CLASSIFICATION OF TIME SERIES OF NDVI FOR ASSESSMENT OF LAND COVER CHANGE IN GHANA USING NOAA/A VHRR DATA.

BY

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DECLARATION

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

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ABSTRACT

Land cover information constitutes key environmental information for many scientific, resource management and policy purposes, as well as for a range of human activities. Hence it has become a major focus for the International Geosphere-Biosphere Program (IGBP) and the International Human Dimensions Program (IHDP) at global and regional levels. Land cover information is currently scarce for Ghana. The country is currently undergoing rapid and wide-range changes in vegetation due to climate change, the practice of slash-and-burn or shifting cultivation. The study of these conversions necessitates the use of remote sensing because it provides data at synoptic scales and facilitates the discerning of largescale ecosystem patterns. Although remote sensing technology has been used for mapping in Ghana for sometime now, there has been no attempt to use either unsupervised or supervised classification methods for NOAA/AVHRR images for the whole of Ghana. Therefore a qualitative approach to the use of historical series of low resolution NDVI data to produce land cover maps of Ghana and also to evaluate the relative change in land cover from 1982 to 2002 has been developed. The study was carried out through the principal component analysis and classification of long term average NDVI values. The interpretation of the resulting classes was based on the comparison between NDVI average temporal profiles of different classes and NDVI reference profiles for selected sites where detailed information about vegetation characteristics are available. The results show the potential of the proposed approach for studies at regional or national level where lack of climate data hinder the utilization of quantitative methods to determine the land cover change within the periods (1982-1992, 1992-2002 and 1982-2002). Again the results of the study shows that the dominant land coverchange process was conversion of natural vegetation to savannah and shrub thicket, which occurred at an annual rate of 4% and 6.5% respectively. Most of the land cover change process occurred in the first period (1982-1992).

The overall annual rate of change in land cover (1982-1992) was highest for Savannah (3.8%) and lowest for water (1.03%).

The results suggest that, year phenological behavior, as revealed by the NDVI data, can be used to map general patterns in the spatial distribution of Ghana‟s main vegetation formation.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

Since the 1970s it has been possible to receive radiometric data from meteorological and Earth resources satellites that allow us to analyze the interactions between the solar radiation spectrum and ocean, atmosphere and land properties. In particular, the high temporal resolution sensor, Advanced Very High Resolution Radiometer (AVHRR), of the meteorological satellite series TIROS-NOAA (National Oceanic and Atmospheric Administration) has been used to gain knowledge of the temporal, spatial and reflective behavior of vegetation. The daily coverage this series of satellites and sensors provide offers a unique and long-term dataset with which to investigate the magnitude of changes in vegetation at continental and global scales (Lambin, 1997; Malingreau, 1986).

Land use and land cover has become increasingly important as the Nation plans to overcome the problems of haphazard, uncontrolled development, deteriorating environmental quality, loss of prime agricultural lands, destruction of important wetlands and loss of fish and wildlife habitat. One of the prime prerequisites for better use of land is information on existing land use cover patterns and changes in land use through time. Since Land cover and land use change is not an event but a process, it can be understood and forecasted quite well before time. Knowledge to the present distribution and area of such agricultural, recreational and urban lands as well as information on their changing proportions is needed by legislators, planners, and local government official to determine better land use policy, to project transportation and utility demand, to identify future development pressure points and areas, and to implement effective plans for regional development.

Current land use and land cover data are needed for equalization of tax assessment in many regions. Land use and land cover data are also needed by the government, regions and local agencies for water-resource inventory, flood control, water supply planning and waste-water treatment. Many local agencies need current comprehensive inventories of existing activities on public lands combined with the existing and changing uses of private lands to improve the management of public lands. Local agencies also need land use data to assess the environmental impact resulting from the development of energy resources, to manage wildlife resources and minimize man-wildlife ecosystem conflicts, to make national summaries of land use patterns and changes for national policy formulation, and to prepare environmental impact statements and assess future impacts on environmental policy.

Remote sensing data has therefore been used in a number of classification schemes at local, regional and continental scales (Townshed et al, 1991). Many of these attempts were based on (1) similarity of reflected radiation spectra of various land cover types in relation to specific training sites or (2) temporal evolution of reflected radiation and its association to various phenological attributes of vegetation (Justice et al, 1985; Tucker et al, 1985; Loveland et al, 1991). Both approaches depend on statistical

similarities to a predefined set of conditions based on observations or existing maps. But the generality of the predefined conditions is a cause for much confusion in classifications that requires enormous amounts of ancillary information to resolve

(Loveland et al, 1991).

Present classification schemes suffer from this ambiguity of what is needed vs. what is possible from remote sensing data alone (Running et al, 1994a). Current continental to global scale classification schemes rely mostly on the magnitude and temporal evolution of Spectral Vegetation Indices (SVI), i.e. combinations of RED and NIR reflectance‟s such as NDVI (Justice et al,1985; Tucker et al, 1985; Loveland et al. 1991). With a few exceptions, very little use has been made of the use of NDVI data for classification of land covers.

1.2 NORMALIZED DIFERENCE VEGETATION INDEX(NDVI)

NDVI provides a measure of the amount and vigor of vegetation at the land surface. The magnitude of NDVI is related to the level of photosynthetic activity in the observed vegetation. In general, higher values of NDVI indicate greater vigor and amounts of vegetation. Many researchers have been able to obtain useful and reliable results in determining vegetation state using vegetation indices, such as NDVI, which are closely related to percent cover, leaf area Index (LAI), and plant canopy (Malingreau et al, 1986; Marsh et al. 1992; Di et al, 1994; John et al, 1998). The NDVI approach is based on the fact that healthy vegetation has a low reflectance in the visible portion of the Electromagnetic Spectrum (EMS) due to chlorophyll and other pigment absorption and has high reflectance in the NIR because of the internal reflectance by the mesophyll spongy tissue of green leaf

(Campbell, 1987). NDVI can be calculated as a ratio of red and NIR bands of a sensor system and is represented by the following equation.

$$\boxed{NDVI = \frac{NIR - R}{NIR + R}} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

NDVI values range from -1 to +1. Because of high reflectance in NIR portion of the EMS, healthy vegetation is represented by NDVI values between 0.1 and 1. Conversely, non-vegetated surfaces such as water bodies yield negative values of NDVI because of the electromagnetic absorption quality of water. Bare soil areas represent NDVI values which are closest to 0 due to high reflectance in both visible and NIR portions of the EMS (Lillesand and Kiefer, 1994). NDVI is related to photosynthetically active radiation (PAR) and basically measures the capability of leaves, which is related to vegetative canopy resistance and water vapour transfer (Malo et al, 1990).

1.3 PROBLEM STATEMENT

With the growing concern of global climate change, regional to global land-cover mapping has become an increasingly important data source in a variety of studies such as land-cover change, bio-geo-chemical cycle modeling and climate modeling. The global change research community is increasingly organized in their call for the development of global land-cover. The International Geosphere-Biosphere Programme (IGBP), for example, has identified land-cover as a top research priority (IGBP, 1990). The IGBP has furthered clarified this requirement by specifying that 1-km AVHRR data are the logical basis for global land-cover dataset (IGBP, 1992). Compared with TM and SPOT imagery, National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) imagery has become a popular alternative

for

land mapping for large area, because it is relatively inexpensive, has high temporal frequency for avoiding cloud cover, and has moderate data volume for collecting, storing and processing.

During the last decade, substantial progress has been made in using AVHRR data for land-cover characterizations, but the result of classification is yet to be further improved. The low accuracy on one hand is due to the coarse spatial resolution and constrained spectral resolution; on the other hand it is also owing to the confusion of some land-cover types with similar phonologies (Townshend et al, 1991). Such land- cover types often share spectral reflectance characteristics on the image, which make it difficult for computer to discriminate different types only based on colorimetry, luminance and the statistics information recorded in the imagery. Remote sensing specialists have long recognized the importance of geo-spatial data for land-cover characterization. Significant advances have been made in developing techniques and strategies for using geo-spatial data as ancillary information to improve the result of the land-cover classification. While many studies on large-area land-cover mapping using ancillary and AVHRR image in concert have been widely carried out in foreign countries, none has been done in Ghana.

The sensitivity of the NDVI data to vegetation classification has not been fully investigated. In this research vegetation classification based on time series NDVI patterns from NOAA AVHRR will be compared with the actual vegetation data, and the feasibility of vegetation classification from time series NDVI will be investigated.

1.4 JUSTIFICATION OF THE THESIS.

The current availability of relatively long time-series (multitemporal) remote sensing data has been utilized to characterize land cover and map change. One of the basic techniques of characterizing land cover is the application of standard unsupervised or supervised classification. The simplest classification technique has each temporal image data set classified sequentially. The success or accuracy of the classification ultimately depends upon the spectral seperability of classes in each image data set. One of the shortcomings of this technique is that it fails to utilize information provided by time-dependent relationships between temporal images during the classification process. To utilize these time-dependent relationships, standard classification techniques have also been applied to all spectral bands of a multitemporal data set (e.g. Schowengerdt, 1983). Although the time-dependent relationships would be analyzed by this multitemporal technique, another problem may appear. Classes exhibiting high frequency time-dependent relationships may be difficult to resolve using this multitemporal classification. When these time-dependent relationships do not contribute significantly to the variance of multitemporal data set, they will be difficult to resolve as independent classes. If they are successfully separated by the classification, the meaning of each class may be difficult to interpret. Fundamentally, standard classifications are not designed to extract time-dependent relationships independently.

Methods have also been developed to classify land cover using multitemporal data based upon time-series analysis of a vegetation index graphed against time (e.g., DeFries and Townshend, 1994). In this technique, land cover is usually characterized by translating the time profile of the vegetation index into land-cover classes based upon prior knowledge of the phenological characteristics of the vegetation cover present. Therefore, this method is dependent upon the extent of knowledge of these phonological characteristics and the results are not objective, making universal application difficult. A different approach to characterize land cover types from multitemporal data sets is through the use of principal component analysis (PCA). PCA has been successfully employed in remote sensing for image data transformation, information compression and change detection analysis. This multivariate statistical technique has proven to be particularly effective when applied to both short and long time-series image data to identify surface change (Byrne et al, 1980; Eastman, 1992a; Eastman and Fulk, 1993; Fung and LeDrew, 1987; Ingebristen and Lyon, 1985; Singh, 1989).

This study conduct specific investigations in the application of PCA with the objective of characterizing land cover in Ghana using long time-series satellite data from the National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR). Prior research (Tucker et al, 1985; Townshend et al, 1987) has demonstrated the feasibility of applying PCA to AVHRR data for land cover assessment. The application of PCA is extended to land cover characterization through the use of a priori knowledge of ground cover and the development of a new technique, which is called a vegetation vector, to visualize variations in vegetation cover and the phenological characteristics of diverse land covers.

To meet the urgent need of global change research, this research performed supervised land-cover classification of Ghana employing 1km AVHRR and geo-spatial data by a multi-layers approach, and tested the effectiveness of the method by Principal Component Analysis.

1.5 RESEARCH QUESTIONS

1. To what extent can NDVI time series technique give a good result in determining the land cover change over the period specified.
2. How NDVI satellite data can improve current available information on national land cover for the application of National research?
3. What is the trend of the land cover change within the stipulated time frame?

4. How do environmental factors affect the change?
5. How early can scientists forecast the onset of a land cover change and what can be done to lessen the economic impact?

1.6 RESEARCH OBJECTIVES

1.6.1 OVERALL OBJECTIVES

The objective of this study is to produce a land cover map of Ghana, showing the land cover changes and also assess the environmental growth of Ghana using the NOAA AVHRR satellite images.

