UNIVERSITY OF CAPE COAST

SPATIO-TEMPORAL INFORMATION AND ANALYSIS OF LAND USE/LAND COVER CHANGES IN THE MUNI-POMADZE WETLAND

BY

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DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature: ………………………….Date: ……………………….......

Gerald Atampugre

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

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Dr. B. K. Nyarko

ABSTRACT

Land use/land cover dynamics in wetland catchments is poorly understood; even though it is an important indicator of wetland ecological health. The study was aimed at detecting and quantifying Land Use/Land Cover (LULC) changes at the Muni-Pomadze Ramsar site in Ghana. The objective was to produce LULC maps for the area, assess the LULC dynamics during a ten year period, and establish statistical relationship between the major LULC changes and biophysical factors that influence human decisions.

Using image processing techniques, an aerial photograph of January 2005, Landsat Thematic Mapper (TM) and Ehanced Thematic Mapper (ETM) data of December 1990 and February 2000 respectively were analysed to produce land use/land cover maps for the Muni-Pomadze wetland catchments. The image analysis produced an overall accuracy of 85% and a kappa coefficient of 81%. The post classification technique involving overlay operation was applied to produce land use/land cover change map and matrix which aided the analysis of LULC dynamics in the area.

During the 10 year period, various land use/land cover units such as farm fields, rangeland, built-up, and barren-land areas increased by 20%, 20.6%, 40.5% and 13% respectively. However, closed forest, open forest, and water reduced by 23%, 8.9%, and 5.9% respectively. The logistic regression in SYSTAT established that altitude, distance to roads, rivers, and settlement were significant in explaining deforestation and afforestation.

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Finally, I will want to say a big thank you to all my friends and course mates especially Simon, Foster, Stephen, Henry for their enormous support during the study period. To my parents, Mr. and Mrs. Akurigo, God bless you for being supportive and caring.

DEDICATION

To my late aunt, Ms. Ruth Ayine Akunvane.

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LIST OF ACRONYMS

BOD	Biochemistry Oxygen Demand
CAWM	Center for African Wetland Management
CLUE	Conservation of Land Use and its Effect
CSIR	Council for Scientific and Industrial Research
CWMP	Coastal Wetland Management Programme
EO	Earth Observation
EPA	Environmental Protection Agency
EPC	Environmental Protection Council
ESRI	Environmental Systems Research Institute
ETM	Enhanced Thematic Mapper
FAO	Food and Agriculture Organization
FoE	Friends of the Earth
GEM	General Ecosystem Model
GERMP	Ghana Environmental Resource Management Project
GIS	Geographic Information System
GPC	Ground Control Points
GPS	Global Positioning System
GWCS	Ghana Wetland Conservation Strategy
HDM	Human Decision Making
ILWIS	Integrated Land and Water Information System
ITC	International Institute for Geo-information Science and
ITFM	Intergovernmental Task Force on Management

LULC	Land Use/Land Cover
MDM	Minimum Distance to Mean Classifier
MEA	Millennium Environmental Assessment
ML	Maximum Likelihood classifier
NDVI	Normalised Differential Vegetation Index
NEAP	National Environmental Action Plan
RS	Remote Sensing
TM	Thematic Mapper
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
WACAF	West and Central Africa Regional Seas Programme
WRC	Water Resource Commission
WRI	Water Research Institute

CHAPTER ONE

INTRODUCTION

Background to the study

Wetlands occupy about 6% of the earth's surface and vary according to origin, geographical location, hydro-period, chemistry, and plant species (Nyarko, 2007). They are among the most productive ecosystems in the world, comparable to rain forests and coral reefs (Costanza, Norton, & Haskell, 1992). As a result wetlands are included as waters and sites for conservation in most countries and policies have been fashioned out to manage their use. However the pattern of use becomes complex and difficult to decipher, especially when heavily influenced by human interventions. Evidence by Mitsch, Mitsch, & Turner (1994) suggests that the present day degradation and extinction rates of wetlands are at least hundreds of times higher than the long-term natural rates. The low topography of these invaluable ecosystems is cited as a contributing factor to their vulnerability to human agency especially in areas where there is an expansion of urban and rural development (Amatekpor, 1995).

Among the many contributing factors of degradation and loss of wetlands is the loss of habitat (Williams, 1993). According to Foley, DeFries, Asner, Barford, Bonan, Carpenter, Chapin, Coe, Daily, Gibbs, Helkowski, Holloway, Howard, Kucharik, Monfreda, Patz, Prentice, Ramankutty, & Snyder (2005), human activities such as farming, ranching, bush fires, and urban and rural development in most cases convert natural landscapes in wetland catchments into mosaics of natural vegetation within matrices of human-dominated land use. These Human activities in and around catchments are potential causes of degradation of most wetlands. There are well-documented relationships between the amount of urban and rural land use and water quality (e.g. Sullivan, Vorosmarty, Craswell, Bunn, Cline, & Meigh, 2006). Similar observations made earlier by McNeely, Gadgil, Leveque, Padock, & Redford (1995) indicated relationships between land use and aquatic biodiversity in streams, rivers, and lagoons. As a result it is widely accepted that in the absence of direct measurements of the health of water bodies, measurements of land use pressure and land cover change might be used to infer likely impacts on the ecosystem's health (Sullivan et al, 2006). According to them the potential land use indicators include:

- Percentage of catchment under cropping or agriculture
- Percentage of urban or rural land use, or population density
- A direct inventory of geographically varying loading

These land use/land cover (LULC) transformations are important human and nature induced environmental changes. Monitoring these changes in catchments has become an important theme of research due to the extent to which they influence both regional and global fluid systems (Meyer and Turner, 1993). In Lambin, Turner, Geist, Agbola, Angelsen, & Bruce (2001) it is indicated that land use/land cover change in catchments has enormous effect on the structure, function, and composition of a water system through the fragmentation of natural habitats.

Ghana's wetland landscape has been categorized into land use/land cover classes such as small and large scale farming, forestry, fuel wood harvesting grounds, cattle grazing grounds, urban and rural development, tree plantations, and game or park reserves (Ministry of Lands and Forestry (MLF), 1999). Asubonteng, (2007) observes that the transformation of land cover as a measure of land use change usually begins with gradual degradation of well-stocked catchments by agricultural activities, urban and rural development, fuel wood collection, salt and sand winning. The process of transfer is often completed by wildfires, illegal occupation and conversion to other land use.

Acknowledging the existence of these dynamics in wetland catchments, wetlands have been a focus of policy and strategy analysis in recent times (Ntiamoa-Baidu & Gordon, 1991). One such strategy is the Ghana Wetlands Strategy (GWS) which is aimed at achieving the guiding principles of ensuring sustainable land use within the general context of Ghana's Land Policy. The Policy seeks to promote the judicious use of the nation's land and all its natural resources by all sectors of the Ghanaian society in support of various socio-economic activities undertaken in accordance with sustainable resource use and maintenance of viable ecosystems. The Government of Ghana, as well as concerned individuals and organizations like Friends of the Earth have also made several initiatives to address the problem of wetland degradation.

Problem statement

Ghana, like many developing countries whose economies depend largely on the utilization of natural resources, is not an exception to catchments land use/land cover (LULC) change problems. The Muni-Pomadze wetland, found in the coastal savanna belt of Ghana is among the five (Songor, Owabi, Keta, and Sakumo wetlands) internationally-recognised coastal wetlands (Ramsar sites) under the Convention on Wetlands of International Importance. It was listed partly because of its importance as a breeding and nesting site for migratory and resident water birds, insects, and partly because of the potential ecological functions it could perform (Ramsar Bureau, 2002a). Unfortunately this wetland is vulnerable to degradation (Allotey, 2000). According to Wuver & Attuquayefio (2006), the degradation in and around the wetland could be largely attributed to neglect and unsustainable human activities upland.

Though regulations and policies have been enacted and aimed at maintaining the wetland's resource base, the degradation at the site is still eminent (Ghana Wildlife Division, 2007). There have been efforts by the Ghana Wildlife Division of the Forestry Commission, Water Resource Commission, and the Lands Commission to improve information and knowledge on dynamics in the wetland's catchment, but after extensive review of available literature (list some lit. And say etc), information gaps still exist in the understanding of the spatio-temporal dynamics of land use/land cover; their impact on landscape attributes like the wetland's physical extent; and the type of tools best suited for monitoring the dynamics of land use/land cover in such heterogeneous environment. Thus, this landscape-scale study seeks to address three main information gaps in the context of the Muni-Pomadze wetland:

- The capacity of Landsat TM data and GIS and RI for land use/land cover mapping in highly dynamic wetland environment
- The evolution of the LULC over time and space and
- The use of spatial models as tools for predicting relationships between LULC and the existing landscape biophysical factors.

Objectives of the study

The main objective of this research is to generate spatio-temporal information on land use/land cover (LULC) dynamics at the Muni-Pomadze Ramsar site in Winneba.

Specifically, the study seeks to:

- Produce LULC maps of the years 1990 and 2000 for the Muni Pomadze wetland Ramsar site using Landsat imageries of the respective years
- Assess LULC dynamics in the wetland site from 1990 to 2000
- Examine the relationship between catchment landscape biophysical factors and the major LULC changes in the wetland catchments and
- Identify the probable effects of LULC transfers on the wetland.

Research hypotheses

The research hypotheses for the study are:

- There is no significant relationship between LULC changes and landscape biophysical factors.
- There is no difference between the LULC in 1990 and 2000.

Rationale

The Muni-Pomadze wetland is one of the most productive ecosystems in Ghana (Gorden, Yankson, Biney, Amlalo, Tumbulto, & Kpelle, 1998). It is a Ramsar site and as such it is protected to foster the continuation of its functions. However, the Ramsar fact sheet for the Muni-Pomadze site suggests that degradation level is still significant. This situation, to a larger extent, has been attributed to the anthropogenic activities in the wetland's catchments (Amatekpor, 1995). The study is thus aimed at improving the understanding/knowlege of the dynamics of land use/land cover change in the catchments.

The role of land cover dynamics in the future of wetland health can be appreciated in full by measuring where and when changes took place, where changes were pronounced, and understanding the driving forces and mechanisms of the changes from spatio-temporal scales (Agarwal, Green, Grove, & Evans, 2001). With the use of Geographic Information System and Remote Sensing tools, areas where these changes are most pronounced are identified, mapped, and analyzed which could be a fundamental basis for management.

Again, appreciating how biophysical and human factors interact in driving land use can help make projections of future land use patterns more accurate and improve our comprehension of human responses to changes (Mather, 1986). The results of this study will be made available to appropriate institutions (District Assemblies and Wildlife Division of the Forestry Commission) to aid in the sensitization of stakeholders for improved catchment management. The output of this research could also provide the basis for policy and strategy improvement or formulation for wetland conservation. The study has the potential of encouraging further research in the Muni-Pomadze site and other catchments.

Study area

Location

The Muni-Pomadze wetland, a closed estuarine coastal lagoon, is found in the Awutu, Efutu, Senya, and Gomoa Districts of the Central Region (Figure 1). It is about 56km west southwest of Accra on the south coast of Ghana. The area is located between 05º 19'N– 05º 22' N, 00º 20'W– 00º 40' W and covers 94.61km^2 (9,461 ha) (Wuven & Attuquefio, 2006). This area is peri-urban implying rapid expansion of human activities. The wetland is bounded on the north by the Yenku A and B Forest Reserves, on the south by the Atlantic Ocean (Gulf of Guinea), to the west by the Mankwaafa, Brounye and Boaku Rivers, and to the east by the River Ayensu and the Pratu Stream. These locational characteristics make the wetland an attractive site for all sorts of human activities.

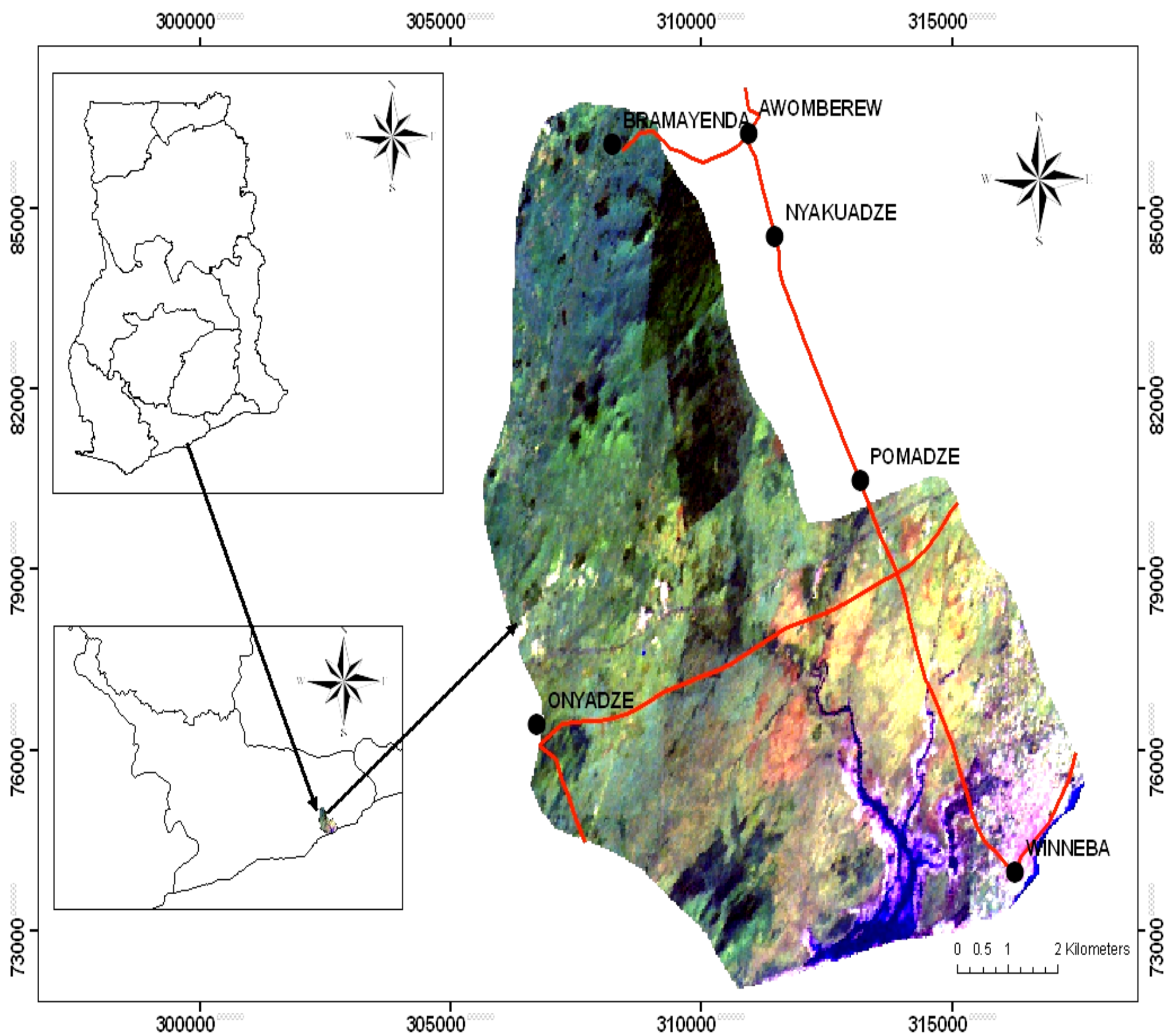

Figure 1: False colour composite of the study area

Source: Fieldwork, 2008.

Geology and soil

The Cape Coast-Wenneba granite complex of the lower Birrimian system and the Accraan Marine sandstone are the major rock types along the coast of the Awutu-

Efutu Senya District. The site is generally undulating with the rock type being mainly Birimian consisting of schist and granite as well as pegmatite. The area comprises rocky cliffs and headlands or promontories covered by cobbles. The soils are mainly vertisols which are impervious and are liable to sheet erosion during periods of seasonal flooding. This gives an indication of how sedimentation in the wetland could be worsened if human activities go on unabated. On the hills, the over burdened soils are Solonchaks while the valleys have fluvisols (Amatekpor, 1995).

Hydrology

There are two seasonal rivers, the Aboaku and Pratu that feed the Muni lagoon with fresh water. The barrier is opened during the rainy season, opening up the Muni-Pomadze-Muni lagoon to the sea (Biney, 1995). The lagoon has a surface area of 4500ha, an average depth of 0.6m and a maximum of 1m which could reduce with human interference. The rainfall in the catchments flows as surface run-off into the two streams that empty into the lagoon. Open water in the lagoon varies seasonally from 100ha in the dry season to over 1000ha in the wet season. It is believed that there is an underground seepage of marine water into the lagoon as a result of human disturbance (Tumbulto & Bannerman, 1995). Salinity varies from 64 g/l at the seaward section to 37 g/l in the northern section.

Climate and vegetation

The monthly temperature ranges from a minimum of 24ºC in July/August to a maximum of 28.9ºC in March whilst humidity ranges from 75% to 80%. The area is characterized by a low mean annual bimodal rainfall of about 854mm. The major rainy season starts from March/April to July/August with peak precipitation in June, while the minor season occurs from September to November. The main dry season occurs from December to March, during which exploitation of the wetland is high. The minor dry season is from August to September.

The vegetation of the wetland is southern marginal forest, comprising mainly of grassland, thicket islands and savanna trees. Dominant grass species include Andropogon gayanus, Hetero-pogon contortus, Panicum maximum, and Sporobolus pyramidalis. The vegetation in the seasonally flooded areas consists mainly of Sesuvium species and Paspalum species. The eastern fringes of the lagoon are marginally covered with Avicennia africana. The drier areas are predominantly grassland, the main species being Imperata, Cyperus, and Panicum. The degraded forests and semi-natural scrubland are dominated by a mixture of coarse grasses and sedges (Vetiveria species, Brachiaria species), herbs (Cassia and Azadirachta indica) and shrubs (Bonnetia, Abutilon) The vegetation on the narrow strip of sand dune which separates the lagoon from sea is mainly Sporobolus and fringed by coconut palms (Cocos nucifera). About 53% of the catchment is classified as natural vegetation, 32.5% is agricultural land (Ryan & Ntiamoa-Baidu, 2000).

Population

In 1984, the population of the area was 89,426 for which 47% were males and 53% females. In the year 2000, the population had increased to 169,972 giving a high growth rate of 4% per annum (Ghana Statistical Service, 2003). The average household size as at 2000 was eight. Population growth in itself should not be considered as a liability; however, the major concern here should be the unprecedented-poverty index of growth among households which propels over exploitation of the natural resource.

In Ghana, settlements with population of over 500 are considered urban. Winneba is one of the fastest growing towns in the district and a major part of the wetland is found here. The environmental and social problems accompanying this trend are evident in these areas. Among these problems are increases in waste generation, unplanned infrastructural development, environmental degradation, just to mention a few (Wuver & Attuguayefio, 2006).

Economic activities

The main economic activities in the district are agriculture, commerce, service, manufacturing and processing in that order. Agriculture constitutes the main economic activity of the district’s economy. Agriculture, according to the Ramsar (2002a), is a major contributor to the current degradation at the Muni site. It employs about 58% of the district population. The population of farmers including fish producers is 99,116. Agricultural production in the district is on two levels: the subsistence level involves 70% of the farming population while the commercial level involves the remaining 30%. The three main sectors of agricultural production comprise crop production, animal rearing, and fish production.

