, 3, 2 for 1986, aster image bands 4, 3, 2 for 2002 and ETM bands 4, 3, 2 for 2007, three true colour composites, a preliminary land cover map was obtained by visual interpretation and the following eight (8) land cover classes were distinguished; Bare Soil/Sand, Built-Up, Croplands, Grassland, High Density forest, Sparse Forest, Water and Wetlands. The classified image was further reclassified as forest and non-forest area and stratified random sample points within the forest area were generated.

3.3.5. Post-classification Technique

In this technique, images of different dates are classified and labeled individually. The classified images are then compared and changed areas extracted. Supervised and unsupervised classifications are used in this approach. Individual classification of two image dates minimizes the problem of normalizing for atmospheric and sensor differences between two dates (Singh, 1989).

The comparison of separately classified images can be carried out visually, or by computer. Computers are better at quantitative analysis, but humans are able to discern patterns and shapes much better, and the effect of misregistrations may be much reduced. Post-classification comparison has been used, e.g., to detect: non-urban to urban, or forest to cropland, conversion and changes in general land use, wetlands and forests.

3.3.6. Persistence of LULC types

The determination of gains, losses and persistence of the various LULC types over the 21 year period were obtained from the change matrix table. The loss to persistence ratio Lp assesses the vulnerability of the various LULC to transition. The net gains or losses to persistence ratio of each of the LULC types between 1986 to 2002 and 2002 to 2007 were computed (Tables 13 and 14). The mathematical formulae for the computations are illustrated below.

The gain to persistence ratio (Gp) is given by,

$$\mathrm{Gp} = \frac{\mathrm{gain}}{\mathrm{persistence}} \quad ----------------(4)$$

The loss to persistence ratio (Lp) is

$$\mathrm{Lp} = \frac{\mathrm{loss}}{\mathrm{persistence}} ----------------- (5)$$

The net change to persistence ratio is $\mathrm{Np{=}Gp{-}Lp}$ ---- (6)

(Pontius et al., 2004; Braimoh, 2005 and Gbekor, 2008).

3.3.7. Fragstats analysis

Change in the landscape structure was analyzed using FRAGSTATS version 3.3 software in ArcGIS environment. 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 the entire landscape (Gbekor, 2008).. This was done for the whole of the study area for the three years, 1986, 2002 and 2007 and it quantifies the areal extent and spatial configuration of the patches within a landscape by comparing and assessing the changes due to LULC conversions (Gbekor, 2008).

The three classified maps were exported in generic binary 8 bit formats in ERDAS Imagine and run with the FRAGSTATS program. At the class, the patch and the landscape levels, these metrics were analyzed; Number of Patches (NP), Patch Density (PD), Largest Patch Index (LPI), Percentage of Landscape (PLAND), Total Class Area (CA) and Total Area (TA) (Table 2).

Table 2: Landscape, Class and Patch Level Metrics used in the study

Metrics	Description	Unit	Range
Number of Patches (NP)	NP equals the number of patches of the corresponding patch type (class).	None	NP ≥ 1, without limit
Patch Density (PD)	PD equals the number of patches of the corresponding patch type divided by total landscape area (m^2), multiplied by 10,000 and 100 (to convert to 100 hectares).	Number per 100 hectares	PD > 0, constrained by cell size.
Largest Patch Index (LPI)	LPI equals the area (m^2) of the largest patch of the corresponding patch type divided by total landscape area (m^2), multiplied by 100 (to convert to a percentage)	Percent	0 < LPI ≤ 100
Percentage of Landscape (PLAND)	PLAND equals the sum of the areas (m^2) of all patches of the corresponding patch type, divided by total landscape area (m^2), multiplied by 100 (to convert to a percentage);	Percent	0< PLAND ≤100
Total (Class) Area (CA)	CA equals the sum of the areas (m^2) of all patches of the corresponding patch type, divided by 10,000 (to convert to hectares); that is, total class area.	Hectares	CA > 0, without limit.

Total Area (TA)	TA equals the total area (m^2) of the landscape, divided by 10,000 (to convert to hectares). Note, total landscape area (A) includes any internal background present.	Hectares	TA > 0, without limit.

McGarigal et al., (1995),

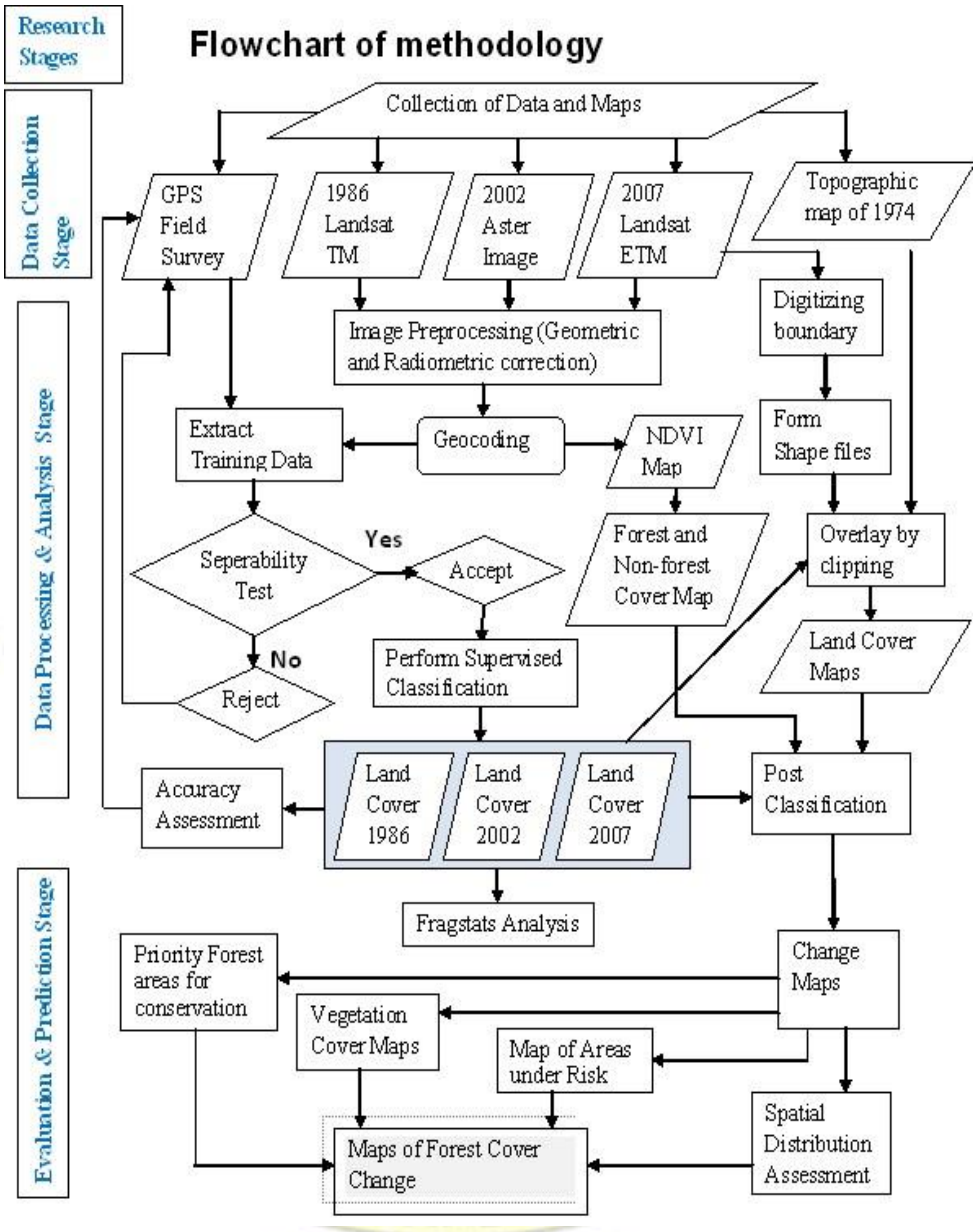


Figure 8: Flowchart of Research Methods

CHAPTER FOUR RESULTS 4.1 LULC Classes of Owabi catchment

The Supervised Classification of the three (3) images yielded land cover maps of the study area and from these, eight (8) LULC classes were identified. The characteristics of these land cover types are described in Table 3.

Table 3: Discriptive analysis of the LULC (ie the definitions of the LULC classes)

LULC	Description
Water	The main water body of the study area -- The Owabi reservoir(river)
Bare soil/sand	This is an area of land covered with gravels
Grassland	These are characterized as lands dominated by grasses rather than large shrubs or trees.
Built-Up	An area densely covered by houses or other buildings and increasing in intensity over a period of time
Sparse Forest	These are sparsely scattered of trees of all ages, plants, and underbrush covering the large area within the study area.
High Density Forest	This comprises the Owabi Forest reserve protecting the Owabi reservoir and other patches covering other areas within the study area.
Croplands	These are lands used for the cultivation of crops.
Wetland	The Ramsar Convention describes wetlands as *"areas of marsh, fen, peat land or Water, whether natural or artificial, permanent or temporal, with water that is static or flowing, fresh, brackish or slat, including areas of marine water, the depth of which at low tide does not exceed six metres"* (Ramsar Convention, 1971, Ministry of Lands and Forestry, 1999).

4.2. LULC analysis of Owabi catchment

4.2.1. LULC analysis of Owabi catchment in 1986

The spatial extent of the 1986 LULC map after the Supervised Classification yielded land cover classes (Figures 9, 10 and 11) with the high density forest occupying the highest percentage of the area (4347.27 ha, 50.21%). This is basically found in the Northern, Eastern and western part of the map with the highest concentration around the

Owabi River. The next LULC class with the highest area coverage is the Sparse forest (1843.74ha, 21.29%) which is scattered around the North, South, East and the Western parts of the area with very small patches within the forest reservoir. Built-Up (1126.8ha, 13.01%) is the next highest area coverage located mainly around the North, South, East and Western part of the study area. Wetland comes next with 409.59 ha (4.73%) and its area coverage consists of small patches along river courses and marshy areas. This is followed by the Glassland 377.46 ha (4.36%) with small patches scattered across the entire map with the exception of the reservoir. Bare soil/Sand and Croplands has respective areas of 270.36 ha (3.12%) and 149.79 ha (1.73%) with former scattered at the Northern, Southern Western parts respectively while the latter has very small patches scattered across the map except the reservior. Water (133.2 ha, 1.54%) is last and the least area coverage and mainly concentrated within the reservoir with very small of it in other areas.

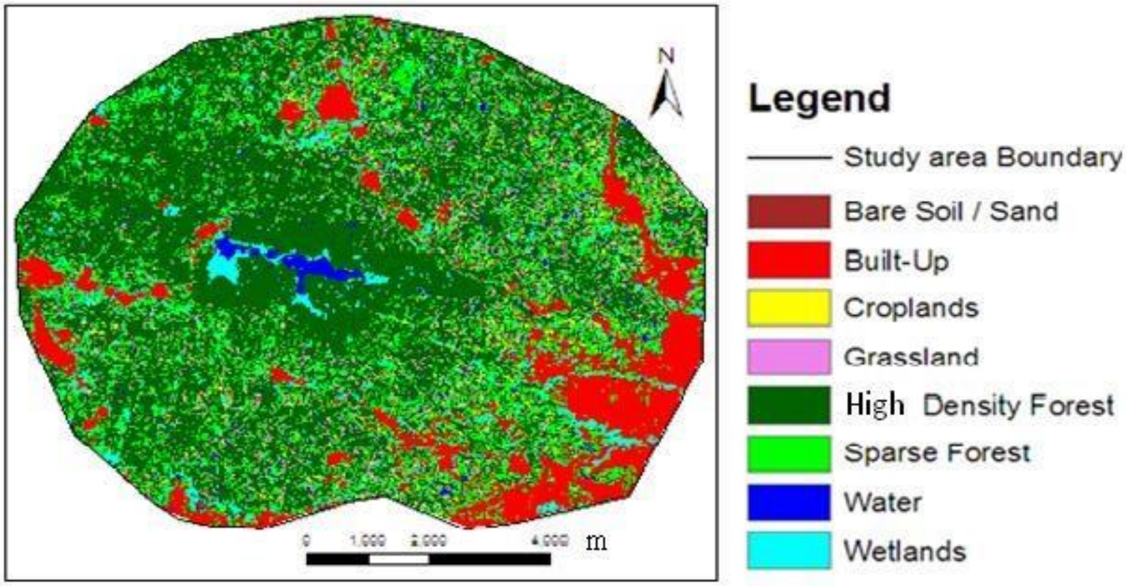


Figure 9: 1986 Supervised Classified Map of the study area.