1.6.2 SPECIFIC OBJECTIVES

1. To evaluate the effectiveness of the Principal Component Analysis.
2. To identify vegetation cover, their spatial distribution and analyze vegetation phenology and dynamics
3. To produce NDVI maps

1.7 RESEARCH CONCEPTUAL FRAMEWORK

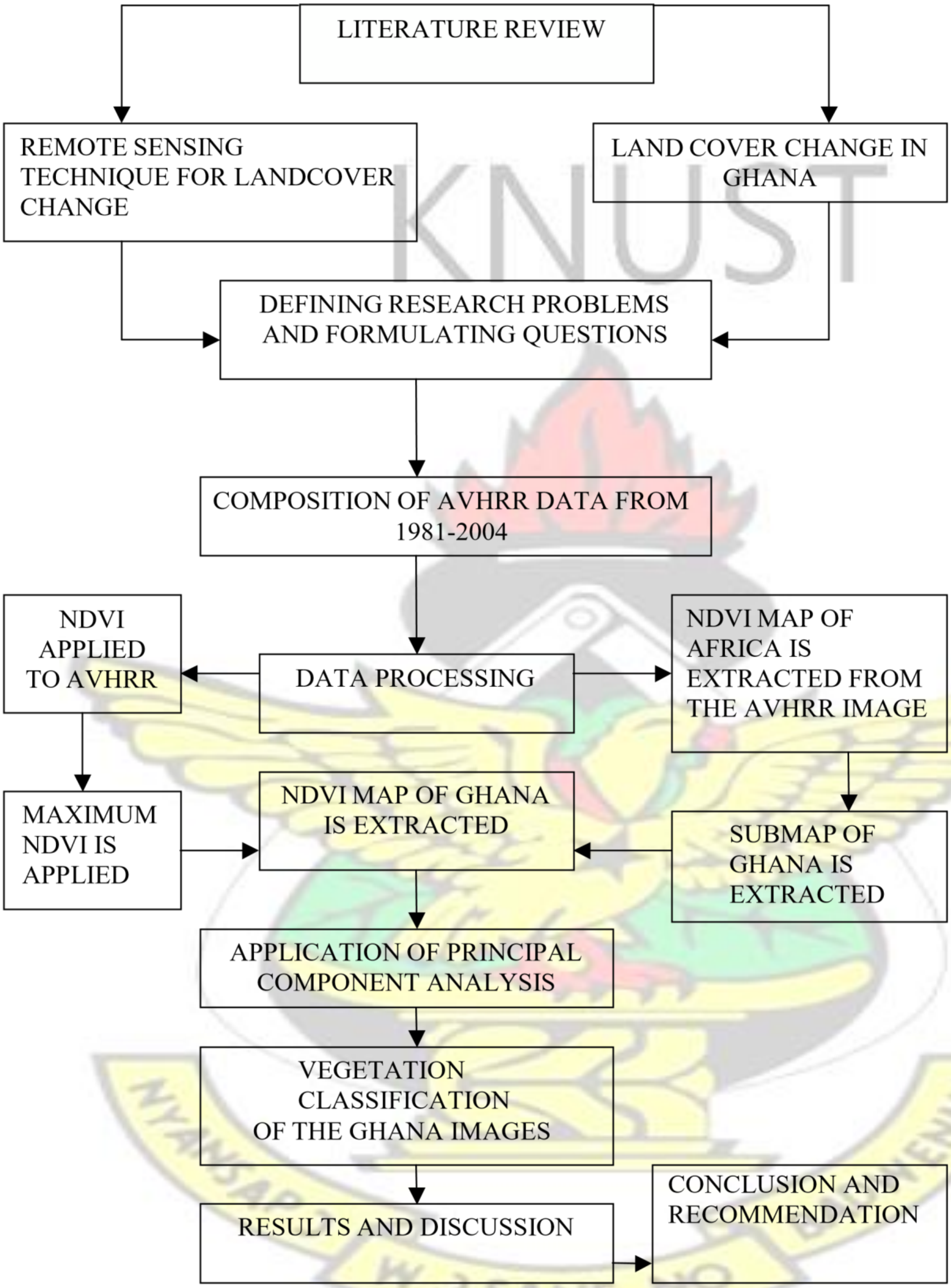


Figure 1.1: Research Conceptual Framework

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

Global, continental and regional land cover data are essential to global change research (Loveland et al, 2000). There is considerable ignorance concerning the global distribution of vegetation types. This is an issue of increasing concern (IGBP, 1990; Townshend, 1991). Reliable and georeferenced data on global vegetation cover is a basic requirement to the modeling of the earth system (IGBP, 1992). Only satellite sensor data can provide us with a truly synoptic view of the earth that may potentially increase the quality, internal consistency, and reproducibility of global land cover information (Townshend et al., 1991) and allow us to study the earth as a whole system (Asrar and Dozier, 1994; Kramer, 1994). National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) data have proven to be a valuable data source for the study of global, continental and regional land cover and long-term terrestrial monitoring (IGBP, 1992, Townshend, 1994). One kilometer AVHRR data has been suggested by the IGBP to be the most appropriate for the generation of a science-quality global land cover database (Loveland et al, 2000). NDVI is also the most widely employed vegetation index and has proven to be useful in large scale vegetation monitoring.

NDVI is broadly correlated in turn with several biophysical parameters such as the level of Photosynthetic Active Radiation (FPAR), Evapotranspiration (Running and Nemani, 1988, Goward and Hope, 1989), biomass of green leaf (Box et al, 1989), leaf area index (LAI), net primary production (NPP) (Tucker and Sellers, 1987; Prince, 1991; Potter et al, 1993; Ruimy et al, 1994) and CO2 flux (Box et al, 1989). During the past

10-15 years, substantial progress has been made in using NOAA AVHRR data for land cover characterization. This include a supervised classification (Tucker et al, 1985;

Townshend et al., 1987; DeFries and Townshend, 1994; DeFries et al, 1998a) and logical classification systems (Running et al, 1995). Also unsupervised classification (Achard and Estreguil, 1995; Driese et al, 1997), in which an initial non-hierarchical and unsupervised classification was refined by a supervised reassignment, by using non-satellite environmental information, for the land cover classification. In recent years, numerous variations have been developed (Cihlar, 2000), For example, decision trees, neural networks, fuzzy classification and mixture modeling for supervised classification; and classification by progressive generalization, classification through enhancement, hierarchical approach and post-processing adjustments for unsupervised techniques have been proposed. Some of them were applied in global, continental or regional land cover classifications (Hansen et al, 1996, 2000; DeFries et al, 1998b; Cihlar et al, 1998). Many of them have not yet been used at large scale. Independent ground information is required by both the supervised and unsupervised methods (Cihlar, 2000) for accuracy assessment of classification results.

It is difficult to only use remotely sensed data to classify land cover types. Metrics such as maximum NDVI, length of growing season derived from a temporal profile of 10 day or monthly NDVI values, rather than directly from the images themselves were used by DeFries et al. (1995b), while, in some cases, additional AVHRR data, multi-resolution imagery and integrated analysis method were included along with NDVI for land Classification (Lambin and Ehrlich, 1995; Cihlar et al, 1996; Laporte et al, 1998; Moody 1998). Multi-source data such as elevation, eco-regions, climate and soil, etc. were considered as important ancillary information for land cover classification (Loveland et al, 1991; Brown et al, 1993). In general, these ancillary data were employed in post-classification in order to split the heterogenous preliminary greenness classes into relatively homogeneous land cover regions (Eidenshink, 1992; Loveland et al, 1997, 2000). Although global land cover datasets derived from AVHRR data are currently available at IGBP Data Information System and the University of Maryland (UMd) 1km land cover maps (Hansen and Reed, 2000), methods for deriving land cover from the satellite sensor data are still being developed (Loveland et al, 2000).

A number of researchers have done work in classifying some parts of Ghana‟s vegetation types. These include the work of Daudze (2004) on Land use and Land cover study of the savannah ecosystem in the upper west region of Ghana using remote sensing and Koranteng (2007) who did land cover land use analysis of Kumasi. In these researches, the normal classification techniques were mainly applied at local or regional scales over limited areas single data or multi-temporal reflectance data. Clearly there is the need for operational methods permitting the application of standard principal component method directly to NDVI images, especially for the whole nation of Ghana.

Therefore a research in this area will be a meaningful challenge.

2.2 WHAT IS LANDCOVER?

In order to appreciate the definitions and concepts of land use and land cover, it may be necessary to, first of all, define the term “land”. According to the FAO (1998),

“land” is any delineable area of the Earth‟s terrestrial surface involving all attributes of the biosphere immediately above or below this surface, including those of the near- surface climate, the soil and terrain forms, the surface hydrology (including shallow lakes, rivers, marshes and swamps), near-surface layers and associated ground water and geo-hydrological reserves, plant and animal populations, human settlement patterns and physical results of past and present human activities (terracing, water storage or drainage structures, roads, buildings, etc). Land is the basic life supporting system that supplies the majority of living forms with space, energy and nutrients that are essential for all biogeochemical cycles both within ecosystems and globally (FAO, 1998).

Many authors or groups have defined “land use” and “land cover”. The UNEP- WCMC (2001) have concisely defined “ land use” as the human activity carried out to obtain goods or benefits from the land, and “ land cover” as the vegetation or the construction, that cover the Earth‟s surface. Cracknel and Hayes (1993) have referred to “land use” as the current use of the land surface by man for his activities, and “land cover” as the state or cover of the land. Smit et al. (1999) have used the term “land cover” to refer to any type of feature present on the surface of the Earth such as tress, grass, open water, and wetlands, but do not assume the specific use of land. They have used the term “land use” to refer to human activity associated with a specific piece of land, which may include characteristics that often cannot inferred directly from the remote-sensing data alone.

The International Geosphere-Biosphere Program (IGBP), the International Human Dimensions Program (IHDP) and the Land Use and Land Cover Change Project (LUCC) have referred to “land use and land cover change” as follows (IGBP/IHDP.1999):

Land cover refers to the physical or biophysical characteristics or state of the Earth‟s surface and the immediate subsurface, captured in the distribution of vegetation, water, desert, ice, and other physical features of the land, including those created solely by human activities such as mine exposures and settlement. Also land use is the intended use or management of the land cover type by human beings. Thus, land use involves both the manner in which the biophysical attributes of the land are manipulated and the intent underlying that manipulation (the purpose for which the land is used, e.g., logging, ranching, agriculture, wildlife reservation, etc).

The biophysical manipulation refers to the specific way in which the resources (e.g., vegetation, soil, and water) are used for a particular purpose. For example, logging, slash-and-burn in many agricultural systems, the use of fertilizers, pesticides, and irrigation for mechanized cultivation on arid lands: or the use of an introduced grass species for pasture and the sequence of movement of livestock in ranching system. Biophysical manipulation can be seen as the techno-managerial system.

Land cover and land use changes: Shifts in intent and/or management constitute land use changes. Land cover and land use changes may be grouped into two broad categories; (1) Conversion and (2) modification (Stolbovoi, 2002). Conversion refers to changes from one cover or use type to another. For instance, the conversion of forests to pasture is an important land use and land cover conversion in the tropics. The abandonment of a piece of land that has been permanently cultivated over a period in the past to regenerate to forest is a land use and land cover conversion. Land use and land cover modification, on the other hand, involves the maintenance of the broad cover or use type in the face of changes in its attributes. Thus, a forest may be retained while significant alterations take place in its structure or function (e.g., involving biomass, productivity, or phenology). Likewise, slash-burn agriculture, a use, may undergo significant changes in the frequency of cropping, and use capital and labour inputs while retaining the rotation, cutting, and burning that constitute such uses. Land use class is a generalized land use description, defined by diagnostic criteria that pertain to land use purpose(s) and the operation sequence followed; it has no location or time indications (de Bie, 2000). Land use classification is the process of defining land use classes on the basis of selected diagnostic criteria (de Bie, 2000). Land use type is a use of land defined in terms of a product, or the inputs and operations required to produce these products, and the socio-economic setting in which production is carried out (FAO, 1998).

Notwithstanding these definitions, it is sometimes difficult to differentiate between land cover and land use. Therefore, Stolbovoi (2002) stated that land use is closely interrelated with land cover in the sense that land cover provides additional information on human activity and specifies this activity in terms of commodity identification, timing, etc. This information, when spatially explicit, may lead to the breakdown of land cover categories into sub-entities, which under various conditions can facilitate further linkages of land use data with other natural characteristics. Land use encompasses a wide range of natural and socio-economic aspects and their interrelations (Stolbovoi, 2002). Land use and land cover information has become so important that it is often parts of studies relating to the environment.

2.2.1 THE CAUSE OF LAND USE AND LAND COVER CHANGE

The pace, magnitude and spatial reach of human alterations of the earth"s land surface are unprecedented. Changes in land cover (biophysical attributes of earth"s surface) and land use (human purpose or intent applied to these attributes) are among the most important (Turner et al, 1990; Lambin et al, 1999). Land use and Land cover changes are so pervasive that, when aggregated globally, they significantly affect key aspects of Earth System functioning. They directly impact biotic diversity worldwide (Sala et al., 2000); contribute to local and regional climate change (Chase et al, 1999) as well as to global climate warming (Houghton et al, 1999). They are the primary source of soil degradation (Tolba et al, 1992); and, by altering ecosystem services, affect the ability of biological ecosystem to support human needs (Vitousek et al, 1997). Such changes also determine, in part, the vulnerability of places and people to climatic, economic or socio- political perturbations (Kasperson et al, 1995). Despite improvements in land cover characterization made possible by earth observing satellites (Loveland et al, 1999), global and regional land covers and, in particular, land uses are poorly enumerated (IPCC,2 000). Scientists recognize, however, that the magnitude of change is large. One estimate, for example, holds that the global expansion of croplands since 1850 has converted some 6 million kilometer square of forests/woodlands and 4.7 million kilometers square of savannas/grasslands/steppes. Within these categories, respectively, 1.5 and 0.6 million kilometers square of cropland has been abandoned (Ramankutty and Foley, 1999). Land cover modifications changes in the structure of an extant cover of a short duration (such as forest succession under slash and burn cultivation are also widespread. Better data alone are insufficient for improved models and projections of land use and land cover change. They must be matched by enhanced understanding of causes of change (committee on Global Change Research, 1999), and this requires moving beyond popular "myths". Such myths are simplifications of cause-consequences relationships that are difficult to support empirically but have gained sufficient public currency to influence environment and development policies. Popular status is gained because the simplification fits within prevalent worldviews, suggests simple technical or population control solutions, and may serve the interests of critical groups.

2.2.2 IMPORTANCE OF LAND USE AND LAND COVER

Land use and land cover information is important for many planning and management activities concerned with the surface of the Earth (Smits et al, 1999; Lillesand and Kiefer, 1994). This is because it constitutes key environmental information for many scientific, resource management and policy purposes, as well as for a range of human activities. This information is significant to a range of themes and issues that are central to the study of global environmental change. For example, alterations in the Earth"s surface hold major implications for the global radiation balance and energy fluxes, contribute to change in biogeochemical cycles, alter hydrological cycles, and influence ecological balances and complexity. For example, large-scale deforestation increases the atmospheric carbon level (IPPC, 2001). Through these environmental impacts at local, regional and global levels, land use and land cover changes, driven by human activity and biophysical factors have the potential to significantly affect food security and sustainability of the world agricultural and forest product supply systems (Mas and Ramirez, 1996; ILASA, 2001). Land cover is an important determinant of land use and hence the value of land to society (Mucher et al, 2000).