Crop production is the major economic activity in the district employing about 50% of the total population in the district. Major crops under cultivation are pineapple, cassava, yam, maize and vegetables. The production of these major crops is concentrated in the Awutu District. Fish production is mainly from marine source. There is little data on fresh water fish production but there are, however, 13 fish ponds in the district occupying an area of 32,263.6 acres. The main types of fish produced are tilapia and mudfish. The system of fishing is mainly by motorized canoe, which engages about 6,000 fishermen. The major fishing communities are Winneba and Senya and the main fish catches are herrings, shrimps, tuna, lobster and octopus.

Commercial activities in these Districts are tied to domestic markets in Accra, Agona Swedro, Oda, Mankesim, Techiman, Adeisu, Kumasi, Bolgatanga, and across the borders to Togo, Cote D'ivoire and Nigeria. The main commodities offered for exchange include fish, maize, gari, cassava, pepper, yam, chicken, chicks, eggs, pineapple, vegetable, and livestock. Other traders from the district travel far and near to bring in products like legumes maize and bush meat. People involved in the trade and commerce are fishermen, fishmongers, farmers, middlemen and other private individuals. Market infrastructure such as physical structure, space, stores, stalls, storage shed, delivery bays and access roads are moderately developed in the district. The Awutu, Effutu and Senya districts also have non-farm economic activities involving manufacturing, processing, quarrying, and mining.

In the area of tourism, the district abounds in natural tourism attractions. This includes a large stretch of coconut fringed sandy beaches with the potential for the development of beach resorts. The Muni Lagoon, with its seasonal array of migratory birds, offers nice sight-seeing. There is also an estuary near the Ayensu River. Strategically located and well-equipped with the requisite infrastructure and services for private enterprise to thrive, Awutu, Effutu, and Senya districts provides great investment opportunities in industry, agriculture, mineral exploitation, and tourism.

Infrastructure

The District Assemblies lay emphasis on a solid infrastructural base to stimulate significant investment towards the growth of the local economy. The road networks are fairly good, connecting most communities with accessible roads. The proposed West African Transcontinental Highway linking the coastal sub-regional countries passes through the district and this has actually cut off one of the feed streams. The district is connected to the national grid. Many communities enjoy this facility while smaller towns have the opportunity to be supplied power through community initiatives, in collaboration with the District Assemblies.

The districts receive their water supply from pipe-borne network, boreholes, and water bodies like streams and rivers. 20% of the populace depends on water bodies while 42% rely on boreholes. 30% of the total population has access to pipe borne water. Thus a sizable proportion of residents in the districts (20%) need potable water sources. Most of the water bodies dry up during the dry season making the acquisition of water difficult.

CHAPTER TWO

LITERATURE REVIEW

Introduction

This chapter reviews issues relating to the classification of wetlands, functions of wetlands, wetland conservation, land use/land cover, driving factors of LULC and effects of land use/land cover. Issues concerning the use of Remote Sensing (RS) and Geographic Information System (GIS) in mapping wetlands and their catchments are also discussed. Finally, the chapter discusses the competing conceptual models in LULC studies.

Wetland classification

The term ‘wetland’ was developed out of the need to manage these specific areas (Ramsar, 2002b). An official definition of wetlands proposed by the Ramsar Convention reads as follows; “areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six meters”. In the coastal context, wetland habitats may include sea grass meadows (and other aquatic macrophyte beds), mangrove areas or salt marsh swamps, dune lakes, wave-dominated and tide-dominated deltas, wave-dominated and tide-dominated estuaries, strand plains and coastal lagoons, coral reefs, sand/mudflats, tidal creeks, coastal floodplains, distributaries, drainage depressions, ox-bow lakes, back levee swamps, sedge lands, and swamp forests

Wetland ecosystems in Ghana constitute about ten percent of the country's total land surface (Ghana Wildlife Division, 2007). Based on the criteria of the Ramsar Convention, of which Ghana is a signatory, three main types of wetlands could be distinguished, namely inland, man-made, and marine/coastal wetlands (Gordon et al., 1998).

Inland wetlands

Inland waters are mainly freshwater ecosystems. They occur wherever groundwater, surface springs, streams or run-off cause saturated soils, frequent flooding or create temporary and/or permanently shallow water bodies. The table below (Table 1) shows those wetlands belonging to this category.

Table 1: Categories of inland wetlands

Inland Wetlands	**Location/Examples**
1. Permanent river/stream	Densu, Afram, Oti and Ankobra
2. Permanent freshwater lake	Bosumtwi
3. Freshwater swamp forest	Amansuri
4. Freshwater marshes	Black, Red and White Volta

Source: Ghana Wildlife Division, 2007.

Inland or freshwater wetlands, especially freshwater marshes are the most widespread in Ghana. They are the most extensive as they are found along all the natural drainage systems.

Man-made wetlands

The Ramsar Convention also recognises four categories of man-made or artificial wetlands. These are wetlands constructed for aquaculture, agriculture, salt exploitation, and water storage for urban and industrial purposes. In Ghana, they are classified as irrigated lands, reservoirs, salt pans, and urban and industrial sewerage (Table 2).

Table 2: Categories of man-made wetlands

Man-made wetlands	Location/Example
Irrigated Land	Tono,Vea, Dawhenya, Anum Valley
Salt Pans	Elmina salt pans, Densu Delta
Reservoirs	Volta lake, Kponghead pond, Brimsu Reservoir
Urban/IndustrialSewerage	Tema sewerage treatment plant

Source: Ghana Wildlife Division, 2007.

Marine/coastal wetlands

The wetlands within this zone are mainly saltwater ecosystems. They are primarily associated with flood plains of estuaries of large rivers, and with watercourses. The major coastal wetlands ecosystems are the rocky marine shores, estuarine waters, mangrove or tidal forest, and brackish or saline lagoons (Table 3).

Table 3: Types of coastal wetlands

Marine/Coastal ecosystem	Location/Example
1. Rocky Marine Shores	Senya Bereku, Cape Three Points
2. Estuarine Waters	Mouths of Volta, Pra, Butre, Ankobra
3. Mangrove/tidal forest	Lower reaches of Volta, Oyibi, Kakum, Ankobra
4. Brackish/Saline Lagoons	a. Opened: Sakumo I, II and Amisa
	b. Closed: Songor and Muni

Source: Ghana Wildlife Division, 2007.

The open coasts not subject to the influence of river water, lagoon systems, and extends to marine waters, the depth of which at low tide does not exceed six mitres are considered coastal wetlands. The wetlands within the coastal zone according to Gordon et al (1998) comprise the estuarine wetlands, lagoons, lagoon depressions and their associated marshes, sandy shores, and rocky beaches and pools. The estuarine and deltaic wetlands consist of mudflats and marshlands that are associated with large watercourses, they include all the areas that are exposed during low tide, and those areas that are inundated during the rainy season.

In Biney (1995) it is established that the lagoon wetlands are shallow waterlogged areas that are associated with small watercourses, and which undergo considerable seasonal variations in size. There are two kinds of lagoon habitats in Ghana; these are the open and the closed lagoons. The open lagoon is characterized by permanent opening into the sea, while the closed lagoon typically lies behind a sandbar, which separates it from the sea. The open lagoons may be fed by rivers, which normally flow throughout the year. Most of them occur along the western half of the Ghanaian coastline where rainfall is high and occurs for most part of the year. Closed lagoons such as the Muni-Pomadze and the Songor lagoons are typically narrow and brackish, and are more common on the eastern half of the coastline where rainfall is low and seasonal.

Functions of wetlands

Most wetlands occur in a topographic, hydrologic, and land use setting which shapes both their functions and values (Spiers, 1999). It is established in Brinson (1993) that all wetlands are made up of a mixture of soil, water, nutrients, as well as plants and animals and the interactions among these components permit wetlands to perform certain ecological or natural function which could lead to the generation of products that are of socio-economic importance to society. The terms “wetland function” and wetland value” are often used interchangeably, but there are fundamental differences between them, with both policy and management implications (Mitsch et al, 1994). Function refers to ecological, hydrological or other processes that contribute to the self-maintenance of the wetland, and which typically exert an influence (either positive or negative) on the surrounding ecosystems. But the values of wetlands are society's perception of the functioning of wetlands; they generally connote something worthy, desirable or useful to humans (Farber & Costanza, 1989).

Wetlands perform several important functions that are beneficial to the wildlife and humans (Mundia & Aniya, 2006). However it is prudent to note that a wetland can only perform most its functions if the level of degradation is at its bearer minimum. Again, it is worth noting that not every wetland serves every role (Spiers, 1999), but most of them provide some combination of the following potential functions:

- Wetlands play a critical role in regulating the flow of water in a watershed (Tumbulto & Bannerman, 1995). One way by which these wetlands regulate water flow is by the storage of water from precipitation. Floodwater storage is the process by which peak flows from runoff, surface flow, and precipitation are retained, thus reducing the danger of downstream flooding. This function is performed at varying degrees by almost all wetlands. According to (Kotze, 1996a), floodwater storage is extremely important in developing areas, because development increases the rate and volume of runoff delivered to surface water systems.
- Runoff attenuation refers to the degree to which coastal wetland vegetation reduces the velocity of runoff. This has two positive impacts on water quality (Foley et al, 2005): First, runoff attenuation reduces erosion. Second, it allows sediments carried in runoff to be deposited in the wetland. Urban storm water runoff and runoff from cultivated fields are rich in nutrients and sediments. Nitrogen and phosphorous assimilated by wetland vegetation can prevent eutrophication (excessive nutrification) in downstream lakes, lagoons, and rivers (Verburg, Overmars, Huigen, Groot, & Veildkamp , 2006). Nutrients can also be trapped in sediments, thereby preventing them from degrading downstream water quality. Biney

(1995) confirms that the filtering capacity of wetlands (which depends on its level of health) protects ground water by removing contaminants before they seep into the aquifer.

- According to McDonnell & Pickett (1990), wetlands have the potential of significantly reducing the deleterious effects of pollutants, and to protect water quality in the watershed through the abatement of non-point source pollution (defined as "a diffuse source of contaminants or pollution with no specific outfall or origin"). Non-point source pollution abatement refers to the degree to which a wetland removes toxins, sediment, and nutrients from a surface water system resulting in a healthier ecosystem downstream. Non-point source pollution often takes the form of soil erosion from construction and agriculture, bacteria from animal wastes, contaminants from vehicle emissions and herbicides and fertilizers from lawns (Kirsten, 2005). In addition, Sather & Smith (2003) indicate that toxins may be immobilized or converted chemically to a less toxic form. This biological or physical entrapment of sediments and toxins is beneficial to aquatic life and downstream water quality (Maltby, 1986). Where no wetlands occur, these toxins and sediments continue downstream to a surface water system where they can impair both public health and ecosystem health.
- Davis (1993) argues that wetlands found along the edges of water bodies protect shorelines and stream banks by dissipating the erosive forces of wave action, currents, and tides. Root systems of wetland vegetation bind

soil at the water's edge, stabilizing sediments. Vegetation also reduces shoreline erosion by slowing wave velocity and current speed, enhancing soil accumulation at the shoreline. When there is removal of wetland vegetation, particularly when coupled with dramatic increases in shoreline and stream bank erosion, there is the likelihood of severe flooding (Tumbulto & Bannerman, 1995). Therefore, coastal wetlands found alongside water bodies where development is fast growing are particularly important in providing shoreline and stream bank stabilization. According to Bird, Martin, Kjerfve, Smith, Maynard, & Drude de (1994) coastal wetlands, such as mangroves and other forested coastal areas, act as windbreaks and help to mitigate the impact of coastal storm surges. A greater part of the eastern shoreline of Ghana, especially at Keta and Ada, is vulnerable to storm surges which could be due to lack of such a natural protective systems (Ghana Wildlife Division, 2007).

- Acreman & Hollis (1996) establishes in his scientific work the critical role wetlands play in recharging valuable groundwater resources. We commonly use groundwater that comes from unconfined shallow water table aquifers. These aquifers interact very closely with surface water, each recharging or "feeding" one another (Biney, 1995). Finlayson, Gordon, Ntiamoa-Baidu, Timbulto, & Storrs (1999) observed that the hydrologic balance of many streams, lakes, and wetlands are maintained by groundwater. Groundwater is recharged through the percolation of rainwater and surface water through the tiny spaces between the soil particles. When a groundwater recharged wetland is left undisturbed, the amount of surface water discharge and groundwater recharge arrives at a natural balance. As wetlands are modified, filled or otherwise disturbed by the changing landscape, less precipitation will be allowed to naturally recharge this valuable resource (Hollis, 1998).

Wetland conservation

Ghana's Wetlands Conservation Strategy is aimed at achieving the guiding principles of ensuring sustainable land use within the general context of Ghana's Land Policy of 1999 and other water related policies (Okyeame, Liang, Punguse, & Sarpong, 1998). These policies seek to promote the judicious use of the nation's land and all its natural resources by all sectors of the Ghanaian society in support of various socio-economic activities undertaken in accordance with sustainable resource use and maintenance of viable ecosystems. The Government of Ghana, as well as concerned individuals and organizations have made several initiatives to address the problem of wetlands management.

Ghana has undertaken a number of projects which have had bearing on wetlands. The Ghana Coastal Wetlands Management Project (CWMP) funded by GEF and implemented by the Wildlife Department as a component of the Ghana Environmental Resource Management Project (GERMP), was aimed at establishing and managing five Ramsar sites along the coast. Wetlands conservation in Ghana focuses mainly on the conservation of water resources and biodiversity (World Bank, 2000). Water conservation involves damming rivers for a more effective use of water for agricultural, industrial, and domestic purposes. Wetlands management traditionally included a conservation component, reinforced by custom, religious taboos, and totem systems. Traditional management practices, which underscore socio-cultural values, are accepted as means of regulating the utilization of wetland resources. During sacred days or periods, fishing is prohibited in streams and lagoons; and certain plants and animals are protected. Despite the effectiveness of these traditional conservation practices, modern wetlands conservation has not been based on them.

The Environmental Protection Council (EPC), under the biodiversity component of the Ghana Environmental Resources Management Project (GERMP), prepared the management plans for the conservation of the five Ramsar sites, that is, internationally important wetlands conserved through multiple-use management. The five sites are Songor, Sakumo, Densu Salt Pans, Anlo-Keta, and Muni. Four others that may also be similarly protected are the Keta, Korle and Amazuri wetlands and the Elmina salt pans.

GERMP has established a project component for wetlands management. Under this programme, a review was conducted of the functions of Ghana's wetlands. This preparatory project showed that most of the stress occured in wetlands of international significance for flora and fauna (Ramsar, 2002b). Consequently, certain wetlands have become high priorities in Ghana's national conservation policies. Because these are designated as Ramsar sites, it is assumed that no specific policies are needed to protect their functions as these are taken care of under the general wildlife-conservation policies.

Conventions on wetlands

Ghana is a party to about eight (8) international conventions which deal with or are of relevance to wetland protection. However, according to Finlayson et al (1999) some provisions of these conventions have yet to be incorporated into national legislation to strengthen enforcement but the fact that the Government has ratified them is an indication of commitment. The most relevant of these conventions is the Ramsar Convention. Ghana has been a signatory to the Ramsar Convention, an international treaty on the conservation of wetlands of international importance, since 1988. A major obligation under the convention is the implementation of the principle of 'wise use' of wetlands, where 'wise use' is understood to mean "their sustainable utilization for the benefit of humankind in a way compatible with the maintenance of the natural properties of the ecosystem" (Wildlife Division, 2007). Six wetlands have been designated for Ramsar list as wetlands of international importance. These are Owabi wetlands, Keta Lagoon complex, Songor Lagoon, Sakumo Lagoon, Densu Delta, and the Muni Pomadze wetland.

Policies and laws governing wetland usage

Several national policies and legislation affect wetlands. These pieces of legislation are scattered throughout the statute books, and though outmoded and failing to address adequately the problem of wetlands in their entirety, they do provide a starting point for the formulation of appropriate laws. Such policies and laws include the Fisheries Decree of 1972, the National Land Policy 1999, the

Water Resources commission Act, 522; Ghana water policy draft of 2002, Decentralization Policy and Local Government Act 462 of 1993, Town and Country planning Ordinance CAP 84, etc.

Institutions on wetland management

Ghana's legal regime for coastal-zone protection is adequate for environmental needs. National Environmental Action Plan (NEAP) established in early 1990s did not suggest any additional studies but implied that coastal-protection works would be environmentally beneficial to coastal wetlands and that there was a need to identify and establish areas for protection and for sustained resource management (Okyeame et al, 1998).

According to the institutional framework outlined in NEAP, the following institutions act as lead agencies:

- Environmental Protection Council (EPC);
- University of Ghana (Geography and Zoology);
- Department of Wildlife (Ministry of Lands and Forestry);
- Forestry Department (Ministry of Lands and Forestry);
- Institute of Aquatic Biology of the Council for Scientific and Industrial Research; and
- District and Metropolitan Assemblies.

The protection and conservation of wetlands resources involve a number of activities. These include data collection, monitoring, standard setting and execution of projects and programmes.

Sub-regional initiatives on wetland management

Several West African sub-regional initiatives, of which Ghana is a party to, exist which relate to wetlands. For instance the Large Marine Ecosystem of Gulf of Guinea Programme funded by Global Environment Facility and administered through UNIDO aims at assisting several West African States to manage their coastal resources sustainably. Other initiatives, such as the West and Central African Regional Seas Programme (WACAF) of UNEP, have also helped establish sub-regional collaboration. Another major initiative is the proposed establishment of the Centre for African Wetlands Management (CAWM), an institution to be located in Ghana, which will co-ordinate wetlands research for the West African sub-region.

Short-comings of management initiatives

A study by Friends of the Earth (FoE-Ghana) in 2000 revealed that:

- All types of wetlands in Ghana have suffered from some form of degradation resulting from externalities;
- Industrial, agricultural and urban/rural development have combined with sewer effluent to reduce the chemical and biological quality of wetlands;
- Most wetlands close to urban areas have been degraded through anthropogenic activities; and
- Wetland degradation in Ghana results from land-use conflicts, information and market failures, and inefficient government policies.

The Ghana Forests and Wildlife Policy covers only those wetlands designated Ramsar sites. Its intention is to ensure that viable populations of all indigenous wildlife species, including passage migrants, are adequately conserved and that rare, endangered species of high conservation interest are especially protected. Having only this policy endangers the other wetlands of local importance, which is one of the most important findings of the study by FoE-Ghana.

Again the agricultural sector has failed to develop any mechanism to systematically differentiate between projects affecting wetlands and those affecting other water resources and drainage. Wetlands-management plans do not include guidelines for designing wetland policies, improving the production base of the communities, and providing well-integrated environmental programs. Moreover, the current Wildlife and Protected Areas Policy emphasizes wildlife resources, with little regard for the wetlands as a whole.

Land Use/Land Cover

Land Use refers to all arrangement, activities, and inputs undertaken in a Land Cover type to reap socio-cultural and economic benefits. On the other hand land cover is the physical appearance of land surface which provides visible proves of land use. In essence land cover is more obvious on the field than land use which is usually inferred from the cover (Deferies, Asner, & Houghton, 2004). These two terms are closely linked such that in mapping, they are sometimes treated together to avoid ambiguity (Lillesand, Kiefer, & Dupman 2004). Nagendra, Mmroe, & Southworth (2004) and Jansen & Di Gregorio (2002) highlighted the difficulty in splitting the two terms. They attributed this difficulty to the complex feedback loop that exists between them. According to Lambin et al. (2001) land use and land cover share a common source of change in the form of human activities that directly alter the physical environment. Land use affects land cover and changes in land cover affect land use.