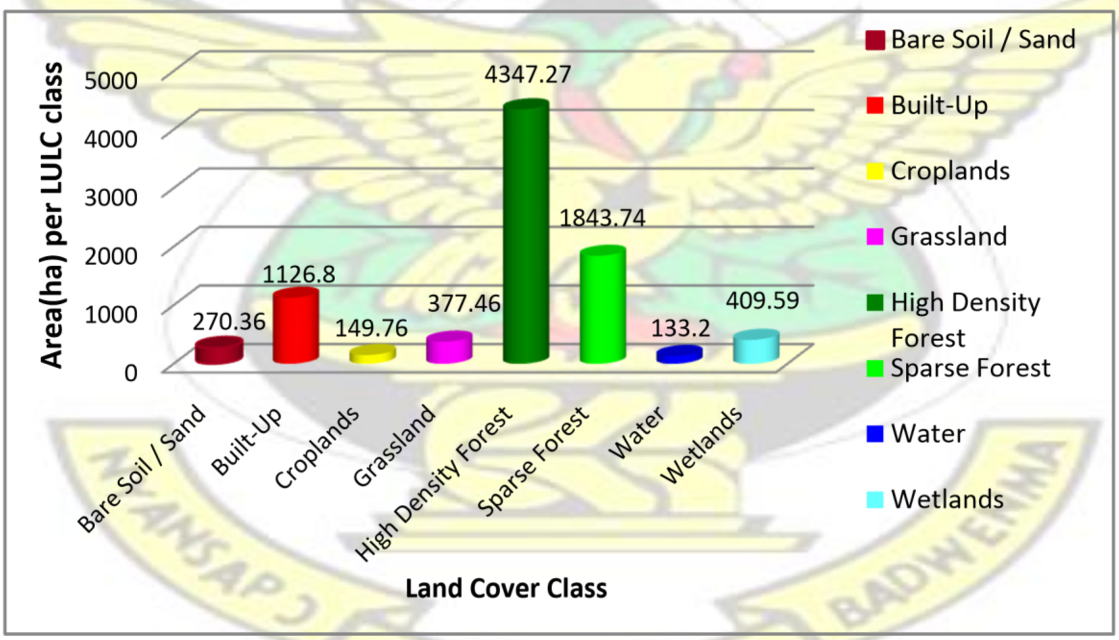


Figure 10: Areas (ha) of LULC classes in 1986

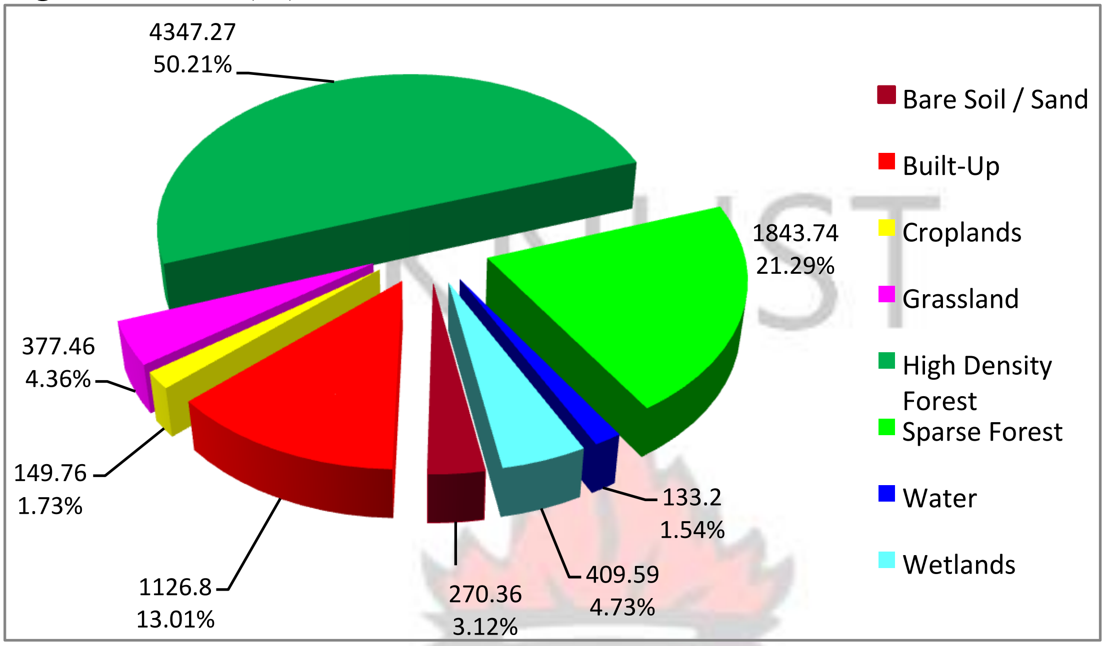


Figure 11: Areas (ha) of LULC classes and their Percentages (%) in 1986

4.2.2. LULC analysis of Owabi catchment in 2002

The Supervised classification procedures applied to the 2002 aster image yielded Land cover map with the High Density Forest occupying the largest area coverage of 2389.32ha (27.60%) as compared to other LULC classes and largely concentrated around the Owabi river with a few around North Western part of the area (Figures 12, 13 and 14). Sparse Forest covers an area of 1665.09ha, (19.23%) and mainly around the Northern, Western, Southern, Eastern and along the fringes of the reservoir. Wetlands could be mainly found along river courses and marshy areas with an area of 327.78 ha (3.79%). Grassland has an area of 413.46 ha (4.77%) which is centered at the Eastern and South Eastern portions of the map. Built-Up occupies an area of 3381.93 ha (39.06%) and mainly concentrated at the Northern, Eastern, Southern and small patches around the western parts of the map**.** Croplands having an area of 259.83 ha (3.00%) are concentrated along the entire scene, mainly around the fringes of the reservoir. Bare Soil/Sand has an area of 160.38 ha (1.85%) with small patches within the entire scene except the reservoir. Water having 60.39 ha (0.70%) is the least area coverage and mainly concentrated within the reservoir with small of it in other areas.

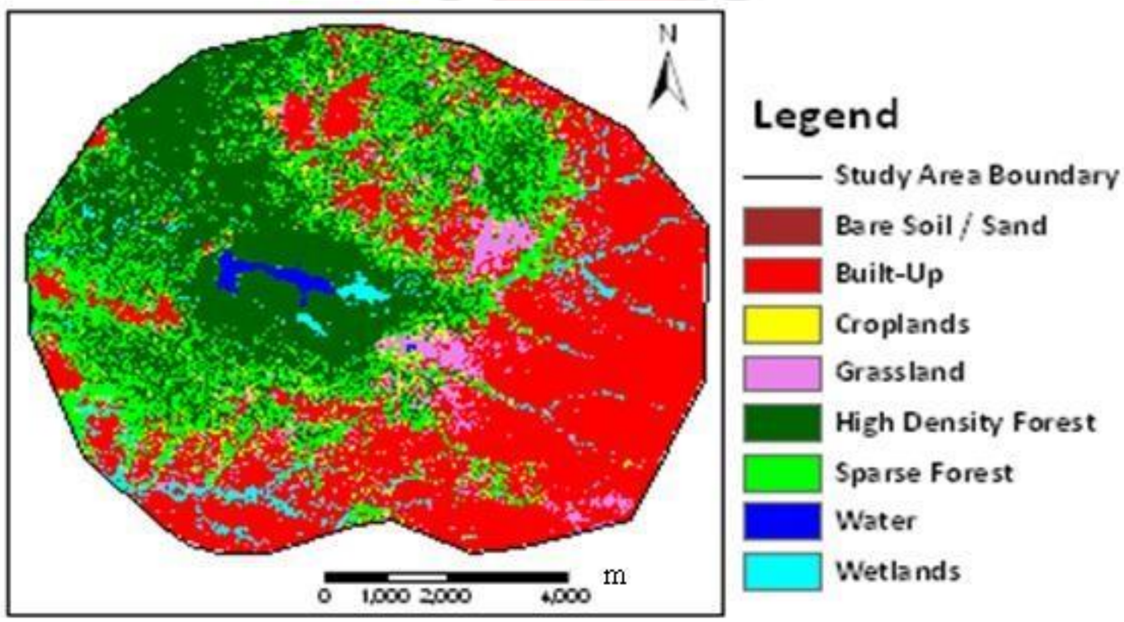


Figure 12: 2002 Supervised Classified Map of the study area

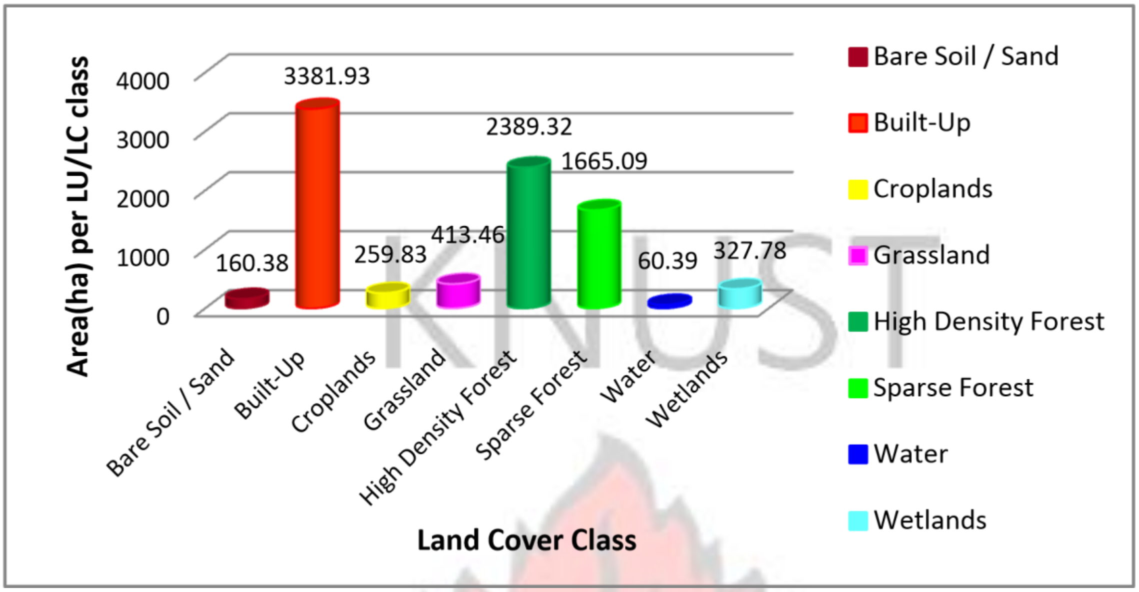


Figure 13: Areas (ha) of LULC classes in 2002

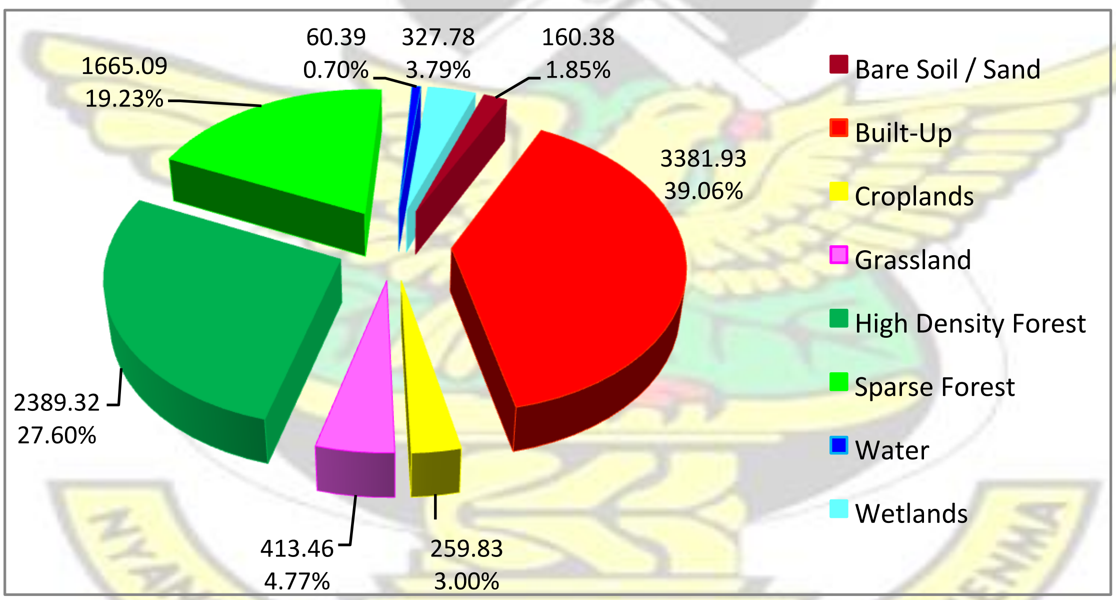


Figure 14: Areas (ha) of LULC classes and their Percentages (%) in 2002

4.2.3 LULC analysis of Owabi catchment in 2007

The 2007 Landsat ETM after classification procedures yielded Land cover map with the High Density Forest occupying 1363.95ha (15.75%) which is concentrated around the Owabi river with a few around North Western part of the area (Figures 15, 16 and 17). Sparse Forest covers an area of 1458.9ha, (16.85%) and mainly around the North Western, Southern, small patches around the North and along the fringes of the reservoir. Built-Up occupies the largest area coverage as compared to other LULC classes having 4351.95ha (50.26%). This is concentrated at the entire map, mainly;

Northern, Southern, Eastern and small patches around the western part of the map. Wetlands could be mainly found along river courses and marshy areas with an area of 288.63ha (3.33%). Grassland has an area 300.87ha (3.48%) of with very small patches centered around North, North East, South East, Western and on the fringes of the reservoir. Bare Soil/Sand has an area of 358.02ha (4.14%) with very small patches within the entire scene except the reservoir. Croplands having an area of 451.26 ha (5.21%) is concentrated along the entire scene, mainly around the fringes of the reservoir, North Eastern, South Eastern and Western parts of the Image. Water, having 84.6 ha (0.98%) is the last and least area coverage and mainly concentrated within the reservoir with very small of it in other areas.

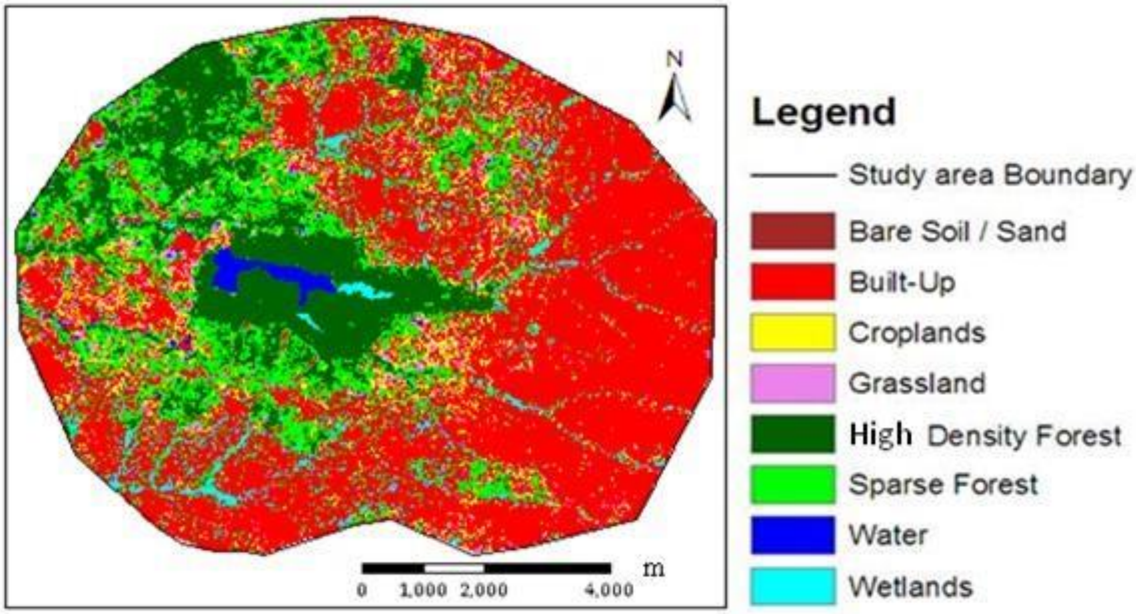


Figure 15: 2007 Supervised Classified Map of the study area (Overall Classification Accuracy of 79.53%).

