Assessing the Effect of Land Use Land Cover Change on Weija Catchment

By

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(BSc. (Hon.) Geomatic Engineering, UMaT)

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April, 2014

Declarations

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.

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Dedication

To My Dad, Mum and sweet Sisters
I love you, ALL

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 Materials and Metallurgical Engineering. All views and opinions expressed therein remain the sole responsibility of the author, and do not necessarily represent those of the institute.

Abstract

Humans have been altering land cover since pre-history and since the advent of plant and animal domestication as well as industrialization, through the clearance of patches of land for agriculture, residential and industrial purposes. In the past two decades, the impact of human activities on the Weija Catchment area has grown enormously, altering entire landscapes, and ultimately impacting the environment. This research seeks to analyse the Land Use Land Cover Change (LULCC) of the Weija catchment area using Remote Sensing (RS) data and Geographic Information System (GIS) based techniques. Field observations and measurements were employed to validate results from the remotely sensed data. LULCC was conducted using Landsat imageries for 1990, 2000 and 2011 applying maximum likelihood classification and change detection techniques. The results show that most of the LULC types have rate of change greater than the national rate of 1.96% especially between 2000 and 2011. Notably, however, the water body gained a surface area of 3.004 km^2 due to siltation. The main force driving the change is the increase in human activities such as farming, sand winning and built-up operations within the Weija catchment area. These are the possible factors responsible for polluting the Weija dam. This research has shown that the use of GIS and RS techniques is a valuable tool for detecting and predicting the rate of forest cover change and the identification of areas under risk for sustainable management.

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Table of Contents

List of Tables

List of Figures

List of Abbreviations

CERGIS	Centre for Remote Sensing and Geographical information System
DRB	Densu River Basin
DRBMB	Densu River Basin Management Board
ETM	Enhanced Thematic Mapper
EM	Electromagnetic
ERDAS	Earth Resources Data Analysis System
ESRI	Environmental Science Research Institute
GIS	Geographical Information System
GPS	Global Position System
GWCL	Ghana Work Company Limited
KWW	Kpong Water Works
LULC	Land Use Land Cover
LULCC	Land Use Land Cover Change
NDVI	Normalized Difference Vegetation Index
RS	Remote Sensing
TM	Thematic Mapper
UNCED	United Nation Conference on Environmental and Development
WWW	Weija Water Works
WSSD	World Summit on Sustainable Development

CHAPTER 1

INTRODUCTION

1.1 Background

Effective management of natural resources, particularly those of remote and inaccessible areas, depends on time and accuracy. To accomplish this calls for the use of tools and technologies, among them remote sensing and geographical information system, which can give accurate information at the least cost.

Remote sensing for the past three decades has evolved to include a suite of sensors operating at a wide range of imaging scales with potential interest and importance to environmental scientists, planners and land managers (Rogan and Chen, 2004). Coupled with the ready availability of historical remote sensing data, the reduction in data cost and increased resolution from satellite platforms, remote sensing technology appears poised to make an even greater impact on planning agencies and land management initiatives involved in monitoring land use land cover change at a variety of spatial scales. Current remote sensing technology offers collection and analysis of data from ground-based, atmospheric, and Earth-orbiting platforms, with linkages to Global Position System (GPS) data, Geographic Information System (GIS) data layers and functions, and emerging modeling capabilities (Rogan and Chen, 2004). This has made remote sensing a valuable source of land use land cover information. As the demand for increased amounts and quality of information rises, and technology continues to improve, remote sensing will become increasingly critical in the future, especially in change detection research. One such area in change detection research, a major global environmental change issue called land use land cover (LULC), is an important component in understanding the interactions of the human activities with their environment.

LULC changes also involve the modification, either direct or indirect, of natural habitats and their impact on the ecology of the area. Land use refers to man's activities and the varied uses which are carried on over land and land cover refers to natural vegetation, water bodies, rocks/soil, artificial cover and others noticed on the land (Prakasam, 2010).

Land Use includes agricultural land, built up land, recreation area, wildlife management area etc. Land use land cover is dynamic. Land is the most important natural resource on which all activities are based. Land use, unlike geology, is seasonally dynamic and indeed is more changing (Gautam and Narayanan, 1983). The increase in population and human activities is increasing the demand on the limited land and soil resources for agriculture, forest, pasture, urban and industrial land uses (Gautam and Narayanan, 1983).

Information on the rate and kind of changes in the use of land resources is essential for proper planning, management and sustainable use of the resources. This can be said of a resource like water in the Weija reservoir, which serves as drinking water for most part of Accra.

Safe drinking water is essential to humans and other life forms. Access to safe drinking water has improved over the last decades in almost every part of the world, but approximately one billion people still lack access to safe water and over 2.5 billion lack accesses to adequate sanitation (Anon, 2013).

At the World Summit on Sustainable Development (WSSD) held in Johannesburg in 2002, the international community took an important step towards more sustainable patterns of water management by including, in the WSSD Plan of Implementation, a call for all countries to "develop integrated water resources management and water efficiency plans."

Accra is the capital city of Ghana, with a population growth rate of 4.4%, much higher than the national average of 2.7% (Kuma and Ashley, 2008). Water supply to Accra is inadequate and regular water shortage in the city is a subject under constant discussion lately. Supply of water to Accra comes from the Kpong Water Works (KWW) and Weija Water Works (WWW) which are about 80 km north and 13 km west of Accra, respectively. Commercial water supply in Ghana is managed by the Ghana Water Company Limited (GWCL). The WWW draws its water from the Weija Reservoir which was constructed in 1952 by damming the Densu River at Weija (hereafter called the Reservoir and River, respectively). The water is treated and supplied to west Accra and some other areas of the city (Kuma and Ashley, 2008).

The major environmental concerns are erosion, siltation and pollution of the river, garbage and human wastes and excreta disposal, effluent from industries, motor garages and mechanical shops. Agricultural activities in the basin have caused considerable damage to the environment and polluted the river (Karikari and Ansa-Asare, 2006). Human contact and use of the water for bathing, washing, swimming, irrigation and gardening are intense in the basin. These situations have resulted in siltation, pollution and prevalence of water-associated diseases (*e.g.* bilharzias, enteric infections and intestinal worms) in the area. Industrial wastes from fruit processing factories and other industries are discharged into the river (Karikari and Ansa-Asare, 2006).

Earlier study by Amuzu (1975)(as cited by Asante *et al*, 2008) revealed that the Densu River water could be generally classified as good source of water supply along most of its stretches, though areas around Nsawam bridge fall into the poor water supply category. Ansa-Asare (1992) also revealed that areas around Suhum, Pakro and Suhyien were of poor water quality. Due to growing population densities, progressive industrialisation and intensification of agricultural activities the Densu river is presently one of the most polluted rivers in the country (Ansa-Asare, 1992).

Effects of rapid urbanization and increased agricultural and industrial activities in the DRB and around the Reservoir have impacted the quality of water in the River and Reservoir. Water from the Reservoir is noted to have characteristic odour arising from eutrophication (Kumah and Ashley, 2008).

With the ever-expanding population in the Densu basin in Ghana, there is the urgency for proper conservation and efficient utilization of freshwater bodies for sustainable development (Karikari and Ansa-Asare, 2006). The population pressures in the basin cause an acceleration of the progressive deterioration of water quality because of increased domestic, municipal, agricultural and industrial activities, and effluent being discharged into water bodies and increase in environmental degradation resulting from urbanization and deforestation (Karikari and Ansa-Asare, 2006).

1.2 Problem Statement

Research has proved that problems associated with environmental monitoring and control persists through the history of mankind (Opeyemi, 2008). The situation is aggravated in recent times due to man's increasing intervention on the environment, hence, there remains few landscapes on the earth's surface that have not been significantly altered by human beings in some ways (Opeyemi, 2008). This might be the case by observations along most reservoirs due to fishing, farming and urban expansion.

Accurate and timely information about land use land cover (LULC) and its changes in urban areas are crucial for urban land management decision-making, ecosystem monitoring and urban planning. Also, monitoring and representation of urban sprawl and its effects on the LULC patterns and hydrological processes of an urbanized watershed is an essential part of water resource planning and management.

The conversion of land from forest cover to urban and industrial development is one of the critical processes of change in developing economies undergoing industrialization, urbanization, and globalization. Urban land use changes taking place in Ghana is drawing the attention of scholars in light of the extensive economic reforms, remarkable economic growth, and profound structural changes.

Wunder and Börner (2011) noted that forests are key global environmental assets, as carbon sinks to mitigate climate change, as main reservoirs of biodiversity, or through their influence on macroregional water balances. Agriculture provides food and energy, but it is often also associated with considerable negative environmental externalities. Changes in agricultural land use strategies and production technologies can potentially trigger large (positive or negative) environmental off farm impacts (McNeely and Scherr 2003).

Due to the increase in anthropogenic activities in the Weija Catchment, the catchment has undergone rapid change with its LULC. Residents and industrialists create the need for the development of land for houses, infrastructures, and social amenities. The pressure of continuously growing population has also resulted in craving for space and this has compelled builders and developers to convert more forest land into industrial and residential land use. This puts pressure on the natural resources and thus makes it important to monitor changes in the urban growth that has occurred so far and those which are yet to occur to be managed.

Monitoring the growth and planning for its control has been made more difficult by the expanse of time involved in producing reliable and up-to-date maps. Hence, the use of RS techniques on remotely sensed images can be efficiently used for this purpose. Thus, this research seeks to map land use changes taking place in the catchment area of the Reservoir through the use of Remote Sensing and GIS.

1.3 Research Objectives

The following section states the main and specific objectives.

1.3.1 Main Objective

The main objective of this thesis is to assess the effects of LULC Change on the Weija dam.

1.3.2 Specific Objectives

The following specific objectives were addressed:

i. The extent of the change in Weija catchment area.

ii. The nature and spatial pattern of the change in Weija catchment area.

iii. The future pattern of LULC Change in the Weija catchment area.

1.4 Structure of thesis

Chapter two contains the relevant literature reviewed to get acquainted with the work that has been done. Chapter three elaborates on the methods used and the mode of application of the methods to achieve results. It gives the step by step approach used in executing the research. Chapter four accumulates the results obtained from the various methodologies used and discusses all the results obtained. Chapter five finally talks about the conclusions observed with regards to the objectives of this thesis and enumerates some recommendations regarded to be necessary and useful as a result of the study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Studies have shown that there remain only a few landscapes on Earth which are currently in their natural state. Due to anthropogenic activities, the Earth‘s surface is being significantly altered and the presence on the Earth of man and his use of land has had a profound effect upon the natural environment (Opeyemi, 2008). As a result since the early 1980s vast transformations have occurred in the LULC patterns as evidenced by persistent expansion in cultivated land, decrease in natural woodland and grassland in the world (Xiaomei & Ronqing, 1999) (as cited by Matsa and Kudakwashe, 2010).

It can therefore be stated that the LULC pattern of a region is an outcome of natural and socio-economic factors and their utilization by man in time and space. Viewing the Earth from space is now crucial to the understanding of the influence of man‘s activities on the natural resource base over time. In situations of rapid and often undocumented land use change, observations of the earth from space provide objective information of human activities and utilization of the landscape. Over the past years, data from Earth sensing satellites has become vital in mapping the Earth‘s features and infrastructures, managing natural resources and studying environmental change (Ikusemoran, 2009).

The observations of the earth from space have impacts on development of classification systems, data collection and information systems in general. It is said that Land Cover is "observed". This means that observation can be made from various "sources of observation" at different distances between the source and the earth's surface: the human eye, aerial photographs, and satellite sensors.

For land use, various approaches are proposed in the literature. Two main “schools” may be distinguished. Land use in terms of functional dimension corresponds to the description of areas in terms of their socio-economic purpose: areas used for residential, industrial or commercial purposes, for farming or forestry, for recreational or conservation purposes, etc. Links with land cover are possible; it may be possible to infer land use from land cover and conversely. But situations are often complicated and the link is not so evident. Another approach, termed sequential, has been particularly developed for agricultural purposes. The definition is a series of operations on land, carried out by humans, with the intention to obtain products and/or benefits through using land resources. For example a sequence of operations such as ploughing, seeding, weeding, fertilising and harvesting (Mücher *et al.*, 2001).

Land use includes such broad categories as human settlements, protected areas and agriculture. Within these broad categories are more refined categories, such as urban and rural settlements, irrigated and rain fed fields, national parks and forest reserves, and transportation and other infrastructure. Land cover refers to the natural vegetative cover types that characterize a particular area. These are generally a reflection of the local climate and landforms, though they too can be altered by human actions. Examples of broad land cover categories include forest, tundra, savannah, desert or steppe, which in turn can be sub-divided into more refined categories representing specific plant communities (*e.g.*, oak-pine scrublands, mangroves, seasonally flooded grassland, *etc*.).

2.2 Land Use Land Cover Concept

Land use land cover change has been identified as one of the prime determinants of global change with major impacts on ecosystems, global biogeochemistry, climate change and human vulnerability (Metzger *et al.*, 2008). New tools and techniques have increased the ability to monitor and explore changes in LULC. Advances in remote sensing and land inventory techniques have enabled localised assessments of land resources, identifying on-going land cover change processes and hot-spots of change (Verburg *et al.*, 2009). Monitoring land use and cover change also includes localised case studies in which the dynamics of change are studied from a sociologic and anthropomorphic point of view, providing in-depth knowledge about the underlying drivers and processes (Keys and McConnell, 2005). Modelling land use and cover change has proven to be an important tool in exploring different scenarios of plausible future developments for place-orientated adaptive responses (Matthews *et al.*, 2007).