Therefore, with the need for environmental planning and management becoming increasingly important, the need for land cover information has emerged parallelly (Cihlar, 2000) at local, regional and global levels. It is, therefore, generated on global, regional and local scales.

2.3 CHARACTERISTICS OF NOAA/AVHRR DATA

The AVHRR-data is particularly suited for monitoring seasonal and inter-annual changes in land cover and land use because of its low cost, temporal and spatial characteristics. There have been a number of studies which have directly linked AVHRR- NDVI to plant phenology (DeFries, 1995; Reed et al., 1994). For instance, the number of periods when the NDVI exceeded a threshold might indicate the number of growing seasons, the time integrated NDVI might indicate gross primary production and the length of the period when

NDVI exceeded a threshold might indicate the length of the growing season. Seasonal and inter-annual variations can be derived from multi-temporal series of NDVI that can be associated with other ecological variables (Mora and Iverson, 1995). The NDVI is also calculated from LANDSAT-TM information by using the combinations of bands 3 (0.63-0.69mm) and 4 (0.76-.90mm). (B4-B3)/(B4+B3). Healthy vegetation will have a high NDVI values near zero. Clouds, water, and snow are the opposite of vegetation in that they reflect more visible energy than infrared energy, and so they yield negative NDVI values.

2.3.1 VEGETATION INDICES

A vegetation indices is a number that is generated by some combinations of remote sensing bands and may have some relationship to the amount of vegetation in a given image pixel. Jim Westphal(2004) at Caltech pointed out that, vegetation indices seemed to be more numerology than science. This may be arguable, since there is some basis for vegetation indices in terms of the features of the vegetation spectrum discussed above, however, Jim Westphal(2004) clarifies that these vegetation indices are generally based on empirical evidence and not basic biology, chemistry or physics.

Live green plants absorb solar radiation in the Photo synthetically Active Radiation (PAR) spectral region, which they use as a source of energy in the process of photosynthesis. Leaf cells have also evolved to scatter (i.e. reflect and transmit) solar radiation in the near-infrared spectral region (which carries approximately half of the total incoming solar energy), because the energy level per photon in that domain (wavelength longer than about 700 nanometers) is not sufficient to be useful to synthesize organic molecules: a strong absorption here would only result in over-heating the plant and possibly damaging the tissues. Hence, live green plants appear relatively dark in the PAR and relatively bright in the near-infrared (Kates, 1980). By contrast, clouds and snow are rather bright in the red (as well as other visible wavelengths) and quite dark in the near-infrared.

2.3.2 NDVI, MOST SUITABLE FOR ALL SERIOUS PROJECTS

There are many vegetation indices but everyone who does much with the remote sensing of vegetation knows NDVI. It has the best dynamic range of any of the indices and it has the best sensitivity to changes in vegetation cover. It is moderately sensitive to the soil background and to the atmosphere except at low plant cover. A quick qualitative look at the vegetation cover in an image reveals importance of NDVI unless one is looking at an area with low plant cover. Perpendicular Vegetation Index (PVI) is somewhat less common in its use, but it is also widely accepted. It has poor dynamic range and poor sensitivity as well as being very sensitive to the atmosphere (Terril, 1994). It is relatively easy to use, and finding the soil line is important for using some of the other indices. It is sometimes better than NDVI at low vegetation cover (Huete, 1998). Modified Soil Adjusted Vegetation Index (MSAVI) is also good, but it has seen very little use.

2.3.3 PERFOMANCES AND LIMITATIONS OF NDVI

It can be seen from its mathematical definitions that NDVI of an area with a dense vegetation canopy will tend to positive values (say 0.3-0.8) while clouds and snow fields will be characterized by negative values of this index. Other targets on Earth visible from space include:

Free standing water (e.g. oceans, sea, lakes and rivers) which have a rather low reflectance in both spectral bands (at least away from shores) and thus results in very low positive or even slightly negative NDVI values; soils which generally exhibit a near-infrared spectral reflectance somewhat larger than the red, and thus tend to also generate rather small positive NDVI values (say 0.1-0.2). In addition to the simplicity of the algorithm and its capacity to broadly distinguish vegetated areas from other surface types, the NDVI also has the advantage of compressing the size of the data to be manipulated by a factor 2 (or more), since it replaces the two spectral bands by a single new field (eventually coded on 8 bits instead of the 10 or more bits of the original data). Using the NDVI for quantitative assessment raises a number of issues that may limit the actual usefulness of this index. The NDVI has tended to be over-used in applications for which it was never designed. Mathematically, the sum and the differences of the two spectral channels contain the same information as the original data, but the difference alone (or the normalized difference) carries only part of the initial information. Whether the missing information is relevant or valuable is for the user to judge, but it is important to understand that an NDVI product carries only a fraction of the information available in the original spectral reflectance data.

Users of NDVI have tended to estimate a large number of vegetation properties from the value of this index. Typical examples include the leaf Area Index, biomass, chlorophyll concentration in leaves, plants productivity, fractional vegetation cover, accumulated rainfall, etc. Such relations are often derived by correlating spacederived NDVI values with ground-measured values of these variables. This approach raises further issues that are related to the spatial scale associated with the measurements, as satellites sensors always measure radiation quantities for areas substantially larger than those sampled by field instruments. Furthermore, it is erroneous to claim that all these relations hold at once, because that would imply that all of these environmental properties would be directly and unequivocally related between them. It should be obvious that the reflectance measurements should be relative to the same area and be acquired simultaneously.

This may not be easy to achieve with instruments that acquire different spectral channels through different cameras or focal planes. Mis-registration of the spectral images may lead to substantial errors and unusable results caused by the following effects during image registration: Atmospheric effects: The actual composition of the atmosphere (in respect to water vapor and aerosols) can significantly affect the measurements made in space. Hence, the latter may be misinterpreted if these effects are not properly taken into account (as is the case when the NDVI is calculated directly on the basis of raw measurements).

Clouds: Deep clouds may be quite noticeable in satellite imagery and yield characteristic NDVI values that ease their screening. However, thin clouds or small clouds with typical linear dimensions smaller than the diameter of the area actually sampled by the sensors, can significantly contaminate the measurements. Similarly, clouds shadows in areas that appear clear can affect NDVI values and lead to misinterpretations. These considerations are minimized by forming composite images from daily or near-daily images (Holben, 1986). Composite NDVI images have led to a large number of new vegetation applications where the NDVI or photosynthetic
capacity varies over time.

Soil effects: Soils tend to darken when wet, so that their reflectance is a direct function of water content. If the Spectral response to moistening is not exactly the same in the two spectral bands, the NDVI of an area can appear to change as a result of soil moisture changes and not because of vegetation changes.

Anisotropic effects: All surfaces (whether natural or man-made) reflect light differently in different directions, and this form of anisotropy is generally spectrally dependent. Even if the general tendency may be similar in these two spectral bands. As a result, the value of NDVI may depend on the particular anisotropy of the target and on the angular geometry of illumination and observation at the time of the measurements, and hence on the position of the target of interest within the swath of the instrument or the time of passage of the satellite over the site. This is particularly crucial in analyzing AVHRR data since the orbit of the NOAA platform tended to drift in time. At the same time, the use of composite NDVI images minimizes these considerations and has led to global time series NDVI data sets spanning more than 25 years.

Spectral effects: Since each sensor has its own characteristics and performances, in particular with respect to the position, width and shape of the spectral bands, a single formula like NDVI yields different results when applied to the measurements acquired by different instruments. For these reasons, the NDVI is used with great caution in any quantitative application that necessitates a given level of accuracy.

2.4 TIME SERIES ANALYSIS.

This is a sequence of measurements that follow non-random orders. Unlike the analyses of random samples of observations that are discussed in the context of most other statistics, the analysis of time series is based on the assumption that successive values in the data file represent consecutive measurements taken at equally spaced time intervals.

There are two main goals of time series analysis (Klema et al, 2004).

1. Identifying the nature of the phenomenon represented by the sequence of observations.
2. Forecasting (predicting future values of time series variables).

Both of these goals require that the pattern of observed time series data is identified and more or less formally described. Once the pattern is established, we can interpret and integrate it with other data (i.e. use it in our theory of the investigated phenomenon, e.g. seasonal commodity prices and vegetation change). Regardless of the depth of our understanding and the validity of our interpretation (theory) of phenomenon, we can extrapolate the identified pattern to predict future events (Klema et al, 2004).

2.4.1 IDENTIFYING PATTERNS IN TIME SERIES DATA

Basically two main patterns are involved, which are Systematic Pattern and Random Noise. As in most analyses such as in time series analysis it is assumed that data consist of a systematic pattern (usually a set of identifiable components) and random noise (error) which usually makes the pattern difficult to identify. Most time series analysis technique involves some form of filtering out noise in order to make the pattern more salient.

2.4.2 TWO GENERAL ASPECTS OF TIME SERIES PATTERNS

Most time series patterns can be described in terms of two basic components: trend and seasonality (Box and Jenkins, 1976). The former represents a general systematic linear or (most often) non linear component that changes over time and does not repeat within the time range captured by our data (e.g. a plateau followed by a period of exponential growth). The latter may have a formally similar nature (e.g. a plateau followed by a period of exponential growth), however, it repeats itself in systematic intervals over time. Those two general classes of time series components may coexist in real-life data (Box and Jenkins, 1976).

2.4.3 TREND ANALYSIS

There are no proven “automatic” techniques to identify trend components in the time series data; however, as long as the trend is monotonous (consistently increasing or decreasing) that part of data analysis is typically not difficult (Box and Jenkins, 1976). If the time series data contain considerable error, then the first step in the process of trend identification is smoothing. Smoothing always involves some form of local averaging of data such that the nonsystematic components of individual observations cancel each other out. The most common technique is moving average smoothing, which replace each element of the series by either the simple or weighted average of n surrounding elements, where n is the width of the smoothing “window” (Box and Jenkins, 1976; Velleman and Hoaglin, 1981). Medians can be used instead of means. The main advantage of median as compared to moving average smoothing is that its results are less biased by outliers (within the smoothing window). Thus, if there are outliers in the data (e.g. due to measurement errors), median smoothing typically produces smoother or at least more “reliable” curves than moving average based on the same window width. The main disadvantage of median smoothing is that in the absence of clear outliers it may produce more “jagged” curve than moving average and it does not allow for weighting.

2.4.4 ANALYSIS OF SEASONALITY

Seasonal dependency (seasonality) is another general component of the time series pattern. It is formally defined as correlational dependency of order k between each i‟th element of the series and the (i-k)th element (Kendall, 1976) and measured by autocorrelation (i.e. a correlation between the two terms); k is usually called the lag. If the measurement error is not too large, seasonality can be visually in time series as a pattern that repeats every k elements. Autocorrelation correlogram: Seasonal patterns of time series can be examined via correlograms. The correlogram (autocorrelogram) displays graphically and numerically the Autocorrelation Function (ACF), that is, serial correlation coefficients (and their standard errors) for consecutive lags in a specified range of lags (e.g. 1 through 30). Ranges of two standard errors for each lag are usually marked in correlograms but typically the size of auto correlation is of more interest than its reliability because we are usually interested only in strong (and thus highly significant) autocorrelations.

2.5 PRINCPAL COMPONENT ANALYSIS (PCA)

PCA is a multi-variate statistical technique used in remote sensing for image encoding and image data compression (Gonzalez, and Wintz, 1977, Ready and Wintz,1973), for image enhancement (Richards 1986), for digital change detection (Byrne et al., 1980; Fung and LeDrew. 1987; Lodwick, 1979; Singh, 1989), and for examining underlying multi-temporal dimensionality of data sets (Townshend et al., 1985). The Principal Components (PC) transformation in a linear transformation which uses image data statistics to define a rotation of original images in such a way that the new axes are orthogonal to each other and point in the direction of decreasing order of the variances. The transformed components are totally uncorrelated. Computationally, there are three processes in PC transformation:

1. Calculation of covariance or correlation matrix using input image data sets.
2. Calculation of eigenvalues and eigenvectors.
3. Calculation of principal components.

The principal components calculated using the covariance matrix is called unstandardized PCs and those calculated using the correlation matrix is referred to as standardized PCs. The use of standardized PCs and unstandardized PCA has been discussed in the statistical literature; this was introduced in remote sensing by (Singh and

Harrison, 1985).

2.5.1 THE EFFECT OF STANDARDIZED PRINCIPAL COMPONENT ANALYSIS AND UNSTANDARDIZED PRINCIPAL COMPONENT ANALYSIS OF SOME REMOTE SENSING IMAGES

There is a growing need for PCA and similar methods within remote sensing for analyzing series of images together. The current trend within remote sensing is moving from the use of one or very few images towards the use of series of images (Singh, 1993). For example, long time series of Normalized Differences Vegetation Index (NDVI) data are available from the National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR). These NOAA series of polar orbiting meteorological satellites collect daily observations for the entire earth surface. Complete global coverage at spatial resolution of 15-20 km exists since 1982. The potential of AVHRR data has been demonstrated in a variety of applications such as mapping and monitoring of vegetation cover at continental and global scales, study of vegetation phenology, estimation of annual primary production and crop monitoring (Prince and Justice, 1991). A user of these data may have to process 52 weekly images or twelve monthly maximum-value images every year for a time span of perhaps several years. One of the important features of PCA is that it produces totally uncorrelated images thereby removing redundancy in the original data sets. Furthermore, large numbers of images can be analyzed together. In remote sensing applications PCA has usually been performed using the covariance matrix. However, Singh and Harrison (1985) demonstrated significant improvement in Signal to Noise (SNR) and image enhancement for two subscenes of Landsat-MSS data using the correlation matrix in the analysis. The use of correlation matrix implies scaling of the axes so that each feature has unit variance. This normalization process prevents certain features from dominating the analysis because of their large numerical values (Duda and Hart, 1973). Fung and LeDrew (1987) found that standardized PCs of Landsat-MSS data were more accurate than the unstandardized PCs because of their better alignment along land cover changes in the multi-temporal data structure. With the growing demand for use of PCA and other data compression techniques, it is vital to know which mode of PCA will yield more useful results for remote sensing applications for different satellite sensor systems.