Foley et al (2005) have argued that land use has caused decline in biodiversity through the loss, modification, and fragmentation of the natural cover; degradation of soil and water; and over exploitation of native species.. They however admit that while land use thus presents us with a dilemma, many land-use practices are absolutely essential for humanity. Land-use activities, whether converting natural landscapes for human use or changing management practices on human-dominated land, have transformed a large proportion of the planet's land surface (Geist & Lambin, 2001).

Rudel, Coomes, Moran, Achard, Angelsen, Xu, & Lambin et al (2005) reported that land-use practices vary greatly across the world but admitted their ultimate outcome is generally the same; namely the acquisition of natural resources for immediate human needs, often at the expense of degrading environmental conditions., because they provide critical natural resources and ecosystem services such as food, fiber, shelter, and fresh water; on the other hand, some forms of land use are degrading the ecosystems and services upon which we depend. However, Riebsame, Meyer, & Turner (1994) stated that changes in land cover as a result of land use do not necessarily imply a degradation of the land. Land cover can be altered by forces other than anthropogenic. Natural events such as the weather, flooding, fire, climate fluctuations, and ecosystem dynamics may also initiate modifications upon land cover.

Turner & Butzer (1992) noted two broad types of global change, systemic and cumulative. Systemic change operates directly on the bio-chemical flows that sustain the biosphere and, depending on its magnitude, it can lead to global change, just as fossil fuel consumption increases the concentration of atmospheric carbon dioxide. Cumulative change has been the most common type of human induced environmental change since antiquity. Cumulative changes are geographically limited, but if repeated sufficiently, become global in magnitude. Changes in landscape, cropland, grasslands, wetlands, or human settlements are examples of cumulative change. Serneels, Said, & Lambin, (2000) categorized changes in land cover driven by land use into two types: “modification” and “conversion”. “Modification” is a change of condition within a cover type; for example, unmanaged forest modified to a forest managed by selective cutting, “conversion” is a change from one cover type to another, such as deforestation to create cropland.

Land Use/Land Cover change and driving forces

Land Use/Land Cover (LULC) change also known as land change is a general term for the human modification of earth's terrestrial surface (Turner, Clark, Kates, Richards, Matthews, & Meyers, 1990). 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 (Pontius & Schneider, 2001). These changes according to DeFeries et al (2004) encompass the greatest environmental concerns of human populations today, including climate change, biodiversity loss and the pollution of water, soils and air.

Turner et al, (1990) groups the possible driving forces of land use and land cover changes into six categories: population; level of affluence; technology; political economy; political structure; and attitudes and values (The first three have been linked to environmental change in the I = PAT relationship that considers environmental impact (I) to be a function of population (P), affluence (A), and technology (T).

Of these three categories of driving forces, population produces the most controversy. It is, however, one of the few variables for which worldwide data of reasonable accuracy are available, providing a basis for statistical assessments of its role in various kinds of environmental change (Serneels & Lambin, 2001). At the global level of aggregation, the neo-Malthusian and "cornucopian" positions use the same data to reach opposite conclusions: that population growth is or is not a cause of environmental damage (Ehrlich & Ehrlich 1990). At the regional scale, several studies relate population growth and deforestation in developing countries in the tropics (Rudel et al. 2005), although their findings and methods have been questioned by scientist like Verburg et al (2006).

Comparative assessments of population and land use by Kotze (1996b) suggest that: (i) population growth is positively correlated with the expansion of agricultural land, land intensification, and deforestation, but (ii) these relationships are weak and dependent on the inclusion or exclusion of statistical outliers. Sub-continental comparisons for Africa have led Allen & Douglas (1985) to conclude that population density and growth ranked below environmental endowment and economy as factors in environmental degradation. Population density was found to be related to agricultural expansion and intensification everywhere, but only in some regions to deforestation. Detailed studies of specific regions for example, modeling exercises with Amazonian data likewise indicate subtle and varying relationships (Etter, Mcalpine, Wilson, Phinn, & Possinggaw 2006).

The interactions of population, affluence, and technology as causes land change have been explored extensively, but research on the direct association of affluence or technology with land use change is not common. This is because of the paucity of globally comparative data for statistical assessments and because of the common assumption that level of affluence or technology do not by themselves govern human-environment relationships but must be considered within a larger set of contextual variables (Global Land Project, 2005).

Nonetheless, some historical assessments associate high levels of affluence and industrial development (and thus the ability to draw resources from elsewhere) with the return of forest cover (Williams, 1993). Global comparisons indicate that afforestation is largely a phenomenon of advanced industrial societies, which are both affluent and have high technological capacity (Global Land Project, 2005). Wealth, however, also increases per capita consumption, bringing about environmental change through higher resource demands, although these higher demands can be reduced by advanced technologies available to wealthy societies. Poverty is often associated with environmental degradation although recent research shows that this relationship is strongly influenced by other factors as well. These mixed conclusions indicate the importance of further studies of the relationship between level of affluence and environmental change.

The role of technology as a potential cause of past and prospective changes in land use and land cover also requires further study. It is obvious that technological development alters the usefulness and demand for different natural resources. The extension of basic transport infrastructure such as roads, railways, and airports, can open up previously inaccessible resources and lead to their exploitation and degradation. Veildkamp & Lambin, (2001) indicate that technological development and their application (such as improvements in methods of converting biomass into energy; use of information-processing technologies in crop and pest management; and the development of new plant and animal strains through research in biotechnology) could lead to major shifts in land use in both developed and developing countries.

To these three sets of forces, three others have been added: political economy, which includes the systems of exchange, ownership, and control; political structure, involving the institutions and organization of governance; and attitudes and values of individuals and groups. The driving forces grouped within these categories have received much less attention than population growth. They do not yet encompass clearly defined variables and causal relationships, but comprise similar explanations of relationships of societal and environmental change (Shu, 2003).

Changes in land tenure (an institution in socio-economic terms) have direct impacts on land use, as does the move from non-market to market exchange of resources (political economy). Changes in attitudes and values may add a dimension to environmental change that cannot be explained otherwise, such as impact on land use of the "green" movement. Detailed examinations link all of these forces (Serneels et al., 2000). For example, the model of socio-economic and environmental interactions with land use developed at Oak Ridge National Laboratory explores the interrelated effects of changes in technology, political economy, and political structure in Amazonia (Van Laake & Sanchez-Azofeifa, 2004). Improved transport facilities are expected to exacerbate land degradation if the region in question is small, but its impact on larger regions will vary by circumstance. Additional comparative studies are needed to address the interactions of different driving forces with their environmental context. Environmental transformations - whether potential climate change or localized impacts such as soil depletion - themselves affect land use. For example, a study in Nairobi, Kenya, indicates that local deforestation has caused a drop in the local water table and/or a reduction in local rainfall, and that the local population has responded by expanding the area under cultivation to maintain production (Mundia & Aniya, 2006). This calls for a better understanding of the interactions of soil depletion, land use systems, and environmental changes.

Heilig (1994) makes mention of unprecedented increase of population; worldwide changes in lifestyles, which are partly, explained by rising per capita income; and the growing influence of geopolitical, economic, and military structures and strategies as important drivers most of which are usually ignored in discussions. However, according to Veldkamp & Lambin (2001) most spatial analysis focus on biophysical driving forces like distance to roads, rivers, and towns rather than underlying drivers for the sake of measuring convenience even though they also explain to some extent, land use decisions.

Effects of Land Use/Land Cover change

Changes in land use and land cover date to prehistory and are the direct and indirect consequence of human actions to secure essential resources (Ruddiman, 2003). 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) accompanied by the intensification of agriculture in the most productive lands (Foley et al, 2005). All of these causes and their consequences are observable simultaneously around the world today, particularly the developing world.

Land use/land cover changes have been in the lime light for reasons of importance attached to its impact on the earth and its occupants (Verburg et al, 2006). On the whole, these changes have significant short and long term impacts on the functions of the physical, chemical, and biological components of the earth

(Lambin, Geist, & Lepers, 2003). Change in land cover and land use and subsequent impacts may be positive or negative spatially and temporally. However the balance is mostly tilted to the negative in wetland catchmnets (Global Land Project, 2005). These negative changes in the long term reduce the continuous ability of the ecosystem to produce goods and services on which humans strive (Turner et al, 1990). These negative changes are grouped under the following themes:

Pollution

Changes in land use and land cover are important drivers of water, soil and air pollution (Lambin et al, 2001). Perhaps the oldest of these is land clearing for agriculture and the harvest of trees and other biomass. Vegetation removal leaves soils vulnerable to massive increases in soil erosion by wind and water, especially on steep terrain, and when accompanied by fire, also releases pollutants to the atmosphere. In Defries et al (2004) it is indicated that this not only degrades soil fertility over time, reducing the suitability of land for future agricultural use, but also releases huge quantities of phosphorus, nitrogen, and sediments to streams and other aquatic ecosystems, causing a variety of negative impacts (increased sedimentation, turbidity, eutrophication and coastal hypoxia). Mining can produce even greater impacts, including pollution by toxic metals exposed in the process.

Modern agricultural practices, which include intensive inputs of nitrogen and phosphorus fertilizers and the concentration of livestock and their manures within small areas, have substantially increased the pollution of surface water by runoff and erosion and the pollution of groundwater by leaching of excess nitrogen (as nitrate) (Islam & Weil, 2000). Other agricultural chemicals, including herbicides and pesticides are also released to ground and surface waters by agriculture and in some cases remain as contaminants in the soil.

Again the dumping of refuse, discharge of industrial and domestic sewerage, as well as agricultural run-off into wetlands increase the organic loading of the wetland waters. This increases the biochemistry oxygen demand (BOD) of the water body (Dye, 2003). This may seriously contaminate the water, endangering plants, animals and people living in and around the water body (Mensah, 2003). Typical examples of such polluted systems are the Fosu and Korle Lagoon.

Biodiversity loss

Biodiversity is often reduced dramatically by LULC change. When land is transformed from a primary forest to a farm, the loss of forest species within deforested areas is immediate (Oteng-Yeboah, 1994). Even when unaccompanied by apparent changes in land cover, similar effects are observed whenever relatively undisturbed lands are transformed to more intensive uses, including livestock grazing, selective tree harvest and even fire prevention. Wuver & Attuquayefio (2006) established that the habitat suitability of forests and other ecosystems surrounding those under intensive use are also impacted by the fragmenting of existing habitat into smaller pieces (habitat fragmentation), which exposes forest edges to external influences and decreases core habitat area.

Smaller habitat areas generally support fewer species (island biogeography), and for species requiring undisturbed core habitat, fragmentation can cause local and even general extinction (McNeely et al, 1995). Research by Ryan & Ntiamoa-Baidu (2000) also demonstrates that species invasions by non-native plants, animals and diseases may occur more readily in areas exposed by LULC change, especially in proximity to human settlements.

Climate change

Land cover changes that alter the reflection of sunlight from land surfaces (albedo) are another major driver of global climate change (Tuner, Moss, & Skole, 1994). The precise contribution of this effect to global climate change remains a controversial but growing concern. The impact of albedo changes on regional and local climates is also an active area of research, especially changes in climate in response to changes in cover by dense vegetation and built structures (Lambin, Geist, & Lepers, 2003). These changes alter surface heat balance not only by changing surface albedo, but also by altering evaporative heat transfer caused by evapotranspiration from vegetation (highest in closed canopy forest), and by changes in surface roughness, which alter heat transfer between the relatively stagnant layer of air at Earth's surface (the boundary layer) and the troposphere. An example of this is the warmer temperatures observed within urban areas versus rural areas, known as the urban heat island effect.

Probable effects of Land Use/Land Cover change on wetland hydrology and geomorphology

Ehrenfeld (2000) proposes the under listed effects:

- Decreased surface storage of storm water results in increased surface run-off (resulting in increased surface water input to wetland)
- Increased storm water discharge relative to base-flow discharge results in increased erosive force within stream channels, which results in increased sediment inputs to recipient coastal systems
- Changes occur in water quality (increased turbidity, increased nutrients, metals, organic pollutants, decreased oxygen concentration etc.)
- Culvert, outfalls, etc. replace low-order streams; this results in more variable base-flow and low-flow conditions
- Decreased groundwater recharge results in decreased groundwater flow, which reduces base flow and may eliminate dry season stream flow
- Increased flood frequency and magnitude result in more scour of wetland surface
- Increase in range of flow rates (low flows are diminished; high flows are augmented) may deprive wetlands of water during dry weather
- Greater regulation of flows decreases magnitude of spring flush
- Decreased sinuosity of wetland/upland edge reduces amount of eco-tone habitat
- Decreased sinuosity and river channels results in increased velocity of stream water discharge to receiving wetlands

- Alterations in shape and slopes (e.g. convexity) affect water-gathering or waste-disseminating properties
- Increased cross-sectional area of stream channels (due to erosional effects of increased flood peak flow) increases erosion along banks.

Wetland health indicators

A wetland's ecological health can be visualized as the relative ability of the wetland to support and maintain its homeostatic ability with respect to species composition, physiochemical characteristics and functional processes as compared to wetlands with less human alteration (Costanza, 1992; Kotze, 1996a). Wetland health indicators are discussed here to facilitate the discussion on the probable impact of the Land Use/Land Cover change on the wetland in Chapter Six. The U.S. Intergovernmental Task Force on Monitoring Water Quality (ITFM) defines an ecological health indicator as a measurable feature which singly or in combination provides managerially and scientifically useful evidence of environmental and ecosystem quality, or reliable evidence of trends in quality.

This definition is particularly useful when the "measurable feature" is associated with an explicit goal or desired outcome. Ecological health indicators encompass a broad suite of measures, including tools for assessment of chemical, physical and biological conditions and processes at several scales. An indicator provides a clue to a matter of larger significance or makes perceptible a trend or phenomenon that is not immediately detectable. It is a sign or symptom that makes something known with a reasonable degree of certainty. An indicator reveals or gives evidence and its significance extend beyond what is actually measured to a larger phenomenon of interest. Ecological health indicators communicate information about the environment and about the human activities that affect it (US Department of Commerce, 1996). When communicated effectively, the indicator highlights problems and draws attention to the effectiveness of current policies. The target audiences are the public and the decision-makers (i.e. governments).

According to Costanza (1992) coastal wetland health is evaluated by assessing wetland condition and the degree to which wetlands perform certain functions. A wetland in good condition is better able to function to its potential capacity. Wetland functions and conditions are important to humans because of the valued goods and services that wetlands provide.

Wetlands are highly diverse resources that reflect the extreme physical and biological variability of their state. This great diversity of wetland types and the variety of functions they perform make it difficult to generalize about wetland resource health (Williams, 1998). In Kassenga (1997), no one indicator provides a suitable or sufficient measure of health for all wetlands, however, wetland catchment is a basic indicator that can be used to track wetland extent and trends. How much of the original wetland catchment remains? What are current loss and degradation rates? Where are these losses pronounced? These area measures are important because, to a greater extent, the health of wetlands in coastal zones for instance is dependent on maintaining and conserving what is left of the wetland catchment, a goal embodied in most government policies and strategies.

However, Kassenga (1997) cautions that area measures alone cannot adequately address overall wetland health. Other measures are needed—the health of native wetland plant and animal communities, the extent to which wetlands have been cut off from one another and from streams, lakes and other aquatic resources, and the degree to which water is available to sustain wetlands. These and similar "condition" indicators are needed to more fully understand the ecological health of coastal wetlands today and their capacity to provide valued goods and services well into the future.

What do we know about the health of coastal wetlands today? Historical information indicates that, developing urban fringes or agricultural areas in particular, wetlands have been drastically and often irreversibly altered. According to the US Department of Commerce (1996) wetland health varies by ecological zones, with urbanized coastal regions and agricultural regions exhibiting the most wetland loss and degradation. Dams, levees and diversions on major rivers and their tributaries that feed wetlands have changed the hydrologic characteristics at the most fundamental landscape levels (Tumbulto & Bannerman, 1995). Settlements, agriculture and roads have eliminated or fragmented wetland systems. For these reasons, monitoring coastal wetland catchments within a time series for aerial variability may be a reasonable measure of the wetland's state of health.

Remote sensing (RS) and Geographic Information Systems (GIS) for wetland catchments mapping

Land Use/land Cover maps are essential tools in natural resource planning and environmental management (Ehlers, 1996). Human activities have led to fast and large changes in land cover, which in turn have a negative impact on the environment as a whole. As a result land cover is one of the most important elements for the assessment of the environment. Chaudhary (2003) argues that land cover is the basic geographic feature serving as a reference base for other environmental applications.

RS and GIS provide a cost-efficient way to assess ecological characteristics and to periodically update baseline data regarding resource distribution and abundance (Sample, 1994). However Green, (1994), indicates that a large number of application show that remote sensing techniques have a variable degree of success corresponding to the difficulty of interpretation of certain ecosystem features. It is believed by many scientists that terrestrial vegetation has the most unique spectral reflectance characteristics and its mapping has been among the most persistent and well developed remote sensing applications (Valentine, Knecht, & Miller, 1998). Geographic Information Systems (GIS) has been shown to be a powerful and flexible tool for environmental resources inventory particularly when conventional photogrammetric techniques cannot be applied.

Wetlands monitoring includes a variety of activities which are directed towards understanding the status and trends of the ecosystem. Monitoring is essential because of the need to gain the feedback from specific management practices and help agencies to execute their mandates in collecting the data for legal purposes. A large number of studies have been conducted that demonstrate the usefulness of information derived from remote sensing data for wetland monitoring. The GIS technologies have the potential to playing an important role in all stages of monitoring programmes (Franklin, 1994). The GIS multi-criteria functions have been used to weigh and combine various environmental parameters and scientific concerns directing the selection of monitoring sites. GIS data management capabilities are largely used to store, query and visualize monitoring data.

Producing Land Use/Land Cover change maps

The first step in attempting to produce use/cover and change maps is the acquisition of satellite imageries. In this study the Landsat 5 images were used. Landsat 5 carries both the multispectral scanner (MSS) and the thematic mapper (TM) sensors. The thematic mapper (TM) is an advanced, multispectral scanning, earth resources sensor designed to achieve higher image resolution, sharper spectral separation, improved geometric fidelity, and greater radiometric accuracy and resolution than the MSS sensor. This sensor also images a swath 185 km (115 miles) wide but each pixel in a TM scene represents a 30 m x 30 m ground area (except in the case of the far-infrared band 6 which uses a larger 120 m x 120 m pixel). The TM sensor has 7 bands that simultaneously record reflected or emitted radiation from the earth's surface (Appendix D). Before classifying acquired data, a selection of the available spectral bands may be made. Reasons for not using all available bands (all seven bands of landsat TM) lie in the problem of band correlation and sometimes, in the limitation of hard- and software (Richards, 1986). Band correlation occurs when a spectral reflection is similar for two bands. An example is the correlation between the green and red wavelength bands for vegetation: a low reflectance in green correlates with the low reflectance in red.

The next step after the acquisition of the images is to geo-reference them. This is a process of relating images to specific map projections. Lillesand et al (2004) concede that the simplest way to link an image to a map projection is to use a geometric transformation. A geometric transformation is a function that relates the coordinates of two systems. The process of geo-referencing involves two steps: selection of the appropriate type of transformation; and determination of the transformation parameters. The type of transformation depends mainly on the sensor platform system used. Successful geo-referencing leads to the classification of the geo-referenced thematic images.