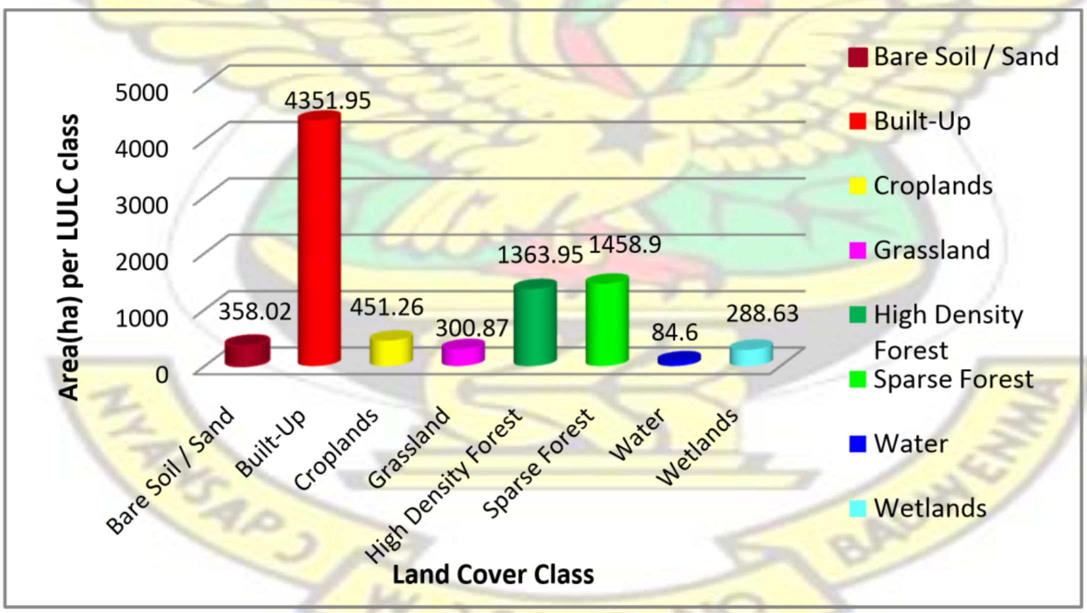


Figure 16: Areas (ha) of LULC classes in 2007

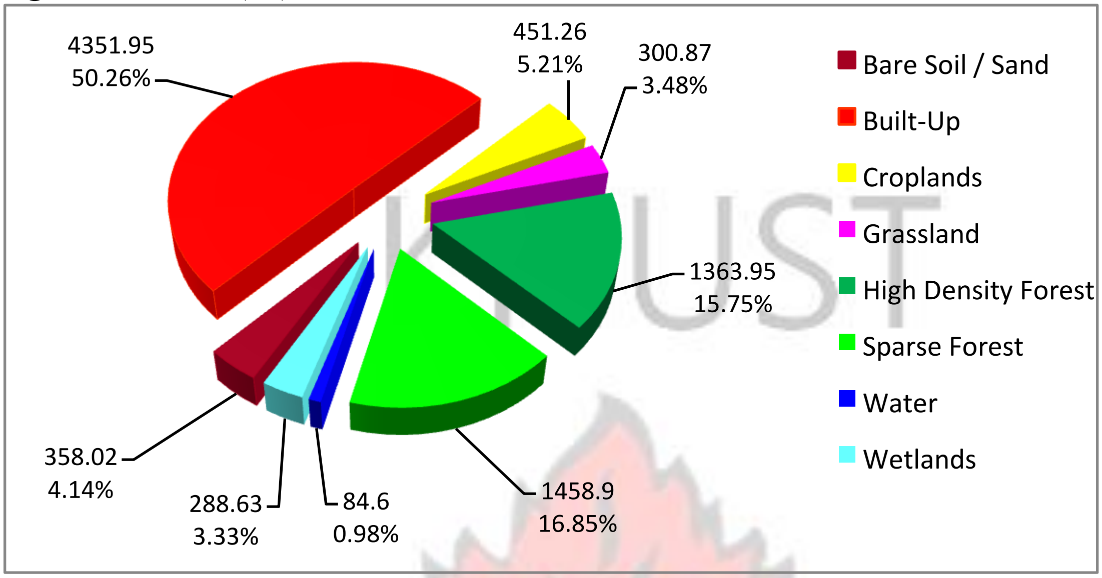


Figure 17: Areas (ha) of LULC classes and their Percentages (%) in 2007

4.3. 2007 LULC Accuracy Assessment

A classification accuracy assessment was performed on the 2007 LULC map for the study area and an assessment report was obtained having an error matrix, accuracy totals and a kappa statistics (Appendix 1, 2 and 3). An overall Classification accuracy of 79.53% (Appendix 2) and a Kappa coefficient (Overall Kappa Statistics) of 0.7465 was achieved (Appendix 3). Only wetland has producer‟s accuracy of 44.44%. Water and grassland have producer‟s accuracy of 50% each with bare soil having the highest, 92.31%. All the remaining LULC classes were having their accuracies above 50%. The user‟s accuracies of all the LULC types were above 60% with grassland having the highest accuracy of 85.71%.

4.4. LULC change within the Owabi catchment.

The LULC maps and the analysis explained above indicate that some changes of the landscape have occurred over 21 year period from 1986 through 2002 to 2007.

4.4.1. LULC proportions for 1986, 2002 and 2007.

Table 4 represent the spatial extent of LULC proportions of 1986, 2002 and 2007 while Figure 18 shows the graphical representation of the LULC proportions for the respective years. The majority of the LULC changes took place within built-up and high density forest environment while the remaining classes made slight changes over the 21year period under study. The coverage of the high density forest in 1986 is equivalent in extent to built-up coverage in 2007 and vice versa, but the built-up cover was slightly higher than the high density forest cover in 2002. In 1986 high density forest covers the highest proportion of the land area, followed by sparse forest, built-up, wetlands, grassland, bare soil/sand, croplands and water respectively. In 2002 built-up occupied the highest proportion and orderly followed by high density forest, sparse forest, grassland, wetlands, croplands, bare soil/sand and then water. Built-up has the highest area coverage in 2007 followed by sparse forest, high density forest, croplands, bare soil/sand, grassland, wetlands and then water having the least area coverage.

Table 4: The Spatial Extent of LULC after classification (LULC proportions)

LULC	Area (ha)			Area (%)		
	1986	2002	2007	1986	2002	2007
Bare Soil / Sand	270.36	160.38	358.02	3.12%	1.85%	4.14%
Built-Up	1126.8	3381.93	4351.95	13.01%	39.06%	50.26%
Croplands	149.76	259.83	451.26	1.73%	3.00%	5.21%
Grassland	377.46	413.46	300.87	4.36%	4.77%	3.48%
High Density Forest	4347.27	2389.32	1363.95	50.21%	27.60%	15.75%
Sparse Forest	1843.74	1665.09	1458.9	21.30%	19.23%	16.85%
Water	133.2	60.39	84.6	1.54%	0.70%	0.98%
Wetlands	409.59	327.78	288.63	4.73%	3.79%	3.33%
TOTAL AREA	8658.18	8658.18	8658.18	100.00%	100.00%	100.00%

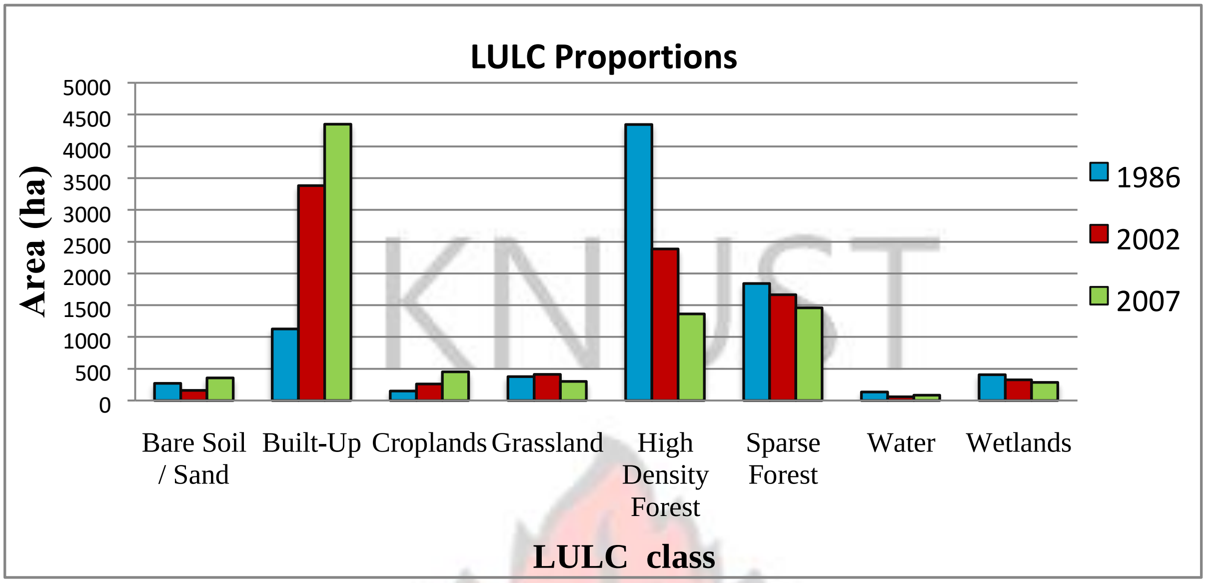


Figure 18: The graphical representation of the LULC proportions for 1986, 2002 and 2007.

4.4.2. LULC trends, 1986 to 2007

The trend analysis of the Owabi catchment reveals a change in size of the eight LULC over the 21 year period of the study (Table 5 and Figure 19). Built-up experienced the most positive change while high density forest experienced the most negative change. From 1986 to 2002, built-up, croplands and grassland experienced a positive change in area while bare soil/sand, high density forest, sparse forest, water and wetland experienced a negative change. From 2002 to 2007, bare soil/soil, built-up, croplands and water have their areas experiencing a positive change, while that of grassland, high density forest, sparse forest and wetland experienced a negative change.

Table 5: LULC change trend, 1986 to 2007

LULC	Change (ha)		% Change	
	1986-2002	2002-2007	1986-2002	2002-2007

Bare Soil / Sand	-109.98	197.64	-1.27 Decrease	2.29 Increase
Built-Up	2255.13	970.02	26.05 Increase	11.2 Increase
Croplands	110.07	191.43	1.27 Increase	2.21 Increase
Grassland	36	-112.59	0.41 Increase	-1.29 Decrease
High Density Forest	-1957.95	-1025.37	-22.61 Decrease	-11.85 Decrease
Sparse Forest	-178.65	-206.19	-2.07 Decrease	-2.38 Decrease
Water	-72.81	24.21	-0.84 Decrease	0.28 Increase
Wetlands	-81.81	-39.15	-0.94 Decrease	-0.46 Decrease

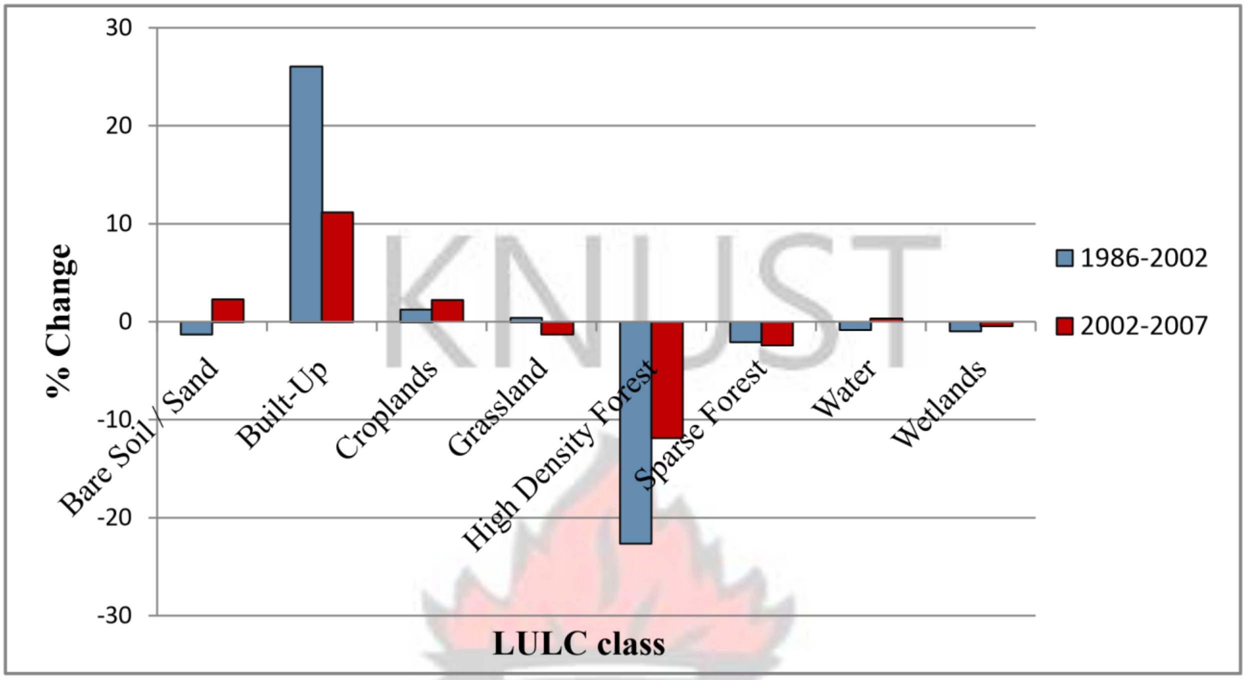


Figure 19: LULC change trend, 1986 to 2007

4.4.3. LULC conversion analysis within the Owabi catchment.

4.4.3.1. LULC conversions, from 1986 to 2002

Table 6 shows a summary of the major LULC conversions that have been taken place from 1986 to 2002 within the Owabi catchment, while Figure 20 shows its corresponding change maps. The diagonal of the table shows the LULC proportions that remain unchanged from 1986 to 2002, a total area of 3234.15 ha representing 37.4% of the study area. From the table, High density forest made the highest conversion of 1033.74 ha to built-up representing 11.9% of the area. 814.41 ha of sparse forest were changed to built-Up, representing 9.4%. The conversion of high density forest to other LULC classes such as water, bare soil, grassland, croplands and wetlands are 8.91 ha

(0.1%), 84.51 ha (1%), 200.34 ha (2.3%), 135.9 ha (1.6%), and 160.56 ha (1.85%) respectively. Other LULC conversions are grassland to croplands 16.92 ha, wetlands to built-up 149.22 ha, croplands to sparse forest 25.83 ha, Sparse forest to croplands 62.55ha.