CHAPTER 3

MATERIALS AND METHOD

3.1 LAND COVER MAP

To prepare a land cover map of Ghana, a set of maps were analyzed with the help of various geographical indicators. The AVHRR is colour coded, ideal for quantifying vegetation. The NDVI is highest in areas that are very green and lowest in non-green areas. Since the NDVI is largely dependent on the time of the year, increasing greener colour indicates the wet season, while the dry season is indicated by a lesser green colour. A computed Long Term Average image representing a 20 year average between 1982 and 2002 is used. This indicator is used as a proxy agricultural productivity.

3.2 STUDY AREA

The whole Ghana is used as the study area of the research.

3.2.1 LOCATION

The Republic of Ghana lies on the western coast of tropical Africa. Ghana extends for a maximum of 672km from north to south between latitudes 4.5°N and 11°N, and for 536km for different satellite sensor systems. east to west between longitudes 3°W and 1°E. It is bordered to the west (668 km) by Cote d‟Ivoire, to the north (548 km) by Burkina Faso, to the south (877Km) by the Gulf of Guinea and the Atlantic Ocean (Clifford et al, 2000). Ghana is one of the five African nations along the northern coastline of the Gulf of Guinea. The total area of Ghana is 238,500sq km (92,090 sq mi). The country consists mostly of low-lying savannah regions, with a central belt of forest. The Capital town of Ghana is Accra. Ghana is a lowland country, except for a range of hills on the eastern border. In the west the terrain is broken by heavily forested hills and many streams and rivers. Ghana‟s highest point, in the eastern hills, is about 884m (2,900ft) above sea level. To the north lies savannah (Oppong-Anane, 2001).

Figure 3.0: Shows the map of Ghana and some capital cities (Oppong-Anane, 2001).

3.2.2 THE CLIMATE OF GHANA

There are nine different patterns of climate in the world. Climate is classified according to temperature and rainfall. Different areas may have the same average annual temperature or rainfall, but a different kind of climate. This is due to seasonal variations in temperature or rainfall.

The climate of Ghana is basically wet and dry tropical. Wet and dry tropical climates are marked by warm to hot temperatures throughout the year, and abundant rainfall in only one season (World Book Encyclopedia, 1999). This condition is especially noticeable in northern Ghana, because of less annual rainfall and the strictly seasonal nature of the rain.

Although this region receives 30 to 40 inches of rain annually, severe dry spells exist from November to March. Most of Ghana receives 40-60 inches of rain annually, characteristic of savanna regions (World Book Encyclopedia, 1999). The rainy season is continuous from April to October in Northern Ghana. It is heavy from April to June and again lighter from September to October in the south. Temperatures range from about 70 degrees Fahrenheit to 90 degrees Fahrenheit (20 degrees celcius to 32 degrees celcius) and the humidity is relatively high. The rest of the year is hot and dry with temperatures reaching up to 100 degrees Fahrenheit (38 degrees celcius). In most areas the temperatures are highest in March and lowest in August, after the rains. Variations between day and night temperatures are small. Temperatures and rainfall vary with distance from the coast and elevation. Annual rainfall ranges from about 37inches in the north to about 59inches in the south-east.

The harmattan, a dry desert wind called the North East Trade Wind (NETW), blows from December to March, lowering the humidity and creating hot days and cool nights in the north. In the south the effects of the harmattan are felt in January. In most areas the highest temperatures occur in March, the lowest in August. A large portion of the West Coast of Africa, and of Central and Eastern Africa, is characterized by this same pattern of rainy seasons and dry seasons (wet and dry tropical Climate).

A second climate region exists in southwestern Ghana. It has a rainy tropical climate- hot temperature throughout the year and abundant rainfall (over 80 inches), well distributed throughout the year (World Book Encyclopedia, 1999). Ghana has warm to hot temperatures throughout the year because of its proximity to the Equator and its relatively low elevation. The average annual temperature in Accra, Ghana, is 80 degrees Fahrenheit (27 degrees Celsius). The northern section of Ghana has hotter temperature and some seasonal temperature variation, because it is farthest from the moderating influence of the ocean, and closest to the Sahara (World Book Encyclopedia, 1999).

3.2.3 AGRO-ECOLOGICAL ZONES

Ghana is divided into six major agro-ecological zones; these are Rain Forest, Deciduous Forest, Forest-savannah Transition, coastal savannah and Northern (Interior) savannah which comprises Guinea and Sudan savannah (Table 3.0). The bimodal rainfall pattern in the Forest, Deciduous Forest, Transitional and Coastal savannah zones gives rise to major and minor growing seasons (Oppong-Anane,2001). In the Northern Savannah the unimodal distribution results in a single growing season. The rainfall determines largely the type of agricultural enterprise carried out in each zone (Oppong-Anane, 2001).

Table 3.0: Shows the Agro-ecological zones Areas and Mean Annual rainfall (SRID, 2001).

Zone	**Area (‘000 ha)**	**Percentage of Total Area**	**Mean annual Rain**	**Growing Period (days)**	
Rain Forest	750	3	2,200	150-160	100
Deciduous	740	3	1,500	150-160	90
ForestTransition	6,630	28	1,300	200-220	60
Guinea Savannah	14,790	68	1,100	180-200	-
Sudan	190	1	1,100	150-160	-
SavannahCoastal	580	2	800	100-110	60

Savannah

3.2.4 SOIL AND TOPOGRAPHY

Most of the soils of Ghana are developed on thoroughly weathered parent material, with alluvial soils (Fluvisols) and eroded shallow soils (Leptosols) common to all the ecological Zones. Generally, most of the soils are plugged with inherent or human induced infertility (MoFA, 1998). The soils in the Forest Zone are grouped under Forest Oxysols and Forest Acid Gleysols. They are Porous, well drained and generally loamy and are distinguished from those of the Savannah Zones by the greater accumulation of organic matter in the surface resulting from higher accumulation of biomass. They occur in areas underlain by various igneous, metamorphic and sedimentary rocks, which have influenced the nature and properties of the soil (MoFA, 1998).

Soils of the Savannah zones, especially in the interior savannah, are low in organic matter (less than 2% in the topsoil‟s), have high levels of iron concretions and are susceptible to severe erosion (MoFA, 1998). Thus well-drained upland areas tend to be droughty and when exposed to severe incident sun scorch, tend to develop cement-like plinthite. These conditions make it imperative for manure be incorporated regularly into the soils in the savannah zones (MoFA, 1998). The topography of the country is mainly undulating with most slopes less than 5% and many not exceeding 1% (Oppong-Anane, 2001).

The topography of the high forest is, however, mainly strongly rolling; the uplifted edges of the voltarian Basin give rise to narrow plateau between 300 to 600m high. Despite the general undulating nature of the terrain, about 70% suffer from moderate to severe soil erosion (Boateng, 1998). A high degree of gully erosion is common in the savannah zones along the north and south, and to some extent along the west (Oppong-Anane, 2001).

3.2.5 AGRICULTURE

Much of the natural vegetation of Ghana has been destroyed by land clearing for agriculture. The majority of people depend on agriculture and live on farms in small villages. Agriculture accounted for more than 40 percent of GDP in 1999 and employed three-fifths of the workforce. However, despite its importance, agricultural growth has lagged behind other sectors of the economy and has been unpredictable, as most farming is reliant upon rainwater. Agricultural output (including forestry and fishing) grew at just 1.0 percent per year between 1980 and 1990, and 2.7 percent between 1990 and 1997. Agriculture growth increased to 5.3 percent in 1998. Ghana is one of the world"s leading producers of cocoa, mostly grown on small farms. In 1998-1999 cocoa production reached 400, 000 metric tons (Encyclopedia of Nations).

Although most of the year-to-year trends are attributable to weather patterns, the longer improvement in performance can be attributed to public changes. As part of the broader macroeconomic reforms (i.e. reforms which affect the whole economy, such as changing the exchange rate, altering controls on interest rates, and adjusting the money supply) the government has removed food price controls, raised cocoa prices paid to producers, and boosted extension services, which help increase farmer productivity. Other cash crops are coffee, bananas, palm oil, coconuts, and kola nuts. The chief food crops are cassava, maize, yams, coco yams, plantain, millet, corm, fruit, rice, and vegetables. Cattle are raised in the north. Yields of food crops, however, have shown disappointing growth with only cassava and millet yields improving in the past decade.

This seems to be a result of low investment and poor technology. The removal of subsidies on fertilizers and other agricultural inputs has also had an effect on several crops. Cocoa is

Ghana‟s most important agricultural export crop, normally accounting for 30-40 percent of total exports (Encyclopedia of Nations).

Most cocoa is produced by around 1.6 million small farmers on plots of less than 3 hectares in the forest areas of the Ashanti, Brong-Ahafo, Central, Eastern, Western and Volta regions. In the 1960s Ghana was the World‟s largest producer of cocoa but it has since been overtaken by neighboring Cote d‟Ivoire. More than one-third of Ghana‟s total land areas are covered by forest, although not all of it is suitable for commercial exploitation. Commercial forestry is concentrated in the Western region in Southern Ghana, and has been the third largest foreign exchange earner in recent years (accounting for about 10 percent of exports) (Encyclopedia of Nations).

3.3 MATERIALS

- ILWIS 3.3
- ARCMAP
- ERDAS IMAGINE 9.2
- NDVI Dekad map
- Topographic Map of Ghana with a scale of 1:50,000

3.3.1 ILWIS 3.2 ACADEMIC SOFTWARE

ILWIS is produced at the International Institute for Geo-Information Science and Earth Observation by the sector of remote sensing and GIS unit Geo Software Development. ILWIS 3.2 was released in January 2004. It is an upgrade of ILWIS 3.1, which was released in April 2002. The ILWIS 3.2 was used because it can easily be used in extracting the NDVI Ghana map from the NDVI Africa map.

3.3.2 ARCMAP

This is a graphical user interface of ArcGIS which is incorporated with some of the functionalities of ArcInfo with a more intuitive interface, as well as an ArcGIS file management application called ArcCatalog. The ArcMap was used for the displaying and subsequent processing and enhancement of the image.

3.3.3 ERDAS IMAGINE 9.2

, ERDAS 9.2 software released in 2008 was designed to be a blend of remote sensing and GIS analysis capabilities. Combining remote sensing with GIS allowed ERDAS to deliver a product which analyzed existing geospatial information and create updated information for re-analysis rather than use outdated data; allowing the customer to make the most informed decision on the their part of an ever changing world. Combining remote sensing and GIS analysis capabilities made the ERDAS software a true decision support tool. This software was used in the project to clip the images to get the coverage map of Ghana for 1982, 1992 and 2002. It was also used for the Supervised Classification.

3.3.4 NDVI DEKAD ACQUISITION

The NDVI raw image is available free of charge at the Africa data dissemination service website. After logging on to the website, you open the required image type needed and download. Twenty four year images were downloaded. All the NDVI data were scaled to 8bits.

Legend

3.3.5 NDVI DEKADFROM 1982-2000

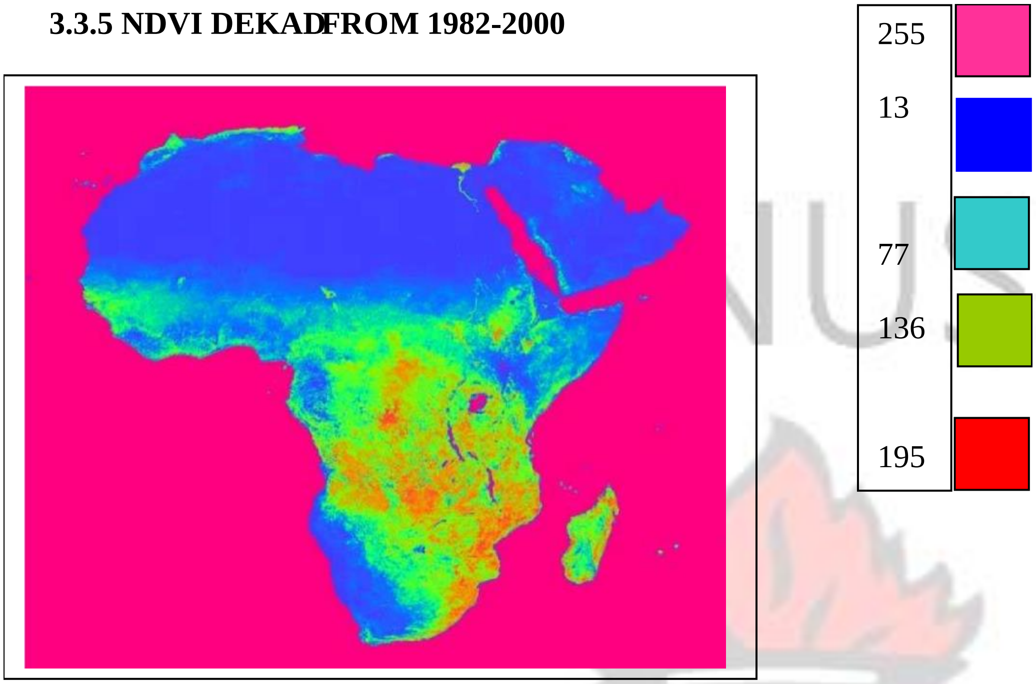


Figure 3.1: Example of how the raw NDVI data or dekad are downloaded from the Africa Data Dissemination service.