Image Classification is the process of assigning pixels to nominal, i.e. thematic, classes (Lillesland et al, 2004). Image classification serves a specific goal: converting image data into thematic data. In the application context, one is rather interested in the thematic characteristics of an area (pixel) rather than in its reflection values. Thematic characteristics such as land cover; land use, soil type or mineral type can be used for further analysis and input into models. In addition, image classification can also be considered as data reduction: the 7 multi-spectral bands (Appendix D) could result in a single band raster file**.** Several land use/land cover (LULC) classification systems have been designed. In this study three different LULC classification systems are discussed. These are the ITC LULC classification approach, the CORINE land cover classification system, the Land Cover classification system of the FAO, and USGS classification system (Appendix D).

The USGS hierarchical system (Appendix D) incorporates the features of several existing classification systems that are amenable to data derived from remote sensors, including imagery and photography from satellites and high-altitude aircraft (Avery & Berlin, 1985). The system attempts to meet the need for current overview assessments of land use and land cover on a basis that is uniform in categorization at the first and second levels of detail. It is intentionally left open-ended so that various levels of users may have flexibility in developing more detailed classifications at the third and fourth levels. Such an approach permits various users to meet their particular needs for land-resource management and planning and at the same time remain compatible with the national system. The types of land-use and land-cover categorization developed in the USGS classification system can be related to systems for classification of land capability, vulnerability to certain management practices, potential for any particular activity, or land value, either intrinsic or speculative, hence its application in this study.

Supervised image classification

One of the main steps in the image classification is the ‘partitioning’ of the feature space (feature space is the mathematical space describing the combinations of observations of a multispectral or multiband image). In supervised classification this is realized by an operator who defines the spectral characteristics of the classes by identifying sample areas. Supervised classification requires that the operator needs to know where to find the classes of interest in the area covered by the image. This information can be derived from ‘general area knowledge’ or from dedicated field of observations. A sample of a specific class, comprising a number of training pixels, forms a cluster in the feature space.

Unsupervised image classification

Supervised classification requires knowledge of the area at hand. If this knowledge is not sufficiently available or the classes of interest are not yet defined, an unsupervised classification can be applied (Lillesand et al, 2004). In an unsupervised classification, clustering algorithms are used to partition the feature space into a number of clusters. Several methods of unsupervised classification exist, their main purpose being to produce spectral groupings based on certain spectral similarities (Burrough, 1986). In one of the most common approaches, the user has to define the maximum number of clusters in a data set. Based on this, the computer locates arbitrary mean vectors as the centre points to the clusters. Each pixel is then assigned to a cluster by the ‘minimum distance to cluster centroid decision rule. Once all the pixels have been labelled, recalculation of the cluster centre takes place and the process is repeated until the proper cluster centres are found and the pixels are labelled accordingly. The iteration stops when the cluster centres do not change anymore. At any iteration, however, clusters with less than a specified number of pixels are eliminated. Once the clustering is finished, analysis of the closeness and separability of the clusters will take place by means of inter-cluster distances or divergence methods.

Merging of clusters needs to be done to reduce the number of unnecessary subdivisions in the data set. This could be done using a pre-specified threshold value. The user has to define the maximum number of clusters/classes, the distance between two cluster centres, the radius of a cluster, and the minimum number of pixels as a threshold number for cluster elimination. Analysis of these cluster compactness around its centre point is done by means of user- defined standard deviation for each spectral band (Richards, 1986). If a cluster is elongated, separation of the cluster will be done perpendicular to the spectral axis of elongation. Analysis of closeness of the cluster is carried out by measuring the distance between the two cluster centres. If the distance between two cluster centres is less than the pre-specified threshold, merging of the clusters takes place. At each iteration, the cluster with less than a specified number of pixels is eliminated. The clusters that result after the last iteration are described by their statistics. The derived cluster statistics are then used to classify the complete image using a selected classification algorithm (similar to the supervised approach).

After the training sample sets have been defined, classification of the image can be carried out by applying classification algorithm. Several classification algorithms exist. The choice of the algorithm depends on the purpose of classification and the characteristics of the image and training data

(Robinove, 1986). The operator needs to decide if a ‘reject’ or ‘unknown’ class is allowed. Three classifier algorithms can be distinguished. First the box classifier is explained, for its simplicity to help in understanding of the principle. In practice, the box classifier is hardly ever used (Lillesand et al, 2004); the Minimum Distance to Mean and the Maximum Likelihood classifiers are normally used (Appendix D).

Land Use/Land Cover change detection

An increasingly common application of remotely sensed data is change detection. Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Turner et al, 1994**;** Foley et al. 2005). Change detection is an important process in monitoring and managing natural resources and urban development because it provides quantitative analysis of the spatial distribution of the population of interest. It is also useful in such diverse applications as land use change analysis, monitoring shifting cultivation, assessment of deforestation, study of changes in vegetation phenology, seasonal changes in pasture production, damage assessment, crop stress detection, disaster monitoring, day/night analysis of thermal characteristics as well as other environmental changes (Mumby, Raines, Gray, & Gibson, 1995). Macleod (1998) listed four aspects of change detection which are important when monitoring natural resources: namely detecting the occurrence of change; identifying the nature of the change; measuring the area extent of change; and assessing the spatial pattern of the change.

Evidence by Singh (1989) has revealed that digital change detection is a difficult task to perform accurately and unfortunately many of the studies concerned with comparative evaluation of these applications have not supported their conclusions by quantitative analysis. All digital change detection is affected by spatial, spectral, temporal, and thematic constraints (Green, 1994). He further argues that the type of method employed can profoundly affect the qualitative and quantitative estimates of the change. Even in the same environment, different approaches may yield different change maps. The selection of the appropriate method therefore takes on considerable significance. Not all detectable changes, however, are equally important to the resource manager. On the other hand, it is also probable that some changes of interest will not be captured very well, or at all, by any given system.

Competing conceptual models

Several models exist for studying land use/land cover dynamics depending on the interest of the study. Four models were reviewed in the study and depending on their strengths, weaknesses, and the interest of the study one of them was selected. These models are the GEM, CLUE, Spatial Markov model, and the three dimensional model of Agarwal et al (2001).

The general ecosystem model (GEM) is a dynamic systems model. The model is designed to capture feedback among abiotic and biotic ecosystem components. The model is made up of fourteen sectors or modules which include hydrology, macrophytes, algae, nutrients, fire, dead organic matter, and separated database for each sector. The GEM has one hundred and three input parameters, in a set of linked databases representing the modules. As with every model, this model has its strengths and weaknesses. GEM is a spatially dependent model with feedback between units and across time. It allows for adding and dropping of sectors and can adapt to resolution, extent, and time set to match the processes being modelled. However, the limiting factor which the proponents admit to is its limited human decision making.

The CLUE model by Veldkamp & Fresco (1996) is a discrete and finite state model that predicts land cover in the future. It has three components; regional biophysical module, regional land use objective module, and local land use allocation module. The variables in the model are grouped into biophysical drivers and human drivers. The biophysical drivers include land suitability for crops, temperature/precipitation, and distance to rivers, distance settlement, distance roads, and pest. The human drivers are population size, level of technology, political structure, attitudes and values, and economic conditions. The strength of this model lies in the fact that it covers a wide range of biophysical and human drivers at differing temporal and spatial scales. However its limited consideration for institutional and economic variables constitutes a limitation.

The proposed spatial markov model is the third model the study reviewed. The model is a temporal and spatial land use change model whose variables are still being developed. The strength of this model is that investigating markov variations relaxes strict assumptions associated with the markov approach. Again it explicitly considers spatial and temporal change. However it has no HDM module. This is not strictly a limitation since this is a work in progress. Based on the weaknesses of these models and the interests of this study the fourth model, the three dimensional model, was reviewed and chosen for the study.

Conceptual model for the study

Land use in space and time is determined by the interaction among biophysical factors (constraints) such as soils, climate, topography, etc. and human factors like population, technology, economic conditions etc (Veldkamp & Fresco, 1996). Based on these critical dimensions Agarwal et al (2001) proposed a three dimensional model (Figure 2) for studying human-environment dynamics. Time and space are the first two dimensions which provide a common context in which all biophysical and human processes operate. This implies that models of biophysical and human processes operate in a temporal context, a spatial context, or both. When the model incorporates human processes, a third dimension—referred to as the human decision-making dimension—becomes important as well. This model is adopted taking in to consideration the approach used in this research.

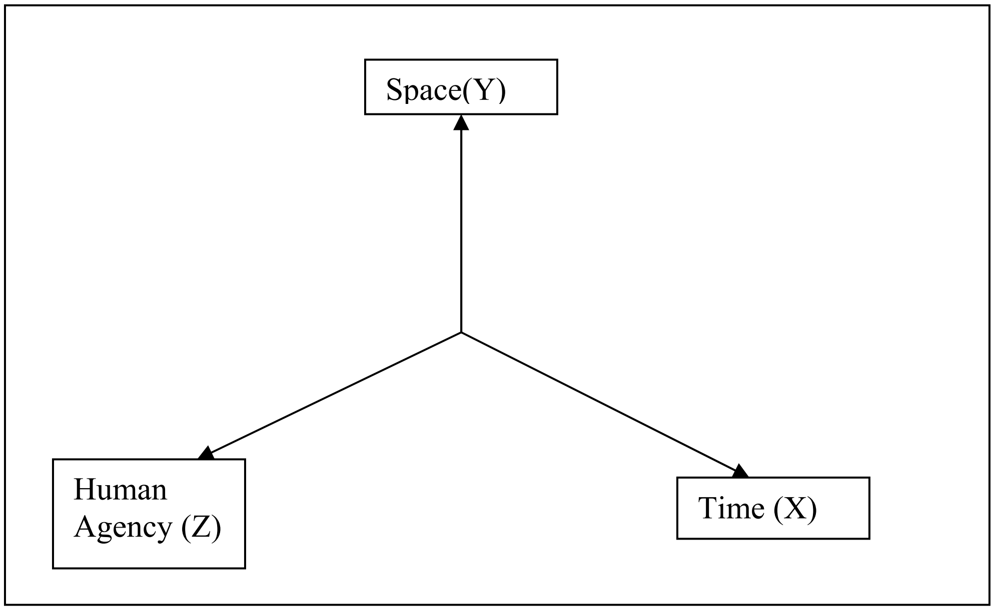

Figure 2: Three dimensional model for Land Use/Land Cover change analysis

Source: Adopted from Agarwal et al, 2001.

There are two distinct and important attributes that must be considered if land use/land cover dynamics are to be understood properly: these are the model scale and model complexity. Real world processes operate at different scales (Ehlers, 1996). When temporal scales of models are discussed, it is usually discussed in terms of time step and duration. Time step is the smallest unit of analysis for change to occur for a specific process in a model. For instance, in this study there is a probability that a farm land's surface area may change seasonally. Duration refers to the length of time that the model is applied, which in this research is 1990 to 2000.

Spatial scale of a model refers to the resolution and aerial extent of the study (US Depatment of Commerce, 1996). Resolution refers to the smallest geographic unit of analysis for the model such as the size of a cell in a raster system. Each cell area is typically treated as constant, while a vector representation would typically have polygons of varying size. A Landsat Thematic Mapper images with a 30m x 30m resolution will be used in this study. For this work, the extent which describes the total geographic area to which the model is applied is $94km^2$.

Like time and space, Agarwal et al (2001) proposed that to articulate scales of human decision-making, two components could be used: these are Agent and Domain. Agent refers to the human actor(s) in the model who are making decisions. The individual is the most familiar human decision-making agent. But there are many human models that capture decision-making processes at higher levels of social organization; such as household, neighbourhood, county, state or province, or nation. While the Agent captures the concept of who makes decisions, the Domain describes the specific institutional and geographic context in which the Agent acts. Representation of the Domain can be articulated in a geographically explicit model through the use of boundary maps or GIS layers (Lillesand et al, 2004). In this research work the Agents are the individual human beings in the communities surrounding the Muni-Pomadze wetland and the domain refers to the communities.

The second important and distinct attribute of this human-environmental model is the approach used to address the complexity of time, space, and human decision-making found in real world situations. Model complexity embraces temporal complexity, spatial complexity and human decision making complexity.

These represent, respectively, the extent to which a model is explicit at temporal, spatial and at the human decision-making scales. The temporal, spatial, or human decision-making (HDM) complexity of any model can be represented with an index, where a low score signifies only simple components and a high score signifies more complex behaviours and interactions (Agarwal et al, 2001). There are important possible interactions between temporal complexity and human decision-making. For example, some human decisions are made in very short time intervals, such as the decision of which tree to cut or grazing a herd is made daily. Other decisions such as whether to increase household farm fields are made over longer term periods.

CHAPTER THREE

METHODOLOGY

Introduction

This research employed remote sensing (RS) and Geographic Information Systems (GIS) techniques. The advent of RS and GIS offers greater possibilities for land use/land cover mapping and are described by Lillesand et al (2004) and Janssen & Di Gregorio (2002) as new and most useful tools for quantitatively measuring land use/land cover (LULC) changes at landscape scale. This chapter discusses the site selection, data type and data source as well as materials used in this study. The processes involved in image processing, change detection and analysis are also discussed in this chapter.

Site selection, data type and data sources

The Muni-Pomadze wetland site was purposefully selected for this study. The selection of this site was guided by the fact that it is a conserved area that is being encroached upon and the fact that the site lacked land use/land cover maps. Land use/land cover maps are very important for monitoring and managing human activities in wetland catchments.

Two sets of data are used in this study, the data from the field and those from existing literature. Three visits to the study site were made; this was to obtain first hand information, training samples for classification, and true world points for validation of classification results. Data from the field was based on field observation, informal interviews and field measurements. The field observation were undertaken to attain a level of generality by locating common factors such as vegetation types and other topographic and land use parameters. Observation technique was used because some of the parameters like farming activities and vegetation types did not require measurements. The field measurement involved the picking of training samples and validation data for classification and accuracy test respectively.

The secondary data was basically satellite images, aerial photographs, and topographic maps of the area (Table 4). The study was based on two cloud-free Landsat 5 satellite imagines (Table 5). The imagines for this research were selected based on availability and cost. They were Landsat Thematic Mapper (TM) imagine of dry season 1990 and an Enhanced Landsat Thematic Mapper plus (ETM +) imagine of dry season 2000. All images were taken in the first weeks of December and February respectively and were all radiometrically and geometrically corrected before acquisition. The images were acquired from USGS. Among the software used in this study were ArcGIS 9.1, ERDAS imagine 9.1, and Garmin 12XL GPS (Table 6).

Table 4: Satellite images

Satellite Type	Sensor	Image number	Number of Bands	Pixel spacing	Observation date
Landsat 5	TM	p193r056	7	30 x 30	12/1990
Landsat 5	ETM+	p193r056	7	30 x 30	02/2000

Source: Fieldwork, 2008.

Table 5: Secondary data

Secondary data	Year
Landsat TM image	1990
Landsat ETM image	2000
Topographic data (1:250000)	1999
Digitised Contour lines	1995

Source: Fieldwork, 2008.

Table 6: Software

Software	Use
ILWIS 3.0, ERDAS 9.1, ArcGIS 9	Image processing and classification
MS Excel	Data entering
SYSTAT 12, SPSS 12	Statistical analysis
MS word	Word processing
MS Visio	Flow charts

Source: Fieldwork, 2008.

Image processing

The images for the study were first geo-referenced. Geo-referencing is a process of relating images to specific map projections. In this study the polynomial transformation procedure was followed. The polynomial was selected because it allows for 1st, 2nd, to nth order transformation which maximizes accuracy (Janssen & Di Gregorio, 2002). This procedure has the ability to accurately relate image coordinates to the topographic map coordinates that will be used for the geo-referencing. An image-to-image registration technique in the ERDAS 9.1 software was used for this transformation. The end product of this transformation was a geo-referenced thematic image for both the 1990 and 2000 images. Ground Control Points (GCP) used for the geo-referencing was validated using GPS set in UTM.

Image classification

The images were first classified into a number of spectral classes using the ISODATA algorithm of ERDAS 9.1 to perform an unsupervised classification. In an unsupervised classification, clustering algorithms are used to partition the feature space into a number of clusters. Performing the supervised classification, the researcher has no control in the classification. This exercise was to aid in the exploration of the LULC types. Using ground-based knowledge after detailed field survey, 178 training samples were purposefully selected and a supervised classification performed using the Maximum Likelihood (ML) algorithm. The decision to use ML was influenced by the fact that ML classifier considers not only the cluster centre, like in the case of Box Plot and Minimum Distance to mean (MDM) classifiers, but also its shape, size, and orientation. It also has an advantage over the other methods because of its probability theory (Lillesand et al, 2000). In using supervised classification one needs to know where to find the classes of interest in the area covered by the image and this information or knowledge is derived from dedicated field observations which are influenced by time and accessibility (Janssen & Di Gregorio, 2002), this justifies why the training samples were purposefully selected.

Bands 7, 5 and 2 were used for the image classification because they are especially responsive to the amount of vegetation biomass present in the images (Campbell, 2002). Band 7 is put in the channel Red, band 5 in the channel Green and band 2 in the channel Blue. After selectively combining classes, classified images were filtered before producing the final output (Figures 6 and7). A 3x3 median filter was applied to smooth the classified images. The 3x3 median filters, according to Lillesand et al (2004), have very minimal effect on pixel values.

Accuracy assessment

To check and quantify the actual quality of the image classification, the stratified random sampling technique was employed to select 220 points for the validation of the classified thematic images. This technique was used because prior to field visits an automated classification of satellite images was carried out in which different classes of land use/land cover were obtained. These classes were considered to represent different strata and different classes of land use/land cover classes, put together, represented the population. Random points were generated in MS Excel and sample points were distributed proportionally according to the size of each land use/land cover class (Table 7). The Garmin 12XL GPS was used to pick the sample points from the different LULC types. The DNR Garmin software was used to extract field point from the GPS and converted into a shape file. Though primary data was generated from 220 samples, only 178 points (Table 7) were used due to some adjustments that were made where it was impossible to access some randomly selected points.

Table 7: Distribution of sample points

LULC units	Area (ha)	Number of Sample points	Number of sample points captured
Water	356.1210	10	7
Alluvial Deposits	403.3456	10	10
Bare Land	2412.0000	40	34
Built-up Area	610.9134	40	38
Grass/shrub/Farm	2687.7601	40	31
Closed Forest	1795.1290	40	29
Open Forest	962.1722	40	29
Total	9227.4413	220	178

Source: Fieldwork, 2008.

The ‘true world classes’ are preferably derived from field data but sometimes sources of an assumed higher accuracy, such as aerial photographs could be used as a reference for validation (Congalton & Green, 1999). Both field data and an aerial photograph of 2005 were employed in order to achieve high accuracy.