Table 6: LULC conversions, from 1986 to 2002

Class names		2002								
		Water	**Bare Soil / Sand**	**Grass Land**	**BuiltUp**	**Sparse Forest**	**High Density Forest**	**Crop lands**	**Wet Lands**	**TOTAL AREA (Ha)**
1986	**Water**	**29.88**	1.35	6.48	40.59	15.21	26.64	1.89	11.16	133.2
	Bare Soil / Sand	0.18	**6.57**	14.94	130.59	55.44	43.2	10.35	9.09	270.36
	Grassland	0.09	7.92	**26.55**	168.12	81.81	62.46	16.92	13.59	377.46
	Built-Up	0.09	9.18	29.43	**961.83**	70.2	21.15	15.84	19.08	1126.8
	Sparse Forest	4.14	38.97	110.79	814.41	**386.1**	355.77	62.55	71.01	1843.74
	High Density Forest	8.91	84.51	200.34	1033.74	944.37	**1778.94**	135.9	160.56	4347.27
	Croplands	0.09	3.33	11.16	83.43	25.83	15.57	**5.67**	4.68	149.76
	Wetlands	17.01	8.55	13.77	149.22	86.13	85.59	10.71	**38.61**	409.59
	TOTAL AREA (Ha)	60.39	160.38	413.46	3381.93	1665.09	2389.32	259.83	327.78	**8658.18**

NOTE: In this case the High Density Forest (**HDF**) and Sparse Forest (**SF**) are combined and designated as **Forest.**

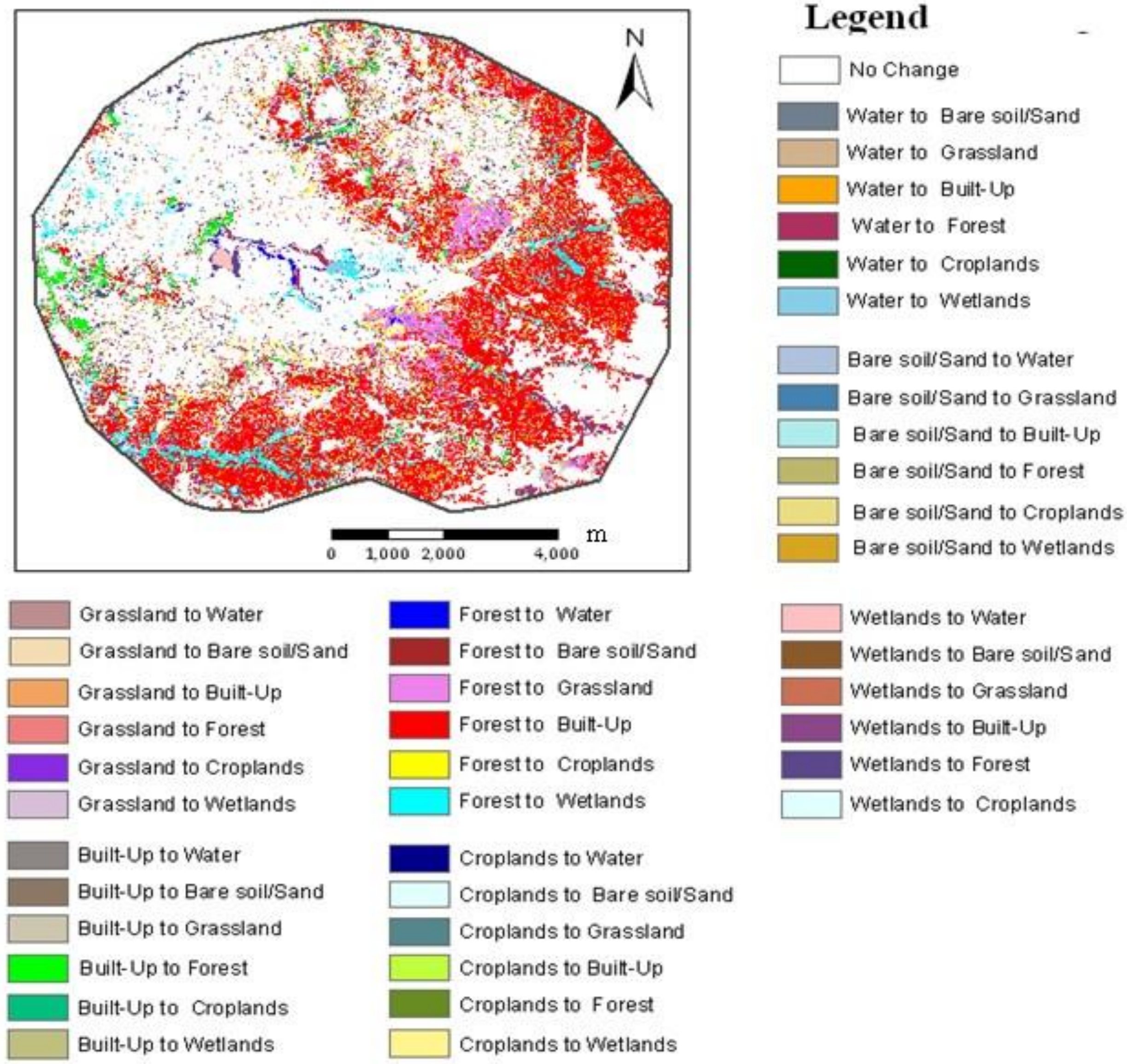


Figure 20: Major LULC conversions within the Owabi catchment 1986 to 2002

4.4.3.2. LULC conversions, from 2002 to 2007

Table 7 shows a summary of the major LULC conversions that have been taken place from 2002 to 2007 within the Owabi catchment, while Figure 21 shows its corresponding change maps. The diagonal of the table shows the LULC proportions that remain unchanged from 1986 to 2002, a total area of 4594.32 ha representing 53% of the study area. High density forest made the highest transfer of 694.17 ha to sparse forest representing 8% of the area. This is follow by sparse forest which had been converted to built-Up, an area coverage of 601.65 ha representing 6.95%. The conversion of high density forest to other LULC classes such as water, bare soil/sand, grassland, croplands and wetlands are 22.41 ha (0.26%), 35.46 ha(0.4%), 85.05 ha (1%), 107.01 ha(1%), and 26.28 ha (0.3%) respectively. Other LULC conversions are sparse forest to croplands 137.97 ha, wetlands to built-up 178.11ha, croplands to sparse forest 53.19 ha, grassland to bare soil 27.72ha.

Table 7: LULC conversions, from 2002 to 2007

Class Names		2007								
		Water	Bare Soil / Sand	Grass land	BuiltUp	Sparse Forest	High Density Forest	Crop lands	Wet Lands	TOTAL AREA (Ha)
2002	Water	**53.64**	0	0.36	0.99	0.54	4.32	0.54	0	60.39
	Bare Soil / Sand	0.18	**18.09**	8.01	78.03	27.9	2.7	17.55	7.92	160.38
	Grassland	0.27	27.72	**35.19**	236.25	50.49	2.61	49.68	11.25	413.46
	Built-Up	0.09	153.63	58.59	**2830.77**	144.9	1.98	109.35	82.62	3381.93
	Sparse Forest	6.03	89.46	97.11	601.65	**460.8**	181.53	137.97	90.54	1665.09
	High Density Forest	22.41	35.46	85.05	301.68	694.17	**1117.26**	107.01	26.28	2389.32
	Croplands	0.99	21.87	14.04	124.47	53.19	6.3	**23.76**	15.21	259.83
	Wetlands	0.99	11.79	2.52	178.11	26.91	47.25	5.4	**54.81**	327.78

	TOTAL AREA(Ha)	84.6	358.02	300.87	4351.95	1458.9	1363.95	451.26	288.63	**8658.18**

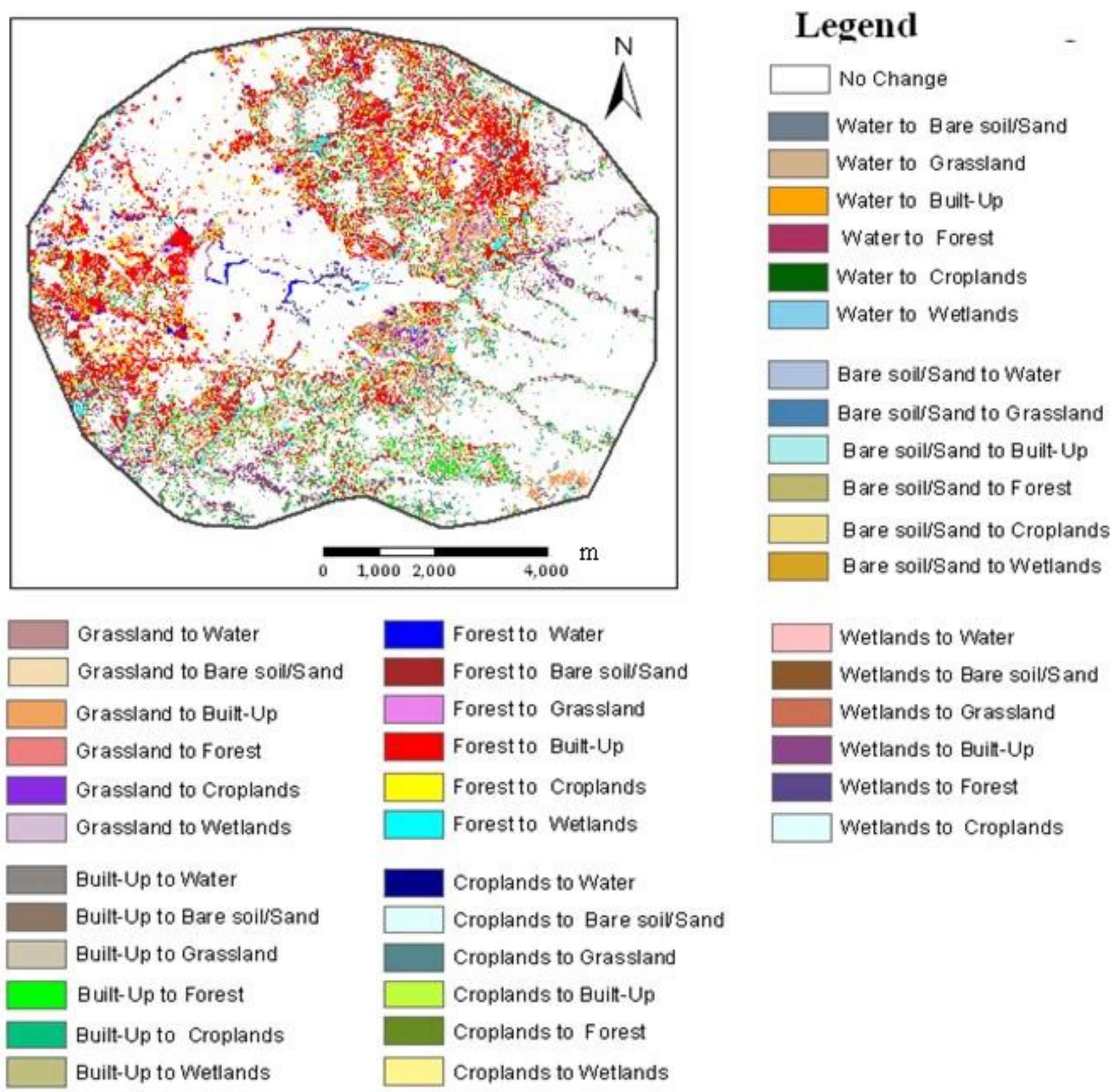


Figure 21: Major LULC conversions within the Owabi catchment 2002 to 2007

4.4.3.3. LULC conversion, from 1986 to 2007

Table 8 shows a summary of the major LULC conversions that have been taken place from 1986 to 2007 within the Owabi catchment, while Figure 22 shows its corresponding change maps. The diagonal of the table shows the LULC proportions that remain unchanged from 1986 to 2007, a total area of 2,457.72 ha representing 28.4% of the study area. From the table, High density forest made the highest conversion of 1606.05 ha to built-Up representing 18.6% of the area. 1045.71 ha of sparse forest were changed to built-Up, representing 12.08%. The conversion of high density forest to other LULC classes such as water, bare soil, grassland, croplands and wetlands are 25.83ha (0.3%), 156.78ha (1.8%), 158.85ha (1.84%), 232.02ha (2.68%) and 137.97ha (1.6%) respectively. Other LULC conversions are grassland to croplands 23.67 ha, wetlands to built-up 191.07 ha, croplands to sparse forest 17.37 ha, Sparse forest to croplands 109.53 ha.