Many existing information systems are mixing land use land cover, where natural and semi-natural vegetation are described in terms of land cover and agricultural and urban areas in terms of land use. However, these are two different issues and distinction between LULC is fundamental though often ignored or forgotten. Confusion and ambiguity between these two terms lead to practical problems, particularly when data from the two different dimensions need to be matched, compared and/or combined.

A useful comparison can be made with approaches for classifying commodities where objects are described according to the material they are made of and the function they serve. It is sometimes possible to determine functional aspect from biophysical aspect (Duhamel and Vidal 1998). A parcel of land covered by a field of maize can reasonably be associated with agricultural use. Similarly, it is possible to infer biophysical aspect from functional aspect. An area used for forest production can reasonably be assumed to correspond to a biophysical class of the “tree” type. However, for others, one biophysical category may correspond to a large number of functional categories. Areas of grass may, for example, correspond to a lawn in an urban environment, an airport runway, grazing land and rough pasture. Conversely, one and the same functional class may cover several biophysical categories: for example, a residential area consists of lawns, buildings, tarmac roads, trees and bare soil. For water, areas consisting of banks of rivers, areas once covered by water, flooded areas and even the expansion of water body by high tide.

There are methodological and technical arguments in favour of the systematic separation of the two approaches. Even if it is difficult to justify when analysing both user needs and the possible costs of simultaneously acquiring, using and managing data obtained through separate approaches, importance of the knowledge for the two dimensions may be illustrated with the following example adapted from Lund (1998).

The scientific research community called for substantive study of land-use and land-cover changes during the 1972 Stockholm Conference on the Human Environment, and again 20 years later at the 1992 United Nations Conference on Environment and Development (UNCED). In the past decade, a major international initiative to study LULC, the LULC Project, has gained great momentum in its efforts to understand driving forces of land-use change (mainly through comparative case studies), develop diagnostic models of land-cover change, and produce regionally and globally integrated models (Prakasam, 2010).

The strong interest in LULC results from their direct relationship to many of the planet's fundamental characteristics and processes, including the productivity of the land, the diversity of plant and animal species, and the biochemical and hydrological cycles. Land cover is continually molded and transformed by land-use changes such as, for example, when a forest is converted to fishing site (de Sherbinin, 2002). Land-use change is the proximate cause of land-cover change. The underlying driving forces, however, can be traced to a host of economic, technological, institutional, cultural and demographic factors. Humans are increasingly being recognized as a dominant force in global environmental change (Lambin *et al.* 2001). LULC change has been identified as a contributing factor to climate change, accounting for 33 percent of the increase in atmospheric CO_2 since 1850, and a leading factor in the loss of biological diversity (Vitousek, *et al.* 1997). Overgrazing and other agricultural practices in developing countries are causes of land degradation and desertification (Vitousek, *et al.* 1997).

Equally important is the impact of these regional and global changes on society. By altering ecosystem services, changes in land use and cover affect the ability of biological systems to support human needs, and such changes also determine, in part, the vulnerability of places and people to climatic, economic or socio-political perturbations. Example, conversion of forested areas to crop lands, pasture or human settlements (de Sherbinin, 2002). Deforestation can result in the loss of biodiversity, especially in the tropics; biodiversity loss results in declines in ecosystem integrity, and also genetic losses that may impede future scientific advances in agriculture and pharmaceutics (de Sherbinin, 2002). Deforestation can also impact hydrological processes, leading to localized declines in rainfall, and more rapid runoff of precipitation, causing flooding and soil erosion. Scientists have come to a better understanding of the role that forests play in the carbon cycle, and how forests burning in certain parts of the world are important contributors to greenhouse gases that contribute to climate change (de Sherbinin, 2002). Clearly, all of these changes impact society (de Sherbinin, 2002). This dual role of humanity in both contributing to the causes and experiencing the effects of global change processes emphasizes the need for better understanding of the interaction between humans and the terrestrial environment. This need becomes more imperative as changes in land use become more rapid. Understanding the driving forces behind land-use changes and developing models to simulate these changes are essential to predicting the effects of global environmental change (Veldkamp and Lambin, 2001).

A major reason for researching historical LULC change is that by understanding the past, we can better understand future trajectories. According to de Sherbinin, (2002), land use changes such as urbanization tend to radiate out from existing areas of the same class, and many models take advantage of this characteristic to make predictions of future change. The most significant historical change in land cover has been the expansion of agricultural lands (Houghton, 1994). Today close to a third of the earth's land surface is devoted to pastures or cropland, which amounts to approximately one-half of all lands suitable for agriculture (Houghton, 1994). Since the dawn of plant domestication the progression of cropland was relatively slow. The past century witnessed over half of the worldwide increase in agricultural lands, and in the developing world half of the land cover conversion occurred in just the past 50 years (Houghton, 1994).

The greatest increases in land used for cultivation are predicted for Africa and Latin America, with substantial additional parts of Europe/Russia and North America also coming under cultivation to meet future demands for food. As Houghton (1994) points out, the major reason for land-use change is to increase the local capacity of lands to support the human enterprise. Yet, together with the "positive" changes - i.e., those that make land more productive - there are also unforeseen impacts that can reduce the ability of land to sustain the human enterprise. Today, localized changes around the world add up to massive impacts that are altering planetary biogeochemical cycles. Thus, it can be argued that even modest changes in land cover have some unintended consequences (de Sherbinin, 2002).

The terms LULC form the two principal components of land transformation. Land cover is more obvious to notice than land use as the term denotes the surface cover over the land. According to Ellis (2010), Land cover refers to the physical and biological cover over the surface of land, including vegetation, water and bare soil; some also include artificial structures as land cover. On the other hand, land use is more complicated as it has different meanings to different scientists. According to natural scientists, the term refers to the application of the land surface to human activities such as agriculture, forestry and building of structures, whilst the social scientists define land use as how the land is managed in terms of socio-economic purposes (Ellis, 2010).

Change detection is the process of identifying differences in LULC overtime. As human and natural forces continue to alter the landscape, various public agencies are finding it increasingly important to develop monitoring methods to assess these changes. Changes in LULC often result in the quality or values of the available resources. Methods for monitoring vegetation change at a landscape scale range from the fieldwork inventories to the modern utilization of remotely sensed data which include satellite imageries, using GIS techniques. Any nation with sustainable utilization of its environment in mind must have adequate information on many complex interrelated aspects of its activities in order to make decisions. Land use is only one of such aspects. Knowledge about LULC has become increasingly important as Ghana plans to overcome the problems of haphazard, uncontrolled development, deteriorating environmental quality, loss of important wetlands, and loss of fish and wildlife habitat. Land use data are needed in the analysis of environmental processes and problems that must be understood if living conditions and standards are to be improved or maintained at current levels (Ikusemoran, 2009).

2.3 Driving Forces of LULC Changes (LULCC)

LULCC is often caused by multiple interacting factors. The driving forces of LULC change vary and their dynamic interactions result in diverse chains and trajectories of change, depending upon the specific environmental, social, political and historical contexts from which they arise (Nagendra *et al*., 2004). The human-environment relationship varies in time and space due to the mix of these driving forces.

The causes of LULCC can be divided into two categories, either due to natural or anthropogenic activities. However, human-induced changes in land cover occur more rapidly than naturally occurring processes. The naturally occurring processes include climatic variations, landslides, volcanoes, flooding, disease and pest infestations on vegetation and wildfire. Land use has been changing since people started managing their environment (Metzgar *et al*., 2006). In response to the growing demands of human survival and developmental needs, the earth‘s surface is altered. Lambin *et al*,

(2001) categorized the influence of LULCC due to human activities based on the following factors: socio-economic, technological, institutional, demographical, cultural, and globalisation. For example, land degradation and other negative environmental consequences of land-use change are often the result of ill-defined policies and weak institutional enforcement that undermine local adaptation strategies. Much research has been carried out to investigate the impact of rapid human population growth on land use land cover (Adu-Poko *et al*., 2012)

2.4 Consequences of Land Use Land Cover Changes (LULCC)

Understanding the implications of past, present and future patterns of human land use for biodiversity and ecosystem function is increasingly important in basic and applied ecology. Land use patterns influence water quality and stream fauna, and they alter the abundance and spatial pattern of native habitats, often resulting in habitat loss and fragmentation. For example, forest cutting patterns have a large and persistent impact on landscape structure (Turner *et al*, 2003). Prior land use can leave a distinctive legacy in composition of terrestrial and aquatic communities, even when the vegetation appears to have recovered (Turner *et al*, 2003).

Changes in land use land cover persists through the history of mankind and are the direct and indirect consequence of human actions to secure essential resources. This may first have occurred with the burning of areas to enhance the availability of wild game and accelerated dramatically with the birth of agriculture, resulting in the extensive clearing (deforestation) and management of Earth's terrestrial surface that continues today. More recently, industrialization has encouraged the concentration of human populations within urban areas (urbanization) and the depopulation of rural areas, accompanied by the intensification of agriculture in the most productive lands and the abandonment of marginal lands. All of these causes and their consequences are observable simultaneously around the world today (Ellis, 2010).

Biodiversity is often reduced dramatically by LULCC. When land is transformed from a primary forest to a farm, the loss of forest species within deforested areas is immediate and complete. Similar effects are observed whenever relatively undisturbed lands are transformed to more intensive uses, including livestock grazing, selective tree harvest and even fire prevention (Ellis, 2010). LULCC plays a major role in climate change at global, regional and local scales. At global scale, LULCC is responsible for releasing greenhouse gases to the atmosphere, thereby driving global warming. LULCC can increase the release of carbon dioxide to the atmosphere by disturbance of terrestrial soils and vegetation, and the major driver of this change is deforestation (Ellis, 2010).

Land use land cover changes that alter the albedo are another major driver of global climate change. It is evident from studies that most cities around the globe have witnessed an increase in urban temperatures as urbanisation of cities increases (Weng, 2001). The results of urban expansion are increases in number of buildings, extensive road networks, and other paved surfaces due to absorption of solar radiation, greater thermal capacity and heat is stored during the day and released by night (Weng, 2001).

Other environmental impacts of LULCC include the destruction of stratospheric ozone by nitrous oxide release from agricultural land and altered regional and local hydrology (dam construction, wetland drainage, irrigation projects, increased impervious surfaces in urban areas). Perhaps the most important issue for most of Earth’s human population is the long-term threat to future production of food and other essentials by the transformation of productive land to non-productive uses, such as the conversion of agricultural land to residential use and the degradation of rangeland by overgrazing. The methods of change detection include remote sensing and geospatial analysis and modelling, together with the interdisciplinary assortment of natural and social scientific methods needed to investigate the causes and consequences of LULCC across a range of spatial and temporal scales ((Ellis, 2010).

2.5 Remote Sensing and Innovative Mapping Technologies

Over the past four decades, the ability to more precisely classify and estimate changes in the composition and extent of land cover has been facilitated by the relatively recent and widespread availability of imagery acquired by sensors on-board aerial and satellite based platforms (Franklin and Wulder, 2002).

Remote Sensing is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation (Bottomeley, 2000). Within the scope of this study, the focus of remote sensing is the measurement of emitted or reflected electromagnetic radiation, or spectral characteristics, from a target object by a multispectral satellite sensor. A multispectral sensor is characterized as a passive sensor. Passive sensors record energy that is naturally reflected or emitted from a target. In contrast, active sensors supply their own source of energy, directing it at the target in order to measure the returned energy (Bottomeley, 2000).

A multispectral sensor acquires multiple images of the same target object at different wavelengths (bands). Each band measures unique spectral characteristics about the target. A spectral band is a data set collected by the sensor with information from discrete portions of the electromagnetic spectrum. The electromagnetic (EM) spectrum is a range of electromagnetic radiation ranging from cosmic waves to radio waves. Multispectral sensors focus on ranges on the EM spectrum where radiation penetrates the air with little or no loss by absorption of the target. Remote sensors on space platforms are programmed to operate in these windows and make measurements using detectors tuned to these specific wavelength frequencies which pass through the atmosphere. Spectral reflectance characteristics of common earth surface materials are located within the visible and near to mid-infrared range (Richards, 1986). In most contemporary land use studies which employ remote sensing imagery from multispectral sensors, the foremost task is the observation of spectral characteristics of measured electromagnetic radiation from a target or landscape. Analysts develop signatures based upon the detected energy's measurement and position in the electromagnetic spectrum. A signature is a set of statistics that defines the spectral characteristic of a target phenomenon or training-sites. Image analysts determine the measurement of signature separability by determining quantitatively the relation between class signatures. Signatures are refined by improved ground-truth and accuracy assessment analysis. By utilizing the developed signatures in multispectral classification and thematic mapping, the analyst generates new data for analysis (ERDAS, 1999).

Today, remote sensing image data of the Earth's surface acquired by spacecraft platforms is readily available in a digital format. Digital remote sensing systems convert electromagnetic energy (colour, light, heat, *etc*.) to a digital form. Spatially, the data is composed of discrete picture elements, or pixels, and radiometrically it is quantised into discrete brightness levels (ERDAS, 1999). The great advantage of having data available digitally is that it can be processed by computer either for machine assisted information extraction or for the enhancement by an image interpreter.

Resolution is an important term commonly used to describe remotely sensed imagery. However, there are four distinct types of resolution that must be considered. These four types of resolution are spatial, spectral, radiometric, and temporal. These resolution characteristics help to describe the functionality of both remote sensing sensors and remotely sensed data (Bottomeley, 2000).

Spatial resolution is the minimum size of terrain features that can be distinguished from the background in an image, or the ability to differentiate between two closely spaced features in an image. It is also defined by the area on the ground that a pixel represents in a digital image file. Large scale in remote sensing refers to imagery in which each pixel represents a small area on the ground. Small scale refers to imagery in which each pixel represents a large area on the ground (Bottomeley, 2000).