Two statistics were used in measuring the accuracy of classification. These are the Proportion Correctly classified (PCC) and the Kappa or k' statistic all derived from the error matrix. The PCC also known as Over-all Accuracy, is the number of correctly classified pixels (i.e., the sum of the diagonal cells in the error matrix) divided by the total number of sampled pixels (Equation 1).

$$PCC = \frac{\text{Number of correctly classified pixels}}{\text{Total number of sampled pixels}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation 1}$$

The Kappa statistic (Equation 2) is an estimate of the measure of overall agreement between image data and the reference (ground truth) data. The Kappa coefficient has a minimum of zero (0) and maximum of one (1) where the latter indicates complete agreement and is often multiplied by 100 to give a percentage (%) measure of classification accuracy. It is computed as:

$$k = \frac{N\sum_{i=1}^{r} X_{ii} - \sum_{i=1}^{r} X_{i+}X_{+i}}{N^2 - \sum_{i=1}^{r} X_{i+}X_{+i}} = \frac{\theta_1 - \theta_2}{1 - \theta_2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation 2}$$

Where

$$\theta_1 = \sum_{i=1}^{r} \frac{X_{ii}}{N} \quad \text{and} \quad \theta_2 = \sum_{i=1}^{r} \frac{X_{i+}X_{+i}}{N^2}$$

X_{i+} is the sum of the ith row, X_{+i} is the sum of ith column, and X_{ii} is the count of observation atbrow i, 'r' is the number of rows and columns in the error matrix, while N is the total number of observations in the error matrix. Any K' value within 0.80 and 1 indicates strong agreement, whilst values between 0.40 and 0.80 indicate moderate agreement. Values less than 0.40 represent poor agreement (Congalton & Green, 1999). The Kappa statistic takes in to account the fact that even assigning labels at random results in certain degree of accuracy.

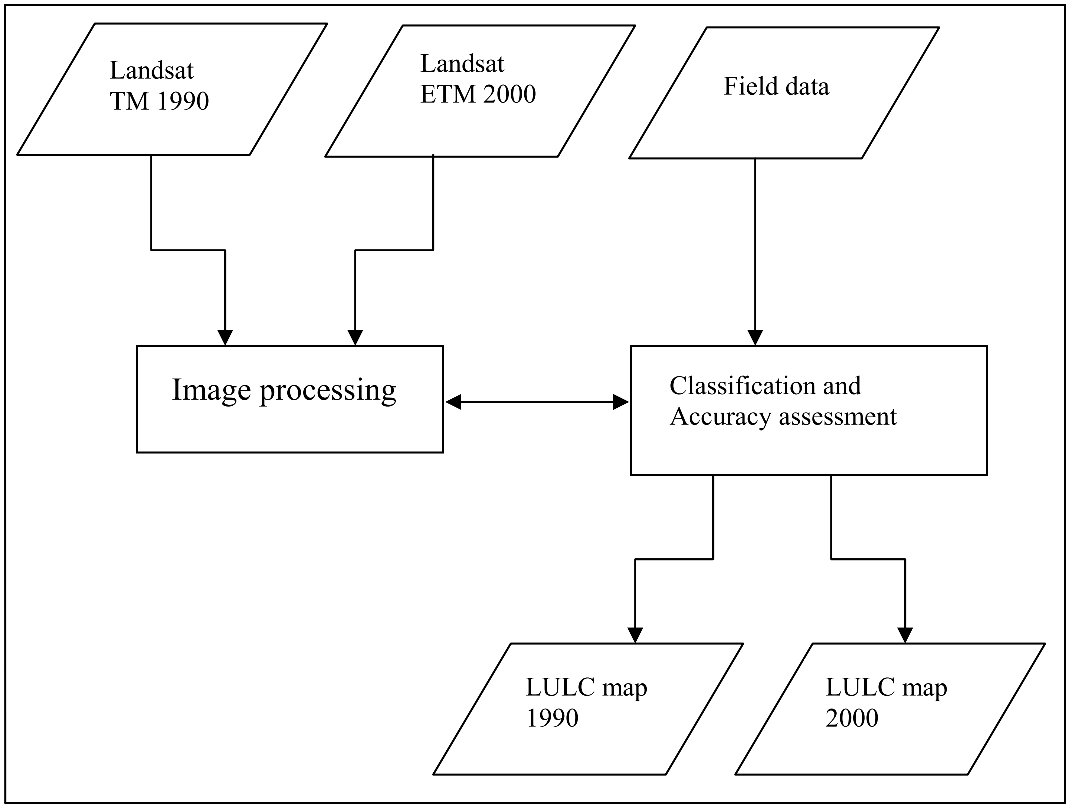

Figure 3: Summary of Land Use/Land Cover mapping procedure

Source: Fieldwork, 2008.

Change detection qualification and quantification

Change detection has different meaning to different users. However, it invariably involves the detection of change in the form of location and extent, and sometimes the identification (Asubonteng, 2007). To identify changes in land use/land cover (LULC) in terms of aerial extent, spots of change, and the path of change, the post-classification change detection technique which involves an overlay of independently classified images was used. It is the most commonly used quantitative method of change detection (Chen, 2002) and it operates on two or more independently classified images as inputs and results in change map and a change matrix. The classified thematic map of TM 1990 and ETM 2000 was loaded in the matrix dialogue of ERDAS 9.1 to indicate changes between both images in the form of change map and change matrix which was then used for the analysis.

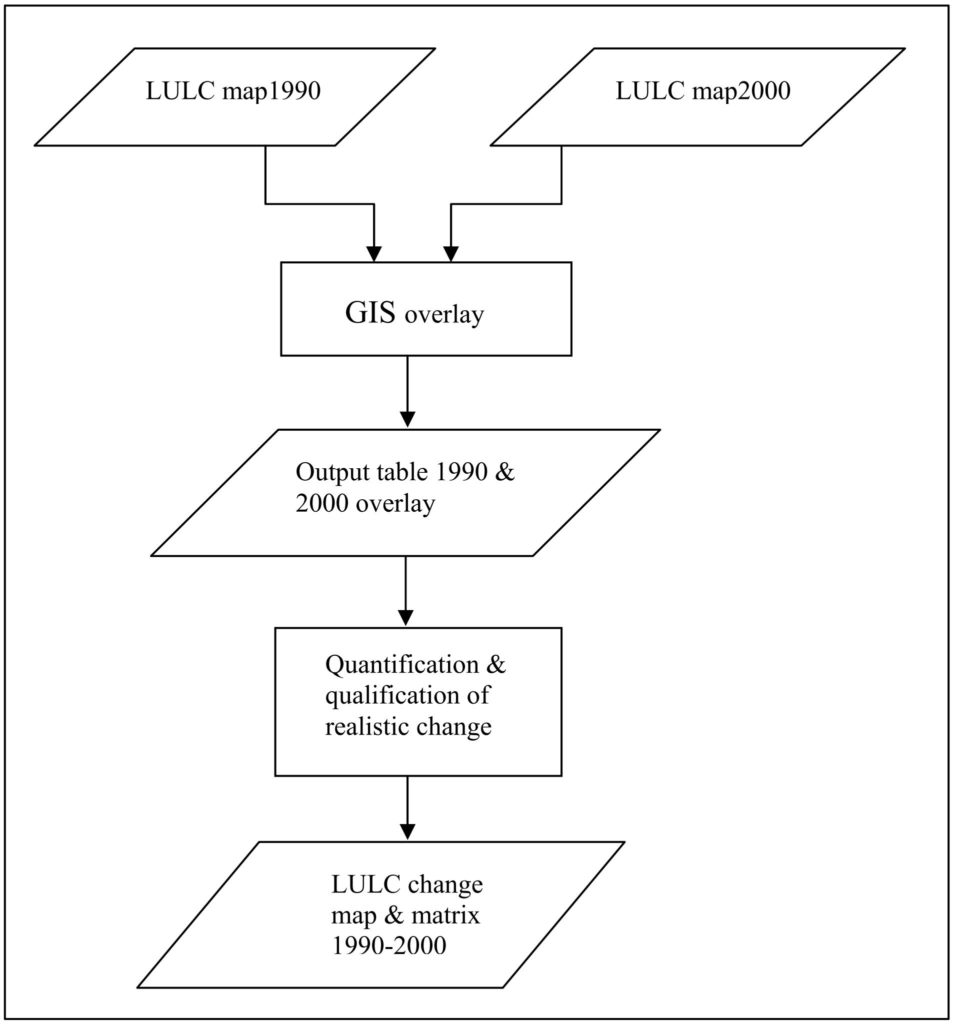

Figure 4: Summary of Land Use/Land Cover change detection procedure
Source: Fieldwork, 2008.

Statistical analysis

The relationship between the main land use/land cover changes (dependent variables) and biophysical factors (independent variables) was investigated statistically. The objective of this activity was to associate LULC change to their determining landscape biophysical factors in the catchments.

Generation of independent variables

Land Use/Land Cover change in the Muni-Pomadze Ramsar site is caused by human activities. Therefore, biophysical factors that guide human decision on land utilization are considered important for analysis in relation to LULC change. These spatially explicit biophysical variables were calculated as maps using GIS tools in ArcMap (Table 8). Then an ILWIS table was created in which the values for each variable for all samples point were digitally extracted from the map. This was achieved by introducing the ILWIS MapCalc expression below on the command line of the table created in ILWIS and columns with the sample point numbers. The various biophysical variables were progressively generated.

Table 8: Biophysical variables and technique used in their derivation

Data set	Derived variables	Technique used to derive variables
Road map	Distance to road	ILWIS GIS MapCalc function
Drainage map	Distance to river	ILWIS GIS MapCalc function
Settlement map	Distance to settlements	ILWIS GIS MapCalc function
Soil map	Soil type	ILWIS GIS MapCalc function
Contour map	Slope and aspect	ILWIS GIS MapCalc function

Source: Adapted from Murwira (2000)

Generation of dependent variables

The major cover changes obtained from change detection (figure 5) were categorized into the following, deforestation and afforestation. The LULC change map was overlaid on field sample points and the type of change that occurred on each location was recorded. This information was then brought together on a common table containing the dependent and the independent variables. This data set was then introduced to the relevant software for analyzing statistically the relationship between biophysical factors and the major LULC changes.

Statistical method

Logistic multiple regression technique in SYSTAT statistical package was used to investigate the relationship between biophysical factors and the major Land Use/Land Cover changes. This regression technique was chosen for the analysis because of its ability to work with binary or dichotomous variables (Mertens, 1999; Mertens & Lambin, 2000; Moore & McCabe, 1998; Murwira, 2000). An additional advantage of this method is its ability to work in situations where the dependent variable is categorical or binary and the independent variable is categorical or continuous. The different LULC changes investigated in this study were binary in nature because they were measured either as present or absent (Table 9).

The analysis followed Stepwise Forward and Backward Wald iteration in SYSTAT statistical package. The interpretation of model results was based on the odd ratio, the t-ratio and logit. The odd ratio is a measure of the association which approximates how much more likely or unlikely it is for the outcome to be present for a set of values of independent variables. The odd ratio and the logit are different ways of expressing the same thing (Mertens, 1999). A significance level of ($\alpha = 0.05$) was used to reject the null hypothesis. The hypothesis developed to test this relationship is as follows:

i. Null hypothesis: there is no significant relationship between LULC changes and biophysical factors Xi

ii. Alternative hypothesis: there is significant relationship between LULC changes and biophysical factors Xi

Mathematically this is expressed as:

$H_o: \beta_1 = 0$

$H_1: \beta_1 \neq 0$

Where: β_1= represents regression slope, and represents all biophysical factors considered in this study.

The generic form of the logistic multiple regression model is:

$$logit\,p = \log\left[\frac{p}{1-p}\right] = \alpha + \beta_1 X_1 + \beta_2 X_2 + \cdots \beta_n X_n \ldots\ldots\ldots\ldots\ldots\ldots \text{Equation 3}$$

The probability value for the occurrence of the dependent variable was quantitatively expressed in terms of the independent variables by:

$$P = \frac{\exp\,(\alpha + \beta_1 X_1 + \beta_2 X_2 + \cdots \beta_n X_n)}{1 + \exp\,(\alpha + \beta_1 X_1 + \beta_2 X_2 + \cdots \beta_n X_n)} \ldots\ldots\ldots\ldots\ldots\ldots \text{Equation 4}$$

Where : P is the probability of the occurrence of the dependent variable, in this case the land use/land cover changes, α is the intercept, $\beta_1 \ldots \beta_n$ are slope parameters, and $X_1 \ldots X_n$ are the predictor or independent variables.

The goodness of fit D^2 (similar to R^2) in conventional statistics was used to assess how well the model predicts the dependent variable. The goodness of fit in the logistic regression is defined as the ratio of the maximum log likelihood. This pseudo D^2 or R^2 is defined as:

$$D^2 = 1 \quad \frac{\log[B]}{\log[c]} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation 5}$$

That is one minus the ratio of the maximized log likelihood of log [B] and constant –only –term log [c] model. Although D^2 ranges from 0 to 1, its value tends to be considerably lower than the value of the coefficient of determination R^2 of conventional regression analysis. It should not be judged by the standards of what is normally considered a good fit in conventional regression analysis (Serneels et al, 2000). Values between 0.2 and 0.4 should be considered very good fit of the model (Mertens, 1999).

Table 9: Variables used in logistic model

	Variable	Type	Unit
Dependent variable	Deforestation	Binary	0 and 1
	Afforestation	Binary	0 and 1
Independent variable	Distance to roads	Continuous	M
	Distance to rivers	Continuous	M
	Distance to settlement	Continuous	M
	Altitude	Continuous	M
	Aspect	Categorical	1 to 3
	Slope	Continuous	Degree
	Soil type	Categorical	1 to 3

Source: Fieldwork, 2008

Testing for collinearity of independent variables

Collinearity occurs when an independent variable has a strong association with one or more of the other independent variables in multiple regression analysis. When the independent variables are highly correlated it becomes impossible to come up with reliable estimates for the individual regression coefficients (Dallal, 2001). According to Mertens (1999), collinearity becomes problematic in logistic regression model when the coefficient of determination (r^2) of the collinear independent variables is greater than 0.8. In such situation, only one of the two collinear variables should be used in the model.

In order to test for collinearity between the independent variables that were significant for each of the three dependent factors, pair wise correlation analysis of each significant independent variable was performed with the other variables and the values of their coefficient of determination (r^2) were compared. The co-efficient of determination (r^2) for all correlation analysis of independent variables were less than 0.8 (Table 10). Though same level of dependence could be observed between the explanatory variables, it was not to levels that collinearity could be feared to wreak havoc in the logistic regression analysis.

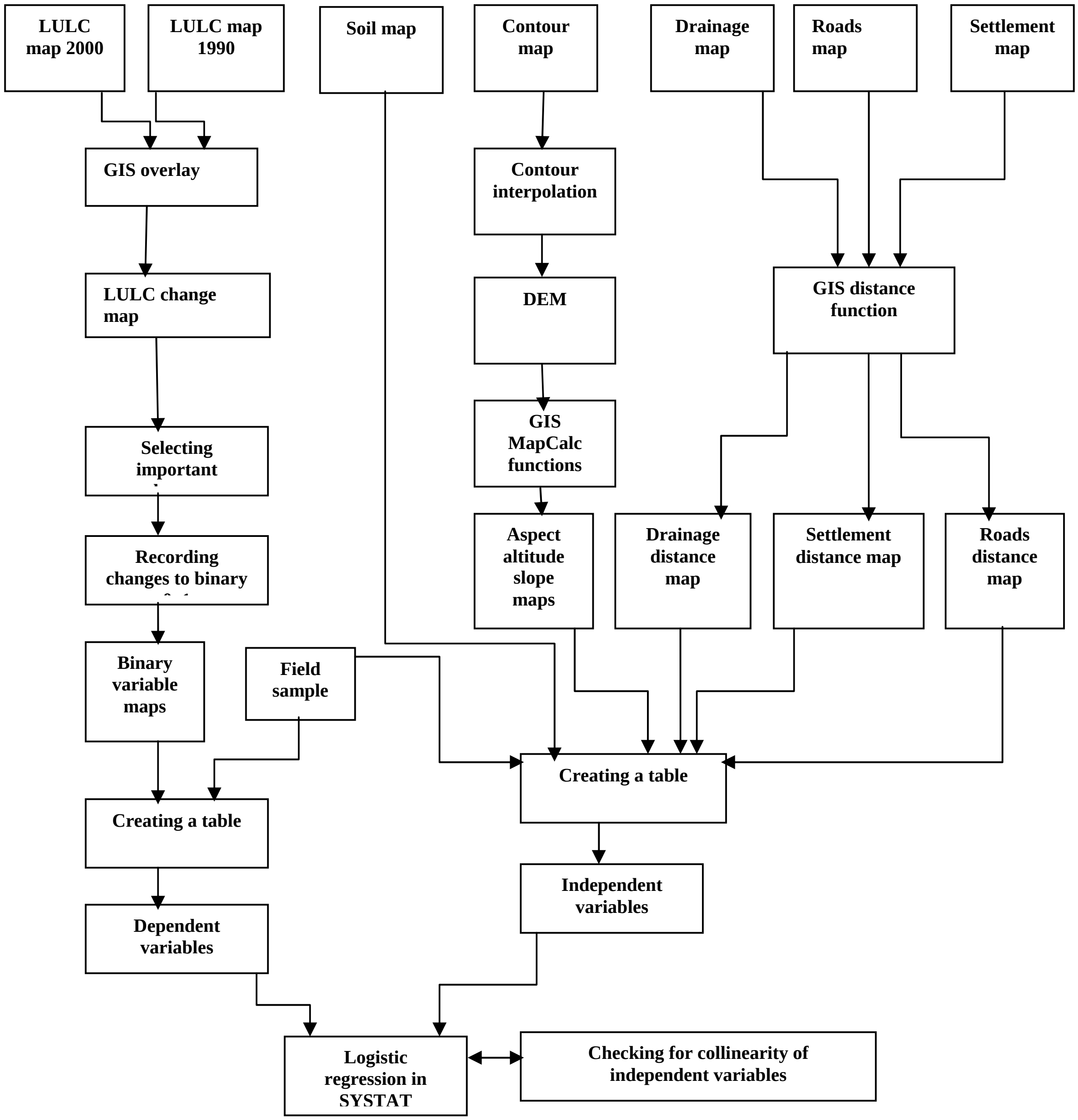

Figure 5: Summary of the statistical analysis

Source: Adapted from Murwira, 2000.

Table 10: Pair wise correlation of significant independent variables

Independent variable 1	Independent variable 2	r^2
Distance from roads	Distance from rivers	0.05
Distance from roads	Distance from settlement	0.29
Distance from rivers	Distance from settlement	0.05

Source: Fieldwork, 2008.

CHAPTER FOUR

RESULTS OF LAND USE/LAND COVER ANALYSIS

Introduction

This chapter presents the output of image processing. The chapter presents the Land Use/Land Cover (LULC) maps of 1990 and 2000, the accuracy assessment results, and the change map that resulted from the overlay of the two LULC maps. LULC change detection qualification and quantification and the relationship between biophysical factors and major LULC changes will also be presented in this chapter.

Land Use/Land Cover mapping

The Land Use/Land Cover (LULC) mapping was based on the segmentation of the study area using the acquired remotely sensed data of 1990 and 2000. Seven LULC classes were discriminated using their spectral and textural characteristics and their feature space. Specifically for vegetation, NDVI was used to facilitate easier discrimination of the various vegetation types. The classes were alluvial deposits, barren-land, built-up land, closed forest, open forest, rangeland, and water (Table 11).