Table 8: LULC conversions, from 1986 to 2007

	Class Name	2007 Water	Bare Soil / Sand	Grass Land	BuiltUp	Sparse Forest	High Density Forest	Crop Lands	Wet lands	TOTAL AREA (Ha)
1986	**Water**	**31.68**	3.33	3.42	50.04	11.97	19.53	5.13	8.1	**133.2**
	Bare Soil / Sand	0.45	**15.03**	10.17	164.61	41.22	13.95	16.47	8.46	**270.36**
	Grassland	0.63	20.43	**14.76**	223.83	64.71	18.72	23.67	10.71	**377.46**
	Built-Up	0.63	37.17	25.92	**968.76**	36.36	4.86	36.54	16.56	**1126.8**
	Sparse Forest	5.49	94.77	68.76	1045.71	**294.93**	155.52	109.53	69.03	**1843.74**
	High Density Forest	25.83	156.78	158.85	1606.05	939.51	**1090.26**	232.02	137.97	**4347.27**
	Croplands	0.36	9.36	4.95	101.88	17.37	3.6	**8.37**	3.87	**149.76**

Wetlands	19.53	21.15	14.04	191.07	52.83	57.51	19.53	**33.93**	**409.59**
TOTAL AREA(Ha)	**84.6**	**358.02**	**300.87**	**4351.95**	**1458.9**	**1363.95**	**451.26**	**288.63**	**8658.18**

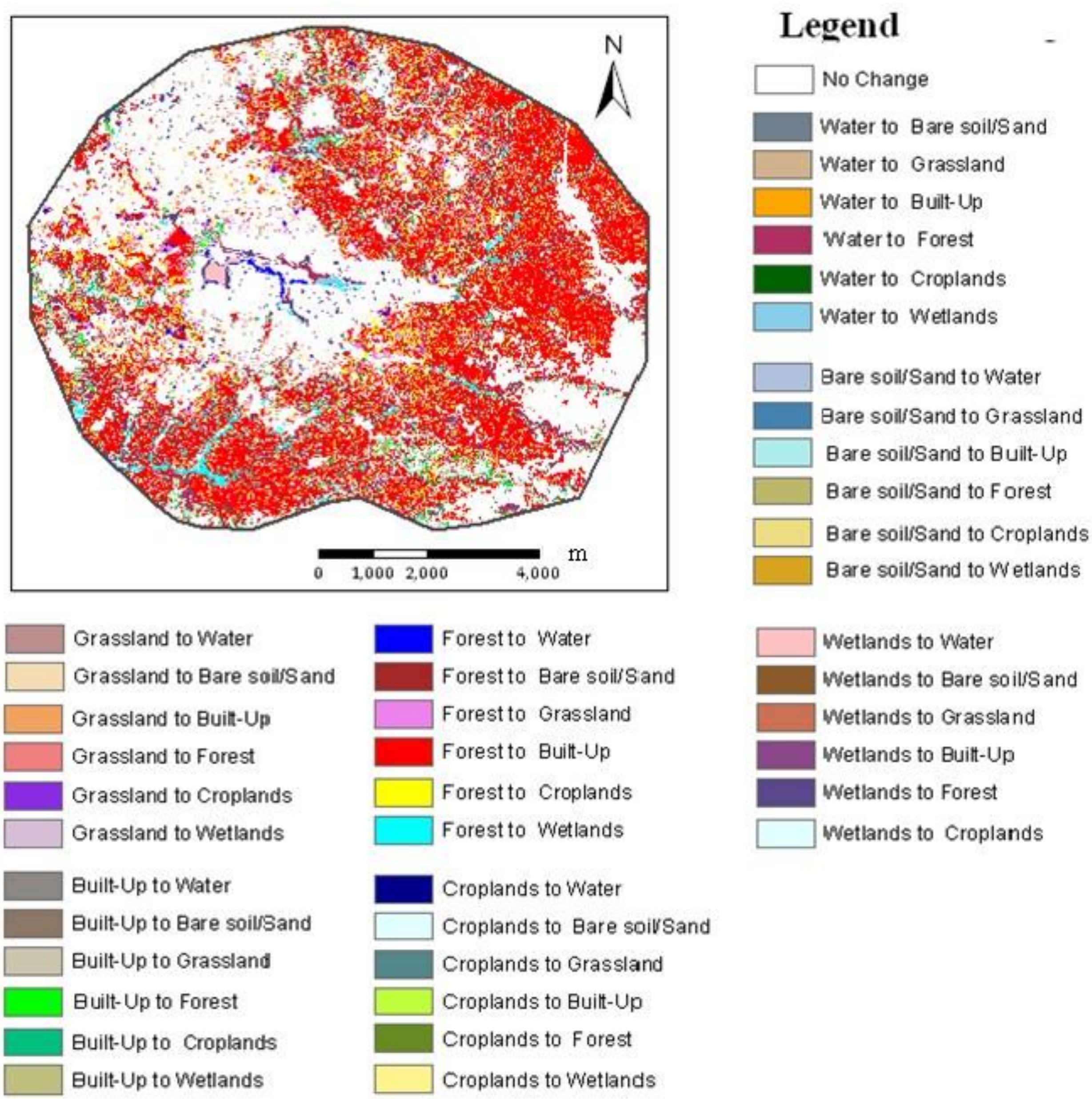


Figure 22: Major LULC conversions within the Owabi catchment 1986 to 2007

4.5. Population growth, Forest cover change and other LULC classes

The rate of population growth within the catchment increased over the 30 year period from 1970 through 1984 to 2000 (Appendix 4), while forest cover reduced considerably over the year‟s from 1986 through 2002 to 2007 (Table 9 and Figure 23). This implies that forest cover is consumed at excessive rates. Between 1970 and 1984 the rate of population in the study area grew by about 82% and between 1984 and 2000 it grew by about 152% (Census of Ghana, 1970, 1984 and 2000). From 1986 to 2002 and 2002 to 2007 the forest cover decreased by an amount of 2136.6 ha (24.7%) and 1231.56 ha (14.2%) respectively. Therefore, the total decrement of the forest from 1986 to 2007 is 3368.16 ha representing 38.9%. The combined areas of the other LULC classes increased along the years.

Table 9: Population growths, Forest cover change and other LULC classes

	Population			**Forest Cover (ha) per year**				**Other LULC classes**		
Year	**1970**	**1984**	**2000**		**1986**	**2002**	**2007**	**1986**	**2002**	**2007**
				HDF	4347.27	2389.32	1363.95			
				SF	1843.74	1665.09	1458.9			
Total	31,257	56,918	143,348		6191.01	4054.41	2822.85	2467.17	4603.77	5835.33

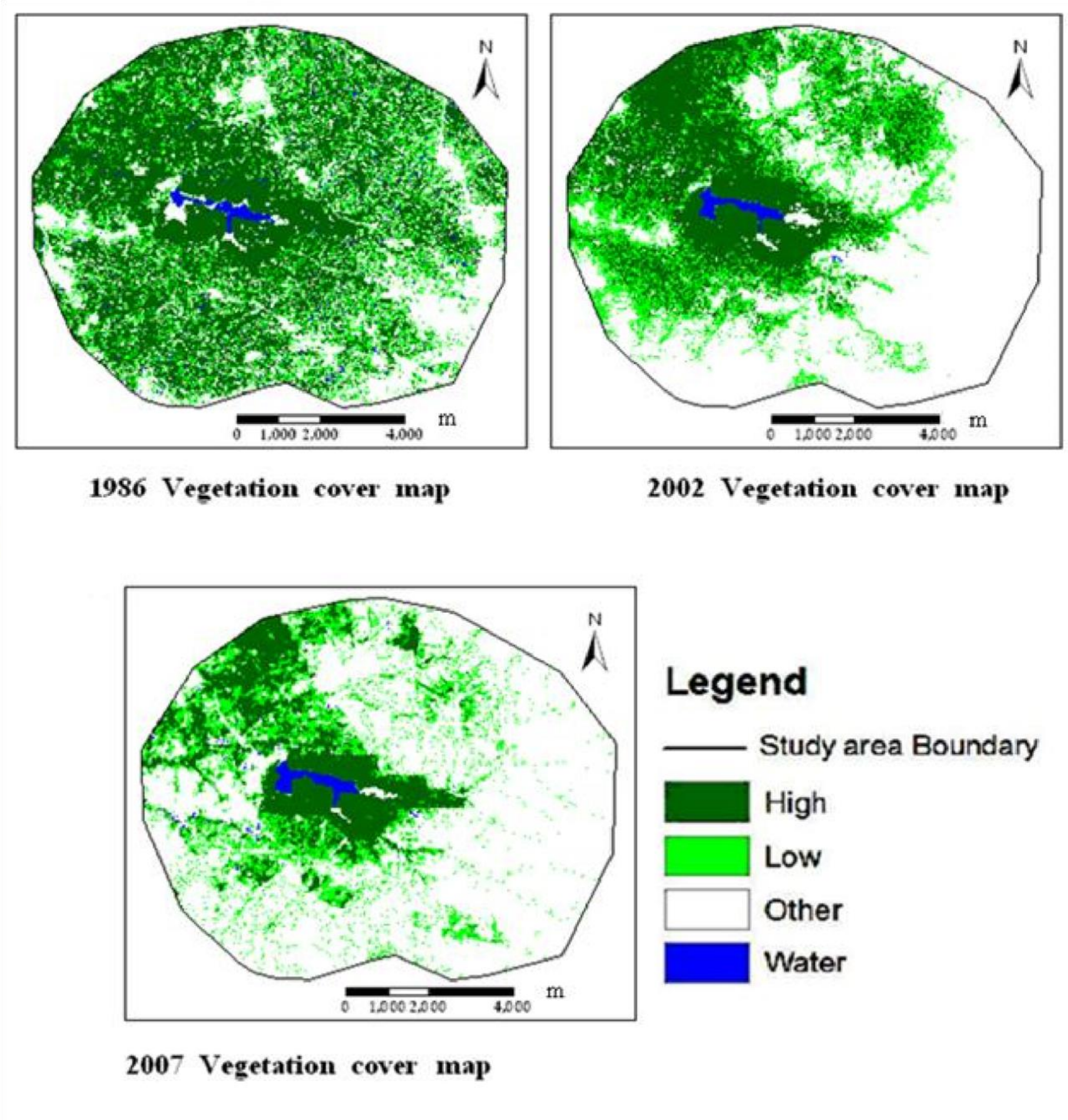


Figure 23: Vegetation cover maps of the study area.

4.6. Spatial distribution of the reserved forest

Figure 24 is an illustration of how the reserved forest is spatially distributed in the study area. This was obtained from the topographic map of 1974 and reprojected into ArcGIS environment with the boundary of the study area. Towns and settlements were subsequently added by clipping with the study area boundary. The total area of the reserved forest were obtained and its value was noted as 141608000 ft^2 (Appendix 5). Mathematical computation analyses were employed to this value and an area coverage of 1,315.58 m^2 was obtained. The computation techniques used is illustrated in Appendix 7.

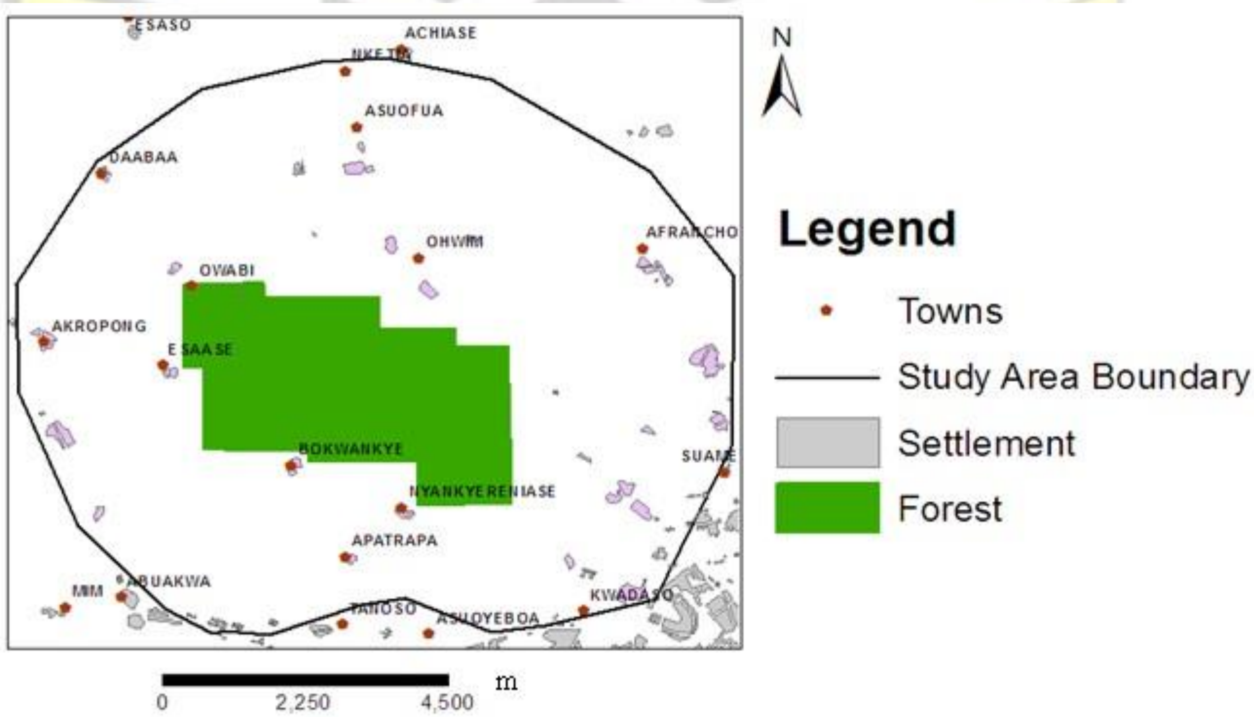


Figure 24: Topographic Map showing the spatial distribution of the reserved forest.

4.7. Reserved forest of 1974, Boundary of study and Classified Maps of 1986, 2002 and 2007.

The Figure 25 below indicates the reserved forest of 1974, boundary of the study area and classified Maps of 1986, 2002 and 2007. Visual inspection shows that the reserved forests have been highly depleted over the past 33 year period, from 1974 to 2007.