Spectral resolution refers to the number and dimension of specific wavelength intervals in the electromagnetic spectrum to which a sensor or sensor band is sensitive or can record. Wide intervals in the electromagnetic spectrum are referred to as coarse spectral resolution, and narrow intervals are referred to as fine spectral resolution (Bottomley, 2000).

Radiometric resolution refers to the dynamic range, or number of possible data files values in each band. This is referred to by the number of bits into which the recorded energy is divided. The total intensity of the energy, from 0 to the maximum amount, the sensor measures is broken down, for example, into 256 brightness values for 8-bit data. The data file values range from 0, for no energy return, to 255, for maximum return, for each pixel (Bottomley, 2000).

Temporal resolution is a measure of how often a given sensor system obtains imagery of a particular area, or how often an area can be revisited. The temporal resolution of satellites is on a fixed schedule. The fixed schedule of satellites allows for more repetitive views. This revisit capability makes it possible to use several passes, perhaps covering two or three seasons or multiple years, for interpretation. In addition, new satellite technology is incorporating pointable or directional sensors allowing for even quicker revisit capabilities (Bottomley, 2000).

Remote sensing has become an important tool applicable to developing and understanding the global, physical processes affecting the earth and believe to be the best technique to be employed where monitoring and evaluation of a resource which is not easily accessible like Weija catchment.

2.6 Land Use Land Cover Change – The Role of Remote Sensing and GIS Application

LULCC is significant to a range of themes and issues central to the study of global environmental change. The global environmental change community recognises the significance of LULCC and the need for an interdisciplinary research approach to the subject. This recognition promoted the International Geosphere-Biosphere Programme and Human Dimensions of Global Environmental change Programme to explore the possibility of cooperative research project/programme. Thus, the creation of the "Science / Research Plan" for LULCC (Turner *et al*., 1995).

Mapping LULCC at global, regional and local scales is essential for a wide range of applications, including landslide, erosion, land planning, global warming etc. LULC alterations (based especially on human activities), negatively affect the patterns of climate, the patterns of natural hazard and socio-economic dynamics in global and local scale. In the global scene, a lot of LULCC research have be conducted with remote sensing and geographical information systems. For examples are Foley *et al*. (2005) quantified the global consequences of LULCC; Reis (2008) analysed Land Use/Land Cover changes using remote sensing and GIS in Rize, North-East Turkey; Methta (2011) studied LULCC detection using remote sensing and geographical information system; and Woldermichael and Hossain (2011) also studied the impact of Dam-triggered LULCC on the modification of extreme precipitation,

In the African regional scale, Mengistu (2008) investigated the use of remote sensing and GIS in LULCC detection in the upper Dijo river catchment, Silte zone, southern Ethiopia; Kigira *et al*. (2010) modelled the Influence of land use/land cover changes on sediment yield and hydrology in Thika River Catchment Kenya, using Swat Model and Tobar (2012) used geostatistical analysis to study the correlation between land use/land cover changes and population growth trends in the Komadugu-Yobe River Basin in Nigeria.

At the local stage, the following LULCC researches have been done. Braimoh (2003) studied the impact of seasonal migration on land-use/land-cover change in an area within the Volta Basin of Ghana; Kusimi (2007) studied the relation between the impact of mining to Groundwater hydrogeochemistry in the Wassa West District of Ghana; Kumi-Boateng and Issaka (2010) assessed and modelled land cover changes using remote sensing and GIS in the Ejisu-Juaben; Attua and Fisher (2011) studied historical and future land-cover change in a Municipality of Ghana; Forkuo and Frimpong (2012) applied of remote sensing and GIS for forest cover change detection in Owabi catchment in Kumasi, Ghana; and Adu-Poko *et al*. (2012)

integrated earth observation, geoinformation systems and stochastic modelling to monitor Land-cover change in Obuasi, Ghana.

LULCC is one of the challenges which strongly influence the process of sustainability of a resource especially the water resources at Weija reservoir. Remote sensing and GIS are important for monitoring, modelling and mapping of LULC across a range of spatial and temporal scales, in order to assess the extent, direction, causes, and effects of the changes.

2.7 Classification Schemes

Classification schemes are tools, describing selected aspects of the real world. Categories chosen do not represent a one-dimensional partition of the real world but a multidimensional one. The partition of the real world through a classification scheme highlights certain aspects of reality: the same reality might well be described according to several classifications. It can to be noticed that a category of a classification can be homogeneous according to one character (a monothetic class), or two, or none (following the concept of polythetic classes proposed by biologists). If the process of aggregation is taken beyond a certain level of significance, categories no longer correctly represent meaningful entities: this is the case of an aggregate which would mix for example agricultural and urban areas within a classification system (Anon, 2001). Therefore a classification scheme is the result of a structure and an order, coming from a system of values, revealing an intention. The purpose for which the classification is designed necessarily shapes its structure and content. This is why each user, in general, builds an individual classification adapted to his specific needs spontaneous development of classifications therefore leads inevitably to incompatibility. A classification system should also be the result of an on-going dialogue between:

- A systematic approach imposing structure on information according to logical principles (completeness, absence of overlap, unambiguous definitions of classes, rules governing the representation of objects within the classification).

- A pragmatic approach taking account user's needs and existing sets of information.

- A contextual approach addressing specific constraints linked to the domain of investigation (Anon, 2001).

2.7.1 Classification of Images

Classification is the process of sorting pixels into a finite number of individual classes, or categories of data based on their data file values. If a pixel satisfies a certain set of criteria, then the pixel is assigned to the class that corresponds to the criteria. There are two ways to classify pixels into different categories.

- Supervise Classification
- Unsupervised Classification

Supervised classification is more closely controlled than unsupervised classification. In this process, pixels that represent patterns recognized or identified with help from other sources is selected. Knowledge of the data, the classes desired, and the algorithm to be used is required before selecting the training samples. By identifying patterns in the imagery, the computer systems can be 'trained' to identify pixels with similar characteristics. By setting priorities to these classes, the classification of pixels are supervised as they are assigned to a class value. Unsupervised classification is more computer-automated. It allows specifying parameters that the computer uses as guidelines to uncover statistical patterns in the data.

2.8 Accuracy Assessment

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

Standard accuracy assessment procedures for one-point-in-time land cover products can be extremely difficult to apply to multitemporal change analysis products (Dobson and Bright, 1994). While accuracy assessment methods are well established for small areas and single time periods, the assessment of accuracies for large areas, past time periods, and change databases can become problematic (Dobson and Bright, 1994).

A standard accuracy assessment procedure for baseline land cover products involves the use of the error matrix. The error matrix is an effective descriptive tool for organizing and presenting accuracy assessment information and should be reported whenever feasible (Stehman, 1997). While the error matrix can be modified and used for change analysis products (Macleod and Congalton, 1998), it is difficult to apply to trend analysis or for adequately assessing more than a handful of categories of change.

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. 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. The Kappa coefficient represents the proportion of agreement obtained after removing the proportion of agreement that could be expected to occur by chance. 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 (Forkuo and Frimpong, 2011). Kappa can be used as a measure of agreement between model predictions and reality or to determine if the values contained in an error matrix represent a result significantly better than random (Forkuo and Frimpong, 2011).

CHAPTER 3

MATERIALS AND METHODS

3.1. Study Area

The study was conducted in Weija and communities around it receiving water supply from the Weija treatment plant. The selection of the location was based on the reason that there is rapid urban expansion and human activities are increasing the rate of land use transformation in and around the Weija shed. The Weija Catchment lies in the Coastal Savannah agro-ecological zone with a generally undulating Relief and a bi-modal rainfall pattern which together with the Densu River, predisposes the District to agricultural development. The Weija catchment has an area of about 1183.167 km^2.

3.1.1 Topography and Drainage

According to Kuma & Ashley (2008), Weija Catchment lies in the Western Lowland of the Densu River Basin. The low and rolling topography characterises the area with base level of about 67 metres above sea level (m asl) and this is broken by steep low ridges in several places ranging from 300 to 567 m asl. The study area comprises mainly gneiss and granite in the west and sandstone, siltstone and shale in the east. The ridges are generally parallel to the northeast trending regional structures, and commonly have steep western slopes and gentler eastern slopes.

3.1.2 The Reservoir

The dam of the Reservoir was breached and destroyed by floods in 1968 and work on a new dam at the same site commenced in 1974 and was completed in 1978 (Kuma and Ashley, 2008). At a normal water level of 14.33 m the Reservoir covers an area of 20.5 $km^2$with a storage capacity of 113.5 × 106 m^3 (25 000 MG) (Kuma and Ashley, 2008). The maximum designed water level is 15.25 m with a capacity of 143.115 × 106 m^3 (31 803 MG) (Kuma and Ashley, 2008). It was projected that inflows into the Reservoir will be 315 000 m^3/day (70 MGD), while expected upstream consumption would be about 40 500 m^3/day (10 MGD) (Kuma and Ashley, 2008).

3.1.3 Land Use

The total area of Weija catchment site encompasses approximately 1183.167 km^2 of which 176.325 km^2 (14.903%) of land is covered by water body; 480.579 km^2 (40.618%) by built-up and bare ground and 526.263 km^2 (44.479%) by vegetation of all kind.

3.1.4 Climatic Condition

Climatic conditions are tropical with temperature averaging 27^oC. Rainfall is moderate with the seasonal average being 65.5 mm. The catchment lies in the coastal savannah zone where rainfall is seasonal, with two rainfall peaks in June and September, while dry periods span between December and March (Asante *et al.*, 2008).

3.2 Materials

The following section discusses the data and software used for the research.

3.2.1 Data

Three (3) multi-date Landsat satellite imageries Thematic Mapper (TM) 1990 and Enhanced Thematic Mapper (ETM+) 2000 and 2011 were used as in Table 3.1. The images were selected from the CERGIS database based on availability and suitability in terms of seasonal compatibility. The images were used for the classification of

Image	Date of Acquisition	Path/Row	Resolution
Thematic Mapper (TM) 1990	10-01-1990	193/56	30x30
Enhanced Thematic Mapper (ETM+) 2000	04-02-2000	193/56	30x30
Enhanced Thematic Mapper (ETM+) 2011	17-01-2011	193/56	30x30

land-use/cover types and change detection.

Table 3.1 Data Source

3.2.2 Software

ERDAS imagine and ArcGIS were the softwares used in this study. ERDAS imagine was used in the remote sensing image pre-processing, image classification and accuracy assessment. Some specific image processing operations were done using the ArcGIS software

3.3 Method

The methods used for the research are stated in the following section.

3.3.1 Image Acquisition and Pre-processing

Geometric and radiometric corrections were performed on the imageries in order to correct for altitude and attitude, scanner distortions, earth motion, variable detector response, *etc.* using the spatial modeller tool in ERDAS Imagine software.

3.3.2 Classification of Images

Supervised classification was performed to classify the image into different land use changes as supervised classification has high accuracy to that of unsupervised classification since the classes were trained. Hence, selected control points that included the LULC classes were sampled to create a signature file to help train the algorithm to classify the entire study areas. Care was taken to minimize error by avoiding mixed pixels, and an effort was made to include areas relatively uniform in spectral pattern.

Maximum likelihood classifier was used for the supervised classification. The training data collected from the field study was used for the classification of 2011 ETM+ satellite image whereas the classification of both 2000 TM and 1990 TM images were georeferenced with Google map and topographic map. Land cover was classified under six types as described in Table 3.2.

Table 3.2 Characteristics of LULC types

LULC	**Description**
Closed/riverine vegetation	very active dense shrub vegetation with scattered trees along water bodies, which looks greenish even in the dry season due to the moisture content
Open/riverine vegetation	thick mat of vegetation, much closed fresh greenish bushes
Dense Shrub	A mixture of shrub (smaller plants) and herbs
Grass	a mixture of all forms of grasses and sparsely distributed herbs

Built up / bare surfaces	areas with intense infrastructural developments and exposed surfaces due to human activities or natural factors
Water body	The main water body of study- i.e. The Weija reservoir and the Densu river.

3.3.3 Post Classification

After combining different classes, the classified images were filtered before producing a final output. Unclassified and false classification was removed.

3.3.4 Accuracy Assessment

After completion of the image classification, the accuracy of the supervised classification was assessed and Kappa coefficient error matrixes were also determined based on classification result of Landsat images.

3.3.5 Change Detection and Analysis

Finally, the classified images in the ERDAS Imagine 9.1 were converted to vector (ESRI shapefile) and were exported to ArcGIS 10 in raster grid for map preparation. The changes in the land were calculated using the raster calculator. The analysis and interpretation of the different aspects of numeric data of the land use dynamics was done in Microsoft Excel. The results were then presented in maps, tables, graphs and charts.

3.3.6 Rate of Change Detection

The formula below was used to estimate the rate of change of forest cover and the land use pattern between 1990 and 2011.

$$Rate\ of\ Change = \left[(a_2/a_1)^{\frac{1}{n}} - 1\right] \times 100 \text{ (Pandit, 2011)}$$

Where a_1 = Base year data

a_2 = end time data

n = number of years

3.3.7 Spatial Projection

The spatial projection was done with the equations in the plot showing the trend patterns of the various LULC classes within the twenty-one years of the study. These are;

For Water body, $y = 0.1266x - 78.323$

For built-up/bare surface, $y = 15.671x - 31048$

For closed Riverine Vegetation, $y = -4.1287x - 8312.6$

For Grass, $y = -2.0864x + 4239.2$

For Dense Shrub, $y = -1.0327x + 2335.2$

For Open Riverine Vegetation, $y = -8.5499x + 17422$

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Result

The results are shown in this section according to the specific objectives.

4.1.1 Extent of Change

The results of the extent of change are presented in the following section.