Table 11: Description of Land Use/Land Cover units

LULC units	General Description
Alluvial Deposits	This constitutes sand, clay, and other types of soil deposits around the water body. The salt ponds in this area are also in this category because of their reflectance.
Barren-land	Barren Land is land of limited ability to support life and in which less than one third of the area has vegetation or other cover. In general, it is an area of thin soil, sand, or rocks. Vegetation, if present, is more widely spaced and scrubby than that in the Shrub and Brush category of Rangeland. Unusual conditions, such as a heavy rainfall, occasionally result in growth of a short lived, more luxuriant plant cover. Categories of Barren Land are: Dry Salt Flats, Sandy Areas other than Beaches; Bare Exposed Rock; Strip Mines, Quarries, and Gravel Pits; Transitional Areas; and Mixed Barren Land.
Built-up land	Built-up land is comprised of areas of intensive use with much of the land covered by structures. Included in this category are cities, towns and villages, strip developments along highways, transportation, power, and communication complexes, and institutions that may, in some instances, be isolated from urban areas.
Closed Forest	Forest lands have a tree-crown aerial density (crown closure percentage) of 10 percent or more, are stocked with trees capable of producing timber or other wood products, and exert an influence on the climate or water regime. Lands from which trees have been removed to less than 10 percent crown closure but which have not been developed for other uses also are included. Categories include deciduous, evergreen, and mixed.
Open Forest	The difference between the closed and the open forest is that open forest has a tree-crown aerial density (crown closure percentage) of less 10 percent but more than 5 percent.
Rangeland	Rangeland is comprised of areas where the potential natural vegetation is predominantly grasses, grass like plants, forbs, or shrubs and where natural herbivores were an important influence in its pre-civilization state. Some rangelands may have been or may be seeded in introduced or domesticated plant species. Categories include herbaceous range, shrub and brush rangeland and mixed rangeland.
Water	Water as includes all areas within the landmass that persistently are water covered. The delineation of water areas depends on the scale of the presentation and resolution of the remote sensor data used; Categories include stream, lakes, reservoirs, bays and estuaries.

Source: USGS classification system, 2007.

State of Land Use/Land Cover in 1990

In 1990, the wetland represented only 4.5% of the entire management area. The most predominant unit was the rangeland which occupied 24.9 % of the area, followed by the Barren-land 24.1 %. About 70% of the Closed Forest was located around the northern portions of the catchment. It represented 12.2 % of the management area. The open forest occupied 23% of the area while the rest of the site was occupied by alluvial deposit and built-up cover (Figure 6 and Table 12).

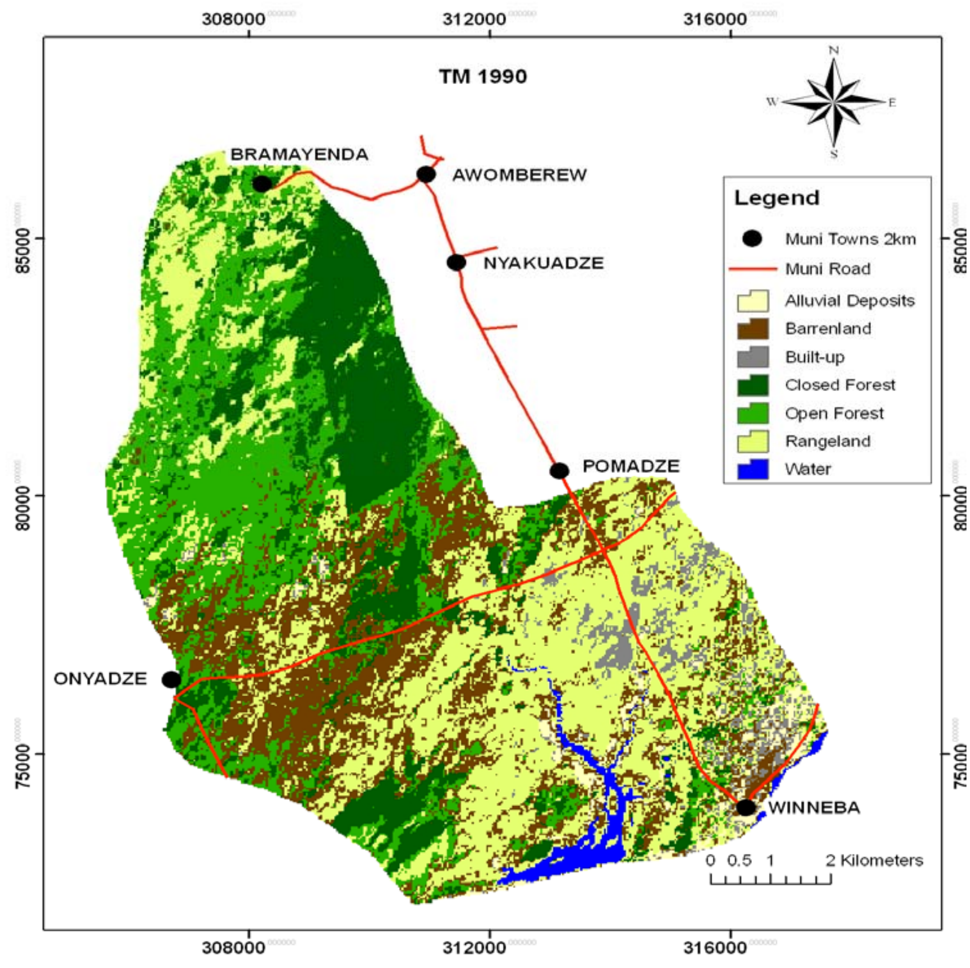

Figure 6: Land Use/Land Cover map of 1990
Source: Fieldwork, 2008.

Table 12: Surface area of Land Use/Land Cover units in 1990

Land use units	Surface area in 1990 (ha)	Proportion (%)
Water	420.96	4.53
Alluvial Deposits	493.50	5.31
Barrenland	2041.48	21.98
Built-up land	506.00	5.45
Rangeland	2320.21	24.99
Open Forest	2301.80	24.79
Closed Forest	1132.32	12.19
Total	9286.21	100.00

Source: Fieldwork, 2008.

State of Land Use/Land Cover in 2000

Land use/land cover units, surface areas and proportions in the Muni-Pomadze Ramsar site in the year 2000 are presented in Figure 7 and Table 13 above. On the whole, the rangeland, the most predominant unit, covered about 28 % while the Open forest represented 21 % of the total surface area. Barren-land, the second most predominant unit occupied 26%. Water, the feature under investigation, covered 3.8% of the catchment. Among the units, about 73 % of the 1990 estimated closed forest, 88 % of the open forest, 70 % of the rangeland and 85% of the Barren-land remained unchanged in 2000. 56%, 91%, and 93% respectively of the built-up, alluvial deposits, and water remained unchanged.

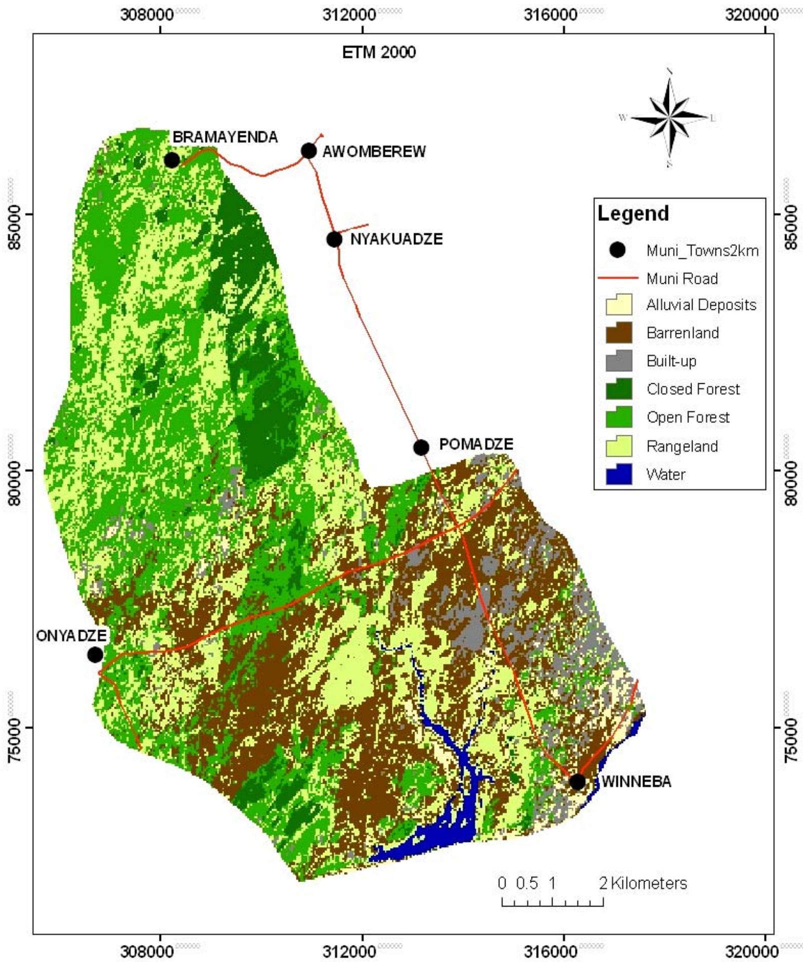

Figure 7: Land Use/Land Cover map of 2000

Source: Fieldwork, 2008.

Table 13: Surface area of Land Use/Land Cover units in 2000

Land use units	Surface area in 2000 (ha)	Proportion (%)
Water	356.1210	3.859
Alluvial Deposits	403.3456	4.371
Barren-land	2312.00	25.055
Built-up land	610.9134	6.621
Rangeland	2587.7601	28.044
Open Forest	2095.1290	21.622
Closed Forest	862.1722	9.344
Total	9227.4413	100

Source: Fieldwork, 2008

Accuracy assessment results

i. Accuracy assessment based on Confusion matrix (Table 14).

Table 14: Confusion matrix

		Reference data								
		W	AD	BL	BU	RL	OF	CF	Total	User accuracy
Classified data	W	**5.0**	2.0	0.0	0.0	0.0	0.0	0.0	7.0	71.43
	AD	1.0	**9.0**	0.0	0.0	0.0	0.0	0.0	10.0	90.00
	BL	0.0	1.0	**30.0**	2.0	1.0	0.0	0.0	34.0	88.24
	BU	0.0	0.0	3.0	**35.0**	0.0	0.0	0.0	38.0	92.11
	RL	0.0	0.0	2.0	0.0	**25.0**	3.0	1.0	31.0	80.65
	OF	0.0	0.0	1.0	0.0	5.0	**22.0**	1.0	29.0	75.86
	CF	0.0	0.0	1.0	0.0	4.0	6.0	**18.0**	29.0	62.07
	Total	6.0	13.0	37.0	35.0	36.0	31.0	20.0	178.0	
	Producer accuracy	80.3	69.2	81.08	100	69.4	70.97	90.0		

Source: Fieldwork, 2008.

The confusion matrix gave an overall accuracy of 85.7%

ii. The Kappa statistic (ḱ) also from the confusion matrix (Table 14), gave an accuracy of 81.3%.

Land Use/Land Cover dynamics from 1990 to 2000

Two maps representing the period from 1990 to 2000 (Figure 6 and7) were superimposed to enable significant evaluation of the Land Use/Land Cover (LULC) dynamics to be determined (Figure 8). The seven LULC units as previously defined were codified and used to present a better understanding of the changes that were detected (Table 15)

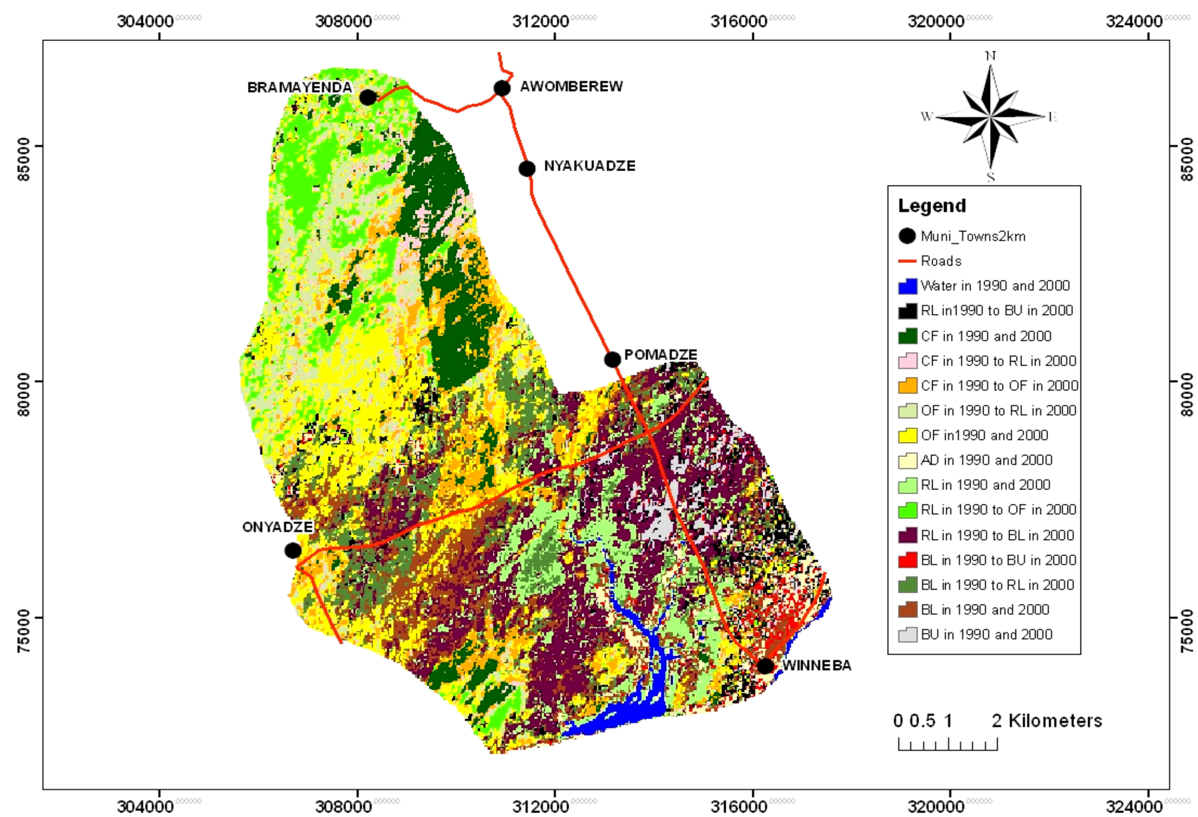

Figure 8: Results of post classification

Source: Fieldwork, 2008.

Table 15: Codification of Land Use/Land Cover units

LULC units	Code
Water	W
Alluvial Deposits	AL
Barren-land	BL
Built-up land	BU
Rangeland	RL
Open forest	OF
Closed Forest	CF

Source: Fieldwork, 2008.

By using the Geo-processing module in ERDAS 9.1 and the Cross Tabulation module in Excel, the following combinations which present the dynamics of LULC in the Muni-Pomadze ramsar site were obtained (Figure 8, and Table 16,17, and 18).

Table 16: Codification of Land Use/Land Cover dynamics

Change code	Direction of change/Description of code
RLBU	Rangeland in 1990 to built-up in 2000
RLBL	Rangeland in 1990 to barren-land in 2000
RLOF	Rangeland in 1990 to open forest in 2000
RLCF	Rangeland in 1990 to closed forest in 2000
CFOF	Closed forest in1990 to open forest in 2000
CFRL	Closed forest in 1990 to rangeland in 2000
OFRL	Open forest in 1990 to rangeland in 2000
OFCF	Open forest in 1990 to closed forest in 2000
OFBL	Open forest in 1990 to barren-land in 2000
OFBU	Open forest in 1990 to built-up land in 2000
BLRL	Barren-land in 1990 to rangeland in 2000
BLBU	Barren-land in 1990 to built-up land in 2000

Source: Fieldwork, 2008.

Table 17: Total change in various classes

LULC units	Area in1990 (ha)	Area in2000 (ha)	Change in 10 years (ha)	Percentage change in 10 years (%)
Water	420.96	396.12	-24.84	-05.91
Alluvial Deposit	473.35	493.50	+20.15	+04.08
Barren-land	2041.48	2312.00	+270.52	+13.25
Built-up land	506.00	710.91	+204.91	+40.50
Rangeland	2320.21	2787.76	+467.55	+20.15
Open Forest	2301.80	2095.13	-206.67	-08.98
Closed Forest	1132.32	862.17	-270.15	-23.86

- = loss, + = gain

Source: Fieldwork, 2008.

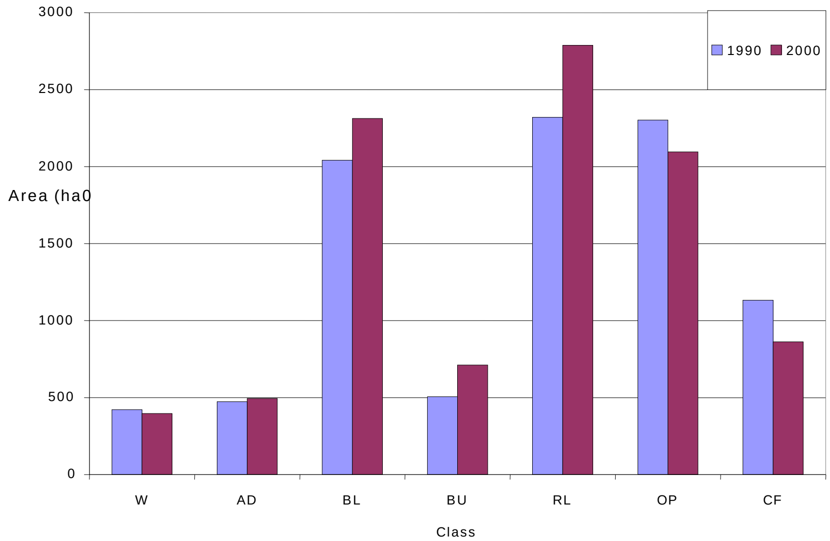

Figure 9: Coverage of Land Use/Land Cover units in 1990 and 2000

Source: Fieldwork, 2008.

Table 18: Land use/land cover dynamics

LULC change	Area (ha)	Percentage change	Observation
RLBU	112.12	23.98	Deforestation/Development
RLBL	301.23	64.43	Deforestation
RLOF	31.41	6.55	Afforestation
CFOF	189.10	69.99	Deforestation
CFRL	61.40	22.73	Deforestation
BLRL	173.41	64.10	Afforestation
BLBU	81.91	30.28	Development
OFRL	181.24	87.71	Deforestation

Source: Fieldwork, 2008.

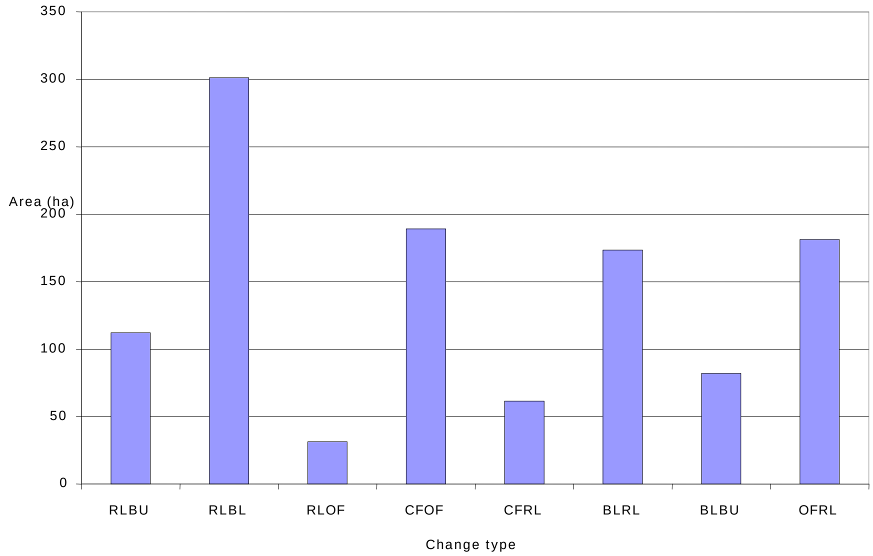

Figure 10: Dynamics of Land Use/Land Cover units from 1990 to 2000
Source: Fieldwork, 2008.