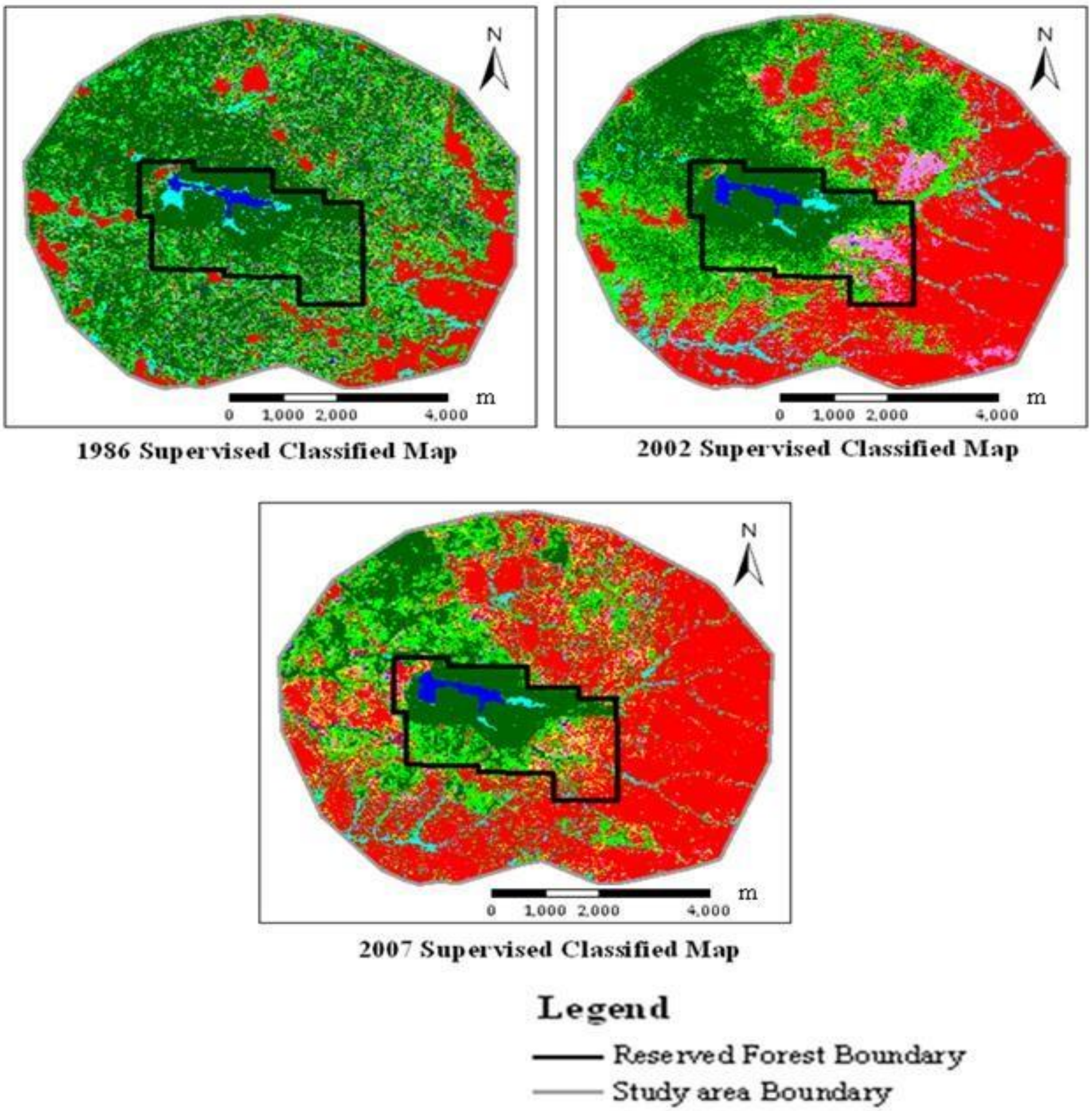


Figure 25: Reserved forest of 1974, Boundary of study and Classified Maps of 1986, 2002 and 2007.

4.8. Normalized Difference Vegetation Index

Using the equation given in section 2.2.8., NDVI images of the study area were generated from the 1986 Landsat TM, 2007 Landsat ETM and 2002 aster imagery (Figure 26). The digital numbers (DN"s) of the pixels for the resultant map ranged from 0 to 255.

Applying Groten et al. (1999) rule (as in section 2.2.8.), pixels with DN greater than 135 appear red in colour which could either be a forest or a cultivated land. DN values less than 135 indicate water bodies, bare soil, built-up area or degraded grassland. Forest areas turns to have higher NDVI values due to their greater green biomass.

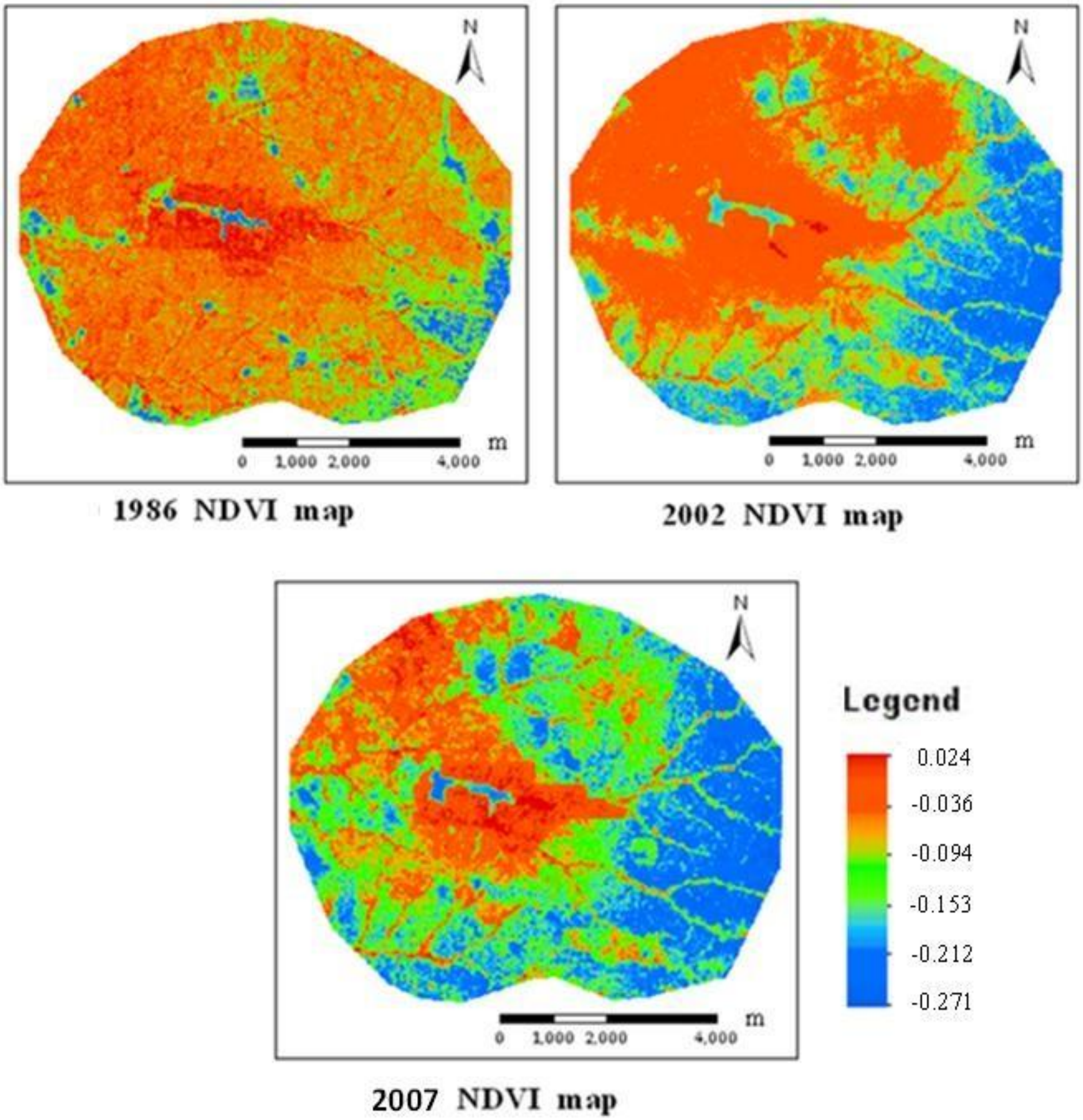


Figure 26: NDVI aggregate map showing forest covers and other LULC types

4.9. Persistence of LULC

4.9.1. Persistence of LULC, 1986 to 2002

From Table 10, croplands have highest Gp followed by bare soil, grassland, wetlands, sparse forest, water with high density forest experiencing the lowest Gp. Bare soil experienced the highest Lp followed orderly by croplands, grassland, wetlands, sparse forest, water, high density forest with the built-up area having the lowest Lp. The Np is negative for all LULC types except grassland, built-up and croplands.

Table 10: Gp, Lp and Np ratios, 1986 to 2002

LULC	Gp	Lp	Np
Water	1.02	3.46	-2.44
Bare Soil / Sand	23.41	40.15	-16.74
Grassland	14.57	13.22	1.35
Built-Up	2.52	0.17	2.35
Sparse Forest	3.31	3.78	-0.47
High Density Forest	0.34	1.44	-1.10
Croplands	44.82	25.41	19.41
Wetlands	7.49	9.61	-2.12

4.9.2. Persistence of LULC, 2002 to 2007

From Table 11, the Gp for bare soil, croplands, grassland, wetlands and sparse forest were relatively higher and lower for water, built-up and high density forest. However Lp is highest for grassland followed by croplands, bare soil, wetlands, sparse forest, high density forest with built-up and water having the lowest Lp respectively. With the exception of water, bare soil, built-up and croplands, the Np is negative for all the other LULC types.

Table 11: Gp, Lp and Np ratios, 2002 to 2007

LULC	Gp	Lp	Np
Water			
Bare Soil / Sand	0.58	0.13	0.45
Grassland	18.79	7.87	10.92
Built-Up	7.55	10.75	-3.20
Sparse Forest	0.54	0.20	0.34
High Density	2.17	2.61	-0.44
Forest	0.22	1.14	-0.92
Croplands	17.99	9.94	8.05
Wetlands	4.27	4.98	-0.71

4.10. Fragmentation statistics of LULC within the Owabi catchmment

Using Fragstats version 3.3 software in ArcGIS environment, some fragmantation statistics of the LULC types were computed. The details of these statistics are shown in the tables below

4.10.1. Class area (CA) from 1986 to 2007

Table 12 illustrates that CA of build-Up, croplands and grassland were increased by 2255.13ha, 110.07ha and 36ha respectively, whilst that of bare soil/sand, high density forest, sparse forest, water and wetlands decreased by 109.98 ha, 1957.95 ha, 178.65 ha, 72.81 ha and 81.81 ha respectively from 1986 to 2002. However, from 2002 to 2007 bare soil/sand, built-up, croplands and water areas increased by an amount of 197.64 ha, 970.02 ha, 191.43 ha and 24.21 ha respectively, whilst that of grassland, high density forest, sparse forest and wetlands decreased by 112.59 ha, 1025.37 ha, 206.19 ha and

39.15 ha respectively.

Table 12: 1986 to 2007 Class level metrics for Class Area (CA)

LULC	CA			Change (ha)	
				Difference	Difference
	1986	2002	2007	1986 to 2002	2002 to 2007
Bare Soil / Sand	270.36	160.38	358.02	-109.98	197.64
Built-Up	1126.80	3381.93	4351.95	2255.13	970.02
Croplands	149.76	259.83	451.26	110.07	191.43
Grassland	377.46	413.46	300.87	36.0	-112.59
High Density Forest	4347.27	2389.32	1363.95	-1957.95	-1025.37
Sparse Forest	1843.74	1665.09	1458.9	-178.65	-206.19
Water	133.20	60.39	84.60	-72.81	24.21
Wetlands	409.59	327.78	288.63	-81.81	-39.15
TOTAL AREA	8658.18	8658.18	8658.18		

4.10.2. Total Area of Landscape (TA)

The TA for the years 1986, 2002 and 2007 remained constant after the fragstats analysis with each having a value of 10857.6000 (Appendix 6).

4.10.3. Percentage of Landscape (PLAND), 1986 to 2007

PLAND for only built-up increases considerably over years (Table 13). Bare soil, croplands and water decreases and then increases while that of grassland, high density forest, sparse forest and wetlands increases and then decreases over the years.

Table 13: 1986 to 2007 Class Level Metrics for PLAND

LULC	PLAND		
YEAR	**1986**	**2002**	**2007**
Bare Soil / Sand	40.04	1.48	3.30
Built-Up	10.38	31.15	40.08
Croplands	16.98	2.39	4.16
Grassland	1.38	3.81	2.77
High Density Forest	2.49	22.01	12.56
Sparse Forest	3.77	15.34	13.44
Water	3.48	0.56	0.78
Wetlands	1.23	3.02	2.66

4.10.4. Patch Density (PD), 1986 to 2007

Table14 illustrates the class level metrics for PD of the various LULC classes. PD for only built-up and high density forest decreases considerably over the years. Bare soil, croplands and water decreases and then increases while grassland, sparse forest and wetlands increases and then decreases over the 21 year period.

Table 14: 1986 to 2007 Class Level Metrics for PD/100ha

LULC	PD / 100ha		
YEAR	**1986**	**2002**	**2007**
Bare Soil / Sand	16.49	13.62	25.25
Built-Up	16.74	16.11	14.50
Croplands	60.72	20.48	30.86
Grassland	13.00	21.92	21.61
High Density Forest	21.85	18.30	14.32
Sparse Forest	24.20	42.64	40.01

Water	29.32	0.61	1.89
Wetlands	7.87	17.29	16.76

4.10.5. Largest Patch Index (LPI), 1986 to 2007

LPI for built-up, high density forest, sparse forest and water increased over the 21 year period while bare soil/sand, croplands and wetlands decreases from 1986 to 2002 and remained constant from 2002 to 2007. Grassland increased and then decreased over the years (Table 15).

Table 15: 1986 to 2007 Class Level Metrics for LPI (%)

LULC	LPI %		
YEAR	**1986**	**2002**	**2007**
Bare Soil / Sand	13.71	0.01	0.01
Built-Up	0.27	4.21	10.49
Croplands	0.04	0.01	0.01
Grassland	0.01	0.02	0.01
High Density Forest	0.01	0.70	0.74
Sparse Forest	0.02	0.06	0.12
Water	0.01	0.03	0.04
Wetlands	0.03	0.02	0.02

4.10.6. Number of Patches (NP), 1986 to 2007

The NP for high density forest and croplands increased from 1986 to 2002 while water, bare soil, grassland, built-up, sparse forest and wetlands decreased over the same year period (Table 16). However, from 2002 to 2007 water, bare soil and croplands increases while grassland, built-up, sparse forest, high density forest and wetlands decreases.