4.1.1.1 Land Use Land Cover Classification for 1990

The LULC classification for 1990 satellite image (Figure 4.1) showed that majority of the study area are under Open riverine vegetation and Dense Shrub accounting for 419.113 km^2 (35.423%) and 237.415 km^2 (20.066%) respectively (Table 4.1 and Figure 4.3), while Closed riverine vegetation, 110.390 km^2 (9.330%); Grass, 89.691 km^2 (7.581%); Built up/Bare surfaces, 152.880 km^2 (12.921%) and Water body accounted for 173.678 km^2 (14.679%).

4.1.1.2 Land Use Land Cover Map of 2000

The Supervised classification procedures applied to the 2000 Landsat image yielded land cover map (Figure 4.2) with the Dense Shrub and Open riverine vegetation occupying the largest area coverage of 351.413 km^2 (29.701%) and 301.628 km^2 (25.493%) as compared to other LULC classes. The other LULC classes are Built up/Bare surfaces which cover an area of 264.987 km^2 (22.396%), Water body174.591km^2 (14.756%), Grass 61.972 km^2 (5.238%) and Closed riverine vegetation covers 28.576 km2 (2.415%) as seen in Table 4.2 and Figure 4.4.

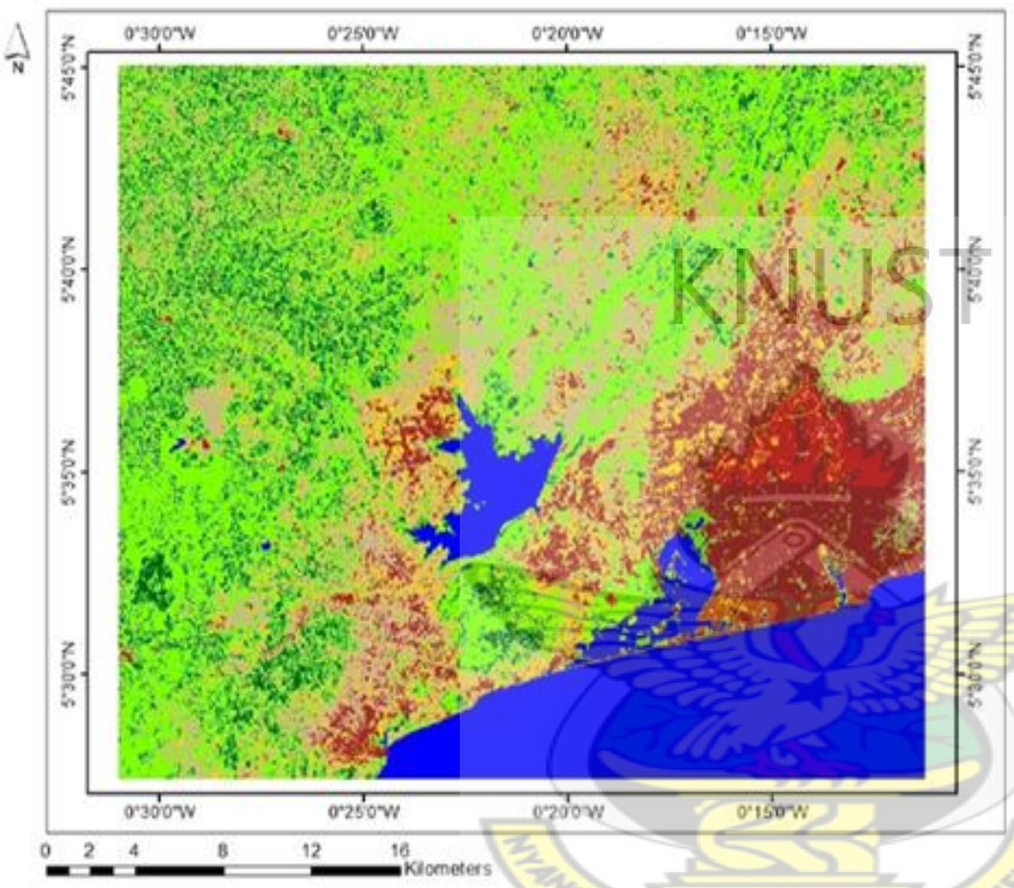
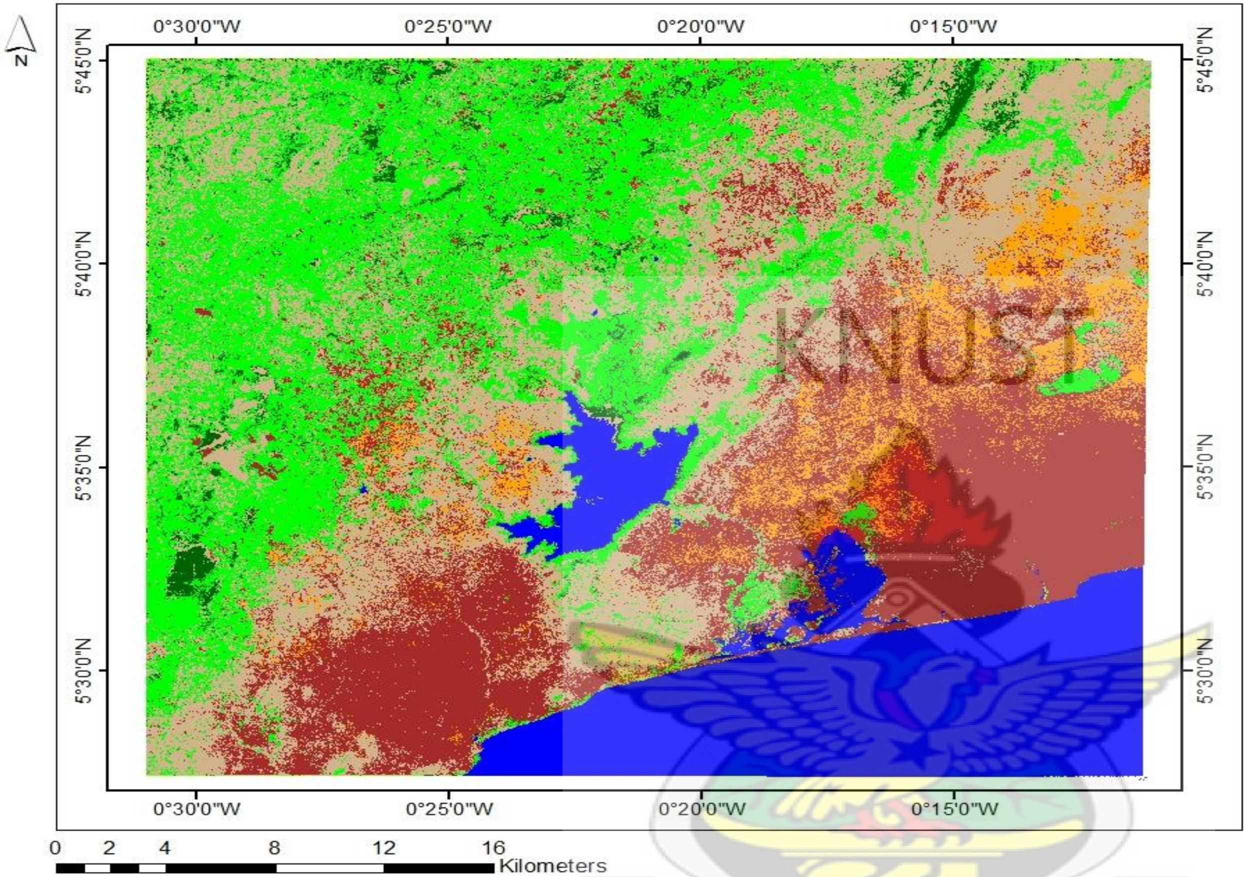


Figure 4.1: Supervised Classified Map of the study area of 1990



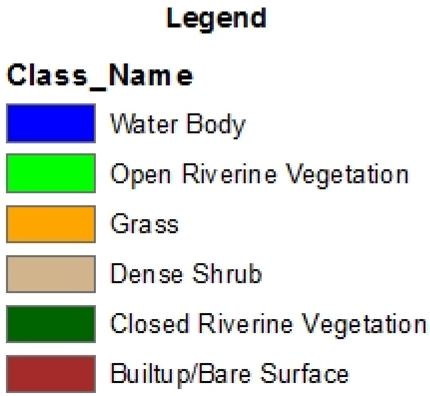


Figure 4.2: Supervised Classified Map of the study area of 2000

Table 4.1 LULC for 1990

Class	Sqkm	%
Closed riverine vegetation	110.390	9.330
Open riverine vegetation	419.113	35.423
Dense Shrub	237.415	20.066
Grass	89.691	7.581
Built up /Bare surfaces	152.880	12.921
Water body	173.678	14.679
Total	**1183.1670**	**100.000**

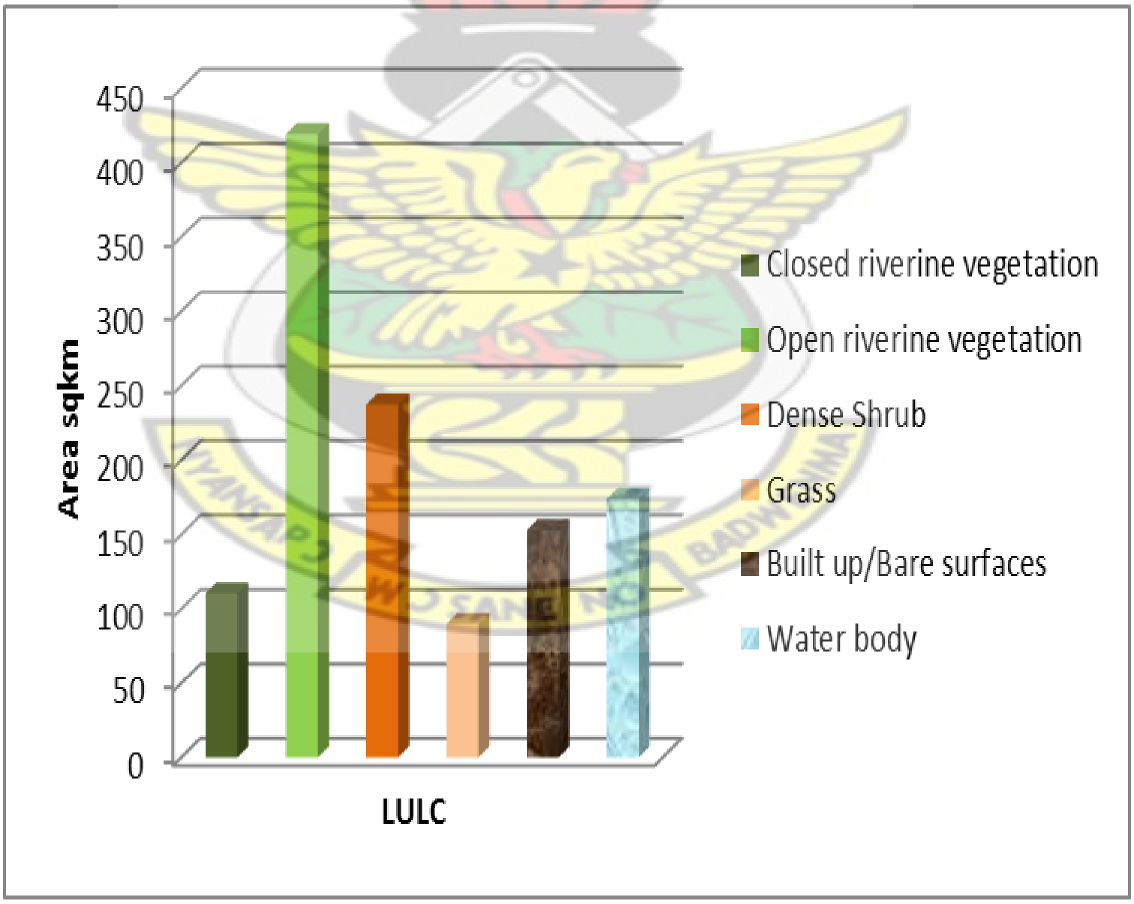


Figure 4.3 Areas (km^2) of LULC classes in 1990

Table 4.2 LULC for 2000

Class	Sqkm	%
Closed riverine vegetation	28.576	2.415
Open riverine vegetation	301.628	25.493
Dense Shrub	351.413	29.701
Grass	61.972	5.238
Built up /Bare surfaces	264.987	22.396
Water body	174.591	14.756
Total	**1183.167**	**100**