Table 19: Land Use/Land Cover changes not considered in the analysis

LULC change	Area (ha)	Area (%)
RLCF	2.49	2.81
OFCF	3.54	3.54
OFBL	4.89	4.11
OFBU	1.50	1.12
ADBL	2.1	10.41
ADBU	1.81	8.93
WAD	2.65	10.70

Source: Fieldwork, 2008.

These changes (Table 19) were not considered in the analysis because of their small magnitude.

The relationship between biophysical factors and major land use/land cover changes

The relationship between the major LULC changes and the biophysical factors is established from the interpretation of the logistic multiple regression results. The interpretation is based on the p-value, t-ratio, and the calculated goodness of fit (D^2) of the model. Values of the D^2 between 0.2 and 0.4 are considered good fit for the model (Nagendra, Mmroe, and Southworth, 2004). The results revealed by Backward Wald iteration indicate that only two independent variables (distance to roads and distance to rivers) significantly explained the dependent variable, afforestation. The t-ratio indicates that distance to roads is negatively related to afforestation while distance to rivers is positively related to afforestation at 0.05 Significance level and with a $D^2 = 0.24$ (Table 20). The p-value of both variables is less than the significant level (0.05) so the null hypothesis that none of the variables explains afforestation is rejected.

Table 20: Biophysical factors significantly related to afforestation

Predictor	Slope	t-ratio	odd ratio ($e^{b'}$)	p-value
Constant	-1.691279	-1.277944		0.201269
Distance to roads	-0.000925	-3.316035	1.000926	0.000913
Distance to rivers	0.000991	2.259134	0.999010	0.023875

Source: Fieldwork, 2008.

Table 21: Biophysical factors significantly related to deforestation

Predictor	Slope	t-ratio	odd ratio ($e^{b'}$)	p-value
Constant	1.060910	1.095120		0.201269
Distance to roads	0.000505	2.276230	1.000505	0.022832
Distance to settlement	0.000406	2.763899	1.000407	0.005712
Distance to rivers	-0.000991	-2.313423	0.999826	0.020699
Altitude	-0.45913	-2.433580	0.955125	0.014950

Source: Fieldwork, 2008.

The t-ratio indicates that altitude and distance to rivers are negatively related to deforestation while distance to roads and distance to settlement are positively related to deforestation (Significance level $\alpha = 0.05$, and $D^2 = 0.21$). The p-value of all four variables is less than the significant level (0.05) so the null hypothesis that none of the variables explains deforestation is rejected (Table 21).

CHAPTER FIVE

ISSUES FROM LAND USE/LAND COVER ANALYSIS

Introduction

Land Use/Land Cover change (LULC) is a well-known phenomenon that greatly affects natural landscape. It is especially true in rapidly developing and urbanizing areas of most developing countries (Lambin et al., 2001). Monitoring these changes is increasingly reliant on LULC maps produced from multi temporal remotely sensed data. The goal of change detection is to discern those areas on digital images that depict change features between two or more imaging dates. This chapter discusses the results of the LULC mapping, the LULC dynamics that occurred between 1990 and 2000, and how the landscape biophysical factors predict the major LULC changes.

Land Use Land Cover mapping

The objective of Land Use/Land Cover (LULC) mapping is to imitate the earth surface as much as possible by delineating the different features as they exist in nature. LULC is a well-known phenomenon that greatly affects natural landscape. It is especially true in rapidly developing and urbanizing areas of most developing countries (Lambin, et al., 2003). Monitoring these changes is increasingly reliant on LULC maps produced from multi temporal remotely sensed data. The goal of change detection is to discern those areas on digital images that depict change features between two or more imaging dates. In this study seven LULC classes (Appendix D) were discriminated from the landsat images using the USGS classification system. The units were discriminated on the basis of spectral values, textural characteristics, NDVI and their feature space. The analysis produced two LULC maps (Figures 6 and 7) which aided in the change detection. The overall accuracy of the classification results from the confusion matrix and the kappa statistic is 85.7% and 81.2% respectively (Table 14). These values fall within the range described by Congalton & Green (1996) as strong agreement. This implies that a significant proportion of the discriminated classes/units represent the true world classes. These relatively high accuracy results demonstrate that the combined use of spectral values, textural characteristics, and the use of field data and aerial photos in accuracy measurements were effective.

Land Use Land Cover dynamics

The Land Use/Land Cover (LULC) through several years has had different characteristics. The results from this study revealed eight important changes. During the 10year period, the LULC dynamics had a fairly noticeable trend (Tables 18 and 19 and Figures 7 and 8). The change was most profound between the rangeland and barren-land within the period. The southeast and the southern zones where the lagoon is found are the most affected (Figure 7). The LULC types had common physical and geographical interconnections. That is, an increase in one type of unit category was associated with a decrease in another unit category. It is also worth mentioning that the reduction in the physical extent of the lagoon by 6% (Table 17) is an indication that there is still a threat of some sort. This reduction could be attributed to the truncating of some of the streams upland and increase in anthropogenic activities like construction of the new Accra-Cape Coast road, urban expansion, increased farming activities.

The LULC dynamics are, to a larger extent, the result of human agency as discussed extensively in the literature. Based on a range of scenarios, the Global Land Project (2005) projections showed that LULC changes associated largely with increasing human activities will remain the dominant driver of change in terrestrial and fresh-water ecosystems. The Ramsar (2002a) asserts that degradation at the Muni-Pomadzi site is largely due to agriculture, development (construction), sand and salt winning, bush fire, hunting, and fishing. Wuver & Attuquayefio (2006) confirmed these as causal factors as they found that the main occupation of the communities around the Muni site was crop farming, sand and salt winning, fishing, and hunting. Even though increase in construction had its toll, deforestation as established in the study was largely a result of enhanced accessibility and increased agricultural activities. The afforestation was mainly due to management initiatives like the planting of eucalyptus plants in barren-lands by Forestry Commission and the implementation of stricter policies and laws.

Land Use/Land Cover dynamics and biophysical factors

Distance to roads, distance to rivers, distance to settlement, and altitude was important in explaining the process of deforestation (Table 21). Distance to roads and distance to settlement were positively related to deforestation, which is the closer to roads and settlement the higher the rate deforestation. This suggests that deforestation was more pronounced around settlements and access routes. This is possibly deforestation caused by local farming activities and the construction of new buildings and access routes. From the change analysis, built-up gained 40% in terms of its coverage while rangeland, which includes farm fields, increased by 20%. As around the settlements became congested, residents through access routes cleared distant lands for farms. This is also an indication that areas accessible by roads and paths were more prone to deforestation during the study period.

Distance to rivers and altitude were negatively related to the deforestation. The negative relationship between deforestation and distance to rivers indicates that areas close to rivers have little or no chance of being deforested while forested areas away from rivers are more prone to deforestation. The significance of altitude in deforestation process can be explained by easy access to low lands for human activities. Other researchers have supported the importance of accessibility as a factor in determining levels of deforestation. Mertens (1999), Mertens & Lambin (2000) found that distance to roads was one of the factors important in deforestation in the East province of Cameroon as roads increased access to forest areas by migrants. Serneels (2001) also emphasized the influence of easy access to the land on deforestation.

Distance to rivers showed a positive relationship with afforestation (measured as the conversion of rangeland to open forest and barren-land to rangeland) while the distance to roads showed a negative relationship with afforestation (Table 20). The positive relationship between distance to rivers and afforestation is not surprising because forest close to rivers tend to receive limited human interferences and thus has time to recover more than forest far from river basins. Shu (2003) argues that a possible explanation to this relationship is the fact that these areas are permanently water logged or temporally inundated. The negative association established between distance to roads and afforestation is also not surprising because areas close to roads are under continuous influences by human agency and recovery along roadsides will be a very slow process. This simply means areas exhibiting signs of afforestation were areas not easily accessed.

Though the soil quality is one of the most important factors in agricultural activities, hence deforestation, it was not significant in this study. This is because the study area is almost dominated by one soil type (Vertisols) and the other soil type (Solonchaks and fluvisols) were restricted to a tiny southern tip of the research area. Due to the dominance of one soil type over the entire area, statistical relationship could not be established between this factor and the investigated LULC changes. This situation is explained in detail in Green (1994).

There were some limitations in this study as with most research work. During classification process it was difficult to separate the built-up and alluvial deposits based on their spectral values. This difficulty is possibly attributed to the similarity in the reflectance of both classes thus leading to the overlap in their spectral characteristics. As a result the textural characteristics of both units were used in their separation. Also, it was not possible to separate barren-land from fallow during the classification. This difficulty occurs in most instances due to seasonal influence; that is the time the image was captured (Avery & Berlin, 1995).

The imageries used were captured in December and February, months which correspond to the dry season in the region. It is possible that reflectance from dry materials abundantly present in fallow lands during this season and for the barren-lands could be the same. This possibly explains why barren-lands and fallow could not be discriminated based on their spectral values and textural characteristics. As a result the classes were put together under barren-land. It was possible to combine them because the USGS classification system allows the user to make inputs not found in the system. A similar problem was encountered during the separation of rangeland and farm fields. This resulted in the combination of the two units under rangeland. This difficulty probably had to do with the period of the year the images were captured. It was realized from the feature space that both units produced similar reflectance. The use of NDVI was employed yet there was no clear distinction between rangeland and farm fields.

Probable effects of the Land Use/Land Cover dynamics on the wetland

At present, Land Use/Land Cover (LULC) dynamics in many developing countries are resulting in land, water, and forest degradation, with significant repercussions for the countries' natural resource base and environmental balances (World Bank, 1992). The diverse effects of LULC change on wetlands may be permanent or reversible depending on the type and cause of the change. However it is important to note that the responses to these effects are generally dependent on the type of wetland.

- *Reduction in the physical extent of the wetland due to increased sediment loading.* As it has been established (Figure 7), the Muni-pomadze wetland catchments experience some degree of deforestation and this could increase run-off in to the wetland since surrounding vegetation is cleared. This, as Roggeri, (1995) admits, with time is capable of filling the lagoon. During the change detection it was realized that the wetland's extent had reduced by about 5%. Increase in sediment loading could also increase biochemistry oxygen demands (BOD) of the ecosystem.
- *Salt water intrusion and salinisation :* When the drainage map was laid over the 2000 LULC map it was revealed that some of the streams were either dried up or cut-off. This as cited in Oteng-Yeboah (1994) leads to reduction in water input from upstream sources which intend leads to increase in intrusion of salt water from the sea into the water table. Hence, soil salinisation.

- *Acidification of soil which renders the soil unproductive:* Deforestation in the site could lead to leaching of exposed soil nutrients. As a result the sulphides in the original soils are converted to sulpheric acids (Ramsar, 2002a). The soil may shrink upon drying up and may render the soil impotent.
- *Eutrophication:* This means excess nutrient loading (e.g. excess lead and other hard metals as a result of unsustainable agricultural practices and effluent). The increase in farming fields and settlements in the site could lead to increase in agricultural run-off and household effluent leading to excess nutrient loading. When this happens the wetland could lose its function of supporting biological life.
- *Loss of Biodiversity:* it has been established by Wuver & Attuquayefio (2006) that the Muni-Pomadze wetland is important as nesting grounds for thousands of migratory birds. With this trend of dynamics the number of migratory birds into the site could reduce. Again, the deforestation could lead to migration of certain types of animals (antelopes and grass-cutters) away from the site. The salinization and eutrophication as mentioned above has the potential of destroying certain types of wetland vegetation (Geist & Lambin, 2001). The possible contamination of the water through agricultural run-off and effluent could endanger plants, animals

and people living in and around the water body. Typical examples of such polluted systems are the Fosu and Korle Lagoon..

- *Fragmentation of the wetland system mostly from constructional works:* For example, from figure 7 and from field work, it was established that some parts of the Muni-Pomadze wetland was truncated by the Accra-Cape Coast road. Truncating of portions of the wetland system could lead to reduction in not only the lagoon acreage but also the volume of water. Amatekpor (1995) argues that when wetlands lose their water as a result of drainage, their soil cover dries out and is no longer able to store large volumes of water. As a result, there is increase in surface run-off and frequency of floods. Annual flow period of the surrounding rivers are reduced and many water courses dry up.

CHAPTER SIX

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Introduction

This chapter of the study presents a summary of the entire research and the conclusions that were drawn from the results and the ensuing discussion. The chapter also presents some recommendations deemed necessary if degradation at the Muni-Pomadze Ramsar site was to be curtailed and for further research.

Summary

The study was aimed at detecting and quantifying Land Use/Land Cover (LULC) changes at the Muni-Pomadze Ramsar site. As a result landsat imageries of 1990 and 2000 were acquired, processed and analyzed. The objectives involved the production of LULC maps for the area, assessing the LULC dynamics during the period, and finally establishing statistical relationship between the major LULC changes and landscape biophysical factors that influence human decision. The probable effects of the trend of the dynamics on the system were also discussed based on the findings.

The LULC maps of 1990 and 2000 (Figure 5 and 6) were derived utilizing the USGS classification system (Appendices). The LULC classification produced seven classes namely; water, alluvial deposit, barren-land, built-up, rangeland, open forest, and closed forest (Table 13). The validation results were established to be satisfactory after employing standardized accuracy assessment measures and comparison with ground truth data obtained from extensive field survey.

The dynamics of the LULC during the period understudy was detected using the LULC maps of 1990 and 2000. The post classification change detection technique in ERADAS 9.1 which involves an overlay of two LULC maps was used. This process produced a change map and matrix representative of the period and site (Figure 7 and Table 19). The change map and matrix revealed eight important transformations. These were the change from rangeland to barren-land, rangeland to built-up, rangeland to open forest, and open forest to rangeland. The rest were closed forest to open forest, closed forest to rangeland, barren-land to rangeland, and barren-land to built-up. Coming up with these transformations, the researcher was then able to put the dynamics in to two major groups, namely the deforestation and afforestation.

This afforded the computation of the relationship between the major land use/land cover changes (deforestation and afforestation) and the biophysical factors that influence land use decisions (Table 20 and 21). ILWIS 3.0 was used to generate both the dependent (deforestation and afforestation) and independent variables for the statistical analysis. The independent variables were altitude, aspect, slope, soil type, and distance to roads, settlement, and rivers. However, the logistic regression in SYSTAT established that only altitude, distance to roads, rivers, and settlement were significant in explaining the dependent variables, deforestation and afforestation. The statistical analysis, distance to rivers and roads were significant in explaining the afforestation while altitude, distance to roads, rivers, and settlement significantly explained the dependent variable, deforestation.

Despite the results achieved in this study, there were some problems that are worth mentioning. The main issues had to do with access to some of the training and validation data in the field which intend introduced the problem of bias. In areas where accessibility was difficult or impossible, points were taken around roads. This problem resulted in the reduction of the sample size from 220 to 178. There were also problems bothering separation of certain classes. Notably were barren-land and fallow, rangeland and farm fields, and built-up and alluvial deposit though the later were separated using their textural characteristics. Haze on the 2000 image also constituted a problem. Though the haze reduction model in ERDAS 9.1 was run to reduce it, its effect was still eminent. Even though these hindrances did not significantly affect the accuracy of the mapping, they are still worth mentioning.

Conclusions

Landsat TM data is an important source of data for mapping the dynamics of Land Use/Land Cover (LULC) in coastal environments. However haze can limit the usefulness of this data source. This is because the separation problems encountered during image classification of the 2000 image could to some extent be attributed to the presence of haze. Therefore a possible limitation of landsat images in mapping LULC dynamics in coastal environment is the effect of haze.

The availability and use of two satellite images permitted the detection and quantification of LULC dynamics in the Muni-pomadze Ramsar site. This has been useful in improving the understanding of past and present changes in the landscape which has a telling influence on the lagoon. The study did not only show amount of changes but also the direction of the change which is vital if we to comprehend fully the LULC dynamics at the Muni-Pomadze site. Moreover, LULC changes in the catchments cannot be assumed to be straight forward. It was revealed that during the ten year period there were counter transformations. For example there was transformation from rangeland to barren-land and from barren-land to rangeland. With this trend, it could be concluded that the LULC dynamics in the area is complex.

The study produced Land Use/Land Cover (LULC) maps for the area under study. There were no LULC maps for the site prior to this study. Therefore these maps will serve as baseline LULC maps for the study area. Successfully establishing the dynamics of LULC in the area and statistically computing the influence of landscape biophysical factors on deforestation and afforestation is a useful contribution towards the management and conservation efforts by stakeholder in the Muni-Pomadze wetland catchments. The study also established that Landsat imageries with the use of remote sensing and geographic information system are very useful tools for the monitoring land use/landcover dynamics in wetland catchments across the Ghana.

Recommendations

Land Use/Land Cover change is a natural and/or anthropogenic phenomenon. However it results more often from human activities than naturally occurring events (Serneels & Lambin, 2001). It is therefore imperative for any possible continuation of this study to include in the statistical analysis the factors relating to population, technology, affluence, attitudes and values, political structure, and political economy. Again the study was not able to separate barren-land and fallow, and rangeland and farm fields due to the period in which the imageries were captured. A study interested in mapping land cover is recommended to bear this seasonal influence in mind.

Understanding the dynamics and trends in LULC change is the first step in decision making to combat the negative effects of the process (Veildkamp & Lambin, 2001). In the light of the quest for understanding, frequent monitoring becomes a tool to obtain such understanding. According to Van Laake & Sanchez-Azofeifa (2004) monitoring deforestation calls for the application of remote sensing and GIS in collection, processing, and interpretation of data in assessing the nature, magnitude, and rates of change. The effectiveness of remote sensing and GIS in monitoring degradation cannot be over emphasized (Valentine, Knecht, & Miller, 1998), therefore stakeholders in the management of the Muni-Pomadze site should incorporate the use of remote sensing and GIS in its management plans. Based on the findings of this study, it will be very prudent for stakeholders in the management of wetlands, in this case the Muni-Pomadze wetland, to continue monitoring the dynamics of the land use/land cover in the catchmnets since this reveals hot spots so management actions could immediately be effected.

Again, the Wildlife Division of the Forestry Commission should endeavour to establish collaboration with the Ministry of Food and Agriculture. According to Finlayson et al (1999) the sustainability of any management policy or strategy is dependent on close and long-term collaboration across the range of stakeholders. It was established in this study that farming (especially irrigation farming) was one of the contributing drivers of change within the catchments. It was also realized from the review of policies, strategies, and laws that the MOFA encourages irrigation around water bodies without proper sensitization of stakeholders on the diverse effects of farming too close to the water bodies. Collaboration between these two ministries could lead to the outlining of measures that would permit farming and at the same time protect the precious ecosystems.

Wetlands management initiatives should include guidelines for designing wetland policies, improving the production base of the communities, and providing well-integrated environmental programs. This will ensure participation of all that matter in the conservation of wetlands. The current Wildlife and Protected Areas Policy should be reviewed to emphasize not only on wildlife resources but all the components of the wetland system. The policy seems to concentrate more on protecting the biodiversity of these invaluable systems with little attention on the other components of the system (functions and structure).