Table 16: 1986 to 2007 Class Level Metrics for NP

LULC	NP			Difference 1986 to 2002	Difference 2002 to 2007
	1986	2002	2007		
Water	854	66	205	-788	139
Bare soil / sand	2372	1479	2742	-893	1263
Grassland	3183	2380	2346	-803	-34
Built-up	1818	1749	1574	-69	-175
Sparse forest	6593	4630	4344	-1963	-286
High density forest	1790	1987	1555	197	-432
Croplands	1411	2224	3351	813	1127
Wetlands	2627	1877	1820	-750	-57

4.11. LULC Projection

4.11.1 Spatial Projection of Owabi Catchment Area.

Spatial projection of areas under risk of invasion was derived using Idrisi Kilimanjaro software. The classified images of 1986 and 2007 were initially exported. They were then processed using Markov model under Change/Time Series analyses. Markov transition area metrix and transition image were then produced wthin the 21 year time period (Appendix 9). Markov model assumes that the future is independent of the past given the present (Norman, 2003). The projection was set for a period of 10 years, from 2007 to 2017. The system undergoes iterations until the projected land cover map was obtained. Projected land cover classes (Figure 27) and its corresponding areas were then generated (Appendix 8).

4.11.2 LULC analysis of Owabi catchment in 2017

Application of Idrisi Kilimanjaro software procedures yielded a projected land cover map for 2017 (Figure 27). Built-Up occupies the highest area coverage of 5460.75 ha representing 63.07% (Figure 28 and Appendix 8). Spatial extent of the remaining LULC classes are Bare soil, 360.72 ha representing 4.17 %, Croplands, 409.05 representing 4.72 %, Grassland, 270.27 ha (3.12%); high density forest, 790.65 ha
(9.13%); Sparse Forest, 1055.07 ha (12.19%); Water, 64.8 ha (0.75%) and Wetlands, 247.23 ha (2.86%).

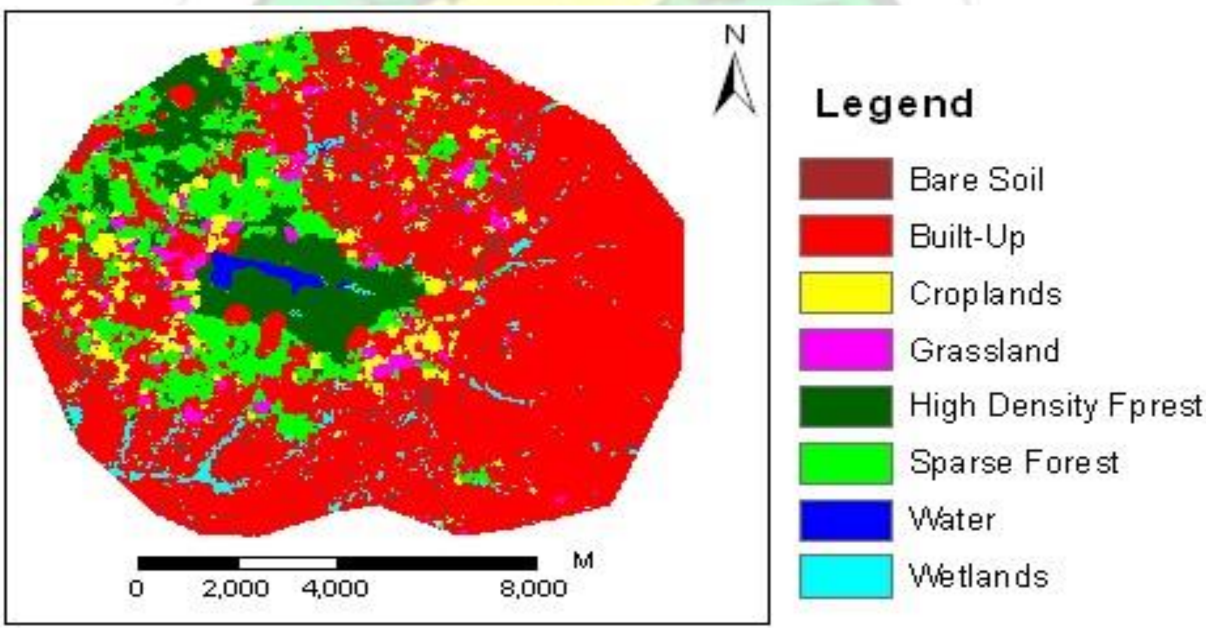


Figure 27: Land Cover Projection Map

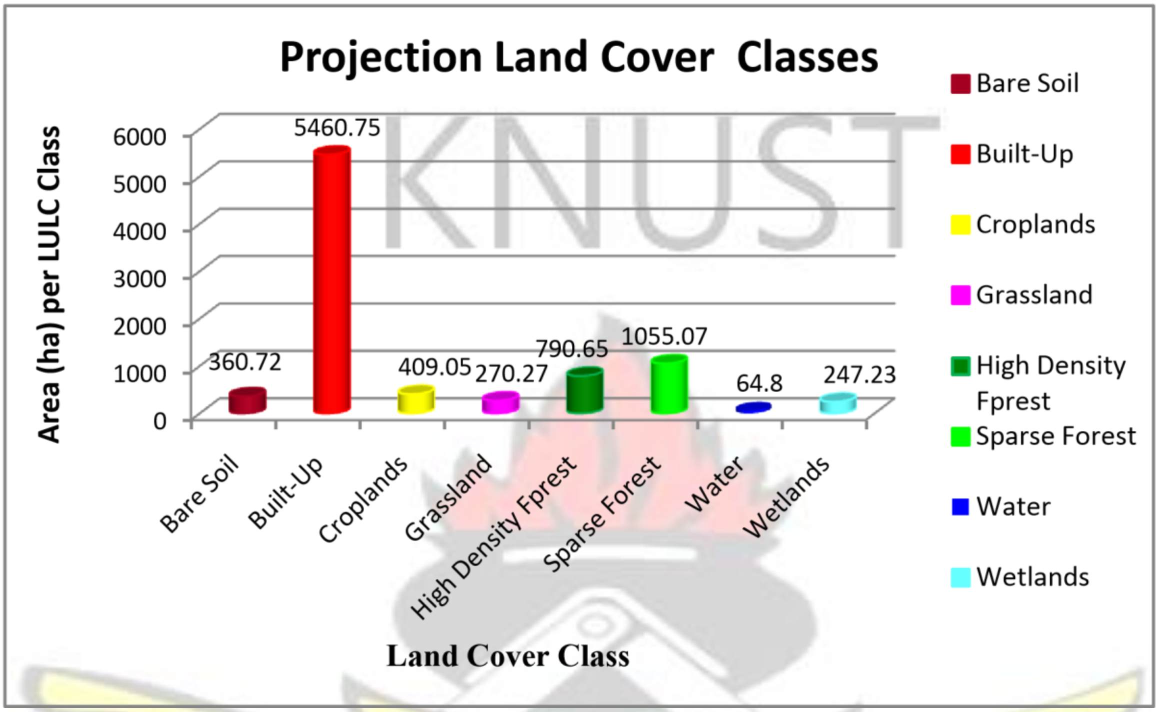


Figure 28: Areas (ha) of Projected LULC classes in 2017.

CHAPTER FIVE

DISCUSSION

5.1. Reserved forest of 1974, Boundary of study and Classified Map of 1986, 2002 and 2007

Overlay of the reserved forest of the 1974 and the classified map of 1986, 2002 and 2007 shows that the reserved forest is highly depleted over the past 33 years (refer to Figure 25). The major causes were identified to be the population growth, agriculture and sand winning (the leading economic activity in the community). The increase in population has significant implications for the conversion of forest covers to farmlands (grassland and croplands) and increase in settlement.

5.2. LULC change analysis of 1986, 2002 and 2007.

In 1986 HDF occupies the highest percentage of area having 50.21%, SF covered 21.29% while built-up and croplands occupied 13.01% and 1.73% respectively (refer to Figures 9, 10 and 11). However in the year 2002, HDF and SF reduced to 27.60% and 19.23% respectively, while built-up and croplands increased to 39.06% and 3% respectively (refer to Figures 12, 13 and 14). In 2007, there was a further reduction of HDF and SF to 15.75% and 16.85% respectively while built-up further increased to 50.26% which is the highest area coverage, and croplands also increased further to 5.21% (refer to Figure 15, 16 and 17). These trends of decrements in HDF and SF coupled with subsequent increments of built-up and croplands is due to population expansion, rapid urbanization of the districts, sand winning activities and uncontrolled grazing (especially the low canopy forest areas). These are the major causes of deforestation in the districts during 1986 to 2007. Unplanned urban sprawl is also damaging the primary drainage system thereby generating excess runoff water during rainy season, which is detrimental to plant growth.

5.3. Image Classification and Accuracy assessment of classified images

The NDVI gave a very good results in identifying forest areas for subsequent investigation and data collection during fieldwork. Although, it was not tested statistically, but there seems to be no significant difference between the results obtained from NDVI classification and those obtained from the supervised classification (Figure 26 compare with Figures 9, 12 and 15).

Supervised image classification method were employed to extract thematic information on the land covers from 1986, 2002 and 2007 satellite images which resulted in the production of the eight (8) LULC classes. Accuracy assessment of the classified image is an important step in image classification. The quality of a thematic map from a satellite image is determined by its accuracy. An accuracy assessment was performed on the 2007 Landsat ETM image and an overall accuracy of 79.53% were obtained. A widely used, acceptable accuracy is 85%, which is striven for in the land use classification (adopted by the U.S. Geological Survey). This accuracy is less than the 85% postulated by the US Geological Surveys.

The Kappa value of 0.7465 represents a probable 75% better accuracy than if the classification resulted from a randomly, unsupervised, assigning labels to areas. This value is between 0.40 and 0.80 (40 to 80%) which represents moderate agreement (Congalton, 1996).

Accuracy assessment were not performed on the 1986 TM and the 2002 aster images due to unavailability of ground validation data and reference points. This has being one of the major problems of remote sensing (Jensen, 1996). To determine the accuracy of classification for these images, stratified random sampling method (Jensen, 1996) could be used to generate reference points for the whole of the study area.

5.4. Fragmentation statistics of LULC within the Owabi catchment

5.4.1. Landscape Total Area

The total area of the landscape (TA) remain constant for 1986, 2002 and 2007 at a value of 10857.6 ha, which is greater than its corresponding class area (CA) having a value of 8658.18 ha because TA includes any internal background present (Appendix 6 compare with Table 12).

5.4.2. Persistence of LULC and Class level metrics in relation to Built-up Expansion.

High density forest and Sparse Forest

From 1986 to 2002 and 2002 to 2007, HDF and SF made huge conversions to built-up. Relatively small conversions were made to other LULC types resulted in the reduction of their CA within the 21 year period (Table 12). The LPI for these three (3) land cover types also increased considerably within the some year period which implies that builtup is increasingly becoming a dominant factor within the landscape. The expansion is mainly away from the fringes of the Owabi forest reserve and spreads along the easterns, westerns and the northern directions. This is attributed to the fact that the reservoir is being strictly protected by the GWCL while the forest reserve is being protected by the Game and Wildlife Conservation Division. The decrease in CA and NP of sparse forest from 1986 to 2002 and 2002 to 2007 can be attributed to its conversion to built-up and other LULC classes.

Water

The decreased in surface area (CA) of water from 1986 to 2002 is attributed to encroachment of human activities along wetland areas and river courses for residential purposes, farming activities as well as the growing of grasses and trees along wetland areas and river banks. The increased in surface area of water from 2002 to 2007 is attributed to the favorable condition of rainfall over the five (5) year period (Appendix 10) and the fact that there was a less human encroachment activities within the catchment due to the strict restriction issued by GWCL and the Wildlife Conservation Division (Table 12). This explanation is also shown in Tables 13, 14 and 16 illustrating PLAND, PD and NP for water which decreases from 1986 to 2002 and increases from 2002 to 2007.

Wetlands

Wetlands also fail to persist within the landscape over the two (2) transition periods from 1986 to 2002 and 2002 to 2007. The largest transitions of wetlands like the other LULC types were made to built-up. The decreased in CA, NP and LPI however is mainly due to the filling up of wetland areas for residential purposes, thus the result of built-up expansion.

Grassland

Grassland had a high tendency to convert to other LULC classes over the 21 year period, the largest transition being the conversion to built-up. The increased in CA, PLAND, PD and LPI from 1986 to 2002 is as a results of merging of grassland covers while the increased from 2002 to 2007 is basically due to the conversions of grassland to built-up and other LULC types.

Bare Soil/Sand

The CA of bare soil/sand decreases within the landscape from 1986 to 2002 and increased from 2002 to 2007 by mainly converting to built-up. This is proportional to PLAND, PD and NP which also decreases and increases over the period. The trooping of inhabitants to the Owabi catchment for residential purposes has resulted in built-up expansion over the last 5 years.

Croplands

The CA and NP of croplands increased considerably over the 21 year period from 1986 to 2002 and then 2002 to 2007. The increase of croplands within the landscape is due to the population explosion in the catchment area. LPI of croplands reduces from 1986 to 2002 which is an indication that the forest is being fragmented into smaller patches. LPI became constant from 2002 to 2007 and this is due to the awareness provided by GWCL and Wildlife Division.

5.5. Consequences of LULC changes on natural resources in Owabi Catchment.

5.5.1. Effect of deforestation on Global Warming

Trees absorb CO_2 that the humans release into the atmosphere through respiration and industralization. They use it to prepare their own food through photosynthesis and release O_2 into the atmosphere. When there is an increase in deforestation (either burning or cutting down of forest), CO_2 is released and its content in the atmosphere increases, which in turn increases the average global temperature of the earth's surface and causes global warming.

There is an extremely controversial theory that claims that climate change is caused entirely by deforestation (http://hubpages.com/hub/Trees-For-the-World, 2009). It claims that if the earth had the degree of forest cover it had in the past we would not be experiencing climate change at all. This is because the trees regulate their growth partly based on CO_2 levels and would be able to absorb excess CO_2 produced by human activities by changing their growth patterns. (http://hubpages.com/hub/Trees-For-theWorld, 2009).

5.5.2. Consequences for biodiversity

Forest loss and fragmentation within the catchment pose a lot of threat to natural habitats, there by affecting the local biodiversity of the landscape. The influence of human activities are altering the natural landscapes by changing the abundance and spatial pattern of these habitats (Harris and Miller, 1984). The increasing problem of the deforestation for agriculture and built-up encroachment has eroded most of the original biodiversity over the past decades.