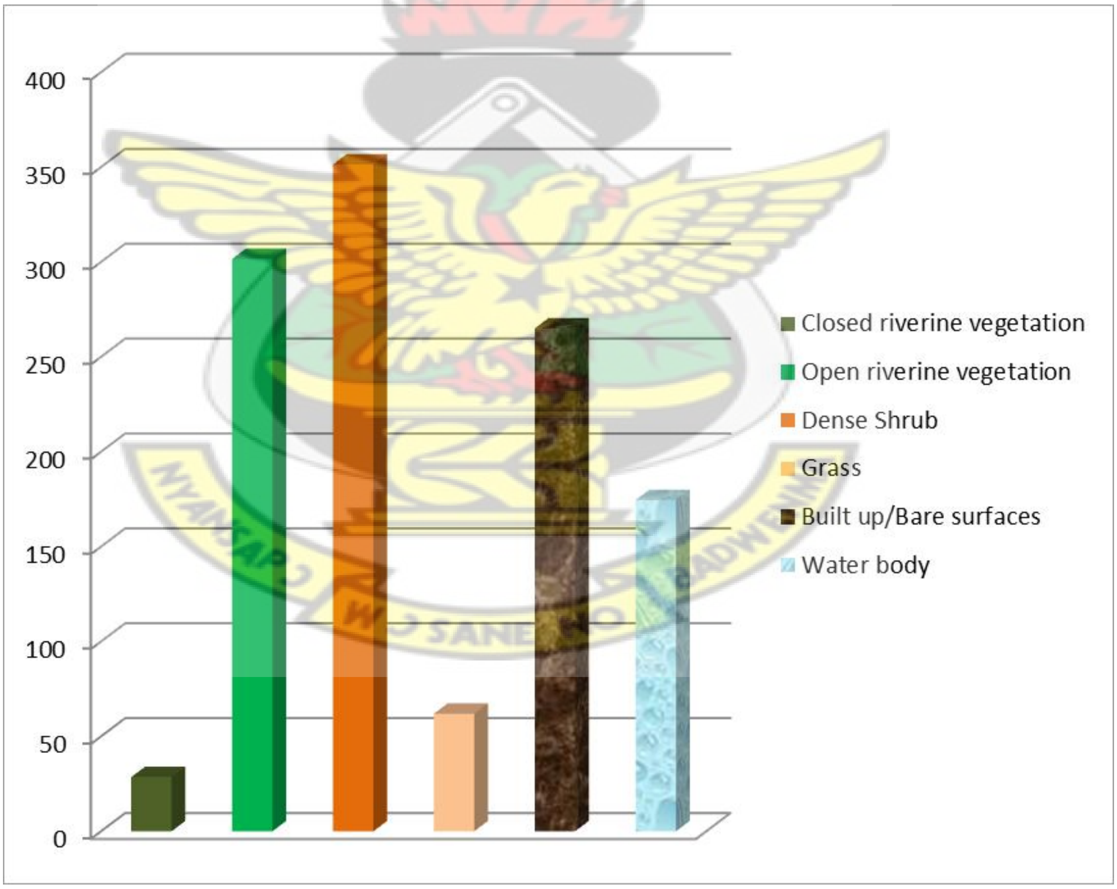


Figure 4.4 Areas (km^2) of LULC classes in 2000

4.1.1.3 Land Use

Land Cover Map of 2011

The land cover analysis for 2011 from Landsat ETM+ imagery showed that majority of the study area in the cover map showed in Figure 4.5 is covered by Built up/Bare surfaces 480.579 km^2 (40.618 %), while Dense Shrub cover and Open riverine vegetation accounting for 219.614 km^2 (18.562 %) and 238.565 km^2 (20.163 %) of the landmass of the study area, respectively. This shows that these cover categories are dominant while the remaining categories, water body, Grass cover and Closed riverine vegetation, accounted for 176.325 km^2 (14.903%), 45.665 km^2 (3.859 %) and 22.421 km^2 (1.895 %) respectively as shown in Table 4.3 and Figure 4.6.

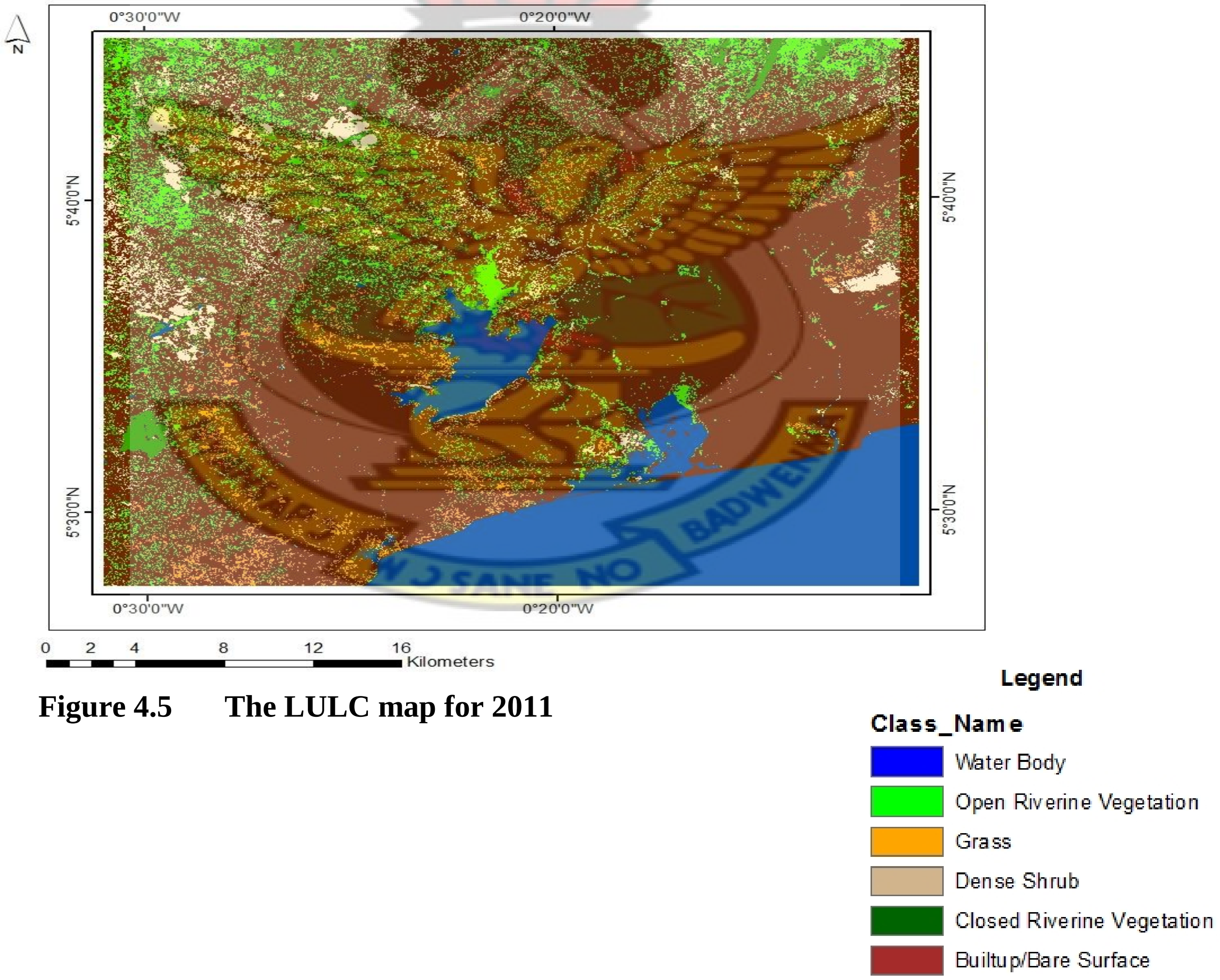


Figure 4.5 The LULC map for 2011

Table 4.3 LULC for 2011

Class	Sqkm	%
Closed riverine vegetation	22.421	1.895
Open riverine vegetation	238.565	20.163
Dense Shrub	219.614	18.562
Grass	45.663	3.859
Built up /Bare surfaces	480.579	40.618
Water body	176.325	14.903
Total	**1183.167**	**100.000**

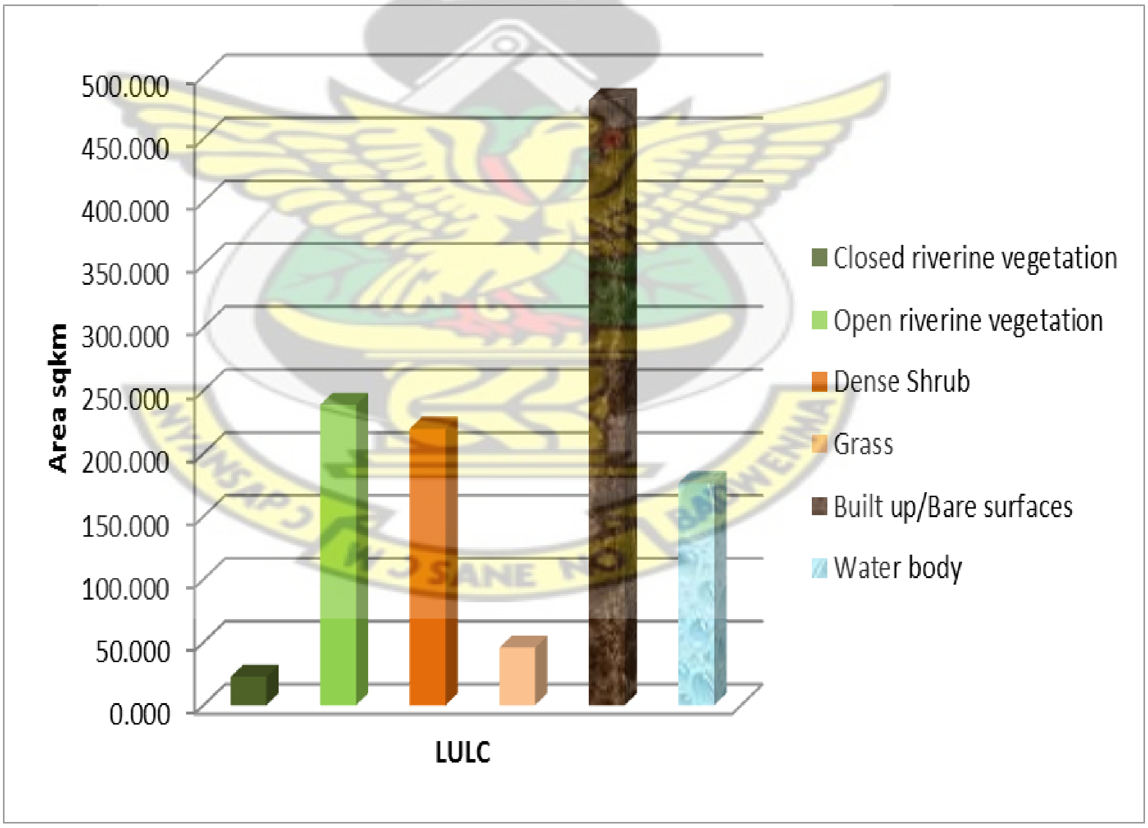


Figure 4.6 Areas (km^2) of LULC classes in 2011

4.1.1.4 Accuracy Assessment

The accuracy assessment was performed on classification results. The accuracy was assessed using the results of error matrix and accuracy statistics (Table 4.4, 4.5 and 4.6) for satellite imagery for 2011, 2000 and 1990 respectively. Reference data listed in the columns of the error matrix represents the number of correctly classified samples. Accuracy statistics lists different statistical measures such as producer's accuracy, user's accuracy and kappa statistics for each class. The overall accuracy of 86.00%, 85.00% and 91.00% was found for 1990, 2000 and 2011 with a kappa statistic of 0.8204, 0.8125 and 0.8376 respectively.

4.1.2 Spatial Pattern and Nature of the Change

4.1.2.1 Spatial Pattern for 1990 to 2000

Table 4.7 summaries the LULC conversion from 1990 to 2000 from the Figure 4.7. The diagonal figures shows areas not affected by the conversion or remain unchanged, total area of 581.100 km^2 of the study area representing 49.11%. Open Riverine made the highest conversion of 156.147 km^2 representing 13.197% of the study area to Dense Shrub. This is followed by Dense shrub to Built-up/Bare Surface convention of 62.679 km^2 representing 5.298%. Other high conversion are Open Riverine to Built-up/Bare surface 46.480 km^2 representing 3.928%, Closed Riverine to Open Riverine 46.133 km^2 (3.900%), Closed Riverine to Dense Shrub 40.999 km^2 (3.465%), grass to built-up/bare surface 31.511 km^2 (2.663%), closed riverine to built-up/bare surface 12.794 km^2 (1.081%) and water to built-up/bare surface 3.143 km^2 (0.265%).

4.1.2.2 Spatial Pattern for 1990 to 2011

The diagonal figures shows areas not affected by the conversion or remain unchanged, total area of 539.579 km^2 of the study area in Table 4.8, representing 45.60%. Table 4.8 summaries the LULC conversion from 1990 to 2011 with Open Riverine made the highest conversion of 130.257 km^2 representing 11.009% of the study area to Dense Shrub. This is followed by Dense shrub to Built-up/Bare Surface convention of 129.495 km^2 representing 10.945%. Other high conversion are Open Riverine to Built-up/Bare surface 89.449 km^2 representing 7.560%, Grass to Built-up/Bare Surface 73.428 km^2 (6.206%) and Closed Riverine to Built-up/Bare Surface 61.755 km^2 (5.219%). Other conversions worth noticing are Closed riverine to Open Riverine 30.736 km^2 (2.598%), Open Riverine to Grass 26.088km^2 (2.205%) and Dense Shrub to Open Riverine 25.028 (2.115%).

4.1.2.3 Nature of the change

The nature of the change analysis of the Weija catchment reveals a change in size of all six LULC over the 21 year period of the study is captioned under Variability of various LULC types (Figure 4.9), LULC trend (Figure 4.10 and Table 9), LULC Proportion (Figure 4.11 and Table 4.10) and Rate of Change (Table 4.11). Built-up experienced the most positive change while open riverine experienced the most negative change.