EROS processes and archives a dekadal (i.e. 10 days, 36/year) Africa NDVI product from the NASA GIMMS group called NDVI-g. This dataset is spatially identical to any other NDVI-e product but has less NDVI signal removed via smoothing. This has resulted in a real-time, operational NDVI product (called NDVI-rg) that can be compared to the historical archive for classification of anomalous vegetation trends. The dataset is intercalibrated with SPOT vegetation NDVI, and uses NOAA -17 data since January 2001. The NOAA-17 NDVI data have also been inter-calibrated with NOAA-16 and previous NDVI products. These data are now available from the ADDS server in WinDisp and generic BIL formats. The NDVI data from July dekad 1, 1982 through March dekad3, and 2002 are NDVI-g. The data from April dekad 1, 2005 to present are NDVI-rg.

3.3.6 OTHER DATA

Other topographic maps, including the national vegetation maps at different scales, national land use maps and national land cover maps were gathered for use in the interpolation phase of the study and served as a reference data which was used as a guide in labeling the clustering results.

3.4 RESEARCH METHODOLOGY

3.4.1 CONVERSION OF NOAA/AVHRR DATA TO NDVI FORMAT

A time series NOAA/AVHRR data was acquired for the years 1982-2002. The „raw data‟ was then converted to NDVI format by using the formulas below; so that the pixels can be between the -1 to 1 range of NDVI.

$$NDVI = \frac{Raw}{250} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

According to NOAA conversion, values greater than 1 are masked as missing and water values. Water pixels have a value of 1.0200. Valid NDVI results fall between -1 and +1. Values greater than 1 are exempted during the analysis. Figure 3.2 is an example of the NDVI map after the division of the "raw data" by 250.

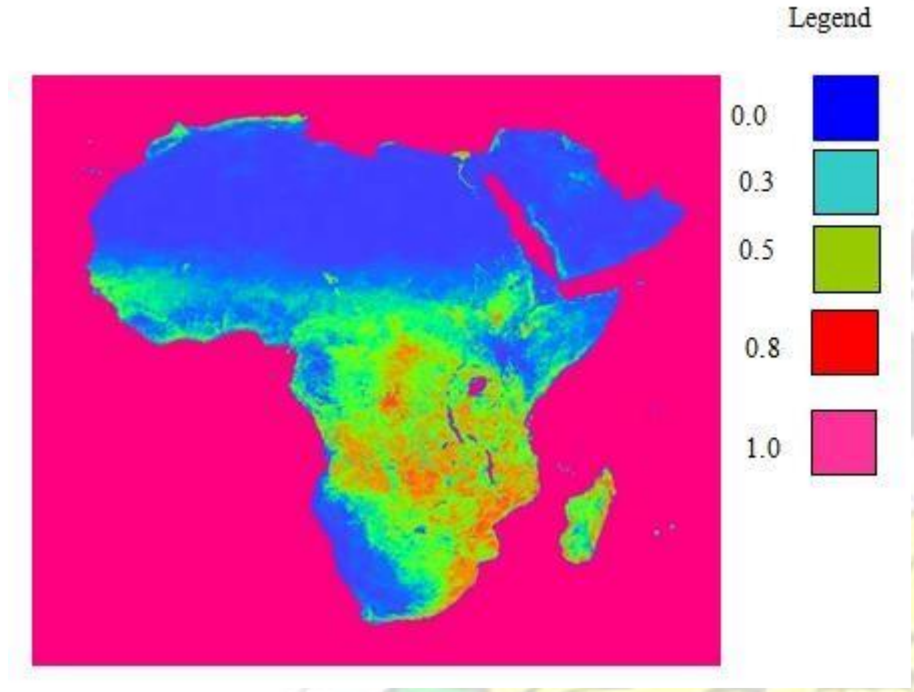


Figure 3.2: NDVI map after the division of the raw data by 250.

3.4.2 EXTRACTING REGION OF INTEREST (ROI)

The map of Ghana is extracted from the NDVI Africa map since it is the study area. To extract the region of Interest (which is the map of Ghana), the formula below is implemented in ILWIS 3.3 Academic software. Though the aim is to extract the map of Ghana, the formula used below first extracts the submap of Ghana.(Figure 3.3)

Output = MapSubmap (input, 420, 270, 110, 80). **………………… (3)**

Where,

Input is the name of the input map (Ghana)

(420, 270, 110, 80) are the extends of columns and rows

Output is extracted NDVI submap of Ghana.

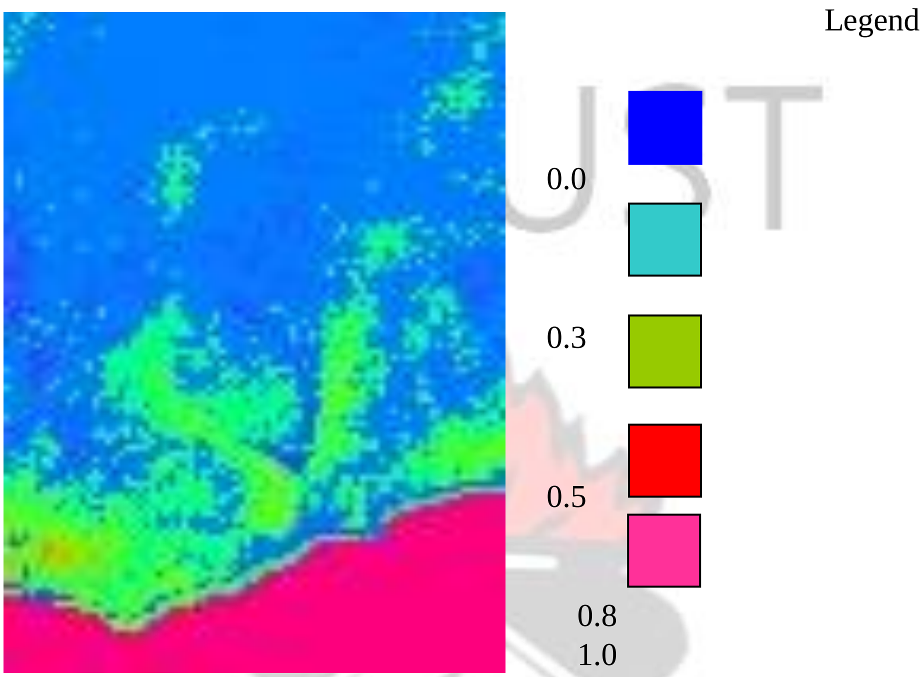


Figure 3.3: NDVI sub map of Ghana.

A Boolean expression is then applied to extract the exact map of Ghana which is the exact area of interest (study area) as shown figure 3.4.The formula used is shown below.

Output = Ifnotundef (Ghana, input) **…………………….(4)**

The input here is equal to the output of the first equation and the output refers to the Ghana map.

Figure 3.4: NDVI map of Ghana.

3.4.3 LAND COVER MAPS

The 10-day NDVI composites images of Ghana from 1982 to 2002 were extracted with the formula above in ILWIS 3.3 software to be used for the land covers types of Ghana. These images were displayed using ARCMAP to have first hand information on the data. The NDVI images of Ghana obtained after the extraction showed that most of the imaging during the wet and dry season was barely obscured by clouds and shadows. The monthly NDVI images were examined to select those with minimal apparent Cloud contamination. Finally NDVI images of 1982, 1992 and 2002 were used for the study.

The topographic map of Ghana was also displayed as a layer. The images were then georeferenced to fit the coordinate system of the country. Thus the Original NDVI data for each year was geometrically corrected in order to fit the topographic map of Ghana. A first order affine transformation was applied, resulting in a RMS error of 0.35. The output images were resampled without any interpolation so that it can be represented at 1km by 1km resolution. By using ERDAS, the images were clipped or subset to get the coverage map of Ghana for 1982, 1992 and 2002.

3.4.4 STANDARDIZED PRINCIPAL COMPONENT ANALYSIS

In testing the technique, a 36 month sequence of AVHRR derived data were analyzed for Ghana. In the application of the standardized principal component analysis, the first six components were retained and analyzed. Analysis was performed on 8 bit geometrically corrected NDVI data set. In order to get a good classification, the original 36 NDVI images were masked by applying a threshold of value of pixels near the northern sector. Out of the six components obtained only components 1, 2 and 3 were used because of their good variances. Components 4, 5 and 6 were ignored because they constituted small percentage of the variances and therefore was considered as noise.

3.4.5 SUPERVISED CLASSIFICATION

For all the regions in Ghana, four data layers (NDVI, PC1, PC2, and PC3) were stacked together and used for supervised classification. Supervised clustering algorithms and maximum likelihood classifications were applied to all the datasets to generate classification clusters. “Ground truth” data were obtained from two sources: an updated high resolution land cover land use map, generated by FAO together with the topographic map of Ghana, where the topographic information were used for selection of training signatures in the NDVI images, and interpretation and labeling of spectral clusters in relation to land cover types.

Because of the large number of training signatures gathered and the potential spectral variability of the training sites within each class, a two-step approach to refine the signatures was used in training the supervised classifier. The resulting cluster was examined by viewing the spectral profiles of the signatures that comprised the cluster in question. Based on the spectral profiles, some of the clusters were eliminated and others were merged resulting in 10 major training signatures (classes) including grasslands, water, farmlands, newly cultivated fields, guinea savannah, savannah grasslands, bare lands, short shrubs, medium shrubs, closed woodland (including thick and tall trees) .

The subclasses helped define each class more accurately, for example, shallow water and deep water were used for water, farmlands and newly cultivated lands for Agricultural land and 5 patches of grassland were used to train for grassland. The supervised classification was done on the entire NDVI image. In the Western region, Ashanti region and Brong- Ahafo regions where there were similar spectral characteristics between Agricultural land and Forest, the binary decision tree method was applied to reduce classification confusion.

The output was 6 classes of land cover map of Ghana.

Table 3.1: Land cover classification scheme

LAND COVER CLASS	DESCRIPTION
FOREST	Mainly thick trees which are very high(>200trees/hec)
SHRUB THICKET	Mainly trees(75-150 tree/hec) with shrub undergrowth
GRASSLAND	Mainly mixture of grasses and shrubs without trees
AGRIC LAND	Agricultural land with crops, harvested agricultural land
SAVANNAH	Tropical grassland with more or less scattered dense tree
RIVERS	Rivers, inland water, Reservoirs

3.4.6 DATA ANALYSIS

To ensure that the information derived from the classification was of high quality and to deduce meaningful indications on thematic correctness, the classified image was assessed for accuracy using Cohen‟s kappa and classification matrix table. In assessment, the classified NDVI image and “ground truth data” were compared. The relationship between these two sets of information was summarized in two ways (i) Contingency matrix, which describes the comparison of the remote sensing derived classification map and “ground truth” reference data (2) kappa statistics, which provides a measure of agreement between the classified remotely sensed data and “ground truth” reference data.

Overall accuracy and class-specific user and producer accuracies were calculated for each of the resultant six land cover classes. Producer‟s accuracy was obtained by taking the number of points classified correctly for a class and divided by the number of ground reference points in that class, while user‟s accuracy was the number of points classified correctly for a class which is divided by the number of points classified as that class.

When a point was incorrectly included in a class, an error of commission has occurred. Inversely, when a point was excluded from the proper class, an error of omission has occurred.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 INTRODUCTION

This chapter seeks to throw more light on the Vegetation maps of Ghana produced from the NDVI map which will help in describing the various vegetation changes that has occurred from 1982 to 2002. The land cover map will help government and other planning agencies to have detailed information about the vegetation of Ghana and the changes that has occurred within the stipulated period. The analysis will be based on the land cover map produced and the NDVI values obtained from the NDVI maps produced.

4.2 IMAGES OF THE STANDARDIZED PRINCIPAL COMPONENT ANALYSIS

The resulting images clearly revealed that pixels along the Northern sector has NDVI values much lower than original values due to the low spatial resolution of original images. The analysis of the percentage of variance is shown by each component and the graphs of loadings are shown in Table 4.1 and Figure 4.1a.

Table 4.1: The variance of the six principal components.