5.5.3. Soil Degradation

When soils are exposed due to drainage or the destruction of vegetation through bush fires, lumbering and fuel-wood harvesting, leaching of soil nutrient take place and the sulphides in the original soils are converted into sulphuric acid leading to acidification. The soil may shrink upon drying and can no longer support good agriculture or plant life. **(**Ministry of Lands and Forestry, 1999)

5.5.4. Hydrological Effects

Remote sensing analysis of the LULC change demonstrated that there has been major increase of built-up areas over the past 21 year period and this is evidence in the increment of population data over the years (Table 4 compare with Appendix 4). As a result a lot of impervious surfaces were produced, accelerating the rate and volume of surface runoff. Flood peaks are going up quickly and remained in the above danger level. As impervious surfaces increased significantly, water levels in the surrounding rivers were augmented to be above of the normal flood level for longer time. So, it can be said that increase of impervious surfaces as a result of LULC changes clearly enhance the river flows (Dewan et al., 2005).

5.6. Spatial Projection of Owabi Catchment Area.

The 10 year spatial projection from 2007 to 2017 shows that 2017 projected cover map has a lot of built-up expansion which has an area coverage of 5460.75 ha representing 63.07% (Figure 27, Figure 28 and Appendix 8). This is due to the conversion of other LULC types to built-up coverage. Population expansion, agriculture and sand winning activities within the catchment and its environs are the major causes of these conversions.

Population growth is widely recognized as a key force behind environmental change, especially in developing countries (Cheng, 1999). The increase in total population of the communities in the catchment from 1973 to 2000 is shown in Table 9.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

The objective of this study was to identify and analyze change detection of forest cover using multi-temporal RS data and GIS based techniques in Owabi catchments in Kumasi, identification of LULC classes and its spatial distribution, preparation of various thematic and NDVI maps and projection of areas under risk. The relationship between the forest covers and its associated LULC classes were investigated and various thematic maps were developed. With these objectives, the answers to the research questions were provided in the study.

The main LULC types identified in the catchment are bare soil/sand, built-up, croplands, grassland, high density forest, sparse forest, water and wetlands. The study used fragmentation analyses of landscape level metrics, persistence and change analyses methods to assess the LULC change within the catchment area. The analyses revealed that the composition and configuration of the LULC within the catchment had changed significantly over the 21 year period of study.

The trend of forest cover loss within the catchment could be explained by the LULC conversions to residential purposes. This loss is attributed to the built-up expansion in the catchment. The nearness of the catchment area to Kumasi and high demand for lands for residential purposes and other activities has resulted in population explosion in the area. The study has revealed that there are areas of the forest which could be protected from invasions by the neighboring villages for farming activities, sand winning and built-up operations.

Using Satellite image data, GIS and RS technique can be a valuable tool in locating and predicting forest cover change. Thematic maps of forest cover types and various LULC classes can be distinguished by the satellite image interpretations and to evaluate their conversions as well as analyzing their trends. These aids in forest cover change detection and identification of areas under risk of invasions.

6.2. Recommendations

By taken more factors such as rainfall, soil moisture etc. into consideration, the study could reach a higher accuracy for forest cover change detection.

Performing multi sensor data classification using neural networks by combination of ancillary data (i.e elevation and aspect) with the Landsat image data would improved the classification result and produce higher accuracy than the use of Landsat image data only.

When multi-temporal satellite data and multi year ground truth data are available, it may be possible and useful to do further studies about change detection analysis to detect deforestation, built-up expansion and other LULC changes within the catchment.

Special attention and effective education programs should be developed for the general population on the need to protect water catchment areas.

Enforcement of laws protecting the Owabi Wildlife sanctuary and its environs by the Wildlife Division of Forestry Commission and GWCL.

Future studies are recommended to asses the prediction of forest cover, which are under risk of invasion.

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Appendix 1 : Error Matrix

2007 Classification Accuracy Assessment Report

Date : Thu Oct 08 05:25:37 2009

CLASS NAME	Water	Bare Soil / Sand	Grass Land	Built-Up	Sparse Forest	High Density Forest	Crop lands	Wet Lands	TOTAL
Water	**3**	0	0	0	0	0	0	1	**4**
Bare Soil / Sand	0	**12**	0	1	0	0	1	2	**16**
Grassland	0	0	**6**	0	1	0	0	0	**7**
Built-Up	0	0	3	**35**	2	0	0	1	**41**

Sparse Forest	2	1	2	1	**29**	4	2	0	**41**
High Density Forest	0	0	0	1	3	**40**	2	1	**47**
Croplands	0	0	1	0	0	1	**7**	0	**9**
Wetlands	1	0	0	0	1	0	0	**4**	**6**
COLUMN TOTAL	**6**	**13**	**12**	**38**	**36**	**45**	**12**	**9**	**171**

Appendix 2: Accuracy Totals

CLASS NAME	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Water	6	4	3	50.00%	75.00%
Bare Soil / Sand	13	16	12	92.31%	75.00%
Grassland	12	7	6	50.00%	85.71%
Built-Up	38	41	35	92.11%	85.37%
Sparse Forest	36	41	29	80.56%	70.73%
High Density Forest	45	47	40	88.89%	85.11%
Croplands	12	9	7	58.33%	77.78%

Wetlands	9	6	4	44.44%	66.67%
TOTALS	171	171	136		

Overall Classification Accuracy = 79.53%

Appendix 3: Kappa (K^) Statistics.

CLASS NAME	KAPPA
Water	0.7409
Bare Soil / Sand	0.7294
Grassland	0.8464
Built-Up	0.8118
Sparse Forest	0.6293
High Density Forest	0.7979
Croplands	0.7610
Wetlands	0.6481

Conditional Kappa for each Category. **Overall Kappa Statistics = 0.7465**

Appendix 4: Population Census of the Study area (Census of Ghana)

Name of Towns	District	2000	1984	1970
Akropon	Atwima	4,045	2,520	1,545
Daabaa	Atwima	878	730	308
Abuakwa	Atwima	16,582	3,581	970
Esaase	Atwima	2,014	885	689
Owabi	Atwima	696	596	185
Nkatia	Atwima	726	269	187
Asuofua	Atwima	5,878	2,250	181
Ohwim	Kumasi Metropolitan Area	3,279	887	439
Bokwankye	Atwima	1,845	805	479
Nyankyereniase	Kumasi Metropolitan Area	3,896	1,496	0
Apatrapa	Kumasi Metropolitan Area	5,028	869	622
Tanoso	Kumasi Metropolitan Area	13,536	2,948	1,319
Asuoyeboa	Kumasi Metropolitan Area	15,226	2,280	4,098
Kwadaso Estate	Kumasi Metropolitan Area	8,773	2,233	902
Kwadaso Nsuom	Kumasi Metropolitan Area	24,255	1,321	10,877
New Suame	Kumasi Metropolitan Area	16,881	14,164	2,595
Old Suame	Kumasi Metropolitan Area	15,392	17,259	4,815
Afrancho	Kwabre	4,418	1,825	1,046
	TOTAL	143,348	56,918	31,257

Appendix 5: Distribution of Reserved Forest

AREA	141608000.00000000000			
PERIMETER	57547.00000000000			

FORESTS_	6				
FORESTS_ID	17				
FCODE	4021				
e00_centro	749125.56000000000				
e00_cent_1	650991.81000000000				
Object_ID	5				
Shape_Leng	57547.03143750000				
Shape_Area	141607995.50000000000				

Appendix 6: Landscape Level Metrics.

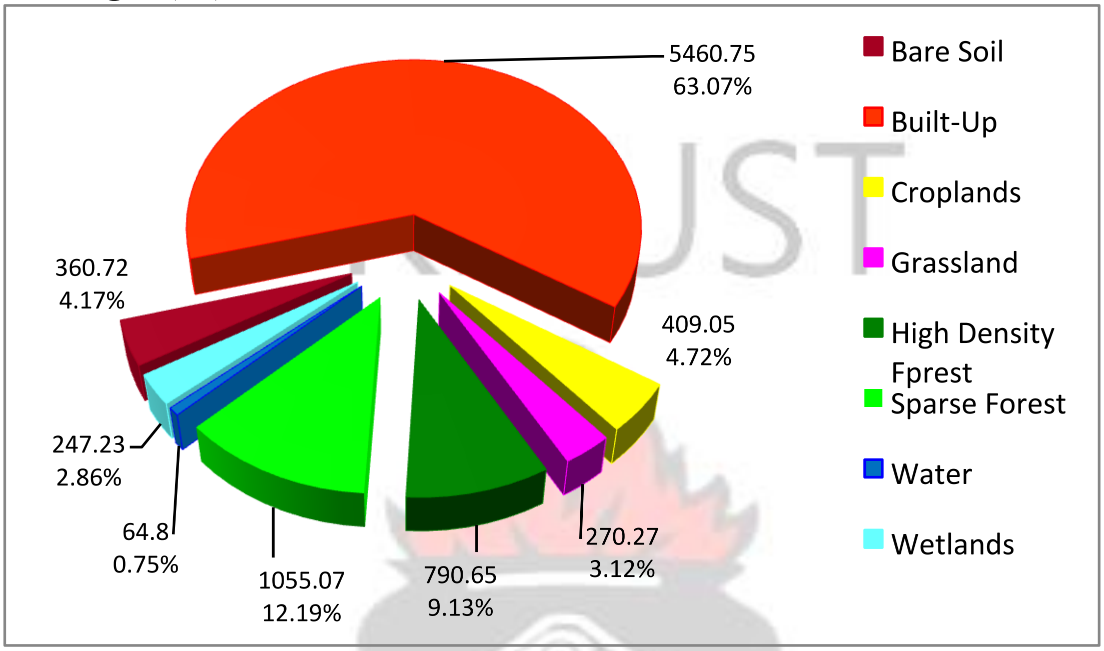
LID	TA	NP	PD	LPI
C:\ADUB\2007code	10857.6000	17937	165.2023	10.4932

Appendix 7: Measurement quantities

1 ft	0.3048 m
1 ft^2	0.0929 m^2
1 m	0.01 ha
1 (m^2)	$1.0 \times 10^{-4} ha$

ft = foot, m = meter

Appendix 8: Areas (ha) of Projected LULC classes and their Percentages (%) in 2017



Appendix 9: Markov transition area metrix

LULC	Water	Bare Soil	Grass land	Built-Up	Sparse Forest	High Density Forest	Crop Lands	Wet lands
Water	361	14	21	199	68	169	32	75
Bare soil	0	273	181	1996	841	233	305	149
Grassland	1	218	161	1590	821	180	266	106
Built-Up	0	1438	1016	43015	912	0	1395	579
Sparse Forest	27	979	718	7208	3530	1788	1182	778
High Density Forest	88	457	603	2606	4321	5724	856	502

Croplands	9	416	190	3049	770	89	346	145
Wetlands	231	197	121	1008	466	612	159	414

Appendix 10: GHANA METEOROLOGICAL SERVICES

ELEMENT Rainfall UNIT mm STATION Kumasi, Ashanti Region

TOTAL	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	YEAR
1669.2	18.5	45.5	247.4	166.9	105.2	159.2	417.1	96.5	202.8	99.7	110.4	52	**1985**
1232.6	9.2	132.9	64.4	70.7	154.8	268	176.3	63.5	114.2	170.6	13	52	**1986**
1292.4	5.9	64.8	110	171	46.3	245.9	156.8	192.1	188.9	74.4	3	13.5	**1987**
1520.4	5.2	10	309.5	135.7	130.3	341.7	138.8	15	185.5	136.4	38.6	78.9	**1998**
1463.9	53.7	2.3	112.6	77.2	126.2	310.4	69.3	199	281.2	136.3	39.5	8.2	**1989**
1192.7	35.8	69.1	110.2	199.1	115.3	126.4	22.6	29.6	159	137.5	104.7	83.4	**1990**
1275.3	54.8	83.9	77.8	133.3	306.9	171.6	88.1	69.9	143.2	122.5	23.7	0.1	**1991**
1063.5	36	5.5	74.3	152.3	150.3	132.9	79.2	30.4	312.8	49.2	65.6	7.1	**1992**
1442	2	53.9	117.5	152.7	140	338.9	31	102.1	168	257.1	54.4	26.7	**1993**
1109.2	52	7.3	52.1	194.9	208.9	116.1	96.5	63.1	156.1	199	35.2	0	**1994**
1327.2	0	0.7	121.6	193.8	175.8	155.1	136.6	148.5	133.8	59.9	40	115.6	**1995**
1040.9	3.7	80.2	72.2	111.8	145.7	106	202.7	109.6	72.5	8.8	2.8	51.9	**1996**
1393.4	53.7	33	138	286.9	213.9	250.2	73.4	59	96.3	162	11.1	11.3	**1997**
1092.2	51.8	26.6	35.9	267.4	133.3	188.7	56.6	75.6	74.9	76.5	23.5	31.9	**1998**
1432.8	61.3	29.5	110.2	217	101.7	317.9	202.6	114.1	135.2	204.3	39	0	**1999**
1488.5	62.4	7.2	110.6	206.2	168.6	383.2	153.2	65.3	144.1	119.9	99.8	0	**2000**
1195.3	52	21.5	220.1	163	106.7	149.7	112.5	48.6	216.9	112.9	15.5	18.4	**2001**
1668	1.6	7.6	99.7	238.9	304.6	265.5	281.1	75.8	123.5	319.1	45.2	5.4	**2002**
1349.2	32.9	74.5	93.1	129.5	188.8	254.6	95.3	26.8	99.2	180.1	163.2	30.9	**2003**

1414.4	25.8	69.9	164.3	100.9	72.3	41.1	229.4	115	243.5	232.4	43.5	76.5	**2004**
1229	12.5	43.9	82.2	146.4	272.1	121.3	18.3	36.7	194.1	231.9	49.8	29.8	**2005**
1159.8	111.1	98.4	112.8	66.9	187.3	145.4	66.9	65.2	111.4	153.4	32.5	3.7	**2006**
1794.4	0.2	16.4	56.2	310.9	164.2	196	192.9	117.7	534.5	153.9	51.7	19.8	**2007**
1452	0	53.9	97.4	132	239.6	286.9	131.1	192.6	190.9	75.1	18.3	54.8	**2008**
1530.7	52	131.4	110.6	139.8	164.6	376.7	273.5	17.6	99.3	138.6	45.2	33.4	**2009**