Table 4.4 Error Matrix for 2011 land-use-land-cover map

Class Name	Reference Total	Classified Total	Number Correct	Producers Accuracy	Users Accuracy	Kappa
Unclassified	0	0	0	---	---	---
Water Body	13	15	13	100.00%	86.67%	0.8467
Dense Shrub	6	4	4	66.67%	100.00%	1.0000
Closed Riverine Vegetation	4	1	1	25.00%	100.00%	1.0000
Open Riverine Vegetation	13	11	10	76.92%	90.91%	0.8955
Grass	3	2	2	66.67%	100.00%	1.0000
Built-up/Bare Surface	61	67	61	100.00%	91.04%	0.7704
Totals	100	100	91			

Overall Classification Accuracy = 91.00%

Overall Kappa Statistics = 0.8376

Table 4.5 Error Matrix for 2000 land-use-land-cover map

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy	Kappa
Unclassified	0	0	0	---	---	---
Water Body	22	22	13	65.00%	100.00%	1
Built-up/Bare Surface	21	19	18	85.71%	94.74%	0.9334
Open Riverine Vegetation	26	29	25	96.15%	86.21%	0.8136
Closed Riverine Vegetation	6	4	4	66.67%	100.00%	1
Dense Shrub	22	25	22	100.00%	88.00%	0.8462
Grass	3	1	1	33.33%	100.00%	1
Total	100	100	83			
Overall Classification Accuracy = 85.00%						
Overall Kappa Statistics = 0.8125						

Table 4.6 Error Matrix for 1990 land-use-land-cover map

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy	Kappa
Unclassified	---	---	---	---	---	---
Water Body	12	14	12	100.00%	85.71%	0.8377
Open Riverine Vegetation	33	36	31	93.94%	86.11%	0.7927
Built-up/Bare Surface	21	19	16	76.19%	84.21%	0.8001
Closed Riverine Vegetation	12	6	6	50.00%	100.00%	1
Dense Shrub	18	20	17	94.44%	85.00%	0.8171
Grass	4	5	4	100.00%	80.00%	0.7917
Overall Classification Accuracy = 86.00%						
Overall Kappa Statistics = 0.8204						

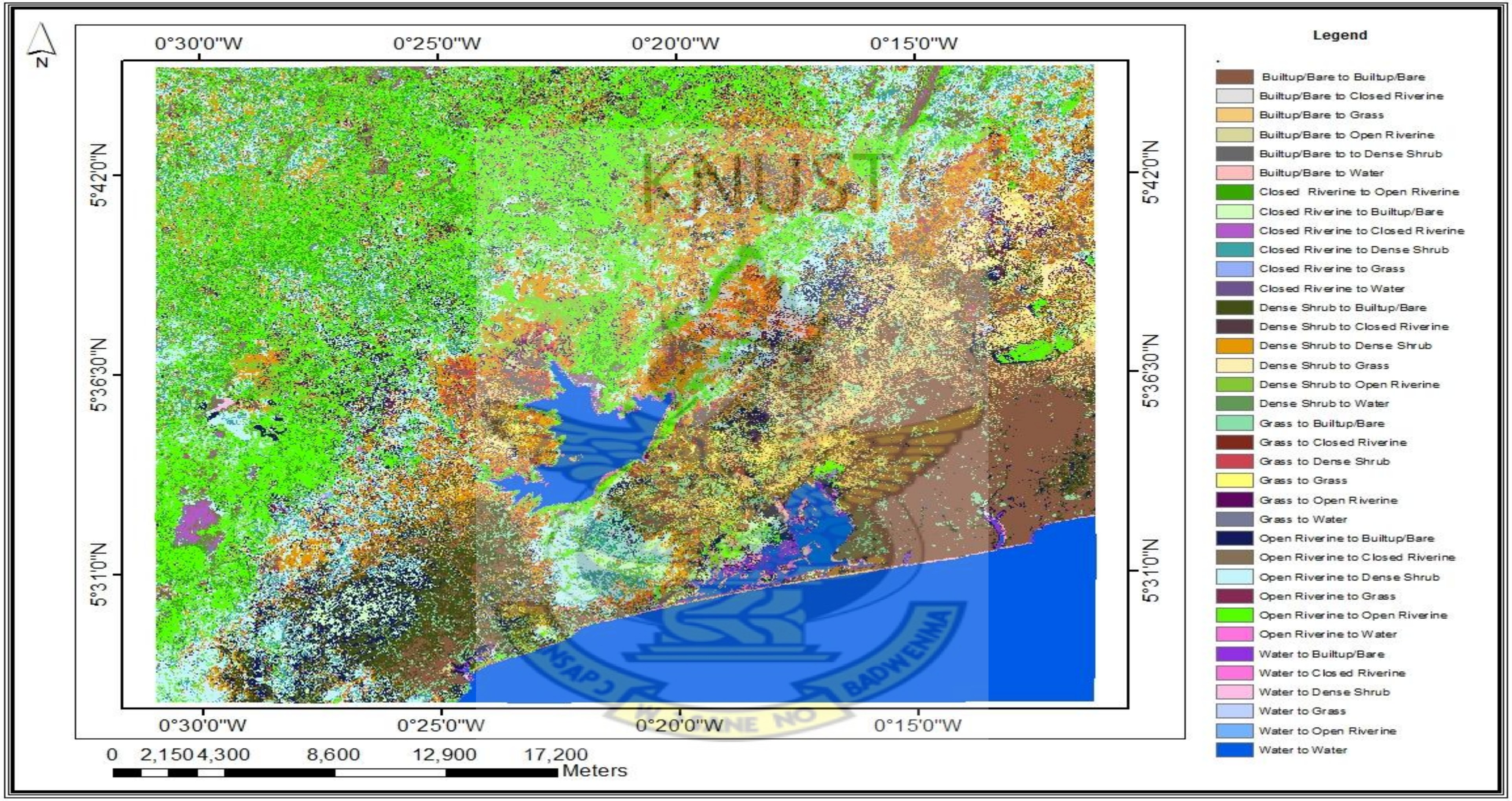


Figure 4.7 **Major LULC conversions within the Weija catchment 1990 to 2000**

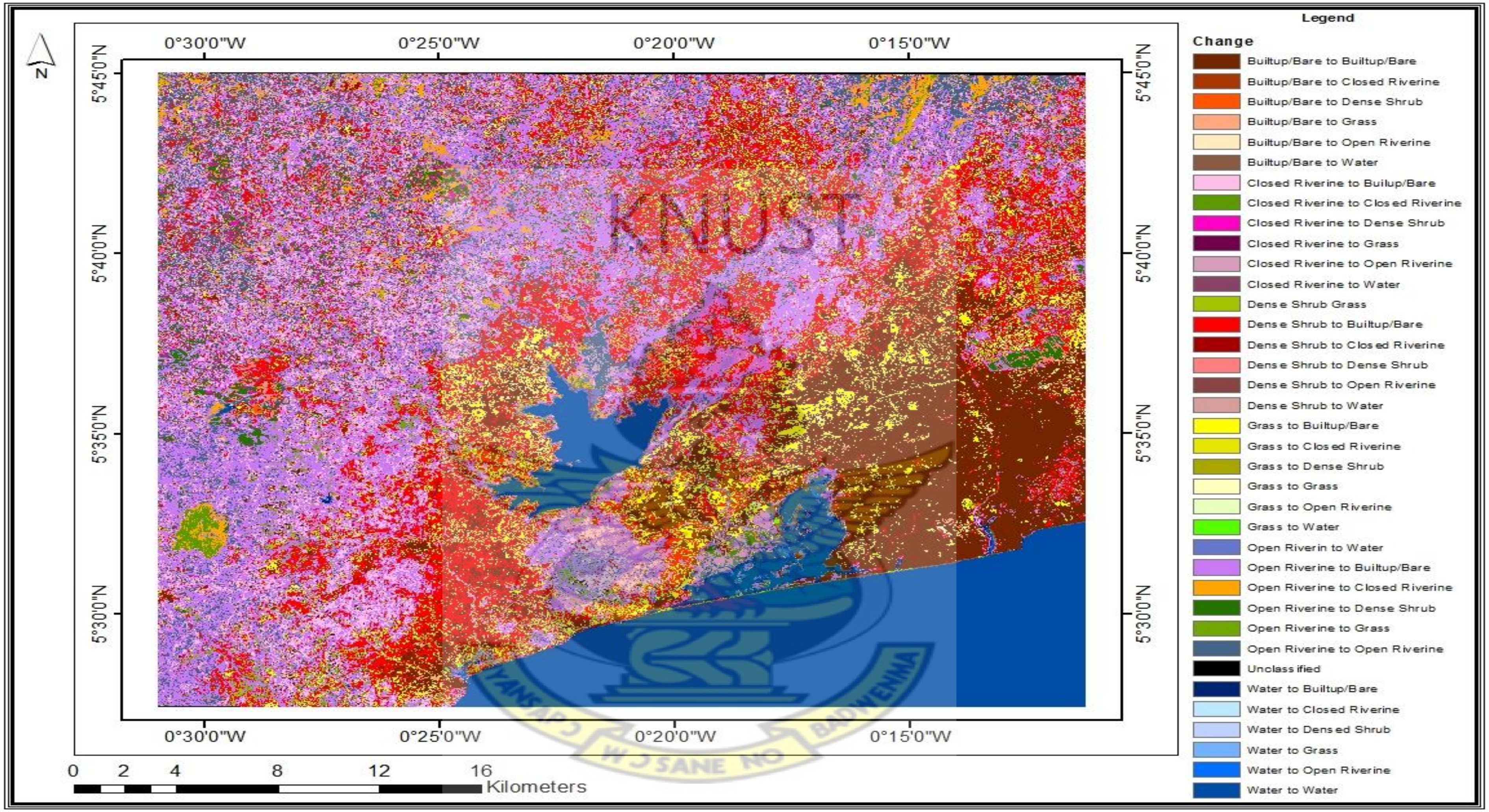


Figure 4.8 Major LULC conversions within the Weija catchment 1990 to 2011

Table 4.7 LULC conversions, from 1990 to 2000

		1990							
		Unclassified	Water	Built-up/Bare	Open Riverine	Closed Riverine	Dense Shrub	Grass	2000 Total
2000	Unclassified	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Water	0.000	**168.290**	1.717	2.993	0.610	0.175	0.253	174.037
	Built-up/Bare	0.000	3.143	**108.265**	46.480	12.794	62.679	31.511	264.871
	Open Riverine	0.000	0.754	4.724	**185.572**	46.133	52.618	12.725	302.525
	Closed Riverine	0.000	0.208	0.124	19.847	**5.950**	2.336	0.497	28.961
	Dense Shrub	0.000	0.945	20.159	156.147	40.999	**101.963**	31.412	351.624
	Grass	0.000	0.012	20.687	9.442	1.766	18.182	**11.060**	61.148
	1990 Total	**0.000**	**173.350**	**155.676**	**420.480**	**108.250**	**237.953**	**87.458**	**1183.167**

Table 4.8 LULC conversions, from 1990 to 2011

		1990							
		Unclassified	**Water**	**Built-up/Bare**	**Open Riverine**	**Closed Riverine**	**Dense Shrub**	**Grass**	**2011 Total**
2011	**Unclassified**	**0.000**	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
	Water	0.000	**170.322**	1.880	2.529	1.013	0.343	0.120	**176.207**
	Built-up/Bare	0.000	2.100	**124.912**	89.449	61.755	129.495	73.428	**481.139**
	Open Riverine	0.000	0.590	20.150	**155.180**	30.736	**25.028**	6.879	**238.563**
	Closed Riverine	0.000	0.013	0.111	16.020	**6.010**	0.120	0.147	**22.421**
	Dense Shrub	0.000	0.140	2.940	130.257	8.335	**76.238**	2.030	**219.940**
	Grass	0.000	0.038	2.320	26.088	2.344	7.190	**6.917**	**44.897**
	1990 Total	**0.000**	**173.203**	**152.313**	**419.523**	**110.193**	**238.414**	**89.521**	**1183.167**

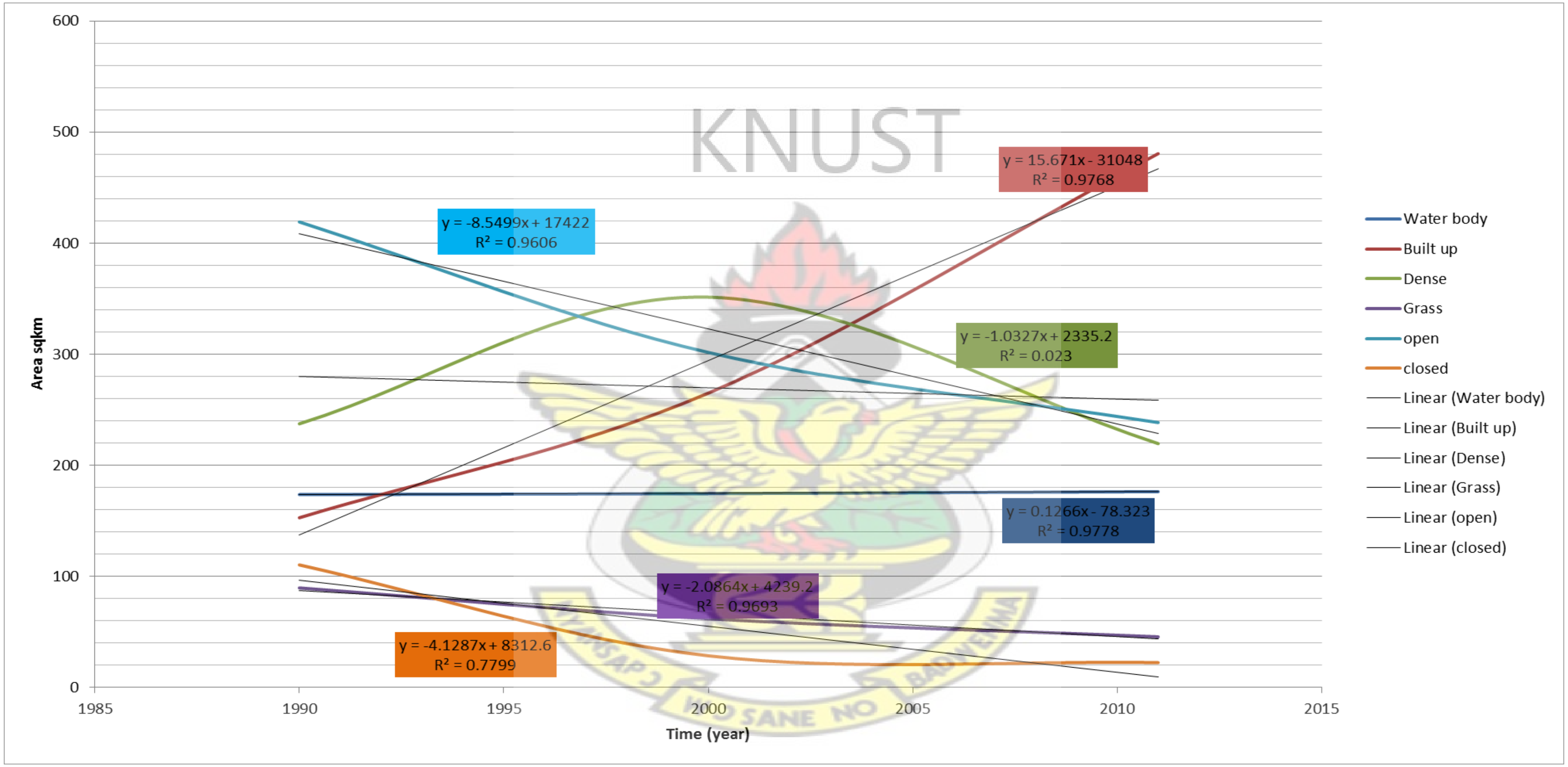


Figure 4.9 **A plot showing the influence of duration of LULC trends**

4.1.3.2 LULC trends, 1990 to2011

The trend analysis of the Weija catchment reveals a change in size of the six LULC types over the 21 year period of the study (Table 4.9 and Figure 4.10) and Figure 4.9 shows the trend durations of the LULC types. Built-up experienced the most positive change while Open riverine experienced the most negative change.