Component	**Variance %**
Comp 1	**98.146**
Comp 2	**0.978**
Comp 3	**0.520**
Comp 4	**0.087**
Comp 5	**0.073**
Comp 6	**0.052**
Total	**99.856**

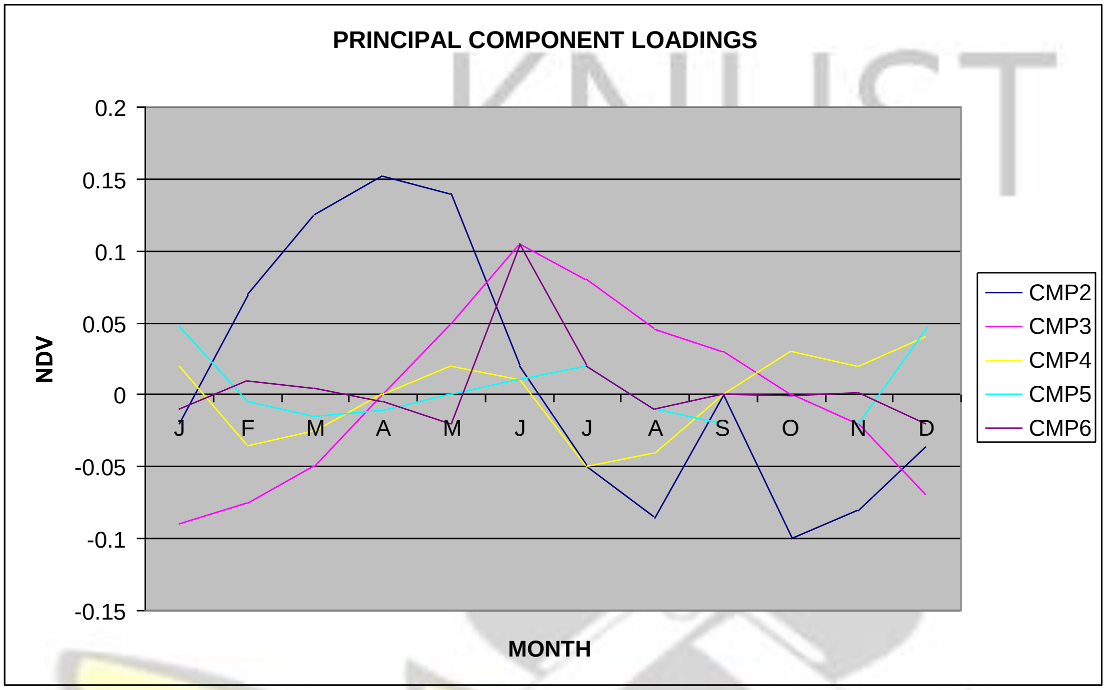
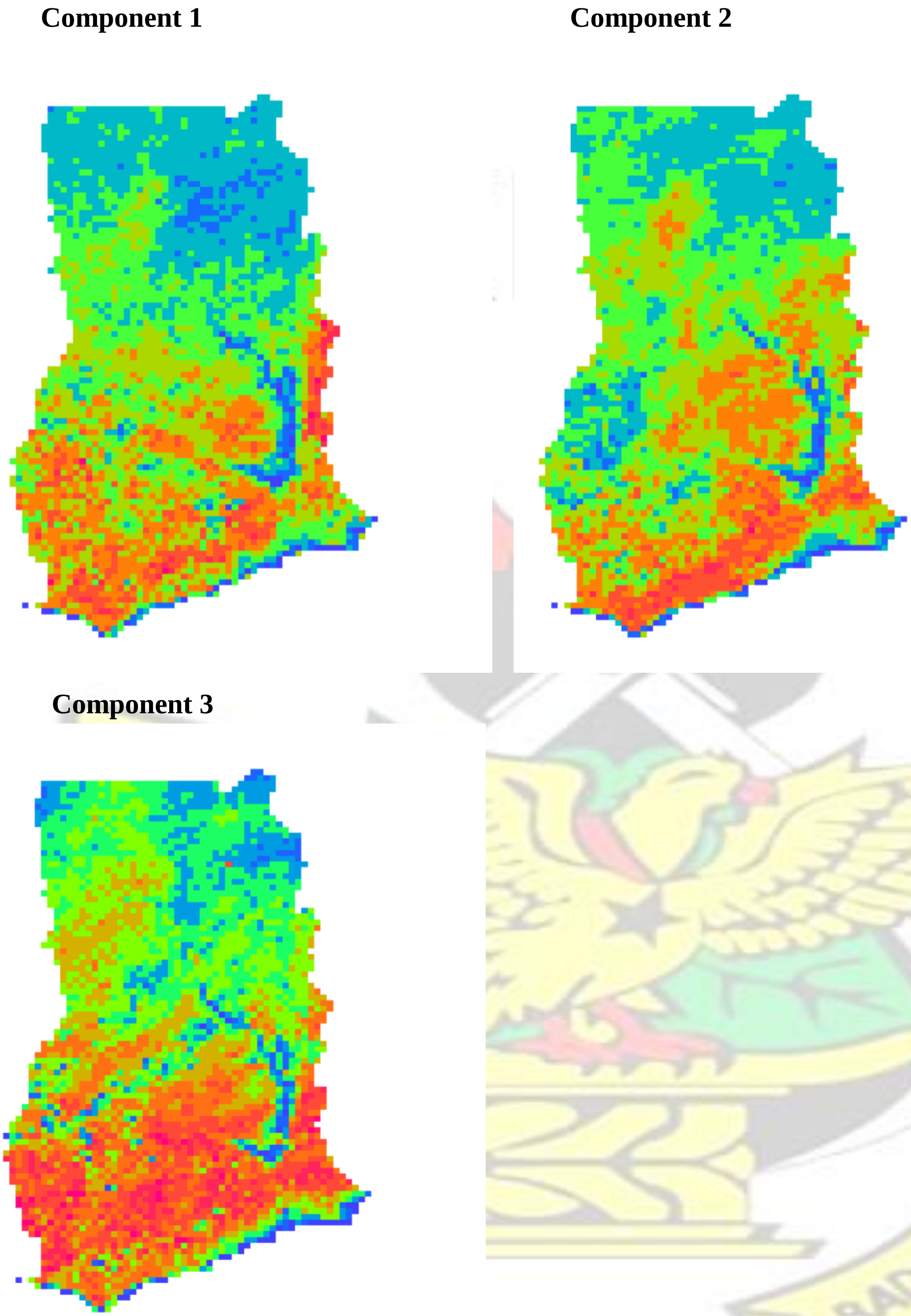


Figure 4.1a: Loadings by dekad of each principal component



Component 1

Component 2

Component 3

Figure 4.1b: First(comp 1), second(comp 2) and third(comp 3) principal component images which were used for the classification.

As shown in table 4.1, the first component explains more than 98% of the total variance.

The high degree of correlation of this component is not demonstrated in the plot of Figure 4.1a, since its variance is above 0.98 throughout the year. This indicates that most part of the variability in NDVI is related to the spatial distribution pattern of vegetation and, by consequence, to the total amount of rainfall.

The components 2 and 3 which accounts for 1.498% are interesting since they depict the different behaviors throughout the year of the different types of land covers. The components from 4 to 6 accounts for about 0.2% of the total variance which gather noise images and is therefore considered as useless.

Component 2 illustrates the first change component, thus a prevalent element of variability in NDVI. As can be seen by the loadings in Figure 4.1a, this component shows an annual cycle indicating that this is a major element of variability of NDVI in Ghana which is caused in the harmattan or rainy seasons. Also from the same figure 4.1a, component correlate positively with the months known to be the early raining season (April-June) and negatively with the early harmattan month (December). This negative correlation indicates that the harmattan months tend to have an inverse pattern to the rainy pattern.

The third component, like the second component, also shows an annual cycle but this time it indicated areas that undergo changes in the late harmattan and early parts of the raining season. Component 3, quite prominent positive and negative anomalies are seen in the northern part of the Brong-Ahafo and southern part of the northern region. These areas experience maximum vegetation peaks in the late raining seasons (October) and late harmattan season(February) respectively due to coincidence of the sun‟s latitudinal position and the rainy season.

4.3 LAND COVER MAPS

The results of the classification for the years **1982**, **1992** and **2002** are illustrated in the

Figure 4.2a, 4.2b and 4.2c respectively.

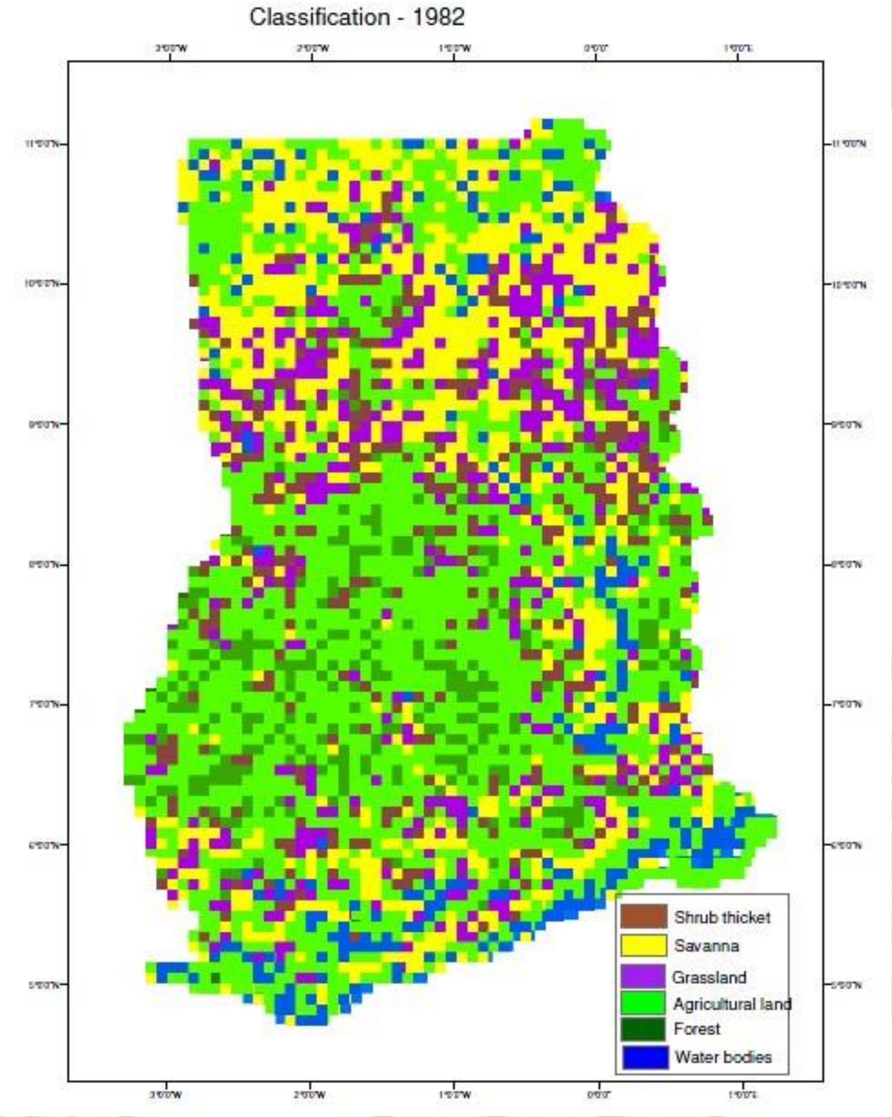


Figure 4.2 a: Land cover map of the year 1982.

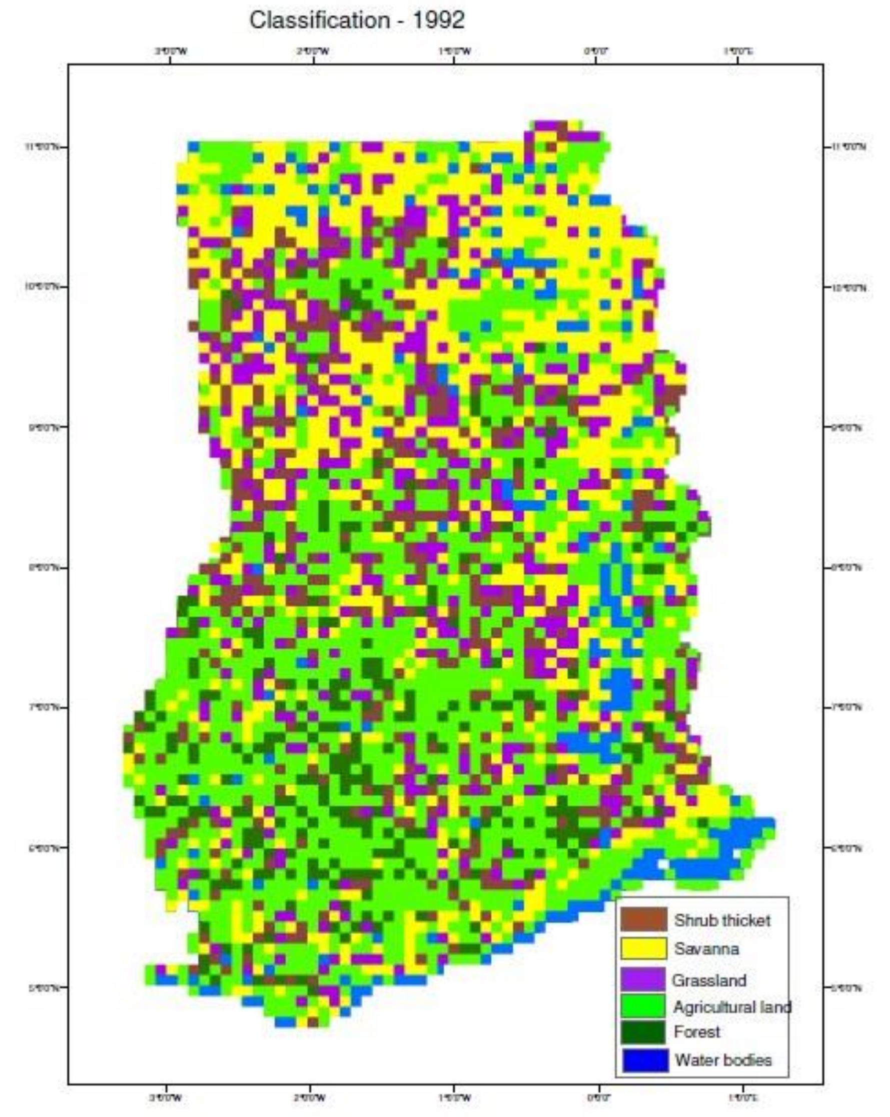


Figure 4.2 b: Land cover map of the year 1992.