Finally, the role of traditional management practices should be critically reviewed and incorporated in management policies and strategies. In the past, depending on the beliefs of the traditional area that claimed ownership, most wetlands and their resources were protected and regulated through varied traditional practices. These traditional practices involved customary laws and taboos, which determined rights to land and resource use. Though these rules and regulations are steeped in traditions, their main effect has always been to control resource use.

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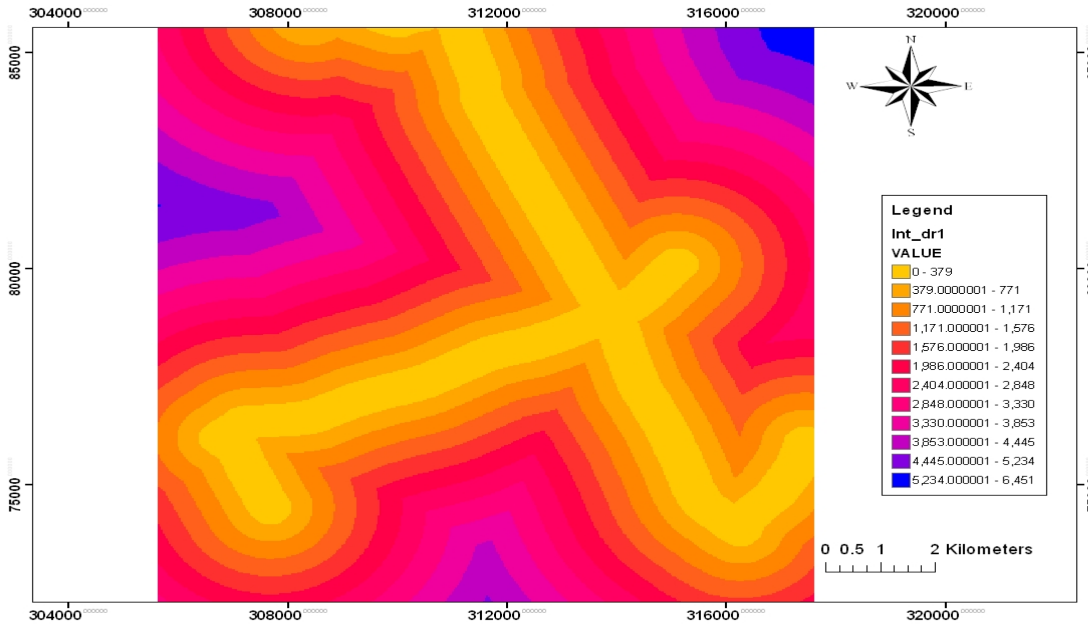
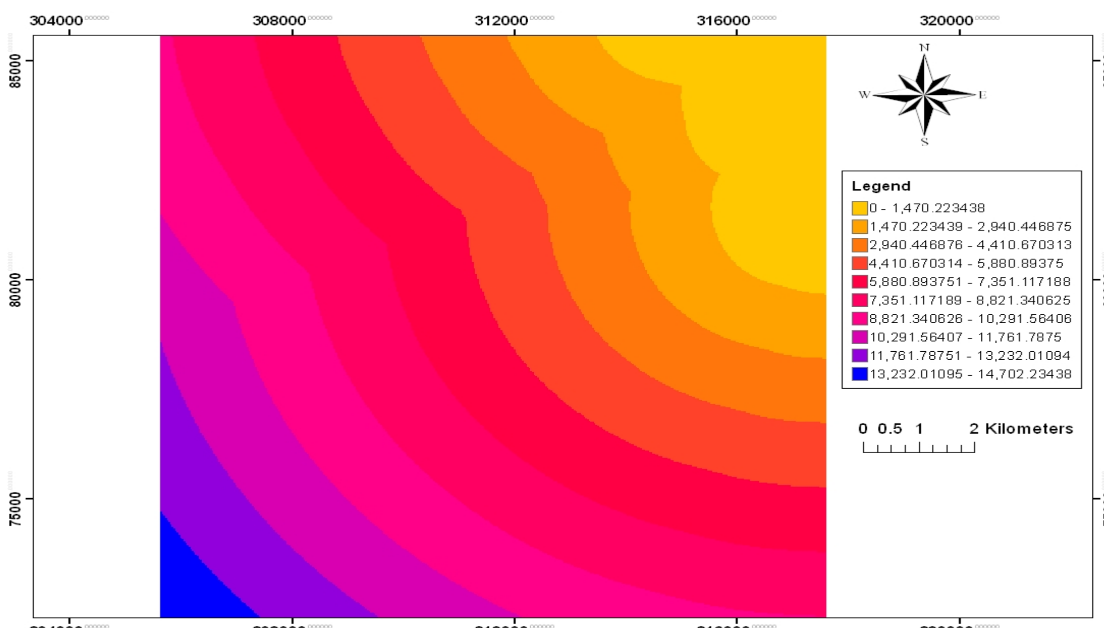
APPENDICES

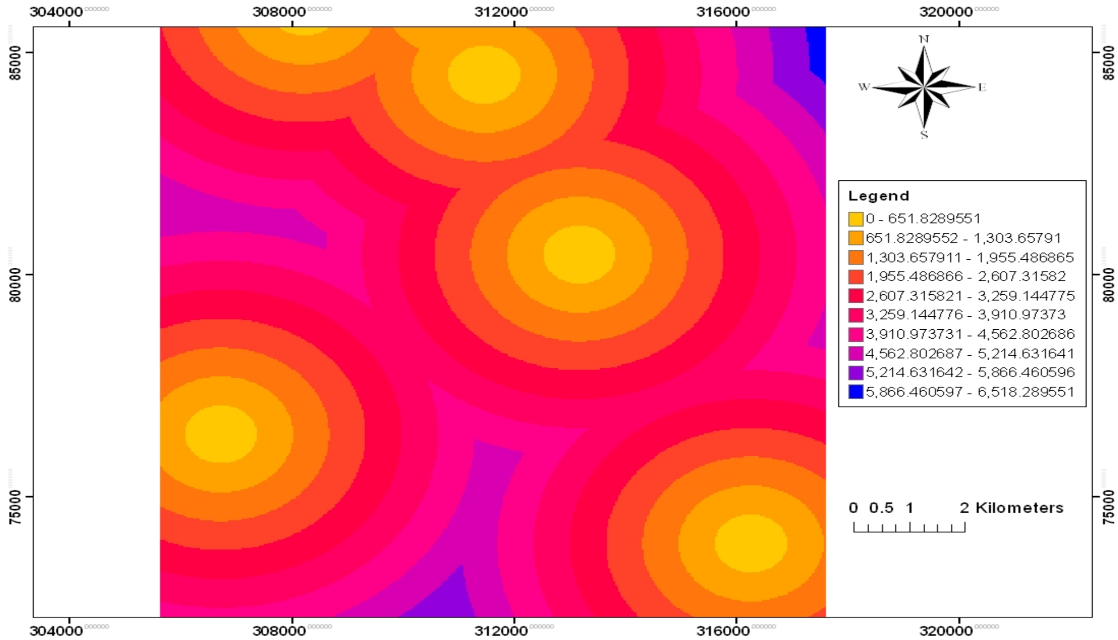
Appendix A: Independent variables



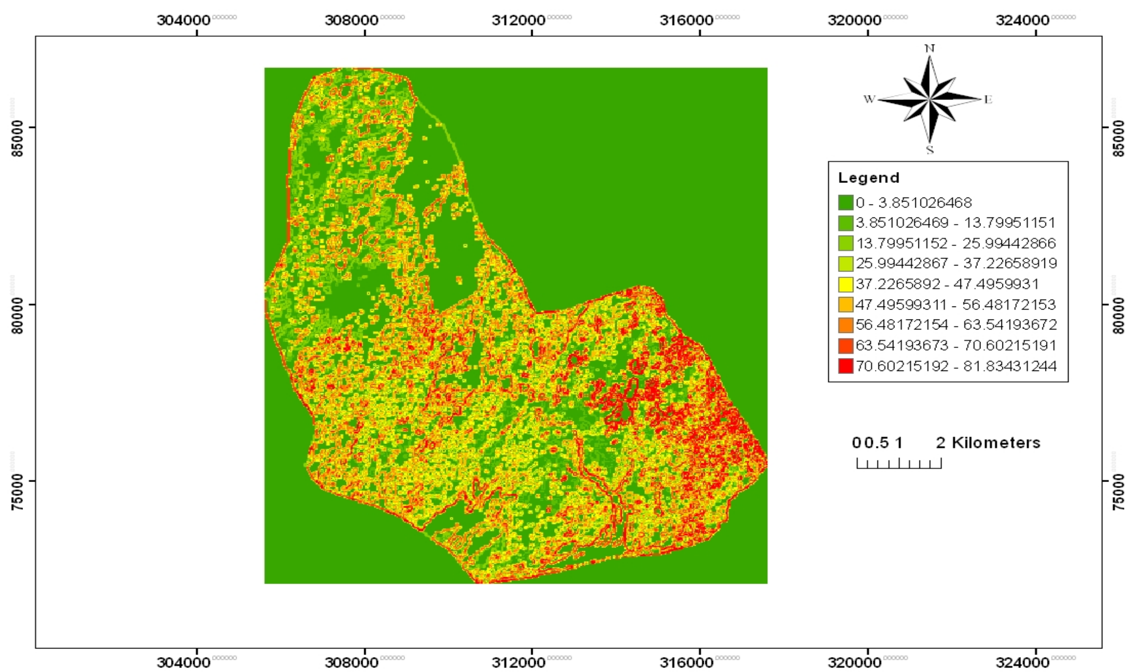
Distance to road map



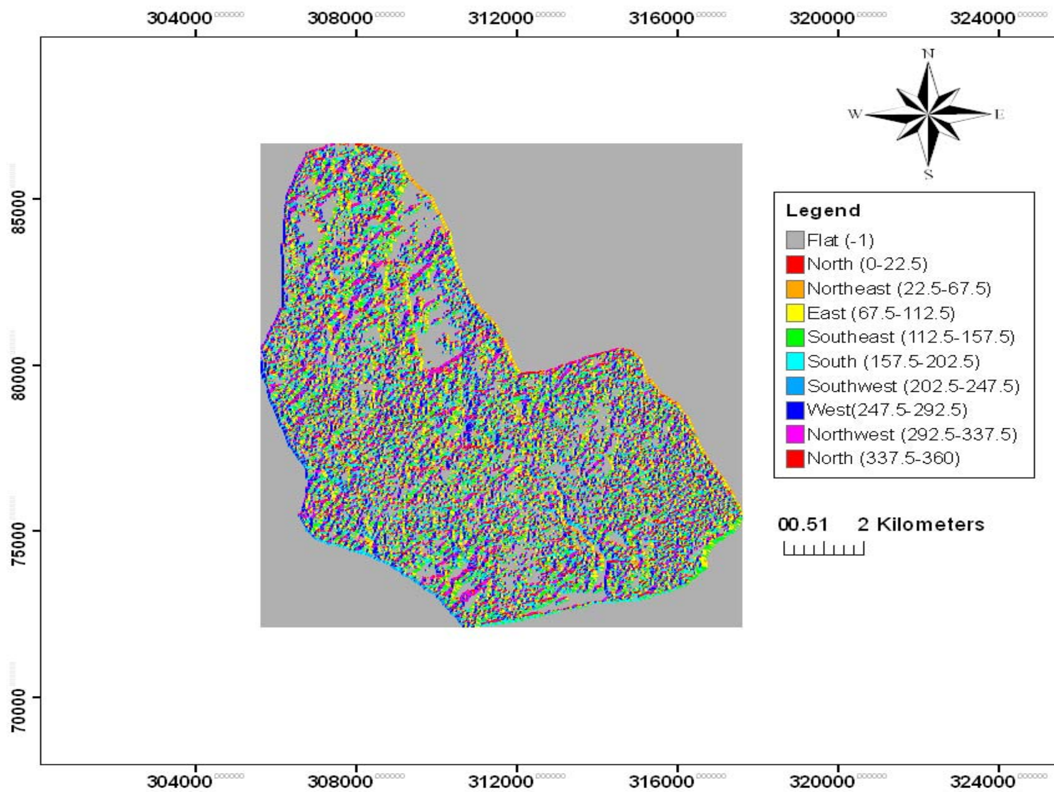
Distance to river map



Distance to settlement map



Slope map



304000
308000
312000
316000
320000
324000
85000
80000
75000
70000
N
W
E
S
Legend
Flat (-1)
North (0-22.5)
Northeast (22.5-67.5)
East (67.5-112.5)
Southeast (112.5-157.5)
South (157.5-202.5)
Southwest (202.5-247.5)
West(247.5-292.5)
Northwest (292.5-337.5)
North (337.5-360)
00.51 2 Kilometers

Aspect map

Appendix B: Biophysical factors not considered

Biophysical variables not significantly related to Afforestation

Biophysical Factor	P-value
Aspect	0.978625
Slope	0.917927
Altitude	0.507586
Soil type	0.991238
Distance to settlement	0.942331

Biophysical variables not significantly related to Deforestation

Biophysical Factor	P-value
Aspect	0.677108
Slope	0.536581
Soil type	0.963283

Appendix C: Field data sheet

Sheet Header

Sample #.............	Date………………………..
Alt……………… Slope………………	Aspect……………………..
UTM: N………. W……….	Location……………………
Observers…………………………………………………………………………	
…………………………………………………………………………………	

Site description

Land cover type	Land use type	Structure	Est.Cov.%	Est.Ht.(m)
		High tree layers		
		Medium tree layers		
		Lower tree layers		
Additional info.				

Appendix D: Processing remotely sensed data using Geographic Information System tools

Bands of the TM sensor

The TM sensor has 7 bands that simultaneously record reflected or emitted radiation from the earth's surface in the blue-green (band 1), green (band 2), red (band 3), near-infrared (band 4), mid-infrared (bands 5 and 7), and the far-infrared (band 6) portions of the electromagnetic spectrum. TM band 2 can detect green reflectance from healthy vegetation, and band 3 is designed for detecting chlorophyll absorption in vegetation. TM band 4 is ideal for near-infrared reflectance peaks in healthy green vegetation and for detecting water-land interfaces. TM band 1 can penetrate water for bathymetric (water depth) mapping along coastal areas, and is useful for soil-vegetation differentiation and for distinguishing forest types. The two mid-infrared bands on TM are useful for vegetation and soil moisture studies, and discriminating between rock and mineral types. The far-infrared band on TM is designed to assist in thermal mapping, and for soil moisture and vegetation studies.

Image classification systems

Within the ITC approach seven main cover categories are distinguished. For each Land Cover possible related Land use(s) are indicated (Asubonteng, 2007). Sub-classes of open natural vegetation, including forest are described according to their structural cover. Here structural vegetation classes are presented either in tabular or graphical format.

The CORINE Land Cover nomenclature has a hierarchical structure and it is organized on three levels (Commission of the European Communities, 1993)

i. The major five Land cover categories on earth (Artificial surfaces, agricultural areas, forest and semi-natural areas, wetlands, and water bodies.)
ii. Fifteen sub-categories for use on a scale 1:500,000 and 1:1,000,000
iii. Fourty four sub-sub-categories for use on a scale 1:100,000

This classification system has been used to map the land cover of 12 countries within the European Union. Each country could add a fourth or even fifth level, according to their specific characteristics, but the first three levels are identical for all countries.

The third classification system, FAO land cover classification system (LCCS) has been designed with two main sequential phases (Jansen and Di Gregorio 2002):

i. An initial Dichotomous Phase, in which eight land cover classes are defined.
ii. Followed by a so-called Modular-Hierarchical Phase,in which land cover classes are created by combination of sets of pre-defined classifiers. These classifiers are tailored to each of the eight major land cover types.

The classifiers are organized according to two or three levels. The 'pure' classifiers can be combined with two types of attributes, for further specification:

i. Environmental attributes that may have an influence on the land cover

ii. Specific technical attributes referring to the technical discipline

With the particular application in mind, the information classes of interest need to be defined and their spatio-temporal characteristics assessed (Anderson et al, 1976). Based on these characteristics the appropriate image data can be selected. Selection of the adequate data set concerns the type of sensor, the relevant wave length bands and the date(s) of acquisition. The possibilities for the classification of land cover types depend on the date an image was acquired (Robinove, 1981). This does not hold for crops, which have a certain growing cycle, but also for other applications.

USGS land use and land cover classification system

Level I (and map color)	Level II
1. Urban or built-up land (red) …………	11. Residential 12. Transportation, communications, and utilities 13. Industrial and commercial complexes 14. Mixed urban or built-up land 15. Other urban or built-up land
2. Agricultural land (light brown) ……..	21. Cropland and pasture 22. Orchards, groves, vineyards, nurseries, and ornamental horticultural areas 23. Confined feeding operations 24. Other agricultural land
3. Rangeland (light orange) …………….	31. Herbaceous rangeland 32. Shrub and brush rangeland 33. Mixed rangeland

4. Forest land (green) …………..	41. Deciduous forest land 42. Evergreen forest land 43. Mixed forest land
5. Water (dark blue) ……………	51. Streams and canals 52. Lakes 53. Reservoirs 54.Bays and estuaries 55. Wetlands
6. Barren land (gray) ……………	71. Dry salt flats 72. Beaches 73. Sandy areas other than beaches 74. Bare, exposed rock 75. Strip mines, quarries, and gravel pits 76. Transitional areas 77. Mixed barren land
7. Tundra (green-gray) …………..	81. Shrub and brush tundra 82. Herbaceous tundra 83. Bare ground tundra 84. Wet tundra 85. Mixed tundra
8. Perennial snow or ice (white) ……….	91. Perennial snowfields 92. Glaciers.

Source: Avery and Berlin, 1985

Types of classification Algorithms

Box classifier

The box classifier is the simplest classification method (Jansen and Di Gregorio, 2002). For this purpose, upper and lower limits are defined for each class. The limits may be based on the minimum and maximum values, or on the mean and standard deviation per class. When the lower and upper limits are used, they define a box-like area of feature space, which is why it as called box classifier. The number of boxes depends on the number of classes. Box classification is also known as parallelepiped classification since the opposite sides are parallel. During classification, an unknown pixel is checked to see if it falls in any of the boxes. It is labelled with the class in which box it falls. Pixels that do not fall inside any of the boxes will be assigned the unknown class, sometimes also referred to as the reject class. The disadvantage of the box classifier, as Mertens, (1999) explains, is the overlap between the classes.

Minimum distance to mean classifier

The basis for the Minimum Distance to mean (MDM) classifier is the cluster centres. During classification the Euclidean distances from an unknown pixel to various cluster centres are calculated. The unknown pixel is assigned to that class to which the distance to the mean DN (digital number) value of that class is least. According to Ehlers (1996) one of the flaws of the MDM classifier is that pixels that are at a large distance from a cluster centre may also be assigned to this center. A further disadvantage of the MDM classifier is that it does not take the class variability into account; some clusters are small and dense while others are large and dispersed.

Maximum likelihood (ML) classifier

The maximum Likelihood (ML) classifier considers not only the cluster centre but also its shape, size, and orientation (Macleod, 1998). This is achieved by calculating a statistical distance based on the mean values and covariance matrix of the clusters. The statistical distance is a probability value; the probability that observation x belongs to specific cluster. The pixel is assigned to the class (cluster) to which it has the highest probability. The assumption of most ML classifiers is that the statistics of the clusters have a ‘normal’ distribution. ML allows the operator to define a threshold distance by defining a maximum likelihood probability value and takes into account class variability.