Table 4.9 LULC Trend from 1990 to 2011

	Change	
LULC	**Km^2**	**%**
Water	3.004 increase	0.254
Built-up/Bare	328.826 increase	27.792
Open Riverine	-180.960 decrease	-15.295
Closed Riverine	-87.772 decrease	-7.418
Dense Shrub	-18.474 decrease	-1.561
Grass	-44.624 decrease	-3.772

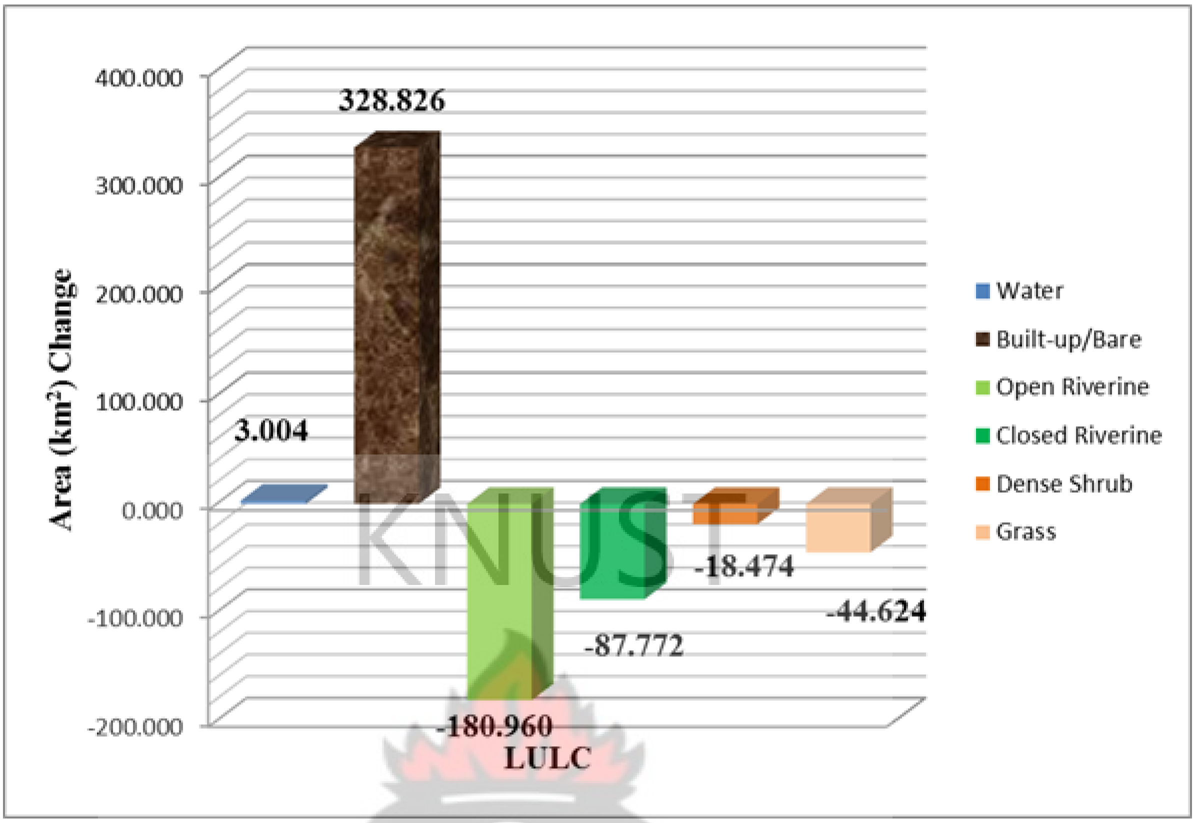


Figure 4.10 LULC change trend, 1990 to 2011

4.1.3.3 LULC Proportion for 1990, 2000, and 2011

Table 4.10 represent the LULC proportions of 1990, 2000 and 2011 while Figure 4.11 shows the graphical representation of the LULC proportions for the respective years. The majority of the LULC changes took place within Built-up, Dense Shrub, Closed Riverine and Open Riverine environment while the remaining classes made slight changes over the 21year period under study. In 1990, open riverine covers the highest proportion of the land area, followed by Dense Shrub, Water body, Built-up, Closed riverine and Grass respectively. In 2000 Dense Shrub occupied the highest proportion and orderly followed by Open riverine, Built-up, Water body, Grass and Closed riverine. Built-up has the highest area coverage in 2011 followed by Open riverine, Dense Shrub, Water body, Grass and Closed riverine coverage.

Table 4.10 LULC Proportion for 1990, 2000 and 2011

Class	Area (km^2)			Area (%)		
	1990	2000	2011	1990	2000	2010
Closed Riverine Vegetation	110.39	28.576	22.421	9.33	2.415	1.895
Open Riverine Vegetation	419.113	301.628	238.565	35.423	25.493	20.163
Dense Shrub	237.415	351.413	219.614	20.066	29.701	18.562
Grass	89.691	61.972	45.663	7.581	5.238	3.859
Built up/Bare Surfaces	152.88	264.987	480.579	12.921	22.396	40.618
Water body	173.678	174.591	176.325	14.679	14.756	14.903
Total	**1183.167**	**1183.167**	**1183.167**	**100**	**100**	**100**

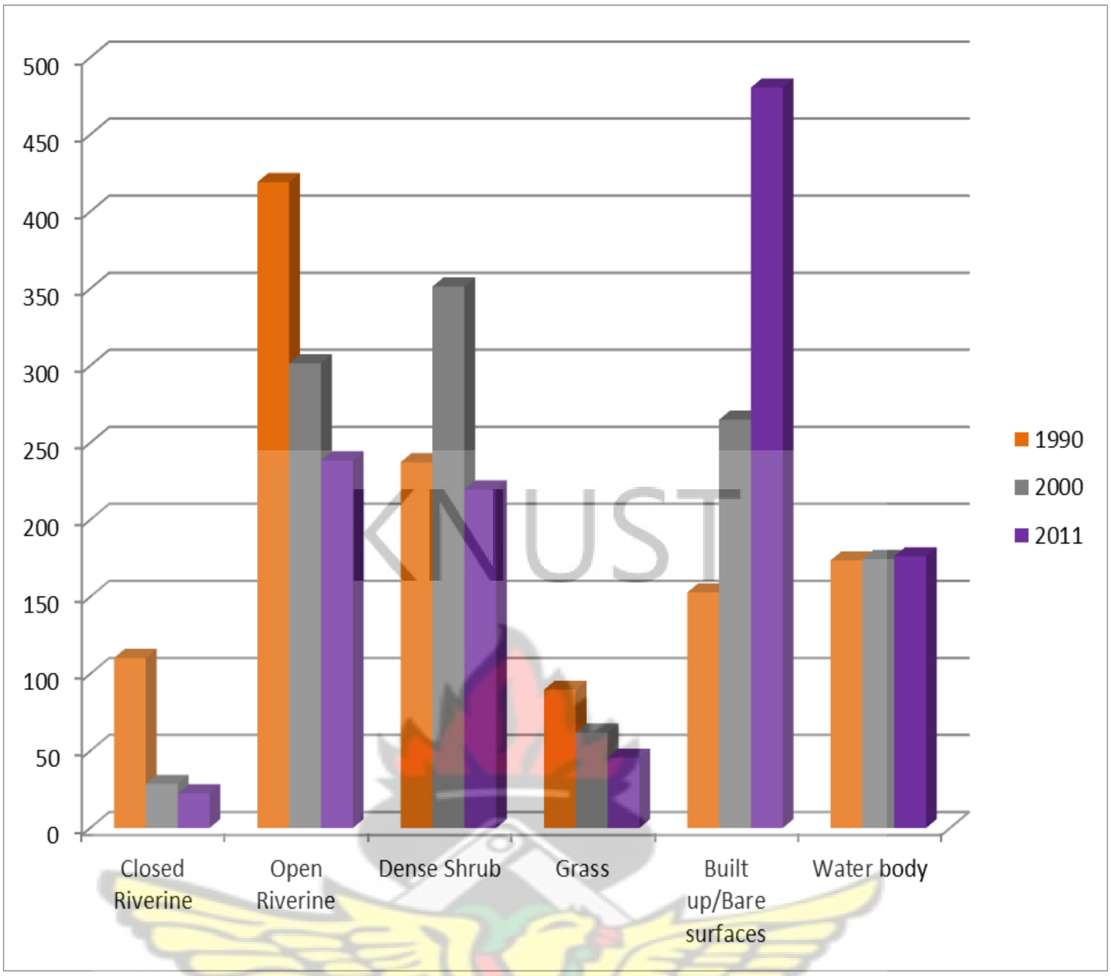


Figure 4.11 The graphical representation of the LULC proportions for 1990, 2000 and 2011.

4.1.3.4 Rate of Change of Detection

The rate of change of forest cover and the land use pattern between 1990 and 2011 is as follows in Table 4.11;

Table 4.11 Rate of Change of LULC types between 1990 and 2011

LULC Types	1990-2000 Percentage (%)	2000-2011 Percentage (%)
Closed Riverine Vegetation	-12.641	-2.181
Open Riverine Vegetation	-3.236	-2.110
Dense Shrub	3.999	-4.184
Grass	-3.629	-2.738
Built up/Bare surfaces	5.654	5.561
Water body	0.052	0.090

Note: Negative sign represent a decrease

4.1.3 Future Pattern of the Change

Figure 4.12 and Table 4.12 summaries the future pattern of the change from 2011 to 2020 showing a lot of built-up expansion which has an area coverage of 607.42 km^2 representing 51.369%. This is due to the conversion of other LULC types to built-up coverage. Population expansion and socioeconomic activities within the catchment are the major causes of these conversions. Population growth is widely recognized as a key force behind environmental change, especially in developing countries. The other land cover classes would be water, 177.409 km^2, representing 15.003%; Dense 249.146 km^2, representing 21.070%; Grass 24.672 km^2, 2.086%, open riverine 151.202 km^2, 12.787% and the existence of closed riverine would negligible or near extinct. The projections are based on the equations in Figure 4.9.

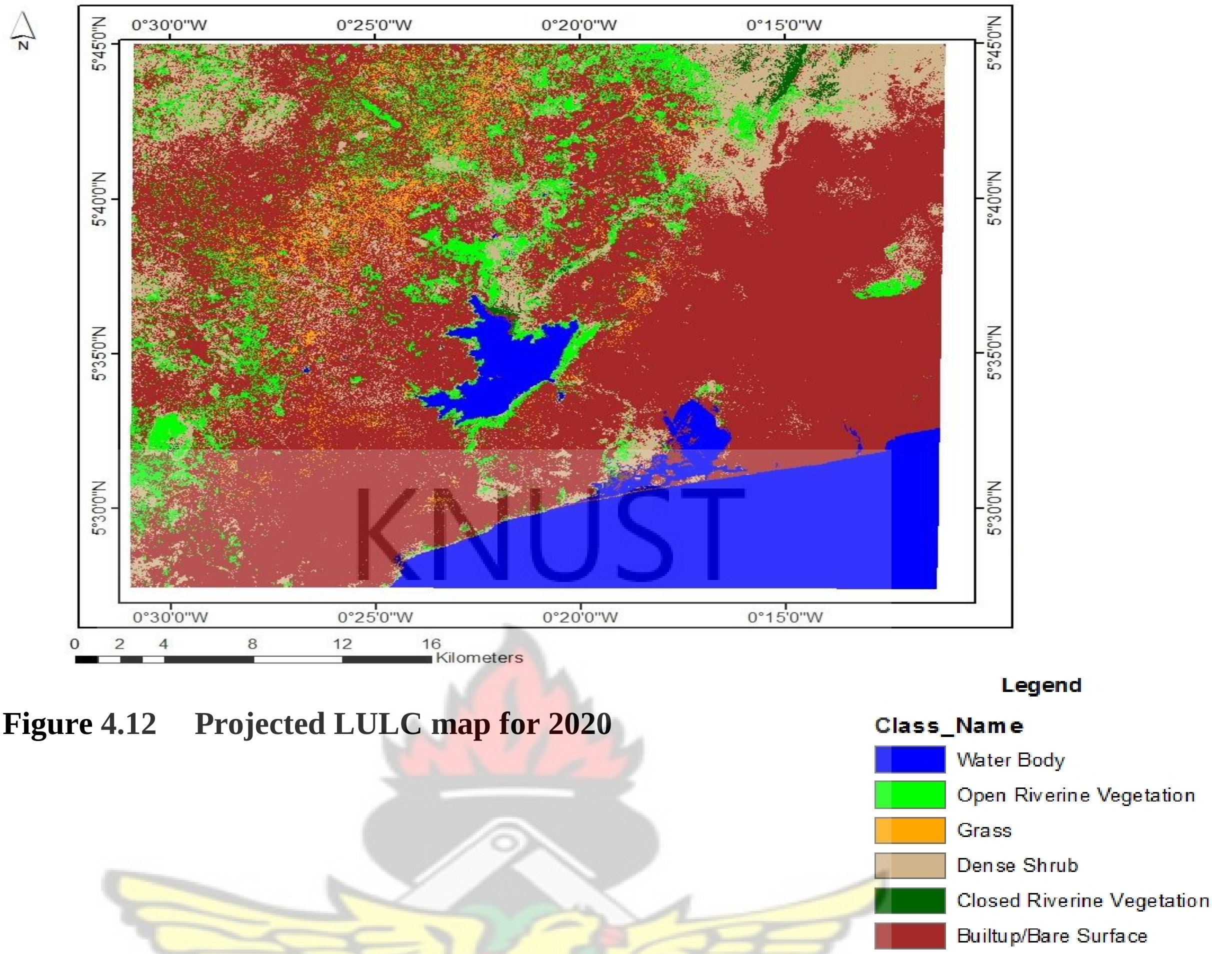


Figure 4.12 Projected LULC map for 2020

Table 4.12 Projected LULC for 2020

LULC Class	**Area (km²)**	**%**
Built up/Bare Surface	607.535	51.348
Water	177.524	15.004
Dense Shrub	249.261	21.067
Grass	24.787	2.095
Open Riverine	151.317	12.789
Closed Riverine	-27.259	-2.304
Total	**1183.167**	**100.000**