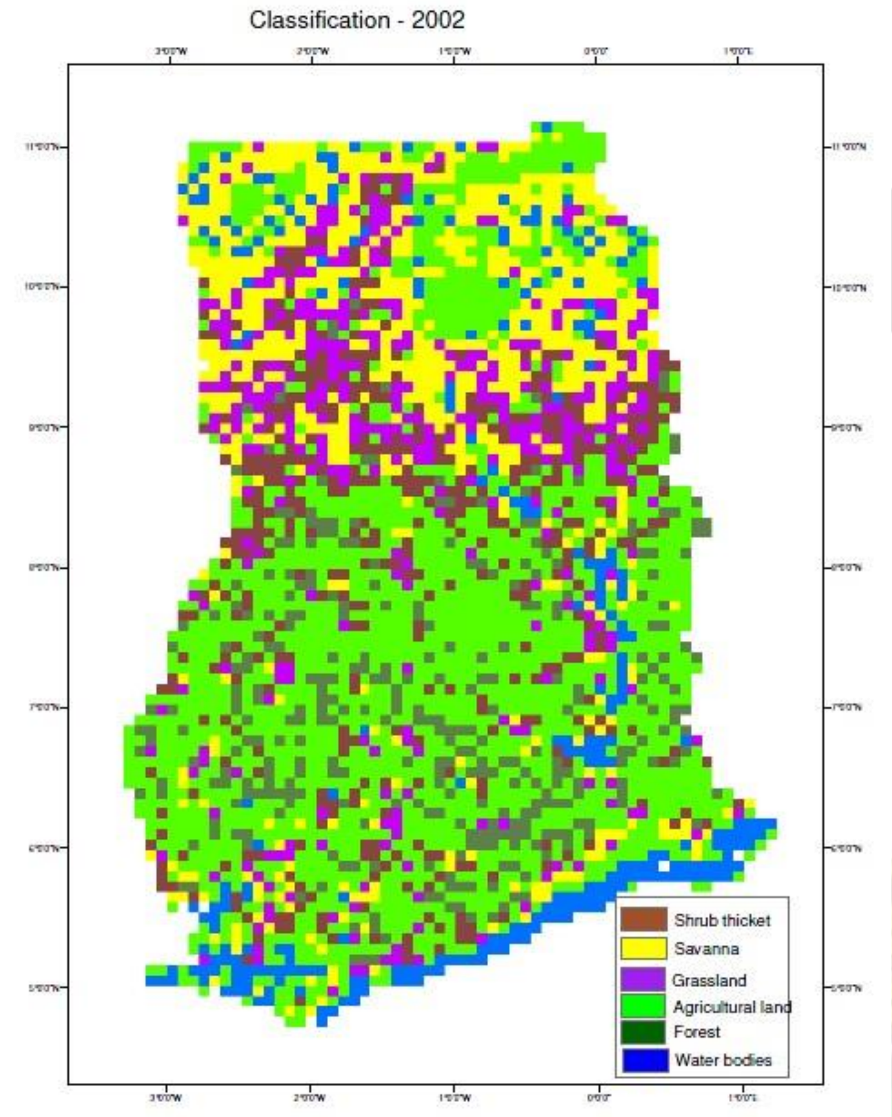


Figure 4.2 c: Land cover map of the year 2002.

The contingency matrix (Table 4.2a-c) shows the accuracy of the classification results. It is derived by comparing the location and class of each ground truth pixel (columns) with the corresponding location and class in the classified image (rows). Each column of the contingency matrix represents a ground truth class, which defines the true class of the pixels. The values in the column correspond to the amount of pixels of that class which the maximum likelihood algorithm classifies to various classes. For instance, in Table 4.2a, out of the 369 Forest pixels, 319 were correctly classified, whereas the remaining 50 were misclassified as

Agricultural lands. The main diagonal elements in Table 4.2 represent correct classifications, whereas off diagonal elements represents misclassification or errors. Overall classification accuracies (sum of diagonal elements divided by grand total, expressed as a percentage) were 86.7%, 83.7% and 77.9% respectively for the periods.

Table 4.2a: Contingency matrices for the maximum likelihood classification 1982

		GROUNDD TRUTH								
		FOREST	AGRIC LAND	GRASS LAND	SAVANNAH	SHRUB THICKET	WATER	ROW TOTAL	USER ACC	ERROR OF COMM
CLASS-FICATION	FOREST	319	100	23	0	0	0	442	0.72	0.28
	AGRIC LAND	50	1570	7	105	0	0	1732	0.91	0.09
	GRASSLAND	0	0	560	222	45	0	827	0.68	0.32
	SAVANNAH	0	0	0	653	135	0	788	0.83	0.17
	SHRUBTHICKET	0	0	0	0	336	2	338	0.99	0.01
	WATER	0	0	0	0	0	268	268	1.0	0.00
OVERALL ACCURACY = 0.87										
COLUMN TOTAL		369	1670	590	980	516	270	4395		
PRODUCER ACCURACY		0.86	0.94	0.95	0.67	0.65	0.99			
ERROR OF OMMISSION		0.14	0.06	0.05	0.33	0.35	0.01			

Over All Accuracy is 86.7%

Table 4.2b: Contingency matrices for the maximum likelihood classification 1992.

	GROUNDD TRUTH									
		FOREST	AGRIC LAND	GRASS LAND	SAVANNAH	SHRUB THICKET	WATER	ROW TOTAL	USER ACC	ERROR OF COMM
CLASS-FICATION	FOREST	273	130	0	0	0	35	403	0.68	0.32
	AGRIC LAND	60	1382	45	0	0	0	1522	0.91	0.09
	GRASSLAND	36	158	455	60	19	0	728	0.63	0.37
	SAVANNAH	0	0	90	884	70	20	1064	0.83	0.17
	SHRUBTHICKET	0	0	0	36	427	0	463	0.92	0.08
	WATER	0	0	0	0	0	215	215	1.0	0.00
OVERALL ACCURACY = 0.83										
COLUMN TOTAL		369	1670	590	980	516	270	**4395**		
PRODUCER ACCURACY		0.74	0.83	0.77	0.90	0.83	0.80			
ERROR OF OMMISSION			0.26	0.17	0.23	0.10	0.17	0.20		

Over all accuracy is 83.7%

Table 4.2c: Contingency matrices for the maximum likelihood classification 2002.

	GROUNDD TRUTH									
		FOREST	AGRIC LAND	GRASS LAND	SAVANNAH	SHRUB THICKET	WATER	ROW TOTAL	USER ACC	ERROR OF COMM
CLASS-FICATION	FOREST	263	100	162	0	0	0	632	0.42	0.58
	AGRIC LAND	100	1570	55	0	0	0	1433	0.88	0.12
	GRASSLAND	6	200	373	0	0	0	579	0.64	0.36
	SAVANNAH	0	0	90	956	75	0	1031	0.93	0.07
	SHRUBTHICKET	0	0	0	0	441	0	485	0.91	0.09
	WATER	0	0	0	0	0	235	235	1.0	0.00
OVERALL ACCURACY = 0.78										
COLUMN TOTAL		369	1670	590	980	516	270	4395		
PRODUCER ACCURACY		0.71	0.76	0.63	0.98	0.85	0.87			
ERROR OF OMMISSION		0.29	0.24	0.37	0.02	0.15	0.13			

Over all accuracy is 77.9%

4.3.1 KAPPA STATISTICS

Formula

$$K_{hat} = \frac{\mathbf{N \sum X_{ij} - \sum (X_i * X_j)}}{\mathbf{N^2 - \sum (X_i * X_j)}} \quad \text{..................................(5)}$$

N = sum of correctly classified

pixels X = various classes i = Row

total j = Column total

Kappa for 1982

$$= \frac{4395\ (319+1570+560+653+336+268) - (442*369+1732*1670+827*590+788*980+338*516+268*270)}{(4395)^2 - (44*369+1732*1670+827*590+788*980+338*516+268*270)}$$

= 0.79

Kappa for 1992

$$= \frac{4395\ (273+1382+455+884+427+215) - (403*369+1522*1670+728*590+1064*980+463*516+215*270)}{(4395)^2 - (403*369+1522*1670+728*590+1064*980+463*516+215*270)}$$

= 0.78

Kappa for 2002

$$= \frac{4395\,(263+1263+373+956+441+235) - (632*369+1433*1670+579*590+1031*980+485*516+235*270)}{(4395)^2 - (632*369+1433*1670+579*590+1031*980+485*516+235*270)}$$

= 0.75

Apart from the overall classification accuracy, which indicates the probability that a given pixel is correctly classified. Other measures that indicate the level of accuracy of the individual land-cover classes exist (Story and Congalton, 1986). The producer accuracy in the Table 4.3a is obtained by dividing the number of correctly classified pixels by the column total. This is important for producing spatial data, as it measures the probability that a reference sample (ground truth data) is correctly classified. This indicates how a given area in a landscape can be mapped. The lowest value of 63% was obtained for Grassland in 2002. The difference between the mapped and reference data may be due to the time difference between the acquired data(1982-2002) and reference data(2000). Pa is also related to the error of omission (Eo) i.e. percentage of pixels left out of classes Eo = 100-Pa.

The error of omission was highest for Savannah in 1982 (33%), Forest in 1992 (26%) and Grassland in 2002 (37%).

Table 4.3a: Producer‟s Accuracy %

	1982	1992	2002
FOREST	86	74	71
AGRICLAND	94	83	76
GRASSLAND	95	77	63
SAVANNAH	67	90	97
SHRUBTHICKET	86	83	65
WATER	99	80	87

The user‟s accuracy in Table 4.3b is obtained by dividing the number of correctly classified pixels by its row total. It indicates the probability that a pixel from the land cover map actually matches what is from the ground truth data. It therefore represents the level of confidence that map users can place on the map. The values of user‟s accuracy are fairly high (65-100%), indicating that users can place a reasonably high confidence in map. The relationship between user‟s accuracy (Ua) and error of commission (Ec) (which is the percentage of extra pixels in a class) is given by the formula Ec = 100-Ua.

Highest Ec was obtained for Forest in 1982 (34%), grassland in 1992 (37%) and Forest in 2002(35%).

Table 4.3b: User‟s Accuracy %

	1982	1992	2002
FOREST	72	68	42
AGRICLAND	91	91	88
GRASSLAND	72	63	64
SAVANNAH	83	83	93
SHRUBTHICKET	99	92	91
WATER	100	100	100

4.4 CHANGES IN LAND COVER

Land cover statistics in Table 4.4 below shows that the natural vegetation (Forest and Grassland) was 58.0% in 1992. After 20years in 2002, these land covers decreased to 41.9%. The proportion of Agricultural land decreased from 55.4% in 1982 to 44.6% in 2002. This loss can be attributed to the conversion of Forest lands to Agricultural lands and also the rampant bush burning occurring in the country. Table 4.5 shows that the annual rate of decrease was 1.3% in the first period (1982-1992) compared to 0.8%, in 1992-2002. Shrub thicket increased slightly from 43.2% in 1982 to 56.8% in 2002. The rate of increase was 2.3% for the first period (1982-1992) compared to 0.27% in second period (19922002). Savannah experienced the highest absolute annual change (increase of about 3%) in the first period, whereas Grassland had the highest annual absolute change in the second period (1.5% decrease). This is as a result of the excessive cutting of trees as timber for wood production and also using them for firewood in the rural areas. Water decreased by 1.6% in1982-1992 but increased by 0.78% in 1992-2002.

Table 4.4: Shows the area covered by the classes of each period.

Classifications	**Area (km²)**		
	1982	**1992**	**2002**
Forest	22,090.75	18,905.25	18,212.75
Shrubthicket	23,268.00	29,569.75	30,539.25
Grassland	38,780.25	31,508.75	25,830.25
Agricultural Land	108,722.5	95,703.50	87,462.75
Savannah	45,220.25	61,217.00	66,203.00
Water	18,559.00	14,888.75	16,273.75

Table 4.5a: Shows the land cover change for the periods 1982-1992.

Classifications	**Changes between 1982 and 1992**			
	1982	**1992**	**Increase**	**Decrease**
Forest	22,090.75	18,905.25		3,185.50
Shrubthicket	23,268.00	29,569.75	6,301.75	
Grassland	38,780.25	31,508.75		7,271.50
Agricultural Land	108,722.5	95,703.50		13,019.50
Savannah	45,220.25	61,217.00	15,996.75	
Water	18,559.00	14,888.75		3,670.25

Table 4.5b: Shows the land cover change for the periods 1992-2002.

Classifications	**Changes between 1992 and 2002**			
	1992	**2002**	**Increase**	**Decrease**
Forest	189,05.25	18,212.75		692.5
Shrubthicket	29,569.75	30,539.25	969.50	
Grassland	31,508.75	25,830.25		5,678.50
Agricultural Land	95,703.50	87,462.75		8,240.75
Savannah	61,217.00	66,203.00	4,986.00	
Water	14,888.75	16,273.75	1,385.00	

Table 4.5c: Shows the land cover change for the periods 1982-2002.

Classifications	**Changes between 1982 and 2002**			
	1982	**2002**	**Increase**	**Decrease**
Forest	22,090.75	18,212.75		3,878.00
Shrubthicket	23,268.00	30,539.25	7,271.25	
Grassland	38,780.25	25,830.25		12,950.00
Agricultural Land	108,722.5	87,462.75		21,259.75
Savannah	45,220.25	66,203.00	20,982.75	
Water	18,559.00	16,273.75		2,285.25

4.5 THE PROPORTION OF LAND COVER CHANGE

About 44% of the landscape experienced a cover change in the period which was considered to be the structural adjustment era (1982-1992), whereas the proportion of changed land in the post structural adjustment period (1992-2002) was about 56%. Between 1982 and 2002, the proportion of changed landscape was about 53%. Thus, annual rates of land cover were about 10% and 12% in the first and second periods respectively, where as the annual rate change (net rate) for the period 1982-2002 was over 8.5%.

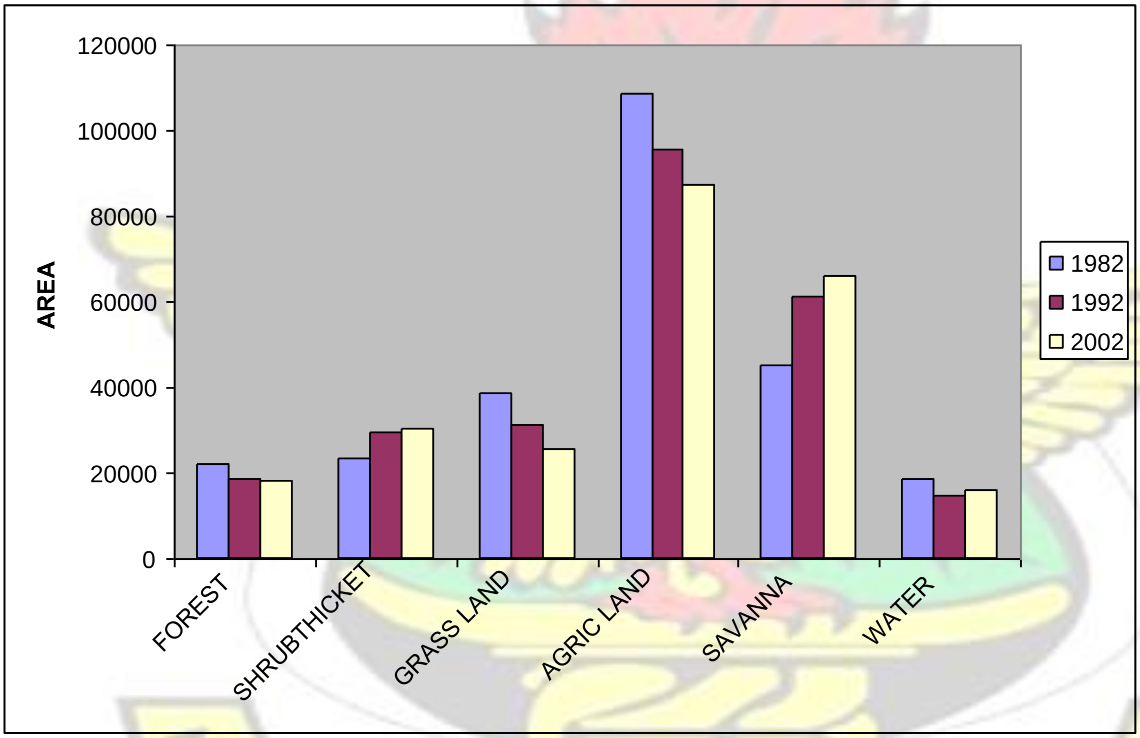


Figure 4.3a: Land covers proportion for 1982, 1992 and 2002.

4.6 THE RATES OF CONVERSION AMONGST LAND COVER TYPES

Changes in land cover proportions were unidirectional for all land covers except water (Figure 4.3b). Grassland, where the absolute annual rates of change was almost the same for the first and second period for the land covers. Most of the land covers change processes occurred in the first period. The overall annual rate of change in land cover (1982-2002) was highest for savannah (3.8%) and lowest for water (1.03%).

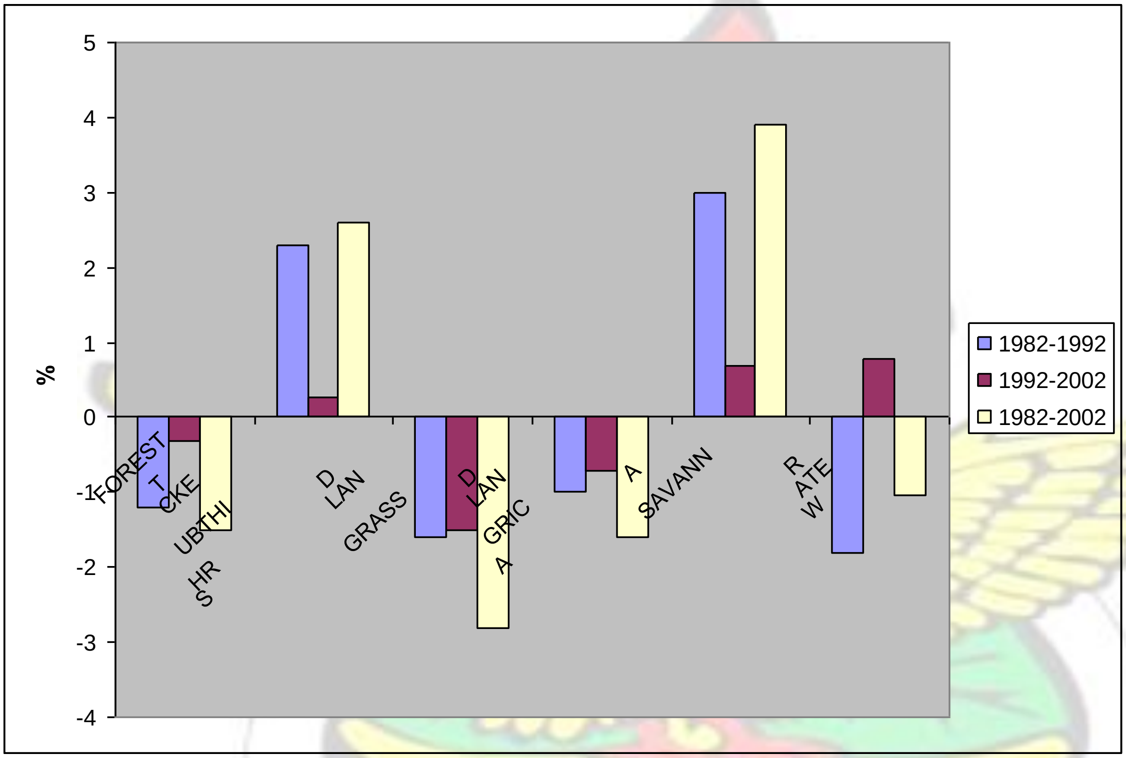


Figure 4.3b: Annual rates of land cover change.

Table 4.6 below showing the land cover change matrices indicate that about 55.7% of the land did not experience a change between 1982 and 1992, whereas between 1992 and 2002, the proportion change was about 47.4% (which is the sum of diagonal elements in Tables 4.4a and 4.4b respectively). For the two periods, the proportion of unchanged land covers highest for grassland (28.1% between 1982 and 1992, and 19.8% between 1992 and 2002).

This suggests that grassland forms highest percentage of the land covers that do not undergo change between the two periods.

Table 4.6: Land Cover Change Matrix (%)

a) 1982 -1992

	FOREST	AGRIC	GRASS	SAVANNAH	SHRUB	WATER
FOREST	9.23	4.23	2.23	1.52	0.11	0.01
AGRIC LAND	9.28	12.50	2.12	1.73	0.04	0.13
GRASSLAND	4.75	4.53	15.12	5.69	0.13	0.09
SAVANNAH	5.45	2.26	8.85	13.51	0.17	0.07
SHRUBTHICKET	3.49	8.22	4.79	1.36	5.05	0.11
WATER	0.18	0.04	0.12	0.05	0.00	0.22

b) 1992- 2002

	FOREST	AGRIC	GRASS	SAVANNAH	SHRUB	WATER
FOREST	5.23	6.01	1.53	3.34	0.71	0.61
AGRICLAND	11.08	9.67	3.43	0.98	0.14	0.03
GRASSLAND	6.71	3.59	11.22	2.09	0.03	0.00
SAVANNAH	9.02	6.32	4.80	11.96	0.37	0.57
SHRUBTHICKET	4.09	7.02	3.71	2.36	9.23	0.01
WATER	0.08	0.04	0.10	0.30	0.16	0.07

(c) 19982- 2002

	FOREST	AGRIC	GRASS	SAVANNAH	SHRUB	WATER
FOREST	7.67	3.93	2.03	1.82	0.11	0.01
AGRICLAND	11.88	10.80	5.54	2.73	0.00	0.13
GRASSLAND	2.85	1.93	12.57	0.59	0.13	0.09
SAVANNAH	8.75	0.26	5.35	9.51	0.07	0.00
SHRUBTHICKET	5.49	3.22	1.09	1.06	5.85	0.11
WATER	0.53	0.09	0.02	0.05	0.00	0.03

4.7 ACCURACY OF IMAGE CLASSIFICATION

The overall accuracy of the land cover classification for the NDVI image is 82.3 % (kappa statistics of 0.78). The contingency matrix showed that the NDVI image classification was the best at distinguishing shrub thicket and savannah cover types. (Table 4.2a-c). Generally, the frequency of confusion of classification was low but did occur. Agricultural lands were sometimes confused with both Forest and Grassland. Forest had the lowest classification accuracy because it was largely confused with Agricultural land and Grassland (refer to Table 4.3a). Overall, instances of confusion were minimal and did not affect user"s classification accuracy (refer to Table 4.3b). The user"s accuracy ranged between 63% and 100% with relatively low errors of commission (excesses), varying between 0% and 48%
(Table 4.2a-c). The producer"s accuracy ranged between 63% and 99%, with similarly low errors of omission (deficits) depending on the class (1%-33%).

4.8 IMPORTANCE OF THE NDVI DATA

The results of the NDVI map produced indicate that, vegetation index change is closely corresponded to the seasonal change. Especially in the western and middle part of Ghana where agriculture is predominant, there is one peak NDVI value in East, two peak NDVI value in middle part of the country, and three Peak NDVI value in South West over the year respectively, which is closely related to crop harvest times during the year. Generally, there is a high NDVI value curve in the Western forest area during the forest growing season, but NDVI value simply does not change much in the North Western part of Ghana over a year due to less vegetation there.

When greenness classification was completed for each NDVI image, the result shows that there is a big NDVI value change between raining and harmattan seasons. In rainy season greenness value of Grassland, Agricultural land, and Forest types classes occupy 76.70% of whole vegetation cover of Ghana, there is no clear difference in vegetation index between western and middle part of the country, but in the dry season this difference is much clear. In dry season, the greenness value of northern region occupies 6.40 % for the total territory due to the monsoon climate effluence.

Also, Vegetation cover change is difficult task due to its dynamism, which is caused by seasonal change as well as long –term climate or land management change. It is therefore necessary to use a long –term time series NOAA AVHRR data as well as historical and ground truth data as proven by this study. Therefore, the availability of long temporal sequences of Local Area Coverage(LAC) NDVI data, at 1 km resolution, could greatly improve the quality of land cover classification results, through a strong reduction in the amount of mixed pixels and, therefore, the building up of better reference temporal profiles by using standardized principal component analysis.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 SUMMARY AND CONCLUSIONS

NOAA-AVHRR data have a daily coverage, synoptic overview, data volume, and low cost, so the global change scientific community has identified the AVHRR data set as an important database for land and vegetation cover mapping and land processes modeling at continental and global scales (IGBP, 1992). In this study, a series of 12 monthly average NDVI data is used to produce a Land Cover map of Ghana of three periods. These maps are used to analyze the vegetation cover change between the three periods for whole Ghana.

In light of the results and discussions, it can be concluded that;

- The project produced a synthesis of available information on land cover changes on the national scale for the three stipulated periods. The land cover maps produced for each of the years are of high quality since each of them has high classification accuracy.

- The most dominant land cover change was conversion of natural vegetation to Savannah and Shrub thicket, which occurred at an annual rate of 4% and 6.5% respectively. In the first period, about 25% of natural vegetation was converted to Savannah and Shrub thicket, whereas a slightly higher fraction (28%) converted to Savannah and Shrub thicket in the second period. The net change from natural vegetation to cropland was 30%.
- The higher percentage of change in the post-structural adjustment period (19922002) can be attributed to the changing economic opportunities and macroeconomic instability in the post-structural adjustment period. This probably affected land cover change more than during structural adjustment.

- Standardized principal components analysis appear to be a remarkably comprehensive tool for the analysis of anomalies and trends in long time series NOAA/AVHRR data for land cover classification. It is also effective in isolating periodic seasonal effects. The ability of Standardized Principal Components to uncover significant change events over long time series is strong. Also the results of the NDVI maps demonstrated the capability of AVHRR-NDVI time-series data for revealing changes in vegetation at the country scale for Ghana. This is evident from both the producer and user accuracy obtained for land covers in each year (Table 4.3 a and b respectively).

5.2 RECOMMENDATION

Analyses of local patterns of land cover change as carried out in this study could provide relevant information for policy makers who are responsible for land use planning and environment protection. As land cover change is multicausal, a set of policy prescriptions is required to address the adverse effects of the phenomenon.

1. Decline in the Forest as a result of wood cutting underscores the need for coercive environmental protection policies to relieve human pressure on vegetation resources.
2. Phenomenal agricultural expansion at the expense of forest leading to nutrient mining should call for agricultural intensification-related policy initiatives to discourage expansion of cultivation on fragile lands. Such intensification strategies should address sustainable land cover management and farming techniques that replenish phosphate.

3. Afforestation is needed to restore the degraded parts of the landscape. The establishment of vigorous vegetation will lead to an increase in biomass. Afforestation strategies in Ghana should involve the choice of appropriate species that are well adapted to the environment.
4. Future studies should look at applying Fast Fourier Transform (FFT) algorithm (which has proven to be a powerful tool from previous researches) to describe the progressive zonal change of climatic variability and its impact on the country‟s vegetation variation in the complex climatic pattern.
5. Further consideration should be made on spatial time series NOAA /AVHRR NDVI data for Ghana using Linear Mixture Technique (LMF).

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