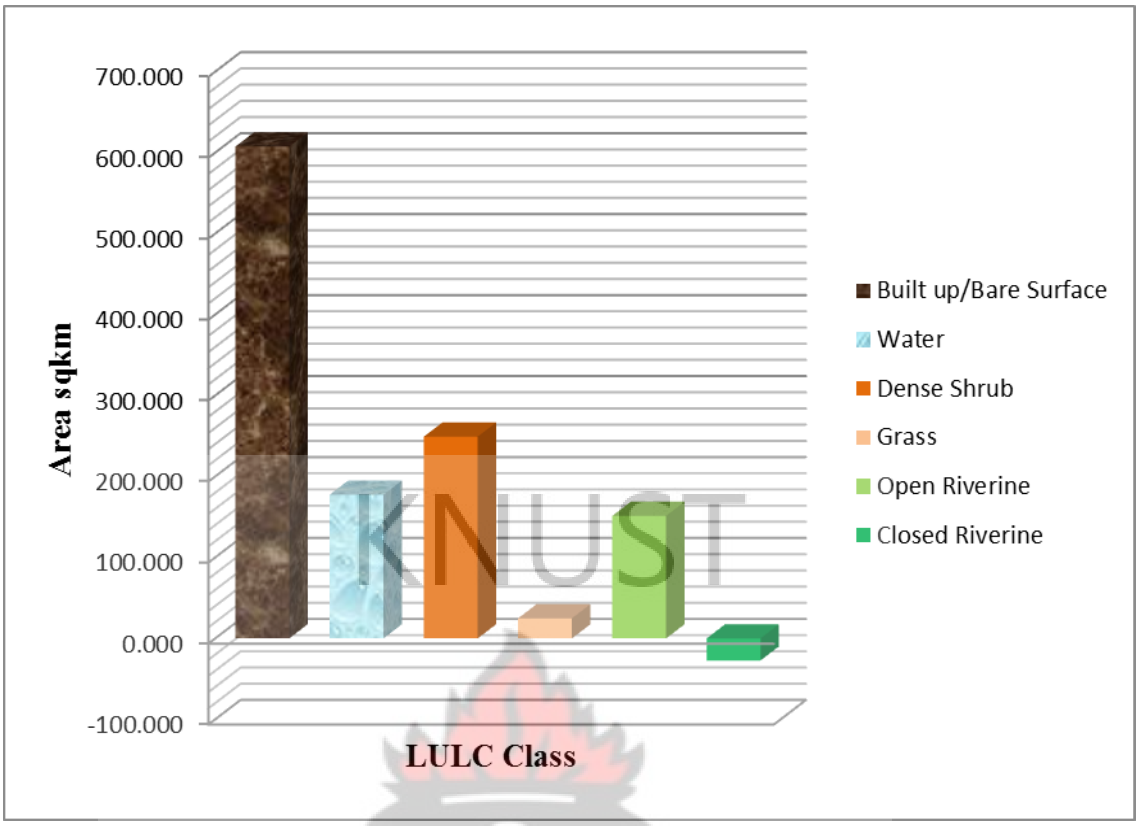


Figure 4.13 Projected Areas (km^2) of LULC classes in 2020

4.2 Discussion

4.2.1 Extent of Change

LULC is often caused by multiple interacting factors. The extent of LULC change vary and their dynamic interactions result in diverse chains and trajectories of change, depending upon the specific environmental, social, political and historical contexts from which they arise. From 1990 to 2000 and 2011, the surface area of the reservoir increased from 173.678 km^2 to 174.591 km^2 and finally 176.325 km^2. This Phenomenon according to Kumah and Ashley (2008), is due to the fact that the residual runoff is in excess of water abstraction. It can be observed that increasing of the unsustainable land use activities within and around the waterways and increase in global warming thus giving rise to increase in water level. Within the same year under review 1991 to 2000 and 2011, Built-up area on the other hand has increased from 152.88 km^2 to 264.987 km^2 and finally to 480.579 km^2. Unlike river and built-up area, there is a significant disparity in the vegetation cover. Thus, vegetal cover decreased from a total 856.609 km^2 in 1990 to 743.589 km^2 in 2000 and in 2011 it further decreased to 526.263km^2. In the vegetal cover, the closed/riverine suffers the most loss from 110.39 km^2 to 28 km^2 and finally 22.421 km^2.

4.2.2 Spatial Pattern and Nature of the Change

4.2.2.1 Spatial Pattern of the Change

An important aspect of change detection is to determine what is actually changing to what *i.e.* which land use class is changing to the other. This information will reveal both the desirable and undesirable changes and classes that are "relatively" stable overtime. This information will also serve as a vital tool in management decisions.

Table 4.7 and 4.8 summaries the LULC conversion from 1990 to 2000 and 1990 to 2011. The diagonal figures shows areas not affected by the conversion or remain unchanged, total area of 581.10 km^2 of the study area representing 49.11% in 1990 to 2000 and 539.579km^2 (45.60%). From 1990 to 2000 and 1990 to 2011, Open Riverine made the highest conversion of 156.147km^2 and 130.257 km^2 representing 13.197% and 11.009% of the study area respectively to Dense Shrub. The amount of gain by Dense shrub explained the rise of Dense shrub coverage before the year 2000.

Table 4.8 clearly shows the conversion of Closed riverine, Open riverine, Dense shrub and Grass to Built-up/ Bare surface. These explain the rapid commercialization of the catchment area owing to the urbanization of Accra and crave for the space for residential and commercial activities.

4.2.2.2 Nature of the Change

4.2.2.2.1 LULC Trend and Proportion

From Table 4.9 and Figure 4.10, there seem to be a negative change *i.e.* a reduction in the vegetal cover between 1990 and 2011. This may be connected to the highly commercialization of the area. This was evident in the decrease in Open riverine by 180.960 km^2 (15.295%) followed by Closed riverine, Grass and Dense Shrub by 87.772 km^2 (7.418%), 44.624 km^2 (3.772%) and 18.474 km^2 (1.561%) respectively while both Built-up /Bare surface and Water body both increased by 328.826 km^2 (27.792%) and 3.004 km^2 (0.254%) respectively. However, Figure 4.9 show the graphical representation of the trends with the decreases in the vegetal cover and increases in the Built-up and Water body. Something worth noticing and commenting on is the attitude of Dense Shrub before and after year 2000. Dense Shrub gained 113.998 km^2 before 2000 and lost 131.799 km^2 after 2000. This shows the quantum of Dense Shrub cover that was converted to Built-up area in Table 4.7 and 4.8.

From Table 4.10 and Figure 4.11, there seems to be a sharp rise in the Built-up /Bare surface by 215.592km^2 from 264.987km^2 in 2000 to 480.579 km^2 in 2011. This may be due to many projects that were embarked on after the area in February, 2008 was inaugurated as a new Municipality. This attracted a lot of people to the area thus contributing to the physical expansion of the catchment area.

Furthermore, water body seem to gain 3.004 km^2 (0.254%) through this period. An important factor which needs to be acknowledged is the effect of the poor land use practices in the catchment area on runoff into the Reservoir as observed by Kumah and Ashley, (2008). These practices enumerated have resulted in vegetation loss with the potential of increasing runoff and sediments into the Reservoir. The increased runoff may create an erroneous impression because while on the one hand there appears to be excess water which will be spilled, on the other hand, siltation is occurring and raising the Reservoir bottom thereby leading to a reduction in the total volume of water available for use.

This vegetation loss leaves soils vulnerable to mass wasting (loss of equilibrium within the soils due to infiltration), which increases the rate of soil erosion by wind and water, therefore large amount of silt are moved into the reservoir.

4.2.2.2.2 Rate of Change of Detection

The rate of vegetal conversion to Built-up through the 21 years, revealed the fast shrinkage of the latter. In 1990-2000, closed riverine recorded the highest loss of a rate of 12.641% as compared to the loss of 2.181% in 2000-2011. The vegetal loss rate in Table 4.11 is higher than the nation's deforestation rate of 1.96 (Yu, 2013). This loss is compensated by the increase in the Built-up / Bare surface area mainly due to human activities.

4.2.3 Spatial Projection

The 9 year spatial projection from 2011 to 2020 was based on the correlation graph in Figure 4.9. This projection shows that 2020 projected cover map has a lot of built-up expansion which has area coverage of 607.535 km^2 representing 51.348% (Figure 4.12, Figure 13 and Table 4.12). This is due to the conversion of other LULC types to built-up coverage. Population expansion, agriculture and commercial activities within the catchment and its environs may be the major cause of these conversions if no mitigation measures are instituted.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

5.1.1 Extent of Change

This study enabled the LULC maps of Weija and its environs to be produced for the years 1990, 2000 and 2011, demonstrating the use of remotely sensed imagery to monitor vegetation over a twenty-one year period.

5.1.2 Spatial Pattern and Nature of the Change

Large areas covered with vegetation were converted to Built-up/Bare Surface over the twenty-one years due to anthropogenic activities like residential and commercial.

The trend of vegetal cover loss within the catchment could be explained by the LULC conversions to residential and industrial purposes. This loss is attributed to the built-up expansion in the catchment. The nearness of the catchment area to Accra 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 neighbouring villages for farming activities, sand winning and built-up operations. The rate of vegetal loss is higher than the nation's deforestation rate of 1.96%

The findings also showed the increase in water body and this could have consequences such as flooding due to the reservoir busting it banks.

5.1.3 Spatial Projection

Projection into the year 2020 reveals that more than half of the study area would be converted into Built-up/Bare surface. This situation would increase the impervious materials in the catchment that might have serious effect on surface temperature.

In general, using GIS and RS technique is a valuable tool in locating and predicting forest cover change and also managing natural resources. 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 analysing their trends.

5.2 Recommendation for Sustainable Land Use Practices

The problems that arise due to the land use practices in the catchment – deforestation, soil erosion, quarrying *etc*, resulting in siltation and poor precipitation and the expansion the water body are not insurmountable. Some of the measures that can be taken to reverse the negative trends in LULC and its consequences in the area are:

5.2.1 Passage and Enforcement of Environmental By-Laws

The DRBMB should enact laws in regulating the activities around the dam. The Integrated water resources management plan for the Densu Basin which is a framework providing a comprehensive and coordinated approach to the development and management of water and other by-laws should be strictly enforced by EPA, GWCL, DRBMB, and the Assembly.

5.2.2 Green buffer and dredging of the reservoir

Due the transfer of volumes of sand into the reservoir, there should be dredging to create space in the reservoir to control the increase in the surface area of the reservoir. Based on the buffer zone policy, there should be a Legislative Instrument (L.I.) on establishment and maintenance of buffer zones, and prescribe control activities for protection of river banks. There should be plans for and initiate tree planting programs and forest protection activities. This would prevent encroachment and prevent evapotranspiration.

5.2.3 Intensification and Modification of Environmental Education

Intensify public awareness raising activities on prudent use of water and its conservation, including adoption of traditional knowledge and cultural practices. Environmental awareness should also be intensified. Those who still do not realize the need for environmental protection can destroy or frustrate the effort of the majority to safeguard the environment. It is thus important that the DRBMB, Municipal Assembly and environmental institutions intensify their environmental education and sensitisation programmes with particular emphasis on the youth. The media, churches, mosques, civil groups and societies are effective channels of promoting environmental protection and particularly, the following should be given attention.

5.2.4 Managing Urban Land Use Change

It is important that necessary steps are taken to reverse the negative impacts of rapid urbanisation on land use. The stakeholders especially the Municipal Assembly must ensure that developers comply with regulations as much as possible. There should be political will on the part of government that will ensure that bye laws passed are enforced.

It’s also recommended that further work be done in the same area and even beyond, with image enhancing techniques such as NDVI in order to obtain improved results and better assessment of the study area. Again, further work should be conducted in the area to the drivers of the change and also the climatic effects of the land use change